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Understanding the Interface Properties of Magnetic Heterostructures

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Engineered interfaces in heterostructures with preferred functionality is frequently tied to a modified behavior at the interfaces and therefore requires detailed knowledge on the chemical, electronic, and magnetic properties as a function of position within the structure. As X-ray reflectometry (XRR) and polarized neutron reflectometry (PNR) provide access to the depth-dependent chemical structure and the magnetization vector, they can provide insights on the relationship between the electronic and magnetic properties and the microstructures, especially at the interfaces. Two examples of our recent work using primarily XRR and PNR will be presented. In the first work, the intrinsic magnetic properties in an Fe/Sm-Co bilayer fabricated under nearly optimal spring-magnet conditions was determined.[1] We found that at the Fe/Sm-Co interface the chemical compositions and magnetic properties change gradually at the length scale of 8 nm via complementary studies of XRR, PNR and micromagnetic simulations. In this intermixed interfacial region, the saturation magnetization and magnetic anisotropy are lower and the exchange stiffness is higher than values estimated from the model based on a mixture of Fe and Sm-Co phases. Therefore, the intermixed interface yields superior exchange coupling between the Fe and Sm-Co layers, but at the cost of average magnetization. In the second work, we investigated LaSrMnO/PrCaMnO superlattices designed as a prototype of magnetically tunable metal–insulator devices by utilizing the competition between the ferromagnetism (FM) and the charge-orbital (CO) ordering [2] . Our XRR studies reveal that the chemical intermixing at the interfaces depends on the deposition order. The preliminary PNR results provide further evidence for the FM/CO phase separation in the real space has been realized with controllable boundaries.

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Structural and Polarized Neutron Reflectometry Characterization of $Fe_{16}N_2$ Thin Films with Giant Saturation Magnetization

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It is well known that the greatest saturation magnetization value that has been achieved so far is M_s=2.45T with $Fe_{65}Co_{35}$ alloy [1]. Recently Wang's group reported the discovery of the origin of the giant saturation magnetization in $Fe_{16}N_2$[2]. More importantly, we have developed a theory to well explain the ordering effect on the giant Ms [3]. This laid out a foundation for further experiment work. T. K. Kim and M. Takahashi [4] firstly reported a material $Fe_{16}N_2$, with a saturation magnetization about 18% higher than $Fe_{65}Co_{35}$ alloy, which was confirmed 20 years later, by Sugita's group [5]. However this topic has been dropped by the magnetic materials community since 1996 and has been viewed as a controversial topic because there is no theory to support the existence of giant M_s and the traditional of methods to test M_s is volume dependence and typically has a large error bar. More importantly, there is lack of advanced experimental technique to probe the magnetization in a direct and independent approach. Furthermore, Wang's group has developed a repeatable and reliable process to fabricate high quality $Fe_{16}N_2$ thin film samples using a facing target sputtering technique [6].

Here we present a careful X-ray diffraction studies with scattering vector both in-plane and out-plane (A typical out of plane x-ray diffraction pattern on one of these samples is shown in Fig.1) confirms the formation of $Fe_{16}N_2$ phase. A rocking curve measurement reveals mosaic spreading of ~0.5°, which is comparable to monocrystaline films.

By using polarized neutron reflectometry at ORNL, for the first time, we directly confirmed the exsistence of giant saturation magnetization in our films. These data resolve a 40 years controversy among magnetic researchers regarding whether $Fe_{16}N_2$ possess giant saturation magnetization. PNR results will be reported at the conference in details.

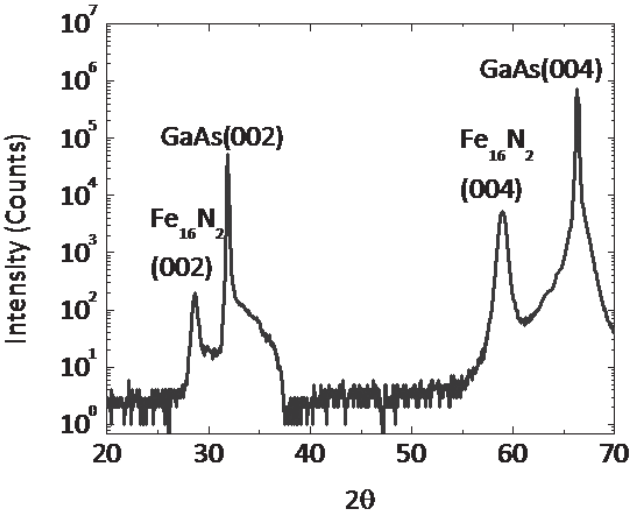

FIG..1 X-ray diffraction on sample with structure GaAs/Fe(2nm)/Fe-N(50nm) (unpublished data). The film peaks can only be indexed to the $Fe_{16}N_2$

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