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Editorial

Critical materials for low carbon society

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1. Introduction

Critical materials are garnering many research interests from academia, industry, and defense sectors due to their increasing demand for clean-energy solutions and the potential for significant supply risks. These materials include cobalt, lithium, manganese, and rare earth elements (REEs), which have limited production capacities but are increasingly used in lithium-ion batteries (LIBs) and neodymium–iron–boron (Nd–Fe–B) magnets for electric vehicles (EVs), and renewable energy generation and/or storage. To achieve net zero emissions by 2050, the demand for these critical materials is projected to surpass the supply. Increased mining of critical materials from ores creates extra burdens or disturbances on the environment and affected communities, and recycling of these valuable materials from end-of-life (EOL) products can be a promising alternative from both economic and environmental perspectives. This special issue aims to gather up-to-date knowledge related to cutting-edge research in the broad scientific area of critical materials for clean energy applications.

2. Contributions

This special issue consists of five articles. In the first paper of this special issue, Alipanah et al. [1] presented a review of emerging technologies and pathways such as refurbishing, direct recycling (i.e., cathode-to-cathode), and hydrometallurgical and pyrometallurgical processes for critical materials recovery from spent LIBs. The study revealed the economic and environmental advantages of LIB reuse over materials recycling, though significant research and infrastructure developments are required. Among the materials recycling methods, direct recycling is superior in closing the loop with less chemicals and energy consumed. However, high operational costs and changes in battery chemistry over time could limit the widespread application of direct recycling. To this end, this paper also reviewed the government policies adopted by Europe and the US for promoting LIB recycling.

In the second review paper, Ji et al. [2] provided a comprehensive review on the recent advancements in each step of the direct recycling process, namely, harvesting cathode materials, separation of cathode active materials from other components through thermal and floatation processes, and regeneration of degraded electrochemical performance of homogenous cathode materials through relithiation (e.g., solid-state relithiation, hydrothermal relithiation). The authors emphasized complete separation of cathode materials from binders and carbon, as the presence of residue affected the electrochemical performance of regenerated cathode materials. Moreover, they suggested future endeavors to minimize fluoride emissions during the separation process.

The special issue includes another mini-review paper on recent advances in acid-free dissolution and separation of REEs from Nd–Fe–B and samarium–cobalt (Sm–Co) magnet wastes by Inman et al. [3]. The research was motivated by the fact that acid-based hydrometallurgical processes generate substantial amounts of hazardous waste, which needs to be controlled to avoid environmental hazards for recovering REEs. A promising solution is to dissolve magnet materials using an aqueous solution of a copper (II) salt, which transfers pertinent REEs to the dissolved solution. With further filtration, precipitation, and calcination procedures, mixed rare earth oxides were produced with a yield of >98%. Separation of heavy REEs (e.g., Dy) from light REEs (e.g., Nd, Pr) was also investigated, highlighting the research need to develop economically and environmentally sound alternatives to traditional solvent extraction (SX) route.

Alongside these review papers, the special issue includes two research articles. In the first article, Maria et al. [4] emphasized the inclusion of temporal information while calculating the environmental impacts of buildings. The authors performed life cycle analysis to evaluate both static and dynamic global warming impact for two newly developed construction materials: (i) goethite-based inorganic polymers (GIP), and (ii) stainless steel slag-based alkali-activated aerated blocks (SSSaer), compared to traditional autoclaved aerated ordinary Portland cement (OPC) concrete. Although both static and dynamic approaches provided similar results, the latter allowed a more informed analysis of emission flows over time. According to their analysis, GIP presents the highest global warming impact at any time horizon, both for the static and the dynamic approach, while SSSaer has the lowest impact.

As the final article of the special issue, Nguyen et al. [5] presented a market-oriented critical-materials database, which aimed to help material researchers gain a better understanding of the market for 29 critical materials. The database provided insightful information regarding the most impactful applications of each element, as well as their industry specifications, prices, product composition, and global consumption.

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Conflict of interest

The authors have no conflicts of interest to declare.

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