특별강연-S1

Atomic scale evolution of magnetic anisotropies in ultrathin ferromagnetic films

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1. Introduction

The effect of a magnetic and nonmagnetic overlayer on the magnetic anisotropy behaviour of an ultrathin film is an important issue which profoundly tests current understanding of the processes involved[1,2]. The addition of nonmagnetic overlayers is known to have a profound effect on the magnetic anisotropy strength due to the intimate dependence of magnetic properties on the nanoscale morphology. It is now recognized that the effects on the magnetic anisotropy can often be surprisingly large since the interface structure, local strain, and surface morphology can all be drastically altered by the addition of magnetic and nonmagnetic overlayers.

2. Experimental method

All experiments were carried out under UHV conditions with a base pressure of 1×10^{-10} mbar. The single crystal Cu substrates were prepared via cycles of 1 kV Ar^+ sputtering and annealing to 700 K, until Auger electron spectroscopy (AES) and low energy electron diffraction (LEED) measurements indicated a clean, well-ordered surface. Co and Cu were evaporated from e-beam evaporators. The pressure remained below 5×10^{-10} mbar during deposition. Magnetic properties were investigated using *in-situ* magneto-optic Kerr effect (MOKE).

3. Experimental results and discussion

To study the influence of nonmagnetic Cu overlayers as a function of Co thickness 6 and 30 ML Co films were grown. For all Co thicknesses investigated, the adsorption of CO gas (but, not O_2, H_2) is found to cause the easy magnetization axis to switch 90° from the [001] to the [1 $\bar{1}$ 0] direction. Auger spectroscopy and STM measurements reveal that the CO gas is adsorbed at island edge sites which arise from the 3D Co growth mode. Subsequent deposition of submonolayers of Cu reverses the effect of the adsorbed CO thereby switching the easy axis back to [001]. The deposition of Cu is assumed to displace the CO gas and reverse the easy axis switch caused by adsorption of CO. Depending on the thickness of the Co film, two distinct modes of switching are identified. For thin Co films (d_{Co}<15ML), Cu overlayers switch the magnetic easy axis back to the [001] direction abruptly. In thicker Co films (>15ML) the easy axis is found to shift gradually from the [1 $\bar{1}$ 0] to the [001] direction. The origin of the observed easy axis switching is attributed to the competition between the cubic anisotropy K_1 and the effective uniaxial anisotropy K_U^{eff}. Since K_1 is vanishingly small for Co thicknesses below 15ML[3], it is also possible to engineer a magnetically isotropic state by reducing K_U^{eff} to zero

with an appropriate deposition of Cu. Further Cu deposition causes K_u^{eff} to become negative, re-establishing the easy axis along the [001] direction. For thick Co films (d_{Co}> 15ML), K_1 becomes comparable to K_U^{eff} and the competition between the two anisotropies as Cu is deposited allows us to controllably engineer the magnetization direction at a constant Co thickness. Figure 1 shows a full angle dependent MOKE study for a 30 ML Co film. The figure clearly shows the shift of the easy axis direction (indicated by the square loops with thicker lines) from [1 $\bar{1}$ 0] to 60° to 45° to 30° to [001] as a function of Cu thickness. The middle panel of the figure shows that a deposition of 0.48 ML of Cu has created a fourfold surface anisotropy with 45° being the easy axis and [1 $\bar{1}$ 0] and [001] being almost equivalent hard axes.

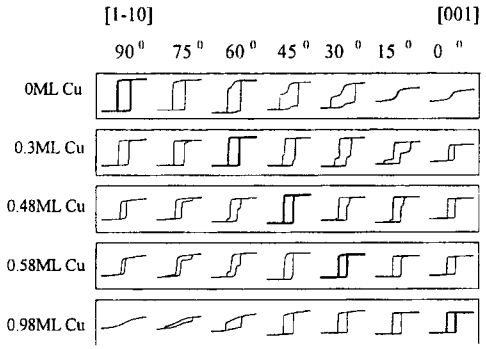

Fig.1: A full angle dependent MOKE measurement performed for each incremential Cu deposition on to the CO exposed 30 ML Co/Cu(110) film. The top panel shows that initially the easy axis is almost along the [1 $\bar{1}$ 0] direction. With further Cu deposition the easy axis direction, which is indicated by the bold square loops, shifts gradually from [1 $\bar{1}$ 0] to [001].

4. Conclusion

In conclusion, we found that the deposition of submonolayer Cu overlayers on to the CO gas exposed Co/Cu(110) system reverses the effect of the adsorbed CO thereby switching the magnetic easy axis by 90°. Two distinct switching modes are identified depending on the Co thickness. For thin Co (<15 ML), Cu overlayers switch the magnetic easy axis back to the [001] direction abruptly after deposition of ~ 0.9 ML Cu. In thicker Co (>15 ML) the easy axis is found to shift gradually from the [1 $\bar{1}$ 0] to the [001] direction, allowing us to controllably engineer the magnetic easy axis direction at a constant Co thickness.

5. References

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