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Uncompensated Magnetization in Antiferromagnets, and New Classification of Exchange Bias Systems

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Exchange bias (EB) is typically observed in a bilayer consisting of a ferromagnet (FM) and an antiferromagnet (AF) as a horizontal shift of the FM hysteresis loop. It is attributed to exchange coupling across the interface. Several experimental findings demonstrate, and most models agree that uncompensated magnetization (UM) in the AF plays an important role in EB. However, the origin of UM remains unknown for most EB systems. Using magnetometry and polarized neutron reflectivity (PNR) we observe UM in antiferromagnet-only, (110)-FeF_2 epitaxially grown on MgF_2, thin-film samples. The PNR reveals the spatial distribution of the UM. This UM exhibits the so-called "*intrinsic exchange bias*": a shift of the hysteresis loop of UM. This effect is similar to the "classical" EB observed in bilayers, except that here, it is observed in a single layer material. The surface is responsible for the macroscopically broken time-reversal symmetry, uncompensated magnetization (UM) in a nominally compensated antiferromagnet [1], and, ultimately, for a new magnetic state. In this magnetic state, zero remanent magnetization cannot be obtained isothermally, because the origin (M(H=0)=0) is outside of the major hysteresis loop. Using symmetry group arguments [1] and results of *ab-initio* calculations [2], we argue that it is an equilibrium state. Below T_N, the UM in FeF_2 is coupled to the bulk antiferromagnetic order parameter as supported by several experimental results, including high value of EB field, its temperature dependence, and the absence of the training effect. Based on the proposed origin of the UM and experimental observations for different EB systems, we discuss a new classification of exchange bias systems into two categories, explaining differences in the observed properties.

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[2] S. López-Moreno *et al.*, Phys. Rev. B (submitted).