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Extractive Metallurgy: Efficiency and Eco-friendliness

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One of the most important missions of extractive metallurgy is to develop innovative processes satisfying the increasing requirements of efficiency and eco-friendliness in metal production. To accomplish this purpose, many versatile techniques/approaches have recently been developed. The current topic, "Extractive Metallurgy: Efficiency and Eco-friendliness" collects together seven articles which demonstrate the potential of novel processing techniques in yielding tangible economic and environmental benefits in the metallurgical field.

Ferrotitanium alloys are important functional materials that can be extracted from oxides including ilmenite. In the first article, "Preparation of Ferrotitanium Alloy from Ilmenite by Electrochemical Reduction in Chloride Molten Salts," Cancan Qi et al. introduce an efficient alternative route for the preparation of ferrotitanium alloy. They obtained Fe_2Ti by electro-reduction of ilmenite in the LiCl-KCl molten salt which has a lower eutectic point than many of reported salts such as $CaCl_2$-NaCl, indicating great potential in energy and cost saving. By taking advantage of the promotion effect of $CaCl_2$ on the reduction reactions, they also successfully prepared another important ferrotitanium alloy, FeTi, in the LiCl-KCl-$CaCl_2$ molten salt under the same conditions.

The cyanidation process is the most frequently used method for the extraction of gold from gold-bearing ores.[1] However, it suffers technical problems caused by other associated elements in the ores, such as copper and zinc, which often disrupt the process by forming copper-cyanide complexes and zinc-cyanide compounds, resulting in increased usage of cyanide. To address this issue, in the second article, "An Improved Process for Precipitating Cyanide Ions from the Barren Solution at Different pHs," Gabriela V. Figueroa et al. report on the use of sulfide precipitation for removing copper, zinc, and other species from barren cyanide solutions. Due to the high reactivity of the sulfide employed (sodium sulfide) with heavy metal ions and insolubility of heavy metal sulfides over a broad pH range, the precipitation method is believed to be an effective alternative to the extensively applied hydroxide precipitation. After removing impurity ions from the solution by controlling the pH conditions (pH 3–4 for Cu and 6–8 for Zn), the sulfide precipitates can be further processed by the existing smelter for metal recovery, and a better quality Doré can be obtained.

Metallurgical processes usually generate a large amount of waste which is now deemed as a useful secondary resource rich in various valuable metallic elements. To effectively recover these elements, viable and ecofriendly methods are developed and applied. In the third article, "Recovery of Copper from Cyanidation Tailing by Flotation," Tingsheng Qiu et al. validate the feasibility of extracting copper from copper minerals in cyanidation tailings by eliminating the depressing effect of cyanide on chalcopyrite, which often causes difficult metal recycling, using a series of activating additives, namely sodium hypochlorite, hydrogen peroxide, sodium metabisulfite, and copper sulfate. The findings obtained confirmed the good performance of these additives in activating depressed chalcopyrite, showing their wide application prospects in recycling of metallic sulfides from cyanide tailings produced by gold plants.

Currently, separation of interfering elements constitutes a crucial threshold for many extractive metallurgical processes. As a representative example, the separation of niobium and tantalum has gained much attention due to the importance of the metallic elements in a number of high-tech industries. In the fourth article, "Hydrometallurgical Separation of Niobium and Tantalum: A Fundamental Approach," Motlalepula Nete et al. focus on

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the separation of Ta and Nb with methyl-isobuthyl ketone in the presence of different concentrations of H_2SO_4. They found excellent Ta and Nb separation with only one extraction step. This approach will help to settle the challenge of dissolution and separation of Ta and Nb due to their metal oxides' (and thus the minerals') high resistance to chemical attack and similar chemical properties.

The separation of niobium from other elements, including rare earth elements (REE) and iron, is also documented in another article in this topic, "Enrichment of Rare Earth and Niobium from a REE-Nb-Fe Associated Ore via Reductive Roasting Followed by Magnetic Separation" by Mudan Liu et al. It proposes an efficient approach, namely coal-based reductive roasting followed by magnetic separation, to recover rare earth, niobium, and powdered metallic iron concentrate from a typical refractory REE-Nb-Fe ore. It was found that the additive used, sodium sulfate, substantially enhanced the reduction of iron oxide and, in turn, improved the separation of rare earth and niobium from iron as a consequence of the faster growth of metallic iron grains when roasted in the presence of sodium sulfate. The approach obtained excellent separation indexes: a magnetic fraction with TFe of 89.3%, iron metallization of 95.8%, and iron recovery of 91.5%, and a non-magnetic fraction with 5.4% rare earth oxides and 4.6% Nb_2O_5 with recoveries of 96.1% and 95.8%, respectively, after magnetic separation preceded by reduction of the raw concentrate at 1100°C for 120 min in the presence of 15 wt.% sodium sulfate.

Vanadium is one of the most important rare metals because of its wide range of uses in ferrous metallurgy and the aerospace and chemical industries with an important source coming from vanadium slag. In the sixth article, "Effects of Microwave Roasting on the Kinetics of Extracting Vanadium from Vanadium Slag" by Guoquan Zhang et al., a novel microwave-roasting and acid-leaching process is proposed for disposal of the slag. The application of low-temperature microwave roasting enhanced the reactivity of the vanadium slag and therefore facilitated subsequent leaching of the metal from its slag, as demonstrated by the reduced activation energy in the kinetic analysis. Without doubt, this study reveals the efficacy and environmental benefits of microwave-assisted metallurgy, mainly attributed to the selective and volumetric heating characteristics of microwave irradiation.[2]

In the last article, "Production of Magnesium and Aluminum-Magnesium Alloys from Recycled Secondary Aluminum Scrap Melts", Adam J. Gesing et al. demonstrate the feasibility of the electrorefining process for the extraction of Mg from Al melt sourced from Al alloy scrap feedstock in the United States. This work is based on the RE12™ project funded by the U.S. Department of Energy Advanced Research Project Agency. The process developed is economical, environmentally friendly, and chlorine free. It exhibits a huge potential in the recycling of 30,000 tons of primary-quality Mg annually. The development of this process will enhance the magnesium supply to meet the U.S. market demand.

The above articles collected in this topic provide representative examples of the state-of-the-art technologies for extractive metallurgy aimed at improving the efficiency and eco-friendliness of relevant metallurgical processes. The discoveries reported are expected to be useful, interesting, and stimulating.

The following papers being published under the topic of Extractive Metallurgy: Efficiency and Eco-friendliness provide excellent details and research on the subject. To download any of the papers, follow the url http://link.springer.com/journal/11837/68/2/page/1 to the table of contents page for the February 2016 issue (vol. 68, no. 2).

- "Preparation of Ferrotitanium Alloy from Ilmenite by Electrochemical Reduction in Chloride Molten Salts," by Cancan Qi, Yixin Hua, Konghao Chen, Yafei Jie, Zhongren Zhou, Juanjian Ru, Li Xiong, and Kai Gong.
- "An Improved Process for Precipitating Cyanide Ions from the Barren Solution at Different pHs," by Gabriela V. Figueroa, José R. Parga, Jesus L. Valenzuela, Victor Vázquez, Alejandro Valenzuela, and Mario Rodriguez.
- "Recovery of Copper from Cyanidation Tailing by Flotation," by Tingsheng Qiu, Xiong Huang, and Xiuli Yang.
- "Hydrometallurgical Separation of Niobium and Tantalum: A fundamental Approach," by Motlalepula Nete, Walter Purcell, and Johann T. Nel.
- "Enrichment of Rare Earth and Niobium from a REE-Nb-Fe Associated Ore via Reductive Roasting Followed by Magnetic Separation," by Mudan Liu, Zhixiong You, Zhiwei Peng, Xiang Li, and Guanghui Li.
- "Effects of Microwave Roasting on the Kinetics of Extracting Vanadium from Vanadium Slag," by Guoquan Zhang, Ting-An Zhang, Guozhi Lü, Ying Zhang, Yan Liu, and Weiguang Zhang.
- "Production of Magnesium and Aluminum-Magnesium Alloys from Recycled Secondary Aluminum Scrap Melts," by Adam J. Gesing, Subodh K. Das, and Raouf O. Loutfy.

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