Poster | Raw materials

Tue. Jul 29, 2025 4:35 PM - 6:00 PM JST | Tue. Jul 29, 2025 7:35 AM - 9:00 AM UTC Green zone, Conference rooms 101 and 102(1F)

[P2] Raw Materials & Recycling

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[P2-26] Facile All-Elements Recycling of HRE-Containing Nd-Fe-B Magnet Sludge by Reduction-Diffusion with CaH_2

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Keywords：recycled magnet、Nd-Fe-B magnet sludge、reduction-diffusion、heavy rare earth

The increasing demand for electric vehicles has led to a significant rise in Nd-Fe-B magnet production, growing by approximately 10 % annually over the past decade. The conventional Nd-Fe-B magnet manufacturing process generates considerable waste, with up to 20–30 % of the material being lost as sludge during cutting or machining. This sludge mainly consists of fine oxidized powder, which cannot be directly reused by remelting or sintering due to its high oxygen content. However, it contains about 30 wt.% of rare earth (RE) elements, including critical heavy rare earth (HRE) elements such as terbium and dysprosium, which makes recycling crucial. Conventional hydrometallurgical recycling techniques face various limitations, such as the use of dangerous chemicals, the inability to recycle boron, and the separate recovery of iron and rare earth elements. Additionally, RE compounds produced after hydrometallurgical processes must be converted back into metals through molten salt electrolysis before being reused for magnet production, which further complicates the process. Therefore, the development of new alternative approaches for Nd-Fe-B magnet sludge recycling is in high demand. One promising candidate is the reduction-diffusion (RD) process, utilizing calcium (Ca) as a reductant. RD involves mixing the sludge with Ca, followed by heating under an inert atmosphere. Upon heating to elevated temperatures, calcium reacts with the compounds in the sludge, reducing oxides to their pure forms, while also promoting the diffusion, leading to the formation of Nd-Fe-B powder. Despite its potential, conventional reduction-diffusion with Ca continues to face challenges, such as incomplete reactions between the sludge and reducing agent at higher reactant quantities, excessive consumption of the reducing agent, and low recovery efficiency.In this study, calcium hydride (CaH_2) was chosen as the reducing agent for HRE-containing sludge recycling due to its advantages over elemental calcium. First, CaH_2 is brittle, which facilitates better mixing and distribution of reagents in the initial mixture, resulting in a more complete reduction-diffusion process. Second, with a lower melting point, CaH_2 enables faster and more efficient RD at the same temperature compared to Ca. To optimize the RD process and produce high-quality Nd-Fe-B powder, various CaH_2/sludge ratios and RD temperatures were systematically examined. The optimal conditions were identified as a CaH_2/sludge

ratio of 0.75 and an RD temperature of 1050°C. Under these conditions, the resulting particles exhibited anisotropic behavior, had an average size below 2 μm, and predominantly consisted of the $Nd_2Fe_{14}B$ phase, with the remainder being an Nd-rich phase. Furthermore, ICP results confirmed that all elements, including critical Dy and Tb, were successfully recycled with a yield of over 98%. The recycled powder was then mixed with commercial HRE-free Nd-Fe-B powder and NdH_x, followed by sintering. The fabricated magnet (attached image) corresponds to 33UH commercial-grade magnets, with a coercivity of 25.3 kOe—the highest coercivity value reported among recycled magnets produced with regenerated RD powder. The properties demonstrated by the recycled magnet are comparable to those of commercial magnets used in robot motors or generators.