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Abstract:

Epitaxial growth of Co on a stepped Cu surface leads to thin films with novel electronic and magnetic properties. The substrate acts as a template for the lateral and perpendicular Co lattice parameters. A dramatic increase in the perpendicular lattice spacing compared to other epitaxial Co systems causes strong ***3d*** electron localization at the surface. The orbital magnetic moment per spin was separated into bulk and surface contributions demonstrating a giant enhancement (260%) at the surface. The origin of this phenomenon is the increased number of Co $3d_{5/2}$ holes due to finite size effects.

Co films grown epitaxially on a planar Cu(OO1) surface adopt the substrate lattice constant in the surface plane and grow in a face-centered cubic (fcc) structure with a 2% vertical lattice contraction. [l] Co growth on a stepped Cu(1 1 13) substrate, however, proceeds via step flow. We find with high-resolution low-energy electron diffraction that this forces the vertical Co lattice constant to equal the substrate step height. [2] Magnetic circular x-ray dichroism (MCXD) experiments performed on beamline ID12B reveal that such a structure with an increased unit-cell volume is still itinerant in the highly coordinated bulk environment, but shows strong electron localization at the surface leading to a giant enhancement of the surface orbital magnetic moment. [2]

X-ray absorption spectroscopy (XAS) intensity integrated over the spin-orbit split $L_3(2p_{3/2})$ and $L_2(2p_{1/2})$ absorption edges is proportional to the number of ***3d*** holes in the ground-state. From the XAS spectra in Fig. 1 it is clear that the L_3 intensity decreases with increasing Co coverage while the L_3 intensity hardly changes. This can only occur when the surface atoms contain additional valence holes with a strong $3d_{5/2}$ character. [3] For these states, dipole transitions are forbidden to a $2p_{1/2}$ core-hole level. The upper inset of Fig. 1 shows that the L_3 intensity reduction is accompanied by an energy shift visible at both edges. The surface electronic structure, which dominates at low coverages, is strongly localized. This causes a

better core-hole screening than in the bulk film, thus, explaining the lower binding energy at the surface The localized nature of the surface electronic structure is also reflected in the appearance of an atomic-like structure (marked by arrow).

The MCXD spectra in Fig. 1 display the same peak shifts as the corresponding XAS spectra. The smaller signal of the 2.5 ML MCXD spectra is caused by a lower ordering temperature compared to the thicker films, so that it is difficult to obtain absolute moments. The strong differences between bulk and surface also lead to dramatic changes in the associated magnetic moments. Using the sum-rules for the integrated MCXD intensities at the $L_{2,3}$ edges, we determined the orbital magnetic moment per spin, r. [4] While r_{bulk} will be constant, $r_{surface}$ should ideally decay with $1/t$. From the variation of $r \cdot t$ with layer thickness t (bottom inset of Fig. 1) we can separate surface and bulk contributions to r. The bulk value is 60% enhanced compared to fcc Co with a 2% tetragonal lattice distortion [4] since the perpendicular layer spacing in the bulk of Co/Cu(l 1 13) films has adopted the substrate lattice constant. While for Co films on planar Cu(OOl) a ca. 40% enhancement of the surface orbital moment compared to the bulk was reported, [4] the enhancement in our case is about 260%. Such a large value for the surface orbital moment exceeds any reported value to date [4] and indicates most clearly the existence of a different modification of Co in the surface region.

References

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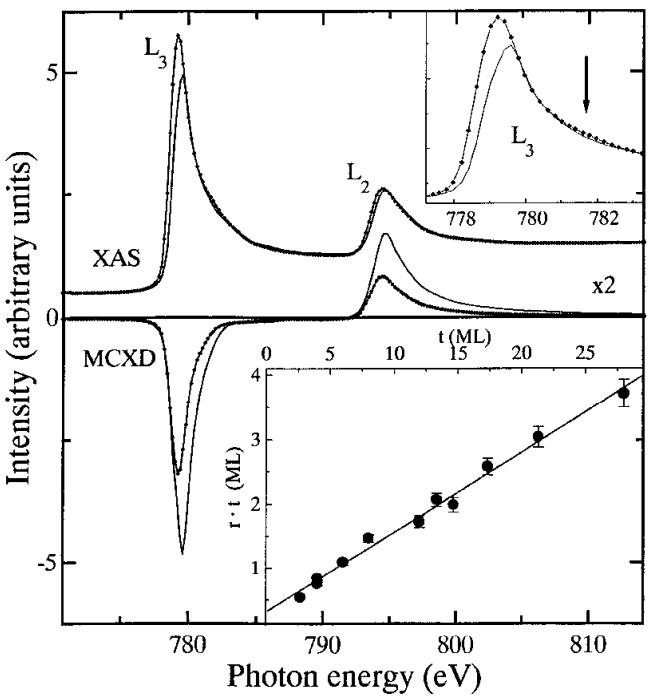

Fig. 1. Sum (XAS) and difference (MCXD) spectra for 2.5 ML (lines and dots) and 28 ML (lines) Co coverage measured with left and right circularly polarized light, incident at 30" relative to the sample magnetization parallel to the steps. The XAS spectra were normalized to a constant edge jump that reflects excitations into delocalized s,p states. Top inset: L_3 absorption edge enlarged; atomic-like structure due to electron localization at the surface is indicated by the arrow. Bottom inset: measured values of the orbital magnetic moment per spin, r (symbols); from the variation of r t versus Co thickness, t, bulk and surface values of r arc obtained via a linear fit (line).