Dynamic Properties of Magnetic Multilayers and Nanostructures .

Zbigniew Celinski, University of Colorado at Colorado Springs, DMR Award # 0303563

The exchange bias systems have been studied for a long time, mostly using static techniques such as SQUID magnetometry. Dynamic techniques, such as ferromagnetic resonance (FMR) can probe effective fields present in the studied system. A particularly intriguing observation in FMR experiments is an effective field that appears to rotate with the ferromagnet. The anisotropy responsible for this contribution has been termed "rotatable". The origin of the anisotropy is associated with the interaction between the ferromagnet and antiferromagnet.

A rotatable anisotropy with magnitude much larger than the bias field was observed with a dependence on temperature independent of crystallographic orientation. In our recent works we proposed the mixed interface model for the rotatable anisotropy which ascribes the existence of exchange bias to small uncompensated regions at the interface and rotatable anisotropy to exchange coupling combined with long range disorder within the antiferromagnet. These interactions may arise due to atomic level disorder giving rise to separate grains or crystallographic orientations due to, for example, twinning or other types of dislocations. Our model also suggests that exchange bias and rotational anisotropy may display different sensitivities to crystalline quality and structure. This model was successful in reproducing resonance field shifts and angular behavior observed in the FMR data.

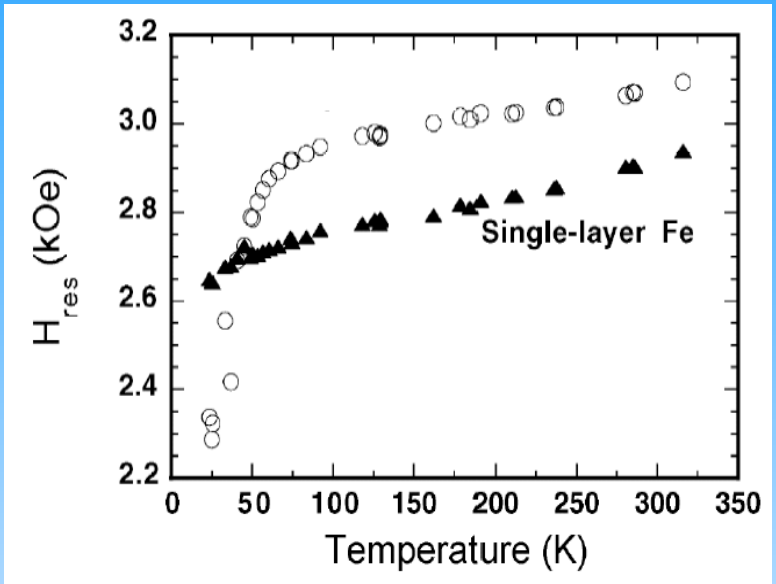

Fig. 1: Temperature dependence of FMR resonance field in the single-layer Fe sample and Fe/KNiF3 structure (open symbols). The Fe films in both samples were identical. The rapid change in H_{res} below 100 K for Fe/$KNiF_3$ is attributed to rotatable anisotropy.

References:

L. Wee et al. Phys. Rev. B **69**, 134426 (2004)
L. Wee et al. Phys. Rev. B **69**, 134425 (2004)

Exchange bias is a very important phenomenon which has many applications. The most spectacular one is associated with information storage – this effect is used in every modern computer. Despite this, the effect is not completely understood, and to make better hard drive systems (ones which store more information, retain this information, and retrieve the information at a faster rate) it is necessary to understand and control the exchange bias effect.

Other applications involve magnetic sensors for both, civilian and military uses. For example, modern ABS brakes may use magnetic sensors which have to operate in extreme conditions (high and low temperatures, high vibration). There is a need to develop systems which will work well in such conditions.

Our objective is to understand this effect by probing exchange bias structures with high frequency probes. In turn, this will allow us to design and produce devices which will increase our safety, standard of living, and create new technology (jobs).

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Figure 2. Toni Talley, a high school student, shown working in the PI's laboratory. Toni has been preparing the exchange coupled structures using the Molecular Beam Epitaxy system.

Figure 3. Tommy Morphet (high school student) and Ian Howard (undergraduate) shown working on 24 GHz Ferromagnetic Resonance (FMR) system. They have been working on correlation between FMR linewidth and structural properties.

Educational:
4 high school students (2 each summer)
3 undergraduate students
1 graduate students,
1 research associates (PDF)
The mentioned above personnel worked at least part time on this project. They received training in areas such as ultra high vacuum deposition and magnetic measurements.

Collaborators:
D. Skrzypek, J. Szade, University of Silesia, Katowice, Poland
L. Wee and R. Stamps, UWA, Perth, Australia
C. Schneider, IFK, Juelich, Germany

Brief summary of outreach activities:
• the PI mentored two high school students working in the lab each summer – the REAP program