MA 50: Bulk Materials: Soft and Hard Permanent Magnets

Time: Thursday 15:00–17:15 Location: POT/0151

MA 50.1 Thu 15:00 POT/0151

Ag-induced hardening and enhanced magnetic performance in SPS-consolidated CoCrFeMnNi high-entropy alloys — •Emmanouil Kasotakis[1], Ivan Tarasov[1], Tatiana Smoliarova[1], Hamed Shokri[2], Bilal Gökce[2], Michael Farle[1], and Natalia Shkodich[1] — [1]Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, 47057 Germany — [2]Chair of Materials Science and Additive Manufacturing, School of Mechanical Engineering and Safety Engineering, University of Wuppertal, Wuppertal, 42119 Germany

Nanocrystalline CoCrFeMnNi-Agx (x = 0; 1; 2.5; 5.5 at. %) high-entropy alloy (HEA) powders, produced via rapid two-step high-energy ball milling (HEBM) in Ar [1], were consolidated into ferromagnetic (Tc ~ 80 K) bulk samples by spark plasma sintering (SPS) at 700 K and 1000 K. Ag-free CoCrFeMnNi sintered at 1000 K formed a single-phase fcc alloy with uniform elemental distribution and a Vickers microhardness (HV0.2) of 2.4 GPa. Ag addition created distinct powder microstructures, from Ag-segregated regions (1 and 2.5 at. %) to uniform Ag distribution (5.5 at. %), increasing HV0.2 by 12% (to 2.7 GPa) in SPS-consolidated HEAs. In-field annealing (up to 700 K, 9 T) enhanced magnetization (M), coercivity (Hc), and remanence (Mr). CoCrFeMnNi-Agx (x = 5.5 at. %, 700 K) showed a tenfold rise in M (9 T, 310 K) to 40.2 Am2/kg, Hc = 46 kA/m, and Mr = 12.1 Am2/kg. We acknowledge DFG support (project ID: FA209/27-1).

[1] E. Kasotakis, et al. Acta Mater. 303, 121717 (2026).

MA 50.2 Thu 15:15 POT/0151

Transition-Metal-Induced Uniaxial Anisotropy in Fe_3Y — •M. Nur Hasan[1], Santa Pile[2], Rafael M. Vieira[1,3], Alexander Kovacs[2], Samuel RJ Holt[4], Martin Lang[4], Swapneel Pathak[4], Andrea Petrocchi[4], Hans Fangohr[4], Thomas Schrefl[2], and Heike C. Herper[1] — [1]Uppsala University, Sweden — [2]University for Continuing Education Krems, Austria — [3]Luleå University of Technology, Sweden — [4]MPSD, Hamburg, Germany

The rising demand for sustainable energy increases the need for rare-earth-free high-performance permanent magnets. The intermetallic compound Fe_3Y is a promising candidate due to its high saturation magnetization and Curie temperature. However, its intrinsic easy-plane magnetocrystalline anisotropy (MCA) hinders its use as a permanent-magnet material. Here, we combine first-principles density functional theory, spin-dynamics and micromagnetic simulations to explore mechanisms for reorienting the MCA toward a desired uniaxial direction through selective transition-metal doping. Our results show that Fe-site substitution, particularly with V, Zn, Nb, and Ta reverses the MCA to a uniaxial, reaching values up to 2 MJ/m^3, while the Curie temperature remains unaffected by these dopants. Micromagnetic simulations reveal dopant-specific hysteresis trends and indicate that the systems maintain stability in low-temperature regimes.

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MA 50.3 Thu 15:30 POT/0151

Magnetic imaging of interaction domains in nanocrystalline Nd-Fe-B by X-rays — P. Klassen[1], D. Günzing[2], A. Aubert[3], B. Eggert[1], T. Feggeler[2,4], •L. Kämmerer[1], G. Kämmerer[1], F. Maccari[3], J. Neethijaran[5], A. Ditter[2], D. Shapiro[2], H. Wende[1], K. Skokov[3], O. Gutfleisch[3], C. Donnelly[5], and K. Ollefs[6] — [1]Uni. Duisburg-Essen and CENIDE, GER — [2]LBNL, ALS, CA US — [3]Mat. Sc., TU Darmstadt, GER — [4]BNL, NSLS-II, NY US — [5]MPI-CPfS, Dresden, GER — [6]KIP, Uni. Heidelberg, GER

Nd-Fe-B magnets play a key role in sustainable energy conversion due to their high energy density. We provide insights into the magnetic domain structure of nanocrystalline Nd-Fe-B magnets obtained by X-ray ptychographic coherent diffractive imaging. The magnetic interaction domains of nanocrystalline Nd-Fe-B magnets with different compositions and grain structures ($Nd_2Fe_{14}B$ and $Nd_{15}Fe_{78}B_7$ melt spun ribbons and hot-deformed Nd-Fe-B from MQU-F) are shown and correlated to its microstructure. The soft X-ray imaging at the Fe L_3 edge provides detailed insights into the complex magnetic structure within the magnets, down to individual grains in the nanometer regime (10 nm). With 3D X-ray ptycho-tomography imaging we investigate the nature and local character of the domain wall in the hot-deformed Nd-Fe-B and correlate it to the microstructure in the material. Misalignment in magnetization of individueal grains from the interaction domain direction can be seen. We gratefully acknowledge funding from the DFG via the CRC/TRR 270 and used resources of the Advanced Light Source (contract no. DE-AC02-05CH11231).

MA 50.4 Thu 15:45 POT/0151

Nanoscale origins of coercivity in Cu-modified Sm(Co,Zr)6.7 alloys with globular 1:5/2:17 nanostructure — •Burcak Ekitli[1], Alex Aubert[1], Xinren Chen[2], Konstantin Skokov[1], Fernando Maccari[1], Esmaeil Adabifiroozjaei[3], Leopoldo Molina-Luna[3], Baptiste Gault[2], and Oliver Gutfleisch[1] — [1]Functional Materials, TU Darmstadt, 64287 Darmstadt, Germany — [2]Max-Planck-Institut for Sustainable Materials, 40237 Düsseldorf, Germany — [3]Advanced Electron Microscopy, TU Darmstadt, 64287 Darmstat, Germany

Sm-Co permanent magnets are commercially available in two main forms: the SmCo5 nucleation type and the more complex Sm(Co,Fe,Cu,Zr)7-7.5 (2:17-type), where coercivity is controlled by domain-wall pinning linked to a Cu concentration gradient within a cellular nanostructure. In this work, we investigate the Sm(CobalCuyZr0.023)6.7 composition to examine how Cu content affects microstructure and magnetic performance. HRSEM, TEM, and atom probe tomography reveal a previously unreported globular nanostructure, consisting of nanoscale 2:17 regions embedded in a continuous 1:5 matrix. Coercivity increases with Cu concentration and reaches up to 2 T when the Cu gradient is sufficiently strong. This underscores the superior efficiency of the cellular structure, which achieves comparable coercivity with less Cu. However the globular structure provides more stable coercivity at elevated temperatures (>700 K). These results connect microstructure and thermal stability, guiding new designs for high-temperature Sm-Co magnets.

MA 50.5 Thu 16:00 POT/0151

Unraveling the Magnetic Interactions of Nanocrystalline Rare-Earth-Lean Nd-Fe-B Powder and the Influence of Additive Manufacturing on the Magnetic Properties — •Priyatosh Sahoo[1], Lukas Schäfer[1], Kilian Schäfer[1], Franziska Scheibel[1], Esmaeil Adabifiroozjaei[1], Rebekka Hlawaty[1], Enrico Bruder[1], Philipp Gabriel[2], Anna Ziefuss[2], Stephan Barcikowski[2], Leopoldo Molina-Luna[1], Karsten Durst[1], Oliver Gutfleisch[1], and Konstantin Skokov[1] — [1]TU Darmstadt, Germany — [2]Universität Duisburg-Essen, Germany

MQP-S powder is a promising material for Laser Powder Bed Fusion (PBF-LB/M) thanks to its excellent flowability and hard magnetic properties. It shows enhanced remanence despite an isotropic microstructure, indicating exchange-spring-like behavior. However, PBF-LB/M processing fully melts the powder, erasing its initial microstructure and possibly affecting magnetic interactions. This study explores how PBF-LB/M parameters influence both density and magnetic performance in MQP-S magnets. Selected samples were characterized using Henkel and Thamm-Hesse plots, First-Order Reversal Curves (FORC) and magnetic domain imaging give insides about the global and local magnetic properties and interaction. A comparative analysis between the initial powder and the additively manufactured samples shows distinct magnetic coupling behaviors linked to the changing microstructure, providing new insights into the relationships among processing, microstructure, and properties in these magnets.

MA 50.6 Thu 16:15 POT/0151

Accelerating Sm-Fe-V Phase-Diagram Mapping via an Active-Learning Pipeline — •Aaron Dextre, Alex Aubert, Konstantin Skokov, Oliver Gutfleisch, and Pelin Tozman — Technische Universität Darmstadt

Sm1Fe12-based compounds are promising candidates to replace Nd-Fe-B, yet realizing their potential requires specific microstructures where grains are isolated by a low-melting-point phase. To locate the specific phase equilibria required for this coexistence, we developed an active-learning framework to accelerate the mapping of the Sm-Fe-V phase diagram. Integrating Neural Networks and Random Forests, our ensemble model iteratively directed the synthesis and annealing of target alloys to refine phase boundaries efficiently. After six cycles, we determined that the 1:12 phase is stable over a broader V range, while the target two-phase field is more confined than previously reported. These findings revise the Sm-Fe-V equilibria and demonstrate active learning*s utility in magnetic materials discovery.

MA 50.7 Thu 16:30 POT/0151

A new look at the magnetic properties of $DyCo_5$ — Alena Vishina[1], Konstantin Skokov[2], Hiroki Tsuchiura[3], Patrik Thunström[1], Alex Aubert[2], Oliver Gutfleisch[2], Olle Eriksson[1,4], and •Heike C. Herper[1] — [1]Uppsala University, Uppsala, Sweden — [2]Technische Universität Darmstadt, Germany — [3]Tohoku University, Sendai, Japan — [4]WISE-Wallenberg Initiative Materials Science, Uppsala University

Rare earth (RE) intermetallics such as $RECo_5$ impress with a huge variety of magnetic properties arising from the interplay of RE 4f and transition metal 3d orbitals. Our recent study provides new insights in $DyCo_5$.[1] Measurements were carried our on single crystals in applied fields up to 14T. We employed a multiscale modelling theory combining dynamical mean field theory (as implemented in the LMTO code RSPt) and atomistic spin-dynamics (UppASD) simulations with the effective spin model for RE compounds to understand the origin of the experimental findings.

Our multiscale method allows to explain the experimentally observed magnetisation anisotropy as well as the behaviour around the magnetic compensation point. For $DyCo_5$, both experiment and theory, show that the compensation is incomplete and field dependent. Furthermore, key experimental features - such as the saturation behaviour at high fields and the evolution of the magnetic moment at different temperatures - are successfully reproduced.

[1] http://arxiv.org/abs/2511.17087

MA 50.8 Thu 16:45 POT/0151

Orbital magnetic moment and magnetocrystalline anisotropy of Fe_2AlB_2 — •Nicolas Josten[1], Benedikt Eggert[1], Benedikt Beckmann[2], Anna Semisalova[1], Ralf Meckenstock[1], Konstantin Skokov[2], Hanna Pazniak[3], Thierry Ouisse[3], Katharina Ollefs[1], Heiko Wende[1], Oliver Gutfleisch[2], Michael Farle[1], and Ulf Wiedwald[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg Essen, Germany — [2]Functional Materials, Institute of Materials Science, Technical University of Darmstadt, Germany — [3]LMGP, Grenoble INP, CNRS, Université Grenoble Alpes, France

Fe_2AlB_2 is a ferromagnet known for its considerably high magnetocrystalline anisotropy (1 $MJ\cdot m^{-3}$ at 10 K [1]), tunable Curie-temperature around ambient temperature (stoichiometric T_C = 291 K [1]) and magnetocaloric effect of moderate size ($\Delta T_{ad}(2\ T) = 2.2$ K [2]). It can be easily synthesized out of earth-abundant and low-cost elements. Here we combine X-ray magnetic circular dichroism (XMCD) and ferromagnetic resonance (FMR) measurements on single crystals to determine the orbital moment and correlate it with the high magnetocrystalline anisotropy. Additional magnetometry measurements along the principal crystallographic directions show the development of anisotropy across the ferromagnetic to paramagnetic phase transition.

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[1] N. Josten et al. Phys. Rev. Materials 9, 054405 (2025)
[2] B. Beckmann et al. J. Appl. Phys. 133, 173903 (2023)

MA 50.9 Thu 17:00 POT/0151

Enabling Ce Substitution in Nd-Fe-B Magnets for Wind Turbines via the 2-Powder Method — •Chi-Chia Lin[1,2], Konrad Opelt[1], Abdullatif Durgun[2], Imants Dirba[2], and Oliver Gutfleisch[2] — [1]Fraunhofer IWKS, Hanau, Germany — [2]TU Darmstadt, Darmstadt, Germany

Wind turbines contain Nd-Fe-B magnets weighing up to several tonnes. As deployment accelerates, demand for Nd rises, increasing supply risk and cost. Ce substitution can reduce critical-RE usage but degrades performance due to inferior intrinsic properties of $Ce_2Fe_{14}B$, formation of detrimental phases, and microstructural degradation.

We present a 2-powder method (2PM) enabling substantial Ce substitution without geometry constraints. A coarser (Ce,Nd)-Fe-B main powder is blended with a finer Nd-Fe-B powder and conventionally sintered, producing a uniform core-shell structure in which Nd-enriched shells magnetically harden $RE_2Fe_{14}B$ grain surfaces. Relative to single-powder processing at identical overall composition, 2PM boosts coercivity, remanence, and energy product by increasing local anisotropy fields at grain surfaces and optimizing grain-boundary chemistry. In addition, we introduce a hybrid segmented magnet that positions the 2PM Ce-substituted segment between Nd-Fe-B segments, extending local magnetic hardening to a bulk macroscopic effect and enhancing demagnetization resistance while concentrating Nd only where peak coercivity is required.

Together, 2PM and hybrid segmentation offer a scalable route to thrift Nd with abundant Ce toward wind-turbine performance targets.