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Microscopic Origin and a Role of Uncompensated Antiferromagnetic Spins in Mn-Ir Based Exchange Biased Bilayers

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Exchange bias of ferromagnetic (FM) / antiferromagnetic (AFM) bilayers, characterized by the horizontally shifted magnetization hysteresis loop, is an indispensable physical phenomenon for the realization of high-density magnetic storage devices such as hard disk drives (HDDs) and magnetic random access memories (MRAMs). The stronger exchange biasing energyis required to achieve the higher storage density. While the microscopic mechanism of the exchange bias has been the subject of extensive studies for the last 50 years, it is not yet fully understood. The information needed to clarify the mechanism is the asymmetry of spin structure in the bilayer system, which is obviously needed to provide exchange anisotropy, against the reversal of the practical external magnetic field. As the only candidate that mediates the spin motion from the FM layer to the AFM layer under the magnetic field reversal, the uncompensated AFM spins might play a key role on the magnetization process of the AFM layer and likely be a clue to investigate the asymmetric spin structure formed in the AFM layer. X-ray magnetic circular dichroism (XMCD) in *transmission mode* is a powerful tool to detect the uncompensated AFM spins at the buried interface because of its element selectivity and excellent sensitivity. We thus investigated the microscopic origin [1] and a role on the exchange anisotropy [2] of the uncompensated AFM spins by means of XMCD spectroscopy for Mn-Ir based exchange biased bilayers, which are widely used for the application of HDDs and MRAMs, nowadays.

From the AFM layer thickness dependence and the FM material dependence of X-ray absorption spectra and XMCD spectra measured for $Mn_{73}Ir_{27}$ / FM bilayers, we experimentally concluded that the uncompensated AFM spins are induced exactly at the interface through the exchange interaction between the FM and the AFM layersand are localized in the interfacial AFM layers less than 2 monolayers (MLs). The micromagnetic simulation within the framework of the classical Heisenberg model well supported this conclusion, showing a modified AFM spin structure only in a few MLs at the interface differently from a bulk (3Q) spin structure in the body of the AFM layer.The element specific magnetization hysteresis (ESMH) loops of Mn, studied to clarify a role of uncompensated AFM spins on exchange anisotropy, did not accompany the vertical offsets. If the uncompensated AFM spins provide the asymmetric spin structure against the field reversal and dominate the exchange biasing strength by themselves, some part of them should be irreversible and result in a vertical offset of their ESMH corresponding with the exchange biasing strength [3]. However, the experimental results indicate that all the uncompensated AFM components follow the rotation of the FM moments and only mediate the spin motion of the FM layer to the AFM layer in Mn-Ir based exchange biased bilayers. Correlation between the uncompensated AFM spins and exchange bias strength will be further discussed in the conference.

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AC02

In-plane and Perpendicular Exchange Bias in [Pt/Co]/NiO Multilayers

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The shift of the magnetic hysteresis loop away from zero field of a ferromagnet (FM) when it is coupled to an antiferromagnet (AF) is called exchange bias [1]. In this study, the structural and magnetic properties of $[Pt/Co]_z$/NiO multilayers were investigated. Different layer thicknesses and number (z) of $[Pt/Co]_z$ multilayers were deposited on top of 20 nm NiO by using a ion-beam deposition technique [2] to create $[Pt/Co]_z$/NiO films. X-ray diffraction and transmission electron microscopy results show that the $[Pt/Co]_z$/NiO multilayers consisted of f.c.c. Pt (a = 3.93 Å), h.c.p. Co (a = 2.46 Å, c = 4.10 Å) and rock-salt NiO (a= 4.26 Å) phases. The grain sizes of in these polycrystalline [Pt/Co]z/NiO multilayers ranged from 5 nm to 15 nm. At 298 K, an enhanced coercivity ($H_c \sim$ 100 Oe) was found in a [Pt(12 nm)/Co(10 nm)]/NiO multilayer compared to that of a Pt(12nm)/Co(10nm) film. In addition, a much larger temperature dependence of H_c and exchange bias field (H_{ex}) was observed in a thicker one Pt/Co unit configuration of [Pt(12 nm)/Co(10 nm)]1/NiO film compared to that of a thinner four Pt/Co unit configuration $[Pt(3\ nm)/Co(2.5\ nm)]_4$/NiO system. At 5 K, where exchange coupling is strongest, the largest coercivity($H_c \sim$ 4800 Oe) and exchange bias field ($H_{ex} \sim$ -1300 Oe) was found in a [Pt(12 nm)/Co(10 nm)]/NiO multilayer, indicating a maximal interface exchange coupling energy of $\sigma_{ex} \sim 1.2$ erg/cm^2. The reduced Hexin thinner [Pt/Co]/NiO multilayers is likely due to intermixing between Co and Pt and thus formation of a disordered CoPt phase, which in turn weaken the exchange interactions between Co and Pt interfaces. A thicker Co layer provides stronger exchange coupling. Furthermore, a $[Pt(3\ nm)/Co(1.3\ nm)]_4$/NiO multilayer exhibits perpendicular exchange bias with $H_{ex} \sim$ -150 Oe at T= 80 K. This behavior is attributed to the magnetic moment of Co being aligned in an out-of-plane configuration which enables strong exchange coupling to the bottom NiO layer.

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