TPS 44A Quick-scanning X-ray Absorption Spectroscopy

- XAS, XANES, EXAFS
- Materials Science, Condensed-matter Physics

References

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Magnetic Proximity Effects in Antiferromagnetic Composite Thin Films

Individual antiferromagnetic films in a composite layer can influence adjacent antiferromagnetic layers, leading to the induction of perpendicular magnetic anisotropy in the neighboring ferromagnetic film.

Spintronic devices have significant value in their ability to store and process information using the spin of electrons, offering faster and more efficient data processing compared to traditional electronic devices. Spintronic devices also have the potential to reduce energy consumption and improve device performance, making them ideal for use in various applications, including data storage, magnetic sensors, and quantum computing.

Antiferromagnetic (AFM) thin films have unique magnetic properties that make them promising materials for manipulating the magnetic properties of ferromagnetic (FM) thin films. **Figure 1** provides schematic illustrations of the three-dimensional quadratic-type (3Q-type) and layered-AFM spin structures of the fcc $Fe_{50}Mn_{50}$ and e-fct Mn films used in the study. In this work, a method to trigger perpendicular magnetic anisotropy (PMA) in FM thin films to valorize AFM composite layers was investigated. They found that individual AFM films in the composite layer can enhance long-range AFM ordering and modulate the spin structure of adjacent AFM layers, ultimately inducing PMA in adjacent FM films. This research provides essential insight into improving control over PMA with AFM layers and offers potential applications in next-generation perpendicular spintronic devices.

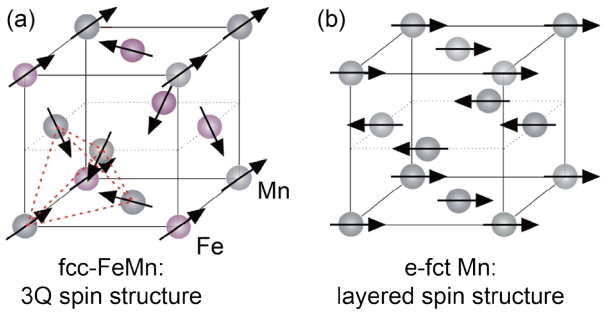

Fig. 1: (a) Schematic illustrations of 3Q-type fcc $Fe_{50}Mn_{50}$ films and (b) layered-AFM spin structures of e-fct Mn films. [Reproduced from Ref. 1]

In **TLS 05B2**, X-ray magnetic circular dichroism (XMCD), magneto-optical Kerr effect (MOKE), and X-ray absorption spectrum (XAS) measurements were conducted to characterize the interface coupling and elucidate the mechanisms underlying the induction of PMA in antiferromagnetic composite thin films. Longitudinal and polar MOKE were performed to investigate the magnetic properties of thin films and provide information about the magnetic hysteresis loops, magnetic anisotropy, and the effects of the AFM composite layers on adjacent FM films. XMCD effects were utilized to detect interfacial magnetic coupling of elements in the AFM/Co/Fe structures. Measurements at the Co, Fe, and Mn $L_{3,2}$ edges provided insight into the magnetic properties and interactions at the atomic level. Moreover, XAS measurements were performed under remanent conditions to study the electronic and magnetic properties of the samples. This work reports that individual AFM films within the composite layer can enhance long-range AFM ordering in their adjacent AFM neighbor and modulate its spin structure, subsequently inducing PMA in an adjacent FM film.

Figure 2 (see next page) shows the XAS and XMCD curves for Co, Fe, and Mn in the 10-ML $Fe_{50}Mn_{50}$/Co/Fe/Cu film. This figure provides the experimental data obtained from the XMCD measurements at the Co, Fe, and Mn $L_{3,2}$ absorption edges, offering insights into the interface coupling and magnetic properties of the composite thin

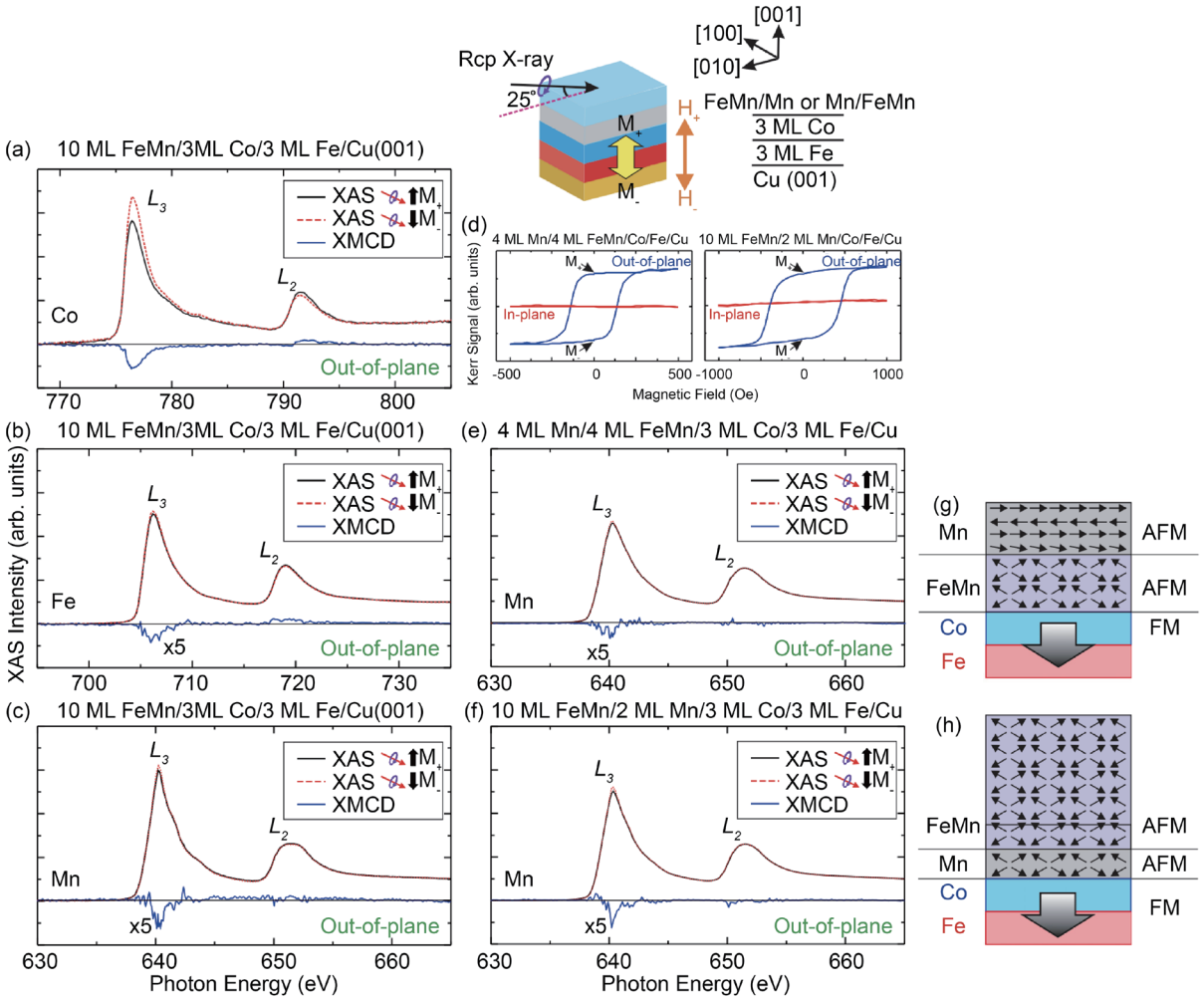

Fig. 2: (a–c) XAS and XMCD curves of 10-ML $Fe_{50}Mn_{50}$/Co/Fe/Cu measured at the (a) Co, (b) Fe, and (c) Mn $L_{3,2}$ edges at 300 K in remanent states. (d) In-plane and out-of-plane magnetic hysteresis loops of 4-ML Mn/4-ML $Fe_{50}Mn_{50}$/Co/Fe/Cu and 10-ML $Fe_{50}Mn_{50}$/2-ML Mn/Co/Cu measured at 300 K. The black arrows (M_+ or M_-) indicate the remanent states of the films under positive (H_+) or negative (H_-) magnetic field. XAS and XMCD curves of (e) 4-ML Mn/4-ML $Fe_{50}Mn_{50}$/Co/Fe/Cu and (f) 10-ML $Fe_{50}Mn_{50}$/2-ML Mn/Co/Cu measured at the Mn $L_{3,2}$ edge at 300 K in remanent states. Schematic illustrations of the possible AFM spin configurations in the films of (g) PMA-established 4-ML Mn/4-ML $Fe_{50}Mn_{50}$/Co/Fe/Cu and (h) 10-ML $Fe_{50}Mn_{50}$/2-ML Mn/Co/Cu. [Reproduced from Ref. 1]

films, and detailed information about the magnetic behavior, spin structure, and magnetic interactions in materials.

The breakthrough in this research lies in the comprehensive investigation of magnetic proximity effects in AFM composite thin films and their role in triggering PMA in FM thin films. This study demonstrates how individual AFM films in the composite layer can enhance long-range AFM ordering and modulate the spin structure of adjacent AFM layers, ultimately inducing PMA in adjacent FM films. This research provides essential insights for improving control over PMA in AFM layers and offers potential applications in next-generation perpendicular spintronic devices. (Reported by Ping-Hui Lin)

This report features the work of Bo-Yao Wang and his collaborators published in Phys. Rev. B ***108****, 184412 (2023).*

TLS 05B2 PEEM

- MOKE, XMCD, XAS
- Spintronic, AFM, PMA

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