Uncompensated Moments in Antiferromagnets: Origin, Properties and Role in Exchange Bias

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Abstract – **Presented is a study of uncompensated magnetization in antiferromagnets performed by SQUID and VSM magnetometry, and polarized neutron reflectometry. This uncompensated magnetization is observed and studied as a function of temperature and cooling conditions. Uncompensated magnetization is found close to the top surface of the antiferromagnet (interface with the ferromagnet) and also in the "bulk" of the antiferromagnetic film. It has been established that this uncompensated magnetization plays crucial role in exchange bias. To understand the origin of uncompensated magnetization, *ab initio* calculations are performed.**

1 DIGEST

Despite over 50 years of studies, the microscopic mechanism of *Exchange Bias* remains a puzzle[1]. Exchange bias is a proximity effect between a ferromagnet (FM) and an antiferromagnet (AF). Exchange Bias manifests itself as a shift of the ferromagnetic hysteresis loop with respect to applied field of zero. It is attributed to exchange coupling across the interface of a FM with an AF [1-3]. This effect is fundamentally important to modern magnetic devices since this shift provides a reference for the direction of the magnetization. Antiferromagnets and synthetic antiferromagnets have been used in magnetic recording to pin the magnetization of the "hard" magnetic layer in the case of Magnetic Random Access Memory (MRAM).

Among the unsolved issues that are critical for understanding of the exchange bias mechanism is the origin of the pinned moments in the AF.

Recently, the depth profile of the magnetization across the interface between a FM (Co) and an AF (FeF_2) in an exchange bias system has been measured [4, 5]. It was found that both uncompensated and compensated magnetic moments are present in FeF_2. A portion of this uncompensated magnetization is pinned below the T_N (i.e. does not respond to the applied magnetic field) and yet some part of it remains unpinned and responses to a small applied magnetic field. It is commonly accepted [1] that the uncompensated magnetization in the AF plays important role in the exchange bias. The pinned portion of this magnetization is responsible for breaking the symmetry and setting the direction of the exchange bias. The unpinned magnetization also participates in the interaction of the AF with the FM, but its exact role in the exchange bias remains an open question. It has been shown that the uncompensated magnetization can affect the properties of the domain structure of the FM [6] and can even participate in the formation of a parallel domain wall [7].

The origin of the uncompensated magnetization in the antiferromagnet remains an open and very challenging question. Our high-resolution STEM study confirms that FeF_2 grows epitaxially on MgF_2, and its structural quality is very high. It also reveals that the substrate surface imperfections do not necessarily affect the quality of the FeF_2 layer. Additionally, some low angle grain boundaries are observed. These grain boundaries may be related to the AF domains measured using neutron scattering [8]. Using SQUID magnetometry of just a thin film of FeF_2, without a FM, we find an uncompensated magnetization. Results of polarized neutron scattering confirm the presence of uncompensated magnetization in the AF and provide its depth profile. This magnetization demonstrates temperature dependence and horizontal hysteresis loop shift, typical for exchange bias. Properties of both pinned and unpinned magnetization and their dependence on temperature and cooling conditions are presented. *Ab initio* calculations of the effect of the AF film interface on the uncompensated magnetization will be discussed.

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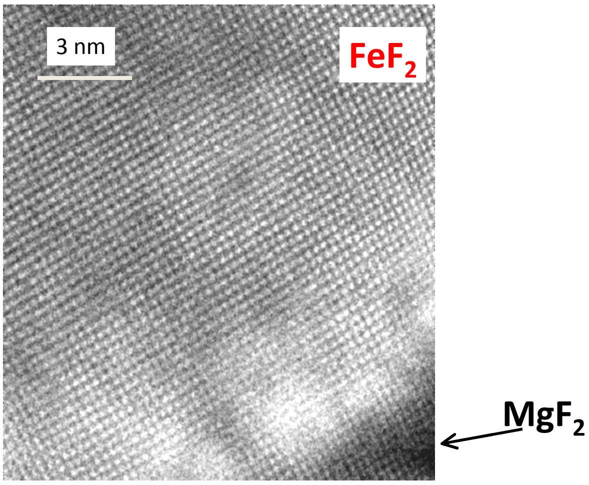

Figure 1: High-Resolution Scanning Tunneling Electron Microscope (STEM) image of FeF_2 grown on MgF_2 substrate.

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