Symposium on:

Sustainable Materials, Processes & Technologies:
Future pathways for reducing greenhouse gas impacts of materials.

7-8 July 2011

Lecture Theatre G02, Building F8, UNSW Kensington lower campus

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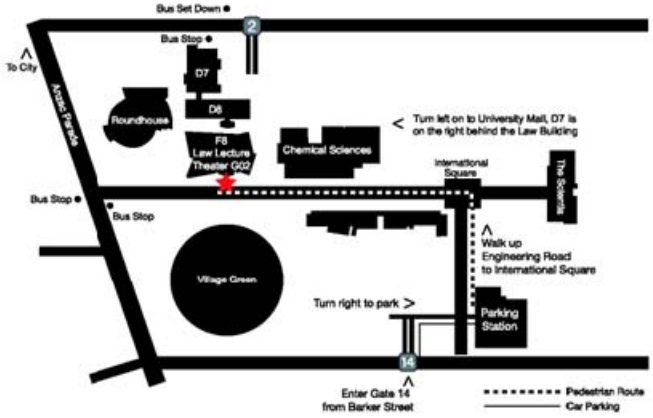

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Ferrous Metallurgy Research Group
Dept of Energy Science & Technology
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University of Tokyo
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International Research Centre for Sustainable Materials
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Plenary Session

Day 1

Keynote Address

Current Status of Technologies for Recycling Rare Earth Metals and Alloys

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In recent years, there have been significant changes in the supply and price situation of rare earth metals and compounds. Considering the serious shortage in the supply of the rare earth minerals and the environmental problems related to the mining and smelting of these ores, it is essential to develop a new process for recycling rare earth metals and their compounds. With this background, researchers in Japan are becoming actively involved in the development of efficient processes for recycling rare earth elements from scrapped electronic appliances.

In this talk, the current status of rare earth metals and compounds, especially in the context of the high-performance magnet industry in Japan will be reviewed. Further, various types of recycling processes that are presently under development, are introduced, and their features and differences are discussed.

Some fundamental research work carried out at the Okabe laboratory is also introduced in brief. For example, the selective extraction of neodymium (Nd) and dysprosium (Dy) by using metal halides to develop a new process for the recovery of Nd and Dy from scrap rare earth magnets. For preliminary experimentation, magnesium chloride ($MgCl_2$) was selected as the extraction agent, and molten $MgCl_2$ was reacted with Dy-containing Nd–Fe–B magnet alloys. Experimental results revealed that the rare earth elements in the magnet alloys were successfully extracted to the $MgCl_2$ in high yields. After the removal of $MgCl_2$ by vacuum distillation, Nd and Dy could be separately recovered by either a wet or a dry process. The effectiveness of $MgCl_2$ and other metal halides (*e.g.,* zinc iodide (ZnI_2)) as extraction agents, and the feasibility of the effective recycling of Nd–Fe–B magnet scrap will be evaluated.

The advantages and disadvantages of the new recycling processes are evaluated, and the possibility of establishing new recycling processes in the future is discussed from a multilateral perspective. The future scope of technologies for recycling rare earth metals and compounds will be discussed in the talk.

Keynote Address

Thermal plasma processing of industrial wastes for recovery of valuable materials

P. S. Mukherjee [(1)] and **B.K.Mishra** [(2)]

[1.] Scientist, Institute of Minerals & Materials Technology(CSIR), India

[2.] Director, Institute of Minerals & Materials Technology(CSIR), India

Disposal of industrial waste generated by developing and developed countries pose a major threat to the environment. Storage in landfills has been used most often in the past, but as more and more of these wastes are being declared hazardous and landfill cost have risen significantly, a method has to be found for treatment of these wastes. The high cost of landfill is a strong incentive for developing such a process with minimum environmental hazards. Further with the depletion of natural industrial mineral resources and the increasing emphasis on the environmental protection from the expanding waste generation, it is critical to develop processes to recover some of the valuable resource from these wastes as well as to make secondary products from these for the benefit of mankind. It is with the above theme in mind the present work was undertaken to find suitable treatment of the large amount of hazardous solid waste generated.

a) Thermal plasma processing of electronic waste for recovery of metal values.

Electronic wastes are physically and chemical distinct from other wastes since it contains large number of toxic ingredient that give rise to environmental risk as well as health hazards. However e-wastes contain a number of valuable metals such as copper, aluminum, iron, lead, cobalt and precious metals like gold, silver and palladium. In course of the present investigation, thermal plasma processing has been developed which not only recovers the present metal values but also destroys large amount of toxic materials including plastics. The flue gas generated is treated separately and can be used for energy generation at an appropriate scale. The obtained metallic product can be subjected to leaching and other chemical routes to recover metal values. The leach residue could be enriched significantly for the precious metal such as gold and silver.

b) Plasma smelting studies of solid waste effluent from dichromate/chromic acid plants for recovery of metal values; the solid waste generated from dichromate/chromic acid plant contains about 1% hexavalent chromium which is toxic and vulnerable to water leaching. However, apart from hexavalent chromium, solid wastes also contain about10 to 15 % iron and chromium. Thermal plasma process is a suitable and eco-friendly method to destroy the toxic hexavalent chromium and recover the metal values as ferrochrome. Process economy can be improved

satisfactorily by adding a defined amount of chromite ore to the waste.

c) Plasma smelting studies of toxic dusts and sludges smelted from steel plants to recover metal values:

Toxic dusts and sludges generated in various steel plants contain heavy metals such as Zn, Pb, Cd & Cr as a result they can not be disposed of in land fill. Thermal plasma process can be used for removal of heavy metals and their subsequent recovery from the dusts and sludges. The heavy metal powders are obtained as condensate powder. The sludge satisfies the toxic characteristics leach procedure and can be disposed of in land fill, while the pig iron can find specific application based on its composition.

Keynote Address

Recycling Rubber Tyres in EAF Steelmaking

Paul O'Kane,
OneSteel, Rooty Hill, Sydney, Australia

Electric Arc Furnace (EAF) steelmaking uses different carbon based materials as foaming agents. Depending on cost and availability, anthracite and metallurgical coke are among the conventional injecting materials. Considering the energy and green house gas emissions requirements, alternative carbon sources are put on the spot to replace, at least partially, the conventional materials, *i.e*. waste materials such as rubber derived from end of life tyres may react with gas and slag phases resulting in devolatilization, combustion and iron oxide reduction reactions. The addition of waste tyres in EAF steelmaking has been studied in detail by our groups at UNSW and OneSteel is developing a method for EAFs to use blends of different proportions of rubber and coke as a slag foaming agent. Initially, laboratory investigations were carried out to establish the feasibility of carbon and polymer blends as foaming agents. The enhanced slag foaming performance compared to coke was found to be in good accordance with the results obtained in the laboratory indicating an increased slag volume when using polymeric blends. Following the successful installation of materials handling systems at both plants, the use of a rubber and coke blend is no longer considered a trial and is instead standard practice.

Sustainable Materials –

Technology and Business

Day 1

The Present & Future of Hyundai Steel

Dr Eungyeul Park,
Hyundai Steel, Korea

As a member of Hyundai-Kia Automotive Group, Hyundai Steel Company has completed the New Integrated Steel Mill Project in Dangjin with the capacity of 8 million tons per year, as of last year, 2010. The New Mill is equipped with state-of-art facilities, eco-friendly raw material storage system, two blast furnaces (4 million capacities each, 5,250Mn^3 inner volume with the designed productivity of 2.1), meltshop/continuous caster, hot strip mill and plate mill.

The main products from the Hot-Strip Mill are Automotive steel sheets to be used for Hyundai-Kia Motors and the part-suppliers for it, and the ones from the Heavy-Plate Mill for various ship-builders.

To satisfy the more getting severed requirement from the customers, Hyundai Steel founded R&D Centre early 2007, three years before the hot commissioning of the blast furnace. Now over 300 researchers are working in the R&D Centre, which is equipped with pilot facilities and Hyundai Steel to be one of the top level manufacturers in the world will be introduced.

Material Sustainability in Small Scale Biomass Production

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The quest for energy sources that are based on renewable resources has become a topic of considerable interest. The use of biomass is one of the more popular approaches since in principle it may be considered to be carbon neutral. Nevertheless, sustainability requires the utilization of all of the biomass material not just the fuel value. In this work, the challenge of a no-waste biogas system is explored. The key to developing the system is in understanding the solids and how they may be processed to become part of the solution rather than part of the problem.

Biowaste residue from a farm, which had implemented an anaerobic digester to produce biogas, was investigated as a potential source of activated carbon. The solids were dried and then carbonized at 700^{o}C and then steam activated at 850^{o}C. In laboratory work, the activation was carried out in a tubular reactor. The conditions for the activation affected the properties of the carbon produced. Although activated carbon has many uses, in this work the specific function required was to clean the biogas of sulphur contaminants and thus avoid a chemical cleaning stage which produces secondary waste. The activated carbon was demonstrated to be very effective in hydrogen sulphide capture as seen in the figure and surprisingly, in converting the hydrogen sulphide to elemental sulphur. The conversion is very beneficial since hydrogen sulphide is an odorous, toxic contaminant, while sulphur in activated carbon has agricultural value. The used activated carbon thus becomes a useful byproduct. XPS analysis of the activated carbon before and after sulphur capture was used to determine the nature of the sulphur loading on the carbon.

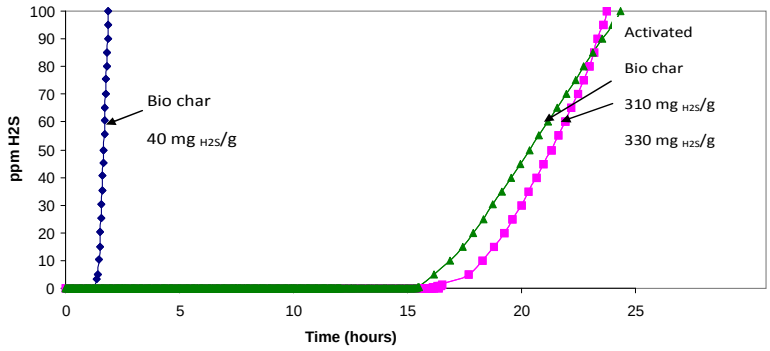

Figure 1 H2S Absorption from a 400 ppm gas stream

E-scrap Recycle in Japan

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A practical usage of urban mine and its system formation are one of the most challenging and important issue to be progressed. In Japan, Home Appliance Recycling Law and End-of-Life Vehicle (ELV) Recycling Law are enforced since 2001 (former) and 2005 (latter). These Laws may play a part to reduce illegal waste disposals and to properly control hazardous substances. However, in the case of recycle, it seems less affected since a further recovery procedure, for example recovery of less-common-metals, has not additionally and adequately installed. Mainly the previously-existing recycling processes are operated. According to the sustainable resource management, further progress for the special minor metals recovery may become the key issue.

On the other hand, there is no regulation and legislation for collecting small-sized E-scrap such as cell phones, mobile audio players, digital cameras, and etc in Japan. The contain ratio of special minor metals in small-size E-scraps can be much higher than that in home appliances and ELVs. To help to figure the operability of special minor metals recovery from small-size E-scraps, we will introduce the estimation on how much less-common-metals are accumulated in a society through all E-scrap from home appliances, ELVs and small domestic appliances in Japan. Then we will introduce experimental trials of collecting small-size E-scrap operated in some parts of Japan and how to recover minor rare metals from them

Modeling the impact of Iron ore properties on Energy Use and GHG Emissions for the primary plants of an Integrated Steel Works.

Harry Brunger, Leigh Harris and Michiel Freislich
HATCH Ltd. Australia

The selection of iron ore for processing into steel products has traditionally been influenced by a number of factors that determine the economics and practicalities of running a successful process. Such factors include the ore grade, cost, geographic location of the plant relative to the ore body, availability, level of contaminants and suitability to the process. However, environmental legislation is rapidly changing - especially around energy efficiency and associated greenhouse gas (GHG) emissions. The additional criteria regarding GHG emissions are becoming more prevalent and will be a major cost factor in the selection and beneficiation of raw materials in general and iron ore in particular.

Recently Hatch developed a sophisticated Value - In- Use Model which enables iron ore producers to investigate the impact of ore chemical and physical properties on blast furnace operation and the corresponding cost implications on steel product. Using this knowledge, ore vendors are able to negotiate an ore price with the blast furnace operator. The model also enables steel producers to assess the impact of a different ore types at various replacement ratios on their blast furnace and steel operations in terms of productivity, chemical energy requirements, scrap requirements and cost.

Modelling the impact of ore properties on blast furnace operation combines a mass and energy balance with a number of modules which describe the effect that the physical properties of ore have on the blast furnace productivity in terms of furnace pressure drop and the necessary blast volume change to maintain stable operation.

We compare the impact of various ore grades on energy consumption and GHG emissions for a typical integrated steel works utilizing a 2 MTPA blast furnace plant and analyse the impact this can have on the production cost if a price on carbon is introduced. Our findings show that if a carbon price is introduced the impact on production can make a material difference to the Value-in-Use of various ore types and varying replacement ratios.

Waste to Wealth: Production of Pig Iron from NALCO Redmud by Application of Plasma Smelting Technology

P. S. Mukherjee [(1)], B.Bhoi [(2)], C.R.Mishra [(3)], R.R.Dash [(4)], B.K.Satapathy [(5)], K. Jayasankar [(6)]

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Red mud (bauxite waste) emerges as by-product from the caustic leaching of bauxites to produce alumina leading to serious storing problems. In this study, red mud, which is the industrial waste of NALCO Plant (India), was investigated for use in the manufacturing pig iron for iron & steelmaking industry. The use of thermal plasma reactors for pyrometallurgical applications is fairly recent and it is slowly gaining the confidence of researchers. Plasma reactors can be designed for various applications such as melting of refractory metals and compounds, smelting of fine ores and decomposition of minerals etc. This present study proposes thermal plasma technology to treat red mud wastes. Since NALCO red mud contains 15-40% iron, the iron can be recovered by the plasma smelting process for the production of high quality pig iron. This material may be considered as low grade iron ore for the production of pig iron. The present paper deals with the use of thermal plasma technology for the production of high quality pig iron from the red mud. The effect of various process parameters like basicity, reductant, plasmagen gas, input electric power and reduction time on recovery of iron has been studied and optimized. In this study, an optimized result shows that the basicity of 0.3 and reduction time of 25 minutes is optimum at which the maximum recovery of iron (70%) is obtained for a scale of 1kg.

High-Sulfur Petroleum Coke-Derived Porous Carbons for Environmental and Energy Applications

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High-sulfur petroleum coke is being produced in large quantities around the world. In Alberta Canada alone, over 20,000 tonnes are produced a day, as a by-product of upgrading bitumen from the Athabasca oil sands deposits, adding to the existing stockpiles of over 45 million tonnes. Despite of its high carbon contents (~85 wt %), the sulphur content of the coke (7 wt%) limits its use as a solid fuel. To utilize the coke, chemical and physical activation processes have been developed by the Green Technologies Lab at the University of Toronto.

These processes convert the coke to carbons with various porous structures and surface chemical groups. The porous carbons are then used for various applications, including air and water purification as well as electrical energy storage. This talk starts with the development of activation processes and the characterization of porous carbons, followed by examples of applications. The specific applications include vapour mercury capture from flue gases, polycyclic aromatic hydrocarbons (PAHs) adsorption from processed waters, and carbon electrode for electrochemical double layer capacitor a.k.a. supercapacitor.

The focus of the talk is on the importance of physical and chemical characteristics of carbons in determining the effectiveness of these applications. At the end of the talk, challenges and future works are discussed.

Reuse, Recycle and Disposal of Used Reverse Osmosis Membranes

William Lawler and Pierre Le Clech,

Reverse osmosis (RO) membranes are now core to modern desalination processes and are widely used. These membranes usually need to be replaced every 5-8 years (several times in a plant's lifetime), with typical replacements being in the order of one hundred elements for each 1000 m3/d of installed product water capacity. Depending on the size of the plant, thousands of membrane elements can be used at once, for example the new desalination plant in Sydney that was recently commissioned uses approximately 36,000 DOW FILMTEC™ reverse osmosis membrane elements. As a result, this recent development of desalination plants based on RO technology in Australia will undoubtedly lead to a significant increase of the amount of spent modules. At present, no option, other than landfill discharge, is proposed to the membrane users. This current convention for end-of-life desalination membranes results into increased pressure on current landfill utilities in the community. The main benefit of this project is to minimise these impacts by increasing the lifecycle of the membrane elements via a secondary use or material reuse and thereby lowering the carbon footprint and improving sustainability of the desalination technology. This presentation will present the initial work conducted for assessing the technological and financial readiness for strategies designed for the reuse, recycling and disposal of aged RO modules: (1) Recycling of RO modules into microporous membranes, where different chemical treatments (i.e. chlorine- and permanganate-based compounds) have been tested to remove the polyamide active layer present on the membrane surface. Once stripped from the dense layer, treated modules have the potential to be reused as porous membranes if the integrity of the supporting layers and the overall stability of the module elements are not significantly challenged. The polymer material removed from the RO modules (dissolved in a solution from the conversion process) could be captured and treated to recover valuable polymer material. (2) Reuse of RO membrane modules. There is a strong potential to directly reuse the spent RO membranes with little treatment (i.e. cleaning) or ideally with no treatment at all. Factors that will be considered in this stage will include technical feasibility via pilot testing of real disposed membranes from desalination plants in partnership with Dow, marketability, and financial assessment; and (3) New methods for disposal of RO at the end of their life time, such as, use in Electric Arc Furnace Steel-making to substitute coke, use as a structural element (traffic bollard, water guttering, water storage container, separation and shredding components for use as filler material, aggregate, and reuse of membrane parts (i.e. endcaps, housing, seals and possibly permeate tube)

Changing World Mining Business & Diversifying Mineral Security Players in Japan

Kenji Sawada
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Adviser, Japan Oil Gas and Metals National Corporation

World mining has been rapidly changing, and paradigm shifts such as emerging market economy, M&A, nationalism over resources, low-carbon society, inflow of investment money, etc are observed at the current mineral commodity market. The presentation will clarify its change and Japanese mineral security players in Japan as is shown below;

1. Change in the World Mining Business
2. World Mining Companies
3. Implications for the Japanese Players

The metal price (Cu, Zn, Ni, Al & Au) from May 2003 to December 2010 shows record high levels; 5～6 times higher for Ni, Zn, and Cu, and 2 times higher for Al and Au. Since July 2008, metal prices fell down to the level of 2003～2005, and once again resume higher prices since 2009. Along with the metal prices, EBIT(Earnings Before Interest and Tax) of BHP Billiton, Rio Tinto, Vale, Anglo American and Xstrata fell to the lowest level at 2009 Ist H, but then increased more than 2008 level.

BHP Billiton is characterized by diversified business such as petroleum, aluminium, base metals, coal, iron ore and minor metals etc. Since July 2008, EBIT margin of base metals, aluminium, nickel declined sharply, but iron ore and coal maintained high EBIT margin, which created rather stable EBIT margin even under the volatile metal prices.

In response to the current competitive markets and low Treatment Charge and Refining Charge, Japanese mining & smelting companies promote mine development for feeding to their smelters and recycling. Trading companies strengthen supply chain toward Japan and Asian countries. Prior to 2000, Japanese mining & smelting companies acquired minor shares and trading companies followed. After 2010, trading companies has invested independently for higher returns by taking advantage of company's scale.

Sustainable Materials – Science

Day 2

Keynote Address

Activities of International Research Center for Sustainable Materials and New Metallurgical Refining Processes for Solar Grade Silicon

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As part of the ongoing efforts toward a sustainable society, International Research Center for Sustainable Materials (IRCSM) was established in the Institute of Industrial Science at the University of Tokyo in April 2004. We are trying to solve various problems such as those encountered in the design, production, and usage of materials and the treatment of those after their lifetime. Materials in a sustainable society refer to those that are manufactured at a reasonable cost to enable sufficient performance and to ensure economic processing after they are past their useful lifespan. Focusing on the development of materials and the process of environmental-load reduction in their efforts to establish a low-carbon society as well as a system to address the approaching resource-depletion problem, IRCSM has been carrying out a number of research activities through 12 of its core members: these individuals are involved in tasks such as inspecting the recycling process of industrially important materials and their by-products, identifying a boundary condition for the design and production of materials and a disposal system, and developing new materials with extra-long life.

IRCSM is also engaged in identifying materials such as silicon, which is used in the manufacture of photovoltaic cells, and rare metals, which should be recycled on a priority basis owing to their scarcity; moreover, it emphasizes that optimal resource utilization strategies and the establishment of a production/recycling process are issues to be tackled even beyond its period of activity. In addition, it is trying to promote collaborative studies at home as well as well abroad. In particular, IRCSM has established academic exchange at the international level and collaborative research with cooperating researchers abroad, by setting up our branch offices at the University of Toronto, Ho Chi Minh City University of Technology, and Kunming University of Science and Technology. We hope this symposium will be the initiation of fruitful cooperation between SMaRT and IRCSM. We would like to contribute to the realization of a sustainable society by fully taking advantage of this opportunity that has been given to us. As a representative of our recent research activities of IRCSM, new metallurgical refining processes for solar grade silicon will be also introduced in the presentation.

Metallurgical challenges in WEEE recycling

Andreas Lennartsson, Caisa Samuelsson and Theo Lehner
Luleå University of Technology and Boliden Mineral AB, Sweden.

Referring to the title: "Challenges" in handling waste are of varying nature; 1/economic, 2/environmental, health and safety (EH&S), 3/ production and 4/product quality.

Literature abounds in laboratory studies regarding hydrometallurgical partial extraction of metal values from metal rich fractions of WEEE. The main route for industrial recovery of metal and mineral products from the same fractions is pyrometallurgy. Smelters such as Boliden have since long been in the field of recycling of electronic scrap. Here we report on some challenges that arise due to the specific nature of e-scrap; change in composition due to change in products and change in composition due to developments in the field of pre-treatment. These changes illustrate also the fact that there is still room for improvement of communication channels between the OEM's and the recyclers, but also between the industrial and academic recyclers.

Pyrometallurgical recovery follows the line; charge preparation, reducing smelting, phase separation, (copper) converting and electrorefining, and (slag) refining. A challenge in the metallurgy of recycling complex feed is the formation of various phases: 1/coexistence of speiss, matte, slag and gas, 2/ coexistence of pig iron, copper bullion, slag, gas and 3/ coexistence of slag phases. Similar challenges may face the operator of the sampling department, as varying fractions of coexisting phases may lead to sampling errors. Here experience comes well into the picture.

Although modeling will not solve all problems connected with metallurgical processes, it can be a good tool when used in combination with industrial experience to describe slag chemistry, element distribution etc. There are two great challenges when using thermodynamic for process simulation. Data used must be valid and evaluated for the actual composition range and the reactions should not be controlled by kinetics. In most pyrometallurgical processes the temperatures are high enough to assume that equilibrium will be reached. However this is not true for all situations.

The flowsheeting tool SimuSage, which is based on ChemApp and its rigorous Gibbs energy minimization routine, together with the extensive collection of thermodynamic data from FactSage is used to simulate the mass and heat balances for various process units. A model for

the copper converter has been constructed and verified against plant data. The non-equlibrium conditions are dealt by dividing the converter into segments. Equilibrium conditions are assumed to be reached within each segment and concentraton and/or temperature gradients exists between the segments. The result so far is in good agreement with plant data, which will be demonstrated in the presentation.

Consideration of the Oxygen Effect on Surface Tensions of Molten Alloys

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To control the liquid-based material processing such as melting, welding and casting process, surface tensions of liquid alloys are important physicochemical properties. For example, marangoni flow, which is caused by the gradient of the surface tension at the melt surface, affects the quality of the crystal produced by the solution growth and the shape of the weld pool. It is well-known that the surface tension of liquid metal is considerably affected by surfactive elements of oxygen, sulfur, selenium and tellurium. Especially, it is essential to understand the oxygen effect because the material in process is exposed to the atmosphere of different oxygen potential. There is, however, no promising model for describing the surface tension of liquid alloys under the oxygen potential.

In the present paper, a concept for evaluation of the surface tension of alloy melts with oxygen is discussed. Its surface structure was considered to be double layers, a surface segregated layer of alloy components and an oxygen adsorption layer. The surface composition of the segregation layer was estimated by Butler's equation and then oxygen adsorption on surface alloy elements at the segregation layer was included with Gibbs adsorption equation. The calculated results reproduced reported surface tension of alloys fairly well and may support the concept of "double layers" of the alloy surface.

Efficient Utilisation of Coal by Integrating Various Industries

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Natural gas, petroleum and coal are hydrocarbons with significantly different molecular weights and hydrogen to carbon ratios. Among the three conventional fossil fuels, coal is the most abundant and the cheapest, while petroleum is a most desirable fuel resource because it is easily processed into valuable petroleum products, especially gasoline and diesel. How to utilise coal resources, especially as a replacement of petroleum, is an important topic.

Significant resources have been devoted in research and development of technology for production of petroleum substitute from coal. There are three technical routes to convert coal into petroleum substitute: Fischer-Tropsch (FT) process, direct coal liquefaction by hydrogenation, and pyrolysis. Among them, pyrolysis is a simple process with mild reaction conditions and low capital investment, but is with the disadvantage of a relatively low yield of total gas and liquid, below 50%. The main problem for a large scale commercialisation of this technology is an efficient utilisation of the liquefaction residue, i.e. char. Integration of various industries can provide an ideal solution for efficient utilisation of coal. This includes processing coal by pyrolysis with production of liquid and solid fuel products, which can be further processed into final products in petroleum refining/petrochemical industry. The solid char generated in coal pyrolysis can be used in metallurgical industry, especially for injection in blast furnace ironmaking process. Char can also be used as fuel for power industry by replacing coal.

Current blast furnaces and coal fired power generation plants use pulverised coal as fuel. Using pulverised char to replace pulverised coal will provide the following advantages to these processes: (1) saving energy of coal grinding and enhancing combustion efficiency; (2) increasing the safety of the pulverisation operation and pulverised char storage, and making the transport of the carbonaceous materials more reliable; (3) potentially, replacing pulverised coal injection by injecting char may make blast furnace operation more stable and more productive; (4) increasing the completeness of combustion of carbon. Integration of various industries in coal utilisation provides a route for efficient utilisation of coal resources which does not need high investment in technology development and building up new plants, and will generate significant economic benefits to the industrial operators. This is especially important when the related industries are under the pressure of increasing their operation costs under the Carbon Trade Systems.

Facilitation of precious metals leaching by Zn vapor pretreatment

Hideaki Sasaki
International Research Center for Sustainable Materials, Institute of Industrial Science, University of Tokyo, Japan

Dissolution of precious metals requires strong oxidizing agents. That makes its recovery costly and involved environmental load large. It has been known that dissolution of precious metals can be enhanced by alloying. Thus we proposed a new recovery process in which precious metals are exposed to Zn vapor prior to acid leaching. If precious metals form alloys or intermetallic compounds with Zn and the products are easy to dissolve, successive leaching becomes less expensive and sounder.

However, the mechanism of the enhanced dissolution is unclear, and further investigation is required to optimize the proposed process. The enhancement may be explained by following reasons. One is an increase in surface area. From precious metal-Zn alloys, Zn dissolves preferentially leaving the precious metal on its surface. This causes generation of cracks, and the increase in surface area accelerates the dissolution of the precious metal as represented by a broken line 1 in a figure below. Another explanation is that precious metals left on the surface have an excess free energy that contributes as a part of driving force of dissolution. If we assume that preferential dissolution of Zn from alloy generates small particles of precious metals, such particles have relatively large excess free energy caused by a surface energy. Gibbs-Thomson equation shows that the excess free energy is inversely proportional to size of the particle. Thus from a thermodynamic viewpoint, small particles can be dissolved at lower potential as represented by a broken line 2 in the figure.

We examined dissolution of precious metals from its alloys containing Zn by using channel flow double electrode method (CFDE). CFDE provides a potential dependency and time variations of the dissolution. From the results, the effect of the pretreatment with Zn vapor was evaluated quantitatively.

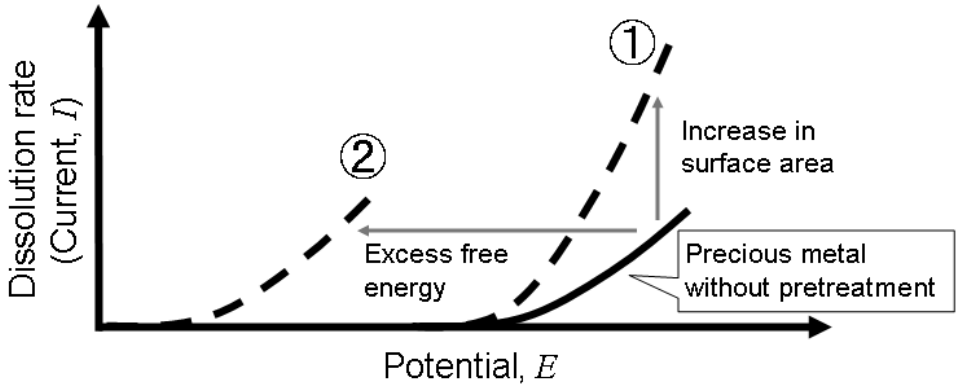

Figure 1 Two explanations for enhanced dissolution of precious metals by alloying.

LCA of a Sustainable Material Using Macadamia Shells and Castor Oil

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Macadamia shells are most commonly used as fuel for boilers (They are also commonly used as mulching). What if this valuable material resource could instead be utilised in a completely renewable, useful composite material?

Such materials could be used in the same way as chipboard, but without the formaldehyde issues. A particular application of interest is wet-area uses such as in kitchens and bathrooms. In this work we present a Life-Cycle Assessment (LCA) for using macadamia nut shells as the filler for a composite material with a castor oil matrix. We compare the environmental impact of using the shells in this way with their use as a boiler fuel. Current results are interim but look promising.

Utilization of steelmaking slag for coastal environment rehabilitation and CO_2 fixation

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Steelmaking slag is one of the main by-products of steelmaking process, and thus it has to be efficiently utilized as much as possible. In Japan, approximately 10 million ton of BOF slag is generated annually and most of them are recycled as civil engineering material. Nevertheless, about 1 % of generated slag is dumped without any utilization. Since the demand of steelmaking slag as construction material is expected to decrease, the new future demand in other fields must be explored by developing or adding the new functions of steelmaking slag.

Recently, the environment along Japanese coast has deteriorated seriously, and the improvement and rehabilitation of coastal environment is a critical issue in Japan. Recovery of marine environment will lead to the growth of sea plants, the increase of fishery, as well as the fixation of CO_2 in the atmosphere. The mixture of steelmaking slag and soil is one of the candidate materials for the recovery of coastal environment. Steelmaking slag contains various nutrition elements for sea plants such as phosphorus or silicon. Especially, ferrous ion contained in the slag dissolves from steelmaking slag into seawater and plays an important role in promoting the growth of various marine planktons. Although the efficacy of the mixture of steelmaking slag and soil on the promotion of various sea plants has been phenomenologically confirmed, the promotion mechanisms are not fully clarified.

In the present study, the dissolution behavior of various elements from steelmaking slag into seawater was studied. The shaking experiments were conducted at room temperature with various synthesized slags and different mass ratio of slag/seawater. The basicity of slag influences the dissolution behavior of elements much rather than the slag/seawater ratio. The dissolution mechanisms of various elements were discussed by using the solubility diagram.

Thermodynamic Measurement on Phosphorus Oxide in Slag Systems by Double Knudsen Cell Mass Spectrometry

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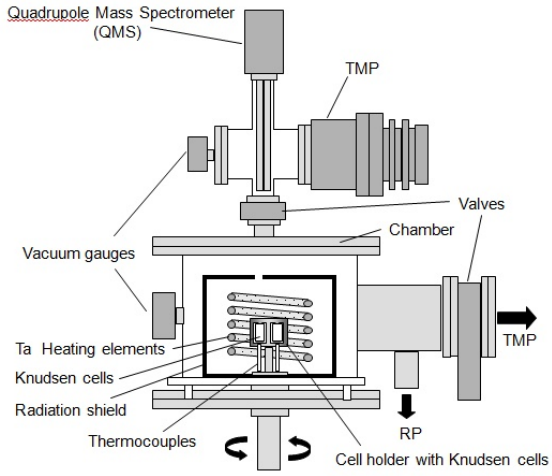
Hot metal pretreatment for de-phosphorization is a common practice in the iron and steel industry, and has been developed as an effective refining process. Although a molten flux was used traditionally in this process, a multi-phase flux, which contained liquids and solidus phases, is used today in order to avoid emission of harmful element for environment such as florin. In addition, it is possible to reduce wasted slag by use of this flux, for P_2O_5 is incrassated to solidus phase in the flux. To develop and improve this process, the thermodynamic information of the flux is necessary. Although activity of P_2O_5 in each phase is very important especially, the data cannot be measured easily by traditional methods for thermodynamic measurement. Many researchers, therefore, reported distribution ratio, L_P (ratio of P_2O_5 content in mass% of solidus phase to that of liquidus phase) of multi phase flux only. But the activity of P_2O_5 in each phase is needed to evaluate de-phosphorization ability of the flux and to discuss it thermodynamically. Therefore, a technique to measure activity of P_2O_5 and other thermodynamic information in oxide systems easily should be developed.

In this study, double Knudsen cell mass spectrometry was adapted to measure thermodynamic information of phosphorus oxide in oxide systems. Using this method, vapor pressure of phosphorus and phosphorus oxide, such as P_2, PO, PO_2 and so on, in equilibrium with P_2O_5 in oxide systems can be measured at high temperature, and the thermodynamic information of P_2O_5 in oxide system can be estimated from the pressures. The Gibbs energies of formation of some of calcium phosphates and other phosphates were estimated by this technique. The activity of P_2O_5 in slag systems was also measured in this study.



Schematic c

Recent Advances in Microscopic Analysis of Coal and Coke for Ironmaking

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Characterization of coke microstructure and mineralogy is critical to reliably predict the effect of coal properties on coke quality. A range of Australian and overseas coals with a mean maximum vitrinite reflectance (R_{max}) range of 0.68–1.71% were carbonized in a test coke oven. Coal properties were characterized using XRF, XRD and automated imaging of polished sections of discrete coal grains. The Full Maceral Reflectance (FMR) parameter, based on automated reflectance data, was modified by diluting the contribution of high reflectance coal grains as well as incorporating the effect of ash contribution to propose a combined coal index. The new coal index is shown to improve the accuracy of coke strength prediction. Current status of other microscopic techniques to characterize coal and coke properties is also discussed to show that SEM offers a promising approach for simultaneous characterization of coke micro-structure and mineralogy.

Dynamic Analysis of an Advanced Constant-Velocity Joint: Thompson Coupling

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Double Cardan and the Rzeppa joints are widely used in industry to transmit power between misaligned shafts. The Thompson coupling, is a recent innovative Australian creation, which is capable of replacing these two joints. It is superior to the double Cardan joint because it is more compact and to the Rzeppa joint as it has to sliding parts.

Since it is a new invention, at this point its dynamic behaviour has not been investigated. Its complex structure raised difficulties in constructing mathematical models for dynamic analysis. Thus, computer simulation by using suitable software packages is an appropriate approach to explore the Thompson coupling's dynamic properties. A schematic line body model of the coupling was first of all built for visualisation of the basic motion of the linkages. This model and the actual model of the coupling were then put into the simulation software for further analysis. In this work, Pro Engineer's –'Mechanism' application and SolidWorks' Motion Study add-in were used as simulation software thanks to their extensive use for dynamic characteristics investigations within industry. Finite Element Analysis, utilising ANSYS, was also employed to find the stress concentration within the coupling in a quasi-static case.

Our dynamic simulation shows that all joints in the Thompson coupling are found to bear fluctuating reaction forces; those connecting the pantograph structure having the highest magnitude. Variations in the joint reaction forces also result in minor fluctuations in the coupling output torque and velocity. Further studies reveal that these fluctuations are likely to relate to the rotational velocity of the coupling rather than the magnitude of input torque. The cause of substantial reaction force fluctuations in the pantograph joints can be explained by utilizing this finding. Pantograph linkages, unlike other components, rotate around the centre axis in an elliptical-like trajectory with varying velocities at different positions. With increasing velocity, larger constraining forces with higher fluctuations are required to maintain the unique trajectory of the linkage due to the increasing centrifugal force. The results of the quasi-static analysis confirmed this finding as the maximum stress concentration was observed in the linkages of the spherical pantograph.

Based on this theory, the fluctuations and the magnitudes of reaction forces in the pantograph joints can be greatly decreased by reducing the weight of the pantograph linkages. Weight reduction could be achieved different material selection and design modification.

A dynamics simulation of Thompson coupling indicates fluctuations in the force reactions, output velocities and output torques which might affect the smooth operation of coupling. Further studies are essential to verify the currently simulation modelling and further finite element analysis can be incorporated in the future to improve the simulation accuracy

Mechanical Behaviour of Kenaf Fibre Polyolefin Matrix Composites

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This work compares the mechanical properties and moisture absorption of chopped kenaf fibre thermoplastic composites with that of wood flour composites at a 40 wt% reinforcement loading. Both high density polyethylene (HDPE) and polypropylene (PP) were used as the matrix materials. The composites were made with and without maleic anhydride coupling agent.

The kenaf fibre composites were found to have generally superior mechanical properties to their wood fibre counterparts with higher tensile and flexural moduli as well as higher impact strength. However there was no significant improvement in either the tensile strength or the flexural strength. The addition of MAPE and MAPP coupling agents substantially increased the tensile modulus and strength. There was a more modest improvement in flexural strength but no significant improvement in flexural modulus. Impact strength was unaffected by the coupling agents in the PP composites but substantially reduced in the HDPE composites. The effects of coupling agent addition were more pronounced for the kenaf fibre composites.

Moisturization caused approximately 40% degradation in the mechanical properties of the composites with the effect being slightly worse in the wood flour composites than in their kenaf fibre counterparts.

Materials for Sustainable Panels: Comparing different matrices and fillers from food and forestry industry by products

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The focus of this research is to find the most suitable forestry and food industry by-products, binders, and technologies in Australia to develop sustainable composite materials for making panels.

Presently, Australia is the main commercial world producer of macadamia nuts, generating around 40,000 tonnes of macadamia nuts a year, out of a total global production of 100,000 tonnes. Australia is also the main eucalyptus producer in the world, with 127,024,000 hectares planted; and has 122,400,000 planted hectares of radiata pine trees (www.fao.org). These large industries produce large amounts of by products which are often treated as waste and sent to landfill; for example, in Australia the silviculture industries generate as much as 150 cubic meters of empty pinecones, and the macadamia nut industries generate as much as 28,000 tonnes of empty shells on an annual basis. These by products are under-utilised, often found in Christmas decorations, garden mulching, and animal fillers, or else incinerated, as their disposal in landfill is prohibitive, through sheer volume.

These by-products are perfectly suited to the manufacture of composite panels, as they are available clean and dry after processing, and have excellent physical properties when exposed to high humidity environments, particularly when compared to softwood. This makes them particularly suited to applications such as composites panels for furniture in high moisture environments, including kitchen and bathroom sink countertops or drawers where dimensional stability, swelling and adhesive problems are often an issue.

This paper presents results of research into composite panels made from forestry and macadamia industry by-products in Australia, identified as being particularly abundant and underused. The matrices of these composite materials have been chosen from recycled, non-toxic and organic bonding agents, being castor oil based polyurethane adhesives and recycled polypropylene. Results are presented for the relevant morphological, physical and mechanical properties. Formaldehyde emissions are compared with a conventional panel utilizing radiata pine wood and castor oil adhesive, and radiata pine wood and a formaldehyde based adhesive.

The results of the castor oil based adhesive and recycled polypropylene samples show that these new materials compare very well with commercially available counterparts, such as pine wood and urea formaldehyde adhesive composite panels, and pine wood and recycled polypropylene wood plastic composites; exceeding their performance in several cases, particularly with respect to water absorption and thickness swelling in the castor oil based samples with the new proposed fillers. The formaldehyde emissions were dramatically lower in the panels with castor oil adhesive as a binder. The mechanical properties were however poorer than those of the conventional radiata pine wood based panels. Nonetheless, it is considered that the macadamia industry and forestry by-product composites do provide a viable material and have the potential to become a sustainable replacement option for high-humidity environment furniture composites panel. This would provide much better utilization of these currently undervalued agricultural waste resources.