Materials Innovation Seminar
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Research Building B110

Magnetic Materials for Green Energy Conversion

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Magnetic materials are essential components for green energy conversion and data storage, and play a critical role in achieving a carbon-neutral society. They include hard magnetic materials, soft magnetic materials, magnetocaloric materials, and magnetic recording media for hard disk drives. One of the key properties that can lead to different functionality in these materials is called "hysteresis". Hysteresis can be controlled by several intrinsic and extrinsic parameters. The design of materials and their microstructure in a broad length scale from atomic to nano- and micro-scale can influence the hysteresis of the magnet and its functionality. In this talk, we will show how integrated materials design, materials synthesis, characterization and microstructure engineering, and microstructure-based computational modeling have enabled us to develop high performance magnetic materials for green energy conversions.

In the first part of the talk, we will focus on permanent magnets. We will show how the selection of appropriate microstructural defects in different permanent magnets can result in a large coercivity, defined as the resistance of the magnet to magnetization reversals. We will show how nano-defects and secondary phases can play different roles in magnetization reversal and hence coercivity in different types of permanent magnets; Sm_2Co_{17} type, $SmCo_5$ type, $SmFe_{12}$ type and $Nd_2Fe_{14}B$ type permanent magnets. Several examples are given of defect engineering that has led to the development of Dy-free Nd-Fe-B magnets with an ultimate performance and the development of high coercivity rare-earth lean $SmFe_{12}$-based magnets [1,2].

In the second part of the talk, we will extend the examples on how nanostructure engineering in Fe-based alloys leads to different functionalities in the materials; from soft magnets with minimal core losses for power electronic applications to the realization of flexible spin-caloritronic materials with giant and transverse thermoelectric conversion [3]. In the last part of the talk, we will show examples of material design of magnetocaloric materials leading to the elimination of their hysteresis, which benefits their cyclic performance towards the realization of environmentally benign and efficient magnetic cooling technology [4]. This talk will provide new insights on how the application of a combinatorial research approach can develop a new fundamental understanding of the physical properties of magnetic materials and improve their functionality closer to their theoretical limits.

References:

[1] H. Sepehri-Amin *et al.* Scripta Mater. 242 (2024) 115955
[2] N. Kulesh *et al.* Acta Mater. 276 (2024) 120159.
[3] R. Gautam *et al.* Nature Comm. 15 (2024) 2181.
[4] X. Tang, H. Sepehri-Amin *et al.* Nature Comm. 13 (2022) 1817.