SPONTANEOUS MAGNETIC ORDERING OF A COMPLEX OXIDE SUPERLATTICE

Interfaces between materials are fascinating places, where reduced dimensionality and proximity effects frequently combine to yield new properties not common to the component materials by themselves. A technologically relevant example is that of synthetic multilayer antiferromagnets. Ferromagnetic materials are characterized by spontaneous, long-range parallel alignment of spins, which gives rise to a net magnetization. Antiferromagnets also exhibit long-range order, but that order is characterized by antiparallel spin alignment, with zero net magnetization. However, ferromagnets can be made to exhibit antiferromagnetism through precise interfacial control. In multilayer structures comprised of thin ferromagnetic metallic layers, separated by paramagnetic (i.e. no spontaneous magnetic order) metallic spacer layers, the thickness and composition of the spacer can be used to tune the coupling between separated ferromagnetic layers to favor parallel or antiparallel alignment. In this way, synthetic antiferromagnets can be constructed without any naturally ferromagnetic material. Such synthetic antiferromagnets can exhibit giant magnetoresistance, and have important applications in magnetic recording and sensor technology.

While this phenomenon has been studied for some time, there is still significant uncharted ground. For example, advances in oxide thin film growth now make it possible to fabricate complex oxide multilayers with extremely high quality interfaces. This leads to interesting possibilities for functional design, as interfacial charge transfer between such oxides can lead to changes in electronic configuration which may then be used to manipulate the magnetic ordering and / or coupling at the interfaces.[1]. With this in mind, Jason Hoffman and Anand Bhattacharya of Argonne National Laboratory have used ozone-assisted molecular beam epitaxy to grow a 14-repeat superlattice of 9 atomic layers of nominally ferromagnetic and metallic $La_{0.66}Sr_{0.33}MnO_3$ (LSMO) interfaced with 3 layers of nominally ferromagnetic and metallic $LaNiO_3$ (LNO). Measurements of the Mn and Ni valence using x-ray absorption spectroscopy indicate that interfacial charge transfer is playing an important role, and measurements of x-ray circular dichroism at the Ni and Mn L-edges indicate that the magnetism of the LNO and LSMO layers are coupled at the interface.[2]

An important question is how the ferromagnetic LSMO layers couple across the full thickness of the LNO spacers in this novel system. In the absence of an applied magnetic field (or in a weak field) do the magnetizations of the LSMO layers align? Put differently, does the composite system act like a uniform ferromagnet, a synthetic antiferromagnet, or a merely a collection of magnetic layers without long-range order? Clues about the magnetic order can be obtained from magnetometry measurements, but it is difficult to get a clear answer without a spatially sensitive probe. Therefore, we will pursue polarized neutron reflectometry measurements using the PBR beamline. This technique gives us sensitivity to the depth profiles of both the nuclear composition and the in-plane vector magnetization in thin films and multilayer structures. We will cool the $[LSMO / LNO]_{14}$ sample to 110 K (well below the ferromagnetic transition temperature of LSMO) and measure the spin and wavevector-transfer (Q) dependent specular reflectivity in a weak 1 mT field (necessary to keep the neutron beam

polarized). Through model fitting of the data, we will determine the spontaneous magnetization depth profile, and thereby determine the nature of the spontaneous magnetic ordering.

[1] T. S. Santos *et al*., *Phys. Rev. Lett*. **107** 167202 (2011).
[2] J. Hoffman *et a*l., *Phys. Rev. B* **88**, 144411 (2013).