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Magnetization reversal in the ferromagnetic layer, the antiferromagnetic layer and near the interface of exchange biased FeF_2 and MnF_2 systems

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Shifts to negative or positive field values, asymmetrical magnetization reversal processes and increased coercivity are only a few of the changes observed in the hysteresis loop of a ferromagnetic (FM) thin film grown on an antiferromagnet after field cooling the system through its Neel temperature. To describe the changes induced by the field cooling or "exchange biasing" a number of models have been proposed emphasizing the role of planar domain walls in the FM [1] and antiferromagnetic (AF) [2] layer or of uncompensated AF moments [3]. Combining x-ray magnetic circular (XMCD) and linear dichroism (XMLD) measurements allows us to monitor the magnetic order in the FM and AF layers as well as to probe uncompensated interface spins and thus to test the applicability of all three models. In this digest, we present our most recent results on the formation of a parallel magnetic domain wall in the FM Fe layer in Fe/FeF_2 systems and AF FeF_2 and MnF_2 in Ni/FeF_2 and Co/MnF_2 bilayers as well as the magnetization reversal of uncompensated Fe interfacial moments in positively and negatively biased Ni/FeF_2.

Measuring the magnetization component parallel, $m_{\parallel}$, and perpendicular, $m_{\perp}$, to the applied field of a thin Co layer inserted at different depth in a Fe layer grown on FeF_2 using XMCD allows us to determine a depth profile of the magnetization reversal. $m_{\perp}$ never exceeds 30% of the saturation magnetization, m_0, indicating that the reversal occurs largely through domains. The magnetization vector can be determined by plotting $m_{\perp}$ as function of $m_{\parallel}$ (Fig. 1) and is indicated by dashed and solid arrows for descending (H=-0.08T) and ascending fields (H=-0.02T) for the surface (black) and interface (gray) near region. Fig. 1 shows that the angle between bias direction and magnetization vector is reduced near the interface as compared to the surface indicating the formation of a partial parallel domain wall in the Fe layer.

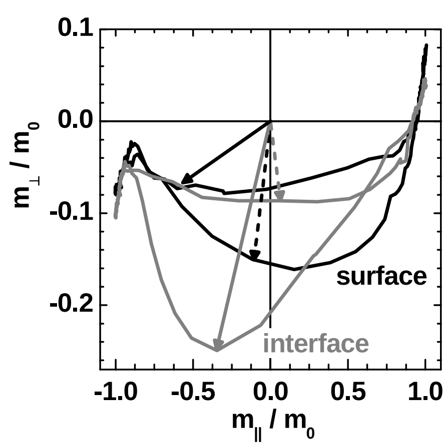

Figure 1

Scholl *et al.* [4] presented evidence for the formation of an AF exchange spring in a NiO single crystal exchange coupled to a Co thin film by recording the magnitude of the Ni XMLD signal as function of an external magnetic field. While the Ni moments can not be influence through small external fields the FM Co acts as a lever that by magnetic exchange pulls the magnetic moments of the AF with it when an external field is applied. In analogue experiments on Co/MnF_2 and Ni/FeF_2 bilayers, i.e. monitoring the Mn and Fe XMLD while reversing the magnetization in the FM Co and Ni layers, respectively, we observe a very small XMLD at the Mn L_3 edge indicating a rotation of the Mn spins upon magnetization reversal in the Co layer. However, no indication for the formation of an AF domain wall in FeF_2 was found. We attribute this difference to the much stronger anisotropy fields in the FeF_2 layer (14.9 T in FeF_2 and 0.7 T in MnF_2).

In positively (cooling field, H_C = 0.55 T) and negatively (H_C = 0.02 T) exchange biased Ni/FeF_2 bilayers, we determined the magnetization reversal of uncompensated Fe moments using XMCD. The loops are almost identical to those of the Ni layer clearly demonstrating FM coupling between unpinned Fe moments and FM Ni. A small vertical loop shift (Fig. 2) indicates that a fraction of the Fe moments is pinned by the antiferromagnetically ordered FeF_2. The pinned moments are oriented antiparallel to small cooling fields leading to negative exchange bias, but parallel to large cooling fields resulting in positive exchange bias.

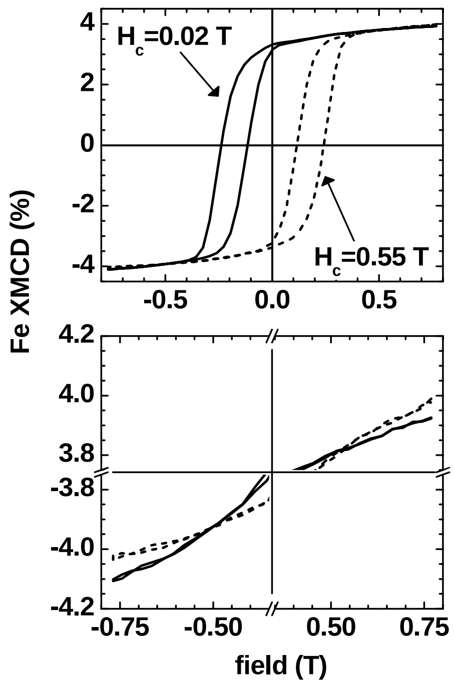

Figure 2

In conclusion, the combination of XMCD and XMLD measurements allows us to test in detail the applicability of theoretical models explaining exchange bias to Fe/FeF2, Ni/FeF2 and Co/MnF_2 bilayer systems.

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