Understanding the Magnetostructural Transformation in FeRh Thin Films

Melissa G. Loving
Department of Chemical Engineering
Northeastern University
Boston, Massachusetts 02115

November 22nd, 2013
Room: 108 Snell Engineering

Magnetostructural materials demonstrate concurrent magnetic and structural phase transformations which may be driven by changes in temperature, pressure (strain), or magnetic field. The ability to alter the phase transformation *via* a variety of routes makes these systems the interest of fundamental studies of the physics underlying the transformation, as well as potential technological applications. Equiatomic α′-FeRh, a model magnetostructural material with the chemically-ordered CsCl-type crystal structure, undergoes a first-order phase transition (FOPT) (upon heating) from antiferromagnetic (AF) to ferromagnetic (FM) order with an accompanying 1% (volume) lattice expansion at T~370 K, in bulk. Thin film forms of α′-FeRh provide an additional degree of complexity to the transformation character as epitaxial film//substrate clamping and reduced-dimensionality promotes anisotropic interface strain, creating a rich arena to explore the FOPT.

In this dissertation, sputter deposited α′-FeRh thin films have been grown to study the role of intrinsic (chemical modification by thermally driven Au-capping layer diffusion) and extrinsic (strain/film lattice distortion and nanostructuring) factors on the FOPT character. Further, magnetic studies coupled with kinetic analysis have been employed to develop an understanding of the phase transformation kinetics (energy barriers and nucleation and growth mechanism associated with the AF-FM FOPT) in α'-FeRh thin films. Results exposed in this dissertation have been obtained with laboratory- and synchrotron-based magnetic and structural probes to advance the understanding of the spin-lattice coupling in the α′-FeRh system with information that allows FOPT tailoring. Specifically, results obtained in this dissertation reveal that thermally-driven Au diffusion, out-of-plane lattice distortion, and nanostructuring lead to a stabilized FM phase in the (bulk) AF regime. Further, the results achieved in this dissertation indicate that the degree of undercooling of the FM phase (phase metastability), AF/FM phase coexistence, and the energy barrier associated with the AF-FM transition may be modified with intrinsic and extrinsic properties, thereby creating a variety of pathways to tailor the FOPT.

Despite the success achieved in this dissertation there remain many avenues which may be explored to further enhance the knowledge-base of FeRh and magnetostructural systems in general. The concluding section of this dissertation provides recommendations for additional experiments which may be pursued to further understand the influence of nanostructuring FeRh and reveal information related to the origin of the FOPT in these systems. These experiments include: lithographically patterning a continuous FeRh film layer to systematically tailor the FOPT response in nanostructured FeRh and time-resolved x-ray magnetic circular dichroism (XMCD) or x-ray diffraction (XRD) experiments which may provide insight into the origin of the FeRh magnetostructural transformation.