SOHN International SYMPOSIUM

on Advanced Processing of Metals and Materials: Principles, Technologies and Industrial Practice

Incorporating the 4th International Symposium on Sulfide Smelting

August 27-31, 2006
Catamaran Resort
San Diego, California, USA

FINAL PROGRAM

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Welcome

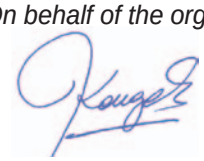
Dear Colleagues:

Welcome to the Sohn International Symposium dedicated to the distinguished work and lifetime achievements of Professor H.Y. Sohn. This symposium has drawn a record response from the international professional community in six continents: 530 abstracts have been received from authors and co-authors from 80 countries; 104 professional societies, organizations and publishers have co-sponsored the symposium, and a record amount of sponsorship funding has been received from various industrial companies. These efforts together make this a world-class symposium.

This symposium covers a range of topics in-depth. It includes ***principles***, ***technologies*** *and* ***industrial practice*** *in nonferrous high temperature extraction and processing; iron and steel making; aqueous, electrochemical processing and molten salts; nano, composite, refractory and polymer materials; recycling, recovery and waste treatment. Of special note is the distinctive symposium on* ***legal***, ***management*** *and* ***environmental issues*** *with prominent lawyers and renowned speakers on industrial management. Also of special interest is the* ***International Symposium on Sulfide Smelting 2006*** *originated by Professor Sohn about 20 years ago.*

I am sure you will have a rewarding time at the symposium as well as an unforgettable experience in magnificent Mission Bay and San Diego.

On behalf of the organizing committees,



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About Professor Sohn

About Professor Sohn

This symposium honors the very distinguished work and lifetime achievements of Professor H.Y. Sohn. He is renowned for his impact in fields such as nonferrous, ferrous and nano-scale materials processing; in many processing routes including pyrometallurgy, hydrometallurgy, chemical vapor synthesis and processing, and recycling; and in several investigating techniques such as experimental measurements, physical modeling and simulation (CFD).

His Research

Professor Sohn has acquired an international reputation for computer modeling and analysis in various metal extraction fields such as flash smelting/flash converting processes as well as the minor element behavior in nonferrous smelting. He has also worked on the analysis of a channel reactor for the continuous production of copper by the countercurrent contacting of slag and matte/metal phases with bottom gas injection through gas-shrouded Savard/Lee injectors. Dr. Sohn has developed a novel solvent extraction process called SOHNEX, which is based on bottom gas injection without mechanical agitation. His latest research involves the chemical vapor synthesis of nano-sized metallic and other inorganic materials, including advanced intermetallic compounds, WC-Co composite powders and metal-hydride hydrogen storage materials.

His Career

Dr. Sohn holds the titles of Professor of Metallurgical Engineering and Adjunct Professor of Chemical and Fuels Engineering at the University of Utah, where he has worked for more than 30 years. Professor Sohn has co-authored two monographs, co-edited 16 books and written 315 papers. He has served on the TMS Board of Directors, organized many international symposia, and delivered numerous plenary and keynote lectures. Dr. Sohn has also received several awards, including the James Douglas Gold Medal Award in 2001 for leadership and outstanding contributions in research and education of nonferrous extractive metallurgy, and for work related to the modeling of gas-solid reactors and the development of novel solvent extraction systems.

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What Your Registration Fee Includes

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- Welcoming and Closing Receptions
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- Symposium Banquet
- Proceedings on CD-ROM

Student

- Technical Sessions
- Welcoming and Closing Receptions
- Coffee Breaks

Social Activities

Welcoming Reception
Sunday, August 27 • 6 to 8 p.m.
Beach North Area of the Catamaran Resort

Session Breaks
Morning/Afternoon
Outside the Technical Session Rooms

Symposium Banquet
Monday, August 28 • 6:30 to 9:30 p.m.
Bahia Hotel

Member, author and nonmember attendees may attend for free. Guests and students may purchase tickets at a cost of $65 each. Tickets may be purchased at the conference registration desk.

Closing Reception
Wednesday, August 30 • 6 to 8 p.m.
Beach North Area of the Catamaran Resort

Meal Plan

Attendees may purchase a meal plan which consists of a lunch buffet for three days (Monday, Tuesday and Wednesday) at a cost of $40. The buffets will be served on the Catamaran Resort lawn near the beach from noon to 1:30 p.m. Meal plan must be purchased by 10 a.m., Monday, August 28.

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At the Symposium

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Session Listing

Plenary Session

Monday AM Room: Kon Tiki Ballroom
August 28, 2006 Location: Catamaran Resort Hotel

Session Chair: Florian Kongoli, FLOGEN Technologies Inc

9:00 AM Opening Remarks and Overview by Florian Kongoli, Conference Organizer

9:15 AM Plenary
Lifetime Achievements of Professor Sohn: *Ramana G. Reddy*[1]; [1]University of Alabama

Life time research, scholarly and teaching achievements of Professor Sohn are briefly described. Professor Sohn has devoted his entire career for the development and application of process engineering principles to the quantitative description of metallurgical and materials systems. He has shown research excellence and the creation of new understanding in many extraction processes including gas-solid reaction engineering which lead to the formation of Sohn's Law and his invention of solvent extraction process with bottom gas injection lead to the novel The Sohnex Process. He is a scholar, visionary for a better Global society and world ambassador of process engineering.

9:45 AM Plenary
It Is Going to Be about Energy: *Patrick Atkins*[1]; [1]Alcoa Inc

The energy requirements to produce metals have long been a subject of significant interest, due in large part to the direct cost implications. As the cost of energy continues to rise, this will be an even more important parameter in the metal production decision making process. However, additional facets of the subject are also becoming more critical and complex. In addition to the immediate costs of energy, the industry must also focus on long term availability (sustainability), the quality of the energy (reliability), the traditional environmental impacts associated with the energy source development and operation (environmental), the social impacts of the energy source development and operation (social/community), the land use and habitat limitations associated with the energy source development and operation (nature) and the long term implications associated with the production and use of the energy. Industry leaders will need to further develop sound and transparent methods totally evaluate all of these facets of energy production and use so that decisions are made with a full understanding of the benefits and risks. This paper will discuss the implications associated with the energy requirements needed to meet the expected growth requirements of the aluminum industry over the next few decades. A model will be described that provides opportunities for decision makers to gain a better understanding of the benefits and risks associated with these energy decisions and for expected aluminum production and use, and forecast possible impacts of various decisions on these benefits and risks.

10:15 AM Plenary
The Precious Art of Metals Recycling: *Francis Vanbellen*[1]; Mathias Chintinne; [1]Umicore Precious Metals Refining

Umicore Precious Metals Refining operates an integrated precious metals smelting and refining plant in Hoboken, Belgium. Once a smelter and refiner of complex concentrates, the plant today's feed consists exclusively of industrial and consumer recycled products, making it the world's largest recycling facility for precious metals. Unlike the fairy tale of the Frog Prince, it took much more than a princess' kiss to successfully realize this makeover. A completely renewed plant has been built over the past decade. The most visible technological innovation was the commissioning of the Pb-Cu smelter. Its flexibility towards very different types of feed makes it perfectly suited as main entry to the Hoboken flow sheet. A new Cu-leaching and electro winning plant and precious metals refinery make up the Precious Metals Operations (PMO) whose targets are fast throughput and maximized yields for gold, silver and the platinum group metals. The Base Metals Operations (BMO), flexibly process the by-products from the PMO, valorizing "impurities" like indium, tellurium, selenium and others. Off gas and waste water treatments ensure compliance with strict environmental standards. Precious metals recycling is an art that goes beyond mastering a unique flow sheet. Umicore Precious Metals Refining offers a complete recycling service, taking care of sampling and assaying, metals management and logistics. The quality of this integral service is recognized through the attribution of ISO certifications for our operational activities, sampling and the environmental care. And it's an art that follows Michelangelo's experience: "Art is 5% of inspiration and 95% of transpiration."

10:45 AM Plenary
Nonferrous Metal Recycling in Korea: Present and the Future: *Kang-In Rhee*[1]; [1]Resource Recycling R&D Center

Nonferrous metal recycling, a significant factor in the supply of various types of the metals used in our society, provides energy saving and environmental benefits. This recycling plays an important role for establishing the sustainability of materials. In addition, total amount of recycled nonferrous metal by weight is less than 5%, its value is larger than 50%, comparing with ferrous metal recycling which consists of about the half of total metal recycling. This paper describes trends and typical achievements in nonferrous metal recycling and introduces the current and future of nonferrous metal recycling technology and business in Korea.

11:15 AM Plenary
The Role of Processes Modeling in Iron and Steelmaking: *Pinakin Chaubal*[1]; [1]Mittal Steel Company

Today's steel industry is in a vibrant and resurgent mode. Driven by consolidations, a vision proposed by Mittal Steel and embraced worldwide, the business of iron and steelmaking has adopted a model that probably was only whispered a decade ago. This transformation has however been in the making for some time now. Over the last few decades, the industry was steadily transforming itself to becoming a high tech industry, not "glam tech" -in the words of an ex-steel industry executive. New technology was adopted, efficiencies were enhanced, lean manufacturing concepts were brought in and a strong customer focus was developed. Today's mills employ sophisticated instrumentation, computerized monitoring, on-line smart systems etc. driving processes that are producing at rates of many tons/minute. All this is not possible without judiciously using the latest available technologies in various fields and developing a more sophisticated work force. Prof. Sohn has been a pioneer in driving the concept of process engineering in process metallurgy. Is process engineering just a phrase for glamorous research adventures or has the steel industry embraced it whole-heartedly? In this paper it will be shown that the latter is the truth. Examples of specific applications, using our experience at Mittal Steel's worldwide operations will be given. The focus will be on process development and optimization in keeping with the overall field of Prof. Sohn's body of research. What are future directions – some thoughts on this question will also be proposed.

11:45 AM Plenary
Liquidus Relations of Calcium Ferrite and Ferrous Calcium Silicate Slag in Continuous Copper Converting: Florian Kongoli[1]; Ian McBow[1]; *Akira Yazawa*[2]; Yoichi Takeda[3]; Katsunori Yamaguchi[3]; Robert D. Budd[1]; S. Llubani[1]; [1]FLOGEN Technologies Inc; [2]Tohoku University; [3]Iwate University

While calcium ferrite slags have been successfully used in continuous copper converting for about 30 years, ferrous calcium silicate slag was proposed about 8 years ago as an additional alternative. Although both slags are normal extensions of each other their phase relations have not been completely clarified. In this paper the liquidus relations of both slags have been quantified at areas that cover them both. The existing experimental data have been reviewed and discussed in relation to the solidification procedure. An original physical model is used to predict various diagrams of the liquidus surface of both slags. It is shown that the ternary liquidus diagrams normally used for FeOx-SiO2-CaO system are not suitable for industrial slags. The new model diagrams of Fe/CaO versus SiO2 and Fe/SiO2 versus CaO as well as Fe/CaO versus Temperature and Fe/SiO2 versus Temperature are proven to be much more convenient for calcium ferrite and ferrous calcium

silicate slags. Based on these diagrams the effect of SiO2 and CaO on the melting temperature is quantified. The effect of Cu2O is also quantified through the model. Some Fe/CaO versus Cu2O and Fe/SiO2 versus CaO at various copper contents are predicted and the results show good agreement with the experimental data. It is also shown that in the presence of liquid copper, Cu2O dissolves in the slag depending on the oxidation degree and might lower the liquidus temperature. Some discussions are also presented taking into account plant observations and important conclusions are drawn for copper smelting and converting.

12:15 PM Plenary

Recent Developments in Copper Hydrometallurgy: *John O. Marsden*[1]; [1]Phelps Dodge Corporation

The past fifteen years have seen a number of important developments in copper hydrometallurgy, including the commercial application of biological heap leaching of secondary (chalcocite-dominant) copper ores, the commercial demonstration of chalcopyrite concentrate leaching technology using pressure leaching and biological processes, and the application of novel configurations of solution extraction circuits. Significant emphasis is now being placed on the development of effective stockpile leaching practices for primary ores (chalcopyrite and bornite-dominant mineralization). Some of these developments have been highly successful, and will pave the way for further development and commercialization. Others have been less successful. These developments are reviewed in the context of the metal price cycle and trends for the future are identified.

Industrial Practice: Metals and Materials Processing

Monday PM Room: Cockatoo
August 28, 2006 Location: Catamaran Resort Hotel

Session Chairs: Ray D. Peterson, Aleris International Inc; Patricio F. Mendez, Colorado School of Mines

2:00 PM Keynote

Sichuan Aostar Smelter in China: *Youlai Wang*[1]; Yinjian Niu[2]; Dingfan Qiu[3]; Cairong Chen[4]; Yong Li[1]; [1]Sichuan Aostar Aluminum Company, Ltd.; [2]Nonferrous Metals Society of China; [3]Beijing General Research Institute of Mining and Metallurgy; [4]Guiyang Aluminum Magnesium Design and Research Institute

Sichuan is the richest province for its waterpower source in China. Its technical developable capacity is 120,000MW that accounts for about 27% technical developable capacity in China. It is estimated that the electricity generation installing equipment scale of Sichuan will reach to 35,000MW upon 2010, among this amount, waterpower is 21,000MW; thermal power is 14,000MW kilowatts. Thus it can be seen, Sichuan suits extremely to develop high consume energy industry. Sichuan Aostar Group company has two Aluminum smelters, Guangyuan Aostar smelter and Sichuan Aostar smelter. The production of Aostar Group is 240,000 tons in 2004. The construction scale of Sichuan Aostar Aluminum smelter is 250,000 tons per year. The first 168 GY-300KA pre-baked anode cells (130,000 tons/year) were put into production in 2003. This company is the first to use transfer gantry technology in China and realizes the process of emendation the cell cover as well as concentrating to construct the lining of the cell at a distance. This company is also the first to use the EIRICH force mixing and cooling technology in China and first to use the CP Company's vertical ball mill technology to produce the pre-baked anode in the world. The carbon anode system was completed its 190,000 tons/year productions scales only using one time, which is the technology most advanced and the scale biggest pre-baking anode manufacture in present China. Since Sichuan Aostar 300KA cell has put into production, it runs normally and smoothly, at present the current efficiency is bigger than 94% and the direct current consumes is only 13300kWh/T-Al.

2:25 PM

Cost-Effective Magnesium Oxide Recycling for Economic Viability of Magnesium Hydride Slurry Technology for Hydrogen Storage: *Rachel De Lucas*[1]; Uday Bhanu Pal[1]; Guoshen Ye[1]; Andrew McClaine[2]; [1]Boston University; [2]Safe Hydrogen

Current methods of hydrogen storage are an impediment to the transition of our energy infrastructure from a hydrocarbon to a hydrogen base. The transportation, handling, and storage costs of hydrogen gas account for a majority of its selling price. Magnesium hydride slurry is a safe, environmentally friendly alternative for hydrogen storage. If this form of storage is to be adopted on a large scale, a cost-effective method for recycling the enormous amounts of magnesium hydroxide byproduct must be identified. The solid oxide membrane (SOM) process can be used to recycle the magnesium hydroxide byproduct into magnesium metal, which can be reformed into magnesium hydride and reused for fuel storage. Conventional magnesium extraction/recycling technologies require a great deal of energy and create byproducts that are harmful to the environment and human health. The SOM process poses none of these detrimental effects and requires less energy and feed preparation. The economic viability of a facility that utilizes the solid oxide membrane process for the direct reduction of magnesium must be examined in more detail if industry is to consider it. Cost analysis data related to the commercial viability of a scale-up will be compared to two standard industrial processes: current magnesium production techniques including electrolytic and metallo-thermic processes. We have shown in our cost comparison that the SOM process is cheaper than these traditional techniques and that it is also comparable to aluminum's Hall-Héroult process in cost but with none of the environmentally harmful byproducts.

2:50 PM Keynote

An Attempt at Direct Ingot Making of Titanium by the Electro-Winning from Molten Salt with DC-ESR Unit: *Masahiro Kawakami*[1]; Masayuki Orisaka[1]; Takahiro Kawabata[1]; Toshihide Takenaka[1]; Seiji Yokoyama[1]; [1]Toyohashi University of Technology

In order to make titanium ingot directly from molten salt, the metal pool was tried to form and used as the cathode. The electro-slag remelting (ESR) unit was used for the purpose. The unit is composed of water cooled copper mold and the DC power source of 2000 A and 100V. The graphite electrode was used for anode and the base plate was used for cathode. The re-melted slag of CaO-CaF2 was melted in the mold with the addition of TiO2. The following reactions are expected to occur. Ti4+ + 4e = Ti at cathode 2O2- + 2C = 2CO + 4e at anode. During the process, large amount of molten salt splashed out from the mold, showing the CO evolution at anode. The metal deposit was obtained but in the form of block and piled up on the base plate. The metal pool was not obtained perfectly because of shortage of heat supply. The cathodic current efficiency was 60% at maximum. The metal deposit contained much impurity. In order to reduce the impurity and increase the current effciency, the twin-cell structure was tried successfully. The results will be given in the symposium.

3:15 PM

Review on the Part of HVOF Thermal Spray Coating in Protection to Corrosion: Hazoor Singh Sidhu[1]; *Buta Singh Sidhu*[2]; Satya Prakash[3]; [1]Yadvindra College of Engineering; [2]GZS College of Engineering and Technology; [3]Indian Institute of Technology

Materials degradation due to corrosion is the major problem in power generation equipment, gas turbine, fluidized bed combustion, industrial waste incinerators etc. Some super alloys have been developed, but they are unable to have different properties to meet the demand of today's industry. Therefore, a composite system of a base material providing the necessary mechanical strength with a protective surface layer different in structure and/or chemical composition can be an optimum choice in combining material properties. Thermal spray coating of the components before they put into service by suitable surfacing alloy and with suitable coating method can increase the life of these components several fold. Choice of right coating method and alloy for a particular application is extremely important to get the desired service life. In the paper the corrosion of some materials and the role of HVOF thermal spray coatings to counteract the same have been

reviewed, with an aim to understand the phenomena and along with various application.

3:40 PM Break

3:55 PM Keynote
The Role of Scaling, Similarity, and Dimensional Analysis in the Modeling of Metals Processing: *Patricio F. Mendez*[1]; [1]Colorado School of Mines

The prediction of performance of metallurgical processes, and also the design of new processes involve unique challenges. Metal processing operations are typically governed by many more physical principles, and have a higher degree of coupling than other manufacturing techniques. For example, arc welding of metals involves heat transfer, fluid flow, and electromagnetism for both the molten metal and the plasma arc. These phenomena are tightly intertwined in each region, and also across regions, coupling through a free surface that involves evaporation, capillary, and thermocapillary effects. While scaling, similarity, and dimensional analysis have been known for a long time, they have not been applied to metals processing with the same consistency they have been applied to other areas such as chemical engineering. This talk will address the potential reasons why these powerful techniques are not currently more widespread in the modeling of metals processes, will review current state of the art in their application, and suggest paths to overcome obstacles to their full implementation.

4:20 PM
A Dynamic Control Model for a Submerged Arc Furnace for P-Production: *Markus Reuter*[1]; [1]University of Melbourne

This paper discusses a dynamic process model that links CFD into the control structure of 60MW submerged arc furnaces for P production. The model combines plant measurements, data reconciliation, dynamic modelling and CFD modelling to predict P-production and slag quality from tap-to-tap. All models have been calibrated by plant measurements, dig-outs, thermocouples placed a strategic places within refractory after relining etc.

4:45 PM
Computational Modeling of a CVD Reactor to Produce Diamond Films: *Miguel Olivas-Martínez*[1]; Manuel Perez-Tello[1]; Rafael Enrique Cabanillas-López[1]; [1]University of Sonora

A two-dimensional computational model for the hot filament chemical vapor deposition (HFCVD) process to produce diamond films is presented. The model incorporates the transport of momentum, energy, and mass inside the reaction chamber of a HFCVD reactor. The gas-phase transport equations were coupled to the kinetic expressions representing the catalytic dissociation of the molecular hydrogen at the filament surface and the deposition rate of the diamond film on the substrate. The computational model was solved numerically by means of a commercial software. The model predictions showed good agreement with the experimental data reported in the literature in terms of both temperature and methyl concentration profiles along the filament-substrate center distance. Examples of the potential applications of the present formulation for the design and further optimization of the HFCVD reactor are discussed.

5:10 PM Keynote
Computational Fluid Dynamics Simulation of High Temperature Raw Materials Processing: *Yongxiang Yang*[1]; Bo Zhou[1]; Jim Post[2]; Emile Scheepers[1]; Markus A. Reuter[3]; [1]Delft University of Technology; [2]Corus Research; [3]Melbourne University

High temperature processing of raw materials in metals production and recycling often involves complex multi-phase fluid flow and heterogeneous chemical reactions at various scales. Good understanding the process physics and chemistry is crucial for process operation and process development. The traditional scale-up process through laboratory scale – pilot scale – commercial scale route has been more and more complemented and partially replaced by full-scale process simulation. Computational fluid dynamics (CFD) has become a very useful simulation tool in process research and development. At the same time industrial applications challenge the CFD development with its complex transport phenomena, often in large-scale reactors with small-scale physics and chemistry. The current paper discusses the applications of CFD to a number of high temperature metallurgical and materials processing applications. The research was carried out by using commercial CFD codes as the framework, and the emphasis was given to the special efforts for the development and implementations of sub-models of process-dependent physical and chemical characteristics. To illustrate the application of CFD simulation to high temperature raw materials processing and coupling of sub-models to general CFD code, five examples are given: (1) melting of aluminium scrap in a rotary furnace for recycling, (2) molten iron flow in a heterogeneous coke-bed of a blast furnace hearth, (3) gas flow and heat/mass transfer in a submerge electric arc furnace for phosphorus production, (4) high temperature incineration of hazardous waste in rotary kiln, and (5) transient heating of metals in heat treatment furnaces.

5:35 PM Invited
Model-Based Electroslag Remelting Control for Simultaneous, Consistent and Responsive Melt Rate and Immersion Depth Control: *David K. Melgaard*[1]; Joseph J. Beaman[2]; Gregory Shelmidine[1]; [1]Sandia National Laboratories; [2]University of Texas

Electroslag Remelting (ESR) furnaces are used to produce high quality specialty alloy ingots. Ingot quality can be directly correlated to variances in melt rate and immersion depth. Conventional ESR furnaces control these quantities using two independent control loops using current for melt rate and ram drive for immersion depth. However it is well known that they are highly coupled, i.e. changing the current to account for melt rate deviations changes the voltage depth relationship and vice verse. In addition the noise in measurements of the ESR process can be considerable, forcing conventional controllers to use damped responses. A new model-based controller has been developed to embody the coupling and improve responsiveness by using estimates from a reduced-order linear ESR model and the typical process measurements to control melt rate and immersion depth simultaneously. Kalman filtering is used to optimally combine the model estimates of nine process states and the measurements of voltage, current, position and mass to estimate the instantaneous melt rate and immersion depth. Several ESR melts under steady state and transient conditions were conducted to evaluate the performance of the new controller. This paper will discuss the design of the new ESR model and controller and will present experimental results demonstrating its improved control and responsiveness.

International Symposium on Sulfide Smelting: Sulfur and Gas Handling

Monday PM — Room: Macaw
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Takahiko Okura, Akita University; Katsunori Yamaguchi, Iwate University

2:00 PM Keynote
Elemental Sulphur Fixation in Smelting Gas: Is it Feasible?: *Takahiko Okura*[1]; [1]Nippon Mining R&T

Sulphur, with its multiple oxidation states, play critical roles in many processes, ranging from regulating enzymes in plants, to acidifying aquatic systems, and to affecting the global climate. Most of non-ferrous smelters have been contributing to reduce atmospheric emissions of sulfur dioxide to acceptable levels, converting it to sulphuric acid and/or gypsum. However, some amount of SO2 gas is still emitted from isolated smelters. Furthermore, sulphuric acid is competing with involuntary elemental sulphur in the market. This situation puts the non-ferrous metallurgical industries to develop a new sulphur fixation process. This paper briefly describes the new technologies for fixation, followed by the novel proposal to convert SO2 gas to elemental sulphur using organic materials. Finally, the feasibility will be presented technologically and economically.

2:25 PM

A Harmony in Natural and Man-Made Sulfur Cycles: *Etsuro Shibata*[1]; Nobuaki Sato[1]; Takashi Nakamura[1]; Takahiko Okura[2]; Masatoshi Ogasawara[3]; Masafumi Maeda[4]; [1]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University; [2]Satellite Venture Business Laboratory, Akita University; [3]Nippon Mining Research and Technology; [4]Institute of Industrial Science, University of Tokyo

For the treatment of huge amounts of the sulfur which is from the earth by both natural and man-made activities, a harmonized sulfur cycle was presented. The man-made sulfur cycle which includes sulfur circulation from oil, coal and ore was analyzed in detail based on the recent world sulfur trend. Then the man-made cycle was compared with the natural sulfur evolution such as volcano. Finally, the harmony in both natural and man-made sulfur cycles was discussed.

2:50 PM

Evaluation of Recent Advances in the Design and Operation of Metallurgical Sulfuric Acid Plants: *Leonard J. Friedman*[1]; [1]Acid Engineering and Consulting Inc

In the last fifteen to twenty years there have been many changes in equipment design and operation of metallurgical sulfuric acid plants, some are advances in the state of the art, some marginal, and some better left alone. Some of these alternate designs include: designs to meet low stack SO2 emission requirements (100 PPMV), low ignition catalyst, alloy towers, pump tanks and converters, fiber reinforced plastic quench towers, plastic electrostatic mist precipitators, heat exchangers inside/outside converters, and acid heat recovery systems. This paper reviews each of the design alternates and evaluates the advantages and disadvantages of each, as well as their effect on the acid plant operation and reliability. The aim of the paper is provide a greater understanding of the design alternates avilable to operating companies for new plants or for modifications to existing plants, and to encourage a more thorough evaluation of proposed designs to reduce metallurgical sulfuric acid plant capital cost, reduce maintenance costs and increase operating reliability.

3:15 PM

New Types of Sulfur and Non-Conventional Methods for Its Use: O. G. Yeremin[1]; V. A. Tanayants[2]; *Valery M. Paretsky*[1]; [1]Gintsvetmet; [2]Inter-S, Astrakhan

The Joint Venture "Inter-S" jointly with the Gintsvetmet Institute have developed a technology for manufacture of sulfoconcrete and sulfoasphalt. The sulfoconcrete manufacturing technology comprises preliminary production of modified sulfur, which is blended in liquid form at a temperature of 120°C with an inert material preheated to the same temperature. The process of sulfur modification is based on a chemical reaction of liquid sulfur with organic modifying agents, i.e. organic compounds preventing a decrease in the volume of sulfur in the process of its solidification. The developed sulfur modification process ensures a possibility for production of sulfoconcrete with strength properties exceeding by a factor of 1.5 to 2 the respective values of regular concrete. The second promising area for the use of sulfur is partial substitution of modified sulfur for more expensive bitumen. The sulfoasphalt manufacturing process comprises preliminary production of a sulfur and bitumen mixture with a sulfur content of 30% to 40%, which is then blended with inert materials using conventional techniques. Sulfoasphalt manufactured at a full-scale plant meets all requirements set to its strength properties for road paving.

3:40 PM Break

3:55 PM

Production of Elemental Sulfur from Metallurgical Gases by Direct High- and Low-Temperature Catalytic SO_2 Reduction: *Andrey V. Tarasov*[1]; O. G. Yeremin[1]; [1]Gintsvetmet

Technology has been developed for production of elemental sulfur from off-gas from autogenous smelting processes based on reduction of sulfur dioxide with natural gas with subsequent treatment of reduced gas containing hydrogen sulfide by the Klaus method. This technology has been applied on a commercial scale at the copper smelter of the Norilsk Mining and Metallurgical Complex for treatment of off-gas from the Vanyukov smelting process (PV). A specific feature of the proposed technology is preliminary wet treatment of gas, which is then sent to reduction in a pressurized hollow cyclone-type reactor. This technique permits production of high-grade sulfur with 99.85% purity. The design capacity of the sulfur manufacturing plant is 80,000 tpy. In the course of further improvement of the technology a catalytic version of the process has been developed based on the use of a catalyst at the reduction stage, which permits a decrease in the natural gas requirement by 25% to 30%.

4:20 PM

Production of Elemental Sulphur From SO_2: *Mahin Rameshni*[1]; S. Santo[1]; [1]WorleyParsons

WorleyParsons innovative SO_2 reduction process efficiently recovers sulphur from SO_2 streams. Effluent gases from ore roasters and smelters and coal-fired power plants can be treated to reduce sulphur emissions. This exciting new process is an innovative combination of well-established processes of reaction of CH_4 and sulphur vapor to produce CS_2, followed by catalytic hydrolysis of CS_2 to H_2S, and Claus reaction of H2S and SO_2 to sulphur. Key advantages are lower fuel consumption, reduced emissions, better product sulphur quality and better operational stability.

4:45 PM

Fluor SOx Cleanup Process: A Cost Effective "SO_2 to Elemental Sulfur" Technology for Global Green Environment: *Thomas Chow*[1]; Vincent W. Wong[1]; Theresa M. Flood[1]; John A. Gebur[1]; [1]Fluor Enterprises, Inc.

For the well-being of all living creatures and in response to green-environment policy from governments around the global, it is essential to reduce SO_2 emissions from mining/smelters as well as other industrial facilities around the globe. However, often times, these SO_2 containing flue gases also include oxygen and SO_3, which complicate the SO_2 removal process and technology. There are many novel technologies recently developed for removing SO_2 from such flue gases. Most of these, however, have not yet commercially demonstrated that they are technically viable and economically feasible. Many of these novel processes also generate undesired byproducts, which themselves then need to be disposed of in a safe and cost effective manner. Fluor has developed the Fluor SOx Cleanup Process with a wide variety of process configurations to customize removal of the undesired flue gas constituents in a cost-effective manner. The process removes practically all SO_2 in the form of salable elemental sulfur and also reduces CO emissions. Successful operation of major components of the Fluor SOx removal technologies has been demonstrated in many commercially operating units. Besides their technical viability and economic feasibility, Fluor SOx removal technologies do not generate any undesired byproducts or encounter SO_2 associated corrosion issues. Moreover, these technologies produce high-purity, saleable elemental sulfur. This paper discusses the merits of the Fluor SOx removal technologies, their technical and cost advantages, their simplicity in design and operation, and their readiness for implementation.

5:10 PM

Evaluation of the Effectiveness of a Gas Purging System in a Copper Anode Furnace: *Klaus Gamweger*[1]; [1]RHI

There are different reasons for purging a metal bath. The operations are varied, for example the purging gas can be used as a reactive gas being part of the metallurgical process or as an inert gas using the rising gas bubbles for agitation only. The different purposes for agitation, chemical and thermal homogenisation or a preferential movement of the slag to the slag skimming door have to be considered. It depends on the furnace type and its dimensions as well as the process characteristics what the focus is on. For an optimised arrangement of numbers and position of all single plugs in the furnace, mathematical modelling - the CFD Computational Fluid Dynamics method - is used. This paper shows how the operation of purging plugs can influence the metallurgical process of an anode furnace by the example of Jinchuan Copper in China. The potentials for savings in energy consumption as well as in time for oxidation and reduction are presented.

5:35 PM

Thermal Reduction of Vaniukov Furnace Sulfurous Oxygen-Bearing Off-Gas by Methane: *O. I. Platonov*[1]; [1]Gipronickel Institute JS

Method of high-temperature reduction of oxygen-bearing sulfurous gas has been developed at Copper Plant (CP) of MMC Norilsk Nickel' Polar Division with the aim of producing elemental sulfur from Vaniukov furnace' off-gas. Non-explosive reduction technology of oxygen-bearing sulfurous gas by methane utilized at Copper Plant has been designed to separate the processes of gas heating and sulfur dioxide reduction based on different kinetic of the reactions oxygen fixing and SO_2 reduction. First, natural gas promptly reacts with oxygen contained in the process gas to heat a gas mixture up to the temperature of sulfur dioxide reduction (~1200°C). Then isothermal reduction takes place within ~ 1 sec. Combustion chamber (pre-chamber) design developed based on the above principles is presented. The pre-chamber design is not directly associated with that of reduction reactor, so it may become a component of any reactor. Practical experience of the two reduction reactors operation at CP since 1996 proves high efficiency of the developed reduction process. The volume efficiency rises dramatically thanks to the fact that both fuel and reducing agent are fed into the reactor volume in the form of high-speed turbulent jets providing an intensive mixing of the reacting gases (at $Re \sim 10^6$). On condition of equal internal volume of the reactors, the developed process offers higher efficiency of reagent interaction resulting in sulfur conversion exceeding 90%, as compared to the equilibrium one.

Legal, Management, and Environmental Issues: Legal Perspectives

Monday PM Room: Kon Tiki Ballroom
August 28, 2006 Location: Catamaran Resort Hotel

Session Chairs: Migen Dibra, Quebec Court of Appeal; Florian Kongoli, FLOGEN Technologies Inc

2:00 PM Keynote

Influence of New Technologies and Globalization on Company Mergers, Acquisitions, and Joint Ventures, Antitrust and Competition Laws and Court Decisions: *Migen Dibra*[1]; [1]Quebec Court of Appeal

Antitrust and competition laws are designed to protect the free markets and promote competition in order to assure a dynamic and efficient economy and to provide competitive prices for quality products and services. They apply to mergers and acquisitions as well as to joint ventures especially among competitor companies who possess market power and these include collaborations on research and development. If it is determined that these actions are likely to substantially prevent or lessen competition the courts might dissolve, stop, alternate them, etc. Two new factors affect this process today: The role of new technologies and the markets globalization. They both have a considerable effect on the way these laws are interpreted by the courts and on their eventual amendments in order to reflect the new reality. A new applied technology may change the factors that determine how anticompetitive a merger or acquisition between competitors may be and may also serve as a basis for amending the antitrust and competition laws. In this paper, a review of the recent mergers and acquisitions of various companies has been carried out along with an analysis of the current antitrust and competition laws in the view of their capacity to handle the new reality. Some related court decisions in USA, Canada and EU are examined and several examples are given in order to illustrate the influence of new technologies on interpreting the existing laws and on their amendment possibilities. Suggestions are given on criteria of interpretations and amendments.

2:25 PM

Mining the Value from Your Intellectual Property Portfolio - The Strategic Role of Intellectual Property in Your Operations: *Jonathan A. Paul*[1]; [1]Tech Law Group, P.C.

The most profitable companies in the world recognize that a huge competitive and financial power lies in their intangible assets. The competition to be in command of raw materials and markets is now waged more and more over the exclusive rights to new technology and ideas. The value gained from mining the innovation in your organization and protecting your intellectual property can be enormous. This paper will address the following topics: 1) understanding the connection between your competitive position and intellectual property, 2) determining the value of your current portfolio and strengthening protection, 3) converting knowledge into assets and adding value to the operation, and 4) litigation strategies to enforce your position and achieve your business objectives. The presentation is designed for company executives and government managers who need to know how to identify and address core intellectual property issues that arise in the minerals, metals and materials extraction and processing industries.

2:50 PM

Patent Protection Strategies: *Mark W. Sajewycz*[1]; [1]Gowling Lafleur Henderson LLP

Creating technology, securing patent rights, and managing a patent portfolio are time-sensitive and dynamic activities. Agreements should be in place with technology partners (employees, contractors, joint venture partners), prior to embarking on research and development projects, so as to mitigate future disputes over patent rights. Technology partners should be educated on patent law basics so as to be mindful of patent bar triggering events. Accurate records must be maintained to capture information relevant for preparation and filing of patent application, including subject matter, names of inventors, and invention date. Developed inventions should be evaluated for whether to file for patent protection, delay patenting until technology is further developed, maintain trade secrecy, or effect deliberate public disclosure. Once decision is made to file for patent protection, time is of the essence, and application for patent protection should be filed as soon as possible, as many countries award patents on a "first-to file" basis. Decisions on where to file are made having regard to potential competitive advantages versus cost considerations, and can be delayed by taking advantage of priority rights recognized in patent legislation of most countries. Once patents are granted, competitors must be policed for potential patent infringement, and legal action may be necessary to prevent patent infringement.

3:15 PM

The Arbitration Process: *Thomas C. Frost*[1]; [1]Shustak, Jalil and Heller

In this time of market globalization, many industrial companies are including detailed arbitration clauses in their international contracts, in order to avoid the potential costs, delays, and uncertainties of litigation in foreign courts. Arbitration is less expensive and more flexible, procedurally, than court proceedings, and arbitral awards enjoy much greater international recognition than judgments of national courts. More than 134 countries have signed the 1958 United Nations Convention on the Recognition and Enforcement of Foreign Arbitral Awards, known as the "New York Convention", which facilitates the enforcement of arbitral awards internationally. There are several other similar arbitration conventions that provide for the enforcement of cross-border arbitral awards. Additionally, arbitral awards are not subject to appeal, whereas judgments of national courts are routinely subjected to a lengthy appeals process, and there are very few viable bases to challenge arbitral awards. This discussion will review key considerations in drafting arbitration clauses, including choice of law and choice of forum considerations; issues surrounding the selection of arbitrators; the discovery process; presentation of evidence; and enforcement of arbitral awards.

3:40 PM Break

3:55 PM

Transborder Legal Issues Concerning Intellectual Property Procurement, Protection and Enforcement: David M. Beckwith[1]; *John A. Hankins*[1]; [1]McDermott Will and Emery LLP

Increased globalization and outsource manufacturing complicate the procurement and enforcement of intellectual property rights on a worldwide basis. Recent legislative and case law developments in the United States highlight the importance of a multinational intellectual property strategy.

IP lawyers David Beckwith and John Hankins will discuss planning and pitfalls in this rapidly changing trans-border environment. Topics to be discussed include harmonization with international patent laws, protecting your technology and market space with a comprehensive approach to IP, and patent enforcement issues relating to import/export of products and components in the United States.

4:20 PM

Patent Litigation in the United States - An Overview: *John D. Kinton*[1]; [1]DLA Piper Rudnick Gray Cary, US LLP

A patent is a right granted by the government to exclude others from making, using, selling, offering to sell, or importing a claimed invention. Once the right is granted, the patentee may use the U.S. Federal Courts to enforce that right. Reading a patent from a litigation perspective is quite different than reading it from a technical perspective. The Judge's interpretation of the claims will affect their scope, and likely the ultimate outcome of a patent case. Additionally, the patent right can be challenged. If done successfully, the patent can be rendered invalid or unenforceable. The likelihood of success, and well as the achievement of other litigation goals is often influenced by the forum where the litigation is initiated. Finally, patent litigation costs are significant, and will weigh heavily in the decision to file (or fight) a patent lawsuit.

New, Improved and Existing Technologies: Aqueous Processing I: Leaching and Biotechnology

Monday PM — Room: Boardroom West
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: S. Komar Kawatra, Michigan Technological University; Rafael D. Padilla, University of Concepcion

2:00 PM Keynote

Pressure Leaching of Sulfidized Chalcopyrite in Sulfuric Acid-Oxygen Media: *Rafael D. Padilla*[1]; Daniel Vega[1]; Maria Cristina Ruiz[1]; [1]University of Concepcion

The recovery of copper from chalcopyrite concentrates by leaching is difficult due to the slow dissolution kinetics of this mineral in most leaching media. However, recovery of copper from sulfidized chalcopyrite (a mixture of CuS and FeS2) by leaching is faster and could be selective depending on the leaching media. In this paper, the result of an investigation on the H2SO4-O2 pressure leaching of sulfidized chalcopyrite is presented. The variables considered in the study were stirring speed, concentration of sulfuric acid, temperature, and partial pressure of oxygen. The experimental data indicated that stirring speed over 500 rpm and sulfuric acid concentration over 0.1 M had very little effect on the leaching rate. An increase in temperature from 90 to 100°C increased both copper and iron dissolution; however, further increase to 120°C affected negatively the copper dissolution. Oxygen partial pressure was found to be the main variable that controls the copper/iron selectivity of the leaching. An increase in oxygen partial pressure increased significantly the rate of copper dissolution but deteriorated the copper/iron selectivity. The analysis for sulfur of the leaching solid residues indicated that most of the copper sulfide sulfur in the sulfidized concentrate oxidized to elemental sulfur.

2:25 PM Invited

Agglomeration of Copper Heap Leaching Feed Using Acid-Resistant Binders: Kimberly A. Lewandowski[1]; Jeff Gurtler[1]; Timothy C. Eisele[1]; *S. Komar Kawatra*[1]; [1]Michigan Technological University

The benefits of agglomeration are well-known in gold heap leaching operations, which can be effectively agglomerated using binders such as Portland cement due to the alkaline leaching solutions used. However, agglomeration has not been very effective in the heap leaching of copper ores, because these ores require an acidic leaching solution. In order to gain the benefits of agglomeration in copper heap leaching, an economical, acid-resistant binder is needed. The two issues that needed to be addressed were: 1) Lack of effective methods for evaluating binder acid resistance before performing expensive, time-consuming, full-scale heap leaching tests, and 2) The vast majority of known binders react poorly to acid conditions, and so a basis was needed for determining which binders are most likely to be acid-resistant. In this paper, the development of two new tests for evaluating binder acid resistance in the laboratory are described. The "soak test" as a rapid means for comparing large numbers of binders, and the "percolation test" measures several different parameters to determine how a binder is likely to perform in heap leaching. Using these tests, a broad spectrum of binders were examined. Soak testing determined that the most acid-resistant binders were nonionic polymers. Five of these binders were further evaluated using percolation testing. Results of percolation tests are presented, and the reasons for the differences in binder performance are discussed.

2:50 PM

New Technology for Microbial Treatment of Chromium-Containing Slag: *Liyuan Chai*[1]; [1]Central South University

Chromium-containing slag was detoxified by the method of microbial treatment using Ch-1 bacteria isolated from nature by our research group, belonging to achromobacter sp. and with the characteristic of reducing high concentration of Cr(VI) in alkaline solution. The detoxifying process of Ch-1 to chromium-containing slag was studied by column-leaching and heap-leaching techniques respectively. The results indicate that Cr(VI) in leachate can not be detected when chromium-containing slag has been column-leached for 7 days, and Cr(OH)3 content of in precipitate is up to 32.8% with great value of resource recycling. Flowchart of engineering experimentation was ascertained based on the parameters of column-leaching experiments. Using the technique of pelletization of chromium-containing slag – heap-leaching by Ch-1, the leaching rate of water-soluble Cr(VI) existing in chromium-containing slag reaches up to 100%, while the leaching rate of full chromium is up to 90%, when the process has been operated for 7-10 days under the conditions of 25-40°C and consecutive spray by circular leachate. The content of Cr(VI) in chromium-containing slag after detoxified meet the national identification standard for extraction procedure inxicity for hazardous wastes(GB5085-1996), moreover approximately 90% Cr(VI) existing in chromium-containing slag has been recycled.

3:15 PM

Hydrometallurgical Approaches for Selecting the Effective Recycle Process of Spent Lithium Ion Battery: *Jeong-Soo Sohn*[1]; Shun-Myung Shin[1]; Dong-Hyo Yang[1]; Soo-Kyung Kim[1]; Churl-Kyoung Lee[2]; [1]Korea Institute of Geoscience and Mineral Resources; [2]Kumoh National Institute of Technology

Physical treatment and chemical treatment of spent lithium-ion battery were studied in our research team. Especially we developed two types of acidic leaching for crushed powders containing LiCoO2 of spent lithium ion battery. One of them is sulfuric acid leaching with H2O2 as a reducing agent. The leaching rates of cobalt, lithium and the other metals were above 99% at the condition of 2 M H2SO4, 10 vol. % H2O2, 75°C, 300 rpm agitation speed, 250 g/5L solid liquid ratio and 75 minutes reaction time. And the other leaching process is the oxalic acid leaching. In this process more than 99% of Li and less than 1% of Co were dissolved at the condition of 3M oxalic acid, 80°C reaction temperature, 300rpm agitation speed, 50g/L initial solid/liquid ratio and 90min extraction time. Each process has its advantage and disadvantage. In sulfuric acid leaching, leaching reagent is very cheap and cobalt could be recovered into cobalt hydroxide. On the other hand, oxalic acid is more expensive than sulfuric acid but lithium could be dissolved selectively. Also cobalt could be recovered into cobalt oxalate and it could be changed into cobalt oxide after heat treatment. In order to select the effective recycling process, recovery rate and purity of cobalt hydroxide and cobalt oxalate were compared and it was investigated which process was more environment-friendly and economical.

3:40 PM Break

3:55 PM Keynote

Pressure Leaching of White Metal as an Alternative to Conversion: *Maria Cristina Ruiz*[1]; Esteban Abarzua[1]; Rafael D. Padilla[1]; [1]University of Concepcion

In the processing of copper concentrates by the conventional smelting-converting technology, complying with the increasingly severity of environmental legislation in some countries has become difficult, mainly due to severe fugitive emissions of gases produced during the batch PS (Peirce-Smith) converting step. In this work, the results of an investigation on the pressure leaching with sulfuric acid and oxygen of white metal (produced in a Teniente Converter reactor) are discussed. The study was carried out at laboratory scale and the main variables studied were temperature, concentration of sulfuric acid and partial pressure of oxygen. The experimental results indicated that most of the sulfur in the white metal was oxidized to sulfate in the whole range of temperature studied (105°C to 150°C). The concentrations of sulfuric acid over 0.05M and oxygen partial pressure over 6 atm had little effect on the dissolution of copper from the white metal. On the other hand, temperature had the most significant effect on the copper dissolution; below 130°C, copper dissolution was incomplete after 5 hours of leaching while at 150°C the dissolution was complete in 90 minutes and 10 atm of partial pressure of oxygen.

4:20 PM

The Bacteria Leaching Process of the Low-Grade Sulfide Copper Ore: *Gang Xie*[1]; Jiangfeng Yan[2]; Haogong Zhang[1]; Rongxing Li[1]; Dajing Yang[2]; [1]Kunming University of Science and Technology; [2]Yunnan Metallurgy Group Ltd. Company

The leaching experiment used by bacteria on the low grade sulfide copper ore which is difficult to leach were carried out. Some leaching bacteria were isolated and domesticated. The bacteria have good physiological and leaching activity, and are adapted to leaching ore. The effective domesticated method was put forward. Some technique parameters, such as ore acidification, potential controlling leaching method, ore granularity, leaching acidity, leaching liquid quantity and acid consumption were obtained by column experiment and leaching ore in situ under the ore well. It could leach 30.62% of copper in the low-grade sulfide copper ore within 24 weeks by column leaching method, and the bioleaching rate of copper is 22.83% months by leaching in situ under the ore well. The results laid the foundations for improving the resource utilize ratio.

4:45 PM

Mechanical Activation of Monazite Processing by Its Simaltaneous Ball-Milling and Leaching: *Aly M. Abdel-Rehim*[1]; [1]Alexandria University

The present work deals with a study of mechanical activation of processing of Egyptian monazite by its simultaneous ball-milling and pressure leaching, to improve the recovery of thorium and lanthanides from monazite. Experiments of ball-milling and alkaline leaching of monazite concentrate were carried out in stainless steel ball-mills of cylindrical shape under different conditions. The ball-mills were heated and mechanically rotated in an electric furnace by means of roll mechanism. The effective rotation speed was fixed at 130 rpm in all tests. The charge of steel balls of different diameters was taken as 45% of the mill volume. Monazite was charged in ball–mill without preliminary grinding. It is found that high rate of monazite leaching by ball-milling method is reached at lower temperature, shorter time and lower expense of alkali than in autoclaves. The results obtained show that complete extraction of thorium and lanthanides from monazite (99.8%) by this method is attained at 140°C within 2 hours. It is concluded that processing of monazite by its simaltaneous ball–milling and leaching is mechanically activated and accelerated as a result of the grinding action of steel balls that caused the continuous removal of the hydroxide product from reacting particle surfaces. This leads to the exposing of fresh and activated monazite particle surfaces to alkaline leach solution and consequently the acceleration of the reaction of monazite processing. The ball-milling method shows many advantages such as: no preliminary grinding of initial ore and grinding and leaching are combined together in one process.

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Process for Selenium Recovery from Copper Anode Slime by Alkali Pressure Leaching: S. Saptharishi[1]; *Debabrata Mohanty*[1]; Balachandran P. Kamath[1]; [1]Hindustan Zinc Limited

Selenium, a 6A group element of the periodic table, constitutes about $7x10^{-5}$ % of the earth's crust. The copper ores are the richest source of selenium and various methods have been developed to recover selenium as a by-product from copper anode slime during copper refining. Selenium being amphoteric in nature, it is soluble in both acid and alkali. While acid roast process is widely used, considerable work has been carried out in Russia for recovering selenium through alkali route. This paper enlightens the process developed at Central Research and Development Laboratory, Hindustan Zinc Limited, for recovering selenium from decopperised slime through alkali pressure leaching. The decopperised slime is pressure leached with alkali under oxidizing conditions by which almost all the selenium present is converted to alkali selenate, which is easily separable from the rest of the decopperised slime. The solution so obtained is neutralized, during which, most of the impurities are precipitated out. Then selenium is precipitated in its elemental form upon purging sulphur-di-oxide under warm acidic medium. The purity of the selenium obtained by this process is higher than that of the selenium from acid roast process. Moreover selenium can be crystallized as sodium selenate and it can be marketed. The acidic content of the effluent is recovered and it is recycled back to the process. The sodium content of the effluent is converted into high purity sodium sulphate, which is marketable. The hazardous waste containing arsenic is precipitated as its sulphide and can be disposed off as landfill.

New, Improved and Existing Technologies: Recycling I: Batteries, Electronic Scrap, and Light Metals

Monday PM — Room: Toucan
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Farouk Tedjar, Recupyl SA; Tomio Takasu, Kyushu Institute of Technology

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2:00 PM Keynote

Recupyl Process for Recycling Lithium Ion Battery from Mobile Phones: *Farouk Tedjar*[1]; [1]Recupyl SA

Among the actual rechargeable systems, Lithium ion batteries have highest voltage and gravimetric energy density. Since their introduction 15 years before, this battery become today the most largely adopted for portable electronic devices. The composition of those batteries imposes a particular consideration of their end of life management due to the environment impact and valuable source of materials. In order to comply with these two parameters, the new Recupyl process was oriented to room temperature and pressure technology. This way avoids any greenhouse gases, acid rain potential gases and other emission and present an important CO2 credit in comparison with thermal processes.

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Processing of Spent Lead-Acid Batteries – Basis for Lead Recycling: *A. D. Besser*[1]; Valery M. Paretsky[1]; [1]Gintsvetmet

The world production of lead has been growing continuously and reached over 7 million tonnes in 2005. At the same time, the structure of lead consumption has changed: the use of lead compounds to liquid fuel has been virtually terminated, the proportion of lead used for rolled and stamped products has decreased substantially, the use of lead for manufacture of lead-acid batteries has been growing and reached 76.7% of the overall world production of this metal. This has taken place against the background of more stringent environmental norms and environmental legislation. This is due to the lack of an alternative for lead in manufacture of local power sources. A solution to the problem of meeting the industrial demand for lead

with simultaneous reduction in the primary lead production is in recycling. A large amount of batteries manufactured worldwide and their short life cycle, as well as the positive economics and a possibility to comply with the environmental requirements encourage the development of secondary lead production. Currently, over 60% of the world demand for lead is met due to recycling. The current situation with collection, transportation, storage and processing of spent lead-acid batteries has been analyzed in this paper. Examples are given to illustrate technological and equipment solutions and trends for improvement of secondary lead production discussed.

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Recycling of Spent Li/MnO2 Batteries: *Jitka Jandova*[1]; Jan Kondas[1]; [1]Prague Institute of Chemical Technology

Consumption of lithium primary batteries, namely Li/MnO2, batteries, is constantly expanding at a very fast rate. Disposal of spent lithium batteries may soon become a serious problem because these batteries are processed only in a few plants in the world using low-temperature process. During the last ten years a great number of research works concerning recycling of lithium-containing batteries have been published, but only few works are focused on processing Li/MnO2 batteries. The aim of this study was to propose and verify on a laboratory scale a simple processing of spent Li/MnO2 batteries in order to recover Li2CO3. This process is based on roasting Li/MnO2 batteries in a vacuum furnace, leaching of calcined electrode material in distilled water and controlled crystallization of pure Li2CO3. Experiments performed was focused on the determination of optimum roasting and leaching conditions, under which practically all lithium contained in the electrode material is transformed to Li2CO3 and dissolved in water solutions. Finally, a dependence between the degree of water evaporation from Li2CO3 solutions processed and the purity of the crystallized Li2CO3 was established to obtain pure Li2CO3 at simultaneous achieving its maximum yield.

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Recycling of Spent Ni-Cd Batteries by Physical-Chemical Processing: Carlos Alberto Nogueira[1]; *Fernanda Margarido*[2]; [1]INETI; [2]Instituto Superior Técnico

Spent Ni-Cd batteries contain in the electrode materials heavy metals like Ni, Cd and Co, which must be recycled due to environmental problems. Pyrometallurgy is normally used for recycling these end-of-life products. But alternative processes by hydrometallurgy, integrating also physical operations, can be used. Hydrometallurgy seems to be useful, because metals can be efficiently recuperated in chemical forms with commercial value. The economical viability of this recycling process can be improved increasing the treatment capacity, through the application to different types of residues with similar characteristics like Ni-MH and domestic batteries, or other residues containing Ni/Co, like sludges, dusts or spent catalysts. Spent Ni-Cd batteries were first physically processed using shredding and wet sieving operations. Best results were achieved using an output of 6 mm in the shredder and 1.7 mm in the separation by wet sieving, resulting a fine fraction with 70% of electrode material recovered which also contains 6% of the initial scrap. The acid leaching of the obtained material in the previous operation was studied, being the parameters like: temperature, H2SO4 concentration and the liquid/solid ratio (L/S) optimized. The values attributed to the factors which concerned the best results obtained on the leaching process were mainly influenced by Ni recovery. In opposition, Co and Cd were easily leached in a wide range of conditions. To attain an overall recovery, with minimum costs, of the three metals, the values of T~100ºC, [H2SO4]=2.3-2.7 M and L/S=8-10 L/kg were considered the most appropriate.

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Study and Development of the Physical Treatment of Spent Batteries in an Integrated Recycling Process: *Fernanda Margarido*[1]; Carlos Alberto Nogueira[2]; [1]Instituto Superior Técnico; [2]INETI

Recovery of metals contained in the electrode materials of batteries, was studied considering an integrated recycling process constituted by physical and chemical operations. The physical treatment included the shredding of the spent batteries, followed by a wet sieving operation of the fragmented material. The physical behavior of Ni-Cd and Zn-Mn based (alkaline and saline) system batteries were studied and compared. In that sense, shredding operation was performed testing three sieves with different apertures. For Ni-Cd batteries the contamination of electrode material with the scrap after the shredding operation was lesser using the 10 mm sieve, while different behavior was observed for the Zn-Mn batteries, where similar result was obtained with the 6 mm sieve. This difference can be explained by the composition of the case materials and the internal physical constitution of the electrodes. The wet sieving studies carried out allowed optimizing the separation of the electrode fine fractions from the scrap materials through the analysis of selectivity Cd/Fe or Zn/Fe. For Ni-Cd batteries, maximum selectivity was achieved at granulometry of 1.4 mm, while for alkaline and saline systems best selectivity were obtained at 2.8 mm and 5.6 mm, respectively. This process allowed the recovery of about 75% of electrodes with less than 5% of scrap as contaminant. This physical step can be considered as a pre-treatment of this type of waste material envisaging its valorization by chemical treatment, as improves the concentration of the elements of interest and decreasing the iron content.

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Utilization of Mn-Zn System Batteries: *Tinatin Lezhava*[1]; [1]R. Agladze Institute of Inorganic Chemistry and Electrochemistry

Recycling technology of spent Mn-Zn system batteries has been worked out and tested in laboratory and large laboratory scale (Georgian Patent #2003 3031). Compared to the analogies existing in the world, the utilization method is characterized by compactness of the technological scheme, simplicity, cheapness and what is most important the process runs at a room temperature (instead of 400-800°C). The proposed technological scheme includes the following basic operations: Breakage of the elements, hydro-vibrated treatment of broken up mass, electrolysis by using of alkali electrolyte. This method enables extracting at 200-220kg of zinc in or powder form 300-350kg of manganese concentrate and 130kg iron in the form of scrap, from each ton of the broken up elements. The products obtained from the reprocessing of the worked out elements can be used: 1) zinc – for metallurgical aims, in powder metallurgy, as reagent in chemical production and even in production of elements as one of the current produced materials, 2) manganese concentrate – for metallurgical aims, further treatment of this metal will cause the obtaining of metallic manganese of high purity, manganese sulfate, potassium permanganate and manganese dioxide and 3) scrap iron – in metallurgy.

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Efficient Processing and Utilization of Precious Metals Scrap: *V. A. Bryukvin*[1]; N. N. Vinetskaya[2]; A. M. Levin[2]; T. A. Makarenkova[2]; Valery M. Paretsky[1]; [1]Gintsvetmet; [2]Russian Academy of Sciences

At present, two classic approaches are used worldwide and in Russia for processing of electronic scrap, i.e. single-stage process using aqua regia dissolution and double-stage nitric acid and aqua regia dissolution. A hydroelectrochemical technology has been proposed and experimentally proven for processing metallic gold and silver-containing concentrates on the basis of copper and copper alloys obtained as a result of preliminary physico-mechanical upgrading of electronic scrap. The proposed technology is based on hydroelectrochemical leaching of scrap using reversible electric current and diluted nitric acid solutions, containing complexing agents, permitting complete separation of gold from the nonferrous matrix without involving gold in the process, and dissolving copper, zinc, lead and tin virtually without any emission of nitrose gases. The gold recovery into gold bullion of at least 99.9% purity by weight is 98.2%. The technology permits simultaneous recovery of up to 65% to 80% silver and up to 85% to 95% palladium. The developed technology with respect to its physicochemical basic principles is unique both for the Russian and foreign practice and provides a firm basis for establishing an integrated environmentally safe waste-less operation for processing of military and general electronic scrap.

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Information Methods of Non-Ferrous Scrap Sorting: *V. Bredykhin*[1]; O. Shevelyev[2]; E. Kazban[3]; V. Kostjuk[4]; V. Kushnerov[5]; [1]Donetsk Physics and Technology Institute of the NAS of Ukraine; [2]Technoscrap Ltd.; [3]Donsplav Ltd.; [4]Vtortsvetmet; [5]Technical University

The efficiency of scrap processing depends firstly on reliability of information about its chemical composition. The paper presents the results of the investigation and development regarding solid copper alloy scrap in the range of lump size 40÷300 mm. Nowadays the sorting of lump scrap is done by two methods: 1. Sorting according to metals and alloys is done at places of scrap generation, and further till metallurgical processing each lot has its "certificate"; 2. Hand sorting of scrap is done according to the marks on solid items in special shops using proximate analyzers or manually by experienced workers. This sorting process is labor - consuming low efficient and involves mistakes. The informational method is a promising trend in the copper scrap sorting. The method is direct, i.e. as a result of sorting the chemical composition of each scrap lump or main elements is determined, and assured data of qualitative and quantitative composition are received.

Thermo and Physicochemical Principles: Aqueous Processing: Leaching and Flotation

Monday PM — Room: Boardroom East
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Derek J. Fray, University of Cambridge; Mark Cross, University of Wales

2:00 PM Keynote

Computational Modelling of Heap Leaching Processes: *Mark Cross*[1]; Chris R. Bennett[1]; Diane McBride[1]; James Gebhardt[2]; David Taylor[2]; [1]University of Wales Swansea; [2]Process Engineering Resources Inc

Heap leaching is a very complex process, where typical ores might be predominantly copper based or complexes of gold, silver and copper. There is a significant challenge to develop comprehensive models of this class of processes that enable reliable predictions of how it will behave over the long term. This task involves appropriately formulated, parameterised and solution procedures for computational models of this family of processes to capture: 1) the liquid and gas flow through heterogeneous porous media structures subject to variably saturated flow conditions, 2) the complexity and possibly dynamically changing nature of the porous media structure, and the flow conditions of either or both the gas and liquid flows, 3) the transport of reactants and products of reaction in both the liquid and gas flow, 4) the simultaneous mass and heat transfer that occurs, and 5) the role of micro-organisms as a catalyst for reactions. Aside from this the second class of challenges here is to identify and then capture all the process data to characterise the reactivity of particular ores, the mine planning for the construction of the heap, leaching schedules, details of the water balance circuit, meteorological data, etc. This challenge is substantial in its own right. The objective of this paper is to outline these challenges and to describe how one such framework has been developed over the last few years, which can cope with arbitrarily complex geometries and provide tools for rapid process assessment.

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Acidic Leaching of Turkish Lateritic Nickel Ore: *Fatma Arslan*[1]; K. Tahsin Perek[1]; Güven Önal[1]; [1]Istanbul Technical University

The Çaldag lateritic nickel ore deposit is situated approximately 75 km north east of the port of Izmir in Western Turkey. The deposit is part of the series of deposits which lie on the Ophiolite belt which runs across the Balkan Region and Turkey. This deposit has a resource of 38 million tones containing 430,000 tones of nickel. The European Nickel PLC, the British company, developing a heap leach process for the production of nickel from laterites built a pilot plant at the Company's trial heap leach site at Çaldag in late March of 2005. The company expects to produce around 8 tons each month of nickel/cobalt hydroxide. The lateritic nickel ore sample subjected to this experimental study was taken from Çaldag ore deposit and contains 1.43%Ni and 0.105%Co. Mineralogical investigations showed that the ore sample contains asbolane ((Co,Ni)1-y(MnO2)2-x(OH)2-2y+2x. n(H2O)), chromite, limonite, hematite, goethite, lepidocrocite, magnetite, serpentine and clay type minerals together with chalcedon, quartz, calcite and chlorite. In the acidic leaching experiments, the effects of temperature, acid (H2SO4) concentration and leaching time on nickel leaching recoveries were investigated. Leaching recovery versus time curves showed a parabolic trend and increasing the temperature shifted that curves to the higher values. The highest nickel leaching efficiency as 71.2% was obtained at 80°C temperature, 100 g/L H2SO4 concentration and 6 hours of leaching time. Dissolution mechanism was also discussed.

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Gold Extraction from a Low Grade Ore Using the System of Metal-Ammonium-Chloride-Ammonia: *Shao-Hua Ju*[1]; Mo-Tang Tang[1]; Sheng-Hai Yang[1]; Yan Luo[1]; [1]Central South University

Although nowadays gold extraction methods are very abundant, none of them is satisfying, especially, in the field of heap leaching of low grade gold ore. The traditional heap leaching with cyanide plays an inglorious role of badly environmental pollution. In this paper, a bran-new and innoxious method of gold extraction system, metal-ammonium-chloride-ammonia (MACA), was proposed, and was also analyzed both thermodynamically and practically. In thermodynamic aspect, according to the principles of simultaneous chemical equilibrium and electronic charge neutrality, the thermodynamics of MACA system was studied by using the exponential computation method and through MATLAB programming, and the solid figure of its potential - c(NH4Cl) - c(NH4OH) was drawn. The results show that, when the concentration of ammonia is higher than 0.6 mol/L, fAu+/Au is only about -0.2 v. Thus using air, oxygen or hypochlorite as oxidant, Au can be leached out. In practical aspect, using hypochlorite as oxidant, the leaching results of a cuprous gold ore showed that the extraction of gold can reach to 80% in this system. The preliminary results of reduction of the rich solution with copper and zinc powders showed that with deoxygenizing, the reduction effects were relatively good. These new findings and results have established a theoretical and practical base for developing a new process for heap leaching of low grade gold ores in this system.

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Modeling Studies of Semi-Commercial Flotation Column for Beneficiation of Sillimanite Using Artificial Neural Network: *Vijay Kumar Kalyani*[1]; Pallavika[1]; V. J. Loveson[1]; Amalendu Sinha[1]; [1]Central Mining Research Institute

The present paper discusses a three layer feed forward artificial neural network (ANN) model, trained using the error back propagation algorithm, has been established to simulate the column flotation circuit used for beneficiation of Sillimanite. Parameters such as superficial air velocity, wash water rate, froth height, % solid, feed velocity, sodium silicate and oleic cid are considered as process operating variables and % yield of Sillimanite is the output of the experiment. The results from the ANN modeling, involving the non linear relationship between inputs and outputs, indicate good agreement with experimental observations. The network model validates the experimentally observed trends. The optimal model parameters in terms of network weights have been estimated and can be used for computing parameters of the process over wide-ranging experimental.

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The Leaching Kinetics of Phase-Transformed Chalcopyrite with Sulfate Roasting: *Song Ning*[1]; Chen Weiliang[1]; Du Jinhong[1]; Yang Bin[1]; Dai Yongnian[1]; [1]Kunming University of Science and Technology

The main mineral constituents of phase-transformed chalcopyrite are CuS and FeS2. CuS is more soluble than FeS2 in an acidic CuCl2 solution with presence of excessive NaCl, so that FeS2 could be removed as solid residue

from a leached solution. The experimental results showed that the efficiency of the copper leaching is heavily determined by the following two factors: a)The degree of the chalcopyrite phase transformation to CuS and FeS2; b)The concentration of Cl- during the leaching, specifically whether there is enough excessive Cl- existed. It was found that when the Cl- in the solution is not excessive, the slowest step of the leaching is the dissolution of Cu2Cl2.

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Adaptability and Kinetics of Gold Leaching from Different Ores in Alkaline Thiourea Solution with High Stability: *Yunyan Wang*[1]; Liyuan Chai[1]; [1]Central South University

In order to examine the adaptability and kinetics for leaching different gold ores in alkaline thiourea system, six kinds of gold concentrate or calcine with different physical and chemical properties were chosen as objectives. The leaching behaviors in alkaline thiourea system with high stability, acidic thiourea system and alkaline cyanide system were compared. Changes of phase, surface appearance, particle distribution and specific surface area of six kinds of gold ores before and after leaching were studied in virtue of modern analytic techniques, e.g., XRD, SEM, and so on. The results indicate that alkaline thiourea solution can be used to leaching gold ore, for 4# oxidized gold concentrate removed arsenic by microbe pretreatment the leaching rate of gold is up to 82.68%, such conclusion overthrows the parlance reported that pH value must be less than 1.78, or gold can not dissolve in thiourea solution. Chemical components and phase are in connection with gold leaching rate, different gold ores are fit for different leaching system, and alkaline thiourea solution are suitable for the pretreated oxidized gold ores with low content of sulfur and in which the main phase was SiO2, phase almost not change before and after leaching basically. Generally speaking, leaching in alkaline thiourea solution, surfaces of gold ores with glaze change greatly to ones with coarseness, distinct trace and holes of corrosion. Particle size decrease and specific surface area increase of gold ores after leaching in alkaline thiourea solution with high stability except 5# gold concentrate of Zhongyuan gold smelter.

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The Leaching of Metal Nickel in Copper Sulfate Solutions at the Presence of Oxygen and Chloride-Ion: *M. I. Kalashnikova*[1]; L. V. Volkov[1]; J. M. Shneerson[1]; E. G. Saltykova[1]; [1]Gipronickel Institute

The leaching of metal nickel in copper sulfate solutions is investigated. It is established, that irrespective of presence or absence of chloride-ion and oxidizer (oxygen) in system process can be divided into three stages, characterizing by restoration and oxidation of metals with formation of metal copper and cuprite and differing in the speeds of sedimentation of copper and transition of nickel into solution. At the initial stage of process along with allocation of metal copper it is besieged cuprite, that results in excess of speed of sedimentation of copper in comparison with dissolution of nickel. At the second stage speed of transition of nickel into solution falls practically to zero, and sedimentation of copper proceeds on reaction of interaction of metal copper with copper sulfate solutions with cuprite formation. During the final period speed of transition of nickel into solution exceeds speed of sedimentation of copper due to course of reaction of restoration of cuprite up to metal. Influence of an ion of chloride and oxidizer on formation of various phases is revealed. It is established, that presence of an oxidizer results in increase in a share of cuprite in a deposit. With increase of the maintenance of chloride-ion speed of metal copper allocation essentially grows even at presence of an oxidizer in system. On the basis of the data of X-ray analysis it is shown, that increase of extraction of nickel at its oxidizing leaching by copper sulfate solutions at the presence of chloride-ion speaks sharp increase.

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Evaluation of Lead-Zinc Flotation Tailings: *Fatma Arslan*[1]; Y. Aykaç[1]; K. T. Perek[1]; G. Önal[1]; [1]Istanbul Technical University

Aladag (Kayseri-Turkey) lead-zinc sulfide-oxide ores contain 10.17% Pb, 10.98 %Zn, 164 g/t Cd and 57 g/t Ag. During the laboratory scale flotation tests of these ores, it was found that almost all zinc was remained in the tailings that contain 11.4% Zn, 1.35%Pb, 198.3 g/t Cd, and 22.3%Fe. Three different methods were studied such as basic (NaOH) leaching, roasting+acidic (H2SO4) leaching and direct acidic leaching for recovering metals that these tailings contain. In the basic leaching tests, effects of solid/liquid ratio, amount of reagent (NaOH), and leaching time on zinc and lead dissolution efficiencies were studied where temperature and stirring speed were kept constant at 95±5°C and 400 rpm, respectively. In the roasting followed by acidic leaching tests, effects of roasting temperature, leaching temperature, solid/liquid ratio, acid concentration, and leaching time on metal dissolution efficiencies were investigated. In the direct acidic leaching experiments, leaching temperature and acid concentrations were the parameters tested. Results of these methods were compared and discussed in terms of metal dissolution efficiencies and reagent consumption. Dissolution mechanism was also discussed in relation to the mineralogy of ore. As a result of direct acidic leaching which gave the best results, zinc with 87%, cadmium with 81% and iron with 8.58% efficiencies were dissolved at the optimum leaching conditions while Pb remained in the leach residues. The leach liquors contained 9.0 g/L Zn, 16.1 mg/L Cd, 1.91 g/L and the acid consumption was 422.3 kg/ton of tailings. These results were combined with the flotation results of the Pb-Zn ore and a process flowsheet for the treatment of the Pb-Zn ore is proposed which partially started to be constructed in an industrial scale.

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Lead Carbonate Colloid Flotation Using Spargered Flotation Cells under Continuous Conditions: F. J. Tavera[1]; *R. Escudero*[1]; [1]Metallurgical Research Institute

The colloid flotation of lead carbonate precipitates in aqueous media is studied at a pH of 7. The flotation system consisted of five spargered flotation cells in a serial array. The flotation system was operated under controlled conditions of superficial air velocity, superficial liquid velocity, frother concentration, and collector concentration. The measured variables were gas hold-up, bubble size, superficial bubble surface flux, and lead recovery (reported to the concentrate). The experimental data show that is possible to separate as much as 97% (w/w) lead from the aqueous media when the superficial gas velocity is 1 cm/s and the superficial liquid velocity is 0.19 cm/s.

Thermo and Physicochemical Principles: Iron Making: Alternative Routes, Blast Furnace Coke and Coal

Monday PM — Room: Russeau Suite
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Yoshiyuki Matsui, Kobe Steel, Ltd.; Pinakin Chaubal, Mittal Steel Company

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2:00 PM Keynote

Gas-Solid Reaction Will Help Solid-Solid Reaction — Novel Iron Ore Agglomerate Bearing Semi-Coal-Char: *Tateo Usui*[1]; Hirokazu Konishi[1]; Noriyoshi Inoue[1]; [1]Osaka University

In the course of carbonization of coal under a rising temperature condition, volatile matter is released. The kind and amount of volatile matter released depend on the kind of coal. Components of volatile matter are tar, hydrocarbons (CH_4, C_2H_4, C_2H_6, C_3H_8), CO, CO_2, and H_2, which are released in this order as a function of carbonization temperature. When the carbonization of coal under a rising temperature condition is interrupted at a certain temperature, say T_c, semi-coal-char with residual volatile matter is obtained. If some optimum interruption-temperature is chosen, small but most suitable amount of volatile matter, namely H_2, is retained. We propose novel iron ore agglomerate bearing such semi-coal-char with some strength. While simple iron ore agglomerate bearing coal char will start the reduction reaction as solid-solid reaction at somewhat higher temperature, the proposed one will start the reduction reaction as gas-solid reaction at somewhat lower temperature but higher than T_c. Samples of semi-coal-char and novel iron ore

agglomerate bearing such semi-coal-char have been prepared and evaluated.

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The Kinetics of Hydrogen Reduction of Fine Iron Oxide Particles: *Moo Eob Choi*[1]; Hong Yong Sohn[1]; Gilsoo Han[1]; [1]University of Utah

The reduction of iron oxide particles by hydrogen is one of the most widely investigated gas-solid reactions. The search for new methods for producing iron by the direct reduction of iron oxide has resulted in a large number of exhaustive studies of the various aspects of this reaction. However, previous studies have largely been done with either pellets or lump ores. Little has been published on the hydrogen reduction of very fine concentrate particles of less than 37 µm (-400 mesh). The kinetics of hydrogen reduction of fine iron oxide concentrates were investigated to determine the feasibility of producing iron by a suspension reduction technology that uses hydrogen as the reducing agent. The experiments were done with samples of various particle sizes less than 37 µm (-400 mesh) at different temperatures and hydrogen and water vapor concentrations.

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A Laboratory Study of the Reduction of Iron Oxides by Hydrogen: *Damien Wagner*[1]; Olivier Devisme[1]; Fabrice Patisson[1]; Denis Ablitzer[1]; [1]School of Mines of Nancy

To reduce the emission of greenhouse gases by the steel industry, particularly for ironmaking, the production of DRI (Direct Reduced Iron) using hydrogen as the reducing gas instead of carbon monoxide is being considered. In this context, the reduction of pure hematite by hydrogen was studied at the laboratory scale, varying the experimental conditions and observing the rate and the course of the reaction. All the reduction experiments were performed in a thermobalance and supplementary characterization methods were used like scanning and transmission electron microscopy, X-ray diffraction, and Mössbauer spectrometry. The influence of rising temperature in the range 550-900°C is to accelerate the reaction; no slowing down was observed, contrary to some literature conclusions. A series of experiments consisted in interrupting the runs before complete conversion, thus enabling the characterization of partially reduced samples. Interpretation confirms the occurrence of three successive and rather separate reduction steps, through magnetite and wustite to iron, and illustrates a clear structural evolution of the samples. Finally, the influence of the sample type was revealed comparing a regular powder, a nanopowder and a sintered sample. The regular powder proved to be the most reactive despite its larger grain size, due to a more porous final structure.

3:15 PM Invited

Unsteady State Heat Transfer Analysis of Lower Part of Blast Furnace with Liquid Flow: *Tsunehisa Nishimura*[1]; Masaaki Naito[1]; Morimasa Ichida[1]; Shinroku Matsuzaki[1]; [1]Nippon Steel Corporation

Stable operation of the blast furnace needs adequate control of the lower part. To clarify the behavior of the lower part of the blast furnace with accurate consideration of the property of slag and its flow characteristic, a new mathematical model has been developed. Using this model, the effects of the change of operational conditions on the behavior of the lower part of the blast furnace were studied. Further, means to control of the lower part of the blast furnace, especially effective means to maintain adequate temperature, were discussed. And desirable slag property and composition, especially the upper limit of FeO concentration dripping from the bottom of the cohesive zone to avoid a decrease in temperature of the lower part of the blast furnace was quantitatively estimated.

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3:55 PM Invited

Advances and Understandings of Phenomena in Blast Furnace Hearth: *Pinakin Chaubal*[1]; Chenn Qian Zhou[2]; [1]Mittal Steel Company; [2]Purdue University Calumet

The blast furnace is a key component in an integrated steel mill. Since most current furnaces have reached their productivity limit, efforts to increase productivity and lower the cost must depend on the infusion of advanced technologies. One major driver for the technological development of blast furnaces is extension of their campaign life. A longer campaign life can significantly lower costs and increase productivity, because less blast furnace downtime would be needed for repairs and refractory relining. It is widely recognized that the main limitation for a long campaign life is the hearth wear, which is significantly affected by the hot metal velocity and temperature distributions and refractory temperatures. Because of the difficulty in making measurements inside the hearth, a new approach to gain fundamental understanding of the detailed physical and chemical processes in the hearth should be developed. In the last three years, a partnership has been established between the US steel industry and universities to develop an advanced computational fluid dynamics (CFD) model specifically for the blast furnace hearth. The 3-D CFD model is being utilized (1) to understand the phenomena in the hearth, (2) to understand the impact of changes in the internal conditions of the hearth on wear patterns; and (3) to design a monitoring/controlling system for prolonging campaign life. In this paper, the results will be reviewed.

4:20 PM

The Boudouard Reactivity Influenced by the Properties of Cokes and Experimental Conditions: *Jakub Kaczorowski*[1]; Tor Lindstad[1]; [1]Norwegian University of Science and Technology

In the production of Mn-alloys, the Boudouard reaction significantly influences the mass and energy balance. The endothermic nature of this reaction requires more energy for the process, while the direct consumption of carbon is reflected in the greater demand for carbonaceous raw materials. Therefore, it is desirable to eliminate or suppress the reaction. The kinetics of the Boudouard reaction are a function of many factors, of which coke properties and the conditions around the particles (i.e. temperature, gas composition) seem to be the most important. In the present study properties of selected single source and commercial metallurgical cokes are compared with reactivity results. The single source cokes represent a single coal that has been carbonized in a laboratory scale furnace. The commercial cokes are products of carbonization of coal blends under industrial conditions. The coke properties include proximate, ultimate and ash analysis. Also, coke petrography with carbon forms is included. The reactivity tests were performed on different particle sizes at various temperatures, gas compositions and gas flow rates. The experimental parameters were chosen to simulate conditions present in an industrial furnace. The results show that highly graphitized structure of cokes, minimal surface area and a low concentration of ash retard the reactivity. Of the other kinetics factors, the temperature and the gas composition have the greatest impact on the reactivity.

4:45 PM

Catalytic Effect of Some Inorganic Materials on the Gasification Reaction of Carbonaceous Materials: Masahiro Kawakami[1]; *Yu Takashima*[1]; Haruki Kamba[1]; Tatsuya Iwabuchi[1]; Toshihide Takanaka[1]; Seiji Yokoyama[1]; [1]Toyohashi University of Technology

In the bast furnace, the reduction of iron oxide and gasification of coke occur simultaneously. It is well accepted that the gasification reaction controls the simultaneous reaction. Therefore, it is important to develop highly reactive carbonaceous materials. It is also known that the reaction is accelerated catalytically with the addition of some materials. In the present work, the catalytic effect of iron, nickel and some other materials was examined. The pulverized sample of coke, graphite and some kind of wood charcoal was reacted with pure CO2 in a thermo-gravimetric balance. From the weight change, the reaction rate was obtained. In some experiments, the amount of adsorbed CO2 was estimated with transient kinetic technique. Some amount of iron, nickel and CaO powder was added to the carbonaceous materials. At 1023K, the reaction rate of graphite increased four times with the addition of 10%CaO. The catalytic effect decreased with the increase in temperature. The catalytic effect of iron and nickel were also obtained at lower temperature but not at high temperature of 1373K. The mechanism of acceleration will be discussed.

5:10 PM

Experimental Effect of Sulfur Removal in Coal with Fungus: *Dewen He*[1]; Wen-Ying Jiang[1]; Liyuan Chai[1]; [1]Central South University

The influence of coal desulfurization by fungus was experimentally studied. The present results suggest that fungus can effectively remove inorganic and

organic sulfur in coal, and main influence factors of desulfurization by fungus of pH value, temperature, coal slurry concentration and coal granularity are studied by orthodox experiment and the optimal experimental conditions are as following: pH value 6, temperature 45°C, coal slurry concentration 10% and coal granularity 100 μm. Under above conditions, fungus can remove up to 44.96% total sulfur and 54.87%inorganic sulfur within two days, and their desulfurization rates will be increase along with time. Compared to sulfolobas, desulphurization by fungus is steady and more effective, and has advantage of high speed.

5:35 PM

Use of Condition of Thermodynamic Equilibrium for Development of Mathematical Model of Blast Furnace Smelting: Andrey Nickolaevich Dmitriev[1]; *Daria Dmitrieva*[2]; [1]Institute of Metallurgy of the Ural Branch of Russian Academy of Sciences; [2]Ural State University

Limit of perfecting of blast-furnace smelting, minimum theoretically possible coke rate including in concept, is determined by thermodynamic equilibrium of oxidation-reduction reactions in separate zones of furnace. It is doubtless, interesting to know, as far as energy carriers are efficiently used in blast furnace smelting that is as far as process comes nearer to equilibrium value. To determine minimum (equilibrium) coke rate it is possible, for example, with help of mathematical model. In base of a mathematical model following premises are laid. Heat exchange in blast furnace is completed. In fixed zone of furnace on reduction stage of magnetite the reaction of wustite reduction aspires to thermodynamic equilibrium. This deduction it is made ground operational analysis more than 50 blast furnaces for 10 years. In this zone so-called zonal reduction when reduction of various iron oxides is combined on time is implemented. The solution of set of equations for bottom zone presented by condition of thermodynamic equilibrium, namely, equilibrium constant of wustite reduction by carbon oxide, material and thermal balances, supplemented by equation of heat balance for top zone, allows to calculate base indices of blast furnace smelting. Calculated thus indices are extreme accessible (minimum) at given parameters of charge and blast. Application of actual degrees of use of gas instead of equilibrium allows to calculate actual indices of blast furnace smelting. Use of mathematical model offered by us has allowed to develop original method of definition of efficiency of blast furnace operation.

Thermo and Physicochemical Principles: Nano and Composite Materials I

Monday PM Room: Russeau West
August 28, 2006 Location: Catamaran Resort Hotel

Session Chairs: Yoon-Bong Hahn, Chonbuk National University; Ray Y. Lin, University of Cincinnati

2:00 PM Keynote

Non-Catalytic Growth of ZnO Nanostructures: Growth Mechanism, Structural and Optical Properties, and Applications: *Yoon-Bong Hahn*[1]; Ahmad Umar[1]; Hyun-Wook Ra[1]; [1]Chonbuk National University

Different shapes of ZnO nanostructures such as nanowires, nanotowers, nanostars, nanoflowers, nanocomb, sea-urchin like nanowires, nano/micro spheres and cages, etc have been synthesized without the use of any metal catalyst or additives on various substrates such as Si(100), Si(111), ZnO/Si(100), and steel alloy substrates. The nanostructures of ZnO were quite dependent on kind of substrate and growth technique as well as the process variables such as temperature, concentrations of oxygen and zinc, pretreatment, and growth time. A cyclic feeding chemical vapor deposition (CFCVD) produced nanoneedles, nanostars and nanoflowers on Si substrates depending on growth condition, but thermal evaporation technique resulted in formation of nanowires, nanotowers, nanotubes etc. The structural and optical properties of ZnO nanostructures were examined using XRD, TEM, selected area electron diffraction (SAED), Ramman, and photoluminescence (PL). The high resolution TEM microscopy and SAED patterns showed that the grown ZnO nanostructures are single crystalline and grew along the [0001] direction. Appearance of sharp, strong and dominant E2 mode and suppressed E1(LO) mode in Raman spectra, for all the cases of ZnO nanostructures, indicated that the grown ZnO nanostructures have good crystal quality with the hexagonal wurzite phase. All the structures except micro spheres and cages exhibited a strong and sharp UV emission at 380 nm with very less or no structural defects. Based on observations, growth mechanisms of ZnO nanostructires were proposed and discussed in detail, depending on substrate and growth process. Possible application areas of the ZnO nanostructures were also proposed, especially for optical devices and biosensors.

2:20 PM

Liquid Phase Migration between Two Aggregates of Solid Particles Intermixed with a Liquid: *Peng Fan*[1]; Zhigang Zak Fang[1]; O. Eso[1]; H. Y. Sohn[1]; [1]University of Utah

A liquid intermixed within aggregates of solid particles tends to migrate towards a region composed of smaller particles and/or lower volume fraction of the liquid phase. The liquid migration in these systems occurs in a solid-liquid two-phase system. This phenomenon is similar to, but should not be treated as, a process induced by the capillary force which causes the imbibition of liquid into porous media. The capillary force is defined as the interaction among three-phase (solid, liquid and gas) interfaces. The liquid migration in a two phase system can be attributed to the driving force for the system to decrease its total interfacial energy. The thermodynamics and kinetics of this phenomenon is of great practical importance for many industrial processes, one of which is the liquid phase sintering of functionally graded composite materials. A recently published method for manufacturing functionally graded WC-Co composites involves creating a carbon gradient in the green state prior to liquid phase sintering. During the liquid phase sintering, the liquid phase volume fraction (i.e., the Co phase) at different locations within the material changes with time and forms a gradient. This paper describes a numerical simulation of the kinetic process of the formation of cobalt gradient during the liquid phase sintering, taking into account both liquid phase migration and diffusion.

2:40 PM

Processing of Al Alloy-AlN Metal Matrix Composites: *Vinod K. Namilakonda*[1]; Ramana G. Reddy[1]; [1]University of Alabama

In situ synthesis of discontinuously reinforced Al alloy metal matrix composites was investigated. Aluminum alloy (A356: Al-7mol%Si) was reinforced with dispersed AlN particles. AlN particles were synthesized via chemical in situ reaction in the Al melt by NH3 gas. Thermodynamic feasibility of AlN in A356 alloy was investigated using Gibbs energy minimization theory. Thermodynamic modeling was carried out to determine the equilibrium composition of various phases formed on adding NH3 to Al alloy melts in the temperature range 1173-1473K. Experiments were carried out in Lindberg furnace to form AlN in the molten A356 alloy at 1473K. Reinforcement in composites was varied from 5 to 35wt%.The products were characterized using SEM, XRD and optical microscope. Effect of processing parameters such as time and flow rate of NH3 gas on the composition of AlN formed in the composites was investigated.

3:00 PM

Silicon Carbide Composite DPF: *Yanxia Ann Lu*[1]; [1]Corning Incorporated

Porous silicon carbide (SiC) has been the top selection for diesel particular filters (DPFs) since 2000 because of its high thermal diffusivity and strong body, which help it to survive in the harsh environment of a diesel exhaust system. However, the process to produce SiC DPFs is a costly one. The work presented herein describes more cost effective composite materials for this application, namely Si-SiC and Si_3N_4-SiC. Both composites have shown excellent filtration efficiency, low back pressure and outstanding survivability of regeneration at high soot loadings. Since the composites are batched from silicon metal, they can be prepared by a low temperature process that is impossible in the production of pure SiC PDFs. In fact, fabrication of SiC composites simply involves reactions between nitrogen gas and silicon metal, or silicon metal bonded with SiC, and as such uses a much less costly

process when compared to the one employed to make SiC. In addition, the pore structure of the composites can easily be tuned by selecting raw materials and changing the ratio of two components. A typical pore structure consists of well connected pores with a median pore size of 5-20 μm and a porosity of 40-55%. This talk will describe the exothermic behavior as well as the mechanical and thermal properties of SiC composites in comparison to those of SiC filters. It will also show the superior thermal shock resistance of Si_3N_4 bonded SiC which is due to the unique combination of these phases that lowers the thermal expansion and elastic modulus relative to pure SiC.

3:20 PM Keynote
Effects of Some Anions on Crystalline of ZnS and CdS Nanoparticles: *Li Qihou*[1]; Bi Dandan[1]; Liu Zhihong[1]; Zhang Duomo[1]; [1]Central South University

During the preparation of ultrafine particles with hydrochemical methods, the growth of particles is a certain physical and chemical process, and their structures and morphologies are closely related to the symmetry of crystal structure, the mutual force among structural units, crystalline lattice imperfection and their growth environments. So the study on the structure and morphology control of ultrafine particles is not only concerned with the inherent crystal habits, but with the effect of physical and chemical conditions in the solution associated with crystalgrowing. In this study, ZnS and CdS nanoparticles were prepared by a homogenous precipitation method, and the effects of Sulfate ion, nitric ion and chloride ion on their crystalline were investigated individually. It was found that under the experimental conditions, anions have no influence on the crystalline of ZnS, but different crystalline CdS ultrafine particles were produced in different anion systems, where the blende-type CdS was obtained from natrate or sulphate solution, and wurtzite-type CdS was obtained from chloride solution. It was ascribed to the coordination of Cl- and Cd2+, which altered the supersaturation of the solution, the existing growth units and their connecting patterns.

3:40 PM Break

3:55 PM
Transport Phenomena in Nanomechanical Systems for Molecular Manufacturing: *David R. Forrest*[1]; [1]Naval Surface Warfare Center

In 1981, K. E. Drexler proposed using massively parallel nanomechanical systems to manufacture large atomically exact structures. As in macroscopic mechanical systems, they would contain components that serve traditional functions such as trusses for support, gears to transmit power, bearings for low-friction support of rotating surfaces, motors to supply torque, pipes and conveyor belts for material transport, and channels for coolant. Many of these components would only contain a few thousand atoms. Specific designs for these devices became available in the early 1990s, and a few working devices appeared in laboratories by the early 2000s. As advances continue, a thorough understanding of the operative transport phenomena will guide the intelligent design and construction of nanomechanical structures, devices, and systems. The familiar equations of continuum mechanics are generally inadequate to describe the flow of heat and mass in the proposed nanosystems. Boundary conditions often need to be described in terms of potential surfaces. Surfaces are not geometrically smooth, but periodic according to the locations of atomic nuclei. Friction occurs not due to the plastic deformation of asperities on mating surfaces, but to phenomena such as thermoelastic damping and phonon viscosity when atoms slide past each other. Electrostatic forces dominate over gravitational forces by orders of magnitude; there is no role here for natural convection. Structural components, no matter how stiff and strong, are in constant motion due to the thermal noise in the system. The fluids are described in terms of individual molecules in constant motion.

4:15 PM Invited
Wear of Dense Metal Matrix Composites: Pranav Deshpande[1]; *Ray Y. Lin*[1]; [1]University of Cincinnati

The wear behavior of metal matrix composites differs from that of the monolithic metallic counterparts. This has arisen from the nature of the composite materials having multiple constituents in the structure and differential degrees of wear exist among them. It was observed that under low wear stresses, abrasive wear prevailed. As the wear stress increases, pullout of reinforcement occurs and both abrasive wear and wear due to pullout contribute to the overall composite wear. A model of wear taking into account both types of wear has been developed. This model successfully predicts the wear behavior of dense copper matrix composites reinforced with tungsten carbide particles. A critical pullout wear stress was suggested for each composite. Below the critical wear stress, no pullout of reinforcement occurs. It turns out that the critical wear stress simply equals to the ratio of the interfacial strength between the matrix and the reinforcement to the friction coefficient between the reinforcement and the wear counter surface. The critical wear stress is independent of the particle size of the reinforcement. A pullout coefficient, η, defined as the ratio of the wear stress to the critical wear stress, is used to represent the degree of pullout during wear. When η is smaller than one, no pullout is possible. When η is greater than one, pullouts of reinforcement happen and composite wear enters a mode with both abrasive wear and pullout wear occurring simultaneously.

4:35 PM
Study of Corrosion Resistance of Nano Composite Coating on Sintering Nd-Fe-B Permanent Magnet: *Weihong Xu*[1]; Baizheng Chen[1]; [1]Central South University

After being pre-treated, composite electro-deposits of semi-brighten nickel-nano SiO2 with brighten nickel or with amorphous Ni-P alloy, and composite electro-deposits of Zinc were prepared on Nd-Fe-B magnetic material. The effect of cathodic current densities, nano- SiO2 concentration, stirring strength and surfactants on the corrosion resistance of electro-deposits were studied. Also surface appearance and structure of the composite coatings were analyzed by SEM. The present investigation shows that the corrosion resistance of composite electro-deposits of semi-brighten nickel-nano SiO2 with amorphous Ni-P alloy was the best, the solution system of semi-brighten nickel-nano SiO2 with brighten nickel was stable and its electro-deposits also had an excellent corrosion resistance, composite electro-deposits of Zinc not only had good corrosion resistance, but also had a low cost, so it was a good electro-deposits for medium or low-class Nd-Fe-B magnetic material.

Thermo and Physicochemical Principles: Non-Ferrous High Temperature Processing: Kinetics

Monday PM — Room: Russeau East
August 28, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Fabrice Patisson, Ecole Des Mines; Seshadri Seetharaman, Royal Institute of Technology

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2:00 PM Keynote
Gas-Solid Reactions: Towards New Frontiers: *Seshadri Seetharaman*[1]; Ricardo Morales Estrella[2]; Ioannis Arvanitidis[3]; [1]Royal Institute of Technology; [2]UMSNH; [3]Sandvik Mining and Construction

Reactions between solids and gas phase have many interesting theoretical aspects as well as technological applications. The present group had carried out experimental investigations as well as theoretical studies of a number of gas-solid reactions over the past decade and was able to derive interesting results. Studies of the decomposition of alkaline earth carbonates were carried out by thermogravimetric analyses. The experiments were carried out using thin powder beds as well as iso-statically pressed compacts with thermocouples embedded in the same. The investigations revealed the complexity of the reactions and the impact of the heat- and mass transfer aspects on the reaction kinetics. In the case of BaCO3, the kinetics of decomposition was complicated by the formation of a liquid phase. In the case of SrCO3, the reaction kinetics could be simulated by theoretical modeling. Gas-solid reactions were also employed as a versatile process tool towards the production of alloys and intermetallics involving transition elements by hydrogen reduction of complex oxides involving transition metals. Thin powder beds were employed to examine the micro-kinetics, while fluidized

bed technique was utilized to produce bulk alloys. Preliminary correlations could be drawn between the thermodynamic stabilities of the oxides and the activation energies of chemical reduction steps. Adjusting the process parameters, products at nano-scale could be produced. The structural, mechanical and thermal properties were investigated in the case of these products. The potentialities of this method as a green route to produce industrially important alloys and intermetallics with unique properties are demonstrated.

2:25 PM

Kinectic Studies on the Soda-Ash Roasting of Titaniferous Ores for the Extraction of TiO2: *Abhishek Lahiri*[1]; Animesh Jha[1]; [1]University of Leeds

Titanium dioxide is extracted from titaniferous ores by chloride and sulfate processes. These processes produce wastes in form of iron chloride, iron sulfate and rare earth oxides gangue, each of which has to go through a further treatment before it can be disposed safely, which may be expensive. The shortage of high-grade ores is also making the two conventional processes less efficient. In view of the above mentioned problems, an alternate beneficiation process of roasting titaniferous ores with soda ash is discussed. The advantage of this process is that, there is no production of wastes. The impurities present in the ore can be selectively separated after the roasting process. The roasting of titaniferous ores with soda ash was carried out between temperatures of 873K and1173K for several hours. The roasting process resulted in the formation of complex alkali compounds and various sodium titanate compounds, depending on the Na2CO3 to ore ratio. The phases formed after roasting were characterized using the X-ray powder diffraction (XRD), X-ray florescence (XRF) and scanning electron microscopy (SEM) techniques. The phase equilibria in the Na-Ti-O system are evaluated and compared with the phases obtained after the roasting process. The effects of temperature and the proportion of sodium carbonate on titaniferous ores are also discussed. From the experimental data, the kinetics and phase analysis data were analysed to ascertain the mechanism of overall reaction and the rate-limiting steps.

2:50 PM

Kinetic Modeling of MnO Reduction from Slags by Dissolved Carbon in Liquid Iron: *Jafar Safarian*[1]; Øystein Grong[1]; Leiv Kolbeinsen[1]; [1]Norwegian University of Science and Technology

A new kinetic modelling technique has been applied to study the rate of MnO reduction from slags by dissolved carbon in liquid iron. Based on a consideration of the fundamental reaction kinetics, a general differential equation for the slag reduction process has been formulated, which then is solved analytically for certain special cases. By re-writing the solutions in a dimensionless form the poorly known kinetic constants are eliminated, which makes model both flexible and applicable to a wide range of experimental conditions. For example, changes in process parameters such as temperature, metal composition, slag composition, gas composition can readily be captured along with variations in the crucible geometry. Based on a comparison with a series of experimental reduction curves being reported in the literature, it is concluded that the predictive power of the model is surprisingly good, yielding outputs that are both reliable and physically reasonable. An attractive feature of the model is that it provides an alternative way of calculating the activation energies from experimental reductions curves. For example, it suggests that the activation energy for the reduction of MnO by dissolved carbon in liquid iron is 154 kJ/mol, which is different with the previously reported activation energies. The model also suggests that the crucible geometry, which affects both slag volume and resulting slag/metal interfacial area, has a significant influence on the overall reduction kinetics. This design parameter is a key to further optimisation of the process on an industrial scale.

3:15 PM Keynote

Using Sohn's Law of Additive Reaction Times for Modeling a Multiparticle Reactor: The Case of the Moving Bed Furnace Converting Uranium Trioxide into Tetrafluoride: *Fabrice Patisson*[1]; Bernard Dussoubs[1]; Denis Ablitzer[1]; Jean Jourde[2]; [1]School of Mines of Nancy; [2]Comurhex

One of the major issues with multiparticle reactors is to handle their multiscale aspect. For modeling, it usually comes to coupling a reactor model (describing the phenomena at the macroscopic scale) with a so-called grain model (simulating the behavior of a single grain or a particle). An interesting approach proposed by H. Y. Sohn (1978) is to use the law of additive reaction times in order to calculate, approximately but analytically, the reaction rate of a particle in the reactor model. Its great advantage, compared to a numerical grain model, is to drastically reduce the computation time, particularly in the case of complex reactor models. This is the approach we retained for modeling the moving bed furnace, a counter-current gas-solid reactor used in the nuclear fuel-making route for producing uranium tetrafluoride from uranium trioxide. The numerical model we developed is 2-dimensional, steady-state and based on the finite volume method. It describes solid and gas flow, convective, conductive and radiative heat transfers, and six chemical reactions involved in the process. The law of additive reaction times is used to calculate analytically the rate of the three principal gas-solid reactions at every discrete point in the reactor. We have demonstrated the validity of this approach by comparing its results with those calculated from a numerical grain model. Also detailed in the paper are the main results of the moving bed furnace model itself and the possibilities of optimizing the process revealed by the calculations.

3:40 PM Break

3:55 PM Keynote

Physicochemical Criteria on the Mechanism of Gas-Solid Reactions Used in Extractive Metallurgy: *Ana E. Bohé*[1]; Daniel M. Pasquevich[2]; [1]Centro Atómico Bariloche/Consejo Nacional de Investigaciones Científicas y Técnicas/Universidad Nacional del Comahue; [2]Centro Atómico Bariloche/ Consejo Nacional de Investigaciones Científicas y Técnicas

Nowadays, Gas-solid processes are widely used in the industry. The chloration and carbochlorination of metallic compounds are some of this kind of non catalitic heterogeneous reactions. In particular those related with extractive metallurgy of refractory elements (Zr, Ti, Nb, Ta, RE, etc). The development of materials to be used in reactors at elevated temperatures and with high corrosion performance, enhance the application of this kind of processes. Although they are currently carried out in the production of many comodities, the mechanism of most of them are yet not well understood. The present work is a deep discussion on the most important aspects to take into account for determining the mechanism of gas- solid reaction, and those criteria fulfil in this analysis were applied to chlorination and carbochlorination examples. The microstructural characteristic of solids, the mass and heat transfer phenomenon, the adsorption and desorption of gaseous species on active surface, surface diffusion processes and chemical elementary steps, which are the mainly contributions to the mechanism of these reactions were analysed. Furthermore, the effect of them on the reactivity of solids and the control step of the reactions were determined. The application of catalitic mathematical models to this kind of reaction and the modification for the better interpretation of experimental results is also undertaken. The most appropriate experimental procedures for following these reactions and the microstructural characterization techniques needed to be use in each case, there limits and applicability are also indicated.

4:20 PM Invited

Modelling of Gas-Solid and Solid-Solid Reaction Kinetics: *Du Sichen*[1]; Seshadri Seetharaman[1]; [1]KTH

A number of metallurgical processes are based on gas-solid and solid-solid reactions. Gas-solid reactions often involve the chemical reaction step as well as the different diffusion steps for the reactants and products. Heat transfer is an important phenomenon in these reactions, where exothermic or endothermic reactions can lead to significant temperature changes at the reaction site. Solid-solid reactions are somewhat similar and can often be a part of the gas-solid reactions, where the solid product can react with the solid reactant. Both gas-solid as well as solid-solid reactions involve further complications like sintering, swelling, melting or cracking. In a number of cases of solid-solid reactions, it is necessary to design tailored experiments in order to evaluate the diffusion coefficients. In such cases, it is necessary to develop suitable models to describe the reaction results. The present paper presents the modeling of gas-solid reactions in the case of the decomposition of CaCO3, describing the reaction kinetics on the basis of heat-transfer concepts which could be compared with thermogravimetric results. In the

case of solid-solid reactions, the present paper describes the model developed for describing solid-solid reactions from dynamic X-ray diffraction technique, developed by the present team. The model has been successful in explaining the solid solution formation in the case of the system NiO-MgO as well as the formation of spinel from MgO and Al2O3.

4:45 PM

Oxidation of Molybdenite by Water Vapor: *Edgar R. Blanco*[1]; Hong Yong Sohn[1]; Gilsoo Han[1]; Kliment Y. Hakobyan[2]; [1]University of Utah; [2]Navro LTD

A thermodynamic and experimental investigation to develop a new process for converting molybdenite concentrate to molybdenum dioxide by a water-vapor oxidation process was carried out. In addition, the behavior of rhenium and selenium in molybdenum concentrate during the process was investigated. The kinetics of the reaction were determined by measuring the weight change of a sample with time in water vapor at temperatures between 900-1000°C. The results were analyzed by a Shrinking Unreacted Core model under chemical reaction control, which showed an activation energy value of 84.1 kJ/mol. To determine the behavior of rhenium and selenium, their concentrations in the molybdenum sulfide and the product molybdenum dioxide were measured by the use of ICP. While most rhenium remained with the molybdenum dioxide after the water vapor oxidation, almost all selenium volatilized. These results agree with thermodynamic analysis.

5:10 PM Keynote

Oxidation Removal Behavior of Boron and Local Nonequilibrium Reaction Field in Purification Process of Molten Silicon by Applying Flux Injection Technique: *Mitsuru Tanahashi*[1]; Masamichi Sano[1]; Chikabumi Yamauchi[1]; Kunihiko Takeda[1]; [1]Nagoya University

Oxidation removal behavior of boron from molten silicon by the CaO-CaF_2 flux powder injection was investigated from a viewpoint of process dynamics. This boron removal method is one of the nonequilibrium processes with oxygen gas injection, which is finished before the overall reaction system approaches the equilibrium state, with highly basic flux based on the high oxygen partial pressure locally established at the flux-O_2-Si interface. By applying this method, the boron concentration in the metallurgical-grade silicon (MG-Si) can be reduced to single-ppm-ordered level. In this study, the local nonequilibrium reaction field of boron oxidation at the interface was focused upon, and the effects of the kinetic energy of the flux particles injected into the silicon melt and the flux-O_2-Si reaction area on the boron removal behavior were discussed. From the results obtained, it was clarified that the kinetic energy of the flux particles is determined by the injection conditions, such as the flow rate of the oxygen carrier gas and the size of the flux particle, and that the boron removal rate is affected by this kinetic energy. At relatively higher oxygen gas flow rates, the injected flux particles have so high kinetic energy that they can break through the bubble formed at the exit of the injection nozzle, which resulted in the formation of a new reaction field of boron removal. On the other hand, at relatively lower gas flow rates, the formation of the reaction field is limited, resulting in the reduction of the boron removal rate.

5:35 PM

Effects of Mass Transfer in Evaporation Process of Alloy Components in Vacuum Processes: *Agnieszka Fornalczyk*[1]; Leszek Blacha[1]; [1]Silesian University of Technology

Since a several year time there is noted an increasing importance of the metallurgical vacuum technology. This refers mainly to the extrafurnace steel treatment processes, melting of steel and special alloys in the induction and arc vacuum furnaces, as well as refining processes of nonferrous metals. In the presented work, there is discussed a phenomenon of evaporation of volatile components of metal bath under reduced pressure with description of kinetics of this process. Presented are the possibilities for evaluation of the values of mass transfer coefficients in the liquid and gaseous phase. Basing on results of own research on removal rate of impurities from liquid copper (bismuth, lead) in vacuum refining process, determined is the thickness of hypothetical boundary layer in gas phase. This allowed to formulate a general kinetic equation defining the evaporation rate of gaseous components from metal bath. The values of overall mass transfer coefficients determined from this equation were compared with experimental results by other authors working on the evaporation effect of liquid components of metal alloys.

International Symposium on Sulfide Smelting: Smelter Projects

Tuesday AM
August 29, 2006

Room: Macaw
Location: Catamaran Resort Hotel

Session Chairs: Yutaka Yasuda, Pan Pacific Copper Company, Ltd.; Florian Kongoli, FLOGEN Technologies Inc

8:00 AM Invited

Expansion and Modernization of Onsan Smelters: Jong-Shin Chang[1]; *Han-Young Cho*[1]; [1]LS-Nikko Copper Inc.

LS-Nikko Copper Inc, has been operating its Onsan copper smelter since 1979. The smelter began its operation with a designed capacity of 80,000 tpa of copper from concentrates and its smelting capacity was increased to 140,000 tpa of copper by modifying the existing line in 1988. The Mitsubishi Continuous Smelting and Converting Process has been started since 1998 as the initial capacity of 160,000 tpa of copper. In 2002, the smelting capacity of Onsan smelter has been increased to 426,000 tpa of copper from concentrate. Now Onsan smelter has plans to increase its smelting capacity of Onsan smelter to 500,000 tpa of copper from concentrates by 2010. During the expansion work, the modernization of facilities will be accompanied by the increase of smelting capacity, especially in Outokumpu process. This paper reviews the brief history of smelting capacity increase in Onsan smelter and its modernization plans of Outokumpu process.

8:20 AM Invited

Expansion Project and Progress in the Sumitomo Metal Mining Toyo Smelter and Refinery: Yasuo Ojima[1]; Harumasa Kurokawa[1]; Katsuhiko Nagai[1]; Masaru Takebayashi[1]; *Keisuke Yamamoto*[1]; [1]Sumitomo Metal Mining Company, Ltd.

Sumitomo Metal Mining decided to expand cathode copper production capacity of Toyo Smelter and Refinery to cope with the recent copper demand growth in Asia, and to survive by reducing cost. The expansion plan is promoted to increase electrorefined copper production capacity from 270,000 metric tons in 2001 to 450,000 metric tons in 2007. The major changes in smelting section are introduction of the rotary steam dryer, renewal of the feeding system for flash furnace, improvement of the concentrate burner, modification of the flash furnace cooling materials, renewal of the slag cleaning furnace, modification of the flash furnace waste heat boiler, installment of a new converter furnace, enlargement of two anode furnaces. In addition, the gas cleaning system was upgraded and the second acid plant was installed. In the refinery section, the existing tank houses have been operated at high current density of 300A/m2 using the conventional starting sheet cathode technology and moreover a new tank house utilizing the permanent cathode technology was constructed. Although the copper production capacity has been increased, SO2 emission has been kept the lowest in the world through consideration of influence on the environment by expansion project.

8:40 AM Invited

Operation Change by the Introduction of Slag Cleaning Furnace: Motomi Furuta[1]; Souichirou Tanaka[1]; Makoto Hamamoto[1]; *Hiromichi Inada*[1]; [1]Hibi Kyodo Smelting

Tamano Smelter of Hibi Kyodo Smelting Co., Ltd. has been continued operation without a slag cleaning furnace (SCF) by our own coke combustion technology since the start-up in 1972. Its technology has developed in the Tamano Type Flash Smelting Furnace (T-FSF). The coke combustion technology, which is the core of the process, and the other technologies such as the installation of the computer guided system and the improvement of the concentrate burner combustion in the T-FSF have contributed to the continence of copper loss in slag without SCF. However, according to short settling time due to high concentrate charge rate and high matte grade in the T-FSF recently, copper loss in slag has become difficult to maintain in lower level. Furthermore it is estimated that it will increase after next production expansion, because the reduction effect for the settler will come to be smaller by the diminution of coke charge with higher matte grade operation (67%). Therefore, in order to maintain the copper loss in slag within the proper level, the installation of SCF was decided. In this paper, it is mentioned the change of operation before and after the introduction of SCF, with some theoretical considerations of slag chemistry.

9:00 AM Invited

Experience and Success with BSF Lead Smelting in Nordenham, Germany: *Ulrich Kerney*[1]; [1]Metaleurop Weser GmbH

In 1996, bath smelting technology for lead recovery from concentrates and secondary materials was introduced in Nordenham to replace the common sinter plant/shaft furnace operation. Since start-up, a continuous improvement of equipment and operation lead to a steady increase of capacity and plant availability. The decision to skip the reduction stage for slag treatment now allows the treatment of 200000 t/a feed materials with a secondary fraction of up to 70%. The main feed source for the furnace is automotive battery recycling, which offers oxide paste and metallics to be molten under oxidizing conditions in the lance fired furnace. The lead bullion is transferred to the refinery, where copper, silver and other impurities are removed. Silver is recovered as doré quality. All loopings are recycled to the BSF. Inert feed material is collected in a so-called lead concentrate of metallurgical origin, which is sold. It is rather a valuable feed material for further processing than a slag. The off-gas is cooled in a flux flow system, entering then an electrostatic dust precipitator. Having passed a further washing and cooling system, SO2 is oxidized and collected and sold as concentrated sulphuric acid. The presentation will cover a review of the start-up phase, the development of significant production parameters over the last years and actual production routes and figures. A comparison of environmental data between new and old applied technology is made.

9:20 AM Invited

Yunnan Copper's ISASMELT - Successful Smelter Modernization in China: Yifeng Shi[1]; *Philip S. Arthur*[2]; [1]Yunnan Copper Company, Ltd.; [2]Xstrata Technology

The ISASMELT process is a submerged lance smelting technology operating in smelters in Australia, the USA, Belgium, India, Germany, Malaysia and China. Further plants are under construction in Peru and Zambia. Initially developed at Mount Isa Mines, Australia, the technology is marketed by Xstrata Technology. Yunnan Copper Corporation (YCC) commissioned the first copper ISASMELT furnace in China in 2002. The plant quickly ramped up to design capacity and the first campaign lasted over 2 years. Now into the second campaign, the furnace is exceeding the original design capacity and YCC has won numerous awards for its contribution to reducing emissions and energy consumption. YCC and Xstrata put great effort into managing the design, construction and commissioning of the smelter. Xstrata's technology was combined with YCC's novel management approach. This effort has been repaid in terms of the outstanding performance of the plant since startup. This paper updates the reader on the first few years' operation of the YCC ISASMELT plant and discusses the way in which the technology was transferred, leading to fast rampup and, as a result, enhanced profitability for the operators.

9:40 AM Break

9:55 AM Invited

Commissioning of the Ausmelt Lead Smelter at Hindustan Zinc: Ross McClelland[1]; Ross Andrews[1]; *Brian R. Baldock*[2]; [1]Ausmelt Ltd; [2]Hindustan Zinc Ltd

Hindustan Zinc Limited (HZL), a Vedanta Resources group company, is one of India's leading base metal producers. HZL activities range from exploration, mining and ore processing to smelting and refining of lead, zinc, cadmium, cobalt, copper and precious metals. It is also an important producer of sulphuric acid. As part of its recent expansion program for the Chanderia complex, HZL installed a new Ausmelt lead smelter of 60,000 MT per annum capacity. The Ausmelt furnace at HZL was designed to produce crude lead bullion and a zinc rich fume in a three stage batch operation smelting local concentrates, and revert materials from within the existing Chanderia complex. This paper discusses the commissioning and initial operations of the Ausmelt furnace at Hindustan Zinc.

10:15 AM Invited

Expansion of Gresik Copper Smelter and Refinery: Mineo Hayashi[1]; *Nozomu Hasegawa*[1]; Budi P. Handogo[1]; Anthonius Prayoga[1]; [1]PT Smelting

Gresik plant, PT Smelting, is the first and only one copper smelter and refinery in Indonesia, with the original design capacity of 200,000 tpy of LME grade A cathode production, by treating copper concentrates mainly coming from Grasberg mine in Papua, Indonesia. The smelter employing the Mitsubishi process was put into operation at the end of 1998, then the refinery capacity was expanded up to 259,000 tpy in April 2004 in order to meet with soaring demand of copper cathode in South East Asian market. In addition, the construction work for the second refinery expansion project to have additional 12,000 tpy capacity, in total 271,000 tpy, was already started, and it is scheduled to be completed in July 2006. This paper describes the chronology of the expansion and future operational strategy of Gresik plant.

10:35 AM Invited

Recent Operational Improvements at Saganoseki Smelter: Yoshiaki Suzuki[1]; Fumio Hashiuchi[1]; *Yutaka Yasuda*[2]; [1]Saganoseki Smelter and Refinery, Nikko Smelting and Refining Company, Ltd.; [2]Pan Pacific Copper Company, Ltd.

In 1996, Saganoseki smelter and refinery successfully shifted to single flash smelting furnace operation, while increasing the copper production capacity to 450,000mtpy in 1998. As the next step, Saganoseki planned the further productivity increase in the smelting process. Applying the latest technology and carrying out the technological innovation, the throughput of the flash smelting furnace has been increased to 195 tons per hour and the matte grade has been raised to 68%. Six PS converters have been successfully consolidated into four in 2005, maintaining the production capacity. This paper introduces recent operation conditions and results with technological improvements implemented.

10:55 AM Invited

SPCC's 1,200,000 tpa ISASMELT Copper Smelter: Henry Walqui[1]; Carlos Noriega[1]; *Phil Partington*[2]; Gerardo Raul Alvear; [1]Southern Peru Copper Corporation; [2]Xstrata Technology

Southern Peru Copper Corporation (SPCC) are currently modernizing the Ilo copper smelter. A single ISASMELT furnace will start smelting 1,200,000 tonnes per year of concentrate during the second half of 2006. The existing Peirce Smith converters are being upgraded for converting the matte to blister copper and a new acid plant and oxygen plant are being installed. Two new anode furnaces and a twin anode casting wheel have been installed in 2005 and commissioned in January 2006. The modernization project will ensure the smelter satisfies new environmental regulations due to come into force in January 2007.

11:15 AM Invited

The Slag Cleaning Technologies for One-Stage Flash Smelting of KGHM Polska Miedz Concentrates: *Jozef Czernecki*[1]; Zbigniew Smieszek[1]; Zdzislaw Miczkowski[1]; Norbert Kubacz[1]; Jerzy Dobrzanski; Janusz Staszak[2]; Leszek Byszynski[2]; [1]Institute of Non-Ferrous Metals; [2]KGHM Polska Miedz S.A.

Chalcocite-bornite concentrates of KGHM contain, similarly to chalcopyrite concentrates, 20-30% Cu but several times less iron (2-7 wt.%) and sulphur (9-12 wt.%). Another useful characteristic of KGHM concentrates is the presence of organic carbon (5.5-8.5 wt.%) in them, which serves as fuel in the flash smelting process. The main contaminants of the concentrates are lead (1.3-2.5 wt.%) and arsenic (0.05-0.4 wt.%) which require appropriate technological treatment in order to remove them from the copper product. Chalcocite-bornite concentrates are processed in KGHM by two different processes: a flash smelting process (Glogow 2 Smelter); a shaft smelting process (Glogow 1 Smelter, Legnica Smelter). The shaft smelting process used in the Glogow 1 Smelter and in the Legnica Smelter has higher production costs than the flash smelting process of HM Glogow 2. Additionally, the shaft smelting process employs several concurrently running installations (six dryers, seven briquetting lines, six shaft furnaces, nine converters), the operation of which, including maintenance, requires significant financial expenditure. Therefore, the Company is currently considering the substitution of the shaft furnace process in the Glogow 1 Smelter and in the Legnica Smelter by the one stage flash smelting process located in the Glogow Smelter, with output equaling the copper production capacity of both smelters, i.e. 320 000 – 350 000 t/a. There are two technological options being considered which differ from each other in their manner of flash slag cleaning.

Legal, Management, and Environmental Issues: Business Management

Tuesday AM
August 29, 2006

Room: Kon Tiki Ballroom
Location: Catamaran Resort Hotel

Session Chairs: Bhaskar Yalamanchili, Gerdau Ameristeel; Pedro A. Morales, Codelco

8:00 AM Keynote

Norddeutsche Affinerie AG: Europe's Leading Copper Producer: *Peter Willbrandt*[1]; [1]Norddeutsche Affiniere AG

Norddeutsche Affinerie's routes date back to the 18th century. NA was established in 1866 as a joint stock corporation. NA's core business covers the production of copper cathodes from primary and secondary raw materials and the processing of them into wire rod and shapes. Part of the shapes are processed into pre-rolled strip and shaped wires within the Group. With some 3,200 well qualified and highly motivated employees, the NA Group produces some 560,000 tonnes of copper cathodes, 370,000 tonnes of wire rod, 230,000 tonnes of shapes, 130,000 tonnes of pre-rolled strip as well as 70,00 tonnes of strips and shaped wires annually. NA's product range is complemented primarily by precious metals, selenium, sulphuric acid, lead and nickel sulphate. The paper will give an insight into the performance of NA and its business units with regard to production, environmental and health protection and occupational safety.

8:25 AM Invited

The Managing System: How to Get Your Dreams to Work: *David A. Army*[1]; [1]Strategic Asset Management Inc.

Many times, we as Maintenance professionals have been involved in changes to processes or systems. Often we relied on seat of the pants knowledge to determine whether or not we were successful. More often than not, once our attention has been turned to other endeavors, the initiative has floundered. This paper will describe those measures that can be most effectively used to track and manage the success of implementing an improved Work Management System. However, not only will the paper discuss traditional work indicators, it will also explain how to establish the behaviors in the work place that will ultimately ensure successful implementation. Combined with the discussion on indicators will be a discussion on how to tie them to bottom line results and display them in the form of a scorecard. Actual results will be discussed.

8:50 AM

The Optimax Program - The Optimal Relationship for Owner/Clients to Procure Industrial Services: *Neil Smith*[1]; Laura Taylor[1]; [1]Auburn Industrial Services Ltd

Mineral processing plants typically procure a range of industrial services from contractors. Their satisfaction and value received is directly affected by how the services are procured, rationalized and delivered. Traditional purchasing strategies often focus on price rather than on optimizing the service relationship between supplier and customer. The nature of this relationship may have the greatest potential to reduce costs and enhance production. It has been documented that a service involves simultaneous production and consumption. A high degree of customer involvement is often necessary for a successful outcome and the expectations and attitudes of the customer can positively or negatively affect delivery of the service. This indicates that the customer can enhance or diminish their own satisfaction and value received and the supplier cannot act alone for best results. The Optimax Program for industrial services is a service delivery framework whereby a customer and supplier work together to raise the efficiency of the service exchange.

The Optimax Program is intended to help the customer optimize costs and maximize production by connecting the customer and supplier through shared information and objectives. This paper will review traditional procurement strategies for services and identify their pros and cons. In addition, the paper will outline the Optimax Program and highlight its features. Some actual case studies will be used to illustrate the successful results of the program.

9:15 AM Keynote
Development Plan for the Codelco-Chile's Smelter and Refinery Business: *Pedro Morales*[1]; Roberto Mac-Kay[1]; Hector Recaval[1]; [1]Codelco-Chile

Current Codelco's smelter and refinery (Smelt and Ref˙s) business has growing complexities, concentrates with lower copper grades, higher impurities contents, and strong environmental restrictions which have led to refocus the Codelco business, not only by considering the isolated developments for each of the Codelco's Smelt and Ref complexes but in an integrated corporative scheme which takes advantages of the economy of scale, optimizes the synergies, and includes new technologies for higher productivity and lower operational costs. Accordingly, for the 2008-2012 period, Codelco has prepared a Development Plan integrated to the Smelt and Ref˙s business units that improves its single potentialities, includes the last advances achieved by the Teniente Converter and Continuous Converting Technologies, and includes the concept of uncoupling the smelting process from the converting process with a higher operational flexibility and better control of its contaminants. Thus processing the white metal generated in the Teniente Converter unit of the smelter A into the smelter B has comparative advantages. These changes in the business concept increases the overall smelting capacity by processing only white metal as a final product through a very marginal investment, by eliminating the total or partial white metal conversion into blister copper and by using the available gas capture-treating capacity and the available acid plants.

9:40 AM Break

9:55 AM
Short Term Forecast of Metal Prices: Commercial Application for Operation on Forwards and Optimization the Hedging: *Boris Arlyuk*[1]; [1]Alumconsolt Ltd

The system of short term forecast of metal prices at LME is based on correlation between prices within the quarter forward and at the first place by economic parameters at the West, determining the consumption of metals. Such economic parameters are presented by data of indexes of Western World industrial production (WW IP), official data of IP and Dow Jones indexes at USA. For price forecast within the quarter forward (one day ahead, 3 day -65 days MA forward prices) are significant the changes of actual prices (official and close) at the past and the parameters of daily trade at LME at the past (futures turnover, open interest, LME stocks). It is developed subsystem of price forecast within the quarter forward based on analytical approach determining the relations between the participants of the market. It gives the opportunity to reduce the number of empirical coefficients at the model and receive good accuracy of forecast the MA prices and its direction at the future. Very important part of short term forecast is subsystem determining analytically the probability that the price forecasted for the next trading day will be the maximum or minimum daily price within the quarter forward. The thresholds probabilities are defined by identification the model at the past by maximal commercial efficiency. Such system was tested at the past at period since 2000 till 2005 and gives very high commercial results at operations on 1M forwards and hedging the sales of nonferrous metals traded at LME (primary aluminium, light alloys, nickel, copper, zinc, lead and tin).

10:20 AM Keynote
Systematic Approach to Rod Mill Technology Upgrade Decisions at Gerdau Ameristeel Beaumont: *Bhaskar Yalamanchili*[1]; [1]North Star Steel Texas Inc

Gerdau Ameristeel Beaumont presents its systematic approach for upgrade decisions that has developed over 30 years of ongoing capital projects for quality and cost improvements. This system serves to identify product needs, select process improvement strategies, justify them, and assist multi-department communications and decision-making. This is illustrated with Beaumont mills' last Stelmor upgrade and leads to a discussion of the need to consider Life Cycles of both products and technologies as we move to answer the challenges of the future.

10:45 AM
An Alternative Approach to Completing Furnace Rebuild Projects: *Mike Santaluce*[1]; Neil Smith[1]; Sandy McKinty[1]; [1]Auburn Furnce Services Inc.

Smelting furnace rebuild projects often require a significant capital expenditure and an extended smelter outage. Increasingly, smelter operators are searching for methods and initiatives to shorten overall furnace rebuild outage schedules and contain costs. This paper discusses a "Partnership Model' for completing furnace rebuilds; a project driven approach which Auburn has developed in response to the need for shorter schedules and manageable costs. The Partnership Model for completing furnace rebuild projects is based on assembling the key project team members at the start of the project life cycle: the owner/client manager, the project/construction manager and the design engineering team. This is in contrast to the traditional EPCM method in which the client first hires the design engineering firm. As engineering nears completion, materials are procured and the construction manager/constructors are hired after a tendering process. In the Partnership Model, all of the key project participants are assembled at the start of the design phase and have input into the overall project planning. This paper will discuss the Partnership Model and the project driven approach for furnace rebuild projects. It will discuss the project management discipline and the importance of modern day project management theory and best practices in the context of the Partnership Model. The paper will identify the merits and challenges of the model and study the use of similar approaches that have succeeded in other industries. The paper will conclude with a case study on the application of the Partnership Model to a furnace rebuild project.

11:10 AM Keynote
Innovations in Performance Management of Integrated Hydrometallurgical Plants: *Osvaldo A. Bascur*[1]; Roberto Linares[1]; [1]OSIsoft, Inc.

Several new hydrometallurgical plants have been built in the past years. They have implemented new processes to treat new type of ores. New technologies have been used to improve metallurgical performance from the start. The cycle times between knowledge generation and innovation are often neglected in the traditional capital expenditures and building of new plants. The paper reviews several implementations in which they have started with new ways of using operational information management. Innitiatives to assist in the implementation of mine to product strategies, metallurgical mass balances, solvent extraction composition statistical process control, methods to minimize organic losses, reduce variable costs and to improve metal extraction are presented.

11:35 AM Invited
Education and Research in the COE on Nature-Guided Materials Processing: *Ken-Ichi Miyazawa*[1]; Shigeo Asai[1]; [1]Nagoya University

Our Nature COE was selected in 2002 as one of the 21st Century COE (center of excellence) in fields of chemistry and materials science and supported by Japanese Ministry of Education, Culture, Sports, Science and Technology. In the Nature COE, under collaboration with researchers in four departments relating to the fields of chemistry and materials science in the university, a new field of material research is being developed through learning the laws of nature, namely, methods of attaining "appearance of the maximum function under the minimum substance and energy consumption", which the nature and living organisms have acquired through their evolution in long period. In the presentation, the education and research in the Nature COE will be discussed. This COE is opened for the outside of the university through an "Open-Cluster Program", which is originated for promoting researches by 23 groups consisting of young researchers in and out of the university and also for fostering them, together with such educational programs for Ph.D. students as research incentive and oversea training programs. Through conducting these programs, world-highest intelligent fruits and a gathering of young minds for leading new fields will be expected.

12:00 PM Invited

Macromanagement of Metallurgical Industries: *N. Lohja*[1]; Z. Lleshi[2]; O. Gliozheni[3]; [1]Polytechnic University of Tirana; [2]General Directorate of Mines; [3]University of Tirana

Macro management of metallurgical industries becomes an important issue in certain situations especially when some government owned metallurgical industries are on the verge or have stopped being feasible. In these cases a government lead macro management is decisive in order to steer them to a profitable path. This process is not necessary an easy one and incorporates many unknowns and various alternatives. In this paper the macromanagement of the metallurgical industries in Albania will be described as a particular case and various published data will be analyzed. As a country with many mineral resources, the exploration, research, exploitation and processing work of mineral ores before 1990 constituted an important activity of its economy, especially in the exportation of various products of this industry. Since 1990 this activity slowed downs considerably for various reasons and this prompted the necessity of a government lead macromanagement. This process aims atimproving and renewing the technologies in the metallurgical industry in order to transform it in to a feasible branch of economy. This goal is being implemented among others through the transformation of the ownership from a state-owned property to local or foreign private administrators. Priority is given to the raising of the processing range of the traditional minerals such as chromium, copper, nickel-iron etc. Some recommendations are also given.

New, Improved and Existing Technologies: Aqueous Processing II

Tuesday AM
August 29, 2006

Room: Boardroom West
Location: Catamaran Resort Hotel

Session Chairs: Maria C. Ruiz, Universidad Nacional de San Luis; Weyman Dunaway, TETRA Technologies, Inc.

8:00 AM Invited

On-Line Free Acidity Measurement in Hydrometallurgical Process Solutions up to 250°C: A New Industrial Sensor: Ming Huang[1]; *Vladimiros G. Papangelakis*[1]; [1]University of Toronto

An electrodeless conductivity-based sensor for on-line measurement of free acid was recently developed at the University of Toronto. Because the sensor does not have metal parts, its operation is corrosion-free. It has been tested against literature data and compared to measurements made using a previously developed contact-type conductivity cell, with an average difference less than 1%. Several H2SO4 – MSO4 (M: Mg, Ni, Co, Mn) solutions were also measured from 15 to 250°C at the equilibrium vapour pressure and up to 50 g/L free H2SO4 and 1.4 mol/L total dissolved metal. Consequently, a semi-empirical model has been developed to account for the contribution to conductivity of metal sulphates and chlorides. This model and sensor were further tested on-line during a pilot plant campaign of a new hydrometallurgical process. The average difference between the measure acid concentration from this sensor system and the one from titration was less than 5%, which provides an excellent tool for quick and accurate free acid measurements on line.

8:25 AM

Extraction and Recovery of Indium and Germanium from Primary and Secondary Hydrometallurgical Streams Using Molecular Recognition Technology (MRT): Ron Bruening[1]; John Dale[1]; *Neil Izatt*[1]; Steven Izatt[1]; [1]IBC Advanced Technologies, Inc.

The use of Molecular Recognition Technology (MRT), a selective separations technology using specifically designed ligands, has been established as an effective process for removal of metal ions found in many hydrometallurgical, chemical, and wastewater streams. The MRT process has been proven to be highly efficient and effective for indium extraction and recovery from zinc acid leach, electrolyte, chemical process and waste streams. A high percentage of the Indium is recovered in a solid product format. MRT has also proven effective for germanium extraction and recovery from similar feed streams. This paper provides the indium and germanium metal recovery flowsheets and analytical results of the metal load and recovery steps.

8:50 AM

Highly Efficient Method of Manufacturing Zinc Bromide: *Weyman Dunaway*[1]; [1]TETRA Technologies, Inc.

This paper will present a description of the development and commissioning of the world's most efficient process for manufacturing high purity zinc bromide. The method for making zinc bromide from metallic zinc and bromine comprises contacting zinc with bromine dissolved in a reaction solvent containing a metal halide salt. During the practice of this method, the reaction temperature is maintained at less than 60°C. The reaction solvent preferably comprises an alkali, alkaline earth or transition metal halide and the halide salt preferably comprises a chloride or a bromide. One preferred method includes the step of recirculating the zinc bromide product stream back to the reaction vessel. The reaction vessel can comprise either a one stage or a multiple stage reactor. The resulting product stream comprises a high density zinc bromide solution. The process is so novel that it was awarded US Patent Number 6,036,937.

9:15 AM

New Process for Extracting Cadmium by the Ammonium-Ammonia System: *Liu Wei*[1]; He Jing[1]; Tang Mo Tang[1]; [1]Central South University

A new process for extracting cadmium from the electric precipitation dust was studied. Leaching the dirt with NH3·H2O-(NH4)2SO4 system has got a good result, the best leaching condition was: the ratio of liquid to solid=2.5, [NH3]/[NH4+]=3/5, total concentration of ammonium and ammonia :8 mol/L, leaching time: 1.5h, temperature:35°C. Under this condition the leaching rate of cadmium reached 90.99%; When the total concentration of Zinc and Cadmium was up to 45g/L and the solution put static more than 17h, the most troublesome impurity Lead could deposit automatically from the solution without adding any reagent, the final concentration of Lead was 0.0047g/l, the removal rate was up to 99%; The metallic Cadmium was prepared by electro-winning, the best condition of electro-winning was: current density: 750A/m2, total concentration of Cd2+ and Zn2+>25g/L,and the metal contains Cadmium 99%, the current efficiency was about 87%, the energy consumption for per ton cadmium is about 548KW·h, the main impurities of the metal was Cupper and Zinc, it could be got rid of in the pyrometallurgical refining step.

9:40 AM Break

9:55 AM

Optimization of the Critical Steps of the Altair Hydrochloride Pigment Process: *Dirk Verhulst*[1]; Bruce Sabacky[1]; Bob Wang[1]; Jeffrey Lang[1]; Douglas K. Ellsworth[1]; [1]Altair Nanomaterials Inc

The Altair Hydrochloride Pigment Process is a new "third route", besides the established high-temperature chloride process and the older sulfate process, to manufacture TiO_2 pigment from ilmenite ore. It has been tested at a scale of 5 t/day feed. The ore concentrate is digested in high-acid, high total chloride solution (+/- 39% Cl). Titanium and iron both go into solution. Iron is separated as $FeCl_2$ crystals after reduction and cooling. Titanium is transferred by solvent extraction into a purified, high-Ti stream. It is spray-hydrolyzed to produce a TiO_2 hydrate and further calcined with additives into high-quality pigment. HCl solutions generated by pyrohydrolysis and spray hydrolysis are treated by pressure-swing distillation to regenerate HCl gas for re-injection into the digestion reactor. All chloride streams are recycled. Recent work has concentrated on optimization, particularly in 3 areas: 1) solvent extraction: a new organic mixture, including a new diluent, makes it possible to work at room temperature, to avoid TiO_2 hydrolysis problems and to improve phase disengagement and impurity separation, 2) pigment finishing: a systematic study of the parameters involved, followed by long runs in the best conditions confirm pigment quality, 3) flow sheet optimization: innovative modifications of the conditions of spray hydrolysis and pyrohydrolysis, combined with re-routing of streams achieve significant energy savings.

10:20 AM
Precipitation of Hematite from Ferrous Sulfate Solutions: Effect of Variables on the Quality of the Precipitates: *Maria Cristina Ruiz*[1]; Julio Zapata[1]; Rafael D. Padilla[1]; [1]University of Concepcion

The removal of iron from the leaching circuits is a common problem in the hydrometallurgical processing of non ferrous metals. Among the currently available processes, hematite precipitation is the most recommendable from an environmental point of view. This paper is concerned with the batch precipitation of hematite from ferrous sulfate solutions. One of the main objectives of the study was to determine the effect of the experimental conditions on the extent of iron precipitation as well as the purity and the particle size distribution of the precipitates. The main variables studied were temperature (180 to 220°C), concentration of sulfuric acid (1 to 10 gpl), initial iron concentration (1 to 15 gpl) and partial pressure of oxygen (3 to 7 atm). The results showed that increasing the oxygen partial pressure from 3 to 7 atm produced a very small increase on the rate of hematite precipitation indicating that a high partial pressure of oxygen is not needed for an effective ferrous to ferric oxidation. An increase in the temperature produced finer precipitates with lower sulfur contents. On the other hand, an increase in sulfuric acid concentration and initial iron concentration produced precipitates with larger particle sizes and higher sulfur contents.

10:45 AM
Precursor Synthesis of Fibrous and Porous Cobalt Powder by Coordination Precipitation Process: *Chengyong Dong*[1]; Chuanfu Zhang[1]; Jing Zhan[1]; [1]Central South University

Generally, cobalt powders used in cemented carbide, catalyst and battery manufacture are often spherical, and little study on the preparation of fibrous cobalt powders is carried out. Now, the fibrous precursor can be obtained by coordination precipitation process, using oxalate, cobalt chloride and ammonia. XRD pattern of precursor precipitated at pH=9.0 is different from that of ß-CoC2O4•2H2O precipitated at pH=1.0 and indicates that the precursor powders are one type of cobalt complex. Based on the analytical results of E-pH and IR, it is concluded that the composition of the precursor is [Co(NH3)x]C2O4•yH2O (x=1.2…..6) formed by the coordination reaction at pH=9.00 in the Co(α)-C2O42—NH3-NH4+-H2O system. It's found that the fibrous cobalt powders have greatly inherited the morphologies of the precursors, so in this paper the author aimed to the precursor synthesis by coordination precipitation process. Many factors could affect the formation of the fibrous cobalt precursor powders, such as the initial Co2+ concentration, pH value and so on. The SEM analysis shows how the initial Co2+ concentration, pH value and temperature influence the morphologies of the precursor powders. By using proper surfactant, the dispersion of the precursor powders would be improved. At last, the final product-fibrous cobalt powders which are about 0.3~0.5μm in size and 20~40 in aspect ratio were produced by thermal decomposition at 400~500° in the weak reducing atmosphere. With the escape of gas in the thermal decomposition process, such as NH3, CO, CO2, the porous cobalt powders were obtained.

11:10 AM
The Separation of Precious Metals from Base Metals in Gold-Antimony Alloy by Selective Chlorination Leaching by Controlling Potential: *Tianzu Yang*[1]; Wei-Feng Liu[1]; Ming-Xi Jiang[1]; [1]Central South University

In this work, a new hydrometallurgical method of the extraction of precious metals from the antimony-gold alloy —— selective chlorination by controlling potential, has been investigated to substitute the previous pyrometallurgical method which has been unable to operate normally due to the increasing of the contents of base metals such as copper, lead and nickel etc. in the gold-antimony alloy. The experimental results show that the recovery of the metals such as gold, lead and antimony etc. increase and the production costs lower when the gold-antimony alloy is treated by the new method. The experiment results of selective chlorination leaching by controlling potential indicate that copper and nickel containing in the gold-antimony alloy can not be removed by the oxidation of hydrogen peroxide in sulfuric acid system, but in hydrochloric acid system the base metals such as copper, nickel and antimony can be oxidized completely and enter into the solution. The effects of the concentration of hydrochloric acid, the concentration of sulfuric acid, the liquid-solid ratio, leaching temperature, leaching time and oxidation potential in hydrochloric acid system on the leaching efficiencies of the base metals have been investigated. Under the following operation conditions: hydrochloric acid concentration [HCl]=4.0mol•L-1, sulfuric acid concentration [H2SO4]=1.2mol•L-1, liquid-solid ratio L:S=7.5:1, leaching temperature 80°, leaching time 2h, the oxidation potential 400±20mV, the leaching efficiencies of copper, nickel and antimony are over 99%. The leaching efficiency of silver and gold are 20% and 0.01% respectively.

11:35 AM
Isolation of Mineral Specific Extracellular Protein from Paenibacillus Polymyxa and Its Application in Complex Sulphide Mineral Processing: *Partha Patra*[1]; [1]Indian Institute of Science

Extracellular bacterial protein (EBP) from Paenibacillus polymyxa was isolated. Adsorption of bacterial cells of Paenibacillus polymyxa as well as EBP onto pyrite, galena and sphalerite was studied. Both bacterial cells and EBP was found to have different adsorption density for different minerals. Protein from mineral surfaces were extrated and examined through SDS PAGE electrophoresis. Specific group of protein was found to be adsorbing, specific to respective minerals. EBP was fractionated through FPLC. Adsorption studies were carried out with each fractions. Difference in adsorption density was observed for individual minerals. Flocculation and flotation experiment were carried out with these mineral specific EBP. Pyrite was selectively removed from ternary mixture of galena and spharite through flocculation anf flotation using pyrite specific EBP. Mineral specific EBP was found to selectively separated remove pyrite from the complex sulphide mixture. Zetapotential studies were carried out to examine the surface chemical changes of the minerals on interaction with EBP. Hydrophobicity of the minerals were carried out on interaction with bacterial cells as well as mineral specific EBP.

New, Improved and Existing Technologies: Iron Making

Tuesday AM — Room: Cockatoo
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Joseph J. Poveromo, Quebec Cartier Mining Company; Alim Ullah, Nemur

8:00 AM Keynote
Dust and Nanoparticulate Issues in Pyrometallurgical Operations: *S. Komar Kawatra*[1]; [1]Michigan Technological University

A growing concern for pyrometallurgical operations is the generation of airborne particulates. These particulates can be generated by combustion processes, or by materials handling. Regulation of these particles by the EPA has become progressively more stringent, first for particulates finer than 10 micrometers (PM_{10}), which are particles fine enough to be inhaled into the lungs. Then, restrictions were introduced on emissions of particles finer than 2.5 micrometers ($PM_{2.5}$), which are fine enough to become embedded in lung tissues. The next stage of regulations is likely to be "nanoparticulates," particles finer than 100 nanometers, which are in a size range where their very high surface area leads to enhanced reactivity. While all of the health effects due to nanoparticulates have not yet been determined, there have been enough studies to indicate that there is a problem, and restrictions on nanoparticulate emissions are only a matter of time. In this paper, it will be demonstrated that dry handling, comminution, and combustion sources represent a significant concern for both PM and nanoparticulate emissions. In regards to dry handling, the effects of utilizing effective dust suppressants on PM and nanoparticulate emissions will be explored.

8:25 AM Invited

Coke Strength and Tuyere Velocity: *Morimasa Ichida*[1]; Tunehisa Nishimura[1]; Shinroku Matsuzaki[1]; Masaaki Naito[1]; [1]Nippon Steel Corporation

One of the most important points of the blast furnace stability operation under the condition with a high-productivity and high-rate pulverized coal injection is to expand the race way and to reduce the dead man area. The descent area expands and the center gas flow is maintained by reducing the above-mentioned dead man area. Then, the cold and hot experiments of race way furnace in which the tuyere velocity and coke strength were changed was executed and fine ratio generated from coke in raceway was measured. The equivalent relation between coke strength and the tuyere velocity concerning fine generation of coke in the race way was led based on the above-mentioned fine ratio and the idea of coke strength when the tuyere velocity rose was examined.

8:50 AM

Process, Quality and Management Control in the Operation of a Direct Reduced Iron Plant: Barbara Franco[1]; Alessandro Martinis[1]; Andrea Tavano[1]; *Alim Ullah*[2]; [1]Danieli & C; [2]Nemur

In order to produce Direct Reduced Iron (DRI) at minimum cost and that meets quality requirements, various forms of control are necessary. In process control, the operators have to control the key process variables like gas composition, reduction temperature, etc., within the specified limits. Statistical Process Control (SPC) techniques can be used to assure that the quality requirements are maintained. One of the key features of SPC is that it separates the variations in quality because of natural causes from those resulting from assignable causes. Whereas the shift operators have to take corrective actions for assignable-cause variations, management intervention is necessary for reducing natural-cause variations. A properly designed and implemented accounting system can be a very useful tool for management to verify if standards are met and, if not, the reasons for deviations. The paper will discuss the key process variables and their effects on productivity and/or quality of the DRI produced. SPC techniques for monitoring the quality of DRI through measurements of metallization or equivalent metallization will be included in the paper. Finally, the paper will describe the implementation of a suggested standard system for analyses of variations, for example, in the consumption of raw material and energy, when they occur.

9:15 AM

Properties of Pig Iron Nuggets Produced Directly from Iron Ore Concentrate: Basak Anameric[1]; *S. Komar Kawatra*[1]; [1]Michigan Technological University

The ITmk3 process is being developed by Kobe Steel as an alternative to the traditional blast furnace process. The pig iron nugget process utilizes coal instead of coke and self reducing and fluxing dried green balls instead of indurated pellets and sinters. The advantages of this approach are (i) the environmental emissions caused by coke production are eliminated, since coke is not needed for the process; and (ii) the elimination of the pellet induration (heat hardening) step of conventional iron production results in a considerable savings of energy. Pig iron nuggets were produced characterized to compare them with blast furnace pig iron. Pig iron nuggets were analyzed using density measurements, optical metallography, electron microscopy with local chemical analysis, bulk chemical analysis, and microhardess measurements to determine chemical composition, degree of metallization, apparent density, and microstructure. It was determined that pig iron nuggets had high apparent density (6.7 – 7 gr/cm^3); were highly metallized, with a slag free structure; had a high iron content (95 – 97 %); and exhibited microstructures similar to white cast iron, which is essentially the same as pig iron from a blast furnace. This indicates that the pig iron nuggets are a competitive alternative to blast furnace pig iron.

9:40 AM Break

9:55 AM Keynote

Experimental Analysis for Thermally Non-Equilibrium State under Microwave Irradiations: A Greener Process for Steel Making: *Motoyasu Sato*[1]; Akihiro Matsubara[1]; Sadatsugu Takayama[1]; Osamu Motojima[1]; Kazuhiro Nagata[2]; Kotaro Ishizaki[2]; Tetsuro Hayashi[3]; Dinesh Agrawal[4]; Rustum Roy[4]; [1]National Institute for Fusion Science; [2]Tokyo Institute of Technology; [3]Research Institute of Industrial Products Gifu Prefectural Government; [4]Pennsylvania State University

Highly pure pig iron can be produced from the 50~100 micron meter powdered iron ores with carbon as a reducing agent in the multimode microwave reactor. The grains in compacted powder absorb microwave energy selectively at microscopic level. It creates thermal non-equilibrium state microscopically and enhances chemical reactions and the phase mixing at the grain boundaries very rapidly. The visible light spectroscopy monitored the reactions. Upon the application of the microwaves with nitrogen atmosphere, the powders gets heated and radiates light according to the blackbody emission up to 650°C. The small non-equilibrium hot spots rise, move and finally burst to brighter emission to blackbody all over the surface at this temperature, that consisted line spectrums of CN and atomic FeI. The line spectrums oriented from CO molecules have not been detected yet. The solid-solid reaction could be expected between the iron oxides and carbon to produce CO2 directly. The loosing of sample weight was accelerated during the excess-emission. These are the clear evidence that microwave excites thermally non-equilibrium state and accelerates reduction process. The reduction finished at 1380°C and the very pure pig ion was produced. It contained with impurities of 1/20~1/10 of Mg, S, Si, P and Ti in comparison to the pig irons produced by modern conventional tall kilns in the steel industries. The necessary amount of carbon was 2/3 compared to conventional kiln to produce the unit weight of steel, if we applied renewable energy or nuclear power for the microwave excitations.

10:20 AM

Homogeneous Heating in Microwave Processing: Xiang Sun[1]; *Jiann-Yang James Hwang*[1]; Shangzhao Shi[1]; Xiaodi Huang[1]; [1]Michigan Technological University

Microwave processing has been under continuous development as an advanced heating method in modern industries. However, problems with uneven heating still remain. Although heating uniformity is highly dependant on the properties of the materials being heated, proper furnace design to prevent uneven field distribution is another important factor. As an alternative to experimental measurements and adjustments to find appropriate furnace parameters, computer simulation is a convenient method for modeling, understanding, and improving the uniformity of microwave heating. This paper discusses current modeling technologies as well as applicable techniques for improving microwave heating uniformity. The purpose is to give a basic understanding on how to find, analyze, and minimize the problems associated with uneven heating in microwave processing.

10:45 AM

Evolution of Ironmaking: *Joseph J. Poveromo*[1]; [1]Quebec Cartier Mining Company

Technical progress in ironmaking will be discussed in three sectors: blast furnace ironmaking, direct reduction and alternative ironmaking to feed electric arc furnaces and ironmaking for waste oxide processing. The contributions of iron ore producer, Quebec Cartier Mining, in each sector will be outlined. The relevance to ironmaking of the fundamental research in transport phenomena and chemical reactions of Julian Szekely and H. Y. Sohn will be noted.

11:10 AM

Development of the Coke Gas Desulfurization Technology: *O. I. Platonov*[1]; [1]Gipronickel Institute, JSC

The process for cleaning of coke gas involving removal of hydrogen sulfide from coke oven gas in a regenerative "scrubber-stripper" system, with acid gas reporting to a Claus sulfur recovery unit (SRU) and tail gas being recycled in a raw coke gas scrubber, has been developed. The core problem of this process is the presence elemental sulfur in the SRU off-gas, which may deposit on gas drive equipments and blower and thus disrupt operation of the SRU. The new technology for treatment of the SRU off-gas developed for a Claus unit operating by «Russian Metallurgical Company» (Magnitogorsk, Russia) is presented. It includes a catalytic hydrolysis/hydrogenation step, where all sulfur-bearing components like sulfur dioxide and carbonyl sulfide are converted to hydrogen sulfide. The SRU treating off-gas at Magnitogorsk

consists of three main units: gas pre-heater; catalytic hydrolysis reactor and waste gas cooler. The pre-heater is used to maintain a temperature level of the process gas required for catalytic conversion (beyond 330-350°C). Oxygen, utilized as an oxidizer, minimizes volume of the waste gas. The operational experience gained since July 16, 2004 shows that the new technology provides a deep purification of the Claus tail gas from elemental sulfur. As compared to the known SCOT–process, the technology in question does not require separate stages of hydrogen sulfide removal and enrichment that simplifies its implementation at lower capital and operational costs.

New, Improved and Existing Technologies: Waste Treatment and Remediation

Tuesday AM
August 29, 2006

Room: Toucan
Location: Catamaran Resort Hotel

Session Chairs: Patrick R. Taylor, Colorado School of Mines; Robert W. Bartlett, Independant Consultant

8:00 AM Keynote
Halide Entrapment from Polymers Using Alkali Compounds: *Scott A. Shuey*[1]; Josh Montenegro[1]; Edgar E. Vidal[1]; Patrick R. Taylor[1]; [1]Colorado School of Mines

The processing of post-consumer materials is an area being addressed by many industries and multiple engineering disciplines. While metal scrap and high-value uniform waste streams tend to find their way back to their respective parent processes, the more complex and low-cost ubiquitous materials, such as Polyvinalchloride (PVC) and Polytetrafluorethane (PTFE), tend to show up in many processing streams. From a metallurgical perspective, pyrometallurgical processing of a mixed metal/organic/oxide waste material allows for the recovery of thermal energy in conjunction with the recovery of metal values. The evolution of halogenic acids during elevated temperature processing can create complications with both the materials of construction of the processing equipment as well as gas stream processing. The need for dust collection coupled with a high acid content, necessitation high-volume scrubbing, increases the costs associated with gas handling. Control of the halides through entrapment as a solid in-situ during processing would simplify downstream processing. Alkali-halide complexes are being evaluated by researchers at CSM for mixed metal/polymer waste material treatment, recovering halogens as salt complexes.

8:25 AM
Stabilization of Heavy Metals and Chlorine Removal in Municipal Solid Waste Incineration Bottom Ash by Carbonation Process: *Gi-Chun Han*[1]; Nam-Il Um[1]; Kwang-Suk You[1]; Ji-Whan Ahn[1]; Hee-Chan Cho[1]; [1]Korea Institute of Geoscience and Mineral Resources

In Korea, most Municipal Solid Waste Incineration(MSWI) bottom ash currently generated is landfilled, while in some European countries such as Germany, the Netherlands about 50% of the stockpiled MSWI bottom ash is used as secondary building material, in road construction. But bottom ash has the potential leaching of harmful cations and anions such as copper, lead, zinc, chlorine, sulfate, therefore, the final management of ash depends on regulatory requirements and disposal objectives. In EU countries, mainly in Germany, weathering of the bottom ash for a period of 3-6months before their final disposal or their eventual utilization is the most commonly employed method due to its low investment and operation costs. In weathering period, oxidation, neutralization, dissolution and precipitation, especially carbonation are some of the reactions that can occur in the weathering of bottom ash undergo their most significant changes. But the weathering mainly plays an important role in diminishing the leaching of heavy metals, not anions such as chlorine has been revealed by many researchers. In this study, the artificial carbonation with washing was used for the removal of anion such as chlorine, and the stabilization of heavy metals. Environmental quality improvement of the bottom ash and generated wastewater characteristics were investigated according to the changes of flow rate of CO2(g), liquid to solid ratio, reaction temperature and so on.

8:50 AM Invited
Elimination of Heavy Metals from Municipal Inorganic Wastes by Chlorination Volatilization Method: *Hiroyuki Sano*[1]; Hidemasa Kodama[1]; Toshiharu Fujisawa[1]; [1]Nagoya University

Recycling process of inorganic wastes discharged from city life, such as incineration bottom ash and fly ash, has been developed. In this process, harmful components in such wastes are eliminated by a chlorination volatilization method, and then a stabilization treatment is conducted for residual harmful components. Finally, functional materials, such as humidity control materials, are produced from the harmlessness treated inorganic wastes. Elimination of heavy metals from the incineration fly ash by this method had been already investigated and the effectiveness of this method was reported. In this study, this method was applied to the elimination of heavy metals, mainly lead, from the incineration bottom ash. Since the fly ash contains a large amount of chloride, heavy metals in the ash are easily chlorinated. On the other hand, the addition of the chlorination agent is a key point for applying this method to the bottom ash, because it hardly contains chloride. The effect of different variables such as a kind of chlorination agent, adding quantity of it and temperature on the elimination ratio was investigated and the harmlessness of the residual ash was evaluated. The preferable condition was proposed from the recyclability of the bottom ash.

9:15 AM Keynote
Anerobic Bioremediation of Metallurgical Wastes Using Organic/Water Emulsions: *Robert W. Bartlett*[1]; [1]Independant Consultant

Hazardous metal contaminants in liquid and solid wastes and from ground spills are important environmental problems in many metallurgical production operations. Acid rock drainage, from mines and huge quantities of permeable mine waste, is probably the most ubiquitous example. Fixing mine waste contaminants in situ has been practiced, using sulfate reducing bacteria (SRB) and organic reagents as electron donors to create anaerobic conditions and precipitate metal sulfides. Solubilities of hazardous metal sulfides are much lower than those obtainable with hydroxide or carbonate precipitation. Aqueous solutions of sugars and alcohol have been percolated into mine wastes with good results. However, maintaining anaerobic conditions permanently is unlikely, as these solutions are eventually washed out of solid waste and contaminated ground by inflow of either groundwater or meteoric water, allowing reoxidation from entering air. Emulsions of inexpensive, non-aqueous organic droplets dispersed in water provide earth wettability equal to aqueous solutions and easy percolation into both the ground and mine waste. Subsequent breakdown of the O/W emulsion provides permanent retention of the organic phase, attached to earth particles, that secures lasting anaerobic conditions, precipitates metals as sulfides and prevents re-oxidation of these sulfides. This process and its optimization are described, including experiments with sand-filled columns representing a vertical section through solid waste. Results of organic and metal retention in solid waste are provided from analyses of acid mine water drainage before and after waste treatment.

9:40 AM Break

9:55 AM Keynote
Chloridizing Volatilization Experiments for Treatment of Fly Ash Generated in Smelting Furnaces of Municipal Wastes: Hideyuki Itou[1]; Satoshi Watanabe[1]; *Tomio Takasu*[1]; Takashi Nakamura[2]; Hiroshi Kubota[1]; Junichi Ohashi[3]; Kenji Onishi[3]; [1]Kyushu Institute of Technology; [2]Tohoku University; [3]Kowa Seiko Company, Ltd.

Municipal wastes are mainly incinerated in Japan. Both bottom ash and fly ash from the incineration treatment are smelted recently to decrease the volume. Direct smelting of municipal wastes is also becoming popular. The smelting treatment generates fly ash which contains concentrated heavy metals such as Zn, Pb, Cu and the harmfulness is concerned. The smelter fly ash is mainly landfilled after stabilization. Effective treatment process of the smelter fly ash is required to recover the metals. For the treatment process, an application of chloridizing volatilization technique is considered. Chloridizing

volatilization experiments were carried out to determine the effects of factors on the volatilization behaviors in this study. Main raw materials mainly consist of hematite are mixed with pretreated ash. Calcium chloride water solution was added into the mixture. The mixture was pelletized, dried and used as samples for the volatilization experiments. The sample was placed in the reaction tube heated in an electric resistance furnace. 5%O2-95%N2 gas with controlled humidity was introduced into the reaction tube. Effects of humidity in the carrying gas, addition of calcium chloride and mixing ratio of the ash to the main raw material were investigated on the volatilization of Zn, Cu and Pb. To know the volatilization behavior, samples were taken from the furnace at specified temperatures on the heating stage. In addition, experiments at specified holding temperatures with shortened heating time were conducted. The two series of experiments revealed effect of heating time on the volatilization behavior.

10:20 AM

Lead Removal from Contaminated Soil by Sequential Application of Chlorination by Mixed Salt and Warm Water Extraction: *Fumiatsu Sato*[1]; Hiroyuki Sano[1]; Toshiharu Fujisawa[1]; [1]Nagoya University

In recent years, an increasing number of urban soil contamination cases have been found during redevelopment of former factory sites. Hydroclassification technique, separating heavily contaminated fine soil particles from contaminated sites, is one of the economical remediation techniques for contaminated soil by heavy metals, but the separated fine soil particles are generally landfilled because of the difficulty in removing strongly adsorbed heavy metals on them. In the previous study, the authors have investigated the mechanism and the optimum condition of chlorination-volatilization technique to eliminate heavy metals from inorganic waste and found it was needed to heat up around 1273K. In this paper, a new remediation technique for lead contaminated fine soil particles is proposed. This technique is composed of chlorination and subsequent warm water extraction. In the chlorination step, water-insoluble lead complex is chlorinated to be water-soluble lead chloride without volatilization, by heating the soils with $MgCl_2$-$CaCl_2$-KCl salt mixture at relatively lower temperature. By subsequent warm water extraction, lead chloride is leached out. Effects of chlorination conditions, such as time, temperature, composition of the salt and added salt ratio, on lead behavior were investigated. It was proved that lead concentration could be reduced below Japanese environmental standard.

10:45 AM

Treatment of Zinc-Containing Wastewater by Immobilized SRB Sludge with Inner Cohesive Carbon Source: *Xiao Bo Min*[1]; [1]Central South University

As for treatment of zinc-containing wastewater, traditional SRB (sulfate reducing bacteria) process was used, however, there exists two defects, like toxicity of heavy metal ions and high effluent COD (chemical oxygen demand) value. In this study, a new technique, called ISIS process (immobilized SRB sludge beads with inner cohesive carbon source), in which SRB sludge is embedded in carrier of PVA (polyvinyl alcohol) with carbon source that adsorbed on certain material, is put forward for the first time to overcome the two defects existing in traditional SRB process. Furthermore, it has been shown that compared to traditional SRB process, ISIS process increases average zinc removal rate up 30%, average sulfate reduction rate up 20%, and decrease average effluent COD value to meet discharge standards. If activated carbon is selected for carbon source adsorption and fixing material, and PVA for immobilization material, the zinc removal rate can reach above 98% under the conditions of 35°C and pH 6. Meanwhile, the mechanism of zinc removal has been determinated according to the results from SEM (scanning electronic microscope) and XRD (x-ray diffraction). Project (50508044) supported by the National Natural Science Foundation of China.

11:10 AM

Waste Water Purification from Ions of Heavy Metals: *Tamaz Lezhava*[1]; Jondo Gvelesiani[1]; [1]R. Agladze Institute of Inorganic Chemistry and Electrochemistry

The basic purpose of the research consists in clearing the waters polluted by ions of heavy metals, these waters are similar to quarry waters polymetallic deposit or waters–solutions of underground leaching of poor polymetallic ores. For this purpose new electrochemical ways and approaches of hydrometallurgy, which simultaneously enable to give to the form of commodity to the components, taken from quarry waters. Their realization in a lot of cases will pay back costs on clearing waters before they become ecologically harmless formations. These waters can be used as pure secondary waters or to be descended in pools of the rivers. In the Institute of Inorganic Chemistry and Electrochemistry in year 2003 began researches on clearing quarry waters of the Madneuli mountain-concentrating plant of Georgia. Debit quarry waters make (8-10)•105m^3 annually composition (kg/m^3):0,8-1,2 Cu;0,4-0,6Zn; 0,1-1,2Fe; pH=1,5-2,5. Quarry waters contain also other colorful and rare elements. Most part of quarry waters get in the rivers of region in the unpurified form, creating serious ecological danger. Modern condition of researches: 1) new electrochemical percolator has been developed, allowing to selectively extracting from 94-97% of copper in the form of a metal powder from quarry waters, 2) the opportunity of melting of 99,9%-s the copper ingot bar containing 30-60g/t Au is established from the received powder, 3) the opportunity of receiving of high-quality copper and the blue vitriol and the waste after dissolution of copper powder in the sulfuric acid is established. This waste contains~50% of elementary sulfur and up to 0,8kg/t Au, and 4) the researches of clearing quarry waters of ions of iron are carried out.

11:35 AM

A Chlorination Process Applied to the Recovery of Alumina and SiC Reinforcement from an Aluminium-Matrix Composite: *Horacio E. Nassini*[1]; Ana E. Bohe[2]; [1]Comisión Nacional de Energía Atómica; [2]Consejo Nacional de Investigaciones Científicas y Técnológicas

Metal matrix composites (MMCs) have emerged as a novel class of materials for structural, aerospace, automotive, electronic, thermal management, and wear applications. Compared to unreinforced metals, MMCs present advantageous physical, thermal and mechanical properties, such as enhanced specific strength and stiffness, improved wear and creep resistances, and higher temperature capabilities. Discontinuously reinforced metal matrix composites (MMCs) have been gaining wide acceptance as important engineering material in automotive, aerospace, and electronic industries. Since the ceramic reinforcements are still quite expensive and contribute significantly to the MMC final cost, the feasibility of their recovery from the composite material scrap and further recycling is a factor of increasing interest. Chlorination process is an attractive method for the metal recovery from complex materials. The process which is performed at high temperatures, allows to turn all the metals contained in the material into their respective chlorides. In this particular case, the constituents of composite metallic alloy matrix can be transformed in gaseous chlorides and they can be dragged by the gaseous stream, while the ceramic reinforcement does not react and remain as a solid residue in the reaction bed. In the present work, a theoretical and experimental study is given for the recovery of Al_2O_3 and SiC particles and fibers from a commercial aluminum-matrix composite produced by molten metal mixing route. A thermodynamic analysis considering all the possible reactions with chlorine was firstly carried out, and then, the conditions for the optimum separation of the Al_2O_3 particles from the metallic matrix were determined by thermogravimetry.

Thermo and Physicochemical Principles: Aqueous and Electrochemical Processing I

Tuesday AM
August 29, 2006

Room: Boardroom East
Location: Catamaran Resort Hotel

Session Chairs: Rajesh K. Mishra, A-1 Specialized Services and Supplies Inc; Vladimiros G. Papangelakis, University of Toronto

8:00 AM

Preparation of Gold Catalysts from Gold Dissolved in Aqua Regia: Eun Duck Park[1]; Eun-Yong Ko[1]; *Kyung Won Seo*[1]; Min Kang[1]; Jae Eui Yie[1]; [1]Ajou University

Gold unlike other noble metals such as platinum, palladium, and rhodium has been regarded as being an inert element for catalysis[1]. This is closely related to the difficulty in preparing well-dispersed gold particles over supports. Since simple methods for preparing nano-sized gold catalysts are disclosed, lots of works have been reported on preparations and applications of gold catalysts[2]. Most gold catalysts have been prepared form AuCl3 which is quite expensive to hinder its commercial application. Gold is recovered from numerous industrial sources as a metallic state. Therefore, this can be an economic raw material for gold catalysts. In this work, some preparation variables for gold catalysts from gold dissolved in aqua regia was examined. Its catalytic activity for CO oxidation was also studied. Gold catalysts were prepared by a co-precipitation method. The pH of an aqueous solution of gold and metal precursors was adjusted by an addition of a base. The initial gold concentration, the final pH, an aging temperature, and the pretreatment condition were found to be critical factors for the active gold catalysts. These were closely related to the amount of residual chloride and the particle size of gold. [1]Schwank J. Gold Bull. 16, 103 (1983); [2]M. Haruta, Catal. Today, 36, 153 (1997).

8:20 AM

Hydrometallurgical Processing of Zinc Sulfide Raw Materials: *Andrey V. Tarasov*[1]; E. M. Timoshenko[1]; P. E. Romanov[1]; [1]Gintsvetmet

Based on the data available in the literature and the practical experience of new metallurgical plants, a method has been proposed and relevant studies conducted for metallurgical processing of zinc sulfide concentrates. Process conditions and parameters have been identified, which ensure high levels of recovery of zinc into solution. This is achieved by leaching concentrates under the normal pressure at a temperature of >90°C in the presence of ferric iron ions. Sulfide sulfur is converted to elemental sulfur in this process. To produce elemental sulfur it is necessary to maintain oxidizing conditions in the system, characterized by a positive Eh value. In order to eliminate the interfering effect of elemental sulfur formed in the process, it is possible to add surfactants into the concentrate pulp. The proposed technology has certain advantages as compared with the high-temperature pressure leaching and is considered as a basic technology to be applied to increase zinc production at one of the Russian zinc plants.

8:40 AM

Interfacial Emulsion Formation Originated from Organic Phase in Copper Solvent Extraction: *Xiaorong Liu*[1]; Guanzhou Qiu[2]; Yuehua Hu[2]; [1]Shanghai Institute of Technology; [2]Central South University

Interfacial crud generated in copper solvent extraction is an unhomogeneous O/W emulsion that consists of organic phase, aqueous phase and solid particles. In order to determine what kind of components in organic phase promotes the emulsion, the organic phase separated from the interfacial crud provided by Dexing Copper Mine in Jiangxi, China was analyzed for its components by combined gas chromatography-mass spectroscopy. It is found that many kinds of emphiphiles containing such hydrophilic groups as carbonyl, carboxyl, or acylamine existed in organic phase, most of which were originated from the reagent degradation. Conclusively, Lix984N will degrade gradually during a prolonged contact with the acidic aqueous feed and strip reagents. Lix84 and nonylphenol, as effective components of Lix984N, degraded almost completely after long-term recycling. As a result, the effective components of Lix984N were far lower in concentration than the dense-aromatic impurities derived from diluent and the degradation products in total. The degradation of Lix984N would deteriorate solvent extraction, disengagement performance and result in more serious interfacial emulsion.

9:00 AM

Chemical Modeling of Calcium Sulphate Solubility in Hydrometallurgical Process Solutions: Haixia Liu[1]; *Vladimiros G. Papangelakis*[1]; [1]University of Toronto

Calcium sulphate precipitation, mainly as gypsum, during neutralisation of acidic hydrometallurgical process solutions can lead to excessive scaling problems. In this work, a self-consistent fundamental chemical model is presented based on the OLI software platform. The model employs the new Mixed Solvent Electrolyte activity model of OLI. A thermodynamic model database has been developed and calibrated on experimental data from sulphate and mixed sulphate-chloride solutions. The model predicts very well the solubility of calcium sulphate within a wide temperature range and can be used to assess the scaling potential of a particular process stream composition. The effect of temperature, acidity, chloride concentration, and divalent metal concentration on the solubility of calcium sulphate in multi-component process streams is also discussed.

9:20 AM

Purification of Phosphoric Acid by a Mixture of Hydrophobic and Hydrophilic Extractants: *Laila A. Guirguis*[1]; Hisham K. Fouad[1]; Fatma A. Salem[1]; [1]Nuclear Materials Authority

Impurities are removed from crude phosphoric acid (57.75% P2O5) with a mixture of low and high molecular weight alcohols, one of which is hydrophilic and the other is hydrophobic namely; methanol and hexanol. In a single stage, the phosphate values segregate to the high molecular weight alcohol fraction and the impurities segregate to the low molecular weight alcohol fraction. The optimum ratio for extraction is found to be 0.5 part methanol, one part impure acid and four parts hexanol where an extraction percent of more than 95% is achieved. Re-extraction of the phosphate value from the solvent is obtained by 6% phosphoric acid and the different factors affecting the re-extraction process have been studied. Finally, the purified acid is concentrated under reduced pressure and passed through activated carbon column, whereas the alcohols are re-circulated. The produced phosphoric acid was found to be in good match with the international specifications of food grade quality acid. A technological flow sheet is elucidated.

9:40 AM Break

9:55 AM

Standard Fingerprint Pattern of Raman Spectrum of Octamolybdate Anion in Aqueous Solution: *Daojin Cao*[1]; Wen-Mi Chen[2]; Bin Jiang[2]; Hong-Zhao Liu[2]; [1]Central South University/Changsha University; [2]Central South University

In the field of production of molybdate industry, octamolybdate is an important isopolymolybdate formed by acidification of weak alkaline molybdate solution, which is obtained by extracting with ammonia from its roasted ores. The method of Raman spectroscopy is usually used to identify octamolybdate anion in aqueous solution. However, there have been more than four different type patterns of Raman spectrum of octamolybdate anion in aqueous solution reported in the previous papers using the method of comparison of Raman spectrum of solution with that of solid of known octamolybdate structure. That is to say, there has not been the direct standard fingerprint pattern of Raman spectroscopy of octamolybdate anion in aqueous solution. The authors have solved the problem by using Raman spectroscopy to measure saturated solution of ammonium octamolybdate hydrate crystal. Under the experimental condition controlled strictly, ammonium isopolymolybdate hydrate crystal was prepared by using a set self-designed double-walled intermittent-type reaction device and the method of acid-sinking. The crystal was characterized to be ammonium octamolybdate hydrate crystal by Raman and FT-IR spectroscopy. By dropping a little distilled water to grain surface of the crystal and keeping solid-solution coexist for 24h, saturated solution of the crystal was prepared, and measured

by Raman spectroscopy. The results show that the highest vibrant frequency of main characteristic Raman spectrum of the saturated solution is 966.2 cm^{-1} and only smaller 0.9 cm^{-1} than that of the crystal, and that the intensity of main characteristic Raman peak at 966.2 cm^{-1} is weaker than that at 965.3 cm^{-1}, and that its main pattern characteristic can be described to be "double peaks with a weak-outside". Standard fingerprint pattern of Raman spectrum of octamolybdate anion in aqueous solution has been thus established.

10:15 AM

Study on Phase Equilibrium and Physicochemical Properties of Me2+-NH4+-SO42—H2O System at 298K: *Chang-Hong Peng*[1]; Si-Guo Mu[1]; Yi-Feng Chen[2]; De-Wen He[1]; Shao-Hua Ju[1]; [1]Central South University; [2]Hunan Metallurgical Institute of Professional Technology

Solubility phase equilibrium in the ternary system of Me2+-NH4+-SO42—H2O (Me2+ represented Mn2+, Zn2+ and Fe2+) was studied by the isothermal method at 298K and physicochemical properties of the saturated solution such as density, refractive index and pH were also investigated. The experimental results show that the solubility isothermal phase diagrams of these systems consist of three invariant branches, two invariant points and three crystallization fields. Corresponding to the three crystallization fields, there have three phases of solid, that is MeSO4·nH2O, (NH4)2SO4 and (NH4)2Me(SO4)2·6H2O, respectively. At the eutectic point, the concentration and the refractive indexes of the saturated solution change evidently. Otherwise, the pH value change slowly in all the systems. The calculated results of the density and refractive index agree with the experimental results.

10:35 AM

Study on the Anodizing of AZ31 Magnesium Alloy in Environmental Friendly Electrolyte: *Xia Yu*[1]; [1]Central South University

Anodizing behaviors of magnesium alloys AZ31 at constant applied current, based on the electrolyte solution free of chromate or fluoride, were investigated. The anodizing process was influenced by constituents of electrolyte greatly. Therein, the oxylate salts played a determinant role which led to the occurrence of the two totally different processes, and they were stable and sparking process respectively. During the stable process, a brown thin film was formed, however the sparking process led to the formation of white hard thick film. The two kinds of films were both porous. The corrosion resistance tests showed that bothe the two kinds of films can improve anti-corrosion properties of magnesium alloys. The anodizing process was also affected many process parameters, such as the concentrations of electrolyte solution, applied current density as well as solution temperature, etc. And those factors had different effects on the two processes. High temperature benefited the stable process but had negative effects on the sparking process. The morphology of anodizing film was observed by SEM and the structure of film was analyzed by XRD. From the results obtained at different anodizing time, the mechanisms of film formation were revealed. The functions of some kinds of additives including some organic and inorganic materials, such as ammonia, glyceryl alcohol and PVP were also studied.

10:55 AM

Effects of Additives on Anodizing of Magnesium Alloy AZ31 in Alkaline Solutions: *Liyuan Chai*[1]; X. Yu[1]; M. Okido[2]; [1]Central South University; [2]Nagoya University

Anodizing behaviors of magnesium alloys AZ31 at constant applied current, based on the electrolyte solution free of chromate or fluoride, were investigated. The anodizing process was influenced by constituents of electrolyte greatly. Therein, the oxylate salts, which led to the occurrence of the two totally different processes, played a determinant role in anodizing. They were stable and sparking process respectively. The morphology of anodizing film was observed by SEM and the structure of film was analyzed by XRD. During the stable process, a brown thin film was formed, however the sparking process led to the formation of white hard thick film. The functions of some kinds of additives, such as ammonia, glyceryl alcohol and PVP etc were also studied. Some of them had great effect on surface morphology of anodic film and some of them affected stability of anodizing process significantly.

11:15 AM

Complex Treatment of the Tetrahedrite-Siderite Mineral Deposit in Silver Mária Bana, Slovakia: *Juraj Schmiedl*; F. Sekula[1]; F. Molnár[1]; [1]Technical University of Košice

Tetrahedrite and siderite are two main valuable minerals present in the silver Mária Bana deposit. The tetrahedrite concentrate prepared from it by flotation has certain specific properties from the metallurgical point of view. Siderite is concentrated in the flotation tailings. The paper presents results of the laboratory and pilot-plant testing of the combined hydrometallurgical and pyrometallurgical methods proposed for treatment of the tetrahedrite concentrate and siderite waste. The testing conditions were based on thermodynamic analysis of the reactions that proceed in the process. The proposed technology makes it possible to separate copper from sulphur, mercury and iron in a straightforward way. Copper, after its refining, can be subsequently treated in the finishing operations. At the same time it is a valuable source of precious and noble metals. The siderite-containing flotation tailings can be converted to iron of the technical purity and slag. The proposed method is a good starting point for the development of the closed-cycle technology.

11:35 AM

Study on the Standard Pattern of Raman Spectrum of Heptamolybdate Ion in Aqueous Solution: *Daojin Cao*[1]; Wenmi Chen[2]; Hongzhao Liu[2]; Bin Jiang[2]; [1]Central South University, Changsha University; [2]Central South University

Aiming at many controversial reports on Raman spectral pattern of heptamolybdate ion in aqueous solution appearing in the literature and the absence of its standard pattern, the comparative investigations on Raman spectral pattern of saturated solution of ammonium heptamolybdate tetra hydrate were done. The results showed that the main vibrant frequencies of Raman spectral pattern of the saturated solution were in good agreement with those introduced in the literature, and that the intensity ratio (4.4) of the strongest peak to the second strongest peak recorded in Raman spectrum of the saturated solution had three obvious characteristics: it was greater than each of the results (ranging from 3.7 to 1.3) reported in the literature, much closer to that (4.7) of crystal and well conformed to the change rule of Raman spectra occurring in the process of the first-step polymerization of acidified molybdate solution. It was found that Raman spectrum of heptamolybdate ion in aqueous solution was determined by not only the main vibrant frequencies but also the intensity ratio, which is also the crucial result in this study. The comparative investigations indicate that the pattern of Raman spectrum of the saturated solution is the standard pattern of Raman spectrum of heptamolybdate ion in aqueous solution essentially. The affirmed standard pattern is reliable and can be used to the identification of heptamolybdate ion in aqueous solution, applied in the research of the equilibrium of acidified molybdate solution and the exploration of the best technologic condition for the production of high quality heptamolybdates.

11:55 AM

Investigation on Chemical Components in Saturated Aqueous Solution of Ammonium Dimolybdate by Comparative Raman Spectroscopy: *Daojin Cao*[1]; Wenmi Chen[2]; Bin Jiang[2]; Hongzhao Liu[2]; [1]Central South University, Changsha University; [2]Changsha University

The chemical components in the saturated aqueous solution of ammonium dimolybdate (ADM) were investigated at room temperature by comparative Raman spectroscopy. In order to explore the further detailed results, a new method of qualitative and half quantitative analyses, based on the main vibrant frequencies and the intensity ratio of the strongest peak to the second strongest peak recorded in Raman spectrum of saturated aqueous solution of ammonium heptamolybdate tetra hydrate (AHM), was put forward and attempted to analyze the chemical components of saturated aqueous solution of ADM. The results showed that there was obvious difference between Raman spectrum of saturated aqueous solution of ADM and that of ADM, but there were good relationships between Raman spectrum of saturated aqueous solution of ADM and Raman spectra of the three samples including AHM, the saturated aqueous solution of AHM and monomolybdate ion in aqueous solution. It was found that aggregated dimolybdate ion ($\{Mo_2O_7^{2-}\}n$)did not

exist in the saturated aqueous solution, and was changed into heptamolybdate ion ($Mo_7O_{24}^{6-}$) and monomolybdate ion (MoO_4^{2-}), which were in equilibrium each other, but the distribution ratio of heptamolybdate ion was larger than that of monomolybdate ion. In addition, Raman spectral pattern of saturated aqueous solution of ADM was reported.

Thermo and Physicochemical Principles: Nano and Composite Materials II

Tuesday AM
August 29, 2006

Room: Russeau West
Location: Catamaran Resort Hotel

Session Chairs: Masahiro Kawakami, Toyohashi University of Technology; Dhanesh Chandra, University of Nevada

8:00 AM Keynote
Synthesis of Compact Nanocrystal Oxides by the Hard Plastic Deformations Methods: N. M. Chebotaev[1]; A. Gedanken[2]; B. A. Gizhevskii[1]; A. V. Fetisov[1]; A. Ya. Fishman[1]; E. A. Kozlov[3]; T. E. Kyrennykh[1]; L. I. Leontiev[1]; S. V. Naumov[1]; A. M. Patselov[1]; S. A. Petrova[1]; V. P. Pilugin[1]; V. B. Vykhodets[1]; R. G. Zakharov[1]; *M. I. Zinigrad*[4]; [1]Ural Division of the Russian Academy of Science; [2]Bar-Ilan University; [3]Russian Federal Nuclear Center; [4]College of Judea and Samaria

The present work presents the original data concerning using a high pressure torsion method and a shock wave loading technique to produce compact oxide nanomaterials and investigations of the effect of severe plastic deformation on a microstructure, crystal lattice and stability of these compounds. This allowed us to compare two ways of deformation action that can be characterized as quasi-static and dynamic effect, correspondingly. Particular attention was paid to a stoichiometry and surface composition changes upon severe plastic deformations. A procedure for studying chemistry of the oxide nanomaterials by means of nuclear microanalysis and Rutherford back scattering has been worked through. For surface studies the X-ray photoelectron spectroscopy has been used. It was shown that both distortion methods permit to produce massive nano-scale oxide materials from the coarse-grained powder during a single technological cycle. Bulk nanocrystalline materials based on $LaMnO_3$, TiO_y and ZrO_2:Y_2O_3 were obtained by the quasi-static deformation technique. Nanoscaled ceramics of CuO, Mn_3O_4 and $LaMnO_3$ were produced by the dynamic deformations. The density of the nanoceramics comes to 99%. Size effects and specific imperfection of the nanoceramics obtained lead to a set of particularities of physical properties.

8:20 AM
Synthesis of Ultrafine Particles of Aluminum Nitride by Evaporation of Aluminum in Argon + Ammonia Gas Mixture: *Seiji Yokoyama*[1]; Sadao Kokubo[1]; Masahiro Kawakami[1]; [1]Toyohashi University of Technology

In this study, molten aluminum was evaporated in gas mixture of argon + ammonia to synthesize the aluminum nitride and to study the evaporation rate, which was production rate of the condensed particles, in a reactive gas flow. Experiments were carried out under various partial pressures of ammonia, temperature and total gas flow rate by using a levitation melting apparatus. The feature of this method is to produce the ultrafine particles of metallic compounds without impeding the vaporization of metal. The characteristics of the condensed particles were studied by TEM, XRD and analysis of concentration. The evaporation rate increased by addition of small amount of ammonia to argon, but it was constant even if the partial pressure of ammonia increased. In the region that the evaporation rate remained unchanged, aluminum nitride was formed. The aluminum nitride was polygonal, and mean size of it was approximately 50 nm, which was not be influenced by the experimental conditions. The particles of metallic aluminum were also found. The ratio of aluminum nitride to the condensed particle was about 92 mass% judging from the analysis of concentration of nitrogen. The observation of TEM revealed that the particles of aluminum nitride formed by the reaction between the ammonia of the gas mixture and the alumina particles that were formed by the condensation of aluminum vapor. Beyond some ammonia partial pressure of the mixed gas, aluminum did not vaporize due to a formation of aluminum nitride on the surface of the levitated aluminum.

8:40 AM
Synthesis of W, WC and WC-Co Nanopowders by Chemical Vapor Condensation Process: *Jin-Chun Kim*[1]; Byoung-Kee Kim[2]; [1]University of Ulsan; [2]Korea Intitute of Machinery and Materials

Research on nanomaterials has been fairly active in the last several years to develop new processes and apply them. The driving force has been the potential to obtain unique physical, mechanical, electric, magnetic and tribological properties. Various kinds of methods have been investigated and developed to synthesize nanostructured powders, their consolidation processes, nanocrystalline bulk materials and thin film materials. Non-agglomerated W-based nanopowders (W, WC, WC-Co) were synthesized by chemical vapor condensation process by using metal-organic precursors. Characteristics of the as-prepared W-based nanopowders with the carrier gases and reaction atmospheres were investigated. Consolidation of the WC and WC-Co nanopowders were conducted by the spark plasma sintering process and the conventional P/M process. Co in CVC WC-Co nanopowder showed intricate long-stand structure because of intrinsic magnetic properties of Co phase. The SPSed WC-Co nanocomposites provided better hardness than the that of the commercial submicron powders.

9:00 AM
CFD Simulation of Flame Spray Process for Silica Nanopowder Synthesis from Tetraethylorthosilicate (TEOS): *B. Wan*[1]; Y. Ji[1]; H. Y. Sohn[1]; H. D. Jang[2]; T. A. Ring[1]; [1]University of Utah; [2]Korea Institute of Geoscience and Mineral Resources

The process to synthesize silica nanopowder by the gas phase thermal oxidation of tetraethylorthosilicate (TEOS) in a diffusion flame reactor was simulated using a commercial computational fluid dynamic (CFD) code. The fuel combustion process and silica particle formation and growth in the flame are modeled. The temperature, velocity and particle size distribution (PSD) fields inside the reactor are computed. Chemical reaction rate and population balance model (PBM) were used to calculate the particle formation and growth and PSD. The final results are compared with experimental data.

9:20 AM
Chemical Vapor Synthesis and Characterization of Aluminum Nanopowder as a Precursor of Hydrogen Storage Materials: *Jin Won Choi*[1]; Hong Yong Sohn[1]; Young Joon Choi[1]; Gilsoo Han[1]; Zhigang Zak Fang[1]; [1]University of Utah

Nanosized aluminum powder will be an important starting material for the preparation of several hydrogen storage materials due to low cost, light weight and high binding capacity for hydrogen. Nanosized aluminum powder was prepared by a chemical vapor synthesis (CVS) process in a tubular reactor. This CVS reactor was designed so that reactant powders can be fed into separate evaporators inside the reactor by means of specially designed powder feeders. This process for aluminum powder synthesis used a high-temperature reaction between a vaporized aluminum precursor $AlCl_3$ and Mg vapor. After the product powder was collected by bubbling the off-gas through ethanol, the powder composition and grain size were determined as functions of the $AlCl_3$/Mg ratio in the feed, residence time, and temperature. Titanium-doped aluminum powder has also been synthesized based on the reported improvement in the hydrogen storage properties of such a material. Doping was achieved by feeding titanium chloride into the reactor during the process of the aluminum-powder synthesis. The properties of the powders were subjected to various instrumental analyses.

9:40 AM Break

9:55 AM
Enhanced Properties of High Capacity Nanostructured Metal Hydrides: Brady G. Butler[1]; Jun Lu[1]; *Zhigang Zak Fang*[1]; Hong Yong Sohn[1]; [1]University of Utah

Many high capacity metal hydrides exhibit a high degree of stability in the hydrogenated state. This stability leads to a number of significant design

problems with regard to the low temperature kinetics and thermodynamics of dehydrogenation. Nanometric metal hydride materials provide a promising route for increasing the reaction kinetics while altering the thermodynamic stability of the material. The use of nanometric metal hydride materials for hydrogen storage has largely been absent because of the difficulties associated with the synthesis of these materials. In this paper, research results on the synthesis of lithium based metal hydrides by vapor phase reactions are presented. The lithium based compounds that have been made in our lab include nanosized powders of metallic Li, Li_3N, $LiNH_2$ and LiH. The vapor phase process has also been used to custom engineer Li-based materials with other alloying elements or doping elements. The dependence of the characteristics of these materials on synthesis process parameters is studied. The effects of nanoscaled particle sizes on the kinetics of dehydrogenation and hydrogenation reactions are also explored.

10:15 AM

Hydrothermal Synthesis and Surface Modification of BaTiO3 Ultrafine Particles: *Guo Jun*[1]; Li Qihou[1]; Liu Zhihong[1]; [1]Central South University

Owing to its excellent dielectric and piezoelectric performance, barium titanium ultrafine particle is widely applied in multi-layered ceramic capacitors, electro-optical apparatus, thermal varistors, piezoelectric switches, nonlinear varistors, as well as electric power converters, etc. In this study, BaTiO3 ultrafine particles surface-modified with stearic acid are synthesized by the hydrothermal method in a system of BaCl2-TiCl4-NaOH. The effects of original pH value in solution, temperature, time, concentration of reactants on structure and morphology of barium titanium ultrafine particles are investigated experimentally. The formation mechanism of different crystalline BaTiO3 particles is discussed, and it is considered that in a hydrothermal system, the main factors determining BaTiO3 crystalline are H+ replacement of Ba2+ causing H+ deficiency and anatase growth units involving in crystal growth, which clogs the axial channel for Ba2+ transference. By means of increasing the alkalinity of system and barium content, H+ deficiency and involvement of anatase growth units in crystal growth could be effectively controlled. The results show that when mole ratio of NaOH to TiCl4 is 10 and ratio of Ba to Ti 1.8, and time 8 hours, high purity tetragonal BaTiO3 ultrafine particles with a narrow grain-size distribution and nonpolar surface are obtained at 240°C. The particles have excellent flowability, which is ascribed that the surface polarity of barium titanium powder modified with stearic acid is changed and the interaction between the particles is weakened.

10:35 AM Invited

Vaporization Behavior of Group VIA to VIIIA Crystalline Carbonyls: *Dhanesh Chandra*[1]; K. H. Lau[2]; [1]University of Nevada; [2]SRI International

Metal carbonyls are of great importance in chemical vapor deposition (CVD), composite materials fabrication, and other near-net shape technologies. Carbonyl CVD application applies to deposition of high-purity metallic/alloy coatings. Vapor pressures of solid $Os_3(CO)_{12}$, $Rh_6(CO)_{16}$, $Ru_3(CO)_{12}$, $Ir_4(CO)_{12}$, $Re_2(CO)_{10}$, $Co_2(CO)_8$, $Cr(CO)_{12}$, and $W(CO)_6$ carbonyls have been measured using gravimetric-torsion effusion system. The vapor pressure data is used for many low and high temperature CVD applications. Interesting decompostion/disproportionation vaporization behavior has been noted for $Rh_6(CO)_{16}$, $Ru_3(CO)_{12}$ and $Co_2(CO)_8$. The vaporization studies of $Rh_6(CO)_{16}$ showed virtually complete decomposition to Rh metal and the measured molecular weight of the effusing gas from the solid $Rh_6(CO)_{16}$ was 27.75 g/mol, close to that of carbon monoxide as compared to 1065.56 g/mol for the value of solid $Rh_6(CO)_{16}$. Electron microscopic characterization, X-ray line broadening results for Rh carbonyl has been performed on the vaporization product. However, $Ru_3(CO)_{12}$, $Co_2(CO)_8$ showed very complex behavior. The molecular weights of the vaporizing species have been estimated and the numbers of vaporizing species are proposed. For example, there was partial decomposition of $Ru_3(CO)_{12}$ to (approx. 52%) metallic Ru and CO gas during vaporization, as suggested by the difference in the molecular weight of the vaporizing species of 107.58 g/mol compared to the actual value of 639.33 g/mol. The dimer $Co_2(CO)_8$ partially disproportionates to tetramer $Co_4(CO)_{12}$, monomer $Co(CO)_4$, and CO gas. Whereas, the $Os_3(CO)_{12}$, $Cr(CO)_{12}$, and $W(CO)_6$ have shown virtually no disproportionation. The total vapor pressures of all the above-motioned carbonyls, partial pressures of various species, average molecular weights of the effusing gases, equilibrium constants for the vaporization reactions, their enthalpies, entropies, and Gibbs energies will be presented. Program funded by U.S. Bureau of Mines and NSF.

10:55 AM

Switchable Magnetism for Arsenic Removal and Biomagnetic Separation: *Cafer T. Yavuz*[1]; J. T. Mayo[2]; William W. Yu[1]; Joshua C. Falkner[1]; Sujin Yean[1]; Li Li Cong[1]; Amy T. Kan[1]; Mason Tomson[1]; Vicki L. Colvin[1]; [1]Rice University; [2]University of St. Thomas

Uniform size and highly monodisperse (ó = 5-10%) magnetite (Fe3O4) nanocrystals were synthesized utilizing two different solvothermal reactions of iron (III) species (FeOOH and Fe(acac)3). Wide range of sizes (4, 6, 8, 11, 12, 14, 20, 26, 33 nm) achieved, characterized and used for further applications. Size dependent magnetic separation was studied and applied to polydisperse samples successfully. Magnetic field strength vs. percent retention of individual sizes reported. Magnetic multiplex separation method is created and proposed for bio-magnetic separations. Superparamagnetic limit for magnetite (Rc = 16 nm) is experimentally reported for the first time. Superparamagnetic property is used to turn on and off the magnetic activity of particles. Arsenic adsorption, 100% removal from wastewaters by nanosize magnetite is shown and compared to bulk material (100x better).

11:15 AM

Synthesis of Nanosized $LiFePO_4$ as a Cathode Material for Rechargeable Li-Ion Batteries by Co-Precipitation Route: Liang-Shi Hong[1]; *Yun-Jiao Li*[1]; Xiao-Ming Xi[2]; [1]Central South University; [2]Changsha Research Institute of Mining and Metallurgy

Olivine lithium iron phosphate ($LiFePO_4$) is considered as one of the most promising candidates for lithium-ion secondary batteries because of its high theoretical capacity, low cost, benign environment, safe and stable cycle performance. In this paper, nano-sized olivine $LiFePO_4$ powders were successfully synthesized by co-precipitation route from aqueous precursor solutions of $(NH4)_2Fe(SO4)2•6H_2O$, H_3PO_4 and $LiOH•H_2O$. The nature of the obtained $LiFePO_4$ powders was characterized by the use of X-ray diffraction (XRD) and scanning electron microscope (SEM). As confirmed by X-ray diffraction and scanning electron microscope, the material obtained by co-operation at temperature range from 60ºC to 100ºC and then followed by moderate heat treatment is a single-phase olivine $LiFePO_4$ with particle size of about 300nm. A carbon-coated olivine $LiFePO_4$/C was also prepared by adding conductive carbon, such as glucose, activated carbon and acetylene black, into the precursor solution. The existence of carbon increases the electronic conductivity of $LiFePO_4$/C composite, and consequently, leads to high rechargeable capacity. The carbon coated material with carbon amount of 7.64%wt obtained from glucose has the first discharge capacity of 150.3mAh/g at a 0.1C rate and 129.3mAh/g at a 1.0C rate, respectively. After cycled for 50 times, the capacity retention rate is 95.13% at a 1.0C rate in the voltage range between 2.5 to 4.3 V vs. Li.

Thermo and Physicochemical Principles: Non-Ferrous High Temperature Processing: Thermodynamics I

Tuesday AM — Room: Russeau East
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Onuralp Yucel, Istanbul Technical University; Mark E. Schlesinger, University of Missouri-Rolla

8:00 AM Keynote

Activities of Lead and Zinc Oxides in $CaO-SiO_2-FeO_x-AlO_{1.5}$ Slag: *Katsunori Yamaguchi*[1]; Shigeru Ueda[1]; [1]Iwate University

The zinc, lead and alumina contents in copper smelting slag are increasing with the increase in waste recycling. The recovery of base metals such as Zn and Pb from copper converter slag is important from both an economical and

environmental perspective. As a fundamental study of the metal recovery by reduction process, activity coefficients of ZnO and PbO in the CaO-SiO_2-FeO_x-10mass%$AlO_{1.5}$ slag under iron saturation at 1573K are derived from the data of slag-metal equilibrium experiments. On the basis of the obtained data, the activity coefficients of ZnO and PbO in the CaO-SiO_2-FeO_x-10mass%$AlO_{1.5}$ slag were compared with those of the CaO-SiO_2-FeO_x ternary system.

8:25 AM

Liquid Miscibility Gap in the Ag-Ag_2S System: *Hurman Eric*[1]; [1]University of the Witwatersrand

The high temperature liquid miscibility gap in the Ag-Ag_2S pseudobinary portion of the Ag-S system has been redetermined by very carefully conducted equilibration-quenching experiments. Samples were contained in evacuated and sealed silica capsules. The stratified liquid phase compositions were obtained by chemical analysis. The miscibility gap extends from 12.8 to 33.3 atomic percent at the monotectic temperature of 906°C and closes at around 1250°C. Thermodynamic properties of the liquid solutions, including the limiting activity coefficient of sulfur in molten silver were expressed analytically by using the sub-regular solution model which proved to be in excellent agreement with the experimental findings.

8:50 AM Invited

Solubility of SO_3 in Na_2SO_4 Melts and Thermochemistry of the Na_2SO_4-$Na_2S_2O_7$ System: *Ray Y. Lin*[1]; John F. Elliott[2]; [1]University of Cincinnati; [2]Massachusetts Institute of Technology

Solubility of SO_3 in Na_2SO_4 melts at temperatures between 1160 and 1250 K under gas mixtures of SO_2, O_2 and argon was investigated applying a thermogravemetric analysis technique. Together with the activity of Na_2O in the melt determined with a high temperature electrochemical cell, thermochemistry of Na_2SO_4-$Na_2S_2O_7$ melts was investigated. Results showed the SO_3 solubility in molten Na_2SO_4 increases with decreasing temperatures. Together with data from Flood and Forland (1947) at 828-928 K, it was concluded that the Na_2SO_4-$Na_2S_2O_7$ melt behaves as a regular solution with the interaction parameter, W, being 2.7 kJ/mol. Enthalpy of SO_3 dissolution in molten Na_2SO_4 was calculated to be -137.71 kJ/mol for infinite dilute solutions. The only other data found in the literature on thermodhemistry of this system (Koskin et al. 1975) was excluded from further analysis since their data appeared to have included points in the two phase region.

9:15 AM Invited

Review of Thermodynamic Properties of Elemental Antimony and Its Binary Compounds: Susan Jacob[1]; *Mark E. Schlesinger*[1]; [1]University of Missouri-Rolla

Thermodynamic properties of elemental antimony and its compounds have been discussed. Various experimental techniques and models to study heat capacity, Gibbs energy of formation and enthalpy of formation for antimonide compounds are also explained. Compounds are described on the basis of groups in the periodic table. Common stoichiometries and available binary phase diagrams are given. Thermodynamic properties studied by different authors are discussed and compared.

9:40 AM Break

9:55 AM Invited

Predicting of Sulfide Capacities of Industrial Lead Smelting Slags: Bora C. Derin[1]; *Onuralp Yucel*[1]; Ramana G. Reddy[2]; [1]Istanbul Technical University; [2]University of Alabama

A continuous improvement in the process technology and capacity of primary lead smelters (ISP, Kivcet, QSL, Kaldo, etc.) has been achieved for the last few decades due to changing economic structures and pollution prevention policies worldwide. However, conventional technologies such as sinter machine/blast furnace and sinter machine/ ISP are still the basis for the primary lead production. In primary lead production, sulfur causes metal losses in both entrained and chemically dissolved forms in the slags. As a result, an understanding of sulfide behavior of slags is essential for the development of clean metal technology. Optimization of slag composition has great importance on effective and clean metal production technologies. Reddy-Blander (RB) model, a priori, is very useful tool for prediction of impurity capacities of industrial slags. In this study, sulfide capacities (Cs) of 19 lead smelter slags indicated in the literature were calculated and effects of Cs values on sulfur content of lead bullions were discussed.

10:20 AM

Hydrogen Atoms as Metallurgical Reductants – The Potential and the Difficulties: David Roy Sadedin[1]; Waven Zhang[1]; Andrew K. Kyllo[1]; *Neil Boon Gray*[1]; [1]University of Melbourne

The highly negative Gibbs free energies of hydrogen atom reactions suggest that refractory oxides such as titanium dioxide should be easily reduced by hydrogen atoms. These reactions appear to be most favourable at low temperatures; metals should be reducible even at room temperature. Since hydrogen atoms are produced in plasmas containing hydrogen a number of investigators have used hydrogen plasmas of various sorts to test these possibilities for reducing refractory oxides, in particular TiO2. None of these attempts has succeeded, a small degree of reduction being achieved in only a thin layer near the surface. A deeper consideration shows that several factors complicate the reactions expected on the basis of the negative Gibbs free energy. One factor is that the back reaction by water molecules produces molecular hydrogen, not hydrogen atoms, and the metal atoms that have been reduced may be immediately re-oxidised. In plasmas there are complications due to diffusion, thermal and charge boundary layers and charged particle reactions. Interpreting the results of hydrogen atom reactions is difficult. Hydrogen is not detectable by electron dispersive spectroscopy and amorphous products are not determinable by x-ray diffraction. Another consideration is economics. The cost of producing hydrogen atoms has a large bearing on the metals for which hydrogen atom reduction may be competitive. In this paper various factors are set out, some necessary basic studies are highlighted and the general principles of a suitable reactor are given, together with the results of tests using ZnO, Cr2O3 and TiO2 as test oxides.

10:45 AM

Metal/Slag Equilibrium of Ca and Al in Silicon: *Cyro Takano*[1]; Joao Batista Ferreira[2]; Eduardo Camargo de Oliveira Pinto[1]; [1]University of Sao Paulo; [2]Technological Research Institute of Sao Paulo State

This is a contribution to fundamentals data on the equilibrium metal/slag for refining silicon with relation to impurities Ca and Al. Silicon containing 0.1% Al and without Ca were placed on the slag composed with different contents of CaO, SiO2 and Al2O3. Al2O3 contents were 11.4%, 25.1% and 29.6% keeping the ratio %CaO/%SiO2 constant and equal to ~0.55. The experiments were conducted at 1550°C, in a graphite crucible with argon atmosphere. The equilibrium was observed with low and medium content of Al2O3. The derived activities coefficients of Ca and Al in dilute solution of Si presented good correlation with those of the literature. Parallels reactions with formations of SiO(g) and CO(g) were observed.

11:10 AM

Thermodynamic and Kinetic Properties of Copper-Sulfur-Oxygen Melt: *V. A. Bryukvin*[1]; Valery M. Paretsky[1]; [1]Gintsvetmet

A characteristic feature of the macrokinetics of the interaction process is the presence of two specifically defined areas of oxidation which had a linear time dependence. The effect of variables, such as residual sulphur content of the melt, temperature and the oxidation potential of the gas phase, on the macrokinetics of oxidation are investigated. Phase composition and structure of products of solidification of partially oxidised melts and thermodynamic properties pentaining to Cu-S-O melts are used to analyze the macrokinetic behaviour and mechanisms of the interaction. The process of interaction of sulfide copper melts with oxygen may be considered as a disproportional absorption process and its mechanism is based on localized interaction on the surface and inside the melt volume. Superficial processes include also the process of primary chemisorption of oxygen by melts at place of metal-metal donor bonds proceeding with formation of oxysulfide liquid solutions and volumetric decomposition of the latter accompanied by evolution of sulfur dioxide and metallization of sulfide melts. It is the degree of dynamic balance of such interaction processes that determines specific individual features of the macro-kinetics and mechanism of oxidation of sulfide copper solutions with oxygen in the gas phase.

11:35 AM

Solid State Reduction of a Barite Ore: *Kamilia El Barawy*[1]; I. A. Ibrahim[1]; A. Eltoni[1]; [1]Central Metallurgical Research and Development Institute

Processing of Egyptian barite ore (85.5% $BaSO_4$; 2.75%SiO_2; 1.56%Fe_2O_3 and 5.1% Al_2O_3) was performed with the aim to prepare pure barium salts. The process took place through pelletisation-solid state reduction and leaching steps. Each of these steps was optimized. Pure barium sulphate (99%<0.82µm) and carbonate (99%<0.75µm) were the final products. This article is interested with the reduction process where coal was added to the ore during pelletisation in the ratio of 5:1 stoichiometry. Optimum reduction of pellets (8-12mm in diameter) was achieved after 60 minutes at 1050°C and under a rate of 5 $lmin^{-1}$ of nitrogen atmosphere, where 87.79% of the ore was reduced. The kinetic studies showed that the reduction process could be modeled according to the core mechanism of diffusion control in which the effective diffusivity is based on the surface area of un reacted ore. The activation energy calculated was 92.7 $KJmol^{-1}$.

Thermo and Physicochemical Principles: Steel Making: Liquid Steel Processing and Reactors

Tuesday AM — Room: Russeau Suite
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Jian Zhang, New Mexico Tech; Sridhar Seetharaman, Carnegie Mellon University

8:00 AM Keynote

Oxidation and Decarburization in TRIP Steels: *Tamara L. Baum*[1]; Richard J. Fruehan[1]; Sridhar Seetharaman[1]; [1]Carnegie Mellon University

External oxidation during in-line heat treatment of TRIP steels can cause problems for the subsequent coating process. This research aims to understand the kinetic rates of internal oxidation, external oxidation and decarburization and their interdependence under different gas atmospheres and temperatures. A steel sample containing 0.14 wt. % C, 1.8 wt. % Mn, 0.6 wt. % Si and 1 wt.% Al was used initially. Thermogravimetric techniques are used to examine the net mass change in a sample during heat treatment, and the results show an initial mass decrease and later an increase, indicating decarburization is initially faster than oxidation. Additional interrupted experiments were done to obtain samples for carbon and metallographic analysis. The dependence of these rates of mass change on the water vapor content in the gas phase is quantified and compared to theories predicting oxidation and decarburization. SEM-EDS, optical microscopy and glancing-angle x-ray is used to quantify the microstructure. The cross-section of the samples have 4 distinct zones: (i) an external scale, rich in fayalite, (ii) an internally oxidized region with Al, Si and Mn oxides in an Fe matrix, (iii) a decarburized steel region, characterized by large grains and low carbon content, and (iv) a relatively unaffected steel region. The thicknesses of these regions at different stages of the annealing cycle is used to elucidate the reaction mechanisms.

8:25 AM Invited

Colemanit is Used as Flux Agent in Steel Production: Levent Ozmen[1]; *Erk Inger*[1]; [1]National Boron Research Institute

In this study colemanite [$CA_2B_6O_{11}$,$5H_2O$] is used as flux agent in steel production. Dissolving velocity, metal-slug reactions and the solubility of (MgO)in the slug are all investigated. The colemanite is a mineral containing varying amounts of (B_2O_3) mainly founded as boron source in Türkiye and USA.

8:50 AM

Determination of Optimum Calcium Carbide for Deoxidation of Slags: *R. Javier Santiago*[1]; Luis A. Mombello[1]; [1]Electrometalúrgica Andina Saic

The lack of information on calcium carbide reaction mechanisms in steel production, leads to erroneous concepts about the evolved phases and also causes distrust when using this powerful deoxidant in the steel industry. This paper tries to find answers for numerous questions as to which is the optimal quality needed (calcium carbide content) to obtain the best results. The paper will focus on the follow-up of different deoxidants operations in the different steel makings and will try to determine if the eutectic points, due to their lower fusion points, influences on its reduction capacity and verify if eutectic calcium carbide reacts in a more efficient manner while reducing iron and manganese oxides. Also the grain size variable will be analyzed and its influence on the carbide's reactivity and reaction time with the slag and foam generation. This is a very important variable to keep in mind, because it is supposed that the bigger grain sizes develop lower reaction rates, directly affecting the treatment time.

9:15 AM

Continuous Cooling Transformation Behavior of an As-Rolled Dual Phase Steel with Low Carbon and Low Alloy: *Tao Li*[1]; Yumei Pu[2]; Guang Chen[3]; Jianping Zhang[2]; Jian Zhang[2]; [1]Nanjing University of Science and Technology; [2]Technological Center of Maanshan Iron and Steel Company Limited; [3]Nanjing University of Science and Technology

The development of DP (Dual Phase) steels and TRIP (Transformation Induced Plasticity) steels has received much attention in recent years due to their high strength and simultaneous good ductility, which provides the potential for weight reduce and resource savings on certain components in automobile or other industries. So a controlled rolling process was simulated in the present study by thermomechanical simulator (Gleeble1500) for producing DP steels on a kind of low carbon steel containing a small amount of Si and Cr. The F+M dual phase microstructure has been obtained during continuous cooling processes of a wide cooling rate range from 10K/s to 60K/s. The grain size of the dual phase steel developed can be refined to less than 5 microns through the mechanism of deformation induced ferrite (DIF) transformation. The ultrafine ferritic grains are equiaxed with high-angle boundary, and the martensite islands of an average size less than 5 microns disperse uniformly in the ferrite matrix. The ultrafine martensite islands not only inhibit the growth of ultrafine ferritic grains and improve the bonding of F/M interface, but also increase remarkably the strain hardening rate in the processing of the present Dual-Phase steel. As a result, the tensile strength of ultrafine grained Dual-Phase steel reaches higher than 1000 MPa. The result shows that an ultrafine grained Dual-Phase steel of low carbon and low alloy is promised to exhibit desired F+M microstructure by means of this new TMCP process.

9:40 AM Break

9:55 AM Keynote

A Fundamental Study of Oxygen-Melt Reactions in the AOD Process: *David G. Robertson*[1]; Ghantasala Satyanarayana Rao[1]; [1]University of Missouri

Levitated drops of Fe-18%Cr-2%C were reacted with oxygen-argon mixtures to study the reactions that occur in the AOD process, where the gases are injected into the melt and form bubbles. In the laboratory an argon-oxygen pulse, followed by pure argon, was flowed past the levitated drop to simulate the transient conditions in the gas phase as the bubbles rise in the melt. Oxide layers formed on the drops immediately when they came into contact with gas pulses containing 75% or more oxygen. Once the oxygen flow had ceased, the oxides reacted with the carbon in the drops to form CO gas and eventually disappeared. The de-carburization reaction occurred without oxide formation when the gas contained 50% oxygen or less. Melts that were sampled after EAF tapping, ready to be charged into the AOD, showed a higher tendency to oxide formation and consequent carbon boil than pure ternary Fe-18%Cr-2%C alloys made in the laboratory. The actual steel samples contained significant impurities, such as 0.25% Si and 0.56% Mn. A similar effect of oxide-forming impurities had been observed previously with binary Fe-C alloys. Movies were taken of the oxide formation and decomposition, and the results will be presented, along with data on the experimental conditions, including temperature and oxide compositions. The results are important because they give an insight into the reaction mechanisms in the AOD, which must be understood in order to improve and model the process.

10:20 AM

The Use of Calcium Carbide in Steel: *R. Javier Santiago*[1]; Luis A. Mombello[1]; [1]Electrometalúrgica Andina Saic

The normal methods of steel production produce oxidizing slags in the electric furnace (or in the converter) and reducing slags in the ladle. During the tapping of the furnace part of the slag is normally carry over to the ladle, wich is the primary carrier of iron and manganese oxides. The oxides present in the slag are found in equilibrium with the oxygen in the steel. Later, the steel is deoxidized in order to reduce the oxygen activity level to a lower level, below the equilibrium with the slag. Consequently the slag is a potent source of oxygen during the refining operations, for which reason, it must convert this oxidizing slag into reducing slag and in this way, avoid future steel reoxidation. Calcium carbide is an acetylure which produces acetylene by hydrolysis. It is a potent reducing agent used in the production of acetylene gas, for the desulphurization of cast-iron and in slag treatment of steel (secundary metallurgy). This paper focuses on the analysis of the use of calcium carbide in slag treatment, in order to understand the intervening reaction principles, as well as to offer steel producers a summary of the advantages of this powerful deoxidant which permits conversion of the oxidizing slag (from the ladle) into reducing slag, achieving improved steel quality and obtaining a decrease in alloy consumption.

10:45 AM

A Study of Droplets during Top Lance Blowing: *Annie Nordqvist*[1]; Anders Tilliander[2]; Pär Jönsson[2]; Gunilla Runnsjö[3]; Kaj Grönlund[4]; [1]Volvo Powertrain Sweden; [2]Royal of Technology; [3]Outokumpu Stainless Avesta Works; [4]CORR-CONTROL

Laboratory trials were performed in an induction furnace to study droplet formation during lance blowing. Compressed air was blown on a molten iron bath consisting of iron alloyed with carbon and silicon. Steel droplets were collected using a specially designed sampler. The average steel droplet composition and the oxide layer thickness were determined using scanning electron microscopy combined with energy dispersed spectroscopy. In addition, the concentration gradient of elements was determined using a microprobe. It should be noted that a specially designed technique had to be developed in order to prepare the droplet sample. The size distribution of the droplets was also determined using the microprobe. It was found that the carbon content in the droplets was lower than the carbon content in the hot spot area and the bulk. The decarburization rate however was the same for the droplets as for the hot spot area and the bulk.

11:10 AM

Experimental Study on the Simultaneous Desulfurization and Denitrification by Duct Injection: *Qin Hui Li*[1]; [1]Tianjin Northern China Geological Exploration Bureau

The highly active absorbent with oxidization based on fly ash, lime and additive was prepared. Experiments of simultaneous desulfurization and denitrification were carried out using fixture bed and duct injection. The influential factors for the absorptive capacity of the absorbent were studied. The absorptive capacities of 120.7mg for SO2 and 43.7 mg for NOx were achieved at a Ca/(S + N) molar ratio 1.2, respectively, corresponding removal efficiencies of 87% and 76%, while spent absorbent appeared in the form of dry powder. The optimal temperature and humidity of flue gas treated with this process were shown to be approximately 50°, and 5% respectively. The mechanism of removal for SO2 and NOx was investigated. In comparison with traditional dry FGD, this process appears to have lower cost, less complicated configuration and simpler disposal of used absorbent. The valuable references can be provided for industrial application by this process. The foreground of application will be vast in China and in the world.

11:35 AM

A Process for Saving Energy and Time in Electric Arc Furnace: *Ali Akbar Mottahedi*[1]; [1]Iranian Research Organization for Science and Technology

It is known for a long, that the reaction of oxygen with carbon, silicon, iron and many other elements is exothermic. The heat of released from these kind of reactions can decrease the time of fusion of iron steel for metallurgical purposes in the electrical arc furnaces. By decreasing the time of fusion, we increase the rate of process and the amount of production. So, by blowing oxygen in to the furnace, we can reduce the consumption of electricity and save money. There are many problems in the procedure of the oxygen blowing. In this project, we investigated the theoretical aspect of the oxygen blowing and its side effects into the arc electric furnaces. We also set up and oxygen blowing System in to the arc electrical furnace of metallurgy department of Machine Sazi factory. This process reduced the consumption of electricity up to 22% and increased the rate of production, by reducing tap – to – tap time up to 15% in this project; we also created all oxygen blowing systems and its control.

Industrial Practice: Iron Making

Tuesday PM — Room: Cockatoo
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Masaaki Naito, Nippon Steel Corporation; Tateo Usui, Osaka University

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1:30 PM Keynote

Recent Process of Practical BF Operations in Japan and Innovative Trials for the Future: *Masaaki Naito*[1]; Morimasa Ichida[1]; Shinroku Matsuzaki[1]; [1]Nippon Steel Corporation

The Japanese steel industry has a long history of introducing new and innovative technologies in the field of ironmaking. The new technologies introduced during the past ten years include technologies to use cheaper and lower-grade raw materials and fuels, measures to prolong the service life of blast furnaces and coke ovens, promotion of energy saving, use of wastes and solutions to environmental problems. This report outlines the condition of production and technological trends and technical development themes in ironmaking technologies.

1:55 PM

Assessment of Metallurgical Performance of Kambra Reactor (KR) Reactor through Physical Modeling: *Varadarajan Seshadri*[1]; Carlos Antonio da Silva[2]; Itavahn Alves da Silva[2]; Versiane Albis Leão[2]; Dimas Bahiense Moreira[3]; Odair José Kirmse[3]; [1]Universidade Federal de Minas Gerais; [2]Universidade Federal de Ouro Preto; [3]Companhia Siderúrgica de Tubarão

Kambara Reactor (KR) consists of a ladle where pig iron is stirred by an impeller. Agitation provides for reactant dispersion, usually a flux powder, throughout the pig iron and this improves desulfurization kinectics by improving solid liquid interaction. The shape, the life of the impeller is limited as it is subjected to abrasion at high temperatures which has an effecton the performance of this reactor. A 1:7 scale cold model of a KR plant was constructed in order to investigate the mixing and mass transfer conditions. Mixing was evalueted by tracer additions and measurement of conductivity. Mass transfer in the reactor was assessed iodine transfer between water and kerozene. Mixing depends on impeller shape and depth of immersion. Mass transfer was assesed through a macroscopic model. The role of dispersion is highlighted by faster kinetics when impeller velocity is increased. The results enable assessment of design aspects of the impeller on the process.

2:20 PM

Blast Furnace Ironmaking and Gas Based-DRI Production – A Case Study in Cross Fertilization of Innovation: *Pinakin Chaubal*[1]; Ali Farhadi[1]; Jorj Tsvik[1]; Frank Huang[1]; [1]Mittal Steel Company

Mittal steel produces steel using both DRI and molten pig iron. DRI is utilized primarily in our EAF operations. We are the largest producer of both DRI via gas-based-shaft furnaces and pig iron via blast furnace technology. It is interesting note that in both reactors the focus in recent years has been towards increasing productivity and decreasing specific fuel usage. Both technologies have been pushed far beyond the original design capacities with innovative modifications. Although the product parameters are quite different and traditionally it has been considered that the characteristics of the

processes in the shaft are also unique to each technology, there are numerous operating improvements that bear resemblance. In this paper we will describe similar concepts such as oxygen injections, natural gas injection, high bustle temperature etc. and compare and contrast their impact on the operation of each reactor. Utilizing experiences from one technology to further the other has become an important part of our technological advances.

2:45 PM

Development of 3-D CFD Model for Blast Furnace Hearth: *Pinakin Chaubal*[1]; Dave Roldan[2]; D. (Frank) Huang[1]; Chenn Qian Zhou[2]; [1]Mittal Steel Company; [2]Purdue University Calumet

Hot metal flow and heat transfer in a blast furnace hearth significantly affect the hearth wear. Due to difficulty to make measurements inside the hearth during operation, computational fluid dynamics (CFD) has been identified as a useful tool to elucidate the internal state of the blast furnace hearth. In this research, a 3-D CFD model has been developed. It includes a complete real geometry including deadman, hot metal flow domain, blowing layer, skulls, refractories, ram, and steel shell. Convection boundary conditions are specified on the outside surface of the steel shell and bottom. It can simulate non-uniform refractory thermal conductivity distributions and thermal connections, as well as actual asymmetric wear profiles. It can simulate both steady and unsteady sate as well as both laminar and turbulent flows. It can include species calculations as well as multiphase (hot metal and slag) flows to predict detailed profile of the liquid level during tapping. It has been extensively validated using both laboratory experimental data and plant measurements. It has been used to analyze the velocity and temperature distributions and wear patterns. Parametric studies have been performed to evaluate the impact of geometry and operating conditions. In this paper, the development of the 3-D CFD hearth model will presented and discussed along with detailed validations and several applications on existing blast furnaces.

3:10 PM Break

3:25 PM Keynote

Effect of Oxygen Potential and Fluxing Components on Phase Relations during Sintering of Iron Ore: *Florian Kongoli*[1]; I. McBow[1]; Robert D. Budd[1]; S. Llubani[1]; [1]FLOGEN Technologies Inc

The optimal operation of the blast furnace depends considerably on the properties of the sinter fed into the furnace. As a result, the optimization of the sintering processes has a direct effect on the overall effectiveness of the iron making processes. In order to produce a good sinter special care needs to be taken in order to assure it has a good permeability and reducibility and it is able to retain these properties for a certain time. If the sinter starts to melt down early in the upper part of the blast furnace, where its solid state reduction is essential, permeability decreases, the gas channels get blocked, reductibility diminishes and serious problems may also follow. Among the factors that influences the above mentioned sinter properties are the oxygen potential and fluxing components. Nevertheless, their effect on the phase relations during sintering and sinter reduction conditions has not yet entirely clarified and confusion exists in literature. This quantification becomes even more important today where many new minor components such as Al_2O_3 and MgO enter the sinter through raw materials. This work quantifies the effect of oxygen potential and fluxing components such as alumina and magnesia on the liquidus and phase relations of the sinter primary melts in the iron rich portion of CaO-FeO-Fe_2O_3-SiO_2 system at sintering conditions. This is carried out by the means of new type of industrial diagrams in the form of Fe/CaO vs. SiO_2 that can directly help the optimization of the sintering processes.

3:50 PM Invited

Development of Visual Evaluation and Numerical Analysis System of Blast Furnace: *Shinroku Matsuzaki*[1]; Masahiro Ito[1]; Morimasa Ichida[1]; Tsunehisa Nishimura[1]; Masaaki Naito[1]; [1]Nippon Steel Corporation

Data the measurement sensor installed with spatial distribution on the blast furnace were successively accumulated online from the process computer to the database system over a long period. This is a new system that accurately considers the relation with the installation position of each sensor, and picture computerization of the measurement data was developed. The overall operation state of a blast furnace, which skilled operators can see in their mind's eye, was objectively visualized as pictorial information.

4:15 PM Keynote

Dynamic Solid Flow in Iron-Making Blast Furnace of Lower Part by Deadman Shape and Raceway Depth: *Yoshiyuki Matsui*[1]; [1]Kobe Steel, Ltd.

As one of the factors of frequent troubles on iron-making blast in recent years, increased size of the blast furnace and high-productivity operation are pointed out. Consequently, great importance is attached to deadman shape and solid flow at the lower part of furnace. In the present study, firstly, the blast furnace raceway formation under the intensive coal injection by measurement of micro wave reflection gunned through a tuyere is discussed. As the flow rate of coke as the momentum of coke into raceway decreases by combustion of coal injected into tuyeres, the depth of raceway defined as the maximum position of micro wave reflection is easy to contract. It is expected that this new technology could detect the raceway collapse phenomena in short time and that the stability of raceway in coal injection is different from that in all coke operation. Secondly, the reduced stockline surface profile was measured by the reflection intensity of microwave struck from the furnace top after blow-off with stockline reduced, and investigation was made on the countermeasures for changes in the raceway depth and furnace body profile during operation. As a result, it has been clarified that flow-down of coke into the lower part of blast furnace and inflow into the raceway are greatly subject to the existence of deadman which is the packed structure of the lower part of furnace, and further, they are closely related to dynamic behavior of the raceway, and affect changes of the furnace body profile.

4:40 PM Invited

Numerical Analysis on Blast Furnace Operations by Multi-Dimensional Mathematical Model Based on Multi-Fluid Theory: *Jun-Ichiro Yagi*[1]; Hiroshi Nogami[1]; Mansheng Chu[1]; [1]Tohoku University

A mathematical model has been developed for simulating the blast furnace operation with carbon composite agglomerates charging based on multi-fluid theory and reaction kinetics. In this model, the behaviours of carbon composite agglomerates are considered based on previously reported experimental research and conservation equations, and reduction rate of carbon composite agglomerates is introduced. A series of calculations are performed to examine the effect of charging carbon composite agglomerates. The model calculation gives two-dimensional distributions of process variables and information on the overall operational parameters. It reveals that in-furnace temperature levels significantly decrease and the reduction of carbon composite agglomerates is retarded with carbon composite agglomerates charging ratio. The furnace performance is remarkably improved with the increase in carbon composite agglomerates rate. The productivity tends to increase while coke rate and total reducing agent rate show decreases at the different degree.

5:05 PM

Numerical Investigation of the Self-Reduction Process of Pellets in a Rotary Kiln with Post-Combustion to Produce DRI: *Jose Adilson Castro*[1]; Cyro Takano[2]; Marcelo Breda Mourao[2]; Jun-Ichiro Yagi[3]; Alexandre Jose Silva[1]; [1]Federal Fluminense University; [2]University of Sao Paulo; [3]Tohoku University

The growing demand of scrap to supply the electric arc furnace has driven to search for new alternatives of raw material. The DRI produced using self-reducing pellets has become competitive due to the potential use of a wide range of carbonaceous materials such as coal, charcoal, biomass etc. In this context, the rotary kiln process using improved technologies such as post-combustion and self-reducing burden is a promising source of high quality raw materials. This paper presents a mathematical model of the rotary kiln process designed for self-reducing pellets and post-combustion. The model is based on the transport equation of two-phase flow, energy and mass transfer. The solid material is composed of a typical self-reducing pellet. The model considers the solid phase (C, volatiles, Fe2O3, Fe3O4, FeO, Fe, H2O, SiO2, Al2O3, MgO, P2O5, K2O, Na2O, FeS, CaO and gangue) and the gas phase (N2, O2, CO, CO2, H2, H2O, SO, SO2 and SiO). For each of the above components a conservation equation is solved and the mass and energy transport is accounted. The set of differential equations are coupled by the

rate equations describing the kinetics of the several reactions, which take place within the rotary kiln. All the conservation equations are solved based on the finite volume method applied for a three-dimensional cylindrical coordinate system. Simulation results are presented for global parameters such as metallization degree, productivity, gas utilization ratio and calorific value. Inner conditions such as three-dimensional gas and solid temperature patter and compositions are discussed.

International Symposium on Sulfide Smelting: Technologies and Recent Developments I

Tuesday PM
August 29, 2006

Room: Macaw
Location: Catamaran Resort Hotel

Session Chairs: Maurits Celine Van Camp, Umicore RDI; Ulrich Kerney, Metaleurop Weser GmbH

1:30 PM Invited

Copper Production with Outokumpu Flash Smelting: An Update: *Ilkka V. Kojo*[1]; [1]Outokumpu Technology

Flash Smelting connected with either Peirce-Smith converting or Flash Converting offers the most economical and environmentally friendly alternatives for the smelting of lean copper concentrates. For rich copper concentrates the feasibility of Outokumpu's Direct Blister smelting is, understandably, beyond compare. When the total investment costs for building a smelter and acid plant are considered, it is clear that Flash Smelting is the more feasible option compared to bath smelting. As an example the Kennecott-Outokumpu Flash Converting Furnace (FCF) has been in operation at Kennecott Utah Copper for 10 years and is achieving excellent results. The FCF treats the entire output of the Kennecott Flash smelting furnace and has excess converting capacity. Furnace life, initially projected at two to three years, is now projected to be more than 5 years. It is likely the life will be essentially the same as a well-operated Flash Smelting furnace. This paper gives an overview of the primary copper smelting business during the last years in the light of various projects. Also the future challenges of copper smelting are addressed with special emphasis on investment costs, operating costs and the environment.

1:55 PM Invited

The Development of the Codelco-Chile Continuous Converting Process: Alex Moyano[1]; Carlos Caballero[1]; Pedro Morales[2]; Domingo Cordero[3]; Jonkion Font[3]; *Roberto Mac-Kay*[3]; [1]FCN, Codelco-Chile; [2]GIIT, Codelco-Chile; [3]IM2 SA Filial Codelco-Chile

The present scheme for the traditional converting process in the Peirce-Smith converter (PSC) used in the Chilean smelters, limits its development for the lack of the production increments. This mainly due to the investment magnitude associated to the fulfillment of the environmental rule. The objective of this paper is present the technological advance reached in the Codelco continuous converting process, for converting mattes and/or white metal to a blister copper, and its future industrial projection, as an alternative for the development of the smelters at Codelco-Chile. Since 1994, Codelco-Chile started to study this technology as a "home made" alternative to the traditional converting process. By 2001, the Caletones smelter processed liquid white metal to a blister copper in a rearranged PSC. Then during the 2001-2003 period, several pilot and industrial scale tests were done in a Teniente Converter unit at the Codelco Norte (CN) smelter, evaluating the continuous converting process, i.e., processing liquid high grade copper mattes (68-75% Cu) to a blister copper, demonstrating its technical feasibility with: (i) constant gas production with flow and SO2 concentration, (ii) production of liquid slag, and (iii) production of a clean blister copper, suitable for the next refining process. The obtained promising results have led Codelco-Chile to plan for the 2006, a next advanced stage of the continuous converting process evaluation by carrying out industrially long term tests in a Teniente Converter of the CN smelter.

2:20 PM Invited

Hypothetical Isasmelt Copper Converting: A Review of Possibilities and Challenges: *John Rapkoch*[1]; Mario Cerna[1]; [1]Fluor Chile S. A.

In the continuing search for copper matte converting methods, commercially available and feasible choices remain Peirce-Smith Converters, Hoboken Converters, Mitsubishi Converting, Ausmelt converting, and Outokumpu/Kennecott Solid Matte Oxygen Converting ("Flash Converting"). While each alternative improves on Peirce-Smith Converters' limited fugitive gas capturing capability, the Peirce-Smith Converter is relatively easy and economical to operate and has an unmatched ability to accept valuable but difficult-to-handle material such as scrap anodes and purchased scrap copper. Recent experience with designing, building, and starting up an ISASMELT facility, applied in primary smelting of copper concentrates, has led the authors to speculate on how suitable the ISASMELT process would be for copper converting, given its low fugitive gas release and its ability to accept a variety of feed types. This paper reviews the potential metallurgical challenges posed by converting copper matte in an ISASMELT vessel and considers possible engineering and design challenges posed by the inclusion of this technology into a new or refurbished copper smelter.

2:45 PM Invited

Technological Innovations in the Mitsubishi Process to Achieve Four Years Campaign: *Toru Taniguchi*[1]; Teruyuki Matsutani[1]; Hideya Sato[1]; [1]Mitsubishi Materials Corporation

The existing Mitsubishi Process line at Naoshima Smelter and Refinery has been operating successfully since 1991, and its present production capacity is 270,000tpy of copper. Furnace relining works have been carried out every two years to coincide with the compulsory bi-yearly boiler inspection, but the next target is to extend the furnace refractory life to four years, while still undergoing the mandatory boiler inspection every two years. Although the damage of hearth bricks beneath lances in the Smelting furnace was a matter of concern, it was reduced by controlling gas velocity and evening solid distribution to each lance. The life of bath level bricks in the Converting furnace was also a concern, four-years continuous use of the bricks was achieved in the course of the last two campaigns. Several other improvements were also carried out to the cooling systems during the shutdown in 2005 to ensure longer campaign life. This paper summarizes recent improvements implemented to enhance the advantages of the Mitsubishi Process.

3:10 PM Break

3:25 PM Invited

ISASMELT - 6,000,000 TPA and Rising: *Philip S. Arthur*[1]; [1]Xstrata Technology

The ISASMELT process is a submerged lance smelting technology operating in smelters in Australia, the USA, Belgium, India, Germany, Malaysia and China. Further plants are under construction in Peru and Zambia. Following the invention of the Sirosmelt lance technology Mount Isa Mines recognised the commercial potential in the novel top blown bath smelting process and embarked on a development program that has lasted more than 25 years. After successful operation of pilot plants and demonstration plants producing copper and lead, Mount Isa Mines decided to license the technology to external companies. Since the purchase of Mount Isa Mines by Xstrata in 2003, Xstrata Technology has assumed responsibility for transferring the technology to ISASMELT licenses. In the 15 years since the first commercial furnaces started operation plants have been constructed (or are under construction) with a combined annual smelting capacity of more than six million tonnes of concentrates or secondary raw materials. Process development continues on the commercial scale plants at Mount Isa and elsewhere. Many of the improvements implemented by plant operators have been passed on to, and adopted by, other licensees. Exchange of ideas and technical improvements occurs through ad hoc visits to fellow licensee sites and through regular licensee workshops arranged by Xstrata Technology. This paper updates the reader on the status of various ISASMELT plants either operating or under construction. It highlights the role that the technology provider's operational experience plays in ensuring that new smelting plants ramp up quickly to nameplate capacity.

3:50 PM Invited

Inco Flash Furnace Froth Column Modifications: *Jin Liu*[1]; Malcolm H. I. Baird[2]; Paul Kenny[1]; Brian Macnamara[1]; Ahmad Vahed[1]; [1]Inco Ltd; [2]McMaster University

In the early 1990's, Inco successfully installed two new flash furnaces as part of their SO_2 abatement project to reduce SO_2 emissions from the Copper Cliff Smelter by 60%. The flash furnace off-gas is cooled and cleaned through two new Monsanto Dynawave gas cleaning systems that replaced the traditional venturi scrubbing system. It was discovered that the flash furnace production capacity is often limited by the capacity of the gas cleaning system. The key task is to eliminate pressure drop from the system. The froth column is responsible for by far the largest pressure drop in the gas cleaning system. Initially, the column was fitted with 22 plates. In 1994, both #1 and #2 froth columns were modified by reducing the number of plates in each column from 22 to 18 and increasing the interplate spacing on lower plates. With increasing demand for more throughput in the flash furnaces, further modifications on the froth columns were made in 2005. This paper describes these modifications and results together with some fundamental analysis of the froth column characteristics.

4:15 PM Invited

Direct Blister Copper Smelting Process – Outokumpu's Methods to Increase Feasibility: *Esa J. Peuraniemi*[1]; Markku Lahtinen[1]; [1]Outokumpu Technology

Copper smelting to form blister in one single step has always been possible. In spite of obvious benefits, it has been economically viable only with few special concentrates having high enough Cu/Fe and Cu/S ratio. Outokumpu Blister Flash Smelting is currently applied at three operations, and two others will be commissioned in near future. With typical chalcopyrite concentrates two main obstacles have prevented wider adaptation of direct blister processing: slag formation and heat generation. Oxygen potential in the reaction shaft must be high in order to produce blister as sulphur content is targeted around 0.2%. If large amount of iron is oxidized, as well as sulphur, inevitably copper is oxidized also into slag. High copper content of slag as well as substantial tonnages of slag derive to costly recovery operations to obtain discardable slag. Almost complete oxidation of sulphur and iron releases high amount of heat that traditionally has been solved by lowering oxygen enrichment of the blast deriving to oversized off-gas line and acid plant. One challenge in direct blister smelting relates to the attack of aggressive high-copper containing slag against furnace refractory lining. In continuously operated Outokumpu Direct Blister Flash Smelting this is taken care with even solids feeding. Stable settler enables the stationary slag against refractory lining to create a protective autogenous layer between aggressive slag and vulnerable refractory. These direct blister smelting challenges are addressed from equipment and process development point of view and, new solutions to overcome them are presented and discussed.

4:40 PM Invited

The State of the Art in Nickel Smelting: Direct Outokumpu Nickel Technology: *Tuula Mäkinen*[1]; Pekka A. Taskinen[1]; [1]Outokumpu

In 1959 Outokumpu started up a nickel smelter and refinery at Harjavalta. The flash smelting – Peirce-Smith converting route was applied, and the converter matte was further refined to nickel cathodes. In 1995 the production capacity was increased from 17 000 mt/a to 52 000 mt/a, based on the Direct Outokumpu Nickel Smelting Process (DON). The additional refinery capacity is based on hydrogen pressure reduction, producing nickel powder and briquettes. In the DON technology, high-grade nickel matte with low iron content is produced in the flash smelting furnace directly without converting. The metal values in the smelting slag are recovered in an electric furnace as an iron containing Ni-matte. The mattes produced differ from the conventional nickel mattes, and therefore focused R&D efforts have been made in order to cope with their melting points, fluidities and settling properties. The low melting points of the high-grade nickel mattes produced in the DON furnace have pointed out challenges in the furnace design, in particular in the hearth and its thermal engineering. Also key issues of the DON technology are smelting of high-magnesia concentrates, the recoveries of nickel and copper, as well as those of PGM's and cobalt. This paper deals with the experience of the DON technology gained over the first ten years of operation, including the significant environmental impacts. Selected results of the thermodynamic modelling of the mattes and high-magnesia slags are reviewed. Also the design principles of the FSF and EF are discussed.

5:05 PM Invited

Two-Zone Vaniukov Furnace: New Opportunities for Copper and Nickel Production: M. V. Knyazev[1]; A. G. Ryabko[1]; L. B. Tsymbulov[1]; *L. S. Tsemekhman*[1]; [1]Gipronickel Institute JS

New method for processing of copper and nickel production feeds has been developed and tested at pilot unit with 10 t/hr capacity. The process allows single-stage treatment of ore feed, including the one with high magnesium oxide content, resulting in the production of rich matte, high-grade matte, or metallized alloy for further leaching, dump slag and off-gases suitable for production of elemental sulphur, liquid sulphur dioxide or sulphuric acid. Results of testing and principal technical and economical parameters are presented.

Legal, Management, and Environmental Issues: Management of Environmental, Recycling and Waste Treatment I

Tuesday PM
August 29, 2006

Room: Kon Tiki Ballroom
Location: Catamaran Resort Hotel

Session Chair: Miguel Palacios, Atlantic Copper SA

1:30 PM Keynote

Environmental Improvements at Onsan Smelter: *Kyung-Soo Jeong*[1]; Han-Gil Kim[1]; Seung-Ho Shin[1]; [1]LS-Nikko Copper Inc.

Since the start-up of Onsan Smelter in 1979, LS-Nikko Copper has grown into the competitive smelter through continuous development. Carrying out several environment improvements, especially the intensive investment for reducing SOx emissions has been executed, such as de-sulfurization plants, fugitive gas capturing, TMS. In addition, LS-Nikko Copper has spent more than 10 million USD every year for improving the environmental condition recently. To be global leading smelter in every aspect especially in environment, LS-Nikko Copper plans to inspire environment-friendly mind, co-operate with shareholders, and participate in global convention. This paper describes what we have done improvements in environment conservation at Onsan plat and briefly introduces sustainable vision to the most green smelter.

1:55 PM

Environmental Issues in Drying Copper Sulfide Concentrates: Shaolong Chen[1]; *Hannu J. Mansikkaviita*[1]; [1]Kumera Corporation

To enhance the smelting furnace performance, the copper sulfide concentrates are normally dried prior to feeding into the furnaces. In both direct heated rotary dryers and flash dryers the hot gas is used as heating medium to dry the concentrate. The hot gas may need to be cleaned when it is produced from fossil fuels containing high sulfur. If the anode furnace gas is used, then the pollutants in the hot gas are not just sulfur dioxide but also un-burnt hydrocarbons generated during the reduction phase. The hot gas passing through the dryers starting from temperature of several hundred degrees centigrade can cause sulfur oxidation of copper sulfide concentrate in presence of oxygen in the gas. Selection of steam dryers for this kind of the minerals would be an ideal solution to avoid polluting the process gas as drying is done with indirect contact to the steam at relatively low drying temperature and high water vapor content in dryer off-gas. The emission can be significantly reduced. The off-gas cleaning units are also simple and small.

2:20 PM

Solution of Environmental Safety Issues at a Zinc Plant: *V. V. Geykhman*[1]; Gl. A. Kazanbayev[1]; P. A. Kozlov[1]; V. A. Lukyanchikov[1]; [1]Chelyabinsk Zinc Plant

1. Air pollution abatement: the CZEP complies with the regulatory maximum permissible concentrations (MPC) of 39 pollutants released to the atmosphere with air emissions. The use of fluxing additives in the Waelz process and modernization of gas treatment equipment makes it possible to reduce the dust content in off-gas to the MPC level (5 mg/Nm^3) and the sulfur dioxide content down to 1 g/m^3. Use of advanced catalysts in the sulfuric acid manufacture process ensures stable autothermic performance of the process, a conversion efficiency of at least 99.8% and the residual sulfur dioxide content at the outlet of the system of not more than 0.05%. 2. Protection of water bodies: overall water re-use system and water recycling systems in the main shops of the plant ensuring a water re-use degree of 95.6%. 3. Solid waste: all types of waste generated in the process of zinc concentrate treatment (i.e. lead and copper-containing residues, copper-containing Waelz slag, sludge from wastewater treatment facilities and from the acid plant) are treated to produce commercial-grade products and semi-final products sold to consumers.

2:45 PM

Environmental Problems of Metallurgical Plants in Polar Regions and Ways for Their Solution (Norilsk Region as an Example): *Andrey V. Tarasov*[1]; L. I. Leontyev[2]; Zh. I. Rozenberg[3]; [1]Gintsvetmet; [2]A.A. Baikov Institute of Metallurgy; [3]Norilsk Nickel

Emission of sulfur-containing gases causes most adverse impact on the natural environment in the process of nonferrous metals production. Under the conditions of Polar regions, in particular in the region of the Norilsk Mining and Metallurgical Complex (Russia), this problem requires a special approach taking into account potential economic and socioeconomic consequences. By reducing the iron sulfide content of flotation concentrates by using new flotation reagents inhibiting pyrrhotite flotation and by applying advanced process flowsheets for flotation it is possible to increase the nonferrous metals content of flotation concentrates by 5% or more along with a corresponding reduction in SO_2 formation during their subsequent pyrometallurgical processing. The ways can be used to resolve the environmental problems in the Norilsk region in the process of nickel and copper production, are based on the improvement of methods for elemental sulfur recovery from metallurgical off-gas by non-conventional techniques, the sulfur recovery from metallurgical gases by production of liquid sulfur dioxide and the technology for pyrometallurgical treatment of sulfide concentrates without SO_2 formation. Another opportunity is the development and commercial introduction of hydrometallurgical technologies for treating copper-nickel sulfide ores.

3:10 PM Break

3:25 PM Keynote

Recycling of EAF Dust by Using Top Submerged Lance Technology: Yong Hack Lee[1]; *Byoung Moon Kim*[1]; Nam Il Moon[1]; Chang Young Choi[1]; Min-Cheol Kim[1]; [1]Korea Zinc Company, Ltd.

Electric Arc Furnace (EAF) dust is generated when scraps are treated in the electric arc furnace and usually classified as hazardous industrial waste in most countries. EAF dust usually contains 15 to 25% of zinc and 3% of lead. It is usually treated in rotary kiln (Waelz process) or landfilled after a solidification and stabilization treatment. Numerous methods have been proposed as the EAF dust treatment technology, but few of them are in operation as a commercial scale except the Waelz process. Korea Zinc performed a plant test in which 600 tons of EAF dust was treated using TSL (Top Submerged Lance) technology. The TSL technology is a low cost, proven technology for processing zinc-bearing residues. The EAF dust was first de-chlorinated and fed to the TSL furnace. Finally, clean slag satisfying toxicity criteria was generated and valuable metals such as zinc and lead were recovered as fume oxide. The fume oxide was de-halogenated by sodium carbonate and sent to zinc refinery to recover zinc and lead. The recovery of zinc and lead was 90% and 93%, respectively. Most of the dioxin in the EAF dust was discomposed so dioxin less than the Korean regulation limit was detected in the offgas, which proves that the TSL technology is the best solution to treat EAF dust.

3:50 PM

Technical and Environmental Considerations of the Injection of Tyre into Blast Furnace Tuyeres: *Paulo S. Assis*[1]; Gerson A. Filho[1]; [1]UFOP

This paper shows the use of tyre as fuel to be employed into blast furnaces. This tyre can substitute coal or even charcoal in the blast furnaces tuyeres. The injection into tuyeres, other than contribute for energy generation, can produce gas for metallic oxide reduction, the former charged into the blast furnace throat, thus contribution for using other forms of wastes. The tyre, as powder to be injected into blast furnaces, contributes for an environmental employee of that waste, so as permit for obtaining a high value product. Then, one advantage of using such material is that it is waste and has lower cost for preparation. The results obtained have showed that the tyres has good combustibility, this was obtained in a model that simulate the same conditions occurring in the blast furnaces tuyeres; these results include tyres and mixtures of tyres with coal or even with charcoal.

4:15 PM

The Formation of Cr(VI)-Containing Stainless Steel Plant Dust and the Stabilization Thereof: *Andrie Mariana Garbers-Craig*[1]; Guojun Ma[2]; [1]University of Pretoria; [2]Wuhan University of Science and Technology

The entrainment of charge materials, evaporation or volatilization of elements and ejection of slag and metal by spitting or the bursting of gas bubbles are mechanisms whereby stainless steel plant dust are generated from the electric arc furnace and refining converter. TCLP and ASTM D 3987-85 tests on dust that was collected from the baghouse filter system of a South African Stainless Steel plant showed that this dust can be considered hazardous according to South African legislation, due to the high degree of Cr (VI) leachability (~13mg/l for TCLP and ~8mg/l for ASTM vs. regulation threshold of 0.05mg/l in drinking water). The dust is therefore considered to be harmful to both the environment and human health, due to its high solubility in water and carcinogenic properties. It should therefore be treated before being stockpiled or land filled.This paper consequently describes an investigation into the formation of Cr(VI)-containing stainless steel plant dust and the stabilization thereof in a sintering process, whereby the dust was mixed with a silica-rich clay. It is postulated that Cr(VI) form when the (Mg,Fe,Mn,Cr)3O4 spinel phase, Ca(OH)2 and CaF2 (all of which are present in the dust) react. This reaction was found to take place both at ambient and at high temperatures (1100°C). Stabilization of Cr(VI) in the dust could be achieved at an optimum sintering temperature of 1100°C for a 50mass% dust : 50mass% clay mixture. Chromium emission during sintering was found to be within environmental limits.

4:40 PM Invited

Environmental Impact of a Metallurgical Complex in Soil Contamination: *A. Cullaj*[1]; B. Hoxha[2]; [1]University of Tirana; [2]University of Elbasan

During a period of 15 years the metallurgical and chemical complex of Elbasan containing more than 15 principal plants, producing cast-iron, steel, coke, nickel carbonate, nickel, cobalt, chromium and other products, discharged into air, river water and soil an extensive amount of hazardous wastes containing high toxic substances. A monitoring study for the levels of heavy metals in soils nearby the former plant is carried out for the first time. Very high levels (total and extractable) of contaminants nickel, cobalt and chromium are found in samples taken from a relatively waste territory including the city of Elbasan, situated 8 kilometres far the plant. The most polluted samples present a total content of about 2000 mg/kg Ni, 180 mg/kg Co and 3000 mg/kg Cr. These levels exceed several times the phytotoxic thresholds and present a potential hazard for the inhabitants. Several possible ways of remediation are also discussed.

5:05 PM

Effective Bacterial Reduction of Hexavalent Chromium under Alkaline Conditions: Wenjie Zhu[1]; *Liyuan Chai*[1]; Yunyan Wang[1]; [1]Central South University

Hexavalent chromium is a widespread environmental contaminant. An Achromobacter sp. strain nominated Ch-1 can reduce soluble and toxic

chromate to the insoluble and less toxic Cr(III) in aerobic cultures, no Cr(VI) decrease was observed in anaerobic cultures. In contrast to other chromium(VI) reducing microorganisms, Ch-1 showed higher chromium(VI) reduction at high pH. Reduction performed under alkaline conditions at pH 7 to 11, optimum is pH 10. During the reduction, pH decrease observed may caused by production of acidic metabolic byproducts from aerobic respiration. In the present study, the ability of Achromobacter sp. Ch-1 to reduce Cr(VI) during growth was evaluated with lactate as an electron donor. In NB medium, Ch-1 reduced 100% of 24mM of Cr(VI) in 35h, but only 73% of 30mM of Cr(VI) after 48h of inoculation. Reduction was inhibited by metal ions like, Ag+, Cu2+, Zn2+, slightly inhibited by Mn2+, and not effected by Mg2+. Results revealed that reduction of Cr(VI) also increased with the increasing of concentrations of lactate, complete reduction was achieved at the concentrations above 4g/L. HPLC analysis demonstrated Cr(VI) reduction was associated with the consumption of lactate. There was a large quantity of dark blue sediment generated in the culture during Cr(VI) reduction by Ch-1. Energy dispersive X-ray (EDX) analysis showed that the major element composed the formed sediment is chromium presented as Cr(OH)3 precipitate. The features characterized Cr(VI) reduction by Achromobacter sp. Ch-1 are high Cr(VI) concentrations and high pH.

New, Improved and Existing Technologies: Aqueous Processing III: Preparation and Synthesis

Tuesday PM
August 29, 2006

Room: Boardroom West
Location: Catamaran Resort Hotel

Session Chairs: Teresa Carvalho, Instituto Superior Tecnico; Dirk Verhulst, Altair Nanomaterials Inc

1:30 PM

Preparation of High Functional Aragonite Precipitated Calcium Carbonate: *Jeong-Hwan Kim*[1]; Woon-Kyoung Park[1]; Ji-Whan Ahn[1]; Sun-Hee Cheong[1]; Hyun-Seo Park[1]; [1]Korea Institute of Geoscience and Mineral Resources

The liquid-liquid reactive process (solution process) is often adopted as a synthetic method of precipitated calcium carbonate (PCC) in a laboratory study because of its simplicity in the operation or its easiness in the control of process variables. Also the effects of characteristics of limestone ores as a raw material in the synthetic system of PCC on the synthetic characteristics of PCC have been investigated. The purpose of this study is to synthesize the aragonite precipitated calcium carbonate by the solution process using Ca(OH)2 slurry and Na2CO3 solution as main reactants. In the synthetic systems, in order to control of the nucleation rate, shape factor was considered as the most important factor. Single phase aragonite PCC could be synthesized under a variety of controlled experimental conditions such as ionic strength, solution composition, concentrations of additive ions and temperature. The pure aragonite was synthesized by adding the Na2CO3 solution to the Ca(OH)2 slurry containing several concentrations of NaOH solution at 75°C and under the addition rate of Na2CO3 at 3ml/min. The formation yield of calcite decreased when the NaOH concentration was increased. In conclusion, in the case of the reaction of the 2.5M NaOH solution over 210minutes, single-phase aragonite with an aspect ratio of 20 was obtained.

1:55 PM

Preparation and Characterization of Ultrafine Magnetite Powder: *Yang XiYun*[1]; [1]Central South University

Ultrafine 0.1μm(μm) spherical magnetite powder was prepared successfully by hydrothermal reaction of ferrous sulfate and sodium hydroxide with activated pyrite as reducing agent in the temperature range 120-140°. XRD and XPS analyses indicate that pH value and pyrite amount have a direct influence on the composition of the product. Stoichiometric Fe3O4 can be obtained only when pH value is 12 and the molar ratio of pyrite/ferrous sulfate is 1:1.8. The hysteresis loop of Fe3O4 shows a ferromagnetic behavior with a saturation magnetization of 75.2 emu/g and a coercivity of 152Oe.

2:20 PM

Preparation and Structural Characteristics of Cobalt-Modified Magnetite: *Yang XiYun*[1]; [1]Central South University

Magnetite was prepared by hydrogen reduction method. For a conversion to cobalt-modified magnetite, the magnetite particles were suspended into a solution containing Co2+ and Fe2+ to precipitate a cobalt ferrite layer on the surface. pH value influences the particles composition directly, the desirable CoFe2O4 is obtained as pH value is 12. The coercivity increases with the increase of cobalt content, cobalt efficiency reaches a maximum value at cobalt content of 2.71wt%. With cobalt modification, the magnetite particles have the similar lattice constant and squareness ratio to that without cobalt modification. TEM and XPS analyses indicate that the acicular morphology is retained during the coating process, the epitaxial growth layer consists of CoFe2O4 and 0.3Co2O3.CoFe2O4 at cobalt content of 2.71wt% and 5.03wt%, respectively.

2:45 PM

Preparation of Mn-Zn Compound Oxide Powder for Soft Magnetic with Manganese Carbonate Ore and Zinc Dust: *Chaobo Tang*[1]; Yuehui He[1]; Motang Tang[1]; Baiyun Huang[1]; [1]Central South University

Employing manganese carbonate ore and zinc dust as material, Mn-Zn compound oxide for soft magnetic ferrite was prepared by a serial methods, as follows: leaching by using sulfuric acid, removing aluminium and silicon by neutralization and flocculation method, using ammonium bicarbonate to coprecipitating Mn and Zn, calcinations and washing to removing impurity content. The optimal technical condition was obtained by experiments. The difficulty of removing impurity such as Si, Al, Ca, Mg, from leaching solution was solved. The impurity content in the production meets with the preparation standard of high quality soft magnetic ferrite. The compound oxide powder obtained in the experiment was made into lower power loss magnetic ferrite, the quality of magnetic ferrite meet the standard of PC40 which was established by TDK corporation.

3:10 PM Break

3:25 PM Keynote

Separation of PET from PVC by Column Flotation: Elsa Agante[1]; Inácio Rodrigues[1]; *Teresa Carvalho*[1]; [1]Instituto Superior Tecnico

Recycling of solid wastes, a common practice nowadays, requires, to increase products value added, the separation of the different materials. The separation of one plastic from mixtures of different types of plastics is not easy due to their similar physical properties, but different techniques are available, from automatic sorting systems based on optical sensors to techniques adapted from mineral processing, namely gravity, froth flotation and electrostatic processes. In the last decade, many researchers have addressed the separation's problem of different polymers. One proposed technique is the classical froth flotation performed in agitated cells. Froth flotation is a versatile and relatively cheap process widely used in mineral separation. It is based on the different behavior of particles in the presence of an inter-phase air-water, which depends on the materials surfaces properties. Froth flotation can be affected by some variables such as impeller speed and air flow rate. Agitated cells, when used with low density materials, like plastics, can produce overstated turbulence that prevents the adhesion and collection of particles in the froths. In this case, separation is favoured by column flotation smoother hydrodynamics. This paper proposes the separation of PET from PVC by column flotation. The experimental work was carried out in a column of 9mm diameter and 1m high. The effects of some operating conditions, such as depressors concentration, pH and proportion of plastic in the mixture (feed grade) on products grade and recovery were evaluated and the best flotation conditions for complete separation between these plastics were established.

3:50 PM

Synthesis of L(+)-Calcium Lactate Using Precipitated Calcium Carbonate in Lactic Acid Fermentation: *Sun Hee Cheong*[1]; Ji Whan Ahn[1]; Jeong-Hwan Kim[1]; Choon Han[2]; Woon-Kyoung Park[1]; [1]Korea Institute of Geoscience and Mineral Resources; [2]Kwangwoon University

The objective of this study was to synthesize the L(+)-calcium lactate using precipitated calcium carbonate in lactic acid fermentation. Generally, precipitated calcium carbonate (CaCO3) has three types of polymorphism such as calcite, aragonite, and vaterite. It occurs abundantly in several natural minerals and it is used in large amounts in the rubber, plastics, pulp and paper industry. However, precipitated calcium carbonate is no used as calcium source in food and drug industry contrary to a shell, hen eggshell, ostrich eggshell and whey calcium in Korea. The reason why precipitated calcium carbonate has little absorption rate in itself and that is lack of high technology applied to the food chemistry. In our preliminary study, we synthesized precipitated calcium carbonate by reacting calcium hydroxide with sodium carbonate in solution process. Calcium lactate is the most widely used as salt of lactic acid with high absorption rate and used to the food and drug chemistry as a calcium additive and/or tissue reinforcing agent in variety of processed agricultural products and pickled foods. Generally calcium lactate has two racemates such as L(+)-lactate and D(-)-lactate. Especially, it is well known that L(+)-lactate is more soluble than D(-)-lactate and L(+)-lactate is generally produced from lactose by homo-fermentative lactic acid bacteria such as Lactococcus spp. Lactobacillus plantarum, Lactobacillus casei, Lactobacillus curvatus and Pediococcus spp. Therefore, we can expect to manufacture the L(+)-calcium lactate from lactic acid combined with precipitated calcium carbonate using bioconversion in progress of lactic acid fermentation.

4:15 PM

Preparation of Monodisperse Rhombohedron-Type Nickel Oxalate Particles from a Highly Condensed Nickel Hydroxide Suspension: *Zhihong Liu*[1]; Qihou Li[1]; Kan Ai[1]; Duomo Zhang[1]; Takeshi Okamoto[2]; Masazumi Okido[2]; [1]Central South University; [2]Nagoya University

Monodisperse micron size nickel oxalate particles with rhombohedron morphology were prepared from condensed nickel hydroxide suspension by a novel gel-sol process proposed by one of the authors. Firstly, condensed nickel hydroxide gel was formed by fast adding 1 mol dm-3 NaOH solution into 0.2 mol dm-3 nickel chloride solution, and then oxalic acid solution with a concentration of 0.25 mol dm-3 was dropped into the gel dropwise through a pump with a pH controller at preset pH value, and in this step, nickel hydroxide gel was converted gradually into monodisperse nickel oxalate sol. The formation of the nickel oxalate particles was found to proceed through a dissolution-recrystallization mechanism from the nickel hydroxide gel. The product particles exhibited a rhombohedron shape with micron size long axis and sub-micron size short axis. The effects of such factors, as temperature, surfactants, et al,on the particles sizes and morphologies, were evaluated experimentally.

4:40 PM

Preparation of Spherical Ultrafine Cobalt Powder by Polyol Reducing: *Sheng-Hai Yang*[1]; Yong-Ming Chen[1]; Shao-Hua Ju[1]; Ze-Qiang Pan[2]; Mo-Tang Tang[1]; [1]Central South University; [2]Zhuzhou Cemented Carbide Works

The ultrafine, monodispersed, spherical cobalt powder has been fabricated by reducing cobalt hydroxide with glycol. It were investigated that the effect of NaOH concentration on the reaction rate and the effects of the concentration of cobalt hydroxide and surfactant on the morphology and particle size. The particles were characterized by the X-ray diffraction(XRD), scanning electron microscope (SEM), laser diffraction particle size analyzer and BET specific surface analyzer respectively. The XRD shows that the cobalt powders exist mostly in face centered cubic (fcc) structure, a little in simple hexagonal. The cobalt powders prepared at Co(OH)¬2 150g/L, NaOH 40 g/L and surfactant 30g/L, its average particle size, specific surface area and cobalt content, were 0.88μm, 2.705m2/g. and more than 99.5% respectively.

5:05 PM

Separation of Pyrite Minerals from Magnetite Slimes by Hydrophobic Flocculation: Rasool Hejazi[1]; *Bahram Rezai*[1]; Abbas Sam[2]; [1]Amirkabir University; [2]Shahid Bahonar University

Fine particles float poorly and less-selectively under normal flotation conditions. One of the promising methods for fine minerals is the utilization of the principle of Flocculation. Hydrophobic flocculation flotation (or floc flotation) was tested on a magnetite concentrate that was finely ground to be micron particles, for producing a concentrate with sulphur grade less than 0.1%. After that, slurry dispersing with water glass as dispersant, pyrite fines were subjected to hydrophobic flocculation induced by xanthate and a small amount of kerosene then the slurry was transferred to a flotation cell for recovering the hydrophobic flocs. The experiments carried out indicated that through one-step rougher and two-step cleaner flotation, sulphur grade was reduced from 1% to 0.1%. It has been found that the separation efficiency of the floc flotation process closely correlates with the main parameters of hydrophobic flocculation such as xanthate addition, conditioning time and kerosene addition.

New, Improved and Existing Technologies: Non-Ferrous High Temperature Processing I

Tuesday PM
August 29, 2006

Room: Toucan
Location: Catamaran Resort Hotel

Session Chairs: Michael W. Potesser, University of Leoben; Toru H. Okabe, University of Tokyo

1:30 PM Keynote

Aluminum Extraction in Ionic Liquids at Low Temperature: *Venkateswarulu Kamavaram*[1]; Ramana G. Reddy[1]; [1]University of Alabama

Ionic liquids are novel salts used as potential non-aqueous electrolytes for aluminum electrolysis at low temperatures. In the present research di-alkylimidazolium chloride ionic liquids such as 1-butyl-3-methylimidazolium chloride ([BMIM]Cl) and 1-hexyl-3-methylimidazolium chloride ([HMIM]Cl) were investigated for aluminum electrolysis. The melt formed by mixing ionic liquid with $AlCl_3$ is termed as chloroaluminate melt and is composed of several polymeric chloroaluminate anions. Ionic liquids were studied as electrolytes for aluminum electrowinning and electrorefining of aluminum based materials (A356, A360, and Al-MMC) at low temperatures. Effect of experimental parameters such as temperature, applied voltage and concentration of electrolyte on electrolysis process was studied. High purity aluminum (>98%) deposits were obtained on copper cathode. At a cell voltage of 1.0 V vs. Al/Al(III), the energy consumption for electrorefining aluminum alloy (A356) was about 3.0 kWh/kg-Al. Low energy consumption and no pollutants emission are the main advantages of this process. Mechanism of aluminum electrodeposition in these chloroaluminate ionic liquid electrolytes was investigated using cyclic-voltammetry and chronoamperometry techniques. Aluminum electrodeposition on copper substrate in $AlCl_3$-[BMIM]Cl melts was found to be quasi-reversible process with a charge transfer coefficient of $\alpha = 0.40$. Chronoamperograms obtained at voltages in the range (-0.1 to -1.0 V) revealed that the initial stages of aluminum deposition was instantaneous nucleation followed by diffusion controlled growth of three-dimensional nuclei. The diffusion coefficient of electroactive species $Al_2Cl_7^-$ in these melts was found to be 6.5×10^{-7} cm^2 s^{-1} from Cottrell equation and 3.9×10^{-7} cm^2 s^{-1} from the dimensionless current-time transients.

1:55 PM

A Comparison of Conventional Copper Anode Furnaces with the New Elliptical Anode Furnace Concept: *Michael Potesser*[1]; Helmut Antrekowitsch[1]; Hans Rinnhofer[2]; Uwe Zulehner[2]; [1]University of Leoben; [2]Maerz-Gautschi Industrieanlagenbau GmbH

In the primary and secondary copper industry the anode furnace is the most important process step in the refining procedure to reach an enhancement in value and quality of copper by selective oxidation and reduction. By combining the advantages of the conventional tilting hearth furnace and the benefits of

the drum type furnace a new aggregate was developed and patented. The cross-section of the furnace is elliptical and the whole unit is tiltable. During the melting period the contact surface between the burners and the bath or the scarp is enlarged – resulting in an increased energy input. For the refining period the furnace is rotated, guaranteeing a high bath level. Due to the longer residence time of the gas in the copper melt, not only the gas consumption is reduced but also the efficiency of the refining process is improved. This investigation shows a metallurgical comparison between the new anode furnace concept with the elliptical cross section and the conventional, tiltable hearth anode furnace as well as the drum type anode furnace. The reduction of the amount of contaminants was calculated by thermodynamic programs and supported by CFD modeling. The investigation covered the refining of blister copper from primary metallurgy, from secondary metallurgy as well as from a mixture of both copper melts. The paper underlines the possibilities for a reduction of the tap-to-tap time and for an increase in production capacity, which can be achieved by applying the new furnace concept in comparison to the conventional furnaces.

2:20 PM Invited

Development and Creation of Modern Metallurgical Technology for Antimony Production with Gold Recovery from Domestic Gold-Antimony Concentrates in Russia: *Andrey V. Tarasov*[1]; F. A. Myzenkov[1]; [1]Gintsvetmet

The technology developed by the authors uses new methods for raw material smelting in electric furnaces, a new autogenous method and apparatus for subliming smelting for antimony trioxide production and separation of antimony and gold. Concentrate produced from the ore deposits in Yakutia has the following average contents of main constituents, % by weight: 29.4 Sb, 1.2 Fe, 13.1 S, 40.0 SiO_2, 0.2 As, 2.6 CaO and 45 g/t of Au. Unlike the technology used abroad a new autogenous method makes it possible to increase considerably specific capacity and reduce gold losses with antimony trioxide by several times. At the same time mineralogical composition of trioxide has improved considerably – it has mainly a cubic base with prevalence of senarmontite. The content of a main component (Sb_2O_3) in the final product has increased from 99.0% up to 99.6% which means better quality and makes it suitable for use in special technologies. Despite a lower antimony content of the concentrate (22.4% as compared with over 33% as common in the world practice), an antimony recovery of 85.3% into a commercial-grade product has been achieved, as well as a gold recovery of 96.65% into a gold-antimony alloy. The technology for processing gold-antimony materials developed and introduced at the Ryaztsvetmet plant is unique in the world with respect to gold recoveries.

2:45 PM Invited

Developments with Imperial Smelting Process: *Roger W. Lee*[1]; [1]Roger Lee Consulting

The commissioning of the first full-scale Imperial Smelting Furnace in 1950 was a technological breakthrough in the pyrometallurgical smelting of zinc offering significant advantages over the existing retort processes. However, for most zinc concentrates the electrolytic zinc process continued to be more economic. Therefore, the ISP specialised in treating concentrates that were less amenable for treatment by either the electrolytic zinc process or the lead blast furnace. Subsequently, improved mineral processing techniques led to a decrease in the availability of these concentrates so the smelting of secondary materials assumed greater importance. This led to the development of techniques such as hot briquetting and tuyere injection. In 2002 over 1 million tonnes of zinc and 400,000 tones of lead were produced by the Process. However, in the 2002-3 the economics of the Process became extremely difficult because of low metal prices and increased operating costs. This resulted in the closure of four ISP smelters in 2003 and two in 2005. Nevertheless, two new ISP smelters are scheduled for commissioning in China in 2006 where local economic conditions continue to favour the process. It is considered that the future of the process is closely linked to its ability to consume secondary materials and an examination will be made of its potential for conversion to 100% secondary operation. Apart from a reduction in raw materials costs, a substantial reduction in operating costs would ensue from not operating sintering and sulphuric acid plants.

3:10 PM Break

3:25 PM Keynote

Furnace Cooling Design in Pyrometallurgical Processes: Performance, Selection and Application Criteria: *Karel Verscheure*[1]; Andrew Kevin Kyllo[2]; Andreas Filzwieser[3]; Bart Blanpain[1]; Patrick Wollants[1]; [1]K.U.Leuven; [2]University of Melbourne; [3]METTOP Metallurgische Optimierungs GmbH

Reliable furnace cooling technology is a domain of increasing concern to the pyrometallurgical industry as it can significantly increase process intensities, productivity and campaign times of furnaces. Although there are many advantages in using cooling systems, they also impose a variety of problems mainly related to safety, heat losses and sustainability of the operations. The choice of cooling system is hence a matter of trade-offs and differs for every metallurgical application. This paper gives a review of different cooling designs used in the metallurgical industry, their performance and the safety aspect of different designs are discussed more in detail.

3:50 PM Invited

Production of Scandium and Al-Sc Alloy by Metallothermic Reduction: Masanori Harata[1]; Takao Nakamura[2]; Hiromasa Yakushiji[3]; *Toru H. Okabe*[1]; [1]University of Tokyo; [2]Chiba Institute of Technology; [3]Pacific Metals Company, Ltd

A fundamental study was conducted on a new process for producing scandium (Sc) metal or aluminum-scandium (Al-Sc) alloy by the calciothermic reduction of scandium oxide (Sc_2O_3). In this study, aluminum (Al) and calcium chloride ($CaCl_2$) were used as the collector metal and flux for the reduction, respectively. A mixture of Sc_2O_3, Al, and $CaCl_2$ in a tantalum crucible was placed inside a stainless steel reaction container, and the feed mixture was reacted with calcium (Ca) vapor at 1273 K for 6 h. After the reduction experiment, the reaction product (CaO), $CaCl_2$ flux, and excess Ca reductant were removed from the obtained alloy sample by leaching using an aqueous solution. The formation of Al_3Sc in the Al matrix phase of the alloy was confirmed by x-ray diffraction (XRD) and electron microprobe analysis (EMPA). This result indicates that Sc_2O_3 was successfully reduced to metallic Sc and alloyed in situ to form liquid Al-Sc alloy during the reduction. When Al was not used in the reduction experiment, a complex oxide (i.e., $CaSc_22O_4$) was formed, and the reduction was incomplete. Through this study, it is demonstrated that Al-Sc alloy can be directly produced by the calciothermic reduction using $CaCl_22$ flux and Al collector metal.

4:15 PM

InduCarb – A New Reducing Facility for Various Oxidic Melts: *Juergen Antrekowitsch*[1]; Alfred Edlinger[2]; Dieter Offenthaler[1]; [1]University of Leoben; [2]Tribovent GmbH

Today reduction of oxidic materials is mainly carried out in typical facilities like shaft furnaces, rotary kilns, reverberatory furnaces etc. Based on carbothermic reduction the reaction is either done by the formed carbon monoxide or the dissolved carbon. Typical problems occur because of interactions with the refractory lining, to low reaction rates and therefore long retention times, as well as inefficient yields. A new development based on an inductively heated coke bed shows an interesting alternative to the above mentioned processes, with a solution for most of the mentioned problems. A lot of trials were carried out with typical metal containing industrial wastes. The results showed a high metal yield in combination with a very fast reduction by forming a metal-slag mixture that can easily be separated in a simple settling unit. Even if a valuable metal is transferred into the gaseous state a separation and recovery can be carried out in a simple way.By the use of a special developed induction equipment that offers a wide variety of settings, different materials can be treated in an efficient way. Reduction is done directly at the high surface of the coke lumps, as well as by the carbon dissolved in the melt-slag mixture. This guarantees a high reduction rate while different temperatures can be adjusted so that uncontrolled solidification is prevented. An off gas mainly consisting of carbon monoxide is formed, that offers an efficient energy recovery. With this an optimization of the overall energy balance becomes possible.

4:40 PM
Kinetics Study of a Decomposition Reaction by Gas Chromatography: D. Quattrini[1]; J. P. Gaviría[2]; G. Fouga[3]; *Ana E. Bohé*[4]; D. Pasquevich[5]; [1]Comisión Nacional de Energía Atómica; [2]Agencia Nacional de Promoción Científica y Tecnológica; [3]Consejo Nacional de Investigaciones Científicas y Técnicas; [4]Centro Atómico Bariloche, Consejo Nacional de Investigaciones Científicas y Técnicas, and Universidad Nacional del Comahue; [5]Instituto de Energía y Desarrollo Sustentable

The kinetics and mechanism in thermal decomposition of the calcium carbonate have been widely studied, it would seem be a simple system however a wide range of factors as particle size, gaseous environment, purge gas velocity, CO2 partial pressure could affect largely the kinetics of the reaction. The reaction is usually studied by thermogravimetric techniques. The aim of the present work is to present the gas chromatography (GC) as an alternative method of analysis in the kinetic studies in reactions that involve gaseous products. Some advantageous of this method is the easily and reproducibility in the measurements in-situ of gaseous product of a decomposition reaction under isothermal conditions. By the other hand, it could be applied for the analysis of more complex system that involve different gaseous products or intermediates of the reaction. GC was employed as a useful tool to study the kinetics in the thermal decomposition of calcium carbonate. The reaction was followed measuring the CO2 produced in the decomposition of the calcium carbonate with a furnace/gas chromatograph (GC) on-line system. One of the advantages of the GC method is the possibility to perform in-situ characterization and quantification of the gaseous products for obtaining kinetics parameters; the method is simple and shows a good repeatability too. The decomposition of calcium carbonate was carried out in isothermal conditions at temperatures from 550 to 715°C with nitrogen as purge gas. Several gas velocities were used to determine the adequate flow that minimizes the effect of diffusion as rate controlling step.

Thermo and Physicochemical Principles: Aqueous and Electrochemical Processing II

Tuesday PM — Room: Boardroom East
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Osvaldo A. Bascur, OSIsoft, Inc.; David Dreisinger, University of British Columbia

1:30 PM Keynote
Electrochemical Removal of Sn(IV) Ion from Aqueous Hydrochloric Solution Containing In(III): *Kazuya Koyama*[1]; Mikiya Tanaka[1]; Shinji Fujiwara[2]; Kunio Saegusa[2]; [1]National Institute of Advanced Industrial Science and Technology; [2]Sumitomo Chemical Company, Ltd

Removal of Sn(IV) ions by an electrolytic reduction from aqueous hydrochloric acid solution containing In(III) was examined in order to recycle indium from indium-tin-oxide(ITO) target. Polarization measurements, potentiostatic electrolysis and galvanostatic electrolysis were carried out under nitrogen atmosphere. In the Sn(IV) solution, current begins to rise at a cathodic potential of around -0.27 V vs SHE, and increases with reductions in cathode potential. In the In(III) solution, current begins to rise at a cathodic potential of around -0.44 V vs SHE. Metallic tin was electrodeposited at cathodic potentials of -0.3, -0.35 and -0.4V vs SHE. More than 98% of Sn(IV) was removed without indium electrodeposition at cathodic potential of -0.40 V after the electrolysis for 3hrs. Both tin and indium were electrodeposited at cathodic potentials of -0.45 and -0.5V vs SHE.

1:55 PM
Thermodynamic Analysis on the Dissolution Equilibria of MgCO3(s) in the System of Mg(α)-NH3-CO32—SO42—H2O: *Chaobo Tang*[1]; Baoping Zhang[2]; Motang Tang[1]; Shenhai Yang[1]; [1]Central South University; [2]East China University of Science and Technology

According to the principles of simultaneous chemical equilibrium and electronic charge neutrality, the system of Mg(α)-NH3-CO32—SO42—H2O at 25αhas been thermodynamically analyzed. The law of solubility of MgCO3(s) in the system is revealed, and the high dissolution field of MgCO3(s) is found too. Furthermore, the solubility of MgCO3(s) is bigger with the increase of the concentration of SO42-. While smaller first then bigger with the increase of the concentration of all the CO32-(CT) and the total concentration of ammonia and ammonium (AT), and smaller with the value of pH being higher. Those results will be of important significant to prepare MgCO3(s) and MgO(s) and other over-purity carbonate that required elimination magnesium with carburization.

2:20 PM
Activated Carbon and Its Reactivation in Hydrometallurgy of Nonferrous and Noble Metals: *V. M. Mukhin*[1]; [1]Elektrostal Research and Production Association "Neorganika"

Among the methods proposed for spent activated carbon regeneration, the most acceptable is, thermal reactivation, because in this case the existing equipment for manufacture of activated carbon can be adapted for this purpose. In order to conduct the process of thermal re-activation of spent activated carbon directly at gold mills, a full-scale drum-type furnace with external electric heating has been developed, i.e. EPV-300 model with a throughput rate of 50 to 120 kg/hour. Its use ensures restoration of the adsorption properties of carbon up to the level of fresh activated carbon with an insignificant (by 0.7%) decrease in strength and with a high (95% to 97%) yield of reactivated carbon. During the recent years, activated powder carbon has been extensively used in flotation processes for treating polymetallic ores at ore treating plants to improve recoveries of main metals (copper, lead, nickel, etc.). Especially large volumes of activated powder carbon are used at the Talnakh concentrator of the Norilsk Mining and Metallurgical Complex in Russia for absorption of residual flotation reagents from recycled water in order to ensure efficient selective separation of minerals with similar physical and chemical properties.

2:45 PM
Decomposition of Ionic Xanthate and Its Characterization through the UV-Spectrophotometry Technique: *Beatriz Ramírez*[1]; Ramiro Escudero[1]; Francisco J. Tavera[1]; [1]Universidad Michoacana de San Nicolás de Hidalgo

Xanthates are anionic collectors normally used in flotation devices to modify the hydrophobic surface of sulphide minerals. Xanthates are heteropolar compounds and in acuous media they dissociate into ionic xanthate and alkali-metal ions; nevertheless their behavior is not well understood yet. This work characterizes the six reactions describing the decomposition of the ionic xanthate in acuous media by analyzing the set of spectra from a UV-Spectrophotometer. Results show the effect of pH on the stability of certain compounds which can be useful to explain the relationships among xanthates and the hidrophobicity of some surfaces (or ions dissolved).

3:10 PM Break

3:25 PM Invited
Garden Dirt, Palm Trees and Ammonia - Making Nickel in the Jungles of Cuba (Nicaro: The First 20 Years): *Larry M. Southwick*[1]; [1]LM Southwick and Associates

In the early 1940's, the Caron ammonia – ammonia carbonate leach process was used to produce nickel from Mayari ores at the Nicaro plant in Oriente Province, Cuba. While plant operation was generally successful, it was not broadly economical and was shut down. The plant was later restarted in the 1950's and a number of investigations initiated to resolve the more serious operational and performance issues. Processing steps studied included iron reduction (chemistry – nickel and iron, reductant, equipment), ore variability (homogeneity and consistency of mineral concentrations, serpentine vs. laterite), leach solution strength, nickel recovery (temperature – reduction and leaching, reoxidation) and a variety of other topics. These studies and their findings will be discussed. Caron himself obtained good results on these ores in the laboratory. They could not be duplicated in the field, the reasons for which will be reviewed. (Note: the ore looked like garden dirt; charcoal made from palm trees was one of the reductants attempted; and ammonia was the leach solution. Mixing the three, so to speak, was to yield nickel.)

3:50 PM

Non-Traditional Methods of Heavy Metals Precipitation from Solution in the Form of Sulphide: *M. I. Kalashnikova*[1]; J. M. Shneerson[1]; M. V. Keskinova[1]; V. V. Chetvertakov[1]; [1]Gipronickel Institute

In hydrometallurgical technological flowsheets several methods of target components removal from solution are used. One of these methods is non-ferrous metals removal in the form of rich selective or collective concentrates. In the present work pyrometallugical mattes, thiosulphate containing solutions and pulps, iron powder with elemental sulphur and calcium sulphate were used as the precipitator. It was shown that depending on precipitator compound and process parameters non-ferrous metals precipitate from solution in the different forms with varying content of components including Ni_3S_2, NiS, Ni_3S_4, NiS_2, $(Ni,Co)S_2$, CuS; $Cu_{1,765}S$; $Cu_{1,97}S$.

4:15 PM

Effects of Ore Mineralogy on the Bioleaching of a Nigerian Complex Sulphide Ore with Mixed Cultures of Mesophilic Bacteria: Peter Olubambi[1]; *Sehliselo Ndlovu*[1]; Joseph Olatunde Borode[2]; [1]University of the Witwatersrand; [2]Federal University of Technology

The effect of ore mineralogy on the bioleaching of metals from complex sulphide was studied by investigating the bioleaching of zinc and copper from bulk complex sulphide ore from Ishiagu, Nigeria, using mixed cultures of Thiobacillus ferrooxidans, Thiobacillus thiooxidans and Leptospirillum in mechanically stirred reactors at varying particle size. Mineral phases within the varied particle sizes of -53, 53, 75 and 106µm were identified using X-Ray Diffraction and Scanning Electron Microscopy (SEM), while the elemental distribution within the varied particles sizes were determined by X-Ray Fluorescence (XRF) and Optical Emission Spectrometry using Inductively Coupled Plasma- Optical Emission Spectrometer (ICP-OES). Bulk ore and the leached residues were examined by Scanning Electron Microscopy (SEM) and X-Ray Diffraction. The highest bioleaching recoveries were obtained at particle size of 75µm, while particle size of 106µm gave the least recoveries. Lower recoveries at particle sizes of 53 and -53µm were as a result of their higher silica content which effects pH, iron mobility and oxidation.

4:40 PM

Hydrometallurgical Treatment of Substandard Pb-Zn Concentrates with Production of Zinc, Lead and Silver: *M. I. Kalashnikova*[1]; Y. M. Shneerson[1]; A. Y. Lapin[1]; P. M. Saltykov[1]; M. V. Keskinova[1]; [1]Gipronickel Institute

Gipronickel Institute has developed the technology of treatment of difficult to concentrate sulphide Pb-Zn concentrates (Zn-19,9%, Pb-8,4%, Cu-0,34%, Fe-8,8%, Ba-6,8%, S-18,7%, Ag-106 g/tonne). The technology consists of pressure leaching, impurity removal from leaching solution, electrowinning and Pb-Ag containing cake treatment. Despite low zinc content in initial concentrate the technology allows production of solution which is suitable, after standard procedure of impurity removal, for electrowinning with production of zinc grade SHG. Comparing to the standard technologies the flowsheet developed provides the lesser expenses per zinc unit because of decreasing of liquid to solid ratio at pressure leaching stage. The initial concentrate is characterized along with low content of principal metals by high content of barite, which makes flotation of pressure leaching residue more difficult. That is why in this case the hydrometallurgical treatment was chosen. At optimal parameters of chloride leaching found during laboratory experiments the principal components extraction was 99.5% for Pb and up to 92% for Ag.

5:05 PM

Adhesion Dispersion of Apolaric Reagents in Flotation of Hydrophobic Minerals: *V. Bredykhin*[1]; O. Shevelyev[2]; E. Kazban[3]; V. Kostjuk[4]; V. Kushnerov[5]; [1]Institute of Non-Ferrous Metal; [2]Technoscrap Ltd.; [3]Donsplav Ltd.; [4]Vtortsvetmet; [5]Technical University

The report is devoted to the investigation and improvement of processes taking place at contact of large quantities of water insoluble liquid and particles of solid phase in a pulp. Theoretical analysis and simulation of acting conditions have allowed to determine that after attaching of oleophilic particles on the «water-reagent» separation surface the break of a formed complex is taking place according to the reagent volume and for oleophobic minerals along the «solid-reagent» separation surface. As a result particles are selectively treated if the magnitude of the reagent adhesion to the surface of solid phase in water is great. The results of dispersion are influenced significantly by availability of sharp edges on the surface of real particles. They keep tree phase perimeter of moistening. It is possible to fix reagent in the form of lens whose contact angle is significantly smaller in comparison to the thermodynamic angle. In adhesion dispersion the reduction of reagent volume, covering the equal area of particles surface is possible when the reagent is in a pulp in the form of thin films on the «water-gas» separation border. The process is tested in laboratory conditions in flotation of sulfide ores, non-ferrous metals, native sulfur and coal.

Thermo and Physicochemical Principles: Ceramics, Refractories and Polymers

Tuesday PM
August 29, 2006

Room: Russeau West
Location: Catamaran Resort Hotel

Session Chairs: Jannie S.J. Van Deventer, University of Melbourne; David R. Forrest, Naval Surface Warfare Center

1:30 PM Keynote

What is Driving the Commercial Acceptance of Inorganic Polymer Technology?: *Jannie S.J. Van Deventer*[1]; John L. Provis[1]; Peter Duxson[1]; Grant Clinton Lukey[1]; [1]University of Melbourne

Geopolymers are novel engineering materials with the potential to play a highly significant role in the transformation of the construction materials and building products industry in the push towards sustainable development. These materials are formed by activation of industrial aluminosilicate waste materials such as coal ash or blast furnace slag with alkaline solutions. Geopolymers derived from coal ash can exhibit superior mechanical properties and chemical stability when compared to ordinary Portland cement (OPC). The use of waste-based geopolymers can also result in significant (up to 90%) reduction in carbon dioxide emissions when used in cement replacement applications. In addition to the formation of conventional pre-cast products, these high performance mineral binders are ideally suited to use in the encapsulation of mine tailings, immobilization of heavy metals and back-filling of mines due to their chemical stability and resistance to acid attack. A key attribute of geopolymer technology is the robustness and versatility of the manufacturing process; it enables products to be tailor-made from a range of raw material sources (waste and/or virgin) with specific properties for a given application at a competitive cost. Despite these key technical and environmental attributes, it is the ability to add significant value to coal ash or and/ or metallurgical slag waste streams which drives the commercial development and uptake of the technology.

1:55 PM

Combustion Synthesis of Silicon-Based Structural Ceramics from Natural Sand: M. Radwan[1]; *K. A. El Barawy*[1]; S. Z. El-Tawil[1]; S. Shimada[2]; Y. Miyamoto[3]; [1]Central Metallurgical Research and Development Institute; [2]Hokkaido University; [3]Osaka University

This research reports on the synthesis of advanced silicon-based structural ceramics from mixtures composed of natural sand (Sinai white sand), reclaimed silicon and graphite by the nitriding combustion synthesis method. With pulverized sand (– 40 µm), we found that the nitriding combustion can be realized at self-sustaining mode in the SiO_2–Si–C system under 3 MPa nitrogen pressure. Depending on the composition of the starting mixtures, single-phase silicon oxynitride (Si_2N_2O) powder as well as new Si_3N_4–Si_2N_2O and Si_2N_2O–SiC composite powders with controllable chemical compositions were successfully developed. The measured thermograms of various combusted mixtures and the thermodynamic characteristics of possible exothermic reactions in this system were discussed to explain the nitriding combustion behaviour and mechanism. Near-full dense Si_2N_2O were fabricated from synthesized Si_2N_2O powder with 5 wt % oxide additive

by the spark plasma sintering (SPS) method at 1600°C. The dense Si_2N_2O samples had good mechanical properties (18.7 GPa Vickers hardness, 3.3 MPa m1/2 fracture toughness and 363 MPa strength) and excellent chemical and oxidation resistance. The synthesized composite powders were also densified to high densities (> 90 % of theoretical values) by SPS technique. The results obtained in this study can be seen as a new route to prepare important silicon-based structural ceramic powders with various compositions/properties from cheap starting materials which makes them potential for wide range of applications.

2:20 PM

New Eco-Process for the Preparation of Metal Oxide Varistors: Renaud Metz[1]; Jonathan Morel[2]; *Ramón Puyane*[3]; Mehrdad Hassanzadeh[3]; [1]UCBL-CNRS-SNPE; [2]UCBL-CNRS-SNPE/AREVA; [3]AREVA

The DOPA process (Direct Oxidation of a Precursor Alloy) was used to prepare ceramic powders based on doped SnO_2 and ZnO. The DOPA process consists essentially in the direct oxidation of a homogeneous precursor alloy. A unique advantage of this process is its rather benign environmental impact since no dangerous reactants are used and no harmful by-products are generated. Only oxygen and the alloy metals participate on the chemical reaction to produce the multi-component oxide. Homogeneous alloys of niobium, cobalt and chromium doped tin have been prepared. The molten metal alloy is atomised in air using a double fluid nozzle to produce metallic powders. A subsequent thermal treatment is carried out to fully oxidise the sprayed metal alloy powders. These raw powders are used to prepare a ceramic powder through a mill homogenisation and atomisation process. The ceramic powder is then uniaxially compacted in disc shape and sintered in an oxidising atmosphere. The resulting sintered bodies are metallised on their flat faces and the cylindrical surface is passivated using lead free glass enamel. These ceramics present excellent semiconducting properties with non-linear (non-ohmic) characteristics. The DOPA process is found to be an attractive procedure to obtain ceramic powders for the preparation of SnO_2 varistors.

2:45 PM

Ceramics Working in Extreme Conditions for BaO-Al_2O_3-SiO_2 Systems: *Z. Kovziridze*[1]; J. Aneli[1]; N. Nizharadze[1]; G. Tabatadze[1]; D. Gventsadze[1]; [1]Georgian Technical University

The object of the work is to produce ceramic composites working in extreme conditions (liquid and gaseous aggressive medium, thermal and gas-thermal shock, high mechanical load, etc.) using secondary raw material, to develop new technologies, to expose synergetic properties of the produced materials, their investigation and working out recommendations for their introduction in production of technologies. In order to achieve this object, on the basis of wastes of barite and perlite production of Georgia, the electro-insulation, thermo-stable, corrosion-resistive celsian ceramics is received for BaO-Al_2O_3-SiO_2 system. Instead of the well-known two-stage technology of celsian ceramics production the project proposes one-stage technology. Using this new technology, ceramics with 94% celsian crystalline phase content is synthesized, the rest consisting of barium aluminates, silicates and a small glass-like phase which helps to consolidate the structure. Material consolidation happens in 1400-1450°C conditions. The advantage of the work compared to the existing one is as follows: the first stage of celsian preparation is entirely removed giving a considerable economical effect. Barium sulphate in the form of barite wastes is, for the first time, used in the production of celsian. In order to develop celsian monoclyne phase the wastes of glass-like perlite production is used. At the decay of barium sulphate in 1135-1160°C interval the trapping of liberated gases happens with ammonia method and mineral fertilizers are obtained. The developed material is super-stable to thermal and gas-thermal shocks and has high dielectric properties. Its specific volume resistance is $p_v = 10^{16}$ ohm.cm. The received ceramic composites are to be used in hydroelectric stations as insulators, in electronic microschemes as condensers, resistors, etc. Because of super-stability to thermal and gas-thermal chocks and high corrosive resistance of these articles in extreme conditions they provide high operational capacity of different dielectric units.

3:10 PM Break

3:25 PM Keynote

Comparison of Oxidation Behavior of Nitride Based Hard Ceramic Thin Film Coatings Using Thermal Analysis Techniques: *Nuri Solak*[1]; Fatih Üstel[2]; Süheyla Aydin[1]; Mustafa Ürgen[1]; Ali Fuat Cakir[1]; [1]Istanbul Technical University; [2]Sakarya University

Physical Vapor Deposited (PVD) coatings, especially TiN and CrN, are widely being used in tribological applications to improve performance and service life of cutting tools, die molds and machine parts because of their hardness, wear, corrosion and oxidation resistance. In service conditions, these coatings are exposed to oxidative atmospheres at high temperatures due to friction. In this media coatings oxidize and service life decrease. Therefore, performance of the coated materials not only depends on mechanical properties but also on oxidation behavior. In this study, CrN, TiN and Ti-B-N coatings were deposited onto H13 hot working tool steel and alumina substrates by arc-PVD. The coatings were characterized with respect to their mechanical and structural properties. Oxidation behavior of the coatings on alumina substrates was investigated by TG/DTA. Coated H13 substrates were oxidized in a tube furnace under atmospheric conditions at specific temperatures determined from TG/DTA tests of the same coating on alumina substrate. The oxide scale morphology was characterized by scanning electron microscopy and X-ray diffraction. Oxide scale thickness change and TG data were used to calculate oxidation reaction activation energies.

3:50 PM

Study of Grinding Process of Titanium Carbide Produced with Self-Propagating High Temperature Synthesis (SPHTS): *Z. Kovziridze*[1]; G. Tabatadze[1]; D. Gventsadze[1]; D. Donadze[1]; [1]Georgian Technical University

It is stated that the specific character of SPHTS-preparations of TiCx consists in crystal lattice strength reflecting the condition of synthesis in "burning wave". The use of roentgenographic and other methods of analysis allow to estimate the effect of the conditions of synthesis, causing the carbon sublattice defect, on grinding intensity of TiC_x-phases. The study of the kinetics of vibro-grinding of TiC_x-phases in ethanol and benzene medium allows to establish high grinding intensity of the phases close to stoichiometry and the possibility of producing high dispersion powders ($S_{sp} \approx 4.5$-6 m^2/g).

4:15 PM

Effect of the TiC Addition on the Corrosion Resistance of Al_2O_3-C Refractory: *Qingcai Liu*[1]; Yi Liu[1]; Jian Yang[1]; [1]Chongqing University

The effect of the TiC addition on corrosion resistance of the Al_2O_3-C refractories in smelting reduction melts has been studied by quasi-station immersion and rotary immersion. The corrosion rate of Al_2O_3-C refractories is decreased with the TiC addition. The corrosion mechanism of Al_2O_3-C refractories is oxidization of graphite carbon by the oxides of the melts and the formation of deteriorate layer. The factors that influence the corrosion rate are iron oxides content of the melts, relative rotary rate of refractory specimens in melts and the molten bath temperature. The corrosion mechanism of Al_2O_3-C refractories in the smelting reduction melts has been investigated.

4:40 PM

Use of Refractory Carbides in Technique: *Z. Kovziridze*[1]; N. Nizharadze[1]; G. Tabatadze[1]; [1]Georgian Technical University

The development of modern technique makes increased requirements to heat resistant refractory cutting tool materials. So, at present the investigations are continued for receiving new materials distinguished for their specific properties. The material received by us on the basis of silicium carbide and synthetic corundum with silicon nitride binder are characterized with high refractoriness, thermal stability and resistance to molten metals and aggressive gaseous medium. The technology of thermocouples protecting casing production from these materials is developed. Different size casings are produced and tested at metallurgical, machine building and other plants with the aim to establish their resistance and to measure the temperature of molten metals. Positive results are obtained. Nowadays, by introducing additives into composition, the work is carried out with the object to improve the properties of these materials. On the basis of the known tungstenless hard alloy TiC-

Ni(Mo) a new hard alloy is received where nickel dispersively strengthened with aluminum (circonium) oxide prepared with a new technology is used as a binder. It is known that the mentioned oxides increase thermal stability of metal phase. Physico-mechanical properties of the obtained new hard alloy are considerably higher compared to the existing one that is absolutely proved by the stability of cutters made of this alloy at metal cutting processing.

5:05 PM

Effect of Relaxation and Other Transitions on the Conductivity of Conductive Polymer Composites: *J. N. Aneli*[1]; M. S. Kutsia[1]; [1]Institute of Machine Mechanics of the Georgian Academy of Sciences

There are many experimental works on the investigation of temperature effect on the conductivity of polymers filled by carbon materials. However frequently the establishment of current nature in the polymer heterogeneous systems becomes difficult. This fact is explained by complexity of calculation of different physical or chemical phenomena passing in materials at variation of the temperature. Among these phenomena it must be noted some morphological changes in the structure of polymers. These changes reflex on the structure of conductive system of composites. So, it was shown, that the character of temperature dependence of thermal noises level and conductivity of some polymers filled by carbon black essentially depend on some relaxation transition in the polymeric matrix. In this paper the effect of difference transitions in polymer matrix of filled by carbon black some polymers and rubbers have been investigated. In the wide temperature range. The importance of such investigation is due to possibility of application of resistive temperature sensors based on conductive polymeric composites (CPC) to measuring technology. The experiments has been carried out in the cavity with regulation of temperature in the range 110-650K. The resistance of samples was measured by four electrodes method. The samples were obtained by hot pressing of dry mixture of powdered components at chosen temperatures, pressures and cooling time in the case of plastics and by peroxide vulcanization of the elastomers in the case of the rubbers. The samples were produced on the basis of the following thermoplastics: low density polyethylene, polytetrafluoroethylene, polycarbonate and polydimethylmethylvinilsiloxane.

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Synergetic Effect in Conductivity of the Polymer Composites Based on Phenolformaldehide Resin: J. N. Aneli[1]; *Z. Kovziridze*[1]; D. I. Gventsadze[1]; N. G. Japaridze[1]; [1]Georgian Technical University

For the improvement of technical characteristics of polymer composites two or more fillers are used often. It is important both type of fillers and their masses ratio in the general content of them. It is known, that the definite (optimal) magnitude of the ratios can lead to such phenomenon, as so called synergetic effect, which is expressed in increase of some physical or chemical properties corresponding to optimal (for given system) ratio of filler masses. These properties are more higher than that for analogous composites containing only one filler from given blend of fillers, if the concentration of these filler is equal to general concentration of fillers other composites. The application of synergetic effect in the polymer composite technology is connected with economic use of the materials, which is expressed in decrease of the expenditures of some deficit component and technology. The present work devotes to investigation of synergetic effect in the composites based on phenolformaldehide resin (PFR) with double fillers. Two types of fillers were used in each composite (the carbon black (CB) with high and low conductivities, metal powders of copper, iron and nickel). The dependence of conductivity of composites on the ratio of fillers was investigated.

5:55 PM

Preparation of Porous Ceramic Pellets by Multiphase Double Emulsion Method: *Liyuan Chai*[1]; Xiaofei Zhang[1]; Bing Peng[1]; Mingming Cheng[1]; Yi Huang[1]; [1]Central South University

This paper focused on the preparation of porous ceramic pellets for microorganism carriers. A new method for the process was developed using simple gel-casting and bubble-in-water-in-oil type of multiphase double emulsion. The globules, consisting of a foamed sepiolite slurry suspension, were dispersed and consolidated in spherical shape in liquid paraffin as gelation progressed. The green pellets were sintered at 1100°C.The influence of surfactants, extension ratio and impeller revolution rate on the process and characteristics of the pellets was investigated. The pellet size was in the range of 1~4mm and determined directly by impeller revolution rate. The fine cell diameter of porous ceramic was in the range of 100~500μm and the micropore diameter was less than 5μm. The inner macropores were interconnected and extend to the external surface. It is impossible to analyze a result by SEM micrographs and digital camera.

Thermo and Physicochemical Principles: Non-Ferrous High Temperature Processing: Thermodynamics II and Physical Properties

Tuesday PM — Room: Russeau East
August 29, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Yoshio Waseda, Tohoku University; Kimio Itagaki, Tohoku University

1:30 PM Keynote

Phase Relations and Activities in the Cu-Fe-S-X and Cu-Fe-S-C-X (X = As or Sb) Systems and Distribution of Precious Metals Relating to Reduction Smelting of Copper: *Kimio Itagaki*[1]; Leandro Voisin[1]; [1]Tohoku University

As a fundamental study for smelting the copper matte with high contents of arsenic and antimony in a strongly reducing condition, phase relations between the liquid matte and copper-rich alloy phases in the Cu-Fe-S-As or -Sb quaternary system and between the liquid matte and iron-rich alloy phases in the Cu-Fe-S-As or -Sb system saturated with carbon were determined at 1473K by a quenching method. Activities of arsenic and antimony in these systems were also measured at 1473K by Knudsen cell-mass spectrometry. Furthermore, distribution ratios of silver, gold and platinum between the liquid matte and copper-rich or iron-rich alloy phases were determined in relation to the arsenic or antimony content in the systems. On the basis of these data, elimination of arsenic and antimony from the matte to the iron-rich alloy (speiss) and recovery of the precious metals in reduction smelting of the copper matte were evaluated. It was suggested that addition of the pig iron to make a strongly reducing condition and form the iron-rich alloy, which is fluid at smelting temperatures, will be useful for fixing arsenic in the speiss.

1:55 PM Invited

Volatilization Behavior of Minor Elements during Non-Isothermal Oxidation of Copper Concentrate Particles Falling in One-Dimensional Laminar Gas Flow: *Yasuhiro Fukunaka*[1]; H. S. Sohn[1]; [1]Kyoto University

Copper concentrate particles of 200 to 300 mesh size were fed from the top of vertical reaction tube of 2.8×10^{-2} m ID and 2 m long with an O_2-N_2 gas mixture. The reaction tube was heated to 900 K to 1100 K. The copper concentrate particles were very rapidly oxidized and melted down during their descent in the reaction tube. The particle temperature were calculated by combining an un-reacted core model, mass transfer between gas and particles, and heat transfer between gas, particles and tube wall. The particle temperature reached its maximum within a distance of 60 cm from the top of reaction tube, and it attained at 2000 K at higher oxygen partial pressure. The most particles were melted at the oxygen partial pressure above 20 kPa. An appreciable amount of As, Sb and Pb in the concentrate particles was eliminated in the upper portion of the reaction tube and the rate of elimination are explained by the rate of mass transfer of volatilized species through the gas film on the particle surface and the variation of particle temperature during the descent.

2:20 PM

Thermodynamics of Tapping Molten Copper: Steven Wright[1]; *Francis R. Jorgensen*[1]; Andrew P. Campbell[2]; [1]CSIRO Minerals; [2]BHP Billiton

BHP Billiton's Olympic Dam copper flash smelter employs the direct to blister process for smelting high grade copper concentrates. SO2

evolution during tapping gives rise to safety and environmental concerns. A thermodynamic model for the blister copper system (Cu-Fe-S-O) was used to predict the volumes of SO2 evolved. Thermodynamics was used to evaluate the slag chemistry inside the furnace. The blister copper model was used to explore the relationship between %S and %O in the copper and the amount of SO2 evolved on cooling. The volume of SO2 evolved was sensitive to the O content with reduction to levels below 0.2 - 0.15% likely to suppress SO2 evolution on cooling. Concentrations of S and O in tapped copper samples from trials clustered around the equilibrium line at an average temperature of 1275°C and a partial pressure of SO2 of 1 atm. A number of potential process options to suppress SO2 evolution on tapping were investigated thermodynamically. Some of the options require treatment of the blister in a forehearthor separate furnace, while others have impacts on current practises in the flash furnace. The opportunities that these options present are discussed.

2:45 PM

Modeling of Minor Elements in Copper Smelting Processes: *Chunlin Chen*[1]; Ling Zhang[1]; Steven Wright[1]; Shouyi Sun[1]; Sharif Jahanshahi[1]; [1]CSIRO

Thermodynamic data of Sb from the literature in the liquid copper, matte and slag have been assessed and optimized using models from literature. The modelling results for Sb in matte, slag and liquid copper are discussed. Validation of the developed databases on the distribution of Sb among the various phases against the literature data is presented. The effect of the CaO/SiO2, Fe/SiO2, temperature and matte grade on the deportment of Sb in the copper smelting process is discussed. The Sb distribution behaviours in the practical flash and bath smelting processes process are analysed. The developed databases have been used for the calculation of the distribution of minor elements among the matte, slag, copper and gas phases under varied operation conditions during copper smelting process. Similar work has been done for other elements such as As, Bi, Pb, Zn, Sn, Cr, Se and Te and some related examples will also be presented and discussed.

3:10 PM Break

3:25 PM Keynote

Thermal Properties of Bulk Glassy Alloys: *Yoshio Waseda*[1]; Hiroyuki Shibata[1]; Hiromichi Ohta[2]; [1]IMRAM, Tohoku University; [2]Ibaraki University

Zr-based and Pd-based glassy alloys with particular composition, such as $Zr_{55}Al_{10}Ni_5Cu_{30}$ and $Pd_{40}Cu_{30}Ni_{10}P_{20}$, are well known to exhibit glass transition with a wide supercooled liquid region. The extremely high level of thermal stability of supercooled liquid state enables the production of bulk amorphous alloys. These bulk amorphous alloys allow us to investigate thermal properties and electrical resistivity of these alloys. The main purpose of this work is to determine values of thermal diffusivity (α), electrical resistivity, specific heat (Cp) and thermal conductivity (λ) of Zr-based and Pd-based glassy alloys. Moreover, the glass-forming ability of these alloys was discussed on the basis of the obtained values. The thermal diffusivity values of the alloys were measured with a laser flash technique. The electrical resistivity of the alloys was measured was measured by a direct current four probe technique. The specific heat of the alloys was measured by the heat flux type differential scanning calorimeter with a triple cell system. The thermal conductivity was determined from $\lambda=\alpha\rho Cp$. The thermal diffusivity values of the three alloys in the liquid state are summarized in the linear equations with positive temperature dependency. The lower the thermal diffusivity values of Zr-based and Pd-based alloys at liquidus temperature, the lower the critical cooling rate to obtain amorphous alloy becomes. Thermal properties and electrical resistivity of the alloys were systematically determined. The obtained values are valuable to discuss the glass-forming ability of Zr-based and Pd-based alloys.

3:50 PM

Activities of Components in Metal Melts Containing Copper Iron Subgroup Metals: *L. B. Tsymbulov*[1]; L. S. Tsemekhman[1]; E. Y. Kolosova[1]; [1]Gipronickel Institute JS

Currently, data on thermodynamic properties of metal melts containing copper and metals of iron subgroup are rather limited. These data are of great importance for the assessment of equilibrium between metal and slag melts in pyrometallurgical processes, as well as for improving our knowledge of liquid phases' structure. Experimental determination of the activities of metal melts' components at high temperature is labour-intensive. Besides, it is not always possible to achieve high degree of accuracy. So, in some cases it seems more reasonable to use various methods that help to reveal thermodynamic properties of ternary systems and even more complex ones based on known thermodynamic properties of binary systems. The article presents the results calculations of the components activity in triple systems' melts Cu-Ni-Fe, Cu-Ni-Co, Cu-Fe-Co and Fe-Ni-Co, as well as in quadruple system melt Cu-Ni-Fe-Co. Satisfactory correlation of the calculation results and the reliable results of experimental studies is demonstrated. Copper behaviour for the entire area of Cu-Ni-Fe-Co system composition has been determined. Activities and activity ratios of all the components have been determined for the most practically important compositions of melts of the discussed quadruple system.

4:15 PM

Modeling of High-Temperature Zinc Fuming Processes for Treatment of Zn-Bearing Residues: *Karel Verscheure*[1]; Maurits Van Camp[2]; Bart Blanpain[1]; Patrick Wollants[1]; Eugene Jak[3]; Peter Hayes[3]; [1]K.U.Leuven; [2]Umicore RDI; [3]Pyrometallurgy Research Centre, PYROSEARCH

EAF dust, hydrometallurgical zinc leach residue, and other Zn-bearing by-products pose potentially serious environmental problems that threaten the sustainability of the operations. A pyrometallurgical process designed for treatment of such residues is the high-temperature submerged plasma Zn-fuming process. The successful operation of this process requires high Zn fuming rates whilst retaining vessel integrity through stable freeze-lining. A Zn-fuming model has been developed and used to systematically investigate a range of operating scenarios to identify potential operating parameters such as feed composition, fluxing, fuel/oxygen ratio, reductant/feed ratio for maximum fuming rates and stable freeze-lining.

4:40 PM

To the Correlation of Solid and Liquid States in Sulphide Systems Containing Cu, Ni, Co, Fe and Its Utilization for Determining the Rate of Metallization of the Components in Melts: *L. B. Tsymbulov*[1]; [1]Gipronickel Institute JS

Sulphide melts formed in the course of nickel and copper-nickel feed (mattes) smelting are, per se, sulphide-metal melts, since sulphur contained in the melts is in deficiency in relation to the metals (Ni, Cu, Fe, Co). Rate of metallization is rather relevant characteristic of sulphide melts, being widely used in calculating material and heat balances for pyrometallurgical processes. Despite the importance of this parameter, there is no consensus of opinion among the investigators as to what should be understood as the rate of metallization. The most common opinion is that the melt metallization rate and mass fraction in iron melt in metal form are the same. But for all that, the possibility of other metals presence in metal form is excluded from the discussion. The article presents the results of in-house experimental and theoretical studies that allowed determination of certain mechanisms of sulphide melts crystallisation. Based on the determined mechanisms, correlation of solid and liquid states in sulphide systems has been revealed, and brand new and scientifically valid approach to the determination of metallization of sulphide melts' components has been offered. It is shown that sulphur distribution between the metals present in melts is essentially different from the generally accepted ideas.

5:05 PM

Thermodynamics Analysis on Reducing-Matting Smelting of Sulfide Ore of Lead, Antimony and Bismuth which Using Ferric Oxide as Sulfur Fixed Agent: *Chao Huang*[1]; Chaobo Tang[1]; Yongming Chen[1]; Motang Tang[1]; Duomo Zhang[1]; [1]Central South University

The thermodynamics analysis on reducing-matting smelting of sulfide ore of lead, antimony and bismuth which use ferric oxide as sulfur fixed agent was first analysied. Due to the analysis of reaction mechanism, ferric oxide is first reduced to ferrous oxide, then ferrous oxide produce reducing-matting reaction with sulfide ore and reducing agent as reaction equation:

MeS+FeO+CO=Me+FeS+CO2. The reaction thermodynamic calculation shows that the reducing-matting reactions of lead sulfide, antimony sulfide, Jamesonite, and bismuth sulfide are feasible, but is infeasible for zinc sulfide. These conclusion provide a feasible methode for solve the pollution produced in the smelting of sulfide ore of lead, antimony and bismuth.

Thermo and Physicochemical Principles: Steel Making: Thermodynamics and Kinetics

Tuesday PM
August 29, 2006

Room: Russeau Suite
Location: Catamaran Resort Hotel

Session Chair: Toshihiro Tanaka, Osaka University

1:30 PM

Activity Coefficient of Nitride in Slag as a Measure of Slag's Ability to Remove Nitrogen from Liquid Metal: *Peng Fan*[1]; W. D. Cho[1]; [1]University of Utah

Nitride capacity is usually employed as the measure of slag's ability to remove nitrogen from liquid metal, since nitrogen distribution ratio between slag and metal can be calculated from nitride capacity provided that the value of oxygen activity in liquid metal is available. However, during liquid metal refining processes, oxygen activity in liquid metal is usually unknown and thus it is impossible to get nitrogen distribution ratio from nitride capacity under this usual condition. In this paper, thermodynamic analysis indicates that the activity coefficient of nitride in slag can be used to measure slag's ability to remove nitrogen from liquid metal, because nitrogen distribution ratio between slag and metal can be calculated from the activity coefficient of nitride in slag provided that the content of oxygen potential controlling element like Al in liquid metal is available. Review of reported nitrogen removal studies and our recent study has verified that for a given Al content in metal, the lower the AlN activity coefficient in slag is, the higher the nitrogen distribution ratio. Titanium monoxide based slag has been found to be much more effective to remove nitrogen than other slags. Since Al content in liquid metal is usually available during liquid metal refining processes, AlN seems to be a better measure of slag's ability to remove nitrogen from liquid metal.

1:55 PM

Thermodynamics of Titanium, Nitrogen and Oxygen in Liquid Stainless Steels: Jong-Oh Jo[1]; Joong-Beom Lee[1]; Sun-In Kim[1]; Tae-In Chung[1]; *Jong Jin Pak*[1]; Joo-Hyun Park[2]; Dong Sik Kim[2]; [1]Hanyang University; [2]POSCO

Titanium is added in many grade steels as an alloying element to improve mechanical properties via the grain refinement. However, Ti is very reactive with N and O in liquid steel, and TiN and TiO_x formed in liquid steel can cause a nozzle clogging problem and surface defects in final products. Therefore, thermodynamics of Ti, N and O in liquid steel is very important to control those non-metallic inclusions. It is the purpose of this study to establish a data base for the prediction of TiN and TiO_x formation in liquid stainless steels containing various elements including Ni, Cr, Si and Al at the temperature range of 1823 to 1923K. The interaction parameters of Ni, Cr, Si and Al on Ti and N were determined using the metal-nitride-gas equilibration technique. The TiN stability diagram for a commercial stainless steel grade constructed from the measured thermodynamic parameters was verified experimentally. The interaction parameters between Ti and O, and the equilibrium constants for Ti deoxidation reactions for the formation of Ti_2O_3 and Ti_3O_5 were also determined by the equilibration of the melts with those oxides identified by the XRD and the EPMA analyses. Using the thermodynamics of Ti and O in liquid iron, the activities of titanium oxides in ladle slags could be measured, and hence the Ti yield in liquid steels could be predicted for various deoxidation conditions in ladle and tundish.

2:20 PM

Influence of an Alloying Element (Cr, Ni, Mn, Mo and Cu) on the Thermodynamic Properties of Titanium in Molten Iron Alloys: *Takeshi Yoshikawa*[1]; Kazuki Morita[1]; [1]University of Tokyo

In order to control the microstructure of steels for the improvement of those mechanical properties, by controlled precipitations of primary/secondary inclusions such as titanium oxides or titanium nitride, the titanium addition is commonly operated for various types of steel. For the purpose of optimizing the inclusion precipitations during cooling of the steels, thermodynamic information on the system is essential. Nevertheless, thermodynamic properties of Ti in iron-alloys have not been sufficiently investigated. The object of the present work is clarifying the stabilities of titanium oxides and titanium nitride with the liquid stainless steel. The interaction parameters between titanium and alloying elements of chromium, nickel, manganese, molybdenum and copper were determined at 1873K. We investigated the effect of the alloying element on the activity coefficient of titanium in molten iron alloys under the condition of Ti_2O_3-Ti_3O_5 doubly saturations. With the determined interaction parameters, the deoxidation equilibria by titanium for stainless steels have been established.

2:45 PM

Effects of CaF_2 and Ilmenite on Dissolution Behaviour of Lime in Al_2O_3-CaO-SiO_2 Slags: *Shahriar Amini*[1]; Michael Brungs[1]; Sharif Jahanshahi[2]; Oleg Ostrovski[1]; [1]University of New South Wales; [2]CSIRO Minerals

The effect of CaF_2 and ilmenite on dissolution rate and diffusivity of CaO in calcium alumino-silicate based slags in the temperature range of 1500–1600°C was studied by using the rotating disk/cylinder technique. The effect of rotation speed on the rate of dissolution in the base slag indicates that mass transfer in liquid slag played a significant role in controlling the dissolution. At a constant rotation speed, the effect of 5wt% addition of fluxes into the slag, on the dissolution rate was investigated at various temperatures. While CaF_2 had the greatest effect, addition of ilmenite increased the rate of dissolution substantially. The diffusivity of CaO in these slags was quantified using the dimensionless mass transfer correlations for rotating disk/cylinder in the melt. The diffusivity values were deduced using the data on dissolution rate and solubility of CaO in the slags. The measured diffusivity in base slag at 1500°C was found to be $1.32\times 10^{-5}cm^2/s$ and increased to $3.07\times 10^{-5}cm^2/s$ at 1600°C. Addition of 5wt% CaF_2 increased the diffusivity by a factor of 3 to 5, while 5wt% ilmenite addition increased the diffusivity by a factor of 2 to 3 in the temperature range of 1500 to 1600°C. The two examined fluxes reduced the activation energy of diffusion. Ilmenite, which does not cause emission of toxic species to the environment, can be considered as a substitute for fluorspar in steelmaking.

3:10 PM Break

3:25 PM Keynote

Predicting Surface Tension and Viscosity of Molten Slag: *Toshihiro Tanaka*[1]; Masanori Suzuki[1]; [1]Osaka University

The information on viscosity and surface tension of molten slag is indispensable to design new refining procedures in ferrous and non-ferrous processes. For example, the authors have tried to develop "Capillary Refining" to remove impurities in liquid metals by applying capillary absorption of molten slag with those impurities into solid fluxes which have a lot of small capillary tubes. It is necessary to adjust the above physico-chemical properties to adequate conditions on the capillary penetration. In the present paper, we discuss our recent trial to predict surface tension and viscosity of molten slag in multi-component systems. We have derived a thermodynamic model to predict the surface tension of molten slag by using ionic size, molar volume and surface tension of pure components. In addition, we have applied neural network computation to evaluate the viscosity of molten slag. We found good agreement of the calculated results with experimental values of the surface tension as well as the viscosity in various slag systems.

3:50 PM

Bubble Formation and Dynamic Slag Foaming Phenomena: Seshadri Seetharaman[1]; *Abha Kapilashrami*[2]; Morten Gornerup[1]; Ashok Kumar Lahiri[3]; [1]Royal Institute of Technology; [2]Corus Research Development and Technology; [3]Indian Institute of Science

Slag foaming proves to be both blessing and curse for the process productivity, depending on where in the process it occurs. In pyrometallurgical processes,

slag foaming is often a result of chemical reactions taking place in the slag. As the slag composition and reaction rates are changing, foaming occurs under dynamic conditions. In the present work, slag foaming was studied with XRF. The foam displayed a fluctuating behaviour, unaccountable by existing models. The concept of foaming index was found not to be satisfactory in describing the foam, resulting in the need for alternative theories. The rate of fluctuations was seen to be related to the difference between rate of gas generation and rate of gas escape from the system (Ug-Ue) as well as the bubble sizes. Thus, model development of dynamic foaming phenomenon has to take the effective chemical reaction rate as well as the bubble sizes into consideration. The first step in obtaining foam is to form bubbles. In the present work, gas bubbles were generated through chemical reaction at interface between two immiscible liquids and the bubble formation was studied optically. The gas bubble size was seen to be uninfluenced by the reaction rate. However, bubble formation was seen to take place in one of the phases and since the bubbles consequently traversed the interface under the influence of buoyancy, the viscosity of the first phase was found to influence the final bubble size where increased viscosity would yield a larger bubble size.

4:15 PM
Transport Phenomena and CFD Application during Process Metallurgy: *Lifeng Zhang*[1]; [1]Norwegian University of Science and Technology

The transport of fluid, heat ,and particles (bubbles and solid inclusions) in flowing molten steel is investigated in steel refining ladles, the continuous casting tundish, continuous casting mold and strand, and steel ingot casting processes. Inclusion removal from the molten steel by flow transport and bubble flotation, and inclusion growth by collision and diffusion are discussed. Removal of impurity elements such as [C] and [O] during steel refining are reported.

4:40 PM
Mixing and Mass Transfer Rates in a Model CLU Converter: Admire Chaendera[1]; *Hurman Eric*[1]; [1]University of the Witwatersrand

An experimental study on the effect of the slag phase, bath height and gas flow rate on the mass transfer rates and mixing time in a one-fifth water model of a 100 ton CLU converter was conducted. Praffin was employed to represent the slag phase. The mixing time, which was determined by a tracer method employing sulfuric acid, increased with increasing bath height and decreasing flow rate at a given slag proportion in the bath. The mixing time data was related to the specific energy dissipation rate through the variables; gas flow rate, bath height and and bath weight. Mass transfer rates were determined by measuring the dissolution rate of benzoic acid cylinders in the bath. Mass transfer rates decreased with increasing bath height and decreasing gas flow rate. A relationship between the derived mass transfer coefficient, gas injection rate and bath height was established. An attempt was made to extrapolate the results to the industrial scale vessel.

5:05 PM
Coupled Thermodynamic and Kinetic Modeling of a Top-Blown Bath: *Mikael Ersson*[1]; Anders Tilliander[1]; Pär Jönsson[1]; L. Jonsson[1]; [1]KTH

A fundamental mathematical model of lance blowing on a bath surface has been developed with a purpose to increase the understanding of various phenomena in top blown oxygen converters. The model is based on the Navier-Stokes equations and turbulence is predicted using the k-e model. In the present model the deformation of the liquid surface, caused by the impinging gas jet, is described using a VOF formulation. The mathematical model results have been verified by comparing predicted penetration-depth data with experimental results from physical model trials. The fluid dynamic modeling has also been coupled with the thermodynamic modeling to predict the reaction rate/distribution occurring in the vessel. The focus has been on carbon and a qualitative comparison of the predicted carbon content in the hot spot area and in droplets with experimental data from laboratory trials has been done.

NOTES

International Symposium on Sulfide Smelting: Technologies and Recent Developments II

Wednesday AM
August 30, 2006

Room: Macaw
Location: Catamaran Resort Hotel

Session Chairs: Adalbert Lossin, Norddeutsche Affinerie AG; Cesar M. Acuna, Codelco

8:00 AM Keynote
Making Initial Bath-Melt at Onsan by Flash Reaction: *Kwang-Ho Lee*[1]; Sung-Sil Park[1]; Won-Chan Seo[1]; Jong-Shin Chang[1]; [1]LS-Nikko Copper Inc.

Onsan copper smelter of LS-Nikko Copper Inc. has operated the Mitsubishi continuous process along with Outokumpu process since 1997. Mitsubishi process is a bath smelting process which needs adequate melts for smelting reaction in the furnace. After a campaign shutdown, it requires time to make this start melt. Onsan smelter has had much experience in flash smelting, including the improvement of the concentrate burner which is one of the most important parts in a flash smelting furnace. Based on this experience, the lances of the Mitsubishi smelting furnace were modified just for making the starter melt with flash reaction. In 2004, flash reaction in the Mitsubishi S-furnace had been achieved to make the starter melt using these modified lances. Although it was still under development at that time, the time for making initial bath-melt was reduced by about half.

8:25 AM
Refining of Blister Copper to Remove Nickel: *Alexander Ivan Volkhin*[1]; [1]JSC Kyshtim Electrolytic Copper Plant

Two main techniques are applied in the metallurgical practice for removal of nickel from blister copper: 1) maximum transfer of nickel into fire refining slag and 2) maximum transfer of nickel into anode copper with subsequent nickel recovery in the form of sulphate or metal. At the Kyshtim electrolytic copper refinery a method has been tested for nickel removal from blister copper with the aid of metallic reagents to form intermetallic compounds of nickel insoluble in sulphuric acid. It has been found that an optimal metallic reagent is silicon forming nickel silicide in molten copper, which is insoluble in sulphuric acid. In the process of copper electrolysis, nickel silicide precipitates into sludge, from which nickel can be recovered by hydrochemical sludge treatment.

8:50 AM
Effect of Calcium Oxide Content in Feed Charge on Performance Indicators of Smelting in Sparged Bath: M. Yu. Malkova[1]; V. V. Kozyrev[1]; *Andrey V. Tarasov*[1]; [1]Gintsvetmet

In the course of research aimed at improving the performance of the Vanyukov smelting process (VP) for treating sulfur raw materials in a pilot-scale furnace it has been found that an increase in the calcium oxide content up to 12% to 14% in case of smelting to produce high-grade matte results in a decrease in the copper content of slag by 0.05% to 0.3%. The residual copper content of slag can be computed by a formula taking into account an increase in the calcium oxide content of the feed material and that in the slag. In the course of research for improving the performance of the zinc-containing slag fuming process with blowing of the slag bath with combustion products of natural gas it has been found that the silica and calcium oxide contents have an effect on the degree of zinc sublimation. In case of slag containing 24.4% SiO_2 and 6.95% CaO by weight (SiO_2:CaO = 3.51), the residual zinc content of slag was 3.25%. The minimum residual zinc content of 1.95% was obtained in case of slag containing 22.5% SiO_2 and 14.5% CaO by weight (SiO_2:CaO = 1.55). An increase in the CaO content of slag up to 16% by weight with a ratio of SiO_2:CaO = 1.25 to 1.35 permits minimization of zinc losses in slag by achieving a residual zinc content of final slag in the order of 1%.

9:15 AM Invited
Practical Metallurgy for Continuous Converting in the Mitsubishi Process: *Fumito Tanaka*[1]; [1]Mitsubishi Materials Corporation

The Converting Furnace (C-furnace) of the Mitsubishi process has solely provided opportunities for producing blister copper continuously from molten matte. Continuous converting originates from the proven technology for controlling the behavior of magnetite in lime-ferrite slag of CaO-FeOX-Cu2O system. Recent improvements in the C-furnace operation have included the slag controls reflecting the impact of minor oxides on the magnetite behavior. Although previous investigations have focused on the magnetite behavior, sulfur has also affected the C-furnace operation because it is of practical importance to avoid the precipitation of gypsum from lime-ferrite slag and the separation of matte from blister copper. This paper will quantify the behavior of sulfur in C-furnace with respect to the gypsum formation and matte separation, and discuss better controls for the C-furnace operation.

9:40 AM Break

9:55 AM Keynote
Phase Relations of Ferrous Calcium Silicate Slag and Its Possible Application in the Industrial Practice: *Florian Kongoli*[1]; Ian McBow[1]; Akira Yazawa[2]; [1]FLOGEN Technologies Inc; [2]Tohoku University

The so-called "fayalite" slag, despite problems associated with it, is the most widely used slag in copper smelting processes. Thirty years ago, in order to overcomes some drawbacks of this slag a new "calcium ferrite" slag was proposed especially for continuous copper converting. Since both slags have strong and weak points depending on the field of their application another new "ferrous calcium silicate" slag was recently proposed that is expected to solve the drawback of each slag. This new slag is defined as consisting of mainly by FeOx, CaO and SiO2 as main components but it can practically have several combinations of these components. In order to determine the best area of this slag for possible industrial application the quantification of phase relations is an important point. In this paper a review of the work carried out by the authors in quantifying through an original physical model the phase relations, liquidus surface, liquidus regions, behavior of solid phases and the effect of minor components is reviewed. Several special compositions of this slag have been identified and discussed for possible applications in the industrial practice.

10:20 AM Invited
Smelting of High Impurity Concentrates via Teniente Converter: *Cesar M. Acuna*[1]; M. Sherrington[2]; [1]Codelco; [2]Training Management Inacap

Scarcity of high grade copper low impurity content ores is a reality and the processing of low grade dirty concentrates is a need. In spite of this fact, innovative strategies have to be looked at to comply with day to day more stringent environmental regulations. From this perspective the production of matte grades over 70% in copper presents several merits, but it must be contrasted with the fractional distribution of impurities reporting to the condensed phases. The processing of high arsenic feed to white metal will result in rather moderate fractions of arsenic to the gas, but high deportment to the matte phase. Therefore, production of anode copper, as required by the electrolytic refinery, may result in several operational difficulties. Furthermore, by recycling the flue dust and slag produced in the smelting-fire refining cycle, the arsenic content in the feed to smelting increases and so does in the resulting anode copper. The Teniente Converter, as a smelting unity, has probed to be suitable for production of high matte grade near white metal composition but regarding distribution behaviour of impurities there is lack of reliable data, specially when processing concentrates over 1% in arsenic content. In the new scenario, i.e. low grade copper high arsenic content concentrates, to fully asses the merits of this technology the effect of matte grade, secondary materials recycling and arsenic in feed upon the distribution coefficient of arsenic between slag and matte, mainly, must be evaluated both from a theoretical approach and by use of industrial data. Based on available data correlations of distribution coefficient, matte grade and matte/slag ratios with arsenic in feed and copper content in slag are worked out. Based on these results suggestions as to matte grades facilitating to deal more efficiently with the handling of smelting byproducts are proposed.

10:45 AM

Specific Features of Autogenous Smelting of Sulfide Raw Materials Using Oxygen-Flame Process: *Valery M. Paretsky*[1]; A. V. Tarasov[1]; [1]Gintsvetmet

Most recent developments made in the Gintsvetmet Institute in the field of technologies and equipment for single-stage autogenous smelting of copper sulfide raw materials to produce white metal and blister copper on the basis of oxygen-flame smelting process and separation of highly basic calcium-containing slags have been discussed. This technology includes the oxygen-flame smelting process (KFP Process) to produce highly basic self-disintegrating ferrite-calcium slags with their subsequent flotation to recover copper and a basically new sparging smelting process (FBP Process) to produce combined slags subjected to decopperizing inside the same furnace. Results of special investigations of the slag structure obtained in the KFP and FBP processes substantiating selection of their chemical and phase composition have been presented. It has been demonstrated that the above processes meet the stringent world-level requirements to advanced technologies with respect to energy conservation and environmental safety with different scales of production and within a wide range of specific conditions of particular operations.

11:10 AM

Study on the Reducing-Matting Smelting of Stibnite Concentrate to Produce Antimony Directly: *Yongming Chen*[1]; Mo-Tang Tang[1]; Chao Huang[1]; Chao-Bo Tang[1]; Weiyi Yao[1]; Sheng-Hai Yang[1]; [1]Central South University

In order to eliminate the serious environmental pollution of low concentration of sulfur dioxide smoke in antimony smelters, a new smelting process that is named as reducing-matting smelting was proposed in this paper. The effects of technical conditions such as smelting temperature, smelting time, the amount of pyrite cinder and the amount of additive on the smelting of stibnite concentrate have been investigated. The results show that the optimum conditions are as follow: the amount of pyrite cinder is 1.2 times of its theoretical amount. The addition amount of soda and sodium sulfate is 15% and 72.6% respectively to the amount of stibnite concentrate when the total amount of sodium is 30%. The reducing-matting smelting is carried out at 1100° for 2h, then the smelting temperature raise to 1200° for 50min. Under the optimum conditions, the direct and the total recovery ratio of antimony is 90.99% and 98.87%, respectively, and the fixed ratio of sulfur is higher than 99%. In conclusion, sulfur in stibnite concentrate is fixed completely in matte and the environmental pollution of sulfur dioxide smoke is avoided in principle. At the same time, valuable metals in pyrite cinder can be extracted effectively. More important, crude antimony is produced directly in one-step and extracting process is simplified greatly. Generally speaking, reducing-matting smelting process has great significance and potential application in the technical renovation of antimony smelters and the utilization of pyrite cinder.

11:35 AM

Sulfidizing Process of Pyrrhotite Concentrate: *L. S. Tsemekhman*[1]; L. N. Yertseva[1]; V. T. Dyachenko[1]; [1]Gipronickel Institute JS

In the current operational environment, development of a technology allowing removal of low-metallized iron sulfides out of pyrometallurgical processing routes has become a matter of high priority. The present work is dedicated to investigation of the sulfidizing process of ore pyrrhotite concentrate with recovery of a sulfide material, enriched with non-ferrous metals, and waste pyrite, with downstream separation by a certain beneficiation method. A run of tests involving heating of the pyrrhotite concentrate in vacuum-sealed ampoules, in the presence of elemental sulfur, within temperature range 200-6000C has been carried out. The obtained products have been examined by X-ray phase analysis and X-ray microanalysis. Its has been established that under certain conditions products of the pyrrhotite concentrate sulfidizing may be: a) pyrrhotite solid solution bearing Ni 1.9 5.4 mass% and Co– up to 0.35 mass%; b) monosulfide solid solution of a pentlandite-like composition; c) pyrite containing Ni 0.22-0.26 mass % and Co– below 0.1 mass %.

Legal, Management, and Environmental Issues: Management of Environmental, Recycling and Waste Treatment II

Wednesday AM, August 30, 2006
Room: Kon Tiki Ballroom
Location: Catamaran Resort Hotel

Session Chair: Mario Sanchez, University of Concepcion

8:00 AM Keynote

Waste Management and Impurities Control at Atlantic Copper Smelter and Refinery: Guillermo Rios[1]; *Enrique Delgado*[1]; Rafael Ramirez[1]; Álvaro Martin[1]; [1]Atlantic Copper

Atlantic Copper Metallurgical Complex in Huelva (Spain) was commissioned in 1970 with a capacity of 40,000 tpy of copper from concentrate. In 1973 the old blast furnaces were replaced by the Outokumpu FSF technology. For the last 30 years, through several expansions and technical modifications, the production has increased up to 300,000 tpy. In 2001 a gypsum plant was built to treat the weak acid from the smelter and the daily electrolyte bleed from the refinery, as an attempt to transform residues in valuable products. This paper describes the developments on the control of impurities that have been made to fit this new situation, such as new electrolyte treatment plant, control of bismuth and arsenic in anodes, new nickel sulphate plant, new tellurium removal plant, and recent operation experiences since 2003.

8:25 AM

Treatment of Acid Mine Drainage Containing Iron Ions and Arsenic for Utilization of the Sludge: *Hiroshi Nakazawa*[1]; [1]Iwate University

The acid mine drainage in abandoned Horobetsu mine in Hokkaido, Japan, contains arsenic and iron ions; total arsenic 10ppm, arsenite 8.5ppm, total iron 379ppm, ferrous iron 266ppm, pH1.8 in average. The mine drainage is nuetralized up to pH7.5 resulting in the formation of iron hydroxide. Arsenic is removed by co-precipitating with iron hydroxide. As there is not enough space to build a sludge dam in the abandoned mine, the sludge is filtered with a pressure filter and transferred into a landfill. In order to cut down on the running cost, it is required to utilize the sludge. Iron content in the sludge is high so that the sludge could be used as raw materials, but it is difficult to utilize becaue it contains arsenic. Arsenate is removed more easily than arsenite, and it co-precipiates with iron hydroxide in the range of pH3-4, indicating that arsenic could be removed without the precipitation of ferrous iron from the mine drainage if arsenite is oxidized to arsenate preferentially. We found that arsenite in the mine drainage was oxidized to arsenate biologically below pH2.0. In this study, we have investigated the bio-oxidation of arsenite and the arsenic removal from the acid mine drainage containg iron ions for the utilization of the sludge.

8:50 AM Keynote

Evaluation of Environmental Burden and Economic Impact with "Landfill Mining Activity" Based on the Waste Input-Output Model: *Kazuyo Yokoyama*[1]; Takashi Onda[1]; Tetsuya Nagasaka[1]; [1]Tohoku University

New environmental assessment model based on the Waste Input-Output analysis has been developed and applied for the "Landfill mining activity". "Landfill mining" implies the digging up of the landfilled wastes, the recovery of valuable material and energy resources and, thus, the reuse of the saved space as a new landfill site. In this study, the landfilled wastes are assumed to be treated by the gasification/melting processes. Two kinds of reactors, the fluidized bed type (FB) and the shaft furnace type (SF), have been considered in this work as the typical gasification/melting processes adopted in Japan. In FB, the dug-up wastes are heated in the sand fluidized bed zone under reducing atmosphere, Fe and Al are recovered in the metallic form, and then, the gasification/melting of residues is made in the second zone. In SF, the waste is charged in the high temperature coke bed, and the gas is recovered together with molten metal and slag. Both processes generate electric power by the recovered heat and fly ash as waste to landfill. It has been found in this study that the both processes can reduce the total volume of waste and save

the available landfill space. SF seems to have higher potential for decreasing volume of wastes because of less emission than FB while FB has great benefit to recover metallic Fe and Al individually. The results of scenario analysis have also indicated that the landfill mining activity is effective for sustainable management of landfill sites.

9:15 AM

Power Plant Fly Ash – A Review of Beneficiation and Utilization: *Haldun Kurama*[1]; [1]Osmangzi University

Worldwide, tremendous quantities of coal are burned to generate electricity. Disposal of coal ash as a by product of incineration is becoming an increasing economic and environmental burden. However a large amount of fly ash has utilized in the construction and cement industry due to the decreased heat rate of hydration and improved workability, the rate of generation clearly far outweighs consumption. The remaining part is generally land filled. Furthermore in recent years, the implementation of more stringent air quality regulations pertaining to coal–burning power plants have resulted the installation and use of combustion gas purification technologies including burners that generate lower levels of NOx in the combustion gases discharged to atmosphere. The use of such burners significantly increase the unburned carbon content of between 6 wt% to 25 wt % that is in the fly ash leaving the burner and causing the decrease of the quantity of available ash that is suitable for use constituents in concrete and shaped building product. In this paper, the used methods such as low temperature combustion, froth flotation, partical size classification and electrostatic separations to remove unburned carbon particles from fly ash is fully discussed. Utilization of fly ash as a value added product in areas such as novel materials, waste management, recovery of metals and agriculture is also reviewed with the aim of helping the expand of the usage of fly ash and reduce the environmental and economic impacts of disposal.

9:40 AM Break

9:55 AM Keynote

Arsenic Management in the Metallurgical Industry: The Chilean Experience: Armando Valenzuela[1]; Eduardo Balladares[2]; Domingo Cordero[3]; *Mario Sánchez*[2]; [1]Chilean Copper Commission; [2]Universidad de Concepción; [3]Institute for Innovation in Mining and Metallurgy

Arsenic has been a common impurity in copper sulfide concentrates treated pyrometallurgically in Chile, which inevitably during the smelting-converting process reports in the final copper product affecting its properties, but also affecting environment as a very toxic occupational hazard. The enforcement of air quality standards, which regulate pollutants such as sulfur dioxide, particulate matter, and arsenic, has resulted in the implementation of pollution abatement plans and emission reduction schedules mainly by state-owned copper concentrate smelters. Investments associated with these plans incorporated gas-handling systems in order to capture polluting emissions. Electrostatic precipitators recover dusts containing mainly Cu and As which are leached to recover copper, while arsenic is disposed currently in the form of ferric arsenate. Gases containing high sulfur dioxide content are treated in plants to produce sulfuric acid, which is used in various classical and new hydrometallurgical processes. Additionally, smelters have effluents treatment plants for arsenic disposal either as ferric arsenate or calcium arsenate/ arsenite. This paper reviews the environmental situation of the Chilean metallurgical industry, and the present trends for arsenic management are particularly emphasized since Chile is the world's largest copper producer.

10:20 AM Invited

Solid Residues of the Metallurgical Industry and Possibilities of Their Utilization: *N. Lohja*[1]; Z. Lleshi[2]; O. Gliozheni[3]; P. Gega[4]; [1]Polytechnic University of Tirana; [2]Ministry of Industry and Energy; [3]University of Tirana; [4]Institute of the Environment

Metallurgical industries are generally big producers of solid residues of various kinds. In contrast with the past where environmental sensibilities were not so elevated and the accumulated mass of these residues were not considerable, these days the solid residues are everywhere scrutinized among others in term of their harmful environmental impact and as possible materials for valuable elements extraction or secondary utilization. As a case study, the present paper deals with the solid residues discharged by the metallurgical industry in Albania for the last tens of years. The results of two monitoring study on the solid residues of copper, iron and Ferro-chromium producing industries will be given. The first deals with the location, quantities and chemical composition of these residues and the second one with the impact of harmful ingredients of these residues in the environment. Some methods for the processing of these solid residues are also proposed in order to ensure a clean environment and to make not just possible but also and economically viable their secondary utilization.

10:45 AM

On the Implementation of Municipal Solid Waste (Rubbish) Sorted Collection in China Cities: *Dewen He*[1]; Liang-Hui Huang[1]; Li-Yuan Chai[1]; Yun-Yan Wang[1]; Bing Peng[1]; Xiaobo Min[1]; [1]Central South University

The increasing population and living standard in urban areas, have accompanied with the growing quantity and composition complexity of rubbish, which are causing well-known social effects of pollution, while rubbish (solid waste) is a recyclable resources. To convert rubbish into useful materials, the essential measure is to carry out sorted collection of rubbish. The preconditions of implementing sorted collection are presented in the paper. 1. Characteristics of rubbish composition and amounts of recyclable contents are basic condition to implement sorted collection. 2. The existing available technologies of recycling, economic benefit from recycling, and disposal scheme of residual rubbish are restrained condition for sorted collection. 3. Public understanding and support to sorted collection are the key to success. 4. The government policies to be favorable for sorted collection is the pledge of success. 5. The establishment of a steady solid waste recycling market is also a guarantee to implement sorted collection continuously. 6. To establish management system of rubbish recycling as soon as possible. Further, the methods and procedure of sorted collection are discussed in detail and beneficial comments and theoretical basis to promote sorted collection of rubbish in urban area are presented; it will contribute reference value to municipal solid waste management.

11:10 AM

Research on Combustion Temperature and Decontamination of Asphalt Smoke: *Rui Huang*[1]; Liyuan Chai[1]; Bing Peng[1]; Yunyan Wang[1]; [1]Central South University

The asphalt smoke is a hurtful gas in the process of alumina electrolyses and other industrial process. The proper combustion temperature and the combustion conditions are the important key of decontamination of asphalt smoke and economizing the supplied energy to keep the combustion process. Through a combustion device of asphalt smoke, a series of experiments and theoretical analysis are carried out to study the combustion temperature for completed reaction of all components of the asphalt smoke, and put forward the control method of the combustion conditions.

11:35 AM

Study of BOD of Dairy Effulent Using Various Microbes: *Madhusudhamrao Vallabhaneni*[1]; Rajinikanth Kondapaneni[1]; [1]Vignan's Engineering College

Environmental problem is the major concern for any industry and there is a great need to that along green lines. Sangam Dairy being one of the most famous Dairy in A.P, produces wide spectrum of milk products. The BOD levels of effluent water of this industry with MIF treatment were found to be around 100 ppm. Lot of research has been expended in the past to bring down the BOD levels to bare minimum. The main objective of the present study is to minimize the BOD level to the required levels stipulated by environmental standards by employing various seeding materials. Different microbes like Bacillus Subtiles, Pseudomonas, Aspergillas, Staphylococcus, and Pencilium have been employed and BOD levels were analyzed. Various Reagents, solutions with different dilution levels have been successfully prepared. Initial and final Dissolved Oxygen levels were determined before and after incubation. From the do data, BOD was evaluated for all samples and comparison analysis of various seeding material was dare to suggest the efficient seeding material for the ETP plant. Various reagents and samples with different dilutions were successfully prepared. Characteristics of BOD levels were determined by using BOD test. Various samples of different

dilutions with various microbes were prepared and also ensure proper aeration to have sufficient DO. Titration was carried out for all the samples initial and final DO levels were estimated and BOD results were determined by using BOD 5-days test. It has been observed that Staphylococcus and Pseudomonas proved to be the best seeding materials. When Staphylococcus, Pseudomonas were employed, BOD level has been dramatically reduced from 340 ppm to 12 ppm and 24 ppm respectively. However when use these seeding medias BOD 5-days test is recommended that Staphylococcus has to be cultured and employed for dairy wastewater treatment plant to meet the environmental standards.

New, Improved and Existing Technologies: Aqueous Processing IV

Wednesday AM
August 30, 2006

Room: Boardroom West
Location: Catamaran Resort Hotel

Session Chairs: Guy Deschenes, CANMET; Neil Izatt, IBC Advanced Technologies, Inc.

8:00 AM Invited
A New Technology for the Control of Lead Nitrate Addition in Cyanidation: *Guy Deschenes*[1]; Mike Fulton[1]; Clint Smith[1]; [1]CANMET

In spite of the wide use of lead compounds to enhance cyanidation of sulphide-bearing gold ores, an industrial control method was only implemented 3 years ago. This study presents the results of an investigation that led to the development of the on-line control strategy for the lead nitrate addition. Two sulphide-bearing gold ores were used in the study. The relationship between the formation of thiocyanate and the addition of lead nitrate was quantified. Two methods for the determination of thiocyanate (visual titration and potentiometric titration) were assessed and proved reliable. The investigation established a link between the concentration of cyanicides in the leach (pyrrhotite and chalcopyrite) and the efficiency of lead nitrate in reducing their detrimental effects.

8:25 AM
High-Efficiency Reactors for Obtaining of Metal Powders: *Tinatin Lezhava*[1]; [1]R. Agladze Institute of Inorganic Chemistry and Electrochemistry

The known methods of metal powder obtaining by electrolysis are characterized by following: process discontinuity, complexity of solution composition, complexity of the product unloading, low productivity of the process. A new model of the reactor with rotating cathodes have been developed, where obtaining of various forms (dendrite, spongy) of metal depositions and their uninterrupted derivation is possible by realization of ultra-high current densities (5000-50 000 A/m2) and low energy consumption (the bath voltage does not exceed 3-6V). The forms of the cathode deposits and granulometric composition regulated by the current density, electrolyte concentration, temperature and speed of cathode rotation. At the same by contrast to existing methods, high quality metal powder may be obtained from concentrated electrolytes without any specific organic or inorganic additives, which makes possible raise the intensity of the process. The reactor can be applied for electrowinning of metals with low adhesive capacity (Pb, Ag, Cu, Zn, Ni, Co etc.) and their alloys powders. Obtained products may be utilized in metallurgy, as well as in powder metallurgy (Gergian Patents #2004 1097 U; #2001 2535; #2001 2537; #1998 1492).An operating ability of the reactor is tested in laboratory and laboratory scales by the example of dendrite zinc and spongy copper isolation from the corresponding model sulfate electrodes. The advantages of the proposed method in comparison with its analogues are: efficient production, automation of the technological processes and improvement of environmental requirements.

8:50 AM
Elimination of Zinc Ferrite for Hydrometallurgical Recovery of Zinc from EAF Dust: *Guozhu Ye*[1]; Eric Burstrom[1]; Massimo Maccagni[1]; Lorris Bianco[1]; Hakan Stripple[1]; [1]MEFOS

Hydrometallurgical zinc recovery from EAF dust has several advantages compared to pyrometallurgical alternatives in terms of low temperature operation, lower energy consumption and higher flexibility. Many hydrometallurgical processes have been suggested and tested over the years without success. The main reasons are: - low leaching yield of zinc due to the fact that a high fraction of ZnO in EAF dust exists in the zinc ferrite structure which makes selective leaching of ZnO not possible; - many of the proposals could not handle the halide in EAF dust. To eliminate these two disadvantages, two zinc ferrite elimination concepts have been tested and developed in the REZIN project of EU 5th Framework Programme. The two concepts for zinc ferrite elimination could be shortly described by the following chemical reactions: 1. ZnO*Fe2O3 + 2CaO = Ca2Fe2O5 + ZnOfree. 2. ZnO*Fe2O3 + C = Femet + CO/CO2 + ZnOfree. These two concepts were investigated in details combined with a subsequent leaching step using the novel EZINEX process for recovery of zinc from EAF dust. Leaching of pretreated samples has shown great increases of a zinc recovery yield. Zinc recovery of over 90% could be reached as compared to about 50% for no-pretreated samples. This paper will describe the two concepts in details.

9:15 AM
Recovery of Ga, Ge, in from Zinc Residues by Hydrometallurgical Processes: *Haibei Wang*[1]; Lei Zhang[1]; Jiangshun Lin[1]; Kaixi Jiang[1]; Dingfan Qiu[1]; [1]BGRIMM

China is the important country of reserves and products of Ga, Ge, In. They usually associates with lead and zinc ores such as Fankou, Dachang, Lanping mines. But until now these metals can not be extracted from zinc residues effectively. The main reason is that it is difficult to separate with zinc and iron. BGRIMM has carried out much research works on it. Hydrometallurgical processes were developed. Zinc residues was pressure leached with reducing agent such as zinc concentrates or SO2 at 110~130°C. The final concentrate of H2SO4 was 30~50g/L. The metals such as Zn, Fe, Ga, Ge, In were dissolved into solution. Pb and Ag in leaching residue could reach 20% and 2000g/t. The feed of solvent extraction was prepared from leaching solution by pre-neutralization – precipitation of Ga, Ge, In – acid dissolving. Then In, Ga, Ge were extracted by solvent extraction with P204 and G315 produced by BGRIMM. After stripping, metallic In and Ga were produced by electrowinning. GeO2 was produced by precipitation. The iron in raffinate was removed by hematite process. The solution after removal iron came back zinc neutral leaching stage. In 2003-2004, pilot tests were finished in BGRIMM cooperated with Fankou Lead and Zinc Mine Ltd. The extraction of Ga, Ge, In were 94%, 83%, 98% in leaching stage. The total recovery rate were 90%, 80%, 95%. The technology has a wide commercial use in the coming five years.

9:40 AM Break

9:55 AM
Recovery of the Chromium (III, VI) from Aqueous Solutions Using Ion Exchange System: *Josiane Costa Riani*[1]; Versiane Albis Leão[2]; Jorge Alberto Soares Tenório[1]; [1]Universidade de São Paulo; [2]Universidade Federal de Ouro Preto

The release of heavy metals into the environment is becoming bigger due to human activities such as paintings and pigments industries, tanneries, metal finishing industries among others. Among metal releases, chromium is notable because this metal is carcinogenic. Thus, the aim of this work is to use an ion exchange system composed of one cationic resin column and one anionic resin column in order to adsorb the chromium (III, VI) of chromium electroplating effluents in order to recycle the water. The methodology consists of chromium adsorption tests using the ion exchange system with the resins: Purolite A 850 (polystyrene matrix, functional group quaternary amine) and Purolite C 150 (polystyrene matrix, functional group sulfonic acid). The contaminated solutions were passed through the columns with the assistance of a peristaltic pump. Samples of the outgoing solution were taken in order to control conductivity and pH and analyze the metals The effects of the feeding outflow on the chromium adsorption were evaluated. The results show that the quality of the water collected at the end of the process is within the Brazilian standards for the discarding of toxic substances in the

environment (CONAMA 357/05). Allowing, therefore, the water recycling in the process and also its discharging into rivers.

10:20 AM

Studies on Several Important Methods of Fe Removal from (Zn, Mn, Cu, Ni and Co) Hydrometallurgy: *Wilson Zhang*[1]; Guanggui Mei[1]; [1]Central South University

This paper described the study on several important methods of removing Fe in hydrometallurgy of Zn, Mn, Cu, Ni, Co and etc. including the methods of neutralized hydrolysis, ammoniojarosite and goethite, and the technical requirements and technical index of each method. Reactions for each major technological process have been expatiated based on the thermodynamic analysis.

10:45 AM

Study on Extracting Indium from Indium-Zinc Concentrates: Mo-Tang Tang[1]; Shi-Qing Li[2]; Sheng-Hai Yang[1]; Chao-Bo Tang[1]; *Shao-Hua Ju*[1]; You-Ming Chen[1]; [1]Central South University; [2]Liuzhou Huaxi Group Corporation

A new process for extracting indium from indium-zinc concentrates was proposed in this paper. The process can directly extract indium from removed copper solution by P204, and cancel the stage of removing iron in the traditional process because of using iron and part of zinc in the In-Zn concentrates for direct preparing high quality Mn-Zn soft magnetic ferrites. The technologies in the processes, such as leaching the neutral leached residues with high concentrated acid at high temperature, reduction ferric and removing copper, and extracting indium, were investigated. The results showed that total recovery ratio of indium has been increased from less than 70% in the traditional process to more than 95%. This process has the advantages of largely simplifying the procedure of indium extraction, zero draining off of iron residue and zero emitting of SO2. So this is a clean production process.

11:10 AM

Sulfur Dioxide in Hydrometallurgical Technologies for Integrated Processing of Polymetallic Concentrates: *Andrey V. Tarasov*[1]; E. M. Timoshenko[1]; [1]Gintsvetmet

In order to improve the efficiency of hydrometallurgical processing of pyrrhotite concentrates, an integrated set of research has been carried out to investigate the use of sulfur dioxide in individual unit operations and as a leaching agent in the autoclave process as a substitute for oxygen. Treating iron-containing raw materials for production of nonferrous metals are based on the selective reaction of SO_2 with iron sulfides and oxides. Iron is dissolved as sulfate, which can be treated in a separate circuit to produce iron-containing pigments or it can be disposed of after neutralization. Nonferrous and precious metals contained in pyrrhotite concentrate do not react with sulfur dioxide and remain virtually completely in the solid phase, i.e. high-grade sulfide concentrate to be treated by hydro- or pyrometallurgical methods. Elemental sulfur formed in the process of leaching is separated from the pulp in granulated form as a result of the use of special surfactants. The process of sulfide concentrate leaching with the use of sulfur dioxide is conducted at temperatures above the sulfur melting point (119°C) with distributed feeding of surfactant and under a partial pressure of sulfur dioxide of up to 0.3 to 0.5 MPa.

New, Improved and Existing Technologies: Materials Processing II: Nano, Ceramic and Composite Materials

Wednesday AM
August 30, 2006

Room: Russeau West
Location: Catamaran Resort Hotel

Session Chairs: Osamu Yamamoto, Akita University; Kazuya Koyama, National Institute of Advanced Industrial Science and Technology

8:00 AM Keynote

Antibacterial Evaluation of Carbon-Ceramic Composites: *Osamu Yamamoto*[1]; Zenbe-E Nakagawa[1]; [1]Akita University

We searched the development of antibacterial ceramics that can be used in the place without the presence of light so far. On the research, we found that three ceramics, such as CaO, MgO and ZnO, which have a strong antibacterial activity without the presence of light. In order to search the inorganic materials with stronger antibacteril activiy, carbon-ceramic composites were synthesized, such as activated carbon dispersed with ceramic nano-particles, and ceramic coated with carbon, because carbon has high absorption performance for bacteria. In the case of activated carbon with nano-particles, the antibacterial activity increased with increasing the amount of ceramics and decreased with increasing carbonization temperature. In contrast to activated carbon with nano-particles, the antibacterial activity of the ceramic coated with carbon was similar to that of ceramic itself. In antibacterial ceramics, the activity of ZnO was in particular interesting. Because ZnO showed antibacterial activity in a neutral region, being different from CaO and MgO. The occurrence of antibacterial activity was supposed to be due to the generation of hydrogen peroxide from ZnO.

8:25 AM Invited

Synthesis of Metal Oxide Nanoparticles by Flame Spray Pyrolysis: *Hee Dong Jang*[1]; Hankwon Chang[1]; Churl Kyoung Lee[2]; Yong Jae Suh[1]; [1]Korea Institute of Geoscience and Mineral Resources; [2]Kumoh National Institute of Technology

Flame spray pyrolysis was applied to produce binary metal oxides nanoparticles such as lithium cobalt oxides, indium tin oxides from the aqueous solution of the precursor. A high enough flame temperature was used for the complete thermal decomposition of the aerosol precursor. Molar concentrations of the precursor solution, and the flow rate of combustion gas such as hydrogen are varied to control particle size, size distribution and crystal structure. Crystalline LiCoO2 and ITO nanoparticles with the average particle diameter ranging from 11 to 35 nm and from 11 to 20 nm were synthesized, respectively. The LiCoO2 powder was proved to have good characteristics as cathode active materials in charge/discharge capacity and cyclic performance.The transparency and conductivity of the ITO film prepared was quite acceptable for the industrial application.

8:50 AM

Synthesis, Structure and Performance Studies of LiFePo4-Based Cathode Materials for Li-Ion Battery: *Xi Dai*[1]; Honghui Tang[1]; Chuanfu Zhang[1]; Ping Yang[1]; [1]Central South University

The Li-ion battery cathode materials LiFePO4 and LiFe0.9Ni0.1PO4 were synthesized with FeC2O4•2H2O and Fe0.9Ni0.1C2O4•2H2O as Fe sources by high temperature solid-state reaction method. The FeC2O4•2H2O and Fe0.9Ni0.1C2O4•2H2O materials were produced by liquid co-precipitation method. The crystalline structure, morphology of cathode materials were characterized by X-ray diffraction and scanning electron microscopy. The composition contents and charge-discharge performances were measured by chemistry analysis and charge-discharge apparatus. The XRD patterns showed that both LiFePO4 and LiFe0.9Ni0.1PO4 samples were pure, well-crystallized, homogeneous olivine-type phase, with only about 0.4% Fe3+ impurities according to chemistry analysis results. Charge-discharge test showed the cathode materials possessed excellent performances in terms of specific capacity, reversibility, cycling stability and rate performance at room

temperature. The first cycle discharge specific capacity of LiFePO4 was up to 150mAh•g-1¬ and was about to 140mAh•g-1 after 30 cycles at 0.1C rate. Additional, the discharge specific capacity of LiFe0.9Ni0.1PO4 was more than 120mAh•g-1¬ after 90 cycles almost without capacity fading¬ at 0.5C rate.

9:15 AM
Chemical Vapor Synthesis of WC-Co Nanocomposite Powders: Manolete Mena[1]; *Taegong Ryu*[1]; Hong Yong Sohn[1]; Gilsoo Han[1]; Young-Ugk Kim[1]; Zhigang Zak Fang[1]; [1]University of Utah

WC-Co nanocomposite powder is among the first group of materials with a promising potential for nanocrystalline-materials application. A chemical vapor synthesis (CVS) process that has previously been used for preparing the aluminides of titanium and nickel, and other metallic and intermetallic powders has been applied to the preparation of WC-Co nanocomposite powder. This CVS system was designed so that a tungsten precursor (WCl_6 powder) and a cobalt precursor ($CoCl_2$ powder) were separately fed into each evaporator in a reactor by means of specially designed powder feeders. The reduction and carburization of the vaporized chlorides by methane-hydrogen mixtures produced nanosized WC and Co composite powder. The product is a very uniform mixture of the constituent powders, which is important to ensure a high quality of the bulk cemented tungsten carbide product after consolidation. In the present work, the effects of reaction temperature, CH_4 to WCl_6 ratio, CH_4 to H_2 ratio, residence time, and Co content on the powder composition and particle size were determined. The products were characterized using XRD, carbon analyzer, and TEM.

9:40 AM Break

9:55 AM
Preparation of the Solution Containing Metal Nano-Particles and Its Characterization: *Toshiharu Hayashi*[1]; Tsutomu Atsuki[2]; Reiko Kiyoshima[1]; Osamu Yamamoto[3]; [1]Mitsubishi Materials Corporation; [2]JEMCO Inc.; [3]Akita University

We prepared aqueous solution containing spherical metal nano-particles, such as Au and Ag, with the size of a few nm by novel chemical processing; generating seeds of metal precursor by adding borane dimethylamine complex into the metal salt solution, and then growing simultaneously with aminoalcohol including in the solution. As-prepared metal nano-particles modified by chemical speices were found to have three active performance as follows. (1) Nano-particles show a high dispersiveness in an aqueous solution in a long time, (2) nano-particles were sintered at room temperature, and (3) the metal films prepared from nano-particles have low resistivity at room temperature. By various measurements, it was found that 2-aminoethanol was modified on the surface of metal nano-particles. The sintering behavior of metal nano-particles were dependent on the elimination of 2-aminoethanol modified on its surface.

10:20 AM
Durability of Two Extractants for Pd(II) Separation, Thiodiglycolamide and Di-N-Hexyl Sulfide: Against a Mixed Solution of HNO3 and HCI: *Hirokazu Narita*[1]; Mikiya Tanaka[1]; Kazuko Morisaku[1]; [1]National Institute of Advanced Industrial Science and Technology

Di-n-hexyl sulfide (DHS) has been extensively employed in the industrial processes for the palladium(II)/platinum(IV) separation. However, some problems (e.g., the slow extraction of Pd(II) with DHS, its low durability, etc.) have not been solved yet. Recently, we have found that N,N'-dimethyl-N,N'-di-n-octyl-thiodiglycolamide (MOTDA) rapidly extracts Pd(II) in hydrochloric acid solutions with a good selectivity. Thus, in this study, the extractability for Pd(II) using MOTDA and DHS and their durability against a mixed solution of HNO3 and HCl was investigated by solvent extraction and FT-IR measurements. Both MOTDA and DHS selectively extract Pd(II) over Pt(IV) from 0.75 M HNO3-2.25 M HCl solutions. The extraction rate of Pd(II) with MOTDA is much greater than that with DHS. In the durability test, the extraction percentage of Pd(II) and FT-IR spectra were measured using MOTDA and DHS in contact with 0.75 M HNO3-2.25 M HCl solutions. The extraction percentage of Pd(II) with MOTDA hardly changes during the two-month contact; however, that with DHS decreases with an increase in the contact time. The FT-IR spectra showed that the peak corresponding to the sulfoxide formed by the oxidation of sulfide appears in the DHS system, but not in the MOTDA system. Consequently, it was found that MOTDA is more durable than DHS.

10:45 AM
Advanced Technology of Manufacture of Layered Composite Materials by the Method of Electro-Contact Heating under Pressure: *David Nozadze*[1]; [1]Georgian Technical University

A new method of isotermal electro-contact diffusion welding of layered composites under pressure is offered. The scheme is developed and laboratory installation is created on which preproduction models of the layered composite of steel and aluminum is produced. A new method of electro-contact hot deformation is proposed for realization of diffusion welding by pressure of stratified blanks providing high-temperature isothermal process. In this case a rolling process or composite pressing is meshed with simultaneous electric current transmission in deformation center. Considering that a resistance of transient layer far exceeds the resistances of composite components, the heat release takes place intensively just in this layer. As the surfaces are approached over a distance of inter-atomic forces, the energy of boundary atoms easily reaches the energy threshold of capture with a formation of qualitatively new metallic bond. Proposed method, providing isothermal process in deformation center, excludes a necessity of previous preparation and prevention of surfaces. In this case strength of layer connection may approximate or exceed a strength limit of cladding layer.

11:10 AM
Surface Material Compensation Film Thickness for Phase-Separated Composite Film: Chia-Fu Chang[1]; Chia-Hi Chan[1]; *Zou-Ni Wan*[1]; [1]Kun Shan University of Technology

The method underlying this development is formulated in terms of multiple-scattering theory with the real-space representation. A method of preparing liquid crystal devices by phase separation of liquid crystal from its solution in a prepolymer, which results in adjacent layers of liquid crystal and polymer, is described. Liquid crystals in these phase-separated composite films exhibit electro-optical properties not observed in devices prepared by conventional methods, polymer dispersion, or polymer-stabilization methods.

New, Improved and Existing Technologies: Non-Ferrous High Temperature Processing II

Wednesday AM Room: Toucan
August 30, 2006 Location: Catamaran Resort Hotel

Session Chairs: Dinesh Agrawal, Pennsylvania State University; Christian Wieckert, Paul Scherrer Institute

8:00 AM Keynote
Microwave Sintering, Brazing and Melting of Metallic Materials: *Dinesh Agrawal*[1]; [1]Pennsylvania State University

Microwave energy has been in use for variety of applications for over 50 years. These applications include communication, food processing, wood drying, rubber vulcanization, medical therapy, polymers, etc. In the last two decades the microwave heating has been also applied very effectively and efficiently to heat and sinter ceramics. The most recent application of microwaves is the processing of metallic materials including sintering, brazing/joining and melting. This is unexpected in view of the fact that the bulk metals reflect microwaves. But if the metal is in the form of powder, it absorbs microwaves at room temperature and then gets heated very effectively and rapidly. This presentation summarizes the important developments in microwave processing of metallic materials. Microwave heating is recognized for various advantages such as: time and energy saving, very rapid heating rates, considerably reduced processing cycle time and temperature, fine microstructures and improved mechanical properties, better product performance, etc. It was recently observed that microwave energy can

be very effectively applied to sinter metal powders and a specially designed microwave cavity can even melt bulk metals very rapidly and uniformly. Several common steel compositions, pure metals and refractory metals have been sintered in microwave to nearly full density with improved mechanical properties. Many commercial powder-metal components of various alloy compositions including iron and steel, copper, aluminum, nickel, Mo, Co, Ti, W, WC, Sn, etc. and their alloys have also been sintered in microwaves producing better properties than their conventional counterparts using 2.45 GHz multimode microwave system. This work has been further extended to join and braze bulk metal pieces, especially super alloy based turbine blades with very attractive advantages. The implications of these findings are obvious in the field of powder metal technology. Metal powders are used in industry for diversity of products and applications. The challenging demands for new and improved processes and materials of high integrity for advanced engineering applications require innovation and newer technologies. The newly developed microwave technology provides an opportunity to develop better and cheaper products.

8:25 AM

Effect of $CaSO_4$ Pelletization Conditions on Pellet Strength and Reactivity for Converting SO_2 to Elemental Sulfur by Reaction Cycles Involving $CaSO_4$/CaS: *Moo Eob Choi*[1]; Hong Yong Sohn[1]; Y. M. Z. Ahmed[2]; F. M. Mohamed[2]; Gilsoo Han[1]; M. E. H. Shalabi[2]; [1]University of Utah; [2]Central Metallurgical Research and Development Institute

A new process for converting sulfur dioxide to elemental sulfur by a cyclic process involving calcium sulfide and calcium sulfate without generating secondary pollutants was developed at the University of Utah. In this process, sulfur dioxide is reacted with calcium sulfide to produce elemental sulfur and calcium sulfate. The latter is reduced by hydrogen to regenerate calcium sulfide. In the present work, the effects of different pelletization conditions for the initial reactant calcium sulfate on the strength and reactivity of the pellets were determined. These conditions include the type, amount, and impregnation method of catalyst, binder amount, and sintering. Experiments were also performed to determine the effects of temperature in the range of 973-1173 K, pellet size, cycle repetition, and water vapor or carbon dioxide content in sulfur dioxide stream on the reaction rates of the cyclic process. Nickel-catalyzed fired pellets produced by the use of molasses or cement as a binder showed good reactivity as well as high compressive strength during the cyclic tests. The binder amount did not significantly affect the reaction rate.

8:50 AM

New Technology for the Treatment of Molybdenum Sulfide Concentrates: *Kliment Y. Hakobyan*[1]; Hong Yong Sohn[2]; Andrey V. Tarasov[3]; Pavel A. Kovgan[3]; Armen K. Hakobyan[1]; Vladimir A. Briovkvine[4]; Vladimir G. Leontiev[4]; Oleg I. Tsybine[4]; [1]Kapan Metallurgy and Enrichment Laboratory of the Academy of Science of Armenia/Navro LLC; [2]University of Utah; [3]Gintsvetmet; [4]A.Baykov Institute of Metallurgy and Materials Science

A new technology for treating molybdenum sulfide concentrates has been developed. It includes roasting the concentrate in a special regime with water vapor, cooling and neutralizing exit gas, oxidation roasting of rhenium containing MoO_2, and the extraction of rhenium from exit gases. This technology allows economically efficient and environmentally safe processing of molybdenum concentrates: The degree of molybdenum extraction is 98.8%, rhenium-90%, sulphur-98.4%. The technology also ensures high extents of extraction of selenium and tellurium as well as the fixation of sulfur in the form of sodium sulfide or elemental sulfur.

9:15 AM

Processing of Lead-Zinc Raw Materials: *Andrey V. Tarasov*[1]; A. D. Besser[1]; [1]Gintsvetmet

The natural resources of lead and zinc are primarily constituted by polymetallic and lead-zinc ores. Beneficiation of these types of ores to produce standard nonmetallic concentrates inevitably results in an increase in the loss of base and precious metals with tailings. An improvement in the grades of lead and zinc concentrates can be achieved by re-cleaner flotation, but it results in production of intermediate products (middlings) to which substantial amounts of lead, zinc, copper and precious metals report. Without an appropriate technology for treating such intermediate products, the recoveries of valuable constituents from lead-zinc ores would remain unsatisfactory. A process has been developed in the Gintsvetmet Institute for processing of polymetallic intermediate products produced at the ore beneficiation plants. This process is based on electrothermic smelting to produce lead bullion containing precious metals, commercial-grade copper-lead matte and high-zinc slags (up to 15-20% Zn) from which zinc can be extracted by slag-fuming or Waelz process. Tests have indicated that the recovery of lead from intermediate products into lead bullion and matte is about 83-85% and 13-14% respectively (the total recovery is 97-98%), while copper recovery into the matte and zinc recovery into the slag is 90-92% and 95-96% respectively. Precious metals (about 96-97%) report into the lead bullion.

9:40 AM Break

9:55 AM Keynote

Pilot Scale Solar Carbothermic Reduction of ZnO to Zn: *Christian Wieckert*[1]; Michael Epstein[2]; Gabriel Olalde[3]; Sven Santén[4]; Aldo Steinfeld[5]; [1]Paul Scherrer Institute; [2]Weizmann Institute of Science; [3]PROMES-CNRS; [4]ScanArc Plasma Technologies AB; [5]Swiss Federal Institute of Technology

Concentrated solar energy can be used as heat source for the production of metals. One of the most promising respective processes, the solar carbothermic production of Zn from ZnO, is investigated within the European research project SOLZINC, a cooperation of institutes and industries from France, Germany, Israel, Sweden and Switzerland. The solar produced Zn can be used as commodity or as an energy carrier for further processing *on demand* to electricity in Zn-air fuel cells/batteries or to generate hydrogen by reaction with steam. In both cases the end product is again ZnO, which can be recycled back to the solar plant. In these cyclic processes Zn acts as a means to store and eventually transport solar energy. Second product of the solar process step is a CO-rich offgas, which may e.g. drive a gas engine or may be shifted to hydrogen in a conventional reaction with steam. A pilot plant using 300kW concentrated solar power input has been constructed and operated successfully. 86mass-% of ZnO mixed with 14mass-% of charcoal are reacted to produce Zn and CO at a temperature of about 1200°C, yielding about 50 kg gaseous Zn per hour. Zn-dust with 95% purity is recovered from the offgas system that was designed to produce Zn for Zn-air fuel cells. Based on the results and findings from the pilot plant, a 2 tons Zn/h solar demonstration plant has been designed conceptually. Cost studies have been performed and scenarios for producing electricity or H_2 via these ZnO/Zn-cyclic processes are evaluated.

10:20 AM Invited

Aluminum Extraction via Batch Recirculation Electrolysis in Ionic Liquids: *Mingming Zhang*[1]; Ramana G. Reddy[1]; [1]University of Alabama

This paper describes the aluminum electrowinning in a batch recirculation cell system using 1-hexyl-3-methylimidazolium chloride and aluminum chloride (ionic liquids) as electrolyte at low temperatures. The technique proposed to deposit aluminum from ionic liquid electrolyte was a three-component electrolytic cell system. Ionic liquid electrolyte was circulated between electrolytic cell and electrolyte reservoir by ceramic piston pump. The cell performance variables studied were the aluminum ion concentration, current efficiency and deposition rate as a function of current density, fluid hydrodynamic conditions, applied voltage, and process operating time during batch recirculation operation. Results indicated that the current density was directly proportional to the applied cell voltage and initial electrolyte concentration. During the electrolytic cell operation, the aluminum deposition rate was proportional to the current density and was inversely proportional to fluid velocity in the range between 0.005 and 0.100 m/s. Under batch recirculation operation at constant applied voltage of 3.0-4.0 V, it was found the current efficiency of 80%-90% of cathodic aluminum deposition can be achieved at temperature range of 80-120°C, and aluminum deposition rates were independent of applied voltage, but were proportional to the ions concentration and operating time.

10:45 AM

Processing Complex Copper Matte by Using Pig-Iron: *Leandro Voisin*[1]; Kimio Itagaki[1]; Alex M. Moyano[2]; Jonkion M. Font[3]; [1]Tohoku University; [2]Codelco-Chile; [3]IM2 SA. Filial Codelco-Chile

A new alternative pyrometallurgical treatment is proposed for cleaning copper matte with a high content of arsenic, In the process, a given amount of pig iron is added to the liquid complex matte with a matte grade between 65 and 75% Cu under a reducing condition to produce three liquid phases of matte, copper-rich alloy and iron-rich alloy. In this study, firstly, a mass balance calculation was made on the basis of the reported data for the distribution ratios of the components among the three phases to look for the optimum condition where most of arsenic in the charge can be fixed in the less valuable liquid iron-rich alloy. By take advantage of the high concentration of arsenic in the iron-rich alloy it may be disposed in a yard with a smaller volume in comparison to the traditional processes, while the precious elements be effectively recovered in the liquid copper-rich alloy or liquid matte. Secondly, laboratory scale experiments were conducted to apply the process proposed to the matte produced in the slag-cleaning electric furnace in conjunction with the matte obtained from the Teniente Converter in Codelco-Norte's smelter, Chile. The obtained results indicate that the process proposed for cleaning the complex matte will be promising.

11:10 AM Keynote

Modeling of Mold Filling of Aluminum Casting: K. P. Nishad[1]; *Amarendra Kumar Singh*[1]; [1]Tata Research Development and Design Centre

The origin of many casting defects can be traced at the mold filling stage. Entrapped air/gas pockets and oxide film formation are notable examples. In the present work, the mold-filling process is simulated using a mathematical model, built on a multi-physics based commercial package PHYSICA. The simulation code has the capability to solve multi-phase problems. The numerical model addresses a complicated dynamics of filling operation including free surface flow and subsequent flow behavior and is based on conservation of mass and momentum. The Free surface is modeled using the scalar equation method (SEM). The model is validated with benchmark experimental results from the literature. The role of turbulence and the pouring rate on variables affecting sites prone to oxide film formation are investigated using a simple but novel technique. Key findings of the work are presented.

11:35 AM

Non-Ferrous and Precious Metals Extraction from Complex Sulfide Concentrates by Pyrometallurgical Processing: *Natasa Mitevska*[1]; Ljubisa Misic[1]; Joksim Marinkovic[1]; [1]Copper Institute

In world, as well as in Republic of Serbia, conventional ore reserves are almost exhausted, so the problem of their shortage is more and more expressed. On the other side, there are many locations with significant reserves of polymetallic ores which present huge potential but cannot be classically processed. Each of these classes of materials has particular mineralogical characteristics which affect their processing. Because of that it is necessary to develop particular technology for each unconventional ore in order to extract valuable elements. The aim of investigation was to define technology for complex processing of the Blagojev Kamen sulfide concentrate by pyrometallurgical procedure in order to valorize valuable non-ferrous and precious metals present, and profit with absolute respect of environmental protection laws. The complex composition of the Blagojev Kamen sulfide concentrate with high content of non-ferrous (15.59% Pb, 9.05% Zn, 2.37% Cu) and precious (697 g/t Au and 744 g/t Ag) metals was the main factor for technological procedure and collector selection. Laboratory investigations are done in four series according to technological scheme: oxidizing roasting, charge preparation (flux addition and agglomeration), smelting under reducing conditions, lead bullion refining, Dore metal refining to final products. It is concluded that precious metals are concentrated in lead bullion (up to 97.95% of gold and 93.37% of silver), which has similar composition to lead bullion produced in lead metallurgy. In this case, simplified technology is used for lead bullion processing because of low content of arsenic, bismuth, etc.

New, Improved and Existing Technologies: Steel

Wednesday AM, August 30, 2006
Room: Cockatoo
Location: Catamaran Resort Hotel

Session Chairs: Shigeo Asai, Nagoya University; Jiann-Yang James Hwang, Michigan Technological University

8:00 AM Keynote

Electromagnetic Processing of Materials - Past, Present and Future: *Shigeo Asai*[1]; [1]Nagoya University

Application of an electromagnetic force to materials processing, so called "Electromagnetic Processing of Materials (EPM)" has been recognized as not only a fundamental technology supporting metals industry, but also a cutting edge technology, especially in the fields of advanced materials processing. It first started as the application of Lorentz force to metals industry in 1980s when it was named an Electromagnetic Metallurgy. The name of "Electromagnetic Processing of Materials (EPM)" was firstly formally used in the Iron and Steel World Congress held at Nagoya 1990. The first Symposium of EPM was held Nagoya, 1994, followed by Paris in 1997, Nagoya in 2000, Lyon in 2003 and Sendai in 2006. Recently, by the advance in super-conducting magnets, a high magnetic field has become readily available and is being applied in various fields of science. In this trend many interesting phenomena relating to the high magnetic field have been found and a new academic field named "Science Relating with a High Magnetic Field" is going to open a gate. In order to connect the seeds sprouting from "Science Relating with a High Magnetic Field" with the needs of "Materials Science and Engineering", the new field of "Materials Processing by Use of a High Magnetic Field" is going to grow under the umbrella of "Electromagnetic Processing of Materials".

8:25 AM

Crystal Orientation of CdTe Electrodeposites by Use of Intense Magnetic Field: *Toshiyuki Kozuka*[1]; [1]Kumamoto University

CdTe semi-conducting materials have been expected as solar cell materials because its theoretical efficiency of energy conversion is very high. The actual efficiency still low, however, many research works have been done in order to improve the efficiency. And crystal orientation is one of possibilities for that. In this work, a new method using intense magnetic field for obtaining crystal orientation of CdTe electro-deposits will be proposed, where the CdTe film was electro-deposited under an intense magnetic field. CdTe is less affected by magnetic field, because of its cubic structure, but Cd or Te has hexagonal structure which is sensitive for magnetic field. In this method, deposition of Cd or Te film is utilized.

8:50 AM

Dissipation of Turbulent Kinetic Energy in a Tundish: *Rodolfo D. Morales*[1]; [1]Instituto Politecnico Nacional

Control of steel turbulence has been always a challenge since it is very important to avoid pickup of nitrogen and oxygen during ladle change operations, avoid a steel eye close to the ladle shroud during steady casting and aiming at an optimum performance of inclusions flotation, etc. For those purposes during the last years flow control devices known as turbulence inhibitors have become common place in steel casters. Various geometries of these devices have been proposed aiming at an optimum fluid flow control that must accomplish with the aspects mentioned above. However, it has been found that the level of performance is very dependent on the geometric features of these inhibitors without a sound study that may explain the existence of those differences. Here we report a study involving different geometries of inhibitors using Particle Image Velocimetry and Computer Fluid Dynamics using the levels of dissipation rate of the kinetic energy as a main criterion to characterize the level of perfromance. It was found that when in the budget of the kinetic energy the transport by convection mechanims is enhanced the control of fluid flow is improved. Then those inhibitors whose geometry redistributes and diffuses kinetic enrgy by convection perform

better in steel casters.

9:15 AM
Modeling Dust Evolution in Electric Arc Furnace (EAF) Fume Extraction System: Anne-Gwenaelle Guezennec[1]; *Fabrice Patisson*[1]; Philippe Sessiecq[1]; Jean-Christophe Huber[2]; Denis Ablitzer[1]; [1]School of Mines of Nancy; [2]Arcelor Research

Electric Arc Furnace (EAF) steelmaking co-produces amounts of dust (15 to 25 kg per ton of steel), which require to be collected and stored in specific landfills. The collection, handling, and possible beneficiation of EAF dust depend on its composition and morphology. We first studied theoretically the chemical evolution of dust particles along the fume extraction system, from the furnace down to the filters, using thermodynamic calculations of the Fe-Zn-O system. We show how it would be possible to favor zincite formation in dust and therefore increase further zinc recovery. Then, we developed a new morphological model, based on population balances, for predicting the granulometric evolution of dust particles as a result of agglomeration and sintering in the fume extraction ducts. The contribution of the various mechanisms (Brownian, turbulent, and sedimentary agglomeration; thermophoretic deposition; coalescence and sintering) is assessed. The influence of the exhausting conditions on dust granulometry is detailed. For the extraction system studied, intense agglomeration of the sub-micronic particles and complete coalescence take place inside the furnace; micronic particles then undergo little evolution from the elbow to the water-jacket, whereas big agglomerates are formed downstream. These results are in good agreement with dust particle observations.

9:40 AM Break

9:55 AM Keynote
New Steel Production Technology with Microwave and Electric Arc Heating: *Jiann-Yang James Hwang*[1]; Xiaodi Huang[1]; [1]Michigan Technological University

The economic growth in new developing countries such as China and India has stimulated strong demands in basic materials such as steel. World steel production has exceeded the milestone of a billion tons a year recently. However, the blast furnace technology, which was invented in 1340 A.D., is still the fundamental route for today's steel production. It is important to develop a new generation of steelmaking technology that can meet the society's needs from the energy, environmental and economic standpoints in the 21st century. The new microwave and electric arc heating technology discussed in this paper provides a totally different mass and heat transfer mechanism from the conventional blast furnace technology and offers a great potential to meet our society's needs.

10:20 AM
Optimization of EAF Practices Based-On Real-Time Off-Gas Chemistry Analysis Using Goodfellow EFSOP™: *Marshall I. Khan*[1]; Howard D. Goodfellow[1]; Joe A. Maiolo[1]; Ovidiu I. Negru[1]; [1]Techint Goodfellow Technologies Inc.

The Goodfellow Expert Furnace System Optimization Process (Goodfellow EFSOP™) is a proprietary process that uses real-time and continuous off-gas analysis, along with process monitoring to optimize the operation of electric arc furnaces (EAF) for steelmaking. With the exception of off-gas composition, dynamic process measurements within the EAF are not possible due to the harsh operating environment. The Goodfellow EFSOP™ system provides a dynamic indication of the operating conditions within the EAF. Continuous measurement of furnace off-gas composition, along with other furnace operating parameters is used to elucidate the fate of chemical energy usage within the EAF including: the evolution of carbon from the molten steel bath; the in-leakage of air into the furnace; the extent of combustion above the molten steel bath and the occurrence of dangerous water-leaks from the furnace cooling system. The ability to measure the process reliably and continuously enables Techint Goodfellow Technologies Inc (TGTI) to implement dynamic process control of combustion within the electric arc furnace and to optimize the overall operation through adjustments to the EAF process based on off-gas measurement. This paper discusses the methodology and results achieved from several recent Goodfellow EFSOP™ installations in South East Asia.

10:45 AM
Potential Applications of Supersonic Liquid Streams in Steelmaking: *Ernest Samual Geskin*[1]; [1]New Jersey Institute of Technology

Supersonic liquid streams have a potential of becoming an effective material production tool. It was shown that at the speed of 1500-1750 m/s the water projectile are able to demolish concrete and reinforced concrete plates, forge, pierce and weld metals, to destroy with no explosion non dischargeable mines, etc. The energy needed for the projectile acceleration can be supplied by the electrical discharge, chemical explosion, mechanical impact, etc. An experimental launcher studied by the NJIT's Waterjet Laboratory constitutes a modified rifle where the powder combustion provides the energy needed for projectiles acceleration. A potential application of the supersonic liquid streams involves the replacement of the oxygen gas by the liquid oxygen in BOF and in the course of the direct steelmaking. This will enable us to increase the rate of processing and to improve the reactor design. Blasting of molten oxides by the hydrogen stream will eliminate CO2 emission and reduce the cost of metal production. Combining liquid jet and mechanical tools in the course of ore mining and grinding will reduce the cost of the formation of fine particles suitable for the solid state oxide separation. The presented paper reviews the results of the experimental study of supersonic liquid jets and discusses their potential applications in steelmaking.

Thermo and Physicochemical Principles: Electrochemistry and Molten Salts

Wednesday AM
August 30, 2006

Room: Boardroom East
Location: Catamaran Resort Hotel

Session Chairs: Adam C. Powell, Massachusetts Institute of Technology; Ryosuke O. Suzuki, Hokkaido University

8:00 AM Keynote
Electrochemical Production of Materials Using Molten Salts: *Derek J. Fray*[1]; [1]University of Cambridge

Molten salts have been used for the extraction of metals since the 19th century but, recently, many interesting processes have been investigated using mixtures of molten salts and different cathodic materials. In several existing processes, the cation is simply discharged from melt but, in some cases, complications arise when the electrode potentials of the cations are relatively close. For example, the co-deposition of sodium with aluminium in the Hall-Heroult process which will be discussed in terms of electrode potentials of the components in the molten electrolyte. Similar considerations will also be given to the anodic reactions with respect to chlorine, oxygen, carbon dioxide or monoxide evolution from chloride-oxide melts. In some cases, the cathodic product interacts with the cathode to produce new and exciting products such as nanotubes from carbon or titanates and reduced titanium oxides from titanium dioxide. Depending on the electrode potentials, it is also possible to completely change the cathodic reaction from discharge of the cation in the salt to ionisation of the anions in the cathode. Examples will be given of the reduction of metal oxides to produce metals, high technology alloys and nanomaterials and the cathodic refining of liquid metals.

8:25 AM Invited
Direct Reduction of Vanadium Oxide in Molten $CaCl_2$: *Ryosuke O. Suzuki*[1]; [1]Kyoto University

Fine metallic particles of vanadium were formed directly from the oxides, when either the melt of V_2O_5, the solid VO_2 or V_2O_3 was reduced in the molten $CaCl_2$. Because the molten $CaCl_2$ can coexist with metallic Ca and because it can dissolve a few mol%Ca and about 20 mol%CaO, it is a suitable media for the calciothermic reaction to dissolve Ca as the reductant and to remove oxygen from the metallic oxides. The dissolved CaO is recycled to metallic Ca using the molten salt electrolysis simultaneously operating. The anode and cathode consisted of carbon crucible and V net, respectively, and

the voltage of 2.0-3.2 V was applied for CaO decomposition. The oxide in the cathode like the basket was reduced by the dissolved Ca in the vicinity of the cathode. When VO_2 or V_2O_3 with the high melting points was used, the produced V powder was round, about 1 micrometer in size. The residual oxygen was lower than 1800 ppm. Because the most stable oxide V_2O_5 melts at the reducing temperature (1073-1273 K), its rapid reduction to VO_2 was needed when V_2O_5 was used as a starting oxide. When the oxide mixture was inserted in the net-shaped cathode, the hydrogen storage alloys such as ternary Ti-V-Cr solid solution was formed. Purity, particle size and homogeneity of the reduced powder seem suitable for future applications for hydrogen storage.

8:50 AM

Electrokinetics of Lead Carbonate, Silica and Alumina and Their Applications on Treating Water Polluted with Lead: F. J. Tavera[1]; *R. Escudero*[1]; [1]Metallurgical Research Institute

A study on the electrokinetics of lead carbonate, silica, and alumina, in aqueous media was carried out at different pH values. The behaviour of ζ potential was determined for these species in the pH range between 3 and 12. Homocoagulation of lead carbonate in aqueous media is analysed at its isoelectrical point. Lead carbonate heterocoagulation is analysed with silica, alumina, and silica – alumina mixtures at low pH values. The experimental results are considered for their possible application to treat residual water polluted with lead.

9:15 AM

Self-Tuning Chemical Sensors for Molten Metals: *R. Vasant Kumar*[1]; Derek J. Fray[1]; [1]University of Cambridge

Measurement and control of trace elements in molten metals are often critical in order to achieve optimum production, refining, alloying or recycling. Solid electrolyte sensors for monitoring oxygen and very recently for hydrogen have made major impact in the metal industry. It has not proved straightforward to develop solid electrolyte sensors for many elements that can be industrially applied in metal production. Novel self-tuning chemical sensors have been developed by the authors that may open up new technological opportunities. Three such examples will be presented in this paper: (i) a self-selecting oxygen-sulfur dual sensor using a composite beta-alumina/zirconia solid electrolyte; (ii) a copper sensor for liquid copper systems based on Cusicon solid electrolyte; and (iii) an aluminium sensor based upon solid NaCl containing channels of molten salt electrolyte formed by electrochemical charging during measurement in molten zinc.

9:40 AM Break

9:55 AM Keynote

Phase Field Modeling of Phase Boundary Shape and Topology Changes Due to Electrochemical Reactions in Solid and Liquid Systems: *Adam C. Powell*[1]; Wanida Pongsaksawad[1]; Uday Bhanu Pal[2]; [1]Massachusetts Institute of Technology; [2]Boston University

A new Cahn-Hilliard phase field model of transport-limited electrochemistry describes phase boundary motion due to oxidation and reduction reactions at metal-electrolyte interfaces. Benchmarks demonstrating the accuracy of the method include open circuit voltage and closed circuit current in metallothermic reduction, and linear stability theory in metal electrolysis, including a new stability criterion for reduction of liquid metal from liquid electrolyte. The model is applied here to understanding cathode interface stability in titanium electrolysis e.g. in the SOM process developed with Uday Pal, and to structure evolution in subhalide reduction of titanium dichloride by magnesium developed by Toru Okabe. Potential for application to new fuel cell and battery systems is also discussed.

10:20 AM

Anodic Dissolution Behavior of Titanium in Room Temperature Molten Salt (TMHA-Tf_2N): *Hidekazu Nakagawa*[1]; Tetsuya Uda[1]; Kuniaki Murase[1]; Tetsuji Hirato[1]; Yasuhiro Awakura[1]; [1]Kyoto University

Electroplating of titanium layer on metal surfaces is very attractive to enhance corrosion resistance. But it is almost impossible to electrodeposit titanium from aqueous media due to its largely negative redox potential, so there is no successful titanium plating carried out at around room temperature. In this study, room temperature molten salts (ionic liquids) was tried as a candidate medium for the electrodeposition of titanium, since they, in some cases, have a wide electrochemical window suitable for the electrodeposition of less-noble metals. We employed an ammonium-imide room temperature molten salt, trimethyl-n-hexylammonium bis((trifluoromethyl)sulfonyl)ami de (TMHA-Tf_2N), which has a wide window of about 5V. As an example, we succeeded to electrodeposit magnesium from TMHA-Tf_2N containing Mg^{2+} ions. Thus, in the view of thermodynamics where redox potential of magnesium is much lower than that of titanium, it has a potential ability to electrodeposit titanium. As a first step for the present study, we revealed anodic dissolution behavior of titanium electrode in TMHA-Tf_2N solutions. So far, we found an experimental condition that allows a continuous anodic dissolution of titanium for approximately 600 sec to feed titanium ions to TMHA-Tf_2N medium although it is not long enough. In this presentation, we report the detail of the anodic dissolution and discuss what depresses anode current during the 600 sec.

10:45 AM

Evaluation of Carbon Materials Produced from Coconut Shell as Anodes for Lithium-Ion Batteries: *M. A. Aziz*[1]; M. Alauddin[2]; [1]Khulna University of Engineering and Technology; [2]Islamic University

The electrochemical performance of a series of carbon materials produced from coconut shells, which are very cheap and readily available in Bangladesh was investigated for their viability as anode materials in rechargeable lithium-ion batteries. X-ray diffraction technique was used to measure the interlayer spacing (d_{002}) of the produced carbon materials. A number of half-cells were prepared with the produced carbon materials from coconut shell as working electrode and metallic lithium as counter electrode with 1M$LiPF_6$ electrolyte in a mixture of ethylene carbonate and dimethyl carbonate. The discharge-charge profiles were measured for the different half-cells by using Arbin 24-channel Cyler. The value of interlayer spacing of the coconut-based carbon material was found to be 0.397 nm at 900°C, which is most suitable for lithium-ion insertion into the carbon structure without any expansion. The specific discharge capacity of carbon material from coconut shell heat treated to 900°C was found to be 1015.65 mAh/g. The coconut carbon material heat treated to 900°C delivered 335.22 mAh/g reversible capacity, which is comparable to the commercial carbon/graphite presently used in lithium-ion battery systems. The irreversible capacity loss and coulombic efficiency in 25th cycle of half-cell made with coconut carbon material were found to be 0.16% and 99.83% respectively. The carbon material produced from coconut shell can, therefore, be used as a potential anode for rechargeable lithium-ion batteries.

11:10 AM

Electrochemical Synthesis and Characterization of Tantalum Ethoxide: Sheng-Hai Yang[1]; Yi-Feng Chen[2]; Jian-Guang Yang[1]; *Shao-Hua Ju*[2]; Mo-Tang Tang[1]; Guan-Zhou Qiu[1]; [1]Central South University; [2]Hunan Metallurgical and Polytechnical Institute

The electrochemical synthesis was conducted in anhydrous ethanol solvent mixed with conductive reagent when tantalum plate was used as anode and stainless steel plate as cathode. The effects of different conductive reagents(such as NH4Br, (CH3)4NCl, (C4H9)4NCl), conductive reagent concentration and the space on the cell voltage and the current density were investigated. The current efficiency of electrosynthesis was more than 95%. The electrolyte, a mixed solution was then undergone air distillation and vacuum distillation to get the final product which was characterized by Fourier Transform Infrared (FTIR) spectroscopy, Raman spectra, 1H-Neclear Magnetic Resonance (1H-NMR) spectroscopy. Carbon and hydrogen contents in the product were determined by elemental analysis instrument. Results consistently show that the product was tantalum penta-ethoxide.

11:35 AM

Prospects for the Use of Symmetric Alternating Current for Hydroelectrochemical Treatment of Various Metallic and Metal-Containing Materials with Selective Extraction of Valuable Components: *V.A. Bryukvin*[1]; A. M. Levin[2]; A. A. Palant[2]; Valery M. Paretsky[1]; [1]Gintsvetmet; [2]Russian Academy of Sciences

It has been found that by superimposing symmetric alternating current over the process, the rate of nickel and cobalt leaching from metallized products with copper sulfate solutions increases by a factor of 1.5 to 2.0 and the apparent activation energy of the process investigated is reduced from 12 down to 6.6 kcal/mole. It appears especially attractive to use alternating current for anodic dissolution (oxidation) of metallic scrap of refractory metals and their alloys in ammonia electrolytes permits production of high-grade commercial products in the form of respective ammonium salts using a short and virtually reagent-free process flowsheet. Similar approaches can be applied also for electrochemical processing of nickel and copper scrap in sulfuric acid media with subsequent recovery of pure sulfate salts or electrolytic processing. Electrochemical technology for recycling of tungsten-cobalt (WC 15) and tungsten-rhenium (WR 20) alloys has been also investigated. In the former case, anodic oxidation of carbide alloy was carried out in nitric acid electrolyte with production of pure tungstic acid. The research conducted has indicated that the physicochemical effect of alternating current results in a lower activation energy of electrode reactions due to changes in the mechanisms of the electrode reactions themselves.

Thermo and Physicochemical Principles: Non-Ferrous High Temperature Processing: Waste Treatment

Wednesday AM — Room: Russeau East
August 30, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Junji Shibata, Kansai University; Akio Fuwa, Waseda University

8:00 AM

A 2-D Mathematical Model of On-Grate Municipal Solid Waste Combustion: *Abhishek Asthana*[1]; Yannick Menard[1]; Philippe Sessiecq[1]; Fabrice Patisson[1]; Denis Ablitzer[1]; [1]School of Mines of Nancy

The incineration of Municipal Solid Wastes (MSW) is an attractive process for reducing the volume of the wastes and recovering their energetic value, which, however, requires to be strictly controlled in order to limit its impact on the environment. In this context, we have undertaken the mathematical modeling of the different sections of a typical incineration plant. The combustion of the waste bed, usually carried out on a moving grate, is at the core of the process. This paper presents the 2-dimensional, steady-state model that we have developed for simulating the MSW bed combustion. The model describes gas flow through the porous waste particle bed, the gas-solid reactions, conductive and radiative heat transfers, drying of the feed, its pyrolysis and the emission of volatile species, combustion of the pyrolysis gases, the formation of char and its gasification by water vapor and carbon dioxide, and the consequent reduction of the bed volume. Pyrolysis kinetics distinguish between cellulosic and non-cellulosic materials and are experimentally derived from our laboratory measurements. The calculated results give a deep insight into the various involved phenomena, an example being the complete consumption of oxygen in a large zone of the bed and the related appearance of a char gasification zone. The influence of various operating parameters, like the temperature and flow rate of primary air, is presented and explained. Finally, the effect of stirring the waste bed on the moving grate is analyzed for different stirring schemes.

8:25 AM

Commercial Research on Separation and Purification of Waste Acid in IT Manufacturing Process: Ju-Yup Kim[1]; *Jae-Woo Ahn*[2]; Chang-Hoon Shin[1]; Junji Shibata[3]; Jong-Gwan Ahn[4]; [1]Daeilgaebal/Research Center; [2]Daejin University; [3]Kansai University; [4]Kigam

Separation and purification process for acids in a waste acid mixture discharged from IT relating industries was established by using solvent extraction. The extraction behaviour and extraction mechanism for each acids were investigated with suitable extractant. By analyzing the extraction and stripping isotherms in terms of the McCabe-Thiele method, a separation process was proposed for each acid recovery from the waste acid mixture. A pilot plant test of the proposed process was conducted using mixer-settler equipment.

8:50 AM

Desulfurization with Hydrogen Production by BS Process: *Nobuaki Sato*[1]; Hiroaki Kanazawa[1]; Etsuro Shibata[1]; Takashi Nakamura[1]; Shin Tomisaki[2]; Hitoshi Kuroda[2]; Hiroshi Shiraishi[2]; [1]Tohoku University; [2]Nippon Steel Corporation

For decontamination of SO_2 containing waste gases from industries such as ferrous and non-ferrous metal companies, desulfurization with hydrogen production by the reaction of Br_2 and SO_2 was proposed as bromine-sulfur (BS) process. In this process, SO_2 is fixed as H_2SO_4 in the presence of H_2O forming H_2SO_4 and HBr. Then hydrogen is produced by the decomposition of HBr and Br_2 as byproduct is recycled. The reaction of SO_2 and Br_2 was found not to occur with water but to occur with steam. The production rates of H_2SO_4 and HBr showed maximum at temperatures around 70°C. The experimental results were discussed by comparing with thermodynamical consideration.

9:15 AM

Re-Use of Muds from Glazing and Pressing Lines of Ceramic Tile Industry in Wall and Floor Tile Formulations: *Alpagut Kara*[1]; [1]Anadolu University

Turkey is the fifth biggest ceramic tile exporter of the world. Considering the expectation that the Turkish tile sector continues to expand, further studies both on the improvement and the development of tile formulations are necessary in order to make the producers advantaged in the world market while maintaining the capital and running costs at reasonably competitive levels as well. In addition to such studies, waste management in tile manufacturing has also become an important issue. Accordingly, the industrial use of wastes in the traditional ceramic industry has been intensively investigated in the recent years. This work describes an extensive research carried out on the possible re-use of muds from glazing and pressing lines of a local tile company in the development of new wall and floor tile formulations. In order to achieve this, the waste material was firstly investigated in function of chemical and mineralogical compositions. Then, the particular focus was given to the evaluation of the effects of the presence of the waste materials in varying amounts on the thermal behaviour and physico-mechanical properties of the re-formulated tile bodies. During the studies, XRD, SEM in combination with EDS, and thermal analysis techniques such as non-contact dilatometry were widely employed. The results indicated that it is possible to use the waste materials in the commercial tile production without deteriorating the relevant technological properties.

9:40 AM Break

9:55 AM Keynote

Chloride Capacity of FeO-Fe2O3-SiO2 Molten Slag at 1523 K: Akio Fuwa[1]; *Yu Yamashita*[1]; Fumito Tanaka[2]; [1]Waseda University; [2]Mitsubishi Materials Corporation

There have been increasing in melting recycled scarps in copper smelting processes, and thus growing interests in the chlorine behavior in the slags. In this study, chloride capacity in FeO-Fe2O3-SiO2 slag at 1523 K has been measured with varying in PCl2 from $5x10^{-7}$ to 10^{-8} atm. and the following oxygen partial pressures encountered in typical copper smelting furnace of: $PO2=10^{-8}$ to 10^{-10} atm. at 1523 K. Discussion is made on the chloride capacity of FeO-Fe2O3-SiO2 slag in terms of its characterisitics and the dissolved chlorine species.

10:20 AM

Usability of Industrial Ashes in Cement Production as a Puzzolanic Material: *Taner Kavas*[1]; Bekir Karasu[2]; Ozlem Arslan[1]; [1]Afyon Kocatepe University; [2]Anadolu University

In the present study the utilization of coal ashes appeared at the end of firing process of brick production in the cement industry was examined. First of all ashes were ground below 250 μm and then added to ordinary Portland cement (PC 42.5) clinker as 10, 20 and 30% in association with 5% lime stone incorporation. Samples produced in 7 different groups and reference one were undergone chemical analysis, specific surface area (Blaine) and mechanical tests. Consequently, it was determined that the ashes could be recycled in the brick production and as a result of such addition the relevant mechanical properties were improved.

10:45 AM

Basic Principles of Environmentally Sound Electrochemical Technology for Processing Carbide Waste in Hard-Alloy Industry: *V. A. Bryukvin*[1]; A. A. Palant[2]; O. M. Gracheva[2]; [1]Gintsvetmet; [2]Russian Academy of Sciences

Regeneration of carbide waste from hard-alloy (sintered carbide) manufacture is an important scientific and technical objective aimed at improving the degree of recycling of rare metals (W, Co, Ta, Ti, Nb). Currently, the degree of recycling of those metals does not exceed 25% to 35% of their total production even in industrially developed countries. This is attributed to a significant extent to the substantial drawbacks of the technologies applied for their processing (environmental pollution, limitations to the use of regenerated products for important applications, sophisticated equipment to be used). An innovative environmentally sound technology has been developed in the Institute of Metallurgy of the Russian Academy of Sciences for processing refractory metals of carbide waste and other carbides using asymmetric alternating current of industrial frequency (the electrolyte used for this purpose is nitric acid solution). The current efficiency under optimal conditions is as high as 96% to 98%. The process has been tested on bench scale. The following commercial-grade products are obtained: pure ammonium paratungstate, tungstic acid, cobalt oxide, titanium dioxide and tantalum-niobium concentrate. The total metals recovery is 98% to 99%.

11:10 AM

Use of Borax Solid Wastes in Floor Tile Glazes: *Bekir Karasu*[1]; Güray Kaya[1]; Özge Özdemir[1]; [1]Anadolu University

Boron raw materials are amongst the most important natural sources for many industrial branches and their values become increasingly raised with the discovery of boron usage in many new technological fields. All the countries in the world are unfortunately not as lucky as Turkey and USA where major boron deposits are mainly located. It is widely known fact that on one side, boron is very precious component with its technological importance, on the other hand; only its limited sources are available. Therefore, even its wastes have to be evaluated and regained. In the present work wastes of Etibor Kirka Borax Company of Turkey were used in floor tile opaque glaze frit recipes. Standard and newly produced glazes were applied on the pre-engobed floor tile bodies and single firing was employed. Final products were examined according to the certain standard tests and their microstructures were also investigated. All the results confirmed the evaluation of boron wastes in floor tile opaque glazes.

11:35 AM

Utilizing of Borax Solid Wastes in Tile and Brick Bodies: Güray Kaya[1]; *Bekir Karasu*[1]; [1]Anadolu University

Boron minerals are widely employed in various fields such as ceramic, glass, cement, metallurgy, etc. Although boron deposits of the world are limited, the production level of boron-based products is continuously increased. Turkey possesses approximately 73% of total world boron resources. Etibor Kirka Borax Company of Turkey produces tincal concentrates and borax pentahydrates. During such productions considerable amount of concentration and derivation wastes appear. Having considered the increased rate of production it is quite obvious that the level of relevant wastes will also be raised. With this study it was aimed to utilize these wastes in tile and brick bodies and to convert them into a form environmentally and human friendly. Newly produced products were undergone to several standard tests for the determination of their shrinkage, water absorption, strength values and coloring parameters. Additionally, micro structural studies were conducted.

Thermo and Physicochemical Principles: Steel Making: Inclusions and Steel Cleanliness

Wednesday AM Room: Russeau Suite
August 30, 2006 Location: Catamaran Resort Hotel

Session Chairs: Hidekazu Todoroki, Nippon Yakin Kogyo Company, Ltd.; Pascal Gardin, Arcelor

8:00 AM Keynote

Magnesium: Origin and Role in Calcium-Treated Inclusions: *P. Chris Pistorius*[1]; [1]University of Pretoria

Calcium treatment of alumina inclusions, to convert the alumina to molten or partially molten calcium aluminates, is a well-established treatment for steel, to improve the castability of aluminium-killed steel. However, the role of magnesium in calcium-treated steel is not fully clear, nor is the origin of the several per cent of magnesium oxide that is often present in calcium-treated inclusions. To study this, steel was sampled after calcium treatment at an industrial steel plant, and the inclusions identified by energy-dispersive X-ray microanalysis (EDX) on polished sections of the samples (analysing the samples in a scanning electron microscope). The predicted fraction liquid in the inclusion was estimated from the ternary alumina-magnesia-lime phase diagram. Inclusions with higher CaO contents generally had lower MgO contents, indicating that the calcium wire is not the origin of the magnesium in the inclusions; this was also confirmed by wet chemical analysis of the calcium wire. Instead, it appears that magnesium-alumina spinel inclusions form during extended ladle contact after aluminium killing and before calcium treatment. While such spinels have been stated to cause poor castability (clogging the submerged-entry nozzle), it is clear that calcium treatment successfully modifies the spinel inclusions to mixed alumina-lime-magnesia inclusions, where the magnesia content contributes substantially to liquefaction of the inclusions: for typical MgO contents of around 10%, the range of Ca:O ratios which yield liquid (or partially liquid) inclusions is extended substantially to lower Ca:O ratios.

8:25 AM

Limitation of Slag Entrainment in Tundish and Consequent Reduction of Ladle Heel: *Jean-François Domgin*[1]; Pascal Gardin[1]; [1]Arcelor Research

The slag inclusions are one of the main problems in steel continuous casting because they can generate some defects on the final products. Slag has different origins: slag coming from the mould, from the tundish or from the ladle. That is why limiting the entrainment of slag from one vessel to the other is still a real challenge in order to improve the final steel cleanliness. Moreover, limiting slag entrainment into the tundish during ladle drainage is very interesting from an economical point of view because ladle heel can be simultaneously reduced. The proposed paper aims at presenting numerical results showing the impact of different parameters on the limitation of entrained slag from ladle to tundish during the ladle drainage. These parameters are process parameters, slag properties or external actuator acting directly on ladle slag behaviour. Numerical simulations based on the use of the CFD Fluent software illustrate the vortexing and non vortexing phenomena appearing during the ladle drainage. This numerical tool validated by experimental data acquired on water model has been applied to industrial configurations. It shows that the slag properties (viscosity, surface tension…) or some modifications of parameters (slide gate opening, ladle bottom geometry…) have a positive effect on the slag entrainment and also on the reduce of the ladle heel. Finally, modelling of the behaviour of an external actuator injecting some gas in the casting hole region reveals interesting possibility for reducing slag entrainment from ladle to tundish during the final steps of the drainage.

8:50 AM

Modeling Steel Cleanness Based on Fundamental Principles and Concepts: *Konstantinos Th. Mavrommatis*[1]; [1]RWTH Aachen University

Cleanness of steel is justified, measured and assessed in steel making process through different concepts which are mainly based on operational, empirical parameters describing cleanness as a static state and property of the material, after finishing the processing operations. This is an a posteriori assessment of cleanness. To be able to produce steels of highest purity, the steel making process chain, as a whole, must be considered, thus one has to develop cleanness concepts which are based on fundamental principles. In this work a theoretical modelling concept is presented, based on fundamental, physicochemical principles and variables, considering "cleanness as a process" and introducing a dynamic aspect into the quantification of cleanness of a steel melt, linking operational parameters, like total oxygen content, with physicochemical variables, which are based on first principles. This concept and the here derived and developed variables and parameters are based on the earlier defined agglomeration index (AI) of a steel melt, the ratio of the mean inclusions diameter (MID) to the mean inter-particle distance (MIPD), which is shown to be a measure of the agglomeration tendency of the melt after deoxidation, and can serve both, to monitoring cleanness during steel making operation and to be useful as a basis for mathematical modelling of cleanness and of the metallurgical measures in plant, associated with production of steels of highest purity.

9:15 AM Keynote

Formation of Spinel Phase in the Liquid Inclusions during Stainless Steelmaking Processes: *Joo Hyun Park*[1]; [1]POSCO

The details of the microstructural characteristics of the CaO-SiO_2-10%MgO-Al_2O_3(-CaF_2) systems crystallized during slow cooling from 1873 K, which are critical to understanding the fundamentals of inclusion formation in the stainless steelmaking processes, were investigated using SEM and EDS. Especially, the effect of CaF_2 on the crystallization behavior of the melts was studied. In addition, the phase equilibria at a specific temperature and composition during cooling cycles were computed using commercial thermodynamic software based on the Gibbs energy minimization principles and were compared to the measured results. In the system of B(=(%CaO)/(%SiO_2))=0.6 containing 30wt%Al_2O_3, the relative fractions of spinel and anorthite continuously increase with decreasing temperature from about 1573 to 1423 K, followed by the constant values at temperatures less than about 1373 K. In the liquid system of B=1.0, the spinel phase appears at temperatures greater than about 1623 K, followed by the formation of melilite and their relative fractions increase with decreasing temperatures from about 1573 to 1473 K. The calculated results could explain the observed phenomena. In the system of B=0.6 containing 10wt%CaF_2 and 30wt%Al_2O_3, the spinel phase was calculated to be in equilibrium with anorthite and merwinite. However, anorthite was not observed in the experiments. This could be understood from the changes in melt composition due to formation of gaseous fluoride SiF_4. The size of spinel in the system of B=1.0 containing 30wt%Al_2O_3 decreased and thus the number of spinel per unit volume increased with increasing content of CaF_2 up to 10wt%.

9:40 AM Break

9:55 AM Keynote

Estimation of Inclusion Size in Stainless Steel Coil Based on Statistics of Extreme Values: Shin-Ichi Nagashima[1]; Yu-Ichi Kanbe[2]; Nobuyuki Hashimoto[2]; *Hidekazu Todoroki*[2]; [1]Nippon Steel Company; [2]Nippon Steel Corporation

It becomes more important to control the composition of inclusions with increasing the demand for quality of products in terms of cleanliness. Along with the development of refining technology to make inclusions harmless, a study was made to develop how to predict the quality of final products. At first, observations of a number of defects revealed that the defects were caused by inclusions larger than 100 µm in diameter. Therefore it is required to detect relatively large inclusions in steel, whose existence is quite rare, to identify the quality. In order to estimate the maximum size of inclusions in a given sample, the method with statistics of extreme values has been applied for continuously cast (CC) slabs, hot-rolled coils and cold-rolled coils of type 304 stainless steel. For the CC slabs the diameter of inclusions, which were analyzed to be mostly silicate with globular shape, in the specimens was measured. For the coils, the width of inclusions was measured at the unit section perpendicular to rolling direction because it corresponds to the diameter assuming that the width of globular inclusions does not vary with rolled. Then maximum inclusion diameter in a specimen was calculated. As a result, the obtained values in the rolled coils are larger than in the slabs. This may imply that the measurement with the coils gives the values closer to the truth. Besides the measurement with the coils is even faster than with the slabs due to its simplicity of preparation of the specimens.

10:20 AM

Characterization of Precipitates in a Structural Titanium Microalloyed Steel by Transmission Electron Microscopy and Analysis by High Resolution (HRTEM): *L. Béjar-Gómez*[1]; A. Medina-Flores[1]; A. Bedolla-Jacuinde[1]; M. Saavedra-Magaña[1]; [1]Universidad Michoacana de San Nicolás de Hidalgo

The aim of this research work is to study and characterize precipitates in a structural microalloyed steel by transmission electron microscopy and analysis by high resolution (HRTEM). Microalloyed steel with titanium was produced by casting in an electrical induction oven of 25 Kg. capacity. Carbon content in steel was less than 0.1 % and titanium content from 0.035 to 0.06%. Steel was processed thermomechanically at an starting temperature of 1150°C with a thickness reduction of 80% at a finishing temperature of 850°C. Steel mechanical properties were yield strength = 324 MPa and tensile strength = 410 MPa. This work shows what precipitates are present in steel, the type of precipitates and their morphology. Analysis by transmission electron microscopy of high resolution (HRTEM) was applied to chemical analysis of precipitate region and of the matrix. Spectroscopy of dispersive energy was applied too (STEM-EDS). Particles of precipitates of Ti (CN) were found with a circular morphology and size of 10 nm or less.

10:45 AM

Characterization of Precipitates in Structural Niobium Microalloyed Steels by Transmission Electron Microscopy and Analysis by High Resolution (HRTEM): *L. Béjar-Gómez*[1]; A. Medina-Flores[1]; A. Bedolla-Jacuinde[1]; M. Saavedra-Magaña[1]; [1]Universidad Michoacana de San Nicolás de Hidalgo

The aim of this research work is to study and characterize precipitates in structural microalloyed steels by transmission electron microscopy and analysis by high resolution (HRTEM). Microalloyed steels with niobium were produced by casting in an electrical induction oven of 25 Kgs. capacity. Carbon content in steels was less than 0.1% and niobium content from 0.03% to 0.06%. Steels were processed thermomechanically at an starting temperature of 1150°C with a thickness reduction of 80% at a finishing temperature of 850°C. Steels mechanical properties were; yield strength from 460 MPa to 480 MPa and tensile strength from 460 MPa to 480 Mpa. This work shows what precipitates are present in steel, the type of precipitates and their morphology. Analysis by transmission electron microscopy of high resolution (HRTEM) was applied to chemical analysis of precipitate region and of the matrix. Spectroscopy of dispersive energy was applied too (STEM-EDS). Particules of precipitates of NbC were found with a cubic morphology and size from 80 to 120 nm, circular morphology and size from 20 to 80 nm, polygonal morphology and size from 10 to 80 nm.

11:10 AM

Analysis of Microstructure and Precipiates in Hot Rolled Low Carbon Steel Sheet by CSP: *Yonggang Liu*[1]; Mingqi Zhao[2]; Wenlin Wu[2]; Guang Chen[1]; Jianping Zhang[2]; Shihuai Su[2]; [1]Nanjing University of Science and Technology; [2]Technological Center of Maanshan Iron and Steel Company Limited

Microstructure and precipitates in hot rolled low carbon steel sheet by CSP were investigated in this paper. It is pointed out the precipitates in low carbon by CSP are different with that by traditional hot rolling. The bainites were found in CSP hot rolled steel sheet by TEM testing and these bainites could maintain in the sheets even after batch annealing. The selected area electron diffraction analyzing indicated that there were many Cr2N and Fe4N phases precipitated in hot rolled steel sheet and no AlN grains precipitated. The

nitrides forming can limit AlN grains precipitating during the batch annealing processing, and this could do harm to the texture pipeline along γ orientation line forming with formed properties.

Industrial Practice: Non-Ferrous High Temperature Processing

Wednesday PM Room: Macaw
August 30, 2006 Location: Catamaran Resort Hotel

Session Chair: Alex Moyano, FCN, Codelco-Chile

1:30 PM Keynote
Furnace Control, Optimization and Automation in Sulfide Smelting Plants: *Florian Kongoli*[1]; Ian McBow[1]; Robert D. Budd[1]; S. Llubani[1]; [1]FLOGEN Technologies Inc

The overall productivity and efficiency of sulfide smelting plants depends considerably on the productivity and efficiency of each unit furnace operations. Furthermore, the efficiency and productivity of each furnace affects and dictates to a certain degree the process of managing the flow of materials from one unit to another. A furnace with low productivity, several technical problems or high frequency of accidental shut downs can easily become a temporary or a permanent bottle neck in the entire flowsheet and can be the cause for a low productivity and efficiency of the entire plant. As a result, controlling, optimizing and automating the individual furnace operations in order to assure a stable process but at the same time to increase productivity is an indispensable need. In this paper, the authors discuss their recent work in effectively controlling acute industrial furnace problems such as magnetite build-up and accretions, eliminating unnecessary slag foaming, decreasing slag losses etc. as well as the intensification, optimization and automation of a series of furnaces in sulfide smelting through a unique physical process modeling that correctly simulate the industrial furnace operations and avoid guessing and uncertainties. The advantages of this new approach have been discussed.

1:55 PM Invited
Optimization of the Anode Sector at Norddeutsche Affinerie: *Peter Willbrandt*[1]; Andreas Specht[1]; Thorben Edens[1]; [1]Norddeutsche Affiniere AG

Norddeutsche Affinerie is the largest copper producer in Europe. Two sites are in operation for the production of refined copper: primary copper production is located in Hamburg and secondary copper production in Lünen. A total of just under 560,000 tonnes of copper cathodes is produced annually at the two sites. Primary copper production using the flash smelter furnace has been in operation in Hamburg since 1972. Over the years, the capacity of the flash smelter has been increased in three expansion projects from 120,000 t to almost 500,000 t of anode copper p.a. The anode sector consisting of two anode furnaces and a 24 mould casting wheel still features just about the same equipment as in 1972. The paper describes the most important steps taken to optimise operation which have put NA in a position to cast meanwhile more than 500,000 t of anode copper annually with two anode furnaces and a 24 mould anode casting wheel.

2:20 PM Invited
Volatilization of Arsenic in the Teniente Converter at the Codelco-Norte Smelter: *Alex Moyano*[1]; Carlos Caballero[1]; Roberto Mac-Kay[2]; Kimio Itagaki[3]; Jonkion M Font[4]; [1]FCN, Codelco-Chile; [2]GIIT, Codelco-Chile; [3]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University; [4]IM2 SA Filial Codelco-Chile

At present, the Codelco Norte (CN) smelter processes in its two main smelting units, the Teniente Converter (TC), and the Flash smelting Furnace (FSF) the concentrates from the Chuquicamata mine with an arsenic content of up to 1.5%. In the near future it will be processing additional concentrates with an arsenic content of up to 6%. For this new endeavor, and because in its smelting process the arsenic bearing concentrates smelted in the TC unit allows a very high volatilization of arsenic, the CN smelter staff started a feasibility technical study to process an arsenic bearing concentrate directly in the TC unit, and in that way to process the concentrates with low arsenic content in the FSF. Accordingly, the CN smelter prepared a laboratory scale test program to evaluate the effect of smelting concentrates with high arsenic content >3% As. The promising results of these tests done at the Tohoku University facilities, allowed a large scale test planning to determine the arsenic fractional distribution in the process units involved in the smelting-converting-refining circuit of the CN smelter. For this purpose, the 7000 t of concentrates with > 3% As were processed in the 2500 tpd TC unit. The obtained results confirmed the stabilization of the arsenic content in the 70% Cu white metal.

2:45 PM Keynote
Energy Saving Activities at Onsan Smelter: *Jong-Shin Chang*; Sung-Hwan Yu[1]; Seung-Ho Shin[1]; [1]LS-Nikko Copper Inc.

Onsan smelter has tried to do various activities for saving operation cost. With several expansion projects, Onsan smelter has aimed at not only quantitative growth but also qualitative growth through efforts improving operation equipment and processes. The activities to reduce operation cost have been one of those efforts. Especially, energy cost of operation costs has been a main target to be reduced. The activities to save energy have been carried out in two ways. One is to recover and utilize waste heat as much as possible and another is to replace existing equipment and processes with more energy-efficient ones. This paper reviews recent improvements and future plans in energy saving activities at Onsan smelter.

3:10 PM Break

3:25 PM Keynote
Recent Advances in Tin Smelting Using Top Submerged Lance Technology: *Jose Antonio Ore Rivera*[1]; [1]MINSUR S.A.

Top Submerged Lance (TSL) smelting technology is currently used in a wide range of applications in the non ferrous and waste product treatment industries. The use of TSL technology for tin concentrates smelting has been successfully applied at the Minsur Tin Smelter and Refinery at Pisco, Perú. The process is based on the air-cooled top entry submerged Sirosmelt lance, developed by Dr. John Floyd at the CSIRO division of Mineral and Process Engineering in the 1970's. Advantages of the process include flexibility to operate the lance, main burner of the Sirosmelt furnace, with different levels of combustion stoichiometry which allows us to get from highly reducing to highly oxydising atmospheres in the smelting reactor according to the type of feed we are processing, ability to utilize cheap energy sources such as natural gas, low capital cost and an environmentally friendly operation. This presentation summarises the application of the Submerged Sirosmelt technology for smelting tin concentrates and a variety of tin containing materials like iron dross, copper dross, tin residues, low tin/antimony slags by applying recent metallurgical developments at the Minsur smelter. The impact of new feed conditions and level of impurities on reactor performance with features of process and operation control are described. As a result of these recent advances in tin smelting using TSL technology, the Minsur Tin Smelter and Refinery improved its overall tin recovery, substantially reduced tin inventories and became the largest tin smelter in the world, currently producing more than 40,000 metric tones of refined tin per year.

3:50 PM
Arsenic and Antimony Removal from a Complex Blister Copper: *Alex Moyano*[1]; Roberto Mac-Kay[2]; Hector Henao[3]; Kimio Itagaki[3]; Jonkion M Font[4]; [1]FCN, Codelco-Chile; [2]GIIT, Codelco-Chile; [3]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University; [4]IM2 SA Filial Codelco-Chile

For the near future, the Codelco Norte (CN) smelter considers to process concentrates from the Chuquicamata and the Alejandro Hales (former Mansa Mina) mines, the last with high arsenic and antimony content of 6% and 0.6%, respectively, which will be producing a complex blister copper with high impurities contents, higher than the present values produced at the smelter. To know both the metallurgical, and anodic copper quality implications when a complex blister copper is processed in the refining process of the CN smelter, the Codelco and IM2 "task force" did a positively evaluation of the

refining test when a complex blister copper is refined with the addition of alkaline fluxes. The promising results of these tests done at laboratory scale in the Tohoku University facilities, allowed a large scale test planning to validate the lab scale results in 3 refining furnaces of 250 t capacity of the CN smelter. The obtained results demonstrate the industrial technical feasibility to process a complex blister copper in the refining furnace producing an anodic copper quality suitable for the electrolytic process, by controlling the process parameters of fluxes dosage and copper oxidation degree.

4:15 PM Keynote

M-DICE: An Impurity Distribution Model for Codelco-Norte Smelter: *Alex Moyano*[1]; Carlos Caballero[1]; Claudio Pizarro[2]; Jonkion Font[2]; [1]FCN, Codelco-Chile; [2]IM2 SA Filial Codelco-Chile

Due to very demanding environmental rules, and to the incrementing impurities contents in the processed concentrates, the Codelco Norte (CN) smelter permanently faces new demands for planning the production program with the present environmental rule fulfillment. Accordingly, the CN smelter along with IM2, developed an impurity distribution simulation model, M-DICE, which predicts the impurities behavior in each of the process units of a smelter complex under different process configurations. The M-DICE development which was based on a mass balance for all the process units involved in the smelter complex, included as a first stage, the gathering of operational data for the process units, including temperature, oxygen enriched air, matte grade, etc, then a thermodynamic evaluation for deriving the fractional distribution among the condensed phases (matte/white metal/copper/slag) and the gas phase for each of the process units. At present, M-DICE is at its last stage of development, and is expected to be a suitable tool for the environmental and process managements of the CN smelter of Codelco-Chile.

4:40 PM

Mathematical and Physical Model for the Teniente Converter Fluid Dynamics: Marco Rosales[1]; Alex Moyano[2]; Alvaro Valencia[3]; Ramón Fuentes[1]; *Roberto Mac-Kay*[1]; [1]IM2 SA Filial Codelco-Chile; [2]FCN, Codelco-Chile; [3]Universidad de Chile

Thru a physical and mathematical modeling the behavior of the tri-dimensional waving, and the movement of the gases at the Teniente Converter was studied. The mathematical model considers the condensed phases of white metal and slags, along the gas phase, and include the k-e model for the turbulence description. Both the physical model and the mathematical model allow a conclusion that from the fluid dynamic stand point the Teniente Converter is suitable to process clearly 3000 tpd of concentrates. Also, both models are suitable to predict the slag fluid dynamics and its spacial distribution inside the converter, and the splashing in the tuyere zone as well.

5:05 PM

Characteristics and Roasting of Zinc Sulfide Concentrates in Fluid Bed: *Boyan S. Boyanov*[1]; Nikolay K. Kolev[2]; [1]University of Plovdiv; [2]KCM SA

The hydrometallurgical technology for zinc production in Bulgaria is characterized by the use of considerable quantities of imported zinc concentrates (from 18 countries) and several kinds of Bulgarian ones which are quite different in chemical, phase and granulometric compositions. Today eighteen components are under control in the zinc concentrates, which by nature are a polymetallic raw material. In order to avoid difficulties in the process of roasting and leaching, a significant part of these components should be in concentrations lower than certain maximum values. In this connection, several sulfide zinc concentrates (Bulgarian and imported ones) were investigated by chemical analysis, DTA, TGA, X-ray diffraction analysis, sieve analysis. Providing optimal mixing proportions can be successfully done by using the PC software we have written, which calculate mixtures of different raw materials. The main base contains data about the content of 18 components in more than 340 concentrates from all over the world. The accomplishment of optimal mixing of concentrates and providing a stable mix composition for a long period of time is a task of primary importance in the technological process control in zinc hydrometallurgy.

Industrial Practice: Steel

Wednesday PM
August 30, 2006

Room: Cockatoo
Location: Catamaran Resort Hotel

Session Chairs: Eugene B. Pretorius, Baker Refractories; Amarendra K. Singh, Tata Research Development and Design Centre Pune

1:30 PM Keynote

Physical Modeling of Mixing and Mass Transfer inside a Torpedo Car: *Varadarajan Seshadri*[1]; Carlos Antonio da Silva[2]; Itavahn Alves da Silva[2]; Versiane Albis Leão[2]; Diego Canez Fernandes[2]; Ildeu Alves de Souza[3]; [1]Universidade Federal de Minas Gerais; [2]Universidade Federal de Ouro Preto; [3]Companhia Siderúrgica Belgo Mineira

Torpedo cars have been extensively used for pig iron desulfurization although its geometry is not deemed to be the ideal one as far as mixing and mass transfer is concerned. Complications arise from scaffolds formed through aggregation of flux, slag and pig iron during operation. Following industry demand a 1:6 torpedo car physical model was used to assess the optimum refining conditions for pig iron desulfurization. Similarity between the model and prototype were established through Froude and turbulent Reynolds criteria. Mixing times were evaluated by pulse tracer addition and the kinetics of metal/slag interactions were assessed from experiments investigating iodine transfer from kerosene to water. The influence of parameters such as level of metal, gas flow rate, lance penetration, lance orientation, presence of scaffold were evaluated. Mixing times were found to be shorter than regular desulfurization time and also not very sensitive to scaffold presence. Scaffold contributes to the reduction of the useful volume only. Mass transfer at the permanent reactor is more effective when the torpedo is operated at its full capacity. The experiments also higlight the dominance of the transitory reactor as compared with the permanent reactor.

1:55 PM

A Setup Model for the Roughing Mill of Hot Rolling in SIDOR, C.A. Venezuela: *Jose Rafael Lara*[1]; Luis Lozano[1]; Olga Prado[1]; [1]SIDOR, C.A.

The team of model of SIDOR has developed a setup model that for a roughing mill with edger, this model optimizing the position of the edger for a better control on the width, optimizing the efficiency of the mill controlling the profile of reductions and increment of the speed rolling and bettering dimensional performance. This model consider as data entry, number of passing, incoming and finish thickness and width, hardness and temperature of the material. The setup model is based on the equations of Ekelund for the width spread calculation and estimate of the rolling force, additionally this model employ a Newton's algorithm for resolve the optimal position of the edger. The preset values calculated by setup model is horizontal screw position, vertical screw position (edger), threading and rolling speed, some parameters calculated for correction of ski. In the revamping in the roughing mill of hot rolling of SIDOR, C.A, made in January of 2005, was implement this setup model and were adjusted the coefficients and parameters the following 15 days. Starting from there the values of preset, send to roughing mill, are calculated by this setup model. The current indicators show an enhancement of 18% in the roughing mill effectiveness and a decrease about 37% in the mill stop by overload in the motors.

2:20 PM Invited

Desulfurization in the Ladle Furnace Using Industrial Slags: Ahmet Geveci[1]; *Ender Keskinkilic*[2]; Yavuz Ali Topkaya[1]; [1]METU; [2]ERDEMIR

Generally accepted formula related to sulfur slag-metal distribution ratio is given by the following equation: (%S)/%S = K.[a(O2-)/activity coeff.(S2-)].fS.[1/a(O)]. According to the above equation it can be deduced that sulfur distribution between metal and slag is governed mainly by metal composition (fS term), slag composition (slag basicity and in turn sulfide capacity), oxygen potential of the system (a(O)term) and temperature (related to equilibrium constant, K). In this study, the results of ladle

furnace operations conducted in Erdemir-Iron and Steel Works Co. (Turkey) in relation to sulfur removal, have been given. Typical ladle furnace slag analyses have been presented and effect of slag basicity and sulfide capacity on sulfur slag-metal distribution ratio, (%S)/%S, have been discussed. Total %FeO+%MnO contents of ladle furnace slags have been examined. Related to ladle operations %desulfurization defined as values have been presented for different steel qualities.

2:45 PM

Formation Mechanism and Control of Corner Transverse Cracks of CC Nb-Contained Slabs: *Guosen Zhu*[1]; Zhiyuan Zhu[1]; [1]Shougang Group

Research on the formation mechanism and control of corner transverse cracks was carried out. The optical microscope and SEM were applied to analyze the characteristics of cracks. It is found that the cracks occur at the relatively lower temperature due to unbending strain and have almost nothing to do with the mold cooling and powder. The keys to prevent corner transverse cracks are to optimize the corner temperature of slab and maintain the good state of casting machine. Increasing casting speed and decreasing the cooling water flux at the corner in the unbending segments, resulting in mild cooling, were applied during investigation to control corner temperature above the upper limit temperature of the No.3 brittlement zone of Nb-contained steel tested by Gleeble-1500 system. As a result, corner transverse cracks were minimized, but centerline segregation got worse. And then increasing the cooling water flux at the corner (intensive cooling) was applied to make corner temperature below the lower limit temperature of the No.3 brittlement zone. Great diminution of both corner transverse cracks and centerline segregation was achieved finally.

3:10 PM Break

3:25 PM

How to Reduce Costs in Steelmaking with CaC_2?: *Javier Santiago*[1]; [1]Electrometalúrgica Andina S.A.I.C.

In the searching of reducing costs, steelmakers always try to test diferents products and operations. In the aluminum killed steels the use of aluminum, some times, increase the costs of steel. Several tests have been made in an argentinean steel plant during the furnace tapping. The target was to reduce the aluminum consumption and to find if the calcium carbide deoxidizes the steel. The results were satisfactory and it could decrease the aluminum consumption allowing to lower the cost of deoxidation of the steel. During the steel making there are diferents points of addition of calcium carbide. Why calcium carbide replace the aluminum? The answer is because it is a great deoxidant. Based on the primary reaction: $CaC_2 + 3O \rightarrow CaO + 2CO$ we can see than one mol of calcium carbide reacts with three mols of oxygen. But so that happen the contact between carbide and steel should be strong. It is for that reason that the addition point is very important. In this presentation, the data, observations and results collected during the period of trials in an argentinean stell plant are shown and compared with the usual practice. Also, this paper discusses an alternative to the aluminum use for the deoxidation of steel.

3:50 PM

Improving Steel Ladle Performance at Bhilai Steel Plant, India: *Rakesh K. Singh*[1]; Laxman Tiwari[1]; Bansi Dhar Chattaraj[1]; D. R. Dinda[2]; [1]Research and Development Centre for Iron and Steel, SAIL; [2]Bhilai Steel Plant, SAIL

Steel Ladle in Bhilai Steel Plant, SAIL, India, passes through VAD and LF-RH route, and this exposes refractory lining to a severe operating conditions. Ladles are lined with in-house manufactured MgO-C refractories. Lining life used to be 35 heats, out of which 18-20 heats were through VAD/LF-RH, hence, ladle availability had become a constraint. Laboratory studies were carried-out to optimize composition and granulometry. Granulometry was developed by adopting Andearssen packing model. A suitable plasiticiser was identified to eliminate inconsistency caused due to variation in resin quality and weather condition. It reduced variation in green bulk density from 6 to 1.3%. Abrasion and slag erosion studies were conducted, which shows that with increase of carbon, abrasion resistance decreases and corrosion resistance improves. Based on these studies, graphite in slag zone was increased from 10 to 12.5% and in metal zone it was reduced to 7.5%. Different process parameters of brick making were optimized to make MgO-C bricks of maximum bulk density with reduced coke porosity. Modified bricks have bulk density of 2.99-3.02 g/cc and coke porosity of 9.5-10.5%. Further, shape of the bricks were changed from side arch to mini keys and thickness was increased from 80 to 100 mm. Mini key bricks are pressed from sides, thus eliminating variation in thickness which is critical dimension for dry joints. These modifications improved average lining life of steel ladles to 62 heats, which includes 30-35 secondary heats. Maximum life obtained is 87 heats.

4:15 PM

Usage of Aluminum Dross for Slag Treatment in Secondary Steelmaking to Decrease Amount of Reducible Oxides in Ladle Furnace: *Ahmet Geveci*[1]; Onur Aydemir[2]; [1]METU; [2]ERDEMIR

In this study it is aimed to assess the plant analytical data from steelmaking shop (120t) which appeared during efforts to decrease the effect of carry-over slag (basic oxygen furnace slag) that can not be prevented to leak during tapping of steel in the ladles. While the amount changes, carry-over slag that escaped to ladle consists of appreciable amount of reducible oxides ('FetO' and MnO) which act as oxygen source for steel bath. Rather than using synthethic slag by skimming ladle slag after tapping from converters (because of high heat loss), it is aimed to refine existing slag by using aluminum dross, containing 30-35% metallic aluminum, which is a non-recoverable process outcome (discard) for most of the aluminum factories. Slag reduction behavior will be worked out considering parameters such as reaction time, initial amount of total Fe (excluding metallic iron) +MnO (determined by X-Ray diffractometer), amount of reducing agent and reducing effect of soluble aluminum in steel bath, while obtaining an optimum slag composition which promotes higher desulphurization capacity and inclusion removal for liquid steel. Starting with a 10% initial reducible oxide amount before ladle furnace operation, it is reduced to 4-5% by slag refining process using aluminum dross that is affected by parameters given above.

New, Improved and Existing Technologies: Electrochemistry

Wednesday PM — Room: Boardroom West
August 30, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Michael Stelter, Technical University Bergakademie Freiberg; Michael L. Free, University of Utah

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1:30 PM Keynote

Corrosion Behavior of Lead-Alloy Anodes in Metal Winning: *Michael Stelter*[1]; Pavel Saltykov[1]; [1]Technical University Bergakademie Freiberg

Lead alloys are a typical material for anodes in technical electrowinning processes. The lifetime of those anodes differs from 2 years to more than 5 years in tankhouse practice depending on the type of alloy, the mechanical damaging and last but not least the chemical corrosion in the electrolyte. Different types of alloys, such as PbSb, PbCa, PbAg, PbSnCa or PbAgCa have been developed and used in the past, their rate of corrosion being more or less a philosophic discussion. Comparable investigations on the corrosion behavior in dependence of the concentrations of alloying metals, the grain structure and the mechanical and thermal treatment during production have not been conducted before. In the last years the Institute for Nonferrous Metallurgy and Purest Materials of the TU Bergakademie Freiberg investigated the corrosion behavior of the typical lead alloys for metal electrowinning under comparable conditions. Correlations between different alloys, mechanical treatments like rolling or thermal treatment like annealing to the rate of corrosion were made, leading to the conclusion that grain structure and grain size are of eminent importance for the rate of corrosion in technical electrolytes. From these results new and optimized lead alloy anodes can be produced with an increase in life time of the factor 3 – 5. The optimized lifetime in terms of corrosion stability can not protect

from mechanical damaging in tankhouse practice, but with a careful practice the increase in lifetime can save a lot of money and problems.

1:55 PM

Improvement of Zinc Production Process at the Chelyabinsk Zinc Electrolytic Plant to Produce High-Grade Zinc: *L. A. Kazanbayev*[1]; P. A. Kozlov[1]; [1]Chelyabinsk Zinc Plant

The Chelyabinsk zinc electrolytic plant was put into operation in 1935. The capacity of zinc production has been increased over the recent years from 100,000 to 180,000 tpy and starting from 2004 the plant has produced zinc of SHG grade attested at the London Metal Exchange. All production circuits at the plant have been modernized, advanced technologies introduced and the existing processes improved: 1) distributed oxygen feeding in the zinc concentrate roasting process, 2) use of a flocculant of Magnafloc type in the calcine leaching process with an improved method for flocculant feeding, 3) use of an activator (antimony trioxide) in the process of solution purification to remove cobalt and nickel, 4) an innovative zinc electrolysis complex commissioned, including automatic cathode stripping for Jumbo cathodes, 5) technology developed for production of zinc-aluminum, zinc-nickel and zinc-antimony alloys, and 6) problems associated with treatment of wastewater and off-gas from sulfuric acid plant have been resolved.

2:20 PM

Electrochemical Studies of the Intermetallic Inert Anodes in Molten Salts: *Xiaobing Yang*[1]; [1]University of Leeds

The present work is focused on developing intermetallic inert anodes for aluminum electrolysis. The anode alloy based on Al-Ti-Cu system was prepared by casting and then protected by oxides coating. The results of the theoretical calculations on phase equilibria and experimental studies of anode in the molten cryolite are presented. Behavior of corrosion and the passivation under anodic condition were characterized using microscopic technique and cyclic voltammetry. Optimal conditions of the anode passivation were determined.

2:45 PM Keynote

Ionic Liquid Electrochemical Processing of Reactive Metals: *James Vaughan*[1]; David Dreisinger[1]; [1]University of British Columbia

Ionic liquids can be used as solvent for the electro- plating, winning and refining of metals. Of particular interest is the possibility of processing reactive metals such as aluminium, magnesium and titanium that cannot be deposited from aqueous solutions. The electrowinning of aluminium from AlCl3 : ionic liquid mixtures has been carried out at a laboratory scale with the advantages of low temperature and low energy consumption compared with conventional Hall-Héroult smelting. Similar benefits have been recognized for the refining of aluminium. Imidazolium ionic liquids are promising due to their relatively high ionic conductivity and cation stability. The less studied and less expensive phosphonium ionic liquids systems may provide a viable alternative to imidazolium ionic liquids for certain applications. New information regarding the physical properties and electrochemical behaviour of phosphonium ionic liquid systems is presented. The advantages and disadvantages of select systems are discussed.

3:10 PM Break

3:25 PM Keynote

Electrochemical Modeling of Electrowinning Performance: *Michael L. Free*[1]; [1]University of Utah

Electrowinning is directly impacted by many parameters that include electrolyte composition, voltage, current density, contact resistance, temperature, electrode spacing, and fluid flow as well as many other interrelated factors. The effects of these parameters are primarily related to thermodynamics, mass transport, and electrochemical kinetics. In this study thermodynamic, mass transport, and electrochemical kinetic equations are simultaneously solved to determine the effects of such parameters on electrowinning current efficiency, power consumption, electrodeposit morphology, and electrodeposit distribution. Modeling predictions will be compared with experimental results.

3:50 PM Invited

Atmospheric Pressure Plasma Process and Applications: *Peter Kong*[1]; [1]Idaho National Laboratory

Plasma is a sufficiently ionized gas with significant energy content. The presence of charged species in plasma makes it a conductor of electricity. Although there are free charges and ambipolar pairs in plasma, overall negative and positive charges compensate each other. Therefore, plasmas are electrically neutral, a property which is known as quasi-neutrality. There are two main types of plasmas, namely atmospheric pressure plasmas and low pressure plasmas. Under atmospheric pressure plasmas there are two distinct categories. The first is thermal plasma in which electron temperatures (T_e) ≈ heavy particle temperatures (T_h). Examples of thermal plasmas are those produced in high intensity arc, plasma torches, or in high intensity, high frequency discharges. The second is the atmospheric non-thermal plasma (ANTP). The ANTP has very high T_e while the T_h, remain ambient. ANTP has very low degree of ionizations and the density of charge species is very low. The electrons and ions never achieve local thermodynamic equilibrium. For this reason the gas temperature is at room temperatures. However, ANTP is extremely effective to produce activated species (free radicals) and is very reactive. Atmospheric pressure plasmas have a wide potential to develop industrial processes. These plasmas have seen applications in extractive metallurgy; metal recovery; novel nano-material synthesis; refractory and wear resistant coatings deposition; chemical synthesis; energy conversion; industrial, medical and nuclear waste destruction; engine combustion enhancement; and exhaust gas pollutants clean up. This paper will present an over view of atmospheric pressure plasma process applications and systems in these areas.

4:15 PM Invited

The Effect of Anode Composition on the Passivation of Commercial Copper Electrorefining Anodes: *Michael S. Moats*[1]; J. Brent Hiskey[2]; [1]University of Utah; [2]University of Arizona

As commercial copper electrorefineries look to expand their capacities by increasing their operating current density, the likelihood of anode passivation intensifies. To improve the industry's understanding of the passivation phenomena, the role of anode composition was evaluated. While previous studies have focused on studying one impurity element at a time, this study was conducted using forty-four commercial electrorefining anode samples supplied by ten copper companies. The passivation response of each sample were evaluated under accelerated galvanostatic conditions in synthetic copper electrowinning electrolyte at 65°C. This information allows for correlations between composition and passivation tendencies over a wide range of impurity elements and concentrations. It was found that selenium, tellurium, silver, lead and nickel accelerated passivation. It appeared that oxygen accelerated passivation when increased from 500 to 1500 ppm, but further increases did not have an effect. Arsenic was the only impurity found that inhibited passivation. Proposed mechanisms for each of these compositional effects will be introduced.

4:40 PM

The Conductivity Measurement of Scandium Doped Barium Zirconate for Fuel Cell Application: *Susumu Imashuku*[1]; Tetsuya Uda[1]; Yasuhiro Awakura[1]; [1]Kyoto University

Doped barium cerates exhibit good protonic conduction in water containing atmosphere at elevated temperatures and have been expected for the use of a fuel cell electrolyte. However, since the barium cerates decompose into barium carbonate and barium hydroxide in the presence of CO_2 and H_2O, it is difficult to apply the barium cerates for fuel cells. In contrast, barium zirconate is much more stable in the same atmosphere than barium cerate. In addition, yttrium doped barium zirconate is known to have the highest conductivity among various doped barium zirconates, the conductivity of which is almost comparative to that of doped barium cerate. However, very recently Yamaguchi et al. have discovered that barium zirconate lost its stability when yttrium is doped. In this study, we investigate the effect of dopant on the stability and conductivity of barium zirconate. Especially, we had an interest in scandium doped barium zirconate. In general, Zr site in barium zirconate is substituted for the doped trivalent cation. The ionic

radius of scandium is almost the same as that of zirconium (Zr^{4+}:0.072 nm, Sc^{3+}:0.0745 nm for six-fold coordination). But ionic radius of yttrium is bigger than that of zirconium (Y^{3+}:0.0900 nm). Therefore, there is possibility that Sc doped barium zirconate is more stable than Y doped barium zirconate. We present the results of AC impedance spectroscopy measurement for Sc doped barium zirconate and its stability examined by TG-DTA in a humidified atmosphere containing CO_2.

New, Improved and Existing Technologies: General Recycling and Waste Treatment I

Wednesday PM Room: Kon Tiki Ballroom
August 30, 2006 Location: Catamaran Resort Hotel

Session Chairs: Kang-In Rhee, Resource Recycling R&D Center; Ana E. Bohé, Centro Atómico Bariloche, Consejo Nacional de Investigaciones Científicas y Técnicas, and Universidad Nacional del Comahue

1:30 PM Keynote
Engineering Aspect on the Removal of As(V), As(III), Cr(VI), B and Se(IV) with Functional Inorganic Ion Exchanger: *Junji Shibata*[1]; Norihiro Murayama[1]; [1]Kansai University

As one of the effective usages of various wastes discharged in non-ferrous metal industry, the synthesis of hydrotalcite was carried out using aluminum dross as a raw material. Hydrotalcite is one of the inorganic anion exchangers and has layered structure of complex hydroxide. The removal of toxic metal ions such as As(III), As(V), Cr(VI) and Se(IV) with the hydrotalcite was investigated, and the removal properties were compared from the viewpoint of the anion exchange amount and exchange rate. Hydrotalcite can be obtained by a co-precipitation method from the aluminum dross and the waste MgCl2 solution discharged in an aluminum regeneration process. Slight amounts of SiO2, Al2O3, Fe2O3 and so on remain in the reaction product as an impurity component. Interlayer distance of the obtained hydrotalcite is about 0.3nm. Hydrotalcite changes to Mg-Al oxide by the calcination at 773K for 3h, and then hydrotalcite is formed again by a rehydration operation after calcination. The toxic metal ions are removed from aqueous solution by the anion exchange reaction in the pH region where toxic metal ions exist as the anionic species like AsO2-, HAsO42-, CrO42-, and SeO32-. The exchange amount is considerably concerned with the valence of anionic species and the size of anionic species. The removal of toxic metal ions were investigated from the engineering aspects such as the low concentration limit to be removed, the amount of hydrotalcite to be used for the perfect removal of toxic metal ions and so on.

1:55 PM
A Novel Green Technique to Recovery Titanium Compounds from Molten Slag under the Dynamic Oxidation Condition: *Zhang Li*[1]; [1]Northeastern University

A novel green technology to recovery Titanium compounds from Ti-bearing blast furnace slag under the dynamic oxidation condition was developed and tested. Air was blown into the molten slag as oxygen resource through a lance during the dynamic oxidation process, in which six important results were found: (1) the TiC, (Ti2O3), Fe and (FeO) in the slag were oxidized, (2) the temperature of slag temperature rapidly increased, (3) the viscosity of slag decreased, (4) the coalescence, growth and drop of the metallic Fe droplets in the molten slag were carried out under an air agitation condition, (5) the dispersed Ti components were selectively enriched into the perovslite phase, and the perovskite phase could be selectively precipitate and grow. And also, the perovskite phase can be separated by the dressing method. The oxidation of molten slag gives off a large amount of heat, which helps chemical reactions proceed, improve the rate of chemical reactions, and promote the precipitation and growth of the perovskite phase. The features of the technique are clean, low–cost and a great capacity to deal with a large quantity of slag. It was confirmed by experiments that the precipitation of the perovskite (CaTiO3) in molten slag is obviously affected by operation factors such as temperature, chemical composition, heat-treatment, additives and so on. The precipitating kinetics and mechanism of the perovskite phase from molten slag during the dynamic oxidation processes were also investigated.

2:20 PM
Sampling of Fine Shredder Residues (FSR) and Characterization Oriented to Physical Separations: *Pierre-François Bareel*[1]; David Bastin[1]; Claude Bodson[2]; Jean Frenay[1]; [1]University of Liège; [2]Comet Traitements

EU legislations impose ambitious recycling targets for various consumer goods. End-of-Life Vehicles (ELVs), scrap iron and various proportions of Waste Electrical and Electronic Equipment (WEEE) are processed by shredding plants which recover most of the metals but produce 20 to 25 wt.% of Shredder Residues (SR) wich are landfilled. Energy issues for the coarse fraction of SR are now largely studied. However, below 2 mm, the calorific value falls off drastically. These Fine Shredder Residues (FSR) represent up to 55 wt.% of the total SR. To meet European objectives other alternatives to landfilling must be considered for the FSR. The present paper describes a study carried out to characterise the FSR and investigates ways to process them and produce marketable products. Applying Gy's theory, a sampling procedure was conducted over two years to statistically quantify the variability of the physical and chemical properties of FSR produced by a Belgian post-shredding treatment plant. Macroscopic characterisation has led to the identification of four material categories which could be separated according to their physical properties: ferrous metals (more or less oxidized), non-ferrous metals, an organic fraction (plastics, rubber, textiles, foams, wood) and a minerals fraction (glass, ceramic, concrete). The entrainment of small metallic particles within the pores of organic fragments will affect the quality of the separations.

2:45 PM
Processing of Man-Made Metal-Containing Raw Materials in DC Electric Furnaces: *G. S. Nus*[1]; Valery M. Paretsky[1]; [1]Gintsvetmet

Technology for treating man-made metal-containing raw materials in DC electric furnaces with polarization of the bottom phase (PDF furnaces) has been developed and proven on a semi-commercial scale. PDF furnaces permit processing of man-made raw materials, i.e. current and accumulated intermediate products with rather high contents of valuable metals (i.e. slags, sludge, residues, Waelz slag, etc.), as well as secondary raw materials and virtually any type of waste using an environmentally safe technique based on sublimation of volatile metals and transfer of non-volatile metals and sulfur into the bottom phase in the furnace. Processes developed on the basis of the use of PDF furnaces make it possible to take advantage on a full commercial scale of electrolysis of molten materials, including electrochemical reduction of metals, intensification of their settling into the bottom phase and sublimation of volatile components, as well as to significantly improve recoveries of nonferrous metals, resolve the problem of excessive accretion formation in slagging processes and substantially improve the environmental situation. The low-grade discard slag obtained can be utilized in the construction industry; in particular, slag can be added to the limestone feed for cement manufacture.

3:10 PM Break

3:25 PM
Recycling of Mo Containing Acid by Ammonia Gas Neutralization: *Jong Jin Pak*[1]; Yeung Ho Park[1]; Wan Yi Kim[1]; Jung Yong Ahn[1]; Duck-Yong Hwang[1]; Dong Hyuk Shin[1]; [1]Hanyang University

In manufacturing tungsten filament coils at lamp industries, a very fine tungsten wire is coiled around molybdenum mandrel wires to form so-called a coiled coil. The formed coiled coil is then heat-treated and cut to a size, and immersed in a solution of mixed nitric acid and sulfuric acid which dissolves the molybdenum mandrel leaving the coiled coil tungsten. In this "spent" acid solution, molybdenum is usually dissolved in amount of 80 to 90 g/liter of acid solution. The volume of spent acid generated from a typical coil manufacturing company in Korea ranges from 300 to 600 liters (containing 25 to 50 kg molybdenum) per day. In the past, it has been a common practice in these companies to neutralize the spent acid with sodium hydroxide and

discharge it into waste water system. The loss of molybdenum in this manner is economically significant, and the discharge of nitrate and sulfate ions and heavy metals like molybdenum into the nation's rivers is undesirable from the environmental view. Furthermore, this disposal method became illegal by the environmental protection law enforced in Korea since 2003. The present work reports the commercialization of a recycling process of spent acid to recover molybdenum. The process consists of ammonia gas neutralization of acid, crystallization and filtration of ammonium molybdate, roasting and hydrogen reduction of molybdic oxide to produce a commercial grade molybdenum metal powder. The mother liquor, residual solution after the filtration of ammonium molybdate, can be utilized to produce fertilizers.

3:50 PM

Pyrolysis of Mixed Plastic Wastes into Alternative Fuel Oil – Pyrolysis Process (300 and 3,000 Ton/Yr) Developed at Korea Institute of Energy Research: Kyong-Hwan Lee[1]; *Dae-Hyun Shin*[1]; Sang-Gu Jeon[1]; Kwang-Ho Kim[1]; Nam-Sun Noh[1]; [1]Korea Institute of Energy Research

The recycling of plastic wastes consisting of elements of C, H and O mainly is one of important issues being faced in all the countries of the world. In recycling methods, pyrolysis that can recover fuel oil and hydrocarbon feedstock is accepted as an effective method of utilization of waste plastics with a great interest both economically and environmentally. Pyrolysis in the absence of oxygen involves the breaking down of the larger molecules into smaller molecular weight hydrocarbons that may be gasoline, kerosene, diesel and heavy oils. KIER (Korea Institute of Energy Research) has developed a 300 ton/yr pyrolysis plant that is capable of converting plastic wastes into alternative fuel oils such as gasoline, kerosene, light oils and heavy gas oils. In the present, commercial plant of 3,000 ton/yr is under installing at Korea R&D Company incorporated in our study. In this paper, the characteristics of the pyrolytic process developed in KIER will be described. In this process, basic unit concepts consist of preliquefaction, thermal cracking and vacuum distillation. Main characteristics are recirculation system of high temperature cracked reactant into preliquefaction reactor to melt solid reactant fast and circulation reaction system of reactant by using both CSTR and Plug reactor to obtain high cracking efficiency in the cracking reactor. Also, this process guarantees the pyrolytic operation near atmospheric pressure, continuous production of fuel oils, continuous feed and discharge of solid residue and reliable operational stability, in order to improve the economic aspect of this plant.

4:15 PM

Chlorination Applied to the Separation of Metals: Fabiola J. Alvarez[1]; Georgina De Micco[2]; Daniel M. Pasquevich[3]; *Ana E. Bohé*[4]; [1]Centro Atómico Bariloche; [2]Centro Atómico Bariloche/Universidad Nacional de Cuyo; [3]Centro Atómico Bariloche/Consejo Nacional de Investigaciones Científicas y Técnicas; [4]Centro Atómico Bariloche/Consejo Nacional de Investigaciones Científicas y Técnicas/Universidad Nacional del Comahue

The National Commission of Atomic Energy is investigating a suitable physicochemical process for the conditioning of spent nuclear fuel of research reactors of the Al-UxSiy type. A possible way of processing is through dry chlorination of the cladding with the purpose of selective separation of the aluminium from the remaining elements such as Fe, Ni, Zn, Cu, etc. transforming them into volatile chlorides. Some important advantages of this method are the thermal stability of the chlorides that allow the easy separation of the halides by physical methods and the low volume of radioactive waste generated. The interactions in the following systems were studied in the range of temperature between 150°-500°C: AA6061, Al-Fe, Al-Ni, Al-Cu, Al-Zn, Cu-Zn and the pure metals. We found that the reactivity was different depending if the elements were alloyed or separated. The separation factors of the systems under study were determined. Nickel is perfectly separated from aluminium for all temperatures, whereas good conditions for copper separation were achieved below 400°C. In the case of iron, complete isolation was never attained, however decreasing temperature to 150°C is possible to obtain aluminium chloride with less content of iron. The separation of zinc from the product was also difficult. It was detected that zinc chloride volatilization decreases when other chlorides were present, for example cooper chlorides. In the Cu-Zn alloy, zinc chlorides remained in the condensed product due to interactions with copper. The samples were characterized by energy dispersive spectroscopy (EDS), scanning- electron microscopy (SEM), x-ray diffraction (XRD), Mössbauer spectroscopy (MS) and x-ray fluorescence spectrometry (XRF). The chemical composition was determined by atomic absorption, spectrophotometry and gravimetry.

4:40 PM

The CMI NESA Pyrolysis: An Attractive Process for the Treatment of Sewage and Industrial Sludges and By-Products: *Paul Dominique Oudenne*[1]; [1]CMI NESA

For many years, CMI NESA has gained considerable experience in a field of alternative thermal processes by which useful by products result in addition to the destruction of the raw wastes. The CMI NESA pyrolysis process has been extensively applied to a wide range of sewage and industrial sludges and residues. The paper describes in details the development works carried out at pilot stage as well as the key parameters of the process. Some of the industrial realisations are briefly described, the most recent one being the erection of a sludge pyrolyser on predried sludges at 90% dryness of a capacity of 100 tons of dry matter per day for the Valenton plant of the SIAPP (city of Paris).

5:05 PM

Using De-Watering Sieve Waste of Borax to Enhance the Properties of Floor Tile: *S. Kurama*[1]; A. Kara[1]; H. Kurama[2]; [1]Anadolu University; [2]Osmangazi University

There are various studies published in the relevant literature on the use of borates in tile production, where borax waste has been mainly used in place of feldispathic minerals and the results showed that borate migration to the surface was the commonly encountered problem. In the present study, dewatering sieve waste (TSW) of Etibor Kirka Borax Company (Turkey) was used for use in a commercial floor tile formulation in proportions up to 20 % as a partial substitution for Na-feldspar. A total of four formulations were prepared with 0.5, 1, 1.5 and 2 wt. % TSW incorporation and shaped by dry pressing. The obtained samples were single fast-fired at a peak temperature of 1200°C for a total firing time of 38 minutes (from cold to cold) under industrial conditions. According to the results, the addition of TSW appeared to improve liquid phase development with better physical properties compared to those of standard composition for the firing regime involved. The results indicated a prospect for using the waste as a co-flux in floor tile formulations.

New, Improved and Existing Technologies: Geothermal in Mineral Recovery and General Minerals Processing

Wednesday PM — Room: Boardroom East
August 30, 2006 — Location: Catamaran Resort Hotel

Session Chairs: J. Michael Canty, U.S. Department of Energy; Gordon Bloomquist, Washington State University Energy Program

1:30 PM Keynote

Geothermal in Mineral Recovery: J. Michael Canty[1]; *Leland L. Roy Mink*[1]; [1]U.S. Department of Energy

The excitement of recovery of minerals from geothermal brines has many positive angles. The economics of certain geothermal site is improved if a revenue is arrived from a sellable commodity with the geothermal power. The use of cleaner geothermal brines also improves the capable use of the brine before reinjection. We will review the opportunities for recovery of different minerals and the markets for them.

1:55 PM Invited

Economic Benefits of Mineral Extraction from Geothermal Brines: *Gordon Bloomquist*[1]; [1]Washington State University Energy Program

The economic benefits of the co-production of minerals from geothermal

brines far exceeds the potential revenue stream from the sale of marketable by-products such as silica, zinc, manganese, lithium and a number of rare earths. Extraction of silica can avoid scaling problems often associated with many geothermal power projects and may allow for additional power production through the use of bottoming cycles or the use of the brine in direct use applications now impractical due to scaling problems. An additional benefit of silica removal is the opportunity to use the geothermal brine as a source of water for enhanced evaporative cooling—a technique that can significantly improve the summer power output from binary power plants employing air cooling for condensing the working fluid.

2:20 PM Invited

Application of Ceramics for Geothermal and Mining Operations: *Anthony C. Mulligan*[1]; [1]Advanced Ceramics Research Inc

Ceramics and glasses typically show higher hardness, wear resistance and corrosion resistance than metallic materials and as such have found extensive use in applications requiring high wear and corrosion resistance. One drawback with the use of ceramics and glasses has been their poor resistance to crack propagation leading to brittle, unpredictable behavior. As the material properties are continuously improved however, these materials are finding an ever growing number of applications in the mining industry. Previous attempts to toughen ceramics have led to high production costs and limited acceptance within the mining industry. Advanced Ceramics Research has been pursuing low-cost fabrication technologies capable of generating near net-shape components with improved toughness. This technology has been licensed in both the US and Japan for drill inserts and is being pursued for high wear components in bucket lips, cyclones and extrusion dies. For high stress abrasion these components have shown a significant performance improvement but for impact wear applications, results have been variable. The application of advanced ceramics to the geothermal industry promises to improve performance and reduce overall production costs. Applications being considered are pipe liners for improved corrosion resistance, energy conversion components within the turbine, heat exchangers and pump liners. The development and testing of these components will be discussed with reference to the performance benefit offered by ceramics over traditional metallic components.

2:45 PM Invited

Geothermal Brines – Problem or Resource: *Mark Patterson*[1]; [1]Advanced Ceramics Research

Hydrothermal brines are extracted from significant depths below the surface and arrive at the surface at elevated pressure and temperature. The exact chemistry and conditions of these brines depends upon the rock formations through which the water travels, but many of the brines are rich in dissolved minerals. At pressure and temperature the minerals remain in solution but in order to extract heat from the brines, they are cooled and many of the minerals precipitate causing problems. Where precipitation is a problem in the downstream processing, the brines are maintained at a high enough temperature and pressure so as to avoid precipitation and injected back into the geothermal formation. This results in a significant loss in potential energy that could be recovered from the geothermal brines. If left to precipitate in an uncontrolled manner, many of the minerals will precipitate as gels, in a high surface area form which is difficult to extract from the liquor and which can causes problems. If the brines are seeded or the precipitation conditions are changed the precipitated minerals can be separated more easily and also can be altered to be made into more valuable particulates. Some of the specific chemistries will be discussed with reference to known geothermal brines.

3:10 PM Break

3:25 PM Invited

Co-Production of Silica and Other Commodities from Geothermal Fluids: *William Bourcier*[1]; Carol Bruton[1]; Elizabeth Burton[1]; Bill Ralph[1]; Mackenzie Johnson[1]; [1]Lawrence Livermore National Laboratory

We are using commercial water treatment technologies to separate spent geothermal fluids into a low salt permeate for cooling applications and a concentrate for extraction of silica and other potentially marketable by-products such as lithium. High temperature reverse osmosis is used to process fluids sampled from downstream of the heat exchanger at the Mammoth Lakes geothermal power plant. Silica is extracted from the concentrate by precipitation in a stirred reactor aided by a commercial agglomerating agent. Cross-flow ultrafiltration is used to concentrate the silica precipitate or silica colloids as a liquid slurry. Work is in progress to optimize the process in terms of maximizing the mass of extracted silica, increasing the capture efficiency of the ultrafilters, and improving post-processing conditions to maintain high surface area and dispersivity of the silica for applications as a tire rubber additive and as a colloidal solution for metal casting applications. Presently we can produce silicas with purities greater than 98% and surface areas in the range of 50-150 m^2/g. Permeates from the reverse osmosis separation have less than 100 ppm total salt and less than 20 ppm silica and are therefore useful for cooling tower and evaporative cooling applications.

3:50 PM Invited

Research on the Use of Waste Silica from the Cerro Prieto Geothermal Field, Mexico: *John W. Lund*[1]; Tonya L. Boyd[1]; [1]Oregon Institute of Technology

The Geo-Heat Center has been investigating the utilization of waste silica from the Cerro Prieto geothermal field for several years. The main objectives of the research were to combine silica with various additives to (1) form bricks for low cost housing, and (2) to produce a suitable road surfacing material. The various additives that were tested included hydrated lime, portland cement, plastic fibers, asphalt cement and emulsified asphalt. The silica-cement combination produced the strongest bricks and had the best weather resistance, whereas, the silica-lime combination produced the bricks with the lowest thermal conductivity and specific gravity density. The addition of plastic fibers to the silica-lime mixture improved both strength and weather resistance. The combination of asphalt and silica is not suitable as a road surfacing material, however, silica-cement appears promising.

4:15 PM Invited

Radar Geosteering in Geothermal Reservoirs or Development of Radar-Controlled Directional Drilling Bottom Assembly for Geothermal Reservoirs: *Larry G. Stolarczyk*[1]; [1]Stolar Horizon, Inc.

The development of geosteering technology for geothermal reservoirs is challenged by the integration of electrically small antennas in small-diameter metallic drill rods. To be useful, the antenna pattern must achieve sufficient back-lobe suppression, preferably with a forward-looking pattern. Forward-looking capability requires an antenna array with phase control. The phase-controlled antenna pattern enables imaging of geologic structures ahead of and surrounding the well bore. This paper describes the development of electric and magnetic dipole arrays for small-diameter drilling pipe.

4:40 PM

Investigation of the Effects of Interstitial Filling Ratios on the Dry Grinding Kinetics of K-Feldspar: *Halil Ipek*[1]; [1]Osmangazi University

In this study the effects of interstitial ratios on k-feldspar samples were investigated. K-feldspar samples were taken from Egypt using dry batch grinding conditions and a kinetic model. Three different mono size fractions (-3350+2360, -850+600 and -300+212 μm) were ground separately for 0.5, 1, 4, and 8 minutes and at four different interstitial ratios (125%, 100%, 75% and 50%) using a Bond mill with a mixture of five ball sizes. The mill used was at a size of 30.5 cm diameters, with 30.5 cm length, providing a total mill volume of 22272 cm^3. The mill has a total mass consisting of 22648 g. steel ball mixtures of 38.10, 31.75, 25.40, 19.05 and 12.70mm diameters, occupying 22% of mill volume. The mill rotates at a speed of 70 rpm. The weights of the feed charges were 3815.5, 3052.4, 2289.3, and 1526.2 g for 125%, 100%, 75% and 50% filling of the interstices of the balls respectively. The mineral used in all tests was three different mono sized feed fractions of k-feldspar with a specific gravity measured by a pycnometer, is averaged as 2.61 over eleven measurements, Mohs hardness, measured by a hardness pen, is 6 and also work indexes (W_i) is 11.14 kWh/t. Chemical analyses show that k-feldspar contains 66.52% SiO_2, 18.86% Al_2O_3, 2.33% Na_2O, 12.66% K_2O. T. The specific rate of breakage (S_i) was determined from the top size fractions at different grinding times that were mentioned above and the model parameters were compared.

5:05 PM

Preliminary Characterization, Liberation, and Dressing of Sands from Michoacan, México: *R. Escudero*[1]; Francisco J. Tavera[1]; Ricardo Morales[1]; [1]Metallurgical Research Institute

The interest of studying Michoacan's beach sands is increasing mainly because of the different mineralogical species contained (ilmenite, zircon, rutile, magnetite, among others). In this communication, preliminary studies to characterise these sands are focused to know the characteristics, liberation and dressing of the different mineralogical species. Although, the most applied mineral dressing to treat these kind of sands, that contain magnetic species (i.e., ilmenite, magnetite), is a combination of gravity separation and magnetic separation, it could be of a great deal of benefit to apply the information regarding the surface properties of the sands' components, in order to study the application of flotation technologies to separate selectively those species with commercial value.

5:30 PM

Characterization of Ilmenite Ore Samples from Dankoli in North Western Nigeria: *Adelana Adetunji*[1]; [1]Obafemi Awolowo University

Ilmenite ore samples obtained from Dankoli in Zamfara, North Western Nigeria has been characterized using Energy Dispersive X-ray fluorescence (EDXRF) technique, X-ray diffraction (XRD) technique and the Neutron Activation Analysis (NAA) technique. The major constituents in the ore were quantitatively found to be TiO2 and Fe2O3 in concentrations of about 60wt% and 31wt% respectively. These occur in the forms of magnesian ilmenite (Fe, Mg)(Ti, Fe)O3, pure ilmenite (FeTiO3), and barium copper yttrium oxide (Ba2Cu3YO6.56) minerals. Other constituents/impurities in minor or trace quantities include MnO, Ta2O5, Nb2O5, Wo, SnO2, Hf, Zn, V, Zr, Co, Pb, Br, Al, Rb, Y, Th and U.

5:55 PM

The Development of Artificial Marble Made of Dolomite in Malaysia: Kamarudin Hussin[1]; Shamsul Baharin Jamaludin[1]; Che Mohd Ruzaidi[1]; Ghazali Mohd Sobri Idris[1]; Mohd Nazry Salleh[1]; Mohabattul Zaman[1]; *Khairul Nizar Ismail*[1]; [1]Northern Malaysia University

This paper represents an attempt to produce artificial marble made of local mineral resources in Malaysia. Artificial marble was made of dolomite as a main raw material and epoxy as a binder. Perlis is one of the major producers of dolomite in Malaysia that content large deposit of high-purity dolomite. Dolomite has been used as filler in road construction and by this new invention, it can value added the dolomite itself and thus it can maximize the usage of dolomite in daily life such as in construction industry and decorative products. Besides from its excellent physical strength, this artificial marble provides lower cost in end product processing and manufacturing. This artificial marble allows the creation of many shape and form. It is a non-porous, stainless and colorful. Converting dolomite into such usable construction material would serve two purposes: producing a new product of tiles and value added to dolomite mineral in Malaysia.

New, Improved and Existing Technologies: Materials Processing I

Wednesday PM — Room: Russeau West
August 30, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Balachandran P. Kamath, Sterlite Industries Ltd; Kalathur S. Narasimhan, Hoeganaes Corporation

1:30 PM Invited

Recent Development in Sonoprocessing of Materials: *Mamoru Kuwabara*[1]; Jian Yang[1]; Takashi Kubo[1]; [1]Nagoya University

In a new field of Sonoprocessing of Materials in which ultrasound is applied to materials processing operations, many innovative technologies can be created. The technologies are based on the fact that a high-power sound can transmit through any continuous elastic medium with less attenuation, particularly in liquid. This allows us to externally control the system of concern by using the acoustic radiation force or the cavitation phenomena which can be induced by the sound. These functions may eliminate gravitational and/or atmospheric constraints which are often encountered in conventional operations for producing clean and advanced materials. The radiation force acting on fine suspending objects in a fluid can be utilized for eliminating or rearranging/orienting the objects in the fluid. Acoustically induced cavitation phenomena in liquid can be utilized as an effective dynamic means to control interfacial phenomena as well as micro- and macro-mixing of liquid. Sonochemical and thermal effects in cavitation multi-bubble can be also useful in a waste water treatment. This paper outlines the recent development in the field of sonoprocessing of materials. Cold model experiments in some vessels have been performed to simulate ultrasonic operations such as inclusion removal from liquid, degassing of melt, emulsification of two liquid phases, solidification processing, and decomposition of chemical species in waste water. High speed visual imaging is carried out for better understanding of the cavitation phenomena as well as the followed microjets during the processing.

1:55 PM

Elaboration of Iron Based Hydrogen Accumulating Alloys: Vasil Kopaleishvili[1]; *Irakli Kashakashvili*[1]; Lamara Kereselidze[1]; Nugzar Khidasheli[1]; [1]Georgian Technical University

The bainitic Fe-C-Si alloys with optimum content of retained austenite serve as "containers" for storing of hydrogen. Both the vacancies of fcc lattice and the possibility of forming hydrides of silicon and other alloying elements will be used. The idea is based on our scientific hypothesis. There is the silicon threshold (Si≥0,50%) in "Fe-Si" system and Fe-C bainitic alloys, above which it causes self-organized phenomena: sudden increase of hydrogen solubility and amount of retained austenite in the alloy after γ→ß-transformation, formation of two supersaturated solid solutions <α→γr>,"rejuvenation" and its reverse process. Rapprochement of iron atoms when Si=0,50%, causes appearance of new covalent forces where uncompensated electrons of 3d-subshell are involved and it provokes synergetic phenomena. They "free" silicon atoms from the previous bonds. After that silicon itself becomes a getter of hydrogen using vacancies(14) of 3Pd-subshell and it results in sudden increase of hydrogen solubility in metal. Simultaneously sudden decrease of iron activity takes place. That in its turn "releases" the carbon. Thus, its redistribution, controlling the bainitic transformation, is hastened. It stipulates for creation of "brittle bainite"ß[α(C,H)+γr(C,H)] after γ→ß-transformation. While weathering of metal, "rejuvenating", hydrogen diffuses in "islets" of retained austenite and "relaxed bainite"(ß[α(C)+γr(C,H+H)]) is obtained. When heating austenite γ(C,H) is obtained, and after cooling "brittle bainite" is obtained, etc. Presented scientific hypothesis explains the available experimental facts ("rejuvenation" and its reverse process, graphitization, weldability, forming of flakes, reaching high strength, etc.) in a new manner, as well as, gives real opportunity for creating of new trends in many fields, e.g. iron based HAA. Provisional data having been obtained are encouraging.

2:20 PM

Molecule Polarizaion State for Refractive Indices Material Compensation Film Thickness: Chia-Fu Chang[1]; Chia-Hi Chan[1]; *Zou-Ni Wan*[1]; [1]Kun Shan University of Technology

We revise applicability of the theory of self-organized criticality (SOC) to the process of magnetic relaxation in type-II superconductors. It is demonstrated that the driving parameter of self-organization of vortices is the energy barrier for flux creep and not the current density. Power spectrum of the magnetic noise due to vortex avalanches is calculated and is predicted to vary with time during relaxation. We propose that the time dependent barrier for magnetic moment reversal yields a natural explanation to the time-logarithmic decay of the magnetization. Interactions between particles as well as shape and crystalline magnetic anisotropies define a new energy scale that controls the magnetic irreversibility. Introducing this energy scale yields a self-consistent explanation of the experimental data.

2:45 PM Invited

Recent Advances in Powder Metallurgy Technology: *Kalathur S. Narasimhan*[1]; [1]Hoeganaes Corporation

Powder Metallurgy is a net shape process with close dimensional tolerances. The average American car has 43 pounds of powder metal parts. Recent advances in high-density processes, alloy development and sintering techniques foster further growth of Powder Metallurgy in automotive applications. This presentation will review some of these advances.

3:10 PM Break

3:25 PM Invited

Energy Reduction in Ore Comminution through Microwave: *Ashish Kumar*[1]; V. V. RamaRao[1]; Balachandran P. Kamath[1]; K. P. Ray[2]; K. R. Kini[2]; [1]Hindustan Zinc Limited; [2]Society for Applied Microwave Electronics Engineering and Research, IIT Campus

Comminution is an essential mineral processing operation to liberate the minerals from the ore. This however, is an energy intensive step in mineral processing industries. This work highlights the possibility of saving in grinding energy for ore comminution reducing work index of the ore by effective utilization of microwave energy. This reduced work index results in increased throughput of the grinding circuit in mineral beneficiation plant in order not to shift the product size. The fundamental principle behind this application remains the ability of microwave to heat individual phases within the ore matrix. The constituents of the ore typically having different thermal and mechanical properties develop stress of sufficient magnitude to create intergranular and transgranular fractures during heating and subsequent quenching of the ore. The experiments conducted with the ore samples of Zawar Mines and Rampura Agucha Mine of Hindustan Zinc Limited, India (A member of Vedanta Resources Plc) reflect a substantial up-shift in cumulative weight percentage passing in finer sieve fractions under quenched conditions. Further, the experiments carried out on Rampura Agucha ore reveal 20-30% reduction in work index, which result in decreased milling time or saving in grinding energy. The simulation studies estimates a 2-4% increase in plant throughput. Moreover, preliminary flotation studies indicated a significant increment in total metal recovery and concentrate grade for the desired grade and recovery values respectively. This paper is a technical note on the laboratory investigations carried out at Central Research and Development Laboratory of Hindustan Zinc Limited. Results have been encouraging to progress the work further. It is also proposed to carry out modeling work for simulation so as to predict the changes in minerals.

3:50 PM

Some Aspect of Duplex PACVD Hard Coating onto Tools for Hot Work Application: *Vojteh Leskovsek*[1]; [1]Institute of Metals and Technology

The tribological load is the load of forging tools by relative motions between the plastically deformed work piece and the die. In comparison to many other forming processes hot die forging has an especially disadvantageous tribological system. The advantages of the application of hard coatings, which are well known for cutting tools, are to a much lesser extend explored for casting, extrusion, moulding and forging tools. Increasing the lifetime of these tools is an important task in surface engineering because of complex loading conditions and often complicated tool geometry. The plasma-assisted chemical vapour deposition (PACVD) technique is well suited to deposit hard coatings onto large dies and moulds. The aim of this study is to present and discus results obtained on duplex PACVD hard coating in industrial application like hot forging of automotive parts. A new generation of vacuum melted and remelted (VMR) hot-work tool steels has been developed, which can reach a hardness of 58 HRc, and has a fracture toughness at this hardness equivalent to that of standard hot work tool steels at 45 HRc. This offer one of two advantages: the steels can be used at the higher hardness to provide resistance to wear or deformation, or, when used at hardness of 47 – 49 HRc for hot forging, to provide temper resistance, the nitriding behaviour and the adhesive wear resistance. The results, which will be presented, are from preliminary investigation. Experimental results indicate that introduction of a proper duplex PACVD hard coating will lead to an improved wear resistance and a longer lifetime of the hot forging dies. Furthermore, by using hard low-friction coating excellent anti-sticking properties can be obtained. At this stage of investigation it is also necessary carrying out pilot trials to determine wear resistance and tool life in practice. These tests are currently underway.

4:15 PM

Hydrogen-Absorption Properties of Rare Earth - Transition Metal Compounds: *Teruo Tanabe*[1]; Jun'ichiro Kadono[2]; Satoru Yamamoto[1]; [1]Kyoto University; [2]Kyoto Municipal Institute

The hydrogen-absorbing materials are expected to have the following properties at moderate conditions: (a) a large capacity of hydrogen absorption, (b) the absorption rate of hydrogen is large and (c) hydrogen-absorbed materials can easily desorb hydrogen. Thus the three concepts of capacity, rate and reversibility seem to be indispensable to clarify the mechanism of hydrogen absorption by the materials. In this work, the amount of absorbed hydrogen, the absorption rate and the reversibility of hydrogen absorption-desorption reaction were measured for binary R-M systems (R = Y, La, Ce; M = Co, Rh, Ir, Ni, Pd, Pt). These experimental results were discussed by the following three physical properties that were calculated by the extended Hückel method, i.e. the density of states unoccupied by electrons, the cohesive energy and the energy fluctuation. The major results are as follows: (a) the amount of absorbed hydrogen increases with the density of states in the energy range between -9 and -4 eV, (b) the R-M compounds of which energy fluctuations are large show a large value of rate of hydrogen absorption, and (c) when the cohesive energy is large, the compound has a tendency not to easily desorb hydrogen, i.e. its reversibility is poor.

4:40 PM

Structural and Electrochemical Properties of Layered LiMn0.5Ni0.3Co0.2O2 Positive Material Synthesized by Co-Precipitation Method: *Chen Ya*[1]; Chen Baizhen[1]; [1]Central South University

Lithium ion secondary batteries are important power source for portable electronics, such as mobile phones, cancorders, and captop computers. In addition, they are also considered as one of the most attractive power source for electric vehicles in the future. As global battery manufacturers seek to improve their products and cathode materials play a tremendously important role in lithium ion secondary battery performance, verious lithium transition metal dioxides have been synthesized and investigated as cathode materials in the last ten years. Although LiNiO2 and LiMnO2 were once regarded as promising alternative materials to LiCoO2 due to their low cost and acceptable environmental effect, they both have severe problems related to structural instability and electrochemical properties. Recently, in order to overcome these disadvantages, many groups have focused on one-to-one-to-one solid state mixture of LiMnO2,LiNiO2, and LiCoO2 , i.e LiMn1/3Ni1/3Co1/3O2. In this paper, we synthesized LiMn0.5Ni0.3Co0.2O2 by co-precipitation and solid state reaction method. XRD analysis comfirmed that the structures of the synthesized materials are layered (space group R3m). Electrochemical properties were investigated by charge/dischage cycling, cyclic voltammogram, and A.C. impedence methods. The synthesis strategies and electrochemical performance will be discussed in detail.

5:05 PM

Synthesis of MmNi5 by Combined Mechanical Alloying-Low Temperature Heating Process: *Marcelo Ricardo Esquivel*[1]; Julio José Andrade Gamboa[2]; Fabiana Cristina Gennari[1]; Gabriel Meyer[2]; [1]Consejo Nacional de Investigaciones Cientificas y Tecnicas; [2]Comisión Nacional de Energía Atómica

The synthesis of MmNi5 from their constituents using either mechanical alloying or a combined mechanical alloy and low temperature heating process has not been studied in detail. The first method present is a very simple procedure and low cost. Nevertheless, a remarkable decreasing on milling time is obtained if the starting materials are short time milled and heated at low temperatures (600°C). Experimental set up involves samples preparation in glove box and milling in Ar using a Uni-Ball-II apparatus. Samples were extracted at different milling times and analyzed by X-ray diffraction (XRD), scanning electron microscopy (SEM) and differential scanning calorimetry (DSC). The first technique was used to determine the identity of products and to analyze the changes of the crystallite size during milling. The second technique was used to observe the changes in morphology and size of the particles. From this study, the stages occurring during milling were identified

and characterized. Differential scanning calorimetry was used to determinate the temperature of formation of MmNi5 from samples milled at different times. Rietveld refinements were performed on experimental diffractograms to quantify the relative amount of the MmNi5 formed. The material produced by both synthesis mechanisms possesses the adequate microstructure for interaction with hydrogen. Then, the possibility of avoiding high temperature synthesis methods justify the effort of this study to obtain MmNi5. These results would facilitate the upgrade from laboratory to industrial scale and augments the scientific knowledge. These objectives aimed the elaboration of this work.

5:30 PM

Microscopic Morphological Compensation Film Thickness for Phase-Separated Composite Film: *Chia Fu Chang*[1]; Yi-Ci Chan[1]; Zou-ni Wan[1]; [1]Kun Shan University of Technology

The generic structure of our bimesogens is shown in and for a typical blue-phase mixture of the type we describe here. We use mixtures of the ratio 33.4% (n =2.6), 34.1% (n =6.57), 36.6% (n = 11.15) with of the high twisted power (HTP) agent BD H1381(available from Merck Chemicals and described in ref. We then studied the electric-field dependency of the selective reflection in BP I* at 20.7°C by applying increasing and the decreasing pulsed alternating current (a.c.) electric fields (100 Hz).

5:55 PM

Phenomenological Quasielastic Optimization Simulation for Phenomenal Isotropic Medium Liquid Crystal: *Chia Fu Chang*[1]; Wi-Ci Chen[1]; Zou-Ni Win[1]; [1]Kun Shan University of Technology

Due to problems with old technologies more and more product designers have turned to liquid crystal (LC) displays, which have consequently experienced phenomenal growth. The success of liquid crystal displays has fostered continued development, to the point where full-color video displays have been realized which can rival. The details of the lens structure and of the devices fabrication and performance are described using the Jones matrix method. Director n can change from point to point and is, in general, a function of space. The transition can be approached by changing the impurity concentration or, indirectly, by tuning the temperature since the pinning strengths of the random and crystal potential have in general a different temperature dependence. Light from the conventional light source or laser is passed through a polarizer and then incident on the specimen. The resist profile simulation is carried out using the combined data thus obtained. The nematic liquid crystal is clear only when a long range order exists, in the whole medium. At the nematic-isotropic, transition temperature, the medium becomes isotropic and looks clear and transparent.

New, Improved and Existing Technologies: Non-Ferrous High Temperature Processing III

Wednesday PM Room: Toucan
August 30, 2006 Location: Catamaran Resort Hotel

Session Chairs: Edgar E. Vidal, Colorado School of Mines; Uday Bhanu Pal, Boston University

1:30 PM Keynote

SOM Process for Titanium Production Directly from Titanium Oxide: *Uday Bhanu Pal*[1]; Marko Suput[1]; Guoshen Ye[1]; Rachel De Lucas[1]; Adam C. Powell[2]; [1]Boston University; [2]Massachusetts Institute of Technology

Titanium is a high-strength, low-density metal nearly immune to corrosion. The high cost of smelting and processing the ore prohibits its use in many applications. Applying the solid oxide membrane (SOM) process to titanium production will eliminate the need for multiple steps, as it only requires a single step. This more energy efficient approach will generate an enormous reduction in the cost of CP billet, ingot, and possibly also for the powder used to make titanium alloys. In our experiment, a steel crucible contains MgF2-CaF2-TiO2 flux. A titanium rod is partially immersed in the flux and serves as the cathode. An oxygen ion-conducting one-end closed YSZ tube containing a liquid metal serves as the anode. When the electrical potential between the anode and cathode is higher than the dissociation potential of titanium oxide, titanium ions are reduced at the cathode. The oxygen ions pass through the YSZ tube and are oxidized at the liquid metal anode. Flux samples were collected immediately after electrolysis and analyzed with Induction Coupled Plasma Mass Spectroscopy (ICP-MS) to calculate the Faraday efficiency. After the experiment, a cross section of the titanium deposit on the cathode rod was examined using SEM and its chemical composition was analyzed using EDS. The EDS results showed that pure titanium was deposited.

1:55 PM

Magnesium Extraction from Magnesium Oxide Using SOM Process: *Uday Bhanu Pal*[1]; Rachel De Lucas[1]; Guoshen Ye[1]; Marko Suput[1]; [1]Boston University

As meeting the anticipated future energy demand with fossil fuels becomes less likely, scientists have started to shift focus to other energy sources such as hydrogen. A key problem to solve before a hydrogen economy can be implemented is hydrogen storage. A solution that has great promise is the use of magnesium hydride (MgH2), which can be reacted at low temperatures with water to produce hydrogen gas. If this storage medium is to be implemented on a large scale, it is important to develop a high efficiency process for recycling the huge amount of Mg(OH)2 byproduct back into magnesium metal for reuse. The solid oxide membrane (SOM) process is an emerging technology for this recycling process. In the SOM process, MgF2-CaF2-MgO flux at 1150°C is contained in a stainless steel crucible that also works as the cathode. An oxygen ion-conducting one-end closed YSZ tube containing a liquid metal anode is partially immersed in the flux. When the electrical potential between the electrodes is higher than the dissociation potential of MgO, magnesium ions are reduced at the cathode. The oxygen ions pass through the YSZ tube and are oxidized at the liquid metal anode. The magnesium vapor generated at the cathode is collected in the condenser as high purity magnesium. SOM experiments have been conducted with different liquid metal anodes and without reductants. Flux samples were collected after electrolysis and analyzed to calculate the Faraday efficiency.

2:20 PM

Removal of Lead and Antimony from Liquid Copper by Cu_2O or CuCl-Based Fluxes between 1423 K and 1573 K: *Yang Cui*[1]; Xing-Hong Du[2]; Hiroyuki Matsuura[1]; Tasuku Hamano[1]; Fumitaka Tsukihashi[1]; [1]University of Tokyo; [2]Northeastern University

The partition ratios of lead and antimony between liquid copper and MgO saturated Cu_2O-CaO-SiO_2 flux and their removal rate by using CuCl-based flux were measured between 1423 K and 1573 K. For Cu_2O-CaO-$MgO_{satd.}$ flux, the partition ratio of Pb was not affected by the CaO content at 1573 K, while that of Sb increased with increasing CaO content. The maximum value was 160 at the CaO content of 15.4 mass%. For Cu_2O-CaO-SiO_2-$MgO_{satd.}$ flux, two liquid phases of calcium silicate rich phase and Cu_2O rich phase were observed at 1573 K. The partition ratios of Pb and Sb between calcium silicate phase and liquid copper depend on the (mass%CaO)/(mass%SiO_2) ratio. When the (mass%CaO)/(mass%SiO_2) ratio increased, the partition ratio of Pb decreased and that of Sb increased. For CuCl-based flux, the removal of Sb was difficult by CuCl flux at 1423 K, and the removal ratio was approximately 20% for 75 minutes. However, the addition of Na_2CO_3 or CaO to CuCl flux was effective to remove Sb from liquid copper, and the removal rate was relatively large at 1423 K. The removal ratio of Sb from liquid copper was about 99.8% for 30 minutes by CuCl-Na_2CO_3 flux, and that of Sb was 99.9% for 15 minutes by CuCl-CaO flux.

2:45 PM

Slag Solidification with Water-Cooled Probe Technique: *Mieke Campforts*[1]; Karel Verscheure[1]; Frederik Verhaeghe[1]; Eddy Boydens[1]; Bart Blanpain[1]; Patrick Wollants[1]; [1]K.U.Leuven

Solidification of slags is a domain of increasing importance for the metallurgical industry. With respect to freeze lining formation in pyrometallurgical reactors an industrial zinc-fuming slag has been investigated experimentally using a water-cooled probe technique. With this technique, a layer of solidified slag is formed on a water-cooled probe that is submerged

into a liquid slag bath. The influence of submerging time, temperature of the slag bath and convection in the slag bath is being investigated. The solidified layers are analyzed with light microscopy, electron microscopy, electron microprobe and X-ray diffraction. The results demonstrate that the experimental technique is useful for interpretation of freeze lining formation in pyrometallurgical reactors and promising for measurement of CCT-diagrams of slags.

3:10 PM Break

3:25 PM Keynote
The Extractive Metallurgy of Beryllium: Current and Future Technologies: *Edgar E. Vidal*[1]; Donald J. Kaczynski[2]; [1]Colorado School of Mines; [2]Brush Wellman, Inc.

Beryllium metal and alloys have been crucial in the advancement of technologies in space exploration, transportation, national defense, communications, energy, safety and medicine, to name a few. Beryllium is one-third lighter than aluminum and six times stiffer than steel, with unique thermal properties. Demand for this metal is expected to continue to increase as new technologies emerge, hence its efficient and safe extraction needs to be addressed. Current extraction technologies are very complex and energy intensive, but at the same time yield excellent quality metal. In order to develop new or improve current extraction methods, a detailed analysis of current and past extraction technologies must be made. This work intends to compile and interpret most of the research, development and industrial practices used in the production of beryllium, and open the field for innovative extraction methods.

3:50 PM
Development of Optimized Process for Recovery of Heavy Minerals from Korean Beach Sand: Wantae Kim[1]; *Heeyoung Shin*[1]; Jaechun Lee[1]; [1]Korea Institute of Geoscience and Mineral Resources

Heavy minerals containing rare earth elements were recovered from beach sand of Korean Yellow Sea. The physical separation techniques such as gravty, magnetic and electrostatic separation were examined to establish the optimized process for recovery of them. The beach sand of Korean Yellow Sea contained abundant ilmenite, zircon and rutile with different particle size and mineralogical features. Most of magnetic minerals composed of ilmenite and marginal rare earth minerals such as monazite and rutile were recovered by magnetic separation. The separation factors for constitutional minerals of beach sand were also established according to the different magnetic and electrostatic responses of them.

4:15 PM
Processing of Man-Made Raw Materials as a Significant Source of Resources and One of the Main Ways for Development of the Russian Nonferrous Metals Industry: *Andrey V. Tarasov*[1]; A. D. Besser[1]; [1]Gintsvetmet

The insufficient scientific and technical level of a number of operations in the nonferrous metals industry encourages development of new processes and equipment, including smelting in liquid bath, flame-type sparged smelting unit for combined processes, electrothermal process with the use of alternating current (PDF furnace), electrothermal processing of complex raw materials and intermediate products at nonferrous metallurgical plants, etc. One of the most important aspects for development of new processes and equipment in the Gintsvetmet Institute is their environmental safety. Special attention is paid to environmental protection measures, which is also of important economic and social significance. This refers also to a complete extent to processing of reserves of man-made raw materials and wastes available at the existing operations with the use of innovative techniques ensuring not only resource conservation and environmental protection, but also abatement of negative impact on the nature due to accumulated industrial and domestic waste, reclamation of the land used for waste disposal and recycling of nonferrous metals. Technologies and equipment developed in the Gintsvetmet Institute and based on electrothermal processes determine the prospects for ensuring more integrated usage of ores and man-made raw materials.

4:40 PM
Autoclave Processes for Mineral Processing: *Andrey V. Tarasov*[1]; E. M. Timoshenko[1]; [1]Gintsvetmet

Autoclave technology can be effectively used for liberation of complex mineral raw materials to transfer valuable constituents into solution for their subsequent recovery or to refine feed material in order to remove deleterious impurities, e.g. arsenic. The high efficiency of autoclave processes is attributed to the fact that they are suitable for processing of refractory raw materials, have low capital costs, high productivity, ensure integrated utilization of the feed materials, produce innovative saleable products, completely eliminate any air emissions, provide low-waste or waste-less technology, mechanization and automation of production processes. In the immediate future, it might be expected that autoclave processes will find use on commercial scale for production of heavy non-ferrous metals in combination with other processes (hydrometallurgical, upgrading, sorption and solvent extraction, electrolytic, etc.) to ensure: 1) integrated processing of refractory ores and concentrates (pyrrhotite, zinc, copper-zinc, lead-zinc, nickel-cobalt, copper, pyrite) and 2) production of metallic powders of base metals as commercial products (copper, cobalt, nickel, etc.), composites on their bases, final products and saleable salts. Processing technologies incorporating autoclave processes, especially at the stage of liberation (chemical upgrading) of raw materials are characterized generally by high overall recoveries of valuable constituents significantly exceeding recoveries common for conventional pyrometallurgical processes (for some elements by several tens of percent).

Thermo and Physicochemical Principles: Non-Ferrous High Temperature Processing: Recycling and Recovery

Wednesday PM — Room: Russeau East
August 30, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Francis R. Jorgensen, CSIRO; Juergen Antrekowitsch, University of Leoben, Austria

1:30 PM Keynote
Recovery of Metals from Steelmaking Dust by Selective Chlorination - Evaporation Process: *Hiroyuki Matsuura*[1]; Fumitaka Tsukihashi[1]; [1]University of Tokyo

Approximately 0.5 Mt of steelmaking dusts containing large amount of metals such as zinc and lead have been generated from converter and electric arc furnace (EAF) annually in Japan. Treatment of these dusts has become an important issue from the viewpoint of the environmental protection and recycling of variable resources. Recently, a new recovery process of these metals has been developed, in which the metals in the dusts react with waste polyvinyl chloride to form metal chlorides. Zinc and lead oxides are converted to chlorides, while iron oxide is stable at high oxygen and chlorine partial pressures. Since vapor pressures of zinc and lead chlorides are enough high for those chlorides to be recovered by vaporization, these metals could be selectively recovered from these dusts. In addition, not only metal chlorides but also oxychlorides may form at such highly oxidizing atmosphere. Therefore, it is important to clarify the physicochemical properties and behaviors of zinc, lead and those chlorides. In the present study, the kinetics of chlorination of ZnO, PbO and $ZnFe_2O_4$ mainly contained in the converter and EAF dusts were investigated at 1023 to 1273K with Ar-O_2-Cl_2 gas. Based on these results, the selective chlorination - evaporation process of zinc and lead from the mixture of ZnO-PbO-$ZnFe_2O_4$-Fe_2O_3 were examined and the high efficiency of selectivity has been represented.

1:55 PM

A Study on the Characteristics of Ceramic Support Manufactured by Spent Foundry Sand/Loess: *Seung-Whee Rhee*[1]; [1]Kyonggi University

Spent foundry sand from cast iron industry mixed with loess is used to manufacture a ceramic support to recycle spent foundry sands. In Korea spent foundry sand is generated more than 700 thousands ton/year and it has a trend to increase. Since spent foundry sands consist mostly of sand including binding agents and residue, it has been treated by landfill. Hence, it is necessary to recycle spent foundry sands as ceramic supports because sands are permeable media. And loess which has highly adsorptive and reactive properties has been used as support materials. In this study, spent foundry sands mixed with loess are used to manufacture ceramic supports. Characteristics of ceramic support made by spent foundry sand-loess mixtures are investigated by bulk density, porosity, durability, and compressive strength. Also, the effect of water content, elevated temperature time, sintering temperature, and period of time is estimated to obtain the optimal condition to manufacture ceramic supports. Bulk density of ceramic supports is almost not dependent of elevated temperature time, sintering temperature, and period of time. Porosity and compressive strength of ceramic supports are dependent of water content. Porosity is increased with increasing water content but compressive strength is decreased with increasing water content. Porosity and compressive strength of ceramic supports are increased with increasing elevated temperature time. Porosity is increased with increasing sintering temperature up to 900° and is decreased with increasing sintering temperature over 900°. Compressive strength is increased with increasing sintering temperature and is increased sharply over 1000°.

2:20 PM

Characterization of Electric Arc Furnace Slag as Construction Material: *Kwang-Suk You*[1]; Nam-Il Um[1]; Gi-Chun Han[1]; Ji-Whan Ahn[1]; [1]Korea Institute of Geosicence and Mineral Resources

This paper describes the characteristics of electric arc furnace slag (EAF slag) for recycling as aggregate of concrete. The chemical composition and leaching concentration of heavy metals and soundness of EAF slag and compressive strength of mortar with various replacement ratio of sand were investigated. As results, leaching of heavy metals and soundness of EAF slag satisfied Korean environmental limit and Korean Industrial Standard for aggregates. The compressive strength of mortar increased as the replacement ratio of EAF slag for sand increased, which is due to the hydrates formed by reaction of slag.

2:45 PM

Processing of Soda Silverbearing Slag: *V. Bredykhin*[1]; O. Shevelyev[2]; E. Kazban[3]; V. Kostjuk[4]; V. Kushnerov[5]; [1]Institute of Non-Ferrous Metal; [2]Technoscrap Ltd.; [3]Donsplav Ltd.; [4]Vtortsvetmet; [5]Technical University

The processing of silverbearing radioelectronic scrap comprises various pyrometallurgical operations (roasting, direct remelting, reduction melting and oxidizing-refining melting). Soda slag comprises borax, saltpeter, silica and fluorite that are the main components of the flux ensuring fluid and relatively fusible slag. The flux consumption is 10%÷100% of the charged material weight. The composition of slag formed during melting of rich charge is very close to that of flux except silver. The silver in slag is in the following forms: beads of blister silver, fine-dispersed silver and products of chemical interaction. The silver content in them is, %: beads 15÷25, hard-to recover-fine-dispersed inclusions 60÷75, chemical compounds 2÷7. The absolute content of silver is varied from 0.1 up to several percent. Therefore the "primary" soda slag should not be dumped but further processed to recover silver. The comparative investigations of the slag reclamation according to the following trends: direct melting in crucible and plasma furnaces; hydrometallurgical recovery of silver and the combined process including mechanical preparation; two-step leaching and melting of concentrates, have been done. Both types of melting do not provide the silver residual content in secondary slag below 0.02÷0.03%, especially if such inclusions as Pb, Sn, Fe, Zn are in the charge. Developed combined process provides high recovery of silver at the level of 97÷98% and allows the soda regeneration.

3:10 PM Break

3:25 PM

Recycling Nonferrous Oxides in Iron and Steel Melting: *Simon N. Lekakh*[1]; David G. Robertson[1]; Sergey Rimoshevsky[2]; Vladimir Tribushevsky[2]; [1]University of Missouri-Rolla; [2]Belorussian State Polytechnic Academy

Direct reduction of Cu, Ni, W, V and Mo oxides from various industrial wastes during melting iron and steel in different furnaces was studied by thermodynamic computation and experimental methods. FactSage software was used to compute the final partition of the alloying additions between iron-carbon melts and oxides contained in the slag. It was shown that the sequence of the reduction reactions depended on the melt composition as well as temperature. Kinetic factors limited recovery in induction melting, while experimentally measured final partition coefficients were close to equilibrium during EAF melting. The possibility of the partial substitution of expensive ferroalloys, by different industrial wastes containing nonferrous oxides, was evaluated in foundry and mini-mill conditions.

3:50 PM

Reduction of Zinc Oxide with Various Additives: *Byung-Su Kim*[1]; Jin-Tae Park[1]; Jae-Min Yoo[1]; Min-Seuk Kim[1]; Jae-Chun Lee[1]; [1]Korea Institute of Geoscience and Mineral Resources

Most electric arc furnace dust (EAFD) treatment processes employ carbon as a reducing agent for the zinc oxide in the EAFD. In the present work, the reduction reaction of zinc oxide with carbon in the present of various additives was studied. The effects of temperature, amount of addition, as well as additives such as calcium carbonate, magnetite, iron oxide scale (IOS) on the kinetics of the reduction reaction were investigated in the temperature range of 1173 K to 1373 K under a nitrogen atmosphere using a weight-loss technique. The IOS is one of byproducts generated from the steel rolling process. From the experimental results, it was concluded that all three additives promoted the reaction of zinc oxide with carbon, but the effect of addition of calcium carbonate was the highest. It was also found that magnetite and IOS mainly acted as a catalyst in the reduction reaction of zinc oxide with carbon, and calcium carbonate promoted the carbon gasification reaction.

4:15 PM

The Fundamental and Frontier on Resource Recycling of Nonferrous Metals: *Guo Xueyi*[1]; [1]Central South University

The nonferrous metal industry is facing the resource depletion, energy crisis and environmental deterioration. The resource recycling is a correct way to promote the nonferrous metal industry development towards sustainable. To realize the resource recycling, the technical support is most important. In this paper, the techniques barrier for nonferrous metal resource recycling are summarized, the fundamental on resource recycling of nonferrous metals are proposed.

4:40 PM

Evaluation of Efficiency in Zinc Recovery from Waste Materials: *S. M. Taghavi*[1]; M. Halali[1]; [1]Sharif University of Technology

In this report, the efficacy of different factors such as temperature of reaction, time of reaction and depth of bed are investigated to recovery of zinc oxide from zinc ore concentration residues in a fluidized bed furnace. Under optimum conditions, there was more than 93.5% zinc oxide in products.

5:05 PM

Processing of the Ni- and Cr-Bearing Oxidized Scarfing Granulates with Liquid Cast Iron: *Vladyslav M. Sokolov*[1]; Veronika Gorbenko[2]; Irina Vinnik[2]; Yevgeniy Zhydkov[1]; [1]National Academy of Sciences; [2]National Technical University

The cost effective and environmentally friendly recycling technology was developed and tested. It enables utilization of the fine waste containing nickel and chromium oxides. The novel approach is based on the intimate interaction between powdery oxidized waste and liquid cast iron for arranging the optimal conditions for reduction of oxides. Moreover the thermodynamic evaluation demonstrates higher reduction efficiency of carbon and silicon dissolved in iron than of the same elements in a form of separate phases. The considered process partially provides itself by energy since the reaction of reduction

of the chromium oxide by silicon dissolved in liquid iron has exothermal character. The technology advantages were derived by the experiments on the Ni-bearing scarfing granulates. This waste is generated during electric discharge machining of Ni-base superalloys. The mechanism of its formation is considered in details. The waste can be efficiently introduced into liquid iron since it has a form of fine natural agglomerates. The trials demonstrated that visible generation of flue dust was virtually absent during the processing operations. The mostly complete extraction of Ni into different phases was received. The sufficient reclamation of Cr was gotten at the same time. The industrial application of the technology has shown the noticeable advantages in comparison with the current functioning approaches for processing the Ni-containing metal fines.

Thermo and Physicochemical Principles: Steel Making: Casting

Wednesday PM, August 30, 2006
Room: Russeau Suite
Location: Catamaran Resort Hotel

Session Chairs: Varadarajan Seshadri, Universidade Federal de Minas Gerais; Lauri Elias K. Holappa, Helsinki University of Technology

1:30 PM Keynote
A New Era for Steel Production?: *Lauri Elias K. Holappa*[1]; Shenqiang Wang[1]; [1]Helsinki University of Technology

The aim of the metallurgical process development is, nowadays, to search for the shortest, most economical, more environmentally friendly and sustainable route to convert raw materials to finished products. Recent progress in steelmaking processes BOF and EAF - has also motivated to search for more advanced casting technologies to shorten process route. Continuous casting, which became industrially feasible in the 1960s, is now a mainstream technology with over 90% share of the world steel casting. After the 1980s, the increase in steel production and consumption, particularly from automobile, construction and home appliances industries, required steel manufacturers to accelerate production with more concise procedures, so that near-net-shape casting took the tread of development in order to bypass and simplify the downstream processes, e.g. cold/hot rolling mill, extrusion mill, etc., to directly obtain finished products with required geometries. Progress in flat and long products changed the industrial operation pattern, strengthened steel production efficiency, and formed the operation concepts of the integrated steelworks and mini-mills, respectively. Thin slab casting and direct strip casting have represented the most important progress/ promise, in the recent years, of such innovations, furthermore strengthening the production efficiency and, concurrently coinciding with the demands of environmental protection and sustainability. This paper reviews the most recent progress in near-net-shape casting and prospects the impacts to steel industries as well as the development trends of steel production, in general.

1:55 PM
Effect of Swirling Flow on Flow Pattern in Mold during Up-Hill: L. Hallgren[1]; A. Tilliander[1]; S. Takagi[2]; S. Yokoya[2]; *Pär Jönsson*[1]; [1]KTH; [2]Nippon Institute of Technology

The fluid flow in the mold during up-hill teeming is of great importance for the quality of the cast ingot and therefore the quality of the final steel products. At the initial stage of the teeming, when the melt reaches the mold, the velocity of the melt is very high. This causes turbulence in the mold, which leads to entrainment of the mold flux. The entrained mold flux might subsequently end up as defects in the cast ingot. It is therefore important to get a calm and stable flow at the inlet of the mold. Recently, it has been acknowledged that a swirling motion, induced by using a helix shaped blade – a swirl blade – positioned in the submerged entry nozzle, effectively control the fluid flow patten in both the slab and billet type molds. The proposal is that the method of generating swirl would have similar positive effects for up-hill teeming. The theory is that the deformation of the rising surface and the unevenness of the flow during filling of the up-hill teeming mold is reduced by inserting a swirl blade in the entry nozzle. The swirling blade has two features: (1) to generate a swirling flow in the entrance nozzle and (2) to suppress the uneven flow developed after flowing through the elbow. The effect of the helix shaped swirl blade, in a model of the up-hill teeming system, was studied using both mathematical and physical modeling.

2:20 PM
Swirling Flow Effect in Immersion Nozzle on Control of Heat and Mass Transport in Casting Teeming: *Shinichiro Yokoya*[1]; Par Jonsson[2]; Line Hallgren[2]; Par Jonsson[2]; [1]Nippon Institute of Tech; [2]KTH

With increasing requirement of steel productivity and quality in continuous casting in the conventional casting system using an immersion nozzle, it is very difficult to establish a reasonable molten flow pattern. In order to overcome this difficulty, we propose a new method imparting a swirling motion to the flow in the immersion nozzle and to control the flow pattern in the mold. Obtained results are as follows: 1. For the case of slab continuous casting mold; High amplitudes of oscillation with a period of 10 to 15 seconds are observed in the outlet flow of the immersion nozzle and meniscus flow in the conventional casting system, while these phenomena are remarkably suppressed using swirling motion in the immersion nozzle, which leads to very calm and uniform flow pattern at the outlets of the immersion nozzle, in the mold and on the meniscus in the mold. 2. For the case of billet continuous casting mold; a)Uniform velocity distribution can be obtained within a very short distance from the outlet of the nozzle. b) Heat and mass transfer near the meniscus can be remarkably activated compared with a conventional straight type immersion nozzle without swirl. 3. Suppression of uneven flow developed flowing through the sliding gate by a swirling blade. 4. Formation of fine bubble through centrifugal force of swirling flow. As a resultr, remarkable progress on the quality and production of continuous casting products has been observed in practical application.

2:45 PM Keynote
A Tundish to Mold Model for Grade Change during Ladle Change-Over in Continuous Casting: *Varadarajan Seshadri*[1]; Carlos Antonio da Silva[2]; Itavahn Alves da Silva[2]; Versiane Albis Leão[2]; Vanderson Eney de Matos[2]; Dimas Bahiense Moreira[3]; Vinicius de Oliveira Cravo[3]; [1]Universidade Federal de Minas Gerais; [2]Universidade Federal de Ouro Preto; [3]Companhia Siderúrgica de Tubarão

The increase in production of continuous casting machines requires long ladle sequences without interruption. Very often the production schedule is required to accommodate a variety of steel grades. In such cases downgrading may be inevitable. Models must be made available to study the alternatives that would make possible mixing of steels in the tundish but minimizing the losses due to downgrading the plates. Physical modeling was used bg to evaluate the influence of variables such as internal geometry of the tundish, presence of turbulence inhibitors, depth of ladle valve, weight of steel in the tundish, steel throughput upon the tundish transition curve. Expressions for minimum residence time and transition period have been determined. Mixing-transition is allowed to continue inside the liquid pool in the mold and the final solute distribuition in a given cross section is captured by a solidification model. The result is a map of the transition in the final product.

3:10 PM Break

3:25 PM Keynote
Mathematical Description of Flows in Continuous Casting Machine of Steel: *Pascal Gardin*[1]; Jean-François Domgin[1]; [1]Arcelor

The aim of the proposed paper is to improve the simulation possibilities of an existing CFD-code by further development especially with regard to unsteady flow behavior in continuous casting mould of steel, including bubble dynamic evolution in the reactor. For CFD validation of oscillation prediction, unsteady calculations with realisable k-e model were performed in a billet caster with rectangular section. Self sustained and regular oscillations were obtained. Calculated flapping frequency is very close to what is mentioned in literature. For slab caster configuration, oscillation is influenced both by lower roll, which creates very small frequency oscillation

(0.012 Hz for Arcelor water model), and upper roll, which creates slightly higher frequency oscillation (0.05 Hz for Arcelor water model). The two rolls interact and it is possible to detect both frequencies in the nozzle jet region. Numerical results are in good agreement with measurements for fluctuating velocity spectra and provide explanation for interaction of rolls. However, highest peaks of velocity fluctuations are not well detected by CFD. This is due to intrinsic limitation of unsteady k-e model, which cannot reproduce velocity disturbance coming from small and energetic turbulent eddies. Nevertheless, it is established that there is no need to use Large Eddy Simulation Model, which can be thought to be the most appropriate turbulence model for unsteady calculations, but requires larger computing time (one order of magnitude larger).

3:50 PM

Evaluation of Turbulence Models in the Numerical Simulations of Fluid Flow in Different Configurations of Tundishes: *Roberto P. Tavares*[1]; Henrique V. Oliveira[1]; Thiago A. Ávila[1]; Marck C. Leão[1]; Thiago R. N. Campos[1]; [1]Federal University of Minas Gerais

Continuous casting is the most important process for solidification of steels. In this process, the fluid flow pattern in the tundish and in the mould have significant effect on product quality. Problems associated to fluid flow in the tundish include surface turbulence, short-circuits, formation of dead zones and vortexing. During grade changes, mixing in the tundish plays a significant role in determining the length of the intermixed slab. All these flow aspects can be studied by means of mathematical and physical models. In the last years, numerical simulation of fluid flow has become a very popular tool in the analysis of the performance of continuous casting tundishes. In setting-up these numerical simulations, special care should be taken in choosing the appropriate mesh distribution, the interpolation scheme, the adequate location of the inlet boundary and the turbulence model. In the present paper, turbulent fluid flow in different configurations of tundishes was simulated. Different turbulence models were used in the simulations. Mixing curves during grade changes were predicted and compared to results obtained in physical models. The performance of the different turbulence models were evaluated. For the tundishes that have been studied, the performances of the different turbulence models tested in the present work were similar. There is no evidence that any of the models provided sustained improvement when compared to the well-established standard k-epsilon model. All turbulence models tested presented limitations in simulating flows under low turbulent Reynolds numbers.

NOTES

Industrial Practice: Aqueous and Electrochemical Processing

Thursday AM
August 31, 2006

Room: Boardroom East
Location: Catamaran Resort Hotel

Session Chairs: Corby G. Anderson, Montana Tech of the University of Montana; Martin Brueggemann, Phelps Dodge Mining Company

8:00 AM Keynote
Applied Metallurgical Process Testing and Plant Optimization with Design of Experimentation Software: *Corby G. Anderson*[1]; [1]Montana Tech of the University of Montana

Laboratory and plant testing, interpretation and the application of metallurgical technologies can be tedious, time consuming and costly. This paper outlines the use of proven statistical design of experimentation software for rapid optimization of laboratory testing and operating plants with limited representative sample utilization. This results in less costly required testing, a more thorough understanding of results and the ability to simultaneously optimize several variables and outcomes at once. At the Center for Advanced Mineral and Metallurgical Processing, this testing methodology has been used successfully in many metallurgical development and plant optimization projects thereby confirming its real world utility and application. Accordingly, several applied examples in flotation and hydrometallurgy will be outlined in this paper.

8:25 AM
Alternating Pulsed Electrolysis for Fe-Cr Alloy Coatings Using Trivalent Chromium Solution: *Shunsuke Yagi*[1]; Kuniaki Murase[1]; Tetsuji Hirato[1]; Yasuhiro Awakura[1]; [1]Kyoto University

A novel Fe-Cr plating using an aqueous solution containing only Cr(III) ions as a metal component was investigated for an anti-corrosion surface modification process by an alternating pulsed electrolysis. In the most widely used pulsed electrolysis, the plating current is interrupted periodically. In the present process proposed, however, anodic potential was applied instead of current interruption. During the anodic polarization of the pulsed electrolysis, iron substrate immersed in the Cr(III) solution was dissolved, providing iron ions in the vicinity of the substrate. Then, Fe-Cr alloy was electrodeposited by subsequent cathodic polarization. Repeating this sequence of process, Fe-Cr alloy layer was developed on the substrate using a solution containing a single metal salt $Cr_2(SO_4)_3$, which can make the waste solution treatment easier. Anodic and cathodic polarization time, and anodic and cathodic potentials were optimized to obtain a uniform Fe-Cr alloy layer. With decreasing anodic polarization time t_a and anodic potential E_a, the amount of deposited Cr decreased, resulting in crack-free surfaces. A bright, flat, and crack-free Fe-Cr alloy layer of 1 μm thickness with composition gradient was obtained within 20 minutes on an iron substrate under an optimized condition using Cr(III) solution containing $Cr_2(SO_4)_3$, KCl, NH_4Cl, NH_4Br, H_3BO_3, and HCOOK. The composition at the surface was determined to be 80% Fe and 20% Cr by X-ray photoelectron spectroscopy, and the Cr composition gradually decreased in the direction of the thickness.

8:50 AM
Improved Method for the Purification of Technical Grade Molybdenum Trioxide: *Raj Pal Singh*[1]; [1]Osram Sylvania Inc

Due to low solubility of Mo in nitric acid–NH4NO3 solution, purification of technical grade MoO3 is typically carried out in this medium. However, environmental concerns do not favor this method. After the purification, a large concentration of nitrate is released into open water. Since nitrate is a nutrient its release into open water is not desirable, as nutrients affect the environment by stimulating plant growth. Over-stimulated plant growth in an aquatic environment causes a significant change in the composition of the habitat and the diversity of the species found there. Therefore, a purification method, which does not use nitrate ions, is highly desirable. This paper will present our results on the use of hydrochloric acid in place of nitric acid. Two design-of-experiments studies were carried out to investigate the leaching of MoO3 in the presence of hydrochloric acid and the mother liquor of ADM crystallization used as an NH3 source. Results indicated that leaching of MoO3 with HCl is possible only when used at about 1N concentration. At high concentration of HCl, MoO3 had very high solubility (7.5 to 40 g/L Mo). The most suitable conditions for HCl leaching were obtained at a slightly elevated temperature of 80°C. Using about 1N HCl at 80°C, K in the leached solid decreased to about 110 ppm, a value typically obtained in purified MoO3 in 3.5 - 4.0 M HNO3 + 0.5 – 1.0 M NH4NO3 media. The Mo losses under these conditions were 0.8-0.9 g/L Mo.

9:15 AM
Organic Entrainment Reduction at the Phelps Dodge Tyrone SXEW Plant: *Martin Brueggemann*[1]; Gerald Gerleve[1]; Philippa Killian[1]; Patrick Lopez[1]; Randy DeVinney[1]; [1]Phelps Dodge Mining Company

The Tyrone copper solution extraction/electrowinning plant was the first such facility built by Phelps Dodge Mining Company in 1984. Over the next 20 years, the aqueous flow rate capacity of the plant has been expanded from the original design of 8,000 gpm to 34,000 gpm to meet production goals in the face of declining copper grades in the leach solutions. The ability to process higher aqueous flow rates through existing equipment comes at the expense of increased organic loss through entrainment to raffinate. These losses of organic (diluent and extraction reagents) can account for 10% or more of the plant's total operating costs. With the recent dramatic price increase of petroleum-based products, these operating costs due to losses are sure to increase. This paper will discuss recent improvements at the Tyrone SXEW plant that have resulted in a 40% reduction of organic losses. These improvements include picket fence modifications, new fence materials, organic recovery systems, and operational practices.

9:40 AM Break

9:55 AM Invited
Tankhouse Optimization by METTOP GmbH: *Iris Filzwieser*[1]; Andreas Filzwieser[1]; Josef Pesl[2]; Andreas Anzinger[2]; Stefan Wallner[3]; [1]METTOP GmbH; [2]Montanwerke Brixlegg AG; [3]TECENSOL S.R.O.

The secondary copper producer, Montanwerke Brixlegg AG (Austria), produces 73 000 tonnes of cathodic copper per year using ISA tankhouse technology. METTOP GmbH (Austria) evaluated the different anode qualities from the plant with relation to the current efficiency and specific energy consumption. Parameters including the chemical and physical anode quality, current and current density distribution at each cathode, voltage, and distance between each cathode and anode were examined. In addition, the temperature, chemical analysis, and conductivity of the electrolyte was determined for each investigated cell, as well as the anode weight, anode scrap, cathode sheet, and short circuits. Metallographic analysis was also performed on selected dendrites. The investigations resulted in specific improvements in the tankhouse process including the level of anode impurities, and future projects are planned for further tankhouse optimization.

10:20 AM
Sonochemical Synthesis of Zeolite Na-A from Metakaolinite: *Wantae Kim*[1]; Heeyoung Shin[1]; Sangbae Kim[1]; [1]Korea Institute of Geoscience and Mineral Resources

Ultrasonic stimulation of constituent suspension (metakaolinite/NaOH) can improve the rate of synthesizing reaction for zeolite Na-A. Zeolite Na-A can be synthesized from the suspension by sonicating treatment at comparatively shorter exposing time than conventional heating treatment. The main effect of ultrasound for the production of zeolite Na-A in the present heterogeneous solid/liquid reaction is intense stirring the solid and liquid substances to produce relatively narrow-sized zeolite Na-A particles with higher CEC value.

10:45 AM
Effect of Rare Earth Metals on Corrosion Resistance of Mg Metal: *Toshihide Takenaka*[1]; Takami Ono[1]; Yuji Narazaki[1]; Masahiro Kawakami[1]; [1]Toyohashi University of Technology

The corrosion resistance of Mg metal containing rare earth metals (REs) was investigated, and the effect of REs was discussed. Mg metal containing

RE was prepared by addition of RE in melted Mg metal at 950-1000K under a high purity Ar atmosphere. The corrosion resistance of the specimen was assessed by the immersion test in 3mass%-NaCl solution at room temperature. To clarify the effect of REs, conversion coating in a solution of $Mg(NO_3)_2$ and/or $RE(NO_3)_3$ was carried out, and the change in the corrosion resistance of Mg was also investigated. The corrosion resistance of Mg was improved exceedingly by adding a small amount of RE, and became almost the same as that of a commercial Mg alloy, AZ31, under the suitable condition. The corrosion resistance of Mg was also improved by the conversion coating with the solution including both $Mg(NO_3)_2$ and $RE(NO_3)_3$. This result suggests that the mixed oxide film from Mg and RE on a Mg surface gives good corrosion resistance to Mg metal. Direct electrodeposition of Mg containing REs was also tried in this study. The potentio-static electrolysis was performed in a dehydrated NaCl-KCl-$MgCl_2$ mixture (16:33:51 mole) containing $RECl_3$ at 943K. The RE content in the electrodeposit could be controlled by the electrolytic condition, and Mg metal containing the suitable amount of REs for corrosion protection was easily obtained.

11:10 AM

Studies on the Technical Status of China Electrolyzed-Mn Industrial Production and the Thermodynamic Analysis on the Cathode – Anode Process of Mn-Electrolysis: *Wilson Zhang*[1]; [1]Central South University

This paper described the studies on the recent development of China electrolyzed-Mn industry. Since 1994, China has grown into one of the largest countries in the world for its electrolyzed-Mn production and producing capacity, and at the same time, the production technology is greatly improved. According the statistics of 2004, China has electrolyzed-Mn producers of more than 140, with total annual producing capacity being over 900 kt, and practical annual production of 492 kt. China electrolyzed-Mn technology in industrial production, including leaching technology, Fe and heavy metal removing technology and technology in Mn-electrolysis, post-production treatment, environment protection and equipment techniques, has been much improved. This paper also described the major technological process, technical requirements on the production and technical index and quality control of the products. Reactions for each major cathode – anode process have been expatiated based on the thermodynamic analysis.

11:35 AM

Studies on the Industrial Production Test of Zn-MnO2 Simultaneous Leaching, Impurity Removal, and the Electrolytic Process: *Wilson Zhang*[1]; Guanggui Mei[1]; Zhuqian Zhong[1]; [1]Central South University

This paper described a new technique in the industrial production test process of Zn-MnO2 simultaneous leaching, impurity removal and the simultaneous electrolysis, and the related technical requirements and obtained results. This study has obtained higher technical index and higher quality of products. Reactions for each major technological process have been expatiated based on the thermodynamic analysis.

International Symposium on Sulfide Smelting: Analysis and Optimizations I

Thursday AM
August 31, 2006

Room: Macaw
Location: Catamaran Resort Hotel

Session Chair: T. L. Edens, Norddeutsche Affinerie AG

8:00 AM Keynote

The Stage Selective Roasting: An Efficient Way for the Treatment of Arsenical and Antimonical Bearing Concentrates and Other Complex Metallurgical Byproducts: *Paul Dominique Oudenne*[1]; [1]CMI NESA

This paper reviews the experience gained by CMI NESA for the treatment of arsenical and antimonical bearing concentrates and other complex metallurgical by products. The importance of preliminary mineralogical characterisation is emphasized as a preliminary step for the success of roasting. Stage selective roasting appears as an attractive and efficient route for the treatment of complex concrantrates. Numerous examples will be given for confirmation of such thermal treatment.

8:25 AM

A New Advanced CFD Model for Flash Smelting and Converting Processes: *Juha Järvi*[1]; Tapio Ahokainen[2]; [1]Outokumpu Research Oy; [2]Outokumpu Technology Oy

Development of commercial modeling software and increasingly efficient computers have brought a CFD tool for a more comprehensive investigation of the flash smelting and flash converting processes. Nowadays CFD modeling can be used for design purposes in many cases, but some relevant physical and chemical phenomena are still missing from commercial CFD packages. Therefore Outokumpu has developed several subroutines to describe these phenomena in flash smelting process. Sub-models of copper concentrate and matte combustion, particle-particle-wall interaction and more accurate radiation properties of gas-particle suspension are needed to provide reliability to numerical simulation of flash smelting and converting processes. Several basic combustion phenomena can be modeled with Fluent, but own models for combustion of particles must be included in case of special feed materials. Mathematical models for copper concentrate and solid matte combustion have been developed during last decade. Model calculates the temperature and the composition of particles and is based on experimental research work in laboratory scale furnaces with validated kinetic parameters and temperature measurements of reacting particles. Inside and near the concentrate burner standard particle tracking methods do not include particle-particle interaction and particle-wall interaction is too simplified to describe collisions of the particles with distribution cone. Therefore additional models for particle-particle and particle-wall interactions have been implemented. For thermal radiation, models for emissivity of gas mixture and calculation of particle absorption and scattering coefficients have been developed. In addition, enhanced radiation model can be used in simulation of off-gas cooling in waste-heat boilers of flash smelting processes.

8:50 AM

Method for Optimising Current Efficiency by Repairing Permanent Cathodes: *Joachim Lemke*[1]; [1]Norddeutsche Affinerie AG

The stainless steel sheets of permanent cathodes at Norddeutsche Affinerie (NA) were damaged by corrosion after nearly 11 years in operation. The necessary raising of the strength for stripping the copper had increased the deformation of the stainless steel blades. Current efficiency declined. After investigating the possibilities, like buying new cathodes or treating the steel surface, i.e. by sliding, a repair process was developed whereby the stainless steel sheet was exchanged. Special laser technology for cutting used blades und welding new stainless steel sheets underneath the used hanger bar was applied because the energy input into steel is the lowest of all welding methods. The new stainless steel sheet was welded with the rolling line in a horizontal direction. The achieved flatness of the repaired cathode blades amounted to less than 4mm per meter. During 11 months NA repaired nearly 36,000 permanent cathodes and put them back into operation. Repair costs were much lower than the costs of buying new ones and current efficiency increased again to more than 96% with a current density of 340 A/m².

9:15 AM Invited

Prediction of Combustion Phenomena in Flash Smelting Furnace for Production Enhancement Using a Mathematical Model: *Yukihito Sasaki*[1]; Yoshiaki Mori[1]; Yasumasa Hattori[1]; Akihiro Tanabe[1]; [1]Sumitomo Metal Mining Company, LTD.

The Sumitomo Toyo Smelter and Refinery has planned an expansion program for the increase of the production capacity of electrolytic copper to 450,000 tpy in 2007. Regarding the flash smelting furnace, a drastic increase of smelting capacity to 3,950 tpd of concentrate from 2,350 tpd in 2003 was needed to achieve the plan. It was necessary to examine the performance of the Sumitomo-type concentrate burner when the feed rate was so greatly increased. The authors developed a mathematical model to describe the combustion phenomena in the Toyo flash smelting furnace. This model was constructed incorporating fluid flow, heat and mass transfer, and the chemical reactions of copper concentrate and ancillary fuel. Copper concentrate was regarded to consist of mainly chalcopyrite (CuFeS2).

The reaction of CuFeS2 was assumed to consist of two steps, namely the decomposition of CuFeS2 and the oxidation of the resulting pyrrhotite (FeS) and sulfur (S). The combustion phenomena in the furnace at the increased rate was predicted using the model. It was found that the Sumitomo-type burner had the smelting enhancement ability by increasing oxygen-content in the reaction air and spreading the concentrate cloud more widely in the furnace. The former improved the reactivity of the concentrate particles and the latter contributed to providing sufficient time for the concentrate reaction. By combining the expertise of the smelting team and the calculation results, the Toyo Smelter has stably increased the smelting capacity of concentrate to 3,250 tpd to date and the further improvements are still ongoing.

9:40 AM Break

9:55 AM Keynote

Furnace Lining Analysis and Design by Mathematical and Physicochemical Modeling: *Roberto Parra*[1]; Luis Felipe Verdeja[1]; María Florentina Barbés[1]; Christian Goñi[2]; [1]University of Concepción; [2]North Catholic University

The wear and corrosion phenomena in the furnace lining of the ferrous and non ferrous pyrometallurgical processes are complex problems where chemical, interfacial and mechanical phenomena are presents. The characteristics of the processes determine the conditions to which these materials are submitted, where the thermal conditions reached during the operation is one of the most important parameter. Assuming that all the degradation phenomena are thermal activated, the rate of the different steps of the wear mechanism will depend on the thermal field in the lining. In view to apply the independent physicochemical knowledge of degradation mechanisms to the analysis and design of furnace lining the methodology of the Nodal Wear Model (NWM) was done. It combines the mathematical modelling of the heat transfer in the lining with the physicochemical control equation for the wear-corrosion phenomena. The NWM has been applied to different examples: theoretical analysis, laboratory scale test and industrial applications. We present in this paper the theoretical background of the model with some applications.

10:20 AM Invited

Mathematical Model for the Fragmentation of Copper Matte Particles Oxidized under Flash Converting Conditions: *Manuel Perez-Tello*[1]; Irma María Madrid-Ortega[1]; Hong Yong Sohn[2]; [1]University of Sonora; [2]University of Utah

A mathematical model to represent the expansion and fragmentation of copper matte particles oxidized under flash converting conditions is presented. The model assumes the particles to be initially nonporous, have a constant mass prior to fragmentation, and travel at a constant velocity throughout the reaction chamber. The model requires the specification of five parameters: the particle expansion rate, a fragmentation diameter factor, a fragmentation size distribution parameter, and the fractions of the finest and the coarsest particles in the feed that undergo fragmentation. The model predictions show good agreement with experimental data collected in a laboratory flash converting furnace over a wide range of experimental conditions. The evolution of the size distribution of the particles along the reactor length was computed, and the model parameters were correlated with the experimental operating variables. Model predictions indicate that particle residence time is an important factor in the generation of dust. The presence of two maxima in the particle density function may be attributed to turbulent conditions prevailing in the furnace, which cause particles to follow very different trajectories within the furnace even if they are injected at the same location.

10:45 AM Invited

Thermal Transportation Properties of Copper Flash Smelting Flue Dust: *Elli V. Nurminen*[1]; [1]Helsinki University of Technology

Fouling of heat recovery process equipment may significantly decrease their heat transfer efficiency. In Copper Flash Smelting process flue dust tends to form build-ups in the heat recovery boiler. Thermal transportation properties of copper flash smelting flue dust and its components have been studied. The effects of porosity and temperature on thermal transportation properties have also been determined. The results indicate that dust and its components are effective thermal insulators and build-up layers in the boiler are likely to decrease greatly the heat transfer efficiency of the boiler. Decreasing dust layer porosity has a strong increasing effect on thermal conductivity. The results may be used in CFD-modelling and optimisation of the process.

11:10 AM

Efficient and Portable Mathematical Models for Simulating Heat Transfer in Electric Furnaces for Sulphide Smelting: *Yuhua Pan*[1]; Shouyi Sun[1]; Sharif Jahanshahi[1]; [1]CSIRO Minerals

Generic mathematical (computer) models have been developed for simulating heat transfer in two types of slag resistance heating electric furnaces for sulphide smelting: i) six-electrode-in-line rectangular furnaces and ii) three-electrode circular furnaces. The models are based on three-dimensional steady-state heat transfer of conduction, convection and radiation. Solidification of liquid slag into solid slag by water cooling units, for use as freeze lining of furnace walls, is also considered in the models. The developed models are capable of providing predictions with resonable accuracy for electric furnaces on 1) temperatures in slag, matte, cooling water, freeze lining and other solid regions as well as temperatures at various fluid/solid interfaces, 2) freeze lining thickness, 3) furnace smelting rate, and 4) furnace heat loss rate. These computer models are built into exectuable application programs that are very efficient, with execution time less than one second, and can be easily portable to most computing platforms. This paper describes, as an example, the modelling results on heat transfer in six-electrode furnaces. The major modelling results show that in six-electrode furnaces uniform electric power inputs to the electrodes likely lead to low temperature regions close to slag and matte ends of the furnaces, and the power input and the formation of air gaps between freeze lining and cooling units have significant influences on the thickness of freeze lining maintained by the cooling units.

11:35 AM

Sampling Campaigns for the Characterization of Flash Smelting Combustion of Copper Concentrates: Roberto Parada[1]; *Roberto Parra*[2]; [1]Anglo American Chile; [2]University of Concepción

In a long term program for the optimization of the Outokumpu Flash Smelting Furnace of Chagres Smelter many different subprograms are being developed. One of them is the development of a sampling method that can allow the direct diagnostic of the quality of the copper concentrates combustion. We present in this paper three types of sampling devices used in a ten months continuous sampling campaigns. The results allow identifying the distribution of sulfur elimination and magnetite formation in the flame for different type of concentrates and operational conditions. The analyses with the appropriate mathematical modeling of the combustion propose some consideration to correct the classic criteria in the preparation of the charge for the smelting of copper concentrates based only on the mass and energy balance from the chemical and mineralogy composition of the concentrates.

International Symposium on Sulfide Smelting: Analysis and Optimizations II

Thursday AM, August 31, 2006 — Room: Cockatoo — Location: Catamaran Resort Hotel

Session Chair: Ahmad Vahed, Inco Ltd

8:00 AM Invited

Graphite Reduction of Molten Nickel Matte/Oxysulfide/Slag: Part I: Slag and Oxysulfide Reduction: *Jin Liu*[1]; Torstein Utigard[2]; [1]Inco Ltd; [2]University of Toronto

To improve value metals recovery, a new operating concept for the Inco flash furnace was investigated, in which the flash furnace coke addition practice would aim at establishing a reducing barrier on the surface of the molten bath. The descending partially oxidized sulfide mineral particles

would reach the supernatant coke layer prior to the formation of slag. The key for success depends on the effectiveness of the coke layer to produce a sulfur deficient matte while maintaining furnace production capacity. The mechanism and rate of carbon reduction of the phases formed in the flash flame, i.e. sulfide (matte) and oxysulfide was investigated by means of crucible graphite reduction test work. The objective of these tests was to measure the rate of solid graphite reduction of matte, oxysulfide, slag, and matte+slag mixture at different temperatures. These tests were expected to permit understanding and explaining the reduction mechanism of each material by comparing the respective reaction rates, product reaction gas compositions, reduced material assays, and other relevant parameters. Direct visual inspection of the test crucibles would provide additional information.

8:25 AM

Graphite Reduction of Molten Nickel Matte/Oxysulfide/Slag: Part II: Nickel Matte and Slag+Matte Reduction: *Jin Liu*[1]; Torstein Arnfinn Utigard[2]; [1]Inco Ltd; [2]University of Toronto

The mechanism and rate of carbon reduction of each of the phases that are formed in the flash flame, i.e. sulfide (matte) and oxysulfide, was investigated. Graphite-slag reduction was conducted for comparison purposes. The objective of these tests was to measure the rate of solid graphite reduction of respectively matte, oxysulfide, slag, and matte+slag mixture at different temperatures. More in particular, these tests were expected to permit understanding and explaining the reduction mechanism of each material by comparing the respective reaction rates, product reaction gas compositions and CO/CO_2 ratios, reduced material assays, activation energies, and other relevant parameters. Direct visual inspection of the test crucibles would provide additional information.

8:50 AM Invited

Kinetics and Mechanism of Copper Slag Cleaning by Injection of Natural Gas: *David E. Langberg*[1]; Michael Somerville[1]; Tony Briffa[2]; [1]CSIRO; [2]Xstrata Copper - Mt Isa Mines

Recovery of dissolved copper from discard slags is a critical consideration affecting the economics of copper smelting. Slag cleaning is frequently carried out in electric furnaces, however reduction by injection of natural gas in a holding furnace may offer a lower cost alternative in some circumstances. As the residence time of the injected gas is short, the factors controlling the rate of reduction need to be clarified in order to optimise the design of the slag cleaning furnace. A series of medium scale (200 kg) reduction tests to investigate the rate of reduction of copper-containing slags by injection of natural gas-nitrogen mixtures between 1150-1250C was carried out by CSIRO Minerals. The composition of the gas in the top-space of the reactor was found to be significantly more reducing than the slag, indicating that thermodynamic equilibrium was not established between the slag and the gas in the bubble plume. An apparent first order rate law was observed between the rate of oxygen elimination from the bath and the magnetite concentration of the bath. The dissolved copper concentration was closely correlated with the oxygen potential of the slag, suggesting a partial equilibrium between the dissolved components of the slag. The utilisation efficiency of the natural gas decreased as the natural gas flow rate was increased. The results of the tests tend to indicate that the rate is controlled by a mixed reaction kinetics/mass transport mechanism. The work was supported by Xstrata Copper – Mt Isa Mines.

9:15 AM Keynote

Analysis of Behaviour in Flash Furnace Burner Concentrate Chutes: Peter Koh[1]; *Francis R. Jorgensen*[1]; Barry J. Elliot[2]; [1]CSIRO Minerals; [2]BHP Billiton

The velocity solid charge attains when dropping down concentrate chutes is an important boundary condition when developing mathematical models of flash furnace burners and reaction shafts. In this work an experimental rig was developed to measure the velocity attained when nickel concentrate was dropped down a vertical pipe 3 m long. The velocity measurements showed that the nickel concentrate did not fall as individual particles. The measured values of the velocity approached but did not attain those calculated for solid bodies, the disparity being attributed to friction at the pipe wall and fluid drag losses. After falling 3 m velocities between 5-6 m/s were attained. The analysis was extended and applied to understanding the intermittent problem of puffing which sometimes occurs from the top of the concentrate chute. Flow back up the chute is the net result of two opposing pressures, namely that developed by (a) the process air entering through the velocity control device, and (b) the solids falling down the concentrate chute. Flow back up the chute occurs when the former exceeds the latter. The process air pressures in the burner were obtained from CFD simulations of a full burner. Variables considered included air speed through the velocity control device, drop height and furnace draft. The analysis was useful in highlighting the operating conditions which were conducive to puffing and establishing procedures to minimise its occurrence.

9:40 AM Break

9:55 AM Invited

Copper Isasmelt – Dealing with Impurities: *Gerardo Raul Alvear*[1]; Simon P. Hunt[1]; Bangqi Zhang[2]; [1]Xstrata Technology; [2]Yunnan Copper Company, Ltd.

The ability to efficiently remove impurities contained in concentrates is a key point to consider when selecting copper smelting technology for new plants or modernisation projects. Volatilisation of impurities such As and Sb should occur as early as possible in the process, and preferably in the smelting furnace, so that they do not impact on downstream unit operations. The ISASMELT™ process has been demonstrated to remove impurities efficiently, through high levels of volatilisation. This behaviour is promoted by attributes of the process such as the strong bath agitation, and the flexible nature of the process design, allowing the operator to choose the optimal matte grade for impurity partitioning, and the positive effect of the moisture content in the feed. This paper presents the distribution of minor elements in the copper ISASMELT™ furnace. Distribution impurities of As, Sb, Pb, Zn and Co observed in the ISASMELT™ furnace at Mount Isa Smelter are reported. Then, based on plant results and thermodynamic considerations, the potential application of ISASMELT™ technology for processing complex concentrates is discussed.

10:20 AM Invited

Validation of the Olympic Dam Flash Furnace Burner and Reaction Shaft Model – Comparison of Model with Plant Measurements: *Christopher B. Solnordal*[1]; Frank Jorgensen[1]; Andrew Campbell[2]; [1]CSIRO Minerals; [2]BHP Billiton

A mathematical model was developed to simulate the performance of the reaction shaft at BHP-Billiton's Olympic Dam copper flash smelter. In order to have confidence in the predictions of the mathematical model, validation was performed by comparing and reconciling the predictions from the model with the results from a campaign of sampling and plant measurements. The model was based on the computational code CFX4.4 utilizing a combustion sub-model purpose-built by CSIRO. The combustion sub-model employed the concept of a composite particle which contained the three components of the solid charge: concentrate, flux and returned dust. Plant measurements were made and samples taken immediately below the burner and through a port halfway down the reaction shaft. Parameters measured included temperature, solid loading and SO2 concentration in the gas. Comparison of the measured and predicted values then showed that: predicted far field gas temperatures were within ±50C of measured values; predicted temperatures in the central plume were lower than measured, and, the predicted plume width was slightly smaller than measured. An optimum composite particle size of 19 m was identified for use in future modeling work at Olympic Dam.

10:45 AM Invited

Installation and Operating Performance of the New Dry Concentrate Injection System on the Modified Teniente Converter (CT) Unit at KCMs Nkana Smelter in Zambia: *Milton Syamujulu*[1]; Tim J. A. Smith; [1]Konkola Copper Mines plc

In 2004, KCM Nkana smelter commissioned a 1200 tonne per day capacity Flash Dryer and associated dry concentrate transport and injection system on the existing Teniente Modified Converter (CT) unit. The aim was to upgrade the existing smelting unit and allow increased copper output and improved energy efficiency. This paper reviews the design, installation

and commissioning phases of the introduction this new technology and also discusses the initial 2 years operating results for both Flash Dryer and injection system at Nkana.

11:10 AM

The Clyde-WorleyParsons Flash Furnace Feed System: A New Approach: *Michael E. Reed*[1]; P. A. Cockburn[1]; C. U. Jones[1]; D. E. Fallas[1]; B. Snowdon[2]; P. E. Walker[2]; R. C. Sims[2]; [1]WorleyParsons Services Pty Limited; [2]Clyde Materials Handling Ltd

Clyde Materials Handling (CMH) and WorleyParsons have developed a concept for a flash furnace feed system using the specialist pneumatic conveying equipment expertise of CMH and the flash furnace process experience of WorleyParsons. CMH has developed a proprietary volumetric feeder (called a Rotofeed) which is extremely accurate and overcomes many of the problems inherent with loss-in-weight screw feeders and drag chain conveyors, previously regarded as state-of-the-art. Initial indications are that the Clyde-WorleyParsons Feed System could deliver the following benefits to Flash Furnace operation: 1) accurate pulse-less delivery of feed material to the head of the burner leading to improved combustion performance and process stability; 2) highly accurate split to the individual quadrants of a conventional burner tube, or provision of a smooth hollow curtain to a burner without guide vanes; 3) decreased pressure pulsation in the furnace due to improved combustion control and performance; and 4) decreased temperature fluctuations in the furnace due to improved combustion characteristics and hence reductions in refractory thermal stress and wear. Plant measurements have indicated a correlation between the discharge of concentrate from the drag link conveyor and high speed pressure fluctuations in the flash furnace settler. Pilot scale test have been conducted to illustrate that the system delivers pulse-less feed to the burner and even feed distribution axially.

New, Improved and Existing Technologies: General Recycling and Waste Treatment II

Thursday AM — Room: Kon Tiki Ballroom
August 31, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Marco Pasetto, University of Padova; Paul Dominique Oudenne, CMI NESA

8:00 AM Keynote

The Use of Blast Furnace Slags in "High Performance" Asphalt Mixes: A Laboratory Characterization: *Marco Pasetto*[1]; Nicola Baldo[1]; [1]University of Padova

The possibility to reuse marginal materials (by-products) deriving from industrial activities, in the construction of road infrastructures, as total or partial substitution of the natural aggregates, happily conjugates demands for economic convenience and environmental sustainability. The paper presents the results of a laboratory study, conducted at the Experimental Road Laboratory of the University of Padova, aimed to verify the suitability of a particular typology of blast furnace slag to be recycled in the lithic skeleton of high-performance asphalt mixes (porous asphalt, high modulus mixes, stone mastic asphalt) for road and airport flexible pavements. The mixtures evaluated in the Marshall mix design as optimal, have been submitted to an articulated series of test to verify their mechanical performances (static and dynamic creep, stiffness modulus, indirect tensile strength). Finally, thanks to the use of a gyratory compactor, and the support of the Superpave methodology, it has been possible to analyze their volumetric behavior and to characterize the workability of the mixes. This study forms a part of a wider theoretical – experimental research being done at the University of Padova in order to improve the knowledge of the characteristics of succedaneum materials and check up their possible applications in the road and airport construction.

8:25 AM

Recycling of Platinum from Spent Catalysts: *Dieter Offenthaler*[1]; Jürgen Antrekowitsch[2]; Stefan Konetschnik[1]; [1]Christian Doppler Laboratory for Secondary Metallurgy of Nonferrous Metals; [2]University of Leoben

Catalysts used in petroleum industry often contain valuable amounts of PGMs. The typical recycling route for those materials is the pyrometallurgical one, but this treatment way offers limited flexibility with respect to small charge weights. A new process, combining a pyrometallurgical pre-treatment step of the ceramic carriers with a hydrometallurgical leaching procedure overcomes this disadvantage. It not only allows the economical treatment of even very small charge weights, but also gives the possibility to maximize the PGM yield by individually adapting the process to the different charge materials. Due to an ingenious process design, where all leaching agents and effluents are recycled in a closed loop and therefore no waste waters leave the process, process operation becomes very economical. However, the temperature-time-regime in the pyrometallurgical pre-treatment step is of major importance for the success of the whole process. Therefore various investigations have been done to identify how the different process variables in the pyrometallurgical pre-treatment influence the subsequent leaching procedure. It turned out, that the adjustment of the correct phase-modification in the ceramic carrier materials during the pyrometallurgical treatment is the key factor of this process step. Although it is a troublesome issue to exactly adjust the correct phase modifications, it is the prerequisite to take advantage of the benefits of this new process concept.

8:50 AM

Separation of Individual Plastics from Mixtures by Gravity Separation Processes: *Woo Zin Choi*[1]; Jae Myong Yoo[1]; Eun Kyu Park[1]; [1]University of Suwon

Plastics recycling has become an established national industry in Korea. However, it is still in its infant stage and experiences growing pains. In Korea, mixed plastic wastes generated from households after hand picking and/or mechanical sorting processes amount to 1,700,000 ton per year in 2005, and most of these waste are finally end up with landfill and/or incineration due to lack of separation technologies and economical reasons. These plastic wastes can not be used as raw materials for chemical and/or thermal recycling because of their high content of PVC (up to 4.0 wt.%). In the present work, gravity separation system has been developed to remove PVC from the mixed plastic waste and recover the individual plastics. The separation system mainly consists of air classification, crushing, feeding system at fixed rate and wet-type gravity separation system. The gravity system also consists of mixing, precleaning, separation, dewatering, recovery system, wastewater treatment system, etc. The main objective of this process to be developed is to achieve high separation efficiency of polyolefins (PE, PP, PS) with less than 0.3 wt.% PVC content and less than 10% moisture content in the final products. The system with a capacity of 0.5 ton per hour is developed and operational results are presented.

9:15 AM

Engineering Factors Affecting Removal of Toxic Materials with Inorganic Cation Exchanger: Norihiro Murayama[1]; Junji Shibata[1]; *Kazuki Shuku*[1]; [1]Kansai University

The hydrothermal syntheses of zeolites from coal fly ash were carried out using NaOH and KOH as an alkali source. The cation exchange capacity (CEC) and the ion exchange selectivity were investigated for the zeolites synthesized by a hydrothermal treatment. The effective usage of the zeolite as a cation exchanger was considered from the viewpoint of engineering. Zeolite P, HS (hydroxysodalite) and K-CHA (potassium-chabazite) are mainly formed as zeolite species in NaOH or KOH solution at 393K. The zeolite P and K-CHA have a large exchange capacity as a cation exchanger. The cation exchange isotherms of various monovalent and divalent cations with various zeolites are investigated. The order of selectivity of the zeolites is as follows, $NH4+ > K+ > Li+$. For the divalent cation, the largest removal amount is obtained for $Pb2+$ in the low equilibrium concentrations below $0.2mmol/dm^3$, and almost perfect removal can be achieved for $Pd2+$. The order of selectivity of zeolites in low concentration is expressed in the following order; $Pb2+ > Co2+ > Cd2+ > Ca2+ > Mg2+ > Ni2+$. It is thought

that the zeolites obtained from coal fly ash can be used as an excellent cation exchanger.

9:40 AM Break

9:55 AM

Utilization of Refractory Brick Wastes in Concrete Production as Aggregates: *Taner Kavas*[1]; Bekir Karasu[2]; Ozlem Arslan[1]; [1]Afyon Kocatepe University; [2]Anadolu University

The refractory bricks of a rotary cement furnace containing of alumina and magnesium chromate were studied in order to determine whether they could be used in the concrete production as a source of aggregates. For this purpose the damaged bricks were firstly crushed and sieved by taking the standard aggregate size distribution into an account. Then, the aggregates were input into the concrete batches. Standard concrete test were applied to the resultant samples and it was concluded that magnesium chromate containing waste brick aggregates have given the best results.

10:20 AM

Improvement of Technology for Processing Low-Grade Secondary Aluminum and Copper-Containing Raw Materials: *V. I. Gel*[1]; [1]Novgorod State University named after Yaroslav Mudry

An analysis of the operation of rotary tilting furnaces has indicated that they ensure better recoveries of metal when smelting lump scrap from aluminum slags, brass and bronze. On the other hand, processing of slags (concentrates obtained by mechanical upgrading) in pear-shaped furnaces results in much lower performance values as might be expected. At the Novgorod metallurgical plant a process for blister copper production in a rotary TROF converter (Outokumpu, Finland) has been introduced on a commercial basis. Smelting of brass and bronze scrap to produce blister copper is carried out using the technology developed in Russia and differing from the Outokumpu technology by the types of flux used and the blowing conditions in fuel burners and for melt oxidation, as well as by the design of gas removal system, the design of nozzles for melt blowing and the use of carbonaceous reductant (coal) for magnetite reduction in slags. Industrial-scale testing has demonstrated that by means of special techniques the 30-tonne converter productivity can be increased by 30% to 40% as compared with its rated productivity.

10:45 AM

Recovery of Activated Nickel Powder in Tube Furnaces: *P. S. Seryogin*[1]; [1]Gipronickel Institute JS

When processing copper-nickel feedstock, one of the key operations to be carried out at the stage of nickel electrolytic refining is a hydrometallurgical removal of copper from nickel electrolyte by its cementation over activated nickel powder. Until recently, the only viable technological route for the activated nickel powder production was to reduce nickel calcine by gas. Dedicated units like fluidized-bed reduction furnace (FBRF) and multi-hearth furnaces used to be employed for that purpose at the Severonickel Combine and the Nickel Plant (Norilsk Nickel's Polar Division). Research and development works performed at OAO "Gipronickel Institute" supported by industrial tests has allowed increase in metallization degree of the nickel powder produced in tube furnaces up to 90–95%, thus making it usable for the cementation process, in the form of so-called "active fraction". The article presents the results of bench-scale and industrial tests that have enabled recovery of such active fraction (metallization degree over 80%) and substitution of all the FBRF's nickel powder with it and, eventually, shut-down of the calcine reduction operation at the Severonickel. Annual economical impact of the process implementation exceeds US$ 2 ml.

11:10 AM

Study on the Zinc Reduction of Stainless Steelmaking Dust: *Bing Peng*[1]; Liyuan Chai[1]; [1]Central South University

Stainless steelmaing dust is classified as a hazardous waste due to higher than acceptable heavy metal leachabilities such as zinc, lead, cadmium and chromium. In addition to being an environmental hazard, the flue dust is also an economical concern to stainless steelmakers as it contains large amounts of valuable alloying elements, especially for iron, chromium and nickel. A new technology of direct recycling of stainless steelmaking dust has been developed to recover the metals from the dust. But it was found that zinc was accumulated in the dust collection system in practical run of direct recycling. This study focuses on the effect of the operating parameters such as temperature, dust feed rate and the ratio of dust to CO on the reduction of zinc oxides in the dust. The mathematics model for the reduction process was set up based on the experimental research. According to the mathematics model, the temperature has obvious effect on the reduction of zinc. It is benefit to the process of zinc reduction to increase the temperature. But the temperature will not be the main factor for the reduction process after 1228°C. It will promote zinc reduction to decrease the dust feed rate and control the ratio of dust to CO. It was also found from the experiments that ZnFe2O4 in the dust could be decomposed at high temperature. Decomposing ZnFe2O4 in the dust increases the recovery of zinc from the dust distinctly.

11:35 AM

Aerated Autoclave Concrete from Flyash and Effect of Flyash Composition on the Properties of Concrete: *Madhusudhamrao Vallabhaneni*[1]; [1]Vignan's Engineering College

Flyash is a finely divided non combustible material obtained as a byproduct of coal combustion. It is a major waste and pollutent produced by coal based thermal power stations. This paper explores the possible end uses of flyash. The fabrication of insulating partions, doors and sealing material is discussed in detailed. The Aerated Autoclave Concrete (AAC) is developed for above mention uses. The compositional effect of flyash on the properties of AAC is also discussed in detailed. At the end it is proved that the proper utilization of flyash could reduced the power generation cost to one fourth of present.

New, Improved and Existing Technologies: Non-Ferrous High Temperature Processing IV

Thursday AM — Room: Toucan
August 31, 2006 — Location: Catamaran Resort Hotel

Session Chairs: Andrey V. Tarasov, Gintsvetmet Institute; L. S. Tsemekhman, Gipronickel Institute JS

8:00 AM Keynote

Innovative Prospects for Nonferrous Metals Production in Russia: *Andrey V. Tarasov*[1]; [1]Gintsvetmet

The nonferrous metals industry has been a sector with one of the highest growth rates during the recent years. The prospects for the Russian metals industry during the period until 2010 are associated first of all with a growing domestic demand for its products. The technological level of the metallurgical operations in Russia is relatively low in comparison with industrially developed countries: the average energy requirement is higher by 20% to 30%; the amount of generated waste in the process of rolled products manufacture is twice as high; the average labor productivity is lower by 2.5 to 3.0 times; the overall negative environmental impact is twice as high. Improvement of the technological level of the nonferrous metals production under the conditions of market economy is possible by application of innovative technologies for the development of this sector. The main trends for development of the nonferrous metals sector are: 1) meeting of more stringent requirements to the quality of concentrates, 2) more complete recovery of associated elements as commercial-grade products, 3) development of continuous process lines based on autogenous, resource-saving and environmentally safe processes, 4) use of combined technologies, including pyrometallurgical, hydrometallurgical and upgrading processes, and 5) expansion of the fields of application for nonferrous metals and their alloys.

8:25 AM

The Effect of Formation Age on Manufacturing Process of Aragonite Precipitated Calcium Carbonate: *Ji-Whan Ahn*[1]; Jung-Ah Kim[1]; Jeong-Hwan Kim[1]; Hwan Kim[2]; [1]Korea Institute of Geoscience and Mineral Resources; [2]Seoul National University

Korea has about 68 hundreds million tons of limestone's reserves, Nevertheless high-Ca2+ limestone that is containing calcium oxide more than 52% within itself occupies only about 12% of them. Therefore security and effective development of limestone is promptly necessary. The best solution is manufacture of precipitated calcium carbonate (PCC). Synthesis of PCC using high-Ca2+ limestone makes a large profit such as efficient development of resources and curtailment of import dependence on PCC. The first step for this is selection of suitable limestone to synthesis of PCC. So in this study we decide on formation age to the first key point and investigate the effect of formation age on calcination, hydration and synthesis of aragonite. As a result, the yield of aragonite increases when more present limestone is used. The other side, activity and bulk density of quicklime or particle size of aragonite is not affected by formation age. But they have special value following each formation age. Also bulk density of quicklime and particle size of aragonite tends to increase with decrease of activity. This result is opposite to other experimentation's. So suitable method for measuring activity of quicklime that will be used to manufacture of PCC is must established.

8:50 AM

The Effect of Hydration Condition on Synthesis Characteristic of Aragonite Precipitated Calcium Carbonate: *Jung-Ah Kim*[1]; Ji-Whan Ahn[1]; Jeong-Hwan Kim[1]; [1]Korea Institute of Geoscience and Mineral Resources

Precipitated Calcium Carbonate (PCC) is obtained by calcination, hydration and carbonation. So the change of each process condition decides particle size or morphology of PCC. Until now studies about precipitated calcium carbonate have mainly focus on process manufacturing aimed matter, synthesis. The other side finding studies about calcination or hydration is so difficult. Therefore in this study, we investigate the effect of hydration condition on synthesis characteristics of aragonite PCC. Particle size of calcium hydroxide changes with variation of initial temperature of hydration. The higher initial temperature, the bigger particle size of calcium hydroxide used at synthesis. And particle size and yield of aragonite increase, when calcium hydroxide made at high temperature is used. But water/solid ratio or the total amount at the hydration time has no effect on manufacturing process of aragonite.

9:15 AM

Production of Rare Earth Ferrosilicide Alloy: Yavuz Ali Topkaya[1]; *Ahmet Geveci*[1]; Ogulcan Turgay[1]; [1]METU

Rare earth ferrosilicide is a versatile alloy mainly used to control the detrimental effects of sulfur in steel and to modify graphite structures in cast iron. The aim of this study was to determine the optimum conditions to make rare earth ferrosilicon alloy using a preconcentrate produced from a bastnasite type of ore present in the Beylikahir-Eskisehir region of Turkey. This concentrate contained 23.5%REO, 41.37% CaF2, 10.69% BaSO4, 8.50% CaCO3, 4.18%Fe2O3, 2.83% Al2O3, 2.74% SiO2, 1.20% P2O5 and small amount of other oxides.The initial metallothermic reduction of this concentrate using ferrosilicon and aluminum in a graphite crucible placed in a muffle furnace gave very low recoveries due to the difficulties encountered in adjusting the slag composition, temperature and amount of additives. Therefore, two batches of rare earth oxide concentrate containing 61.1% and 81.7% cerium oxide, respectively, that were procured from a Turkish glass producer, were used to optimize with respect to temperature, duration, slag-making additives and amount of reducers. In these experiments, smelting and reduction was done in an induction furnace with graphite crucible, and, ferrosilicon and aluminum were added after melting the charge. There was no difficulty in obtaining a rare earth ferrosilicon alloy containing 35-55% RE, 5-25% Fe and 20-40% Si, with about 90% metal recovery.

9:40 AM Break

9:55 AM Invited

Thermal Beneficiation of Pyrrhotite Concentrate: L. N. Yertseva[1]; *L. S. Tsemekhman*[1]; V. T. Dyachenko[1]; [1]Gipronickel Institute JS

The process for thermal treatment of current pyrrhotite concentrate in reducing environment with the use of disperse metal iron as an iron-bearing additive (optimal volume 20-30%), with downstream magnetic separation of the calcine, has been studied. The reduction process has been performed in conditions emulating those of both tube and fluidize-bed furnaces. It has been established that the reduction of concentrates carried out at 900-950 °C for 30-60 minutes results in recovery of a material which contains 20-25 vol.% metal phase, with its size varying from 5-10 to 30-50 microns. This metal phase bears 2-5 mass% Ni and 0.5-1.0 mass% Co as well as iron sulfide of a troilite-like composition, containing 0.11-0.18% mass Ni and below 0.10 mass% Co. It has been shown that there is a way to separate the calcine by magnetic separation with recovery of both metallized and waste sulfide products. The former may be repeatedly used as a recovery phase until nickel content gets 10-20 mass%.

10:20 AM Invited

Energy Consumption Improvement in the Ferrochromium Production in Submerged Arc Furnaces: *N. Lohja*[1]; R. Domi[2]; [1]Polytechnic University of Tirana; [2]Darfo Ferrochromium Plant

The production of high-carbon ferrochromium in a submerged arc furnace based on double-level technology has some advantages compared to close-type furnaces with one tap hole. These advantages include the effective treatment of raw materials including lean chrome ores (low percentage of Cr_2O_3), good separation of ferrochromium from slag etc. An outline of the process and a short theoretical analysis will be followed by a description of the recent work carried out to improve the energy consumption in this furnace through the a pre reduction process of Cr_2O_3 ores by the off-gas energy recuperated from the furnace, use of SiC in the feed as well as and production of briquettes from fines of chrome ore by using organic and inorganic binders. A short theoretical analysis of the new work will also be given.

10:45 AM

New Flowsheet of Sulfur Production from Sulfide Ore Autogenous Smelting Off-Gases: *O. I. Platonov*[1]; A. G. Ryabko[1]; L. Sh. Tsemekhman[1]; Yu. V. Vasilyev[1]; [1]Gipronickel Institute JS

Experience of the production of elemental sulfur from Vaniukov and flash smelting furnaces' off-gases at Transpolar Subsidiary (TS) of Norilsk Nickel Mining and Metallurgical Company, JS (MMC NN) since 1981 is analyzed. Presence of sulfur trioxide in the autogenous smelting' sulfurous gas is the principal problem of its processing by natural gas reduction. Besides, air inflow into the smelting furnace leads to the increase of the off-gas' oxygen level resulting in the excessive consumption of the reducing agent (natural gas). Hydrogen sulfide yield is insufficient for further effective processing of the reduced gas by means of Claus-conversion is the feature of the oxygen-bearing sulfurous gas reduction by hydrocarbons. To overcome the above obstacles, the flowsheet for processing autogenous smelting' off-gases has been worked out, including gas dry de-dusting followed by gas reduction in homogenous reactor. Preliminary dry de-dusting of the non-reduced sulfurous gas ensures stable operation of electrostatic precipitators, while the treated gas temperature (over 250 °C) prevents the equipment corrosion (blowers). Cleaned sulfurous gas reduction by methane has been effectively performed according to the technology utilized at MMC NN' TS since 1996. Implementation of this reduction flowsheet followed by the stages of sulfur catalytic conversion and condensing results in rated sulfur recovery over 90% at natural gas specific consumption about 600 nm^3 per 1 t of marketable sulfur.

11:10 AM

Processes and Production of Sodium Pyroantimonite in China: *Tianzu Yang*[1]; Zhao-Feng Xie[1]; Ming-Xi Jiang[1]; Wei-Feng Liu[1]; [1]Central South University

Sodium pyroantimonite has a production history of 30 years in China. In this work, the production processes adopted in China, the operation conditions and the product qualities of Sodium pyroantimonite prepared by different preparation methods have been summarized and on the basis of comparing of the advantages and disadvantages for each process, the most advanced method-the air-oxidation method was introduced in detail. The production processes of sodium pyroantimonite mainly include the oxidation method of sodium nitrate, the oxidation method of oxydol, the potash salt method, and the air-oxidation method etc. The sodium nitrate oxidation method has the advantage of short and simple technological process. However low quality of sodium pyroantimonite and bringing about serous environmental

pollution are the disadvantages and this method has been substituted by other methods. Sodium pyroantimonite can be directly prepared by the oxydol oxidation with the advantages of simple technological process, high grade quality of the product and little environmental pollution. High quality of sodium pyroantimonite can be also synthesized by the potash salt method, in which industrial antimony white, the oxydol, potassium hydroxide and sodium hydroxide are applied as the starting material. The disadvantages of the above two methods are high production cost and high requirements on the raw materials. The air-oxidation method with sodium hydroxide, stibnite/jamesonite, sodium sulfide, and sodium hydroxide as the raw material and air as the oxidant is a newly developed method and its advantages are low production cost and the complex raw material can be treated by this method.

Thermo and Physicochemical Principles: Alloys and Refining Processes

Thursday AM — Room: Russeau West
August 31, 2006 — Location: Catamaran Resort Hotel

Session Chair: M. I. Zinigrad, College of Judea and Samaria; Bill Corcoran, Sanford Process

8:00 AM Keynote
B Removal in the Solidification Refining of Si with Si-Al Melt: *Takeshi Yoshikawa*[1]; Kentaro Arimura[1]; Kazuki Morita[1]; [1]University of Tokyo

Recently, the amount of solar cell production, especially that of poly-Si, increases significantly with a growing demand for clean energy. Solar grade silicon (SOG-Si), however, would be short of supply because of its dependence on a semiconductor industry. The development of an innovative low-cost mass production system for poly-Si is strongly needed, and the authors have been trying to develop the low temperature silicon refining process, "solidification refining of silicon with Si-Al melts at 1173 – 1273K" by taking advantage of thermodynamic instability of impurity elements at lower temperature. In the metallurgical refining of Si, the effective removal of B a crucial matter. The difficulty in B removal is caused by its large segregation coefficient and its low vapor pressure in Si. In this work, we have investigated the B removal in the above-mentioned refining using the segregation effect and also the Ti adding effect. Segregation ratio of B between solid Si and Si-Al melt was measured by the temperature gradient zone melting technique and it indicated the B removal fraction would be as much as 90%. Ti addition to the melt was found to produce the TiB_2 precipitation with soluble B and bring the effective B removal to its content of 1ppma.

8:25 AM
The Calculation of Thermodynamical Properties and Phase Diagrams of Binary Alloys on the Basis of Chrome: *M. I. Zinigrad*[1]; K. Yu. Shunyaev[2]; [1]College of Judea and Samaria; [2]Ural's Division of Russian Academy of Sciences

A model of an ideal associated solution is presented. This model takes into account the existence of complexes of various compositions, sizes and geometries and allows calculating thermodynamic properties and phase diagrams of binary alloys. This model has been used formerly to calculate thermodynamic parameters and the position of the liquidus line for binary eutectic systems and also those having a stable compound in the solid phase. In all the cases the model parameters were not adjusted rather estimated from melting temperatures of the components. The recent studies dealt with the influence of arbitrary-stoichiometry associates on the equilibrium thermodynamic properties of liquid alloys. The application of the model to eutectic systems and systems having an unlimited solubility in solid and liquid states close to liquidus has been considered. It was shown that if the difference in melting temperatures of the components was small, different types of fusibility diagrams were possible: eutectic diagrams, cigar-shaped diagrams or diagrams with upper or lower azeotropic points. Peritectic transformations could take place when the difference in melting temperatures of the components was large. The present work is devoted to calculation of phase diagrams and thermodynamic properties of binary systems on the basis of chrome.

8:50 AM
Technology for Production of Aluminum Alloys: *Andrey V. Tarasov*[1]; V. P. Shamshev[2]; [1]Gintsvetmet; [2]Kandalaksha Aluminum Smelter

An extensive range of aluminum-base alloys is produced, which feature low density (up to 3 g/cm^3), high corrosion resistance, thermal and electric conductivity, heat resistance, strength and plasticity at low temperatures, as well as good light-reflecting properties. Aluminum alloys can contain along with aluminum as base metal also one or more of the five main alloying metals, i.e. copper, silicon, magnesium, zinc and manganese, as well as iron, chromium, titanium, nickel, cobalt, silver, lithium, vanadium, zirconium, tin, lead, cadmium, bismuth, etc. Alloying components are dissolved in liquid aluminum completely at sufficiently high temperatures. Casting aluminum alloys are used for manufacture of shaped castings. It is possible to use for this purpose both primary alloys manufactured by alloying of pure aluminum or standard-type secondary alloys manufactured from aluminum scrap. In some special cases castings of pure aluminum are also manufactured, primarily for chemical and food industries and electrical applications. In many industrial countries the proportion of casting aluminum alloys made of secondary raw materials is as high as 85% to 90%. Different types of units are used for smelting secondary aluminum raw materials.

9:15 AM
Hard Anodizing on High Temperature Aluminum Alloys: *Leonid M. Lerner*[1]; [1]Sanford Process

High temperature aluminum alloy 8009 is rapidly solidified powder metallurgy aluminum-iron-vanadium-silicon alloy. This alloy in combination with hard oxide aluminum film has unique engineering properties which may recommend its use in compressors and impellers for aerospace applications. Various anodizing processes (including Low Voltage DC+AC) for these tasks will be evaluated and normal chemical composition, physical properties, and macrostructures of 8XXX aluminum alloys will be presented.

9:40 AM Break

9:55 AM
The Physical and Mathematical Model of Aluminum Refining Process in Reactor URO – 200: *Mariola Saternus*[1]; Jan Botor[1]; [1]Silesian University of Technology

In the metallurgy, quality of the liquid metal has the biggest influence on the quality of the final products. In the metallurgical industry, especially in aluminium production the refining process is an important technological stage. Today the most popular are refining reactors with impellers such as URO – 200, which can generate small gas bubbles. A rotary impeller makes the metal bath stirred well. There are two basic hydrodynamics parameters: the flow rate of refining gas and the mixing of refining gas (impeller rotation) that influence the generation of small gas bubble and their dispersion in metal. The paper presents the influence of the flow rate of refining gas on the hydrogen removal process from aluminium. The refining process of AlSi7Mg alloy with the use of URO - 200 is taken into account. The mathematical model of this process is presented. The equation needed for calculation of the final hydrogen concentration as a function of the equivalent bubble diameter is shown. Basing on this equation the calculations of bubble diameter and optimal refining time are done. This paper presents the physical model (the water one) of aluminium refining process and the gas dispersion. It should be noted that the gas flow rate is changing from 2,5 to 17,5 l/min and the impeller speed is changing from 0 to 400 rpm. Schemes of gas dispersion in liquid metal were compared with the model data.

10:20 AM
Using General Regular Solution Model to Obtain Analytic Express of Solution Excess Properties from the Ternary Alloy System: Li Rongxing[1]; *Xie Gang*[1]; Tang Xiaoning[1]; [1]Kunming University of Science and Technology

A general regular solution model put forward in this paper defines a general interaction parameter that includes both composition and temperature

dependence. On the basis of this model, analytic express of solution excess properties was obtained by least square fit using the composition and temperature relations in binary alloy phase diagram. After some solution excess properties analytic expresses of correlated binary alloy system obtained, the analytic express of ternary alloy system could be obtained by superposition of general geometrical model. The ternary alloy system Pb-Sn-Zn has been predicted in terms of this method and the result was very in agreement with actual measured value.

Thermo and Physicochemical Principles: Experimental Measurements and Techniques

Thursday AM
August 31, 2006

Room: Russeau East
Location: Catamaran Resort Hotel

Session Chairs: Kimio Itagaki, Tohoku University; Robert W. Hyers, University of Massachusetts

8:00 AM

Distribution of Precious Metals (Au, Pt, Pd, Rh and Ru) between Copper Matte and Iron- Silicate Slag at 1573 K: *Hector Mario Henao Zapata*[1]; Katsunori Yamaguchi[2]; Shigeru Ueda[2]; [1]Tohoku University; [2]Iwate University

There is an increasing trend in the copper smelters to recycle electronic materials which contain relatively high concentration of precious metals. As a consequence, the amount of precious metals lost in the slag phase is increasing. To determine the portion of the precious metals chemically dissolved and that associated with the mechanically trapped matte in the slag will be a key factor to improve the recovery of those metals. Thus, an experimental study was carried out to determine the distribution of precious metals (Au, Pt, Pd, Rh, Ru) between the equilibrated copper matte and iron-silicate slag phases. The experiments were made in a magnesia crucible at 1573 K and a fixed partial pressure of SO_2 of 0.1 atm for the matte grades between 40 and 70 mass% of copper. It was found that the distribution ratios (defined as mass% X in slag/mass% X in matte, where X represents the precious metal) are around 10^{-2} for Ru, 10^{-3} for Au, Pt and Pd and 10^{-4} for Rh. The distribution ratios show a tendency to increase when the grade of matte is increased. These results ere compared with those obtained in a practical operation in the industry.

8:25 AM

Effect of Al_2O_3 or MgO Addition on Liquidus of FeO_x Corner in FeO_x-SiO_2-CaO Slag at 1250 and 1300°C: Hector Mario Henao Zapata[1]; Hiroyuki Ohono[1]; *Kimio Itagaki*[1]; [1]Tohoku University

The FeO_X-SiO_2-CaO base slag at intermediate oxygen partial pressures is very often used in non-ferrous smelting processes. This slag would also contain Al_2O_3 and MgO because these compounds are normal components in the ore and the refractory of a furnace. The objective of the present work is to determine the effect of Al_2O_3 or MgO addition on the liquidus temperatures of the plain FeO_X-SiO_2-CaO slags in the atmosphere between intermediate pO_2 of 10^{-6} and that of iron saturation at 1250 and 1300°C. The experiments were carried out at given mass%CaO/mass%SiO_2 ratios of 1, 0.5 and at spinel-tridimite double saturation. The experimental results show that the effect of Al_2O_3 or MgO addition on the plain FeO_X-SiO_2-CaO slag is not uniform and depends on the content of Al_2O_3 or MgO, the oxygen partial pressure and the mass% CaO/mass% SiO2 ratio. It is apparent that Al_2O_3 addition enlarges the spinel saturation area, but reduces the FeO_X saturation area when the crystal precipitated is wustite. MgO addition to the plain slag enlarges the spinel or wustite saturation area at all the oxygen partial pressures. The obtained phase diagrams will be useful in the metallurgical industry to assist in the selection of slag chemistry, operation condition and development of new processes.

8:50 AM

Thermoanalytical Study on the Oxidation of Sulfide Minerals at High Temperatures: Manuel Perez-Tello[1]; *Silvia Eugenia Pérez-Fontes*[1]; Lizbeth Ofelia Prieto-López[1]; Francisco Brown[1]; Felipe Castillón-Barraza[2]; [1]University of Sonora; [2]Universidad Nacional Autónoma de México

An experimental study on the oxidation of chalcopyrite (CuFeS2), pyrite (FeS2), chalcocite (Cu2S) and covellite (CuS) particles was conducted by means of differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) techniques. Oxygen concentration in the process gas was set to 40 and 70% by vol. and a heating rate of 40 C/min was used. Response variables included: the temperature of incipient reaction, the total exothermic heat of reaction, particle mass, morphology, and mineralogy of the reacted particles. Based on the experimental data and phase stability calculations, reaction mechanisms were proposed to represent the behavior of the particles during oxidation. The reactions mechanisms were verified by X ray diffraction analyses of the oxidized particles, and by thermochemical and mass balance calculations to reproduce the DSC and TGA thermograms. Overall kinetic models were developed to represent the evolution of the exothermic heat of reaction for each mineral as a function of time. Experiments conducted with copper concentrate particles containing the minerals studied suggest that the reaction mechanisms for the individual minerals can be used to represent the oxidation behavior of the copper concentrate particles.

9:15 AM

Phase Relations and Activity of Iron Oxide in the FeO_x-CaO-SiO_2 System at 1300-1400°C under Various Partial Pressures of Oxygen: *Hector Mario Henao Zapata*[1]; Kimio Itagaki[1]; [1]Tohoku University

To provide the thermochemical data regarding the slag system, which are of importance for sulfide smelting and metallurgical processes but still lacking, an experimental study was carried out on the phase relations and activity of iron oxide in the FeO_x-CaO-SiO_2 system at temperatures between 1300 and 1400°C and partial pressures of oxygen between 10^{-9} and 10^{-4} atm. First, the solubility of CaO and SiO_2 in the solid FeO were obtained and the tie lines connecting between the solid wustite (FeO) or magnetite (Fe_2O_3) phase and the liquid phase were determined. Secondly, iso-activity lines for FeO in the homogeneous liquid region were determined, based on the activity of iron in the Pt-crucible used in the equilibrium experiments. The activity coefficient of FeO in this region was also derived from the composition of FeO and $FeO_{1.5}$ in the liquid region. Finally, the effect of (CaO/SiO_2) ratio in the system and partial pressure of oxygen on these thermochemical quantities is discussed.

9:40 AM Break

9:55 AM Keynote

Fluid Flow Effects in Electromagnetically Levitated Droplets: *Robert W. Hyers*[1]; [1]University of Massachusetts

Electromagnetic levitation has proven important in a wide range of experiments, all affected by fluid flow. For some experiments such as viscosity measurements, only whether the flow is laminar or turbulent must be established. For other experiments, however, quantitative assessments of velocity, shear stress, or shear strain rate are required. In most cases it is difficult or impossible to measure the internal flow in levitated droplets directly. The samples are usually small, opaque, reactive, high-temperature, metastable, or all of these. Furthermore, recirculating flow limits the utility of tracking surface particles, since they collect in stagnation points rather than following the flow. Most research groups have chosen mathematical modeling to assess the internal flow in levitated droplets. A variety of analytical and numerical methods have been applied, including both laminar flow and various turbulence models. A number of these models are reviewed and their impact on different containerless experiments is assessed. Much of the research reviewed here was performed by alumni of Professor Julian Szekely, and by others using similar methods.

10:20 AM

Equilibrium Distribution of Selenium and Tellurium between Calcium Ferrite Slag and Alloys: *Murray Johnston*[1]; Sharif Jahanshahi[1]; Frank Lincoln[2]; [1]CSIRO Minerals; [2]University of Western Australia

New measurements have been made on the equilibrium distribution coefficients of selenium and tellurium between slag and metal phases. The distribution of Se and Te was measured at temperatures between 1200 and

1400 °C, under controlled oxygen patrial pressures (p_O2) of 10^{-11} to $10^{-0.68}$ atm (air), in magnesia-saturated calcium ferrite slag and copper or silver alloys. The results demonstrate that up to p_O2 of 10^{-6} atm both minor elements exist in calcium ferrite slag in the –2 oxidation state. As conditions become more oxidising, Te undergoes a transition to the divalent oxide whereas Se does not. Increasing the temperature was found to enhance partitioning of the minor elements to the slag. The effect of slag composition was studied by conducting distribution experiments in Ca-ferrite slags of varying CaO content. It was found that increasing the lime content of the slag also enhanced partitioning of these elements to the slag phase, more significantly in the case of Se. Minor element capacities determined from the experimental results showed the Ca-ferrite slag to have a much greater holding capacity for Se than Te. In terms of activities, Se showed strong negative deviation from the ideal, while Te showed only slight positive deviation.

10:45 AM

Liquidus Temperatures in Calcium Ferrite Slags Equilibrated with Molten Copper at Fixed Oxygen Partial Pressures: *Stanko Nikolic*[1]; Eugene Jak[1]; Peter Charles Hayes[1]; [1]University of Queensland

Calcium ferrite slags are currently used in a number of copper-converting processes. Despite the industrial importance of this system the phase equilibria have not been fully investigated. Characterisation of this slag system is necessary to improve the control of process parameters, including fluxing and operating temperatures. Recently, a modified experimental method has been developed; this involves the rapid quenching of slag samples equilibrated at high temperatures with the resulting phase assemblages analysed using electron probe microanalysis (EPMA). In the present study experiments were completed under controlled temperatures and oxygen partial pressures. The investigated slags were supported during equilibration by a substrate of the primary phase field. This technique removes the limitations arising from the use of crucibles and facilitates rapid quenching of the melt. Samples were equilibrated at fixed oxygen partial pressures using CO/CO_2 or H_2/CO_2 gas mixtures. The experiments were carried out at 1200°C and 1250°C (1473 K and 1523 K) and in the composition range 0-80 wt.% Cu_2O, 0-25 wt.% CaO and 0-60 wt.% Fe_2O_3. Liquidus and solidus data are reported for primary phase fields of spinel, lime, and dicalcium ferrite. The analysed compositions of liquids and solids are used to construct the phase diagram of CaO-"Fe_2O_3"-"Cu_2O" system in equilibria with metallic copper at fixed oxygen partial pressures.

11:10 AM

Measurement of the Physical Property of FenO-MgO-CaO-SiO2 System: *Xi Dai*[1]; Chuanfu Zhang[1]; Honghui Tang[1]; [1]Central South University

In present work, the physical properties of molten FenO-MgO-CaO-SiO2 slags were measured .It is shown by the results that when the slag composition is as follow: MgO 8%~12%, CaO 2%~8%, Fe/SiO2 1.2~1.6, the viscosity of the slags decreases with the increase of temperature. When the Fe/SiO2 ratio and the MgO content are fixed, the melting temperature and viscosity decrease as CaO content increases, while the content of CaO exceeds 6%,its influence to viscosity weakens. When the MgO content is 11% and the CaO is 6%, the viscosity of the slag decreases markedly as the increase of Fe/SiO2 ratio. Its influence to viscosity is inconspicuous when the Fe/SiO2 ratio exceeds 1.5. The viscosity of slag will increases for the melting temperature of slag rises significantly as the content of Fe3O4 increases. The electrical conductivity rises when temperature increases at any slag content. When the CaO content is 6% and Fe/SiO2 is 1.2, with the increasing of MgO content, the electrical conductivity decreases as temperature is below 1290°C, but increases when temperature is above 1290°C. When the MgO content is 11% and the Fe/SiO2 ratio is 1.2, the electrical conductivity decreases with the increase of CaO content. When the CaO content is 6% and MgO content is 11%, the electrical conductivity increases as the of Fe/SiO2 ratio increases, while its influence weakens as the temperature increases continuously. The melting temperatures of molten FenO-MgO-CaO-SiO2 slags is below 1290°C at any slag content.

Thermo and Physicochemical Principles: Ferro Alloys and Titanium Extraction

Thursday AM
August 31, 2006

Room: Boardroom West
Location: Catamaran Resort Hotel

Session Chairs: Animesh Jha, University of Leeds; R. Hurman Eric, University of the Witwatersrand

8:00 AM Keynote

Phosphorus Distribution between Metal and Slag Phases Pertinent to Ferromanganese Smelting: Habib Saridikmen[1]; Serdar Kucukkaragoz[1]; *Hurman Eric*[1]; [1]University of the Witwatersrand

In this experimental study the phosphorus distribution ratios between the slag and metal phases encountered in ferromanganese smelting have been determined as a function of composition at 1500°C. The distribution results were employed to calculate the phosphide capacities of the SiO_2-Al_2O_3-CaO-MgO-MnO slags in equilibrium with the Mn-Fe-Si-C metal phase. The classical gas-slag-metal equilibrium-quenching technique was employed using CO gas atmosphere and graphite crucibles to saturate the metal phase with respect to carbon. The phosphorus distribution ratio increased from 0.045 to 0.375 when the slag basicity increased from 0.63 to 1.16. As expected, the distribution ratio decreased from 0.4 to 0.105 when silica increased from 37.4% to 45.8% in the slag phase. Empirical relationships are being developed to express the phosphorus distribution ratios and phospide capacities of the above slags.

8:25 AM

The Effect of Carbon Material Properties on the Reduction Kinetics of Manganese and Silicon from Slag to Metal: *Gabriella M. Tranell*[1]; Sean G. Gaal[1]; Dechun Lou[1]; Jaafar Safarian[2]; Leiv Kolbeinsen[2]; Merete Tangstad[2]; [1]SINTEF Materials and Chemistry; [2]Norwegian University of Science and Technology

In the manganese ferroalloys industry, there is increasing focus on the performance of different carbonaceous materials within the smelting processes. With a developing scarcity of traditional raw materials, new carbon sources are being identified for potential use in the processes. For this purpose, it is important to be able to predict the suitability of different materials in the process. Hence, the effects of both the physical and chemical properties of the carbon material on the reduction kinetics of manganese and silicon from slag to metal, have been investigated using an advanced sessile drop technique. Using this technique, the reaction patterns of SiO2-MnO containing slag droplets in contact with various solid carbon materials (graphites with different properties as well as cokes and charcoals) at 1400 to 1600°C were studied in-situ. In addition, slag and metal reaction products from kinetic experimental series were analysed. From these results, differences in reactivity between various carbon materials and slags were demonstrated and explained. Mechanisms for both manganese and silicon reduction were proposed.

8:50 AM

The Importance of the Slag Phase in Electric Smelting of PGM Containing Sulfide Concentrates: *Hurman Eric*[1]; [1]University of the Witwatersrand

In this review paper the effect of composition and temperature on electrical conductivity and viscosity of the slags encountered in electric smelting of PGM-containing sulfide concentrates is described along with their liquidus temperatures. Optimization of slag composition is attempted on the basis of opposite trends of viscosity and electrical conductivity. Metal losses to slag, matte-slag separation and matte settling are also discussed in conjunction with interfacial and surface tension concepts. The electrode immersed in the slag phase is the main factor in the design and operation of the furnace. The most important elctrode parameters are the size and the positioing in the slag phase which are determined by the slag resistivity, furnace resistance, cell constant and power input. The flow of heat generated by the electrode current determines the energy distribution and furnace dimensions creating viscosity

profiles within the slag phase which in turn affects the flow conditions. Thus the flow of slag is discussed together with furnace geometry, stirring action, buoyancy and electromagnetic effects. The action of the electric furnace as a settler is emphasized. A discussion on the design and production capacity of the furnace is provided which are based on considerations derived mainly from slag properties.

9:15 AM

Tracking Chromium Behaviour in Submerged Arc Furnace for Ferrochrome Production: Yanping Xiao[1]; *Yongxiang Yang*[1]; Lauri Elias K. Holappa[2]; [1]Delft University of Technology; [2]Helsinki University of Technology

In submerged-arc furnace for smelting chromite ores into ferrochrome, there exist large temperature gradients and wide distributions of mineralogy and compositions in the furnace, due to the complexity of feed structure and electrical-thermal-chemical interactions. This leads to various zones in the furnace and thus different reaction mechanisms. In the present paper, the behaviour of chromium in the submerged arc furnace is discussed in steps in various reaction zones of the production process, including chromite reduction with CO in solid state, structural changes of partially reduced chromite in the smelting zone and recovering chromium from slag to metal. In the gas-solid reaction zone, the reaction kinetics is presented and compared for both lumpy ore and pellet reduction. The reaction mechanism is discussed based on the experimental observations and analysis. In the smelting zone, the behaviour of partially reduced chromite is examined, and slag formation is addressed. The slag in FeCr process contains mainly Al2O3, MgO, SiO2, CaO and CrOx, featured by chromium with both divalent and trivalent oxidation state. The role of slag for chromium recovery is very important, and thus the relevant thermodynamic properties of FeCr slag are summarized. In addition, the factors influencing the slag/metal reaction and the chromium recovery are described. A concept of process model is established based on the process fundamentals and experimental data, which is aimed to improve the process understanding and performance.

9:40 AM Break

9:55 AM Keynote

Selective Separation of Rare Earths from Titaniferous Ores during the Production of High-Grade Synthetic Rutile: *Jeya Kumari*[1]; Animesh Jha[1]; [1]University of Leeds

The demand for titania pigments and the shortage of higher-grade titaniferous ores worldwide has encouraged new techniques for the beneficiation of lesser grade titaniferous ores. The presence of zircon and monazite in ore also increase the chlorine gas consumption in FBCR (Fluidised bed chlorine reactor) and contribute to a larger volume of hazardous waste, which must be neutralised before being disposed off. In view of the problems described for lanthanide and actinide trace impurities in titaniferous ores, an alternative route, for processing difficult ores, is discussed. In the new process, the ore is roasted with sodium carbonate below 950°C to promote the formation of water soluble sodium ferrite and insoluble sodium titanate phases. In this investigation, the roasting process and the ensuing hydrometallurgical leaching steps have been analysed in context of selective separation of lanthanide and actinide minerals from the main minerals. Evidences for the selective separation are presented based on the chemical (XRD, XRF) and microstructural analysis (SEM, EDX, EPMA) of roasted mass and the leached product. The paper highlights the various thermodynamic aspects of reaction equilibrium in the Fe-Ti-O-Na system, and the effect of Eh-pH diagram in the determination of pH required for the better removal of iron and sodium. Two different types of Ti ores, namely ilmenite and anatase, their crystal structure and the phase transformation will also be explained on the basis of wet chemical analysis, XRF, XRD, EPMA and SEM-EDX studies. The method developed examines the technological feasibility of the selective separation process.

10:20 AM

Reduction Behaviour of Chromite in the Presence of a Hydrocarbon Gas: Maria de Campos[1]; *Hurman Eric*[2]; [1]Hatch South Africa; [2]University of the Witwatersrand

The pre-reduction behaviour of chromite particles in methane-argon and methane-hydrogen gas mixtures was investigated between 1050°C and 1250°C. Loose bed of chromite particles were reacted in a vertical tube furnace under a pre-set gas mixture for predetermined time intervals. Metallisation results were obtained for the Cr and Fe components by chemically analysing the reaction products. SEM-EDAX techniques and X-ray diffraction were employed to elucidate the reduction mechanism. It was found that higher reduction kinetics and higher Cr:Fe ratios in the metal phase could be achieved when hydrocarbon gas was used in comparison to classical carbothermic reduction at a given temperature. The reduction rate was generally bulk gas mass transfer controlled to the reaction site for initial stages which then was followed by ionic diffusion rate control. It is proposed that methane did not partake directly in the reduction but cracked, presenting the reaction site with hydrogen gas and atomic carbon, which was able to immediately react at the immediate area of reduction regenerating CO and H_2 and thus maintaining a low partial pressure of oxygen at the reaction site.

10:45 AM

Prereduction of Chromite Agglomerates: Serdar Kucukkaragoz[1]; *Hurman Eric*[1]; [1]University of the Witwatersrand

The Kinetics of pre-reduction of chromite by carbon was studied under argon atmosphere at temperatures between 1000° and 1300°C. The compacted and agglomerated specimens were reacted by using a TGA system. The mixing characteristics and the degree of compaction of the chromite and coke particles were the main parameters influencing the reduction kinetics. The reduction rate increased with temperature reaching 81% reduction at 1300°C. Metallization started around chromite particles at 1100°C. The particles were surrounded by the metallic phase at approximately 40% reduction level obtained at 1200°C. At 1300°C, the reduction proceeded with a high rate during initial stages and with a low rate at final stages. The reduction was found to proceed in the sequence of Fe^{3+} to Fe^{2+} to metallic Fe and Cr^{3+} to metallic Cr with the formation of carbides.

11:10 AM

Carbothermic and Magnesiothermic Reduction of Titanium Dioxide - A Thermodynamic Analysis: *Dinabandhu Ghosh*[1]; [1]Jadavpur University

The stability diagram of the ternary system Ti-C-O is drawn in the present work for four temperatures, 1473 K, 1573 K, 1673 K and 1873 K, showing the stability fields of TiC, Ti, TiO, Ti_2O_3 and TiO_2. An analysis of the system reveals that it is not possible to produce Ti in a carbon-saturated system; instead, the stable product is TiC. However, Ti can be an equilibrium product in a carbon-unsaturated system at prohibitively low values of p_{CO} and $p_{CO}2$; for example, at 1873 K, these limiting values are: $p_{CO} = 10^{-6.76}$ atm and $p_{CO}2 = 10^{-13.36}$ atm, which, when exceeded, produce TiC and TiO respectively. The magnesiothermic reduction is examined through the stability diagram (log p_O2 vs. 1/T) of the system Ti-Mg-O, drawn for a number of p_{Mg} values, presenting the pairwise stability fields such as Mg(l) + Ti(s), Mg(v) + Ti(s), MgO(s) + Ti(s), etc. The diagram shows that magnesium reduction of TiO to Ti is possible only at T < 1641 K with $p_{Mg} = 1$ atm and only at T < 1569 K with $p_{Mg} = 0.5$ atm. An experimental scheme for Mg vapor reduction of TiO_2 is proposed in which an argon stream is passed over a Mg (liquid) evaporator at temperature T_1 (say, 1234 K); the resulting Ar-Mg mixture at 1 atm is subsequently flown over a bed of TiO_2 at temperature T_2. A thermodynamic analysis establishes that complete reduction to Ti is possible and that the best results are obtained when $T_1 = T_2$.

Thermo and Physicochemical Principles: Steel Making: Modeling and Processing

Thursday AM
August 31, 2006

Room: Russeau Suite
Location: Catamaran Resort Hotel

Session Chairs: Heikki Kusti Jalkanen, Helsinki University of Technology; Peter J. Koros, Koros Associates, Inc

8:00 AM Keynote
Experiences in Physicochemical Modelling of Oxygen Converter Process (BOF): *Heikki Kusti Jalkanen*[1]; [1]Helsinki University of Technology

BOF is a highly complex metallurgical process comprising a number of simultaneous chemical reactions proceeding in several reaction environments in connection with complicated heat and mass transport procedure in the reactor. It is obvious that even a simplified model describing the chemical and thermal progress of the process requires combination of thermodynamic and mass transfer phenomena. The basic characteristics of the process to be taken in to account in simulation of BOF are: 1) Thermodynamic affinities of oxidation reactions control the oxygen distribution between oxidising elements; 2) Intensity of agitation in the iron bath controls the concentration of impurity elements at superficial regions of iron bath where the primary oxidation reactions proceed; 3) Heat from highly exothermic oxidation reactions is consumed in heating up the fluid phases in the reactor, heating up and melting the solid charge and lost by radiation and conduction during and between the blows. Oxygen converter simulator CONSIM-5 simulates the chemical and thermal evolution of the process on the base of the above mentioned three groups of phenomena combined with parameters assessed against or obtained from actual BOF practise. Simulation program basic chemical reaction and mass transfer models and several submodels for "secondary" phenomena taking place during a blow. The basic chemical, thermal and transport phenomena and problems involved in the simulation of BOF-process is analysed and discussed independently as well as in connection with experience from simulation of actual converter blows using CONSIM-simulator.

8:25 AM
Reduction Behavior of BOF Slag: *Sung-Mo Jung*[1]; Young-Ju Do[1]; [1]Pohang University of Science and Technology

In the first part of this research, experiments were carried out on a system with artificially prepared slags in a graphite crucible, in order to examine the possibility of recycling BOF slags produced in the steelmaking process. More than 80% of FeO and P2O5 was reduced within 20 minutes and the FeO reduction rate was greater than that of P2O5. P2O5 reduction began after more than 60% of FeO was reduced. Increasing slag basicity enhanced the reduction of FeO and P2O5. Temperature also improved slag reduction. The overall reduction rate was controlled by the chemical reaction at the slag/carbon interface. The reduction rates of FeO and P2O5 were second and first order with respect to their respective contents. Most of the reduced phosphorous is believed to vaporize in the form of P2 gas. In the second part of this work, BOF slag was reduced by dissolved carbon in iron for examining its smelting reduction. The reduction reactions of FeO and P2O5 steadily proceeded and the reduction rate of FeO was almost similar to that of P2O5. The reduction reaction of FeO and P2O5 in BOF slag at the slag/gas interface would be rate-controlling step. The reaction rates of FeO and P2O5 by dissolved carbon in molten iron were first orders with respect to their respective concentrations. The reduction reactions of FeO and P2O5 by dissolved carbon in iron were believed to be much closer to equilibrium state compared with those by solid carbon. It is important to control the portion of phosphorus vaporization during the reduction treatment for the efficient operational conditions of BOF slag reduction.

8:50 AM
An Explanation for the Effect on Steelmaking of Titanium in Hot Metal: *Peter J. Koros*[1]; Stuart Street[2]; Randall P. Stone[3]; [1]Koros Associates Inc; [2]Severstal, NA; [3]Heraeus Electro-Nite, Company

The recent interest in this topic is the result of increased use of titaniferous ores, e.g. of ilmenite, in blast furnace burdens for the purpose of repairing hearth damage. However, the titanium compounds that promote deposition of "patching" materials in the Blast Furnaces are the cause of downstream problems in the steelmaking shops. Steelmakers historically have objected to the presence of titanium in hot metal for several reasons: (1) accretions caused by the TiC.TiN needles that float out of the iron as it cools in transit and in transfers make the accompanying slag sticky and crusty, causing problems in desulfurization and the subsequent raking step, (2) a rationale has been developed for the effectiveness of a defensive measure taken in treatment, such as use of argon for carrier gas, (3) there is significant difficulty in removal of the ladle slag by the raker, with subsequent sulfur addition to the vessel charge, and (4) transfer into the BOF and/or formation of a very corrosive TiO2 containing acid slag during the early part of the BOF blow which, in addition to causing lining damage, results in loss of sulfur removal capability by the vessel slag. These issues, and related effects on sampling the hot metal, are examined in detail with reference to the literature and actual plant experience.

9:15 AM Keynote
A Study of Freeze Layers in Smelting Furnaces: *Fernando J. Guevara*[1]; Gord A. Irons[1]; [1]Steel Research Centre, McMaster University

Many Smelting and slag-cleaning furnaces operate with cooling systems designed to freeze a slag layer over the refractory to protect it. The fluid flow and heat transfer conditions associated with the freeze layer and mushy zone are poorly understood. These phenomena were simulated with a small-scale room temperature, 2-dimensional model, using an aqueous solution of calcium chloride to simulate the slag. Reasonable similarity with conditions encountered with copper and nickel smelting systems was achieved ($Pr \approx 50$ and $Ra \approx 10^8$, in the laminar-turbulent transition). Measurements of the freeze layer development and velocities were made with the Particle Image Velocimetry (PIV) technique. Direct Numerical Simulations (DNS) were also made of the unsteady fluid flow and heat transfer problem. It was found that the solidification process is well-described using an improved model for high molecular viscosity in the mushy zone. Solid front growth, isothermal profiles, velocity profiles and heat transfer through the walls showed good agreement between the PIV and DNS results. Experimental and numerical velocity profiles close to the freeze layer show a parabolic behaviour in the vertical velocity profile which is completely different from the calculation of heat transfer using a sharp interface model. The reason for this is attributed to the effects of the mushy zone with a high viscosity and high shear stresses acting on that area.

9:40 AM Break

9:55 AM
Physical Modeling of a RH Degasser to Study Decarburization Rate: *Roberto P. Tavares*[1]; Tiago J. P. Belarmino[1]; Alysson T. P. Almeida[1]; Jairo A. Alvarenga[1]; [1]Federal University of Minas Gerais

Steels with low concentrations of nitrogen, hydrogen and carbon have in large demand lately. The RH process is a secondary refining process that can simultaneously attain significant levels of removal of these interstitial elements from liquid steel. In the RH process, the melt circulation rate plays a very important role in determining the productivity of the equipment, since it affects the decarburization rate. In the present work, a physical model of a RH degasser in a 1:5 scale of an industrial reactor has been built and used in the study of the circulation rate and of the kinetics of decarburization. The effects of the following parameters have been analyzed: - gas flow rate;- configurations of the nozzles used in the injection of the gas. Different number, diameter and location of the nozzles have been tested in the experiments; - diameters of the upleg and downleg snorkels. The decarburization reaction of liquid steel was simulated using a reaction involving CO2 and caustic solutions. The concentration of CO2 in the solution was evaluated using pH measurements. The experimental results indicated that the kinetics of

decarburization can be described by a first order equation. Based on the results, it was possible to determine the contributions of the decaburizations in the upleg and in the vacuum vessel.

10:20 AM

Design of Steel for High Speed Machining: *Mani Subramanian*[1]; [1]McMaster University

The tooling for high speed machining is well advanced but the steel design for high speed machining has lagged behind. The paper examines the design of steel in order to control the sliding tribology for high speed machining under dry machining conditions. In high speed machining of steel, accelerated chemical wear of the tool occurs once atomic contact is established at the tool-chip interface, resulting in poor tool life even with high performance tools such as cubic boron nitride. Recent research has confirmed the occurrence of nanocrystalline grains in the interfacial layer of the chip at the tool-chip contact. The volume percentage of grain boundary is increased significantly (10 to 30%) as the nanocrystalline grain size is decreased well below 30 nm. The solubility of tool material into the nanocrystalline grain boundary is two or three orders of magnitude greater than in the crystal lattice. Further the kinetics of diffusion in the grain boundary is seven or eight orders of magnitude greater than in the crystal lattice. The accelerated chemical wear is caused by enhanced nanocrystalline grain boundary diffusion occurring in the interfacial layer at the tool-chip contact. Significant improvement in tool life could be achieved in machining of steel by engineering glassy oxide inclusions designed to self-lubricate the tool-chip interface in-situ at higher cutting speeds. Thus the control of sliding tribological conditions at the tool-chip interface is key to suppress nanocrystalline layer formation at the tool-chip contact and hence prevent accelerated chemical tool wear.

10:45 AM

Elastic T-Stress Evaluation from FE Analysis for Mode (I) Loading in X52 Arc of Pipe Specimens: M. Hadj Meliani[1]; M. Benarous[2]; A. Ghoul[3]; *Z. Azari*[4]; [1]University of Chlef/University of Metz; [2]University of Chlef; [3]Detached with the Ministry of Labour Public; [4]University of Metz

This paper explores direct use of finite element analysis by CASTEM 2000 in order to determine the evolution of T-stress term for arc of pipe specimens with external surface crack. A simple method, called the stress difference method proposed by Yang (1999), is used to compute the elastic T-stress in mode I at a crack tip. The different crack geometries and length-to-thickness ratio on T-stress and stress-intensity factor (SIF) are examined. The revisited stress difference method is shown to be an accurate and robust scheme for evaluating T-stress in arc of pipe.

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