High Resolution Imaging and Determination of the Uncompensated Spin Density in Exchange-Biased FM/AF thin Films

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Basic research in magnetism can result in important developments in applied physics and engineering. One example is exchange biasing of a ferromagnetic thin film (FM) by an adjacent antiferromagnetic layer (AF). The additional AF/FM interfacial exchange can significantly alter the hysteresis processes of the FM. The AF/FM interaction provides an effective bias field that gives rise to a horizontal shift in the hysteresis loop. Furthermore it can increase the anisotropy of the FM layer and often enhances the coercive fields. As such, exchange biasing has become an important tool for the control of domain formation in magnetic devices. While routinely exploited, the microscopic origin of exchange bias is still open to debate. It is generally believed that the bias is related to defects in the antiferromagnetic order that leads to uncompensated spins at the AF interfaces. For the first time, we have imaged the uncompensated spins at the AF/FM interfaces of a CoO/(CoPt) multilayers using high-field magnetic force microscopy at low temperatures [1]. Quantitative analysis of the MFM images [2], revealed that about 7% of the interfacial spins are uncompensated [3], and that these spins are coupled *antiferromagnetically* to those of the FM layers. During reversal, the domain structure of the ferromagnetic layers exactly replicated the spatial variation of the uncompensated spins. In recent MFM experiments the uncompensated spin density of a single AF/FM interface was mapped with a lateral resolution sufficiently high (10nm) to distinguish single grains. Surprisingly, grains with an extremely high density of uncompensated spins were found. The relatively low average uncompensated spin density (7%) was found to be caused by grains with an extremely low spin density and grains that even have a spin direction that is aligned *ferromagnetically* to those of the FM layer, i.e. substantially lower the exchange biasing effect. Based on these images and the quantitative analysis of the MFM data, a considerably improved fundamental understanding of magnetic exchange coupling is expected.

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