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New Developments in Pyrometallurgy

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Research and development in pyrometallurgy continue to attract attention from the scientific and engineering community as a result of the irreplaceable role of pyrometallurgy in the extraction and processing of metals for society. Development of energy-efficient and environmentally friendly pyrometallurgical processes continues to be pursued in the advancement of metallurgical technology and to contribute to continuous innovations in the field. In this section of the journal, ten articles are presented to address many new and diverse fields in pyrometallurgy.

In the first article titled "Highlights of the Salt Extraction Process," Aida Abbasalizadeh et al. discuss the characteristics, achievements, and future potential of a new process using molten (chloride) salts for the recovery of metals from several primary and secondary resources. The process has been identified for application in a broad range of areas, such as the treatment of metallurgical slags, recovery of lead from cathode ray tube glass, and recovery of rare earth metals from magnet scrap. It is considered a promising process for the recovery of strategic metals with the apparent advantage of being environmentally friendly. This could be one technology to watch.

In the next article, Mohassab Yousef Mohassab-Ahmed and Hong Yong Sohn report on the effect of water vapor on slag chemistry associated with a novel flash ironmaking technology in their article titled "Application of Spectroscopic Analysis Techniques to the Determination of Slag Structures and Properties: Effect of Water Vapor on Slag Chemistry Relevant to a Novel Flash Ironmaking Technology." The University of Utah has been studying this process for many years, and this article serves as an update on aspects of this important work. The CaO-MgO-SiO_2-Al_2O_3-FeO-MnO-P_2O_5 slag system with the CaO/SiO_2 ratio ranging from 0.8 to 1.4 was selected for the new flash process operating temperatures between 1550°C and 1650°C. It shows that water vapor significantly affects the chemistry of the slag and strongly affects the phase equilibria in the slag as well as the equilibrium distribution of elements (e.g., S, P, and Mn) between slag and molten metal. These results may provide a useful guide for controlling the quality of the produced iron, the iron loss into the slag, and the lining erosion.

The next article titled "Thermodynamic Analysis of Looping Sulfide Oxidation Production of MoO_2 from Molybdenite for Energy Capture and Generation" by Joseph D. Lessard et al. reports on the new looping sulfide oxidation process. Building on an earlier *JOM* article, it describes the selective and efficient production of MoO_2 from MoS_2 concentrates through the conversion of MoS_2 to MoO_2 with O_2 and MoO_3.

The fourth article is concerned with new developments in nickel laterite technology. In this article titled "Carbothermic Reduction of Nickeliferous Laterite Ores for Nickel Pig Iron Production in China: A Review," Mingjun Rao et al. review new developments in laterite metallurgy, in particular, in the so-called Krupp Renn process for producing a type of nickel pig iron from several nickel laterite ores. It shows that the relatively low temperature (below approximately 1300°C) solid-state reduction of nickeliferous laterite ores followed by magnetic separation offers an interesting route for producing a ferronickel at potentially lower cost by eliminating high-temperature electric furnace smelting. Conventional technologies are also reviewed. The article includes several interesting graphs presenting statistical data on the nickel market.

The measurement and control of pyrometallurgical processes are vitally important issues. Jan Matousek, in the fifth article in this series titled "Oxidation Potentials in Iron and Steel Making,"

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reviews one such measurement tool. This is the application of solid electrolyte sensors based on ZrO_2 and a reference electrode (e.g., Cr/Cr_2O_3) in important oxygen partial pressure measurements in several pyrometallurgical operations. These sensors have become an important quality control tool in the ladle refining and continuous casting of steel. It was pointed out that the solid electrolyte sensors can be applied throughout the process of iron and steel making.

In the sixth article titled "Reduction Roasting of High Iron-Bearing Zinc Calcine under a CO-CO_2 Gas—An Investigation of the Chemical and Mineralogical Transformations," Huan Yan et al. propose a selective reduction roasting process to transform zinc ferrite ($ZnFe_2O_4$) present in some zinc plant residues to ZnO and Fe_3O_4 under a gaseous reducing atmosphere corresponding to 10% CO and 90% CO_2 between 700°C and ~800°C. It was concluded that this approach is technically feasible, but the authors noted that the formation of $Fe_{0.85-x}Zn_xO$ at temperatures above 750°C inhibits the separation of zinc and iron.

In the seventh article titled "Study of Reaction Mechanisms for Copper-Cobalt-Iron Sulphide Concentrates in the Presence of Lime and Carbon," Yotamu Stephen Rainford Hara reports on the reaction mechanisms occurring during the carbothermic reduction of complex sulphide concentrates in the presence of added lime. It was found that the rate of reduction increases with an increase in the CaO/C ratio. Preferential metallization of metals can be achieved by controlling the reduction temperature at an appropriate CaO/C ratio.

In the eighth article titled "Vacuum Carbothermal Reduction for Treating Tin Anode Slime," Wei Li et al. propose a process of vacuum carbothermic reduction for treating tin anode slimes containing antimony and lead. The antimony and lead were selectively and simultaneously removed by reducing and decomposing the less volatile mixed oxides of lead and antimony into the more volatile Sb_2O_3 and PbO. Tin was subsequently enriched in the distilland and mainly present as SnO_2, from which crude tin with the purity of 94.22 wt.% was obtained by vacuum reduction with addition of 12.5 wt.% of charcoal at 900°C for 60 min under a gas pressure of 40–400 Pa.

In the ninth article titled "Preparation of Steels and Cast Irons with the Addition of Molybdenum and Vanadium," Piotr Jarosz reports on the alloying of cast irons and steels by alloy additives in the form of molybdenum and vanadium oxides with an admixture of ferrosilicon as a reducer. The thermodynamic analysis confirmed the possibility of the alloying method, and the experimental measurements demonstrated a very high ratio ($>95\%$) of transferring of the alloy additives to the alloyed materials. This process eliminates the need to prepare ferroalloys in pursuit of alloying.

All pyrometallurgical processes use refractory bricks as furnace linings, and therefore, brick integrity is a key factor in all such processes. It is perhaps fitting that the last article of this group of ten articles in this issue of the *JOM* deals with advanced testing and measurement techniques to monitor refractory brick performance. Thus, Dean Gregurek et al. discuss refractory wear mechanisms in the tenth article titled "Refractory Wear Mechanism in the Nonferrous Metal Industry—Testing and Modeling Results." Refractory corrosion testing of several test bricks was carried out at high temperature using two industrial slags (a fayalite slag and a calcium ferrite slag). The test results provided a basis for optimal refractory selection for a particular plant duty.

In summary, the collection of articles described here offers us views on diverse topics in extensive applications of pyrometallurgy. These articles serve as paradigms representing the most recent advances in pyrometallurgical processing. We trust you will find them stimulating and valuable.