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## A combined hydro- and pyrometallurgical process for REE recovery from used permanent magnets

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Rare earth elements (REE) have become essential for our modern economy, in relation to the development of new energy and communication technologies. Albeit being considered today as the most critical raw materials group with the highest supply risk, the recycling of REE from electronic waste and end-of-life products (permanent NdFeB magnets, Ni-MH batteries etc.) is almost inexistent.[1] Therefore, a large research effort is needed for overcoming the current scientific and technological issues and improving the recycling efficiency. Innovative, eco-designed processes have to be developed, which require extensive R&D effort from basic research to technological developments.

The CEA has gained a world-class expertise in the field of separation processes by hydrometallurgy and pyrometallurgy, several solvent extraction processes being developed and industrially implemented for the nuclear fuel cycle. In this communication, an efficient combined hydro- and pyrometallurgical process aimed at REE recovery and separation from used NdFeB permanent magnets will be presented.[2] The process integrates the mechanical and physico-chemical treatment of NdFeB magnets, followed by a liquid-liquid solvent extraction step for the recovery and intra-separation of REE using a selective extractant with excellent affinity for heavy REE which are today the most expensive REE. Experimental liquid-liquid extraction and modeling data allowing the recovery of a 99.91% pure Dysprosium solution will be discussed in this paper. A subsequent pyrometallurgical treatment via molten chloride salt electrolysis allowed the isolation of pure Dy metal with 80% faradic yield. The results obtained at laboratory-scale for validating the whole process from used magnets will be equally presented. This is one of the first examples of a successful, closed-loop REE recovery and separation process, starting from magnet scrap down to individual pure REE as metals, which paves the way for future developments in the field of REE recycling.

At the European level, the CEA aims at enhancing the coordination and integration of the academic and industrial community in the field of critical metals recovery and recycling. This strategy which directly includes the REE, involves the creation at the CEA Marcoule site of a European Institute of Hydrometallurgy (EIH) and the launching of the European research network PROMETIA in December 2014 to support innovation for the industrial partners in the field of mineral processing and extractive metallurgy for critical metals.

### References:

1. K. Binnemans *et al.*, Recycling of rare earths: a critical review. *Journal of Cleaner Production*, **2013**, 51,1.
2. M. Miguirditchian *et al.* Procédés de récupération sélective de terres rares présentes dans les phases aqueuses acides issues du traitement d'aimants permanents usagés ou rebutés, **2014**, patent application 1459023.