Interfacial Magnetic Structure of Mn between Ferromagnetic/Antiferromagnetic Bilayers in Magnetic Sensor Heads

Higher recording density hard disk drives (HDD) are indispensable devices for our information-oriented society. Since the annual growth rate of the recording density of HDD is over 40%, many researchers have focused on the development of advanced HDD with a recording density of 1 Tb/in^2. Issues regarding their development are 1) high sensitivity and nanomachining of magnetic sensor heads, and 2) high resolution in recording media.

Recently, with the decrease in track size in sensor heads, instability of exchange coupling between ferromagnetic (FM) / antiferromagnetic (AFM) bilayers comes to the surface, that is, magnetization in the FM layer, which is pinned by the AFM layer, has rotated or flipped through the nanomachining process. Therefore, a higher robustness of exchange coupling is indispensable to realizing high recording density HDD. To improve the robustness, it is necessary to understand the mechanism of exchange coupling and control the magnetic structure at the FM / AFM interface by optimizing parameters such as materials, orientation, grain size and so on (see Fig. 1).

X-ray magnetic circular dichroism (XMCD) and element specific magnetic hysteresis (ESMH) analyses are powerful techniques for investigating the interface magnetic structure. Ohldag *et al.* reported the existence of pinned interfacial AFM spins (Mpin), as determined from observing the vertical offset of hysteresis loops of uncompensated AFM spins (Mn) [1]. Up to now, the exchange coupling energy J, calculated for ideal interface is higher by orders of magnitude than the observed one, J_k, for nonideal interface such as polycrystalline bilayers. They estimated a small Mpin fraction, ρ, of 4% for uncompensated Mn spins and explained that $J_k \sim \rho J$. This idea is reasonable, but a mechanism that stabilizes Mpin at the interface is unclear. We, therefore, verified the existence of Mpin by measuring the Mn hysteresis loops for FM (CoFe) / AFM (MnPt) bilayers by XMCD and ESMH analyses. The samples were glass(sub.)/ underlayer/ MnPt(15)/ CoFe(2)/ Cu(1)/ Ru(2). The numbers in parentheses are the nominal thicknesses in nanometers. J_k was 0.1 ~ 0.3 erg/cm^2 obtained by controlling the MnPt orientation. X-ray absorption spectra were measured by the total electron yield (TEY) method, which has high sensitivity to the interfacial region. We used left and right elliptically polarized X-rays from a twin helical undulator at beamline **BL25SU**. The X-rays were incident at a grazing angle of 30° from the exchange bias direction on the sample surface. Magnetic fields were applied using an electromagnet along the axis

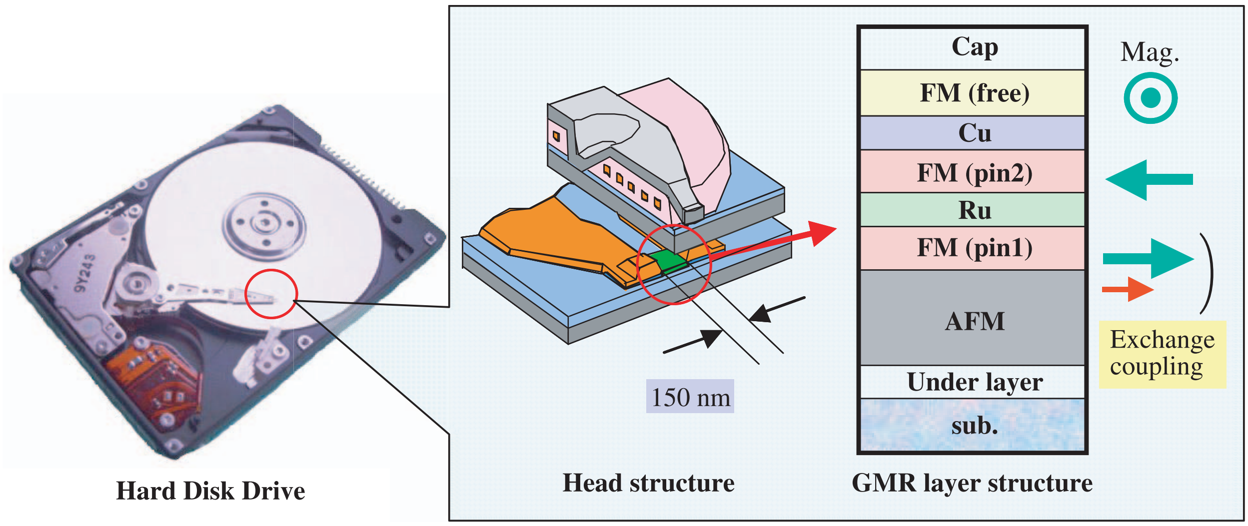

Fig. 1. Schematic drawing of hard disk drive, head structure and giant magneto resistance (GMR) layer structure. AFM means antiferromagnetic layer; FM, ferromagnetic layer; Cap, capping layer and Mag., magnetization. It is necessary to understand the mechanism of exchange coupling and control the magnetic structure at the FM / AFM interface to realize high recording density HDD.

raised 20° from the sample surface. To realize a near antiparallel configuration of the exchange bias direction to the incident X-rays, two divided MnPt samples were set by the antiparallel configuration for the TEY method. We performed the following to measure at a higher S/N ratio: 1) adjustment of slit size under the monochromator and undulator gap, and 2) maintaining a low noise around the sample and output signal processing.

Figure 2 shows the Mn and Co ESMH loops for the FM (CoFe) / AFM (MnPt) bilayers samples. The red and blue lines show the parallel and antiparallel configurations between the exchange bias direction and the incident X-rays, respectively. Co ESMH loops exhibited the typical exchange bias phenomenon, i.e. a horizontal loop shift. We could observe the Mn ESMH loops, which mean the induced ferromagnetic component (uncompensated spins) through the exchange coupling at the FM / AFM interface. The Mn ESMH loops also exhibited a horizontal shift, corresponding well with that of the respective Co loops. If the Mpin of Mn exists, the Mn ESMH loops will vertically shift. However, no vertical offsets of the Mn ESMH loops were observed for all samples, meaning no existence of Mpin. These results indicate that the insignificant uncompensated Mn spin was pinned at the interface to induce exchange coupling on the FM layer (CoFe) [2].

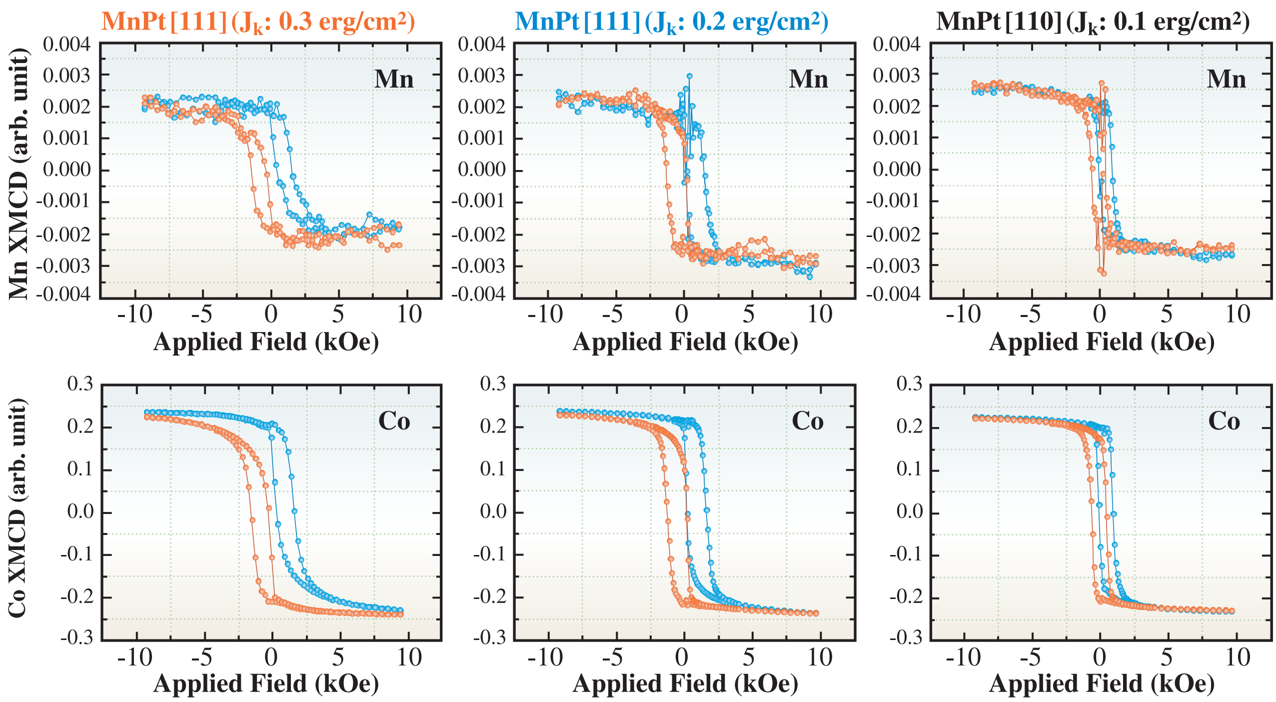

Fig. 2. Mn and Co ESMH loops for FM (CoFe) / AFM (MnPt) bilayers samples. The hysteresis loops were acquired with the exchange bias direction either parallel (red lines) or antiparallel (blue lines) to incident X-rays. No vertical offsets of Mn ESMH loops were observed.

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References

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