RECYCLING OF NdFeB MAGNETS BY HIGH-TEMPERATURE LEACHING WITH THE IONIC LIQUID [HBET][TF$_2$N]

Martina OREFICE[1,], Koen BINNEMANS[1], Tom Vander HOOGERSTRAETE[1]

[1] Department of Chemistry, KU Leuven, Celestijnenlaan 200F - PO box 2404 3001 Heverlee, Belgium

martina.orefice@kuleuven.be

The industrial demand of rare-earth elements (REEs) is increasing, especially that of the critical rare earths like, *e.g.*, neodymium (Nd) or dysprosium (Dy), because of their use in permanent magnets. Recycling of rare earths from magnet-containing urban waste could generate an independent supply of these elements outside China. Recycling is also of interest to mitigate the so-called Balance Problem, since it avoids producing excesses of lanthanum and cerium from mining primary rare-earth ores. Stockpiling a resource has relevant costs that the producer try to compensate by increasing the price of the more required resources, Nd and Dy in this case.[1, 2]

Ionic liquids are solvents that consist entirely of ions. They could contribute to the development of sustainable recycling routes. They have been used as alternatives to molecular solvents in solvent extraction processes. Ionic liquids functionalized with an acidic group can be useful for selective dissolution or leaching of metals from complex solid materials.

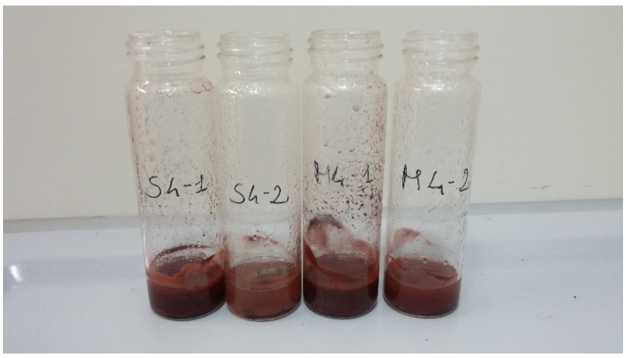

Fig. 1: Leachates from milled and roasted NdFeB magnets at the end of a test of 96 hours with dried [Hbet][Tf$_2$N] as lixiviant.

In this work, the ionic liquid betainium bis(trifluoromethylsulfonyl)imide [Hbet][Tf$_2$N] was used to leach the valuable metals neodymium, dysprosium and cobalt from end-of-life NdFeB magnets and NdFeB production scrap. The leaching process was carried out at high temperatures (>100 °C) to increase the kinetics. This is an innovation in the application of ionic liquids, which have mostly been used to work at low temperatures.

The solid materials were milled to reduce the particle size and roasted to oxidise the metals. The dissolution of oxides can be more selective than the dissolution of the alloys. A physical and chemical characterization of the powders (particle sizes, molecular structure of the roasted material and elemental analysis) was performed**.** Leaching performances of dry [Hbet][Tf_2N] were tested at 175 °C, for 24 and 48 h.

The leaching efficiencies were very low, <10%, even after 48 h of leaching at 175 °C. However, the dissolution of pure metal oxides in [Hbet][Tf_2N] at 175 °C resulted in recovery efficiencies close to 100%. The difference is due to different molecular structure of the powders: the roasted magnets revealed to contain a ternary oxide of neodymium and iron, $FeNdO_3$. The ternary compound is more difficult to leach than the pure metal oxides. The results from the leaching process were also compared to the ones previously obtained by Dupont and Binnemans in a similar process.[3] It was proved that water-containing [Hbet][Tf_2N] can be used to recover Nd, Dy and Co from NdFeB magnets at 90 °C. Water has a crucial role in driving the leaching mechanism. The effect of water on the mass transfer and metal coordination was investigated. The viscosity of dried [Hbet][Tf_2N] at 175 °C is very close to the viscosity of water-saturated [Hbet][Tf_2N] at 90 °C. However, it was proved that there are no water molecules coordinating to the rare-earth ions after leaching with the dry ionic liquid at 175 °C. The dried [Hbet][Tf_2N] is not able to efficiently saturate the coordination sphere of the rare-earth ions in contrast to water-containing [Hbet][Tf_2N].[4]

Reference

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