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Recycling Silicon and Silicon Compounds

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Recycling can be defined as the process of collecting materials and treating and processing them to be used again as new products instead of throwing them away as trash. Waste treatments can be physical (e.g., shredding), chemical (e.g., incineration) and biological (e.g., an anaerobic digestor). Recycling has many benefits, such as conserving natural resources, reducing the amount of waste sent to landfills and incinerators, preventing pollution and thus protecting the environment, saving energy and stimulating the development of greener technologies, supplying valuable raw materials to industry and thus reducing material production costs, supporting economics and increasing its security, supporting manufacturing and creating new job opportunities. In addition, increasing the rates of recycling and re-using waste leads to the derivation of new materials and products and thus creates new applications and markets for these materials. Hence, recycling is a very important issue for industries, research centers and all technologies today. TMS has prioritized recycling, through the Recycling and Environmental Technologies Committee, in addition to other committees, and encourages interactions between research and industry to expand and spread knowledge and to understand the importance of recycling and waste treatment as well as how they benefit the environment, industry and economics.

Silicon compounds such as silica and silicates are the most plentifully available compounds in the earth's crust, and silicon is widely used in electronics industries to produce the chips used in many devices such as computers and cell phones. It is also used in the production of solar cells, which are the building blocks of solar panels, which are used for a wide variety of applications including telecommunications equipment, remote sensing and the production of electricity by residential and commercial solar electric systems. Silicon compounds have many uses in several industries, such as glass, ceramics, electrical insulators, petrochemical and solar cells. Throwing away huge quantities of these devices and equipment when they are no longer useful represents a significant financial loss. In addition to losing materials that were expensive to produce, the materials could be used again after recycling. In addition, the accumulation of large stocks of end-of-life photovoltaic modules (EOL PV), computers and electronic devices is a type of pollution that is harmful to the environment. All these issues make the recycling of silicon, silicon compounds and silicon products an important issue that deserves attention and hard work for its success. Therefore, this topic of recycling silicon and silicon compounds is required for a cleaner and greener environment, to save money and to support the economy.

This topic includes 14 papers covering different aspects of recycling silicon, silicon products and silicon compounds including silicon wafers, silicon waste, saw silicon powder and discarded ICs.

Two of the papers discuss recycling of EOL PV using different methods. The first paper, entitled "Physical separation and beneficiation of end-of-life photovoltaic panel materials: utilizing temperature swings and particle shape" by Pamela Bogust and York R. Smith, presents a potential method to liberate and separate shredded EOL PV panels for the recovery of Si wafer particles. The authors used submersion in liquid nitrogen to remove the backing material, pyrolysis to remove encapsulants and mechanical screening of particle size and shape to separate the liberated particles (i.e., Si wafers and glass). The second paper, entitled "Recovery of Si via using KOH-ethanol solution by separating different layers of end-of-life PV modules" by Yang Yanet al., investigates the recovery of Si by separating the layers of end-of-life PV modules using a KOH-ethanol solution, where KOH ethanol is a green reagent with low environmental toxicity. The study explores the effect of different factors on the separation ratio of the PV modules and investigates the mechanism for separating their layers.

Shadia J. Ikhmayies is the guest editor for the invited topic Recycling Silicon and Silicon Compounds in this issue.

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Four of the papers on this topic discuss recycling and purification of saw silicon waste and powder by different methods. One of them is a review paper entitled "Review of silicon recovery and purification from saw silicon powder" by Kuixian Wei et al., where the authors comprehensively review some processes and technologies for silicon recovery and purification from loose abrasive slurry silicon powder (LASSP) and diamond wire saw silicon powder (DWSSP). Also, the authors propose that high-purity silicon for industrial implementations can be recycled from LASSP and DWSSP via a combined process of an acid-leaching pretreatment and high-temperature treatment. The other three papers are research papers. The first is entitled "Impurity removal from diamond-wire cutting waste by slag refining and electromagnetic stirring" by Yunyang Zhu et al. and proposes a method of recycling and purifying silicon from diamond-wire cutting waste by a combined process of slag refining and electromagnetic stirring. This proposed refining method is found to be effective in removing impurities from diamond-wire cutting waste. The authors also find that the mass ratio of slag to silicon has a significant effect on the separation efficiency of silicon. The second paper, entitled "Microwave assisted acid leaching for recovery of silicon from diamond-wire cutting waste slurry" by Si-yi Hou et al., studies the recovery of crystalline silicon from diamond-wire cutting waste with microwave-assisted hydrochloric acid leaching. The authors found the optimum experimental conditions under which the purity of silicon could reach 99.57%. The third paper, entitled "Research on the interaction of Ca, Al and Fe in recovering and purifying silicon" by Fan Yang et al., found that the presence of Ca in Si helps in removing Al and Fe from silicon cutting waste with metallurgical methods. The authors also determine the effects of Ca on the saturation solubility of Al and Fe in Si solutions.

Three papers on this topic investigated slag recycling to prepare or purify silicon and silicon compounds. The first, entitled "Boron removal from industrial silicon by combined slagging and acid leaching treatment technology" by Qiang Zhou et al., investigates a new dual method for removing boron from industrial silicon using ternary CaO-SiO_2-$CaCl_2$ slag flux refining followed by an acid leaching treatment using a mixed HCl-HF solution. The second paper, entitled "A method of high-quality silica preparation from copper smelting slag" by Qinmeng Wang et al., investigates the production of high-quality silica from copper smelting slag through in situ modification. The authors studied the effects of the amount of polyethylene glycol-6000 as a modifier, modification temperature and modified endpoint pH on the particle size and specific surface area of the silica. The third paper, entitled "Decrease of material burden in the novel alkali-saving reduction treatment process of nickel slag based on NaOH roasting" by Hai-yang Liu et al., presents a reduction treatment method for high silicon wastes, especially nickel slag. In this method, the authors lowered the alkali-ore ratio (mass ratio of NaOH to ore) by introducing a high-speed premixing procedure before roasting, decreasing the material burden and reducing environmental pollution. The final product in this procedure is high-purity (i.e., 99.92%) amorphous silica.

Three of the papers included on this topic investigate recycling of waste, solution and ash. The first of this set, entitled "Phase transition of waste silicon carbide side block from aluminum smelters during vacuum-high temperature detoxification process" by Mingzhuang Xie et al., proposes a joint temperature-vacuum controlling process for treating the waste silicon carbide side block (WSB) from aluminum reduction cells, which are considered hazardous materials. The authors carried out thermodynamic analysis and then a series of experimental investigations and characterizations to find the optimum removal conditions for detoxification of WSB. The second paper, entitled "Desilication and recycling of alkali-silicate solution for low-grade high-silica bauxite utilization" by Yingpeng Xu et al., studies the effects of the amount of CaO addition, initial caustic and silica concentrations, and reaction temperature on the desilication ratio in an alkali-silicate solution (ASS) and investigates the desilication of ASS by adding dosages of lime (Ca/Si mole ratio or C/S), and the authors attempt to recycle ASS. The third paper is a simulation work by Chunhe Jiang et al., entitled "Study on structure and properties of high-calcium coal ash in high temperature zone of blast furnace: A molecular dynamics simulation investigation." The authors found that as the CaO content increases ($\geq$ 40%), the transport properties of the coal ash become better, and the viscosity is lower, accordingly, because CaO depolymerizes the microscopic network structure of aluminosilicate.

The last two papers include "Investigation on the function of zero-valent iron (ZVI) in the process of fayalite formation" by Dawei Wang et al., which discusses a solid-phase method to synthesize fayalite (Fe_2SiO_4), which is widely used in various fields. This paper investigates the function of ZVI during the formation of fayalite, where excess ZVI is used to regulate oxygen fugacity during the fayalite synthesis process. The second is entitled "Physical processing of discarded integrated circuits for recovery of metallic values" by Amit Barnwal and Nikhil Dhawan, where the authors present an attempt to physically separate metallic and silica values from discarded ICs prior to hydrometallurgical processing. To recover Cu, Fe, Ni and Si values, the authors follow a physical processing comprising water fluidization, magnetic separation and density separation of discarded units.

To read or download any of the papers on this topic, follow the URL http://link.springer.com/journal/11837/72/7/page/1 to the Table of Contents page for the July 2020 issue (vol. 72, no. 7).