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Sustainable Design of New Permanent magnets

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Abstract

The increasing efforts towards a greener and more sustainable future has significantly enhanced the demand for permanent magnets based on rare-earth elements (RE-PM), which are key components of environmentally friendly energy technologies, such as hybrid and electric vehicles and wind turbines [1]. To respond to this growing demand and to cope with the Chinese monopoly [2] of the production and treatment of RE elements, an intense computational and experimental activity has been recently carried out to develop effective solutions that allow reducing the demand and use of REEs, including: 1) the recycling/reuse of End-of-Life (EoL) magnets; 2) the optimization of existing materials; 3) the development of new hard magnetic phases. In this framework, Nanostructured magnetic materials laboratory (www.nm2lab.com) is proposing specific strategies to implement a sustainable design of new permanent magnets.

Among the different strategies for recycle and reuse of EoL magnets, we are focusing on the magnet-to-magnet approach, where EoL PMs are first processed to obtain a powder that is then used to re-build a new magnet. This strategy allows minimizing waste and resource depletion, while using only mechanical processes that enable reducing the environmental footprint associated with chemical usage and harmful emissions typical of other approaches.

As an alternative approach to face the REE criticality issue, RE-free hard/soft exchange coupled nanocomposite powders containing $BaFe_{12}O_{19}$ hexaferrites (HFs) as the hard phase and $CoFe_2O_4$ (CoFe) spinels as the softer phase will be synthesized to manufacture mid-range PMs filling the gap between HFs and RE-PMs. Such systems can be prepared by using chemical synthesis strategies or high energy ball milling approaches, to produce strongly exchange-coupled composites finely controlled at the nanoscale, which is a prerequisite to obtain composite systems with enhanced performance [3, 4].

Finally, with the idea to develop new hard magnetic phases considerable efforts has been done in the synthesis of L10-FeNi binary alloy that is a promising candidate for next generation rare earth-free permanent magnets. We propose to use an effective, single-step, easily scaled-up, and sustainable chemical synthesis route, called Preordered Precursors Reduction, already successfully exploited by the authors to obtain M-Pt alloy nanoparticles (M = Fe, Co, Ni) under milder conditions than common thermal processes [5]. The perfect atomic order of the precursor drives the formation of FeNi nanoparticles (20 – 120 nm) covered with a protective carbon shell, with a 50% of the L10 phase and good magnetic properties (H_c up to 65 mT and M_s = 130 - 140 kAm^2/kg close to the bulk value, 154 kAm^2/kg), thus paving the way for the development of a sustainable process for massive production of FeNi-based permanent magnets.

References:
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Bio-sketch

Davide Peddis (DP) graduated magna cum laude in Physical Chemistry (2003) and obtained his PhD in Physical Chemistry (2007) at the University of Cagliari. Since 2022 DP is Full Professor of Physical chemistry @ University of Genova and associate researcher at CNR-ISM. Research activity of DP is developed in the framework of Solid State Physical-Chemistry and Condensed Matter Physics, studying the relationship between physical properties, crystalline structures, and morphological features of magnetic nano–hetero-structures (nanoparticles, particles embedded in matrix, core shell structures, hollow nanoparticles, anisometric particles). DP research activity is presented in over 160 peer reviewed papers (h-index/Cit.: 39/4646- Google Scholar) and 6 book chapter in the period 2006-2023. He was co-editor of a book titled “New Trends of Nanoparticles Magnetism” (Springer, 2021). DP has been co- supervisor of 5 master students, 5 PhD student, 3 post-docs, 5 researchers in formation and he was also appointed for three international PhD committee (February 2015, November 2017 Uppsala University, 2020, Basel University). Davide Peddis has been personally granted over 1.3 milion of euro to date, coming for national and EU project.