MA 30: Bulk Materials: Soft and Hard Permanent Magnets

Time: Wednesday 16:00–18:00 Location: H18

Invited Talk MA 30.1 Wed 16:00 H18

Boosting Coercivity in Additively Manufactured Magnets Through Nano-Functionalization of NdFeB Powder — •Anna Ziefuss — Technical Chemistry I and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg Essen, 45141 Essen, Germany

Permanent magnets are indispensable in the 21st century, powering applications in energy generation, transportation, and telecommunications. However, the high cost of rare-earth magnets, their supply, and availability represent critical factors, and novel technologies that avoid or minimize the use of such rare elements in permanent magnets need to be developed immediately. Additive manufacturing (AM) offers a promising solution by enabling complex structures with minimal material waste, reducing rare-earth usage. Yet, the successful printing of magnetic powders remains challenging, as printed magnets often exhibit brittleness and low magnetic properties. This contribution highlights how nanotechnology-driven innovations address limitations in additive manufacturing, unlocking the potential of printed magnets for sustainable, high-performance applications. Nano-functionalization emerges as a crucial approach to enhancing coercivity in additively manufactured magnets, emphasizing the importance of understanding the entire process chain - from nanoparticle production and feedstock modification to evaluating printed magnet properties.

MA 30.2 Wed 16:30 H18

Strategies for Nd-Fe-B Magnet Recycling in a Circular Economy — •Aybike Paksoy[1], Amrita Khan[1], Abdullatif Durgun[1], Mario Schönfeldt[1,2], Mahmudul Hasan[2], Iliya Radulov[2], Jürgen Gassmann[2], Imants Dirba[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Department of Materials and Geosciences, Functional Materials, Peter-Grünberg-Str. 16, 64287 Darmstadt, Germany — [2]Fraunhofer IWKS, Fraunhofer Research Institution for Materials Recycling and Resource Strategies, Aschaffenburger Str. 121, 63457 Hanau, Germany

Nd-Fe-B magnets have the highest energy product (BH)max at room temperature, making them the preferred material for various applications. However, their reliance on critical rare earth elements raises significant environmental, economic, and geopolitical challenges, particularly due to China's dominance as the primary global supplier. Both industry and academia are increasingly focusing on recycling end-of-life Nd-Fe-B permanent magnets.For an environmentally friendly product, it is necessary to reduce the criticality and increase the sustainability of rare earth permanent magnets [1]. We compare three advanced recycling routes to produce sustainable Nd-Fe-B magnets without sacrificing their performance. Scrap magnet material is processed via the hydrogen-assisted magnet-to-magnet route as well as the nanocrystalline hot pressing route and spark plasma sintering. The resultant magnetic properties and microstructure are systematically studied comparing the advantages and disadvantages of each process.
[1] M. Schönfeldt et al., J. Alloys and Compounds (2023)

MA 30.3 Wed 16:45 H18

3D magnetic of interaction domains in nanostructured Nd-Fe-B using X-ray imaging techniques — •P. Klassen[1], D. Günzing[2], A. Aubert[3], T. Feggeler[4], B. Eggert[1], J. Neethirajan[5], L. Schäfer[3], F. Maccari[3], M. Guizar-Sicairos[6,7], V. Scagnoli[8,6], M. Holler[6], D. Shapiro[2], A. Ditter[2], E. Bruder[3], H. Wende[1], K. Skokov[3], O. Gutfleisch[3], C. Donnelly[5], and K. Ollefs[1] — [1]Fac. of Phys., UDE, Duisburg GER — [2]LBNL, ALS, CA US — [3]Mat. Sc., TU Darmstadt GER — [4]BNL, NSLS-II, NY US — [5]MPI CPfS, Dresden GER — [6]PSI, SLS, Villigen CH — [7]Inst. of Physics, EPFL, Lausanne CH — [8]Dep. of Mat., ETH Zürich CH

Nd-Fe-B magnets play a key role in sustainable energy conversion, for example in wind turbines or electric motors, due to their superior magnetic performance and high energy density. Here, we provide insights into the 3D magnetic domain structure of (therm.) demagnetized nanostructured Nd-Fe-B magnets obtained by X-ray ptychography and tomography at room temperature. We have imaged the magnetic interaction domains inside a hot-deformed, anisotropic, nanocrystalline Nd2Fe14B magnet to correlate the crystal and microstructure and the configuration of the magnetic moments. The combination of hard and soft X-rays enables the comparison of the domain structure between bulk and lamellae and provides detailed insights into the complex magnetic structure in deeper sections of the magnet and down to individual grains, which can be shown to partly exhibit a single-domain state. We gratefully acknowledge funding from the DFG via CRC/TRR 270.

MA 30.4 Wed 17:00 H18

Combined theoretical and experimental study of magnetic properties of Fe-Sn intermetallics — •Martin Friák[1], Petr Čípek[1,2], Pavla Roupcová[1], Oldřich Schneeweiss[1], Jana Pavlů[2], Dominika Fink[3], Šárka Msallamová[3], and Alena Michalcová[3] — [1]Inst. Phys. Mater., Czech Acad. Sci., Brno, Czech Rep. — [2]Dept. Chem., Masaryk Uni., Brno, Czech Rep. — [3]Dept. Metal Corr. Eng., Uni. Chem. Technol. Prague, Czech Rep.

There are conflicting literature reports related to Fe-Sn intermetallic phases, when, for example, the $FeSn_2$ phase is theoretically predicted to be dynamically unstable due to imaginary phonon modes (see, e.g, C.-J. Yu et al., New J. Chem. 44 (2020) 21218, DOI:10.1039/d0nj04537c). We have, therefore, performed a combined theoretical and experimental study of both $FeSn_2$ and FeSn intermetallics. The theoretical part consists of quantum-mechanical calculations of ground-state properties, including structural, vibrational and magnetic properties. Computing phonon modes allowed for testing the dynamic stability and the thermodynamic properties were subsequently assessed using quasi-harmonic approximation (QHA). The $FeSn_2$ phase is computed stable, i.e., free of imaginary phonon modes. We have also characterized Fe-Sn phases using Mössbauer measurements of magnetic properties, including a temperature-dependent Mössbauer factor, which we compared with theoretical results based on quantum-mechanical calculations of thermal vibrations.

MA 30.5 Wed 17:15 H18

Pr-Fe-B hot deformed magnets for low-temperature applications — •Priyatosh Sahoo[1], Alex Aubert[1], Fernando Maccari[1], Yuye Wu[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt, Germany — [2]Beihang University, China

Nd-Fe-B based PMs are the most prevalent in various applications due to their high coercivity and remanence, which result in exceptional energy product values near room temperature. However, their performance significantly diminishes below 135 K due to Spin Reorientation Transition (SRT). In contrast, when Nd is substituted by Pr, these magnets do not exhibit such transitions at low temperatures, making them preferable for cryogenic applications such as space industry. In our study, we compared the low-temperature performance of Pr17Fe76.5Cu1.5B5 and Nd17Fe76.5Cu1.5B5 hot deformed (HD) magnet. The microstructure of HD magnets consists of grains in the range of the critical single domain particle size of these systems, i.e., 200-300 nm, which enhances coercivity without the necessity of adding heavy rare earth elements. We conducted a comprehensive analysis that examined intrinsic magnetic properties based on single crystal studies and the transition to extrinsic properties through microstructure engineering along the hot deformation process. Additionally, we explored the effect of doping Pr-Fe-B with Cu in the hot deformation process and correlated its influence on the magnetic properties and microstructure. We acknowledge Deutsche Forschungsgemeinschaft's (DFG) funding within the CRC/TRR 270 (Project-ID 405553726).

MA 30.6 Wed 17:30 H18

Peculiar low-temperature properties in the ferromagnetic pyrochlore metal $LuInCo_4$ — •Taiki Shiotani[1], Hiroyuki Nakamura[1], and István Kézsmárki[2] — [1]Department of Materials Science and Engineering, Kyoto University, Kyoto 606-8501, Japan — [2]Experimental Physics V, Institute of Physics, University of Augsburg, D-86159, Augsburg, Germany

The pyrochlore lattice, a network of corner-sharing tetrahedra, is attracting attention due to geometrical frustration as well as nontrivial topology of the band structure. $LuInCo_4$ is C15b-type laves phase compound with a Co-based pyrochlore sublattice. We have successfully synthesized single crystals of $LuInCo_4$ and found strong ferromagnetism with the $T_C = 306$ K [1]. The ferromagnetic nature was reproduced by density functional theory calculations, suggesting that

Co-3d flat bands near the fermi level induce the spin polarization. The magnetization has no detectable anisotropy down to ≈100 K, below which the anisotropy gradually becomes stronger with the cubic 100-type axes being the easy-axes. For fields applied along the cubic 111-type directions the material goes through a metamagnetic transition.

Here, we will focus on the low-temperature phase of $LuInCo_4$ to discuss the origin of the anomalous behavior of the magnetization.

[1] T. Shiotani *et al.*, Phys. Rev. Mater. 8, 114409 (2024)

MA 30.7 Wed 17:45 H18

Laser powder bed fusion of hard magnetic composites — •Kilian Schäfer — Functional Materials, Institute of Material Science, Technical University of Darmstadt

Hard magnetic materials are essential for advancing carbon-neutral technologies and medical devices. While traditional manufacturing methods suit large, simple magnets, there is increasing demand for resource-efficient processes to create intricate small magnetic components. Additive manufacturing offers a promising solution, enabling the production of complex, tailored magnetic components with improved efficiency. This study explores composites made via laser powder bed fusion, combining hard magnetic powders with polyamide and thermoplastic polyurethanes. It examines how the magnetic powder*s fraction, morphology, and particle size impact performance. Results show that anisotropic magnetic properties can be achieved with specific powder particle shapes. Additionally, localized mechanical properties were achieved by adjusting laser parameters, enabling the production of magnetically controllable actuators for applications like biomedical devices. These findings provide guidelines for optimizing hard magnetic composite performance using laser powder bed fusion.