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Hysteresis Design of Magnetic Materials for Efficient Energy Conversion

Tuesday, 27 January 2026, 9:00 s.t., via Zoom



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Non-trivial magnetic textures in chiral magnets from combined in-situ microscopy techniques

Abstract:

In chiral magnets, the interplay of symmetric exchange, asymmetric Dzyaloshinskii–Moriya interaction (DMI), magnetic anisotropies, and external magnetic fields not only results in complex magnetic phase diagrams, but also promotes the emergence of topologically nontrivial spin textures such as (anti-) skyrmions and chiral soliton lattices. The talk will review how the combined use of Lorentz transmission electron microscopy (LTEM), resonant elastic X-Ray scattering (REXS), in-situ Hall measurements in the electron microscope, theory and micromagnetic simulations allows to better understand the nature of chiral spin textures, their topological protection, and specifically the magnetic field-induced transitions between these different magnetic states, part of which necessitate the overcoming or bypassing of topological barriers.

Our comprehensive investigations are focused on the half Heusler compound $\text{Mn}_{1.4}\text{PtSn}$. It will be shown that the magnetic ground state of the material – a chiral soliton lattice (CSL) with 180° (π) domain walls – undergoes a remarkable transformation into a classical 2π -CSL in increasing magnetic fields. These observations are elegantly captured by a double sine-Gordon model, which not only reveals the relevance of the competition between the magneto-crystalline anisotropy and magnetostatic interactions for tuning this transformation, but also provides the framework to understand soliton lattices in materials with a variety of D_{2d} , S_4 , C_{nv} , and C_n symmetries. The mutual interplay between CSLs and magnetic fan domains emerging in particular field orientations leads to the nucleation of non-topological magnetic bubbles just by providing some right and left-handed chiral "ingredients" to their texture. Understanding the nature of these transformations allows us to unveil the microscopic mechanisms that govern the formation of anti-skyrmion lattices in the material. Notably, in-situ monitoring the Hall effect during the switching between non-topological bubbles and topological anti-skyrmions does not reveal any signs of a topological contribution to the Hall voltage, i.e., of a topological Hall effect.

About the speaker:

Bernd Rellinghaus is a physicist and materials scientist. He has earned his Ph.D. in physics from the University of Duisburg, Germany, in 1995. After a period as a postdoctoral Research Stipend of the German Science Foundation (DFG) at the IBM Almaden Research Center in San Jose, CA, USA (1995 to 1996), he returned to the University of Duisburg as a research assistant, before he accepted a position as Department Head at the Leibniz Institute for Solid State and Materials Research Dresden e.V. (IFW Dresden, 2004 to 2017). Since 2018 he serves as the Director of the Dresden Center for Nanoanalysis (DCN) at the TUD Dresden University of Technology. Bernd Rellinghaus is an internationally recognized expert in aberration-corrected high resolution analytical transmission electron microscopy and related spectroscopy and in-situ techniques. His expertise comprises (besides others) magnetic materials, metallic materials, structure-property relations, (nano)magnetism, and nanoparticles. He has (co-) authored more than 200 scientific papers in peer-review journals.

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