Applications of Thermodynamics in Rare Earth Recycling Research

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Rare earth elements such as Nd and Eu have important technical applications in e.g. magnets and lamp phosphors. The rare earth element group is abundantly available in the earth's crust, but the supply is dominated by China, and ores require elaborate processing for separation of the more valuable elements from the bulk elements such as Y and Ce as well as from the radioactive ones. Recycling could lead to a single-element supply from local sources.

Thermodynamic modelling is an efficient and robust technique to understand production processes. Therefore, it is a useful tool to study new processes in rare earth production and recycling, or to develop sustainable recycling solutions. Thermodynamic databases are not yet available for many rare earth systems, partially because of a lack of experimental results. Consequently, some of the recycling research has included equilibrium experiments and database construction work. This paper focuses on Nd recycling, for which a number of high-temperature recycling processes are under investigation.

For magnet production, the understanding of the Nd-Fe-B system is an important basis, and models for the metal melt have been described, which can serve to study melt-spinning and the formation of the magnetic $Nd_2Fe_{14}B$ phase. However, the interaction with hydrogen, which is important to decrepitation-based production and recycling processes[1], or the interactions with Ce, important for substitution[2], are not described in much detail. Also, there are gaps between the status of publications, commercial databases and private databases. For recycling from mixed streams, the oxide system has been under investigation. The behaviour of Nd_2O_3 in slags[3,4] based on CaO, SiO_2, and Al_2O_3 has been studied and modelled. For other rare earths, mainly the interactions with Al_2O_3 have been described. The application to a potential precipitation and concentration process from slag will be discussed.

Apart from the metal and oxide systems, other systems may be relevant as well. Potential roasting processes[5,6] for magnet recycling will be discussed. However sulphates and other phases, relevant to this approach, are practically unavailable.