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Synthesis of Highly Magnetostrictive Single Crystal $Fe_{1-x}Ga_x$ Thin Films

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The $Fe_{1-x}Ga_x$ alloy system is a highly anisotropic magnetostrictive material at the appropriate alloy concentration (termed Galfenol at x ~ 0.2) [1]. In thin film form, the atomic pinning of such a material to a substrate can strongly modify the magnetic anisotropy and therefore the magnetization dynamics in a non-isotropic manner, as is demonstrated by a strong angular dependence of the ferromagnetic resonance (FMR) linewidth.

Single crystal $Fe_{1-x}Ga_x$ thin films of various Ga concentrations were prepared on GaAs(001) and MgO(001) substrates by molecular beam epitaxy (MBE), with and without ZnSe buffer layers, respectively. For both substrates, reflection high energy electron diffraction (RHEED) measurements, performed *in-situ* during the growth, show single crystal epitaxial growth of the bcc structure for alloy compositions up to x = 0.7, well beyond the bulk stability region. Vibrating sample magnetometry (VSM) measurements show a reduction in the saturation magnetization with the incorporation of Ga, as well as a migration of the magnetic easy and hard axes that varies slightly between the two substrates. This slight variation is most likely due to the additional uniaxial magnetic anisotropy present in the films grown on the GaAs substrate due to the directional bonding from the zinc-blende surface. X-ray magnetic circular dichroism (XMCD) performed at the Fe $L_{2,3}$-edges reveals a very gradual decrease (10%) in the elemental Fe moment as the Ga concentration approaches 20% followed by a precipitous drop in moment for higher concentrations, while X-ray absorption spectroscopy (XAS) and XMCD measurements performed on the Ga $L_{2,3}$-edges shows an evolution in the local Ga electronic structure (a narrowing of 1.6 eV in the L_3 peak position) and establishes an induced moment in the gallium of 0.1 μ_B anti-aligned to the Fe moment, in remarkably strong agreement with *ab-initio* density functional (GGA) calculations.

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