New Kind of Spin-Reorientation Transition of Magnetic Films

A new kind of spin-reorientation transition was found in ferromagnetic/antiferromagnetic bilayer system. With increasing of Mn thickness, the magnetic easy axis of Fe and Co ultrathin films grown on n ML Mn/Cu_3Au(100) was observed to switch from the in-plane to perpendicular direction by magneto-optical Kerr effect and PhotoEmission Electron Microscopy in application of synchrotron radiation. With help of magnetic circular dichroism effect and element sensitivity of spectro-microscopy, the magnetic domain of antiferromagentic Mn layer was shown to be anti-parallel to the Fe domain. The perpendicular magnetization together with enhanced coercivity is supposed to be induced by exchange coupling from Fe/Mn interface, which overcomes the in-plane shape anisotropy of the magnetic films.

In the last decade, the study of spin-reorientation transition (SRT) in magnetic ultrathin film drew a lot of attention owing to both fundamental research and application. Due to the reduced dimension, the competition between interface anisotropy and volume anisotropy would be a key issue in magnetic ultrathin film system. For example, Co/Pt(111) and Fe/Pt(111) with low coverage reveal perpendicular anisotropy due to perpendicular interface anisotropy. With increasing of the film thickness, the in-plane shape anisotropy contributed from dipole-dipole interaction dominates the anisotropy energy of magnetic thin film. Therefore, this kind of magnetic thin films reveals SRT from perpendicular to in-plane direction with the increasing of film thickness. For another systems such as Ni/Cu(100) and Ni/Cu_3Au(100). The interface anisotropy prefers in-plane direction but the volume anisotropic energy dominated by strain energy prefers perpendicular direction. With increasing film thickness, the SRT from in-plane to perpendicular direction was carried out.

In this study, a new kind of SRT based on the exchange coupling from FM/AFM interface was discovered by using photoemission electron microscopy (PEEM) and magneto-optical kerr effect (MOKE) in Fe and Co/Mn/Cu_3Au(100) bilayer systems. The Fe grown on Mn/Cu_3Au(100) and Mn grown on Cu_3Au(100) reveal single crystalline bct and fcc crystalline structures by the measurement from low energy electron diffraction (LEED). The PEEM chamber

Beamline

05B Spin-polarized PES/PEEM

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connected with a new designed UHV Multifunctional NTU-NSRRC Nanomagnetism Preparation Chamber (with LEED, MEED, AES, and MOKE) can provide the *in-situ* measurement in various studies.

Figure 1(a) shows the magnetic domain of 6 ML Fe on wedge Mn/Cu_3Au(100). The arrow at 25° from the [$\bar{1}$00] (for (a)) or [100] (for (b) and (c)) shown in right cartoon displays the direction of incoming X-ray. Mn thickness (t_{Mn}) increasing from left to right is indicated for all three images at the bottom of axis. Based on the selection rule in quantum mechanism, the intensity of absorption is determined by the relative orientation between the polarization of incoming X-ray and magnetization vector. Comparing Fig. 1(a) with 1(b), due to the same $\sigma_\perp$ but inverse $\sigma_{//}$, the domain with in-plane magnetic easy axis should reveal inverse domain contrast. In the contrary, comparing Fig. 1(a) with Fig. 1(c), due to the same $\sigma_{//}$ but inverse $\sigma_\perp$, the domain with perpendicular magnetic easy axis should reveal inverse domain contrast. Thus, the discussion above suggests the domain with perpendicular magnetic easy axis is observed as t_{Mn} > 2 ML.

For comparison, the Kerr hysteresis loops of various 6 ML Fe/Mn/Cu_3Au (100) measured at 220 K are shown in Fig.2. Consistent with the measurement from PEEM, for t_{Mn} up to 2.5 ML, the easy axis of 6 ML Fe is changed from in-plane to perpendicular direction. The perpendicular coercivity increases dramatically from 10 Oe to as larger than 100 Oe with the t_{Mn} increasing from 3 ML to 4 ML. As a result, such coercivity enhancement could be attributed to the coupling effect from adjacent AFM fcc-Mn. In addition, the SRT of magnetic layer with the increasing of t_{Mn} not only shown in 6 ML Fe/Mn/Cu_3Au(100), but also in 2.8 ML Co/Mn/Cu_3Au(100) with t_{Mn} up to 4 ML (not shown in figure). This result demonstrates the generality of AFM fcc-Mn supported perpendicularly magnetic anisotropy.

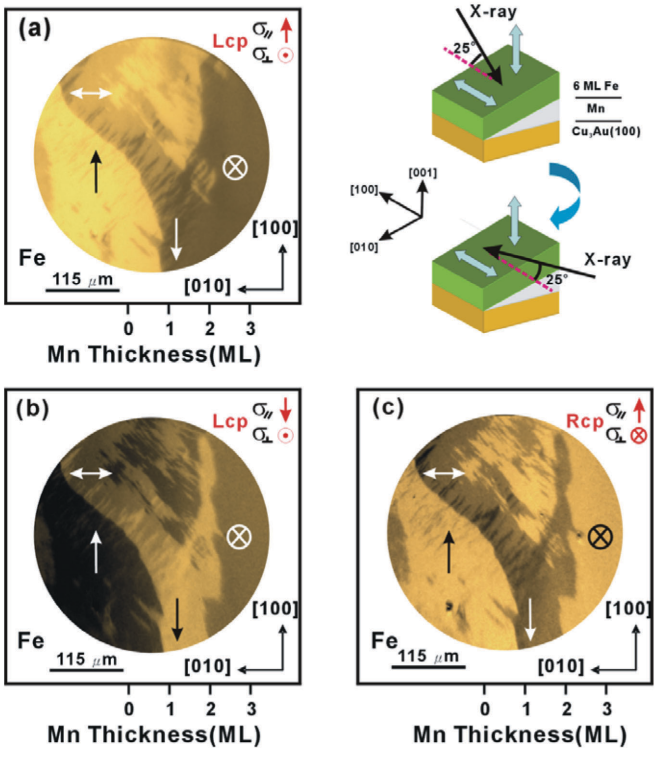


Fig. 1: Magnetic domain images of 6 ML Fe/Wedge Mn/Cu_3Au(100). The incident direction for X-ray is along [$\bar{1}$00] direction (for (a)) and [100] direction (for (b) and (c)). The polarization of X-ray is LCP for (a) and (b), and RCP for (c). The Perpendicular domain is observed as t_{Mn}> 2 ML which is checked by changing the relative orientation between the X-ray and the sample.

Figure 3(a) shows the magnetic domain of Fe in 6 ML Fe/Wedge Mn/Cu_3Au(100) at 190 K with LCP incoming X-ray in as grown condition. Consistent with the result in Fig. 1, the SRT of Fe domain from in-plane to perpendicular direction is observed as t_{Mn} > 2 ML by changing the relative orientation between incoming X-ray and sample. Figure 3(b) shows the domain image of Mn at 190 K, the weak ferromagnetic domain was observed as $t_{Mn} \geqq$ 1.5 ML. The vague domain structure of Mn as t_{Mn} < 1.5 ML might be due to the weaker signal collected from the thinner Mn layer. The inverse contrast but similar shape of magnetic domain of Fe and Mn suggests the domain of Mn is anti-parallelly and ferromagnetically coupled with

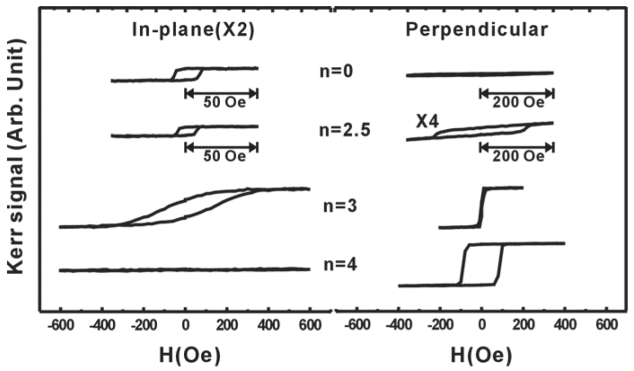


Fig. 2: Kerr hysteresis loops for 6 ML Fe/n ML Mn/Cu_3Au(100). The easy axes of 6 ML Fe switches from in-plane to perpendicular direction as t_{Mn} > 2 ML. The coercivity enhancement of perpendicularly magnetic Fe with t_{Mn} suggests the perpendicular anisotropy of Fe is contributed from Fe/fcc-Mn exchange coupling.

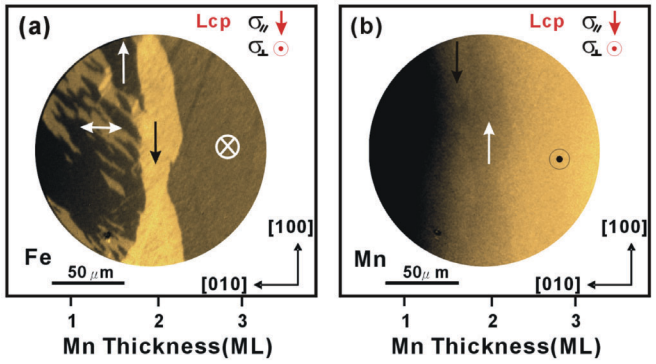


Fig. 3: Element specific magnetic domain images for (a) Fe and (b) Mn of 6 ML Fe/Wedge Mn/Cu_3Au(100). The polarization of X-ray is left circular polarization (LCP). The magnetic domain of Fe is anti-parallelly and ferromagnetically coupled with the magnetic domain of antiferromagnetic Mn.

the domain of Fe in interface.

The evidences such as coercivity enhancement in Polar MOKE and Fe/Mn domain coupling in PEEM suggest that the perpendicularly magnetic Fe films could be stabilized by perpendicular exchange coupling from Mn underlayer. Moreover, based on the phenomenological model of magnetic anisotropic energy, we could estimate the perpendicular anisotropic energy contributed from FM/AFM exchange coupling (t_{Mn} = 16 ML and T = 220 K) could up to 3 erg/cm^2.

In this work, a new kind of SRT by the FM/AFM exchange coupling was discovered. Different with the mechanisms mentioned in previous, we demonstrate that fcc-Mn/Cu_3Au(100) could provide perpendicular magnetic anisotropy to Fe magnetic overlayers in which the mechanism is originated from the exchange coupling from Fe/fcc-Mn interface. The discovery of new mechanism could draw a lot of attention so as to bring various new ideals or prospects of the application.

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Experimental Station

PEEM station

Publications

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