SPIN-POLARIZED LOW ENERGY ELECTRON STUDIES OF ULTRA-THIN MAGNETIC FILMS

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Low-energy electron microscopy (LEEM) offers the possibility to measure directly and in real time, during in-situ during deposition, properties of films as a function of film thickness. When a spin-polarized electron source is used for illumination [1], a powerful method (SPLEEM) providing detailed view of magnetic properties is obtained. It currently achieves a resolution of 10 nm, and up to video-rate imaging. In this work we will discuss selected studies to highlight some advantages and limitations of this technique.

In this type of microscopes, a beam of electrons is reflected from a surface to form a magnified real space image of the surface [2]. Imaging rate is sufficiently fast for dynamic studies [3]. In addition there is access to local-area diffraction information [4] and dark-field imaging modes mixing real-space and reciprocal space information [5]. The technique is still being extended, both in its application to new physical problems [6] and in terms of improving its capabilities, for example through the planned addition of aberration correction optics in the near future[7].

We will present results in ferromagnetic films, where we imaged defect-free film regions in which thickness is perfectly homogeneous on the atomic scale. We couple the observations to fully relativistic ab-initio calculations.

When we deposit films of Co onto Ru(0001) substrates in the thickness range of up to 3 atomic monolayers, SPLEEM reveals that the easy axis of magnetization switches twice in this range: both one-monolayer and three-monolayer thick regions are magnetized in a direction within the film plane, while two-monolayer thick Co/Ru(0001) regions are magnetized perpendicular to the film plane. By measuring the thickness-dependent relaxation of epitaxial strain in the Co layers and combining the experimental information with ab-initio computations of the magnetic anisotropy energy, we show how the unusual layer-by-layer double-spin-reorientation transition results can be understood in detail [8].

Moreover, we find rather curious, additional possibilities to induce dramatic changes of the magnetism by adding atomic monolayers of non-magnetic material on top of the Co films. When we add just one single atomic Cu layer on top of in-plane magnetized Co/Ru(0001) films of three or four monolayer thickness, the magnetization axis switches to the direction perpendicular to the film plane. Adding just one additional Cu atomic layer flips the magnetization again to an in-plane configuration.

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