Recent Developments in Deriving Values from Resource Recovery at Multiple Scales

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This topic contains articles on selective extraction of disposed materials for a specific next use, such as recycling or generating energy, to extract the maximum values from products, delay the consumption of virgin resources, or reduce the amount of waste generated.

Recycling valuable metals from electronic waste materials has been attracting increasing attention among researchers because of the rapid increase of electronic product consumption. A sustainability analysis has been presented by Gabrielle Gaustad on creating the 2020 Tokyo Olympic medals from electronic scrap. For the upcoming 2020 Olympic Games, which are to be held in Tokyo, Japan, it has been proposed that recycled metal from electronic waste should be used to create the gold, silver, and bronze medals that will be awarded to athletes. Gaustad explores the feasibility of this goal, quantifies the required electronic waste, identifies the limiting material constraints, and addresses a selection of sustainability metrics. His results show that the environmental benefits from recycling metals from electronic waste are identified as being a savings of approximately 4,806,959 MJ of energy, which is equivalent to CO₂ emission reductions of 424 tonnes. Additionally, Gaustad presents qualitative potential benefits to environment, human health, economic recovery of valuable materials, and supply stability based on the proposed recycling methodology.

Another article is focused on economic assessment for recycling critical rare earth elements (REEs) from hard disk drives (HDDs). Ruby Thuy Nguyen et al. evaluate the economic viability of recycling critical REEs, such as praseodymium, neodymium, and dysprosium, from HDDs based on an electro-

hydrometallurgical process. In the simulation model, these authors combine techno-economic information of the electro-hydrometallurgical process with end-of-life HDDs availability and show that adding REE recovery to a HDD base and precious metal recovery process can be profitable given current prices.

This topic also features several articles on hydrometallurgical and pyrometallurgical recovery of valuable metals. Zhiwei Peng et al. reviewed the recovery processes of platinum group metals (PGMs) from spent catalysts. As an important secondary resource with abundant PGMs, spent catalysts demand recycling for both economic and environmental benefits. This article reviews the main pyrometallurgical processes for PGM recovery from spent catalysts. Existing processes, including smelting, vaporization, and sintering processes, are discussed based in part on a review of the physiochemical characteristics of PGMs in spent catalysts. The smelting technology, which produces a PGM-containing alloy, is significantly influenced by the addition of various collectors, such as lead, copper, iron, matte, or printed circuit board (PCB), considering their chemical affinities for PGMs. The vaporization process can recover PGMs in vapor form at low temperatures, but it suffers high corrosion and potential environmental and health risks resulting from involvement of the hazardous gases. The sintering process serves as a reforming means for recycling of the spent catalysts by in situ reduction of their oxidized PGMs components. Among these processes, the smelting process appears more promising although its overall performance can be further improved by seeking suitable target-oriented collector and flux together with proper pretreatment and process intensification using an external field.

Junwei Han from Central South University China, along with his co-authors, investigated a copper recovery process from a complex copper oxide

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ore. A combined process of flotation and high-gradient magnetic separation was proposed to use the complex copper oxide ore. The effects of particle size, activator dosage, activating time, collector dosage, and magnetic intensity on the copper recovery were investigated. The results show that more than 90% of copper can be recovered by flotation followed by magnetic separation. The proposed process has been successfully applied to industrial scale production.

This topic also features an article presented by Zhiyuan Yu addressing NO_x reduction in an iron ore sintering process with flue gas recirculation (FGR). FGR has been implemented for exhaust gas emissions reduction in iron ore sintering for a long time, but the mechanism of NO_x reduction through FGR is still not clear. In this article, laboratory pot-grate sintering test results are presented and a 30% reduction in gas flow and a 16% reduction in NO_x emissions are achieved with a 30% FGR ratio; also, the sinter indexes almost matched that of the conventional process. It was found that NO–CO catalytic reduction occurs in the range of 500–900°C. When the sinter temperature reaches 700°C, the highest nitrogen reduction ratio (NRR) achieved is 8%; nevertheless, the NO_x reduction is inhibited as the post-combustion of CO starts when the temperature increases beyond 700°C. The existence of NO in the FGR gas inhibits the NO_x generation from the fuel combustion, and the NO elimination through the NO-carbon reaction is significant in the combustion zone.

More and more battery-powered electric vehicles are being used as a result of recent technological developments and an increased focus on renewable energy. A popular strategy to advance sustainability is “beginning with the end in mind”. In this special issue, Mikaela DeRousseau et al. provide a review on end-of-life options for used electric car batteries, including remanufacturing, repurposing for a different application, and recycling. The advantages and challenges of these options are discussed from both the engineering and economic perspectives. Successful implementation of these processes will not only enable high-value materials reuse rather than disposal but also bring both economic and environmental benefits.

Pietrogiorgio Cerchier from the University of Padova, Italy, reported on a new process for synthesizing tin oxide and silver nanoparticles from electronic wastes with the assistance of ultrasound and microwave. In his work, a precursor of tin oxide was first precipitated from the nitric acid solution by three different techniques, i.e., conventional

heating, microwave irradiation, and ultrasound treatment. Then, this precursor was transformed into tin oxide nanoparticles by heat treatment in a furnace. Hydrochloric acid was added to the nitric acid solution to induce the precipitation of silver chloride. Silver chloride was reduced to metallic silver nanoparticles in an ammonia solution using glucose syrup as both the reducing and the capping agent.

Resource recovery at multiple scales is ever evolving, and how to derive values from the resource recovery is still in a phase of technology development and upscaling. This special topic is trying to cover the wide range of technologies and startups that specialize in specific and highly technical processes. It is expected that continuous efforts in research at multiple scales will lead to full industrial deployment of the resource recovery.

The following articles are published under the topic “Deriving Value from Resource Recovery at Multiple Materials Scales: Part I” in the September 2017 issue (vol. 69, no. 9) of *JOM* and can be accessed via the *JOM* page at <http://link.springer.com/journal/11837/69/9/page/1>:

- “Creating the 2020 Tokyo Olympic Medals from Electronic Scrap: Sustainability Analysis” by Alexandra M. Leader, Xue Wang, and Gabrielle Gaustad
- “Economic Assessment for Recycling Critical Metals from Hard Disk Drives Using a Comprehensive Recovery Process” by Ruby Thuy Nguyen, Luis A. Diaz, D. Devin Imholte, and Tedd E. Lister
- “Pyrometallurgical Recovery of Platinum Group Metals from Spent Catalysts” by Zhiwei Peng, Zhizhong Li, Xiaolong Lin, Huimin Tang, Lei Ye, Yutian Ma, Mingjun Rao, Yuango Zhang, Guanghui Li, and Tao Jiang
- “Copper Recovery from Yulong Complex Copper Oxide Ore by Flotation and Magnetic Separation” by Junwei Han, Jun Xiao, Weiqing Qin, Daixiong Chen, and Wei Liu
- “NO_x Reduction in the Iron Ore Sintering Process with Flue Gas Recirculation” by Zhiyuan Yu, Xiaohui Fan, Min Gan, Xuling Chen, and Wei Lv
- “Repurposing Used Electric Car Batteries: A Review of Options” by Mikaela DeRousseau, Benjamin Gully, Christopher Taylor, Diran Apelian, and Yan Wang
- “Synthesis of SnO₂ and Ag Nanoparticles from Electronic Wastes with the Assistance of Ultrasound and Microwaves” by Pietrogiorgio Cerchier, Manuele Dabalà, and Katya Brunelli.