Direct Determination of an Antiferromagnetic Surface Spin Structure by (Soft) X-Ray Magnetic Linear Dichroism


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Magnetic multilayer structures exhibit fascinating scientific effects and have important applications in the high-tech industry. An important class of magnetic multilayers contains antiferromagnetic thin films, which are used to pin the magnetization direction of an adjacent ferromagnetic layer, thereby defining a unique magnetization direction. This pinning effect, which is referred to as ‘exchange bias’, has been discovered more than 45 years ago and although it is of great technological importance, the origin of the exchange bias effect is despite active research still unknown. One of the obstacles preventing a better understanding of its origin is the lack of sensitivity of conventional techniques to address the surface and interface magnetic properties of thin antiferromagnetic films. On the other hand, it is clear that the surface/interface structure should play the key role in the exchange bias effect. Lacking experimental information most common exchange bias models have assumed a bulk like spin structure at the interface, i.e., the possibility that the magnetic structure of the thin film surface might differ from the known antiferromagnetic bulk structure is generally ignored.

We have studied the antiferromagnetic structure in the surface region of structurally well-characterized antiferromagnetic LaFeO$_3$ films. These some ten nm thin films were grown on SrTiO$_3$ (110) and SrTiO$_3$ (100) substrates. Plan-view electron-diffraction and conventional TEM have been used to resolve the crystallography. The magnetic spin structure has been investigated via the x-ray magnetic linear dichroism (XLMD) effect. This gives rise to a polarization dependence of the absorption coefficient on the orientation of the antiferromagnetic axis relative to the electric field vector of linearly polarized x-rays. From the experimentally observed polarization dependence one can directly conclude that the magnetic structure in the surface region of the thin films differs significantly from the magnetic structure of LaFeO$_3$ bulk. In particular, for LaFeO$_3$ on SrTiO$_3$ (110) we find that the antiferromagnetic axis is rotated from the in-plane bulk direction into an orthogonal direction pointing out of the film surface. After correcting the data for the non-linear polarization component and for experimental saturation effects, we can quantitatively derive the direction of the antiferromagnetic axis. For both substrate orientations we find the rotated antiferromagnetic axis to lie in an SrTiO$_3$ (111) plane.

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