DETERMINATION OF UNCOMPENSATED MAGNETIC MOMENT IN ANTIFERROMAGNETIC LAYER IN SPIN VALVE SYSTEM

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Meiklejohn and Bean first discovered the hysteresis loop displacement in 1956, when they were studying fine particles of cobalt (ferromagnet) with the cobaltous oxide (antiferromagnet) shell [1,2]. This displacement was known as the exchange bias (H_E). Research on the exchange bias phenomenon has attracted a flurry of activity during recent years, which stems from its use in magnetic recording media or domain stabilizers in recording heads based on anisotropic magnetoresistance. On the other hand, the long-range exchange coupling between two ferromagnetic layers (FM) separated by a nonmagnetic metal (M) spacer is discussed a lot both in the theories and experiments in the past decade [3,4]. The interlayer exchange coupling (IEC) between two FM behaves oscillatory with the M thickness and alternates between ferromagnetic and antiferromagnetic coupling. In recent years, the IEC between a ferromagnetic (FM) and antiferromagnetic (AFM) layer through a nonmagnetic conduction metal (M) has attracted a lot of attention in the experiments [5-8]. Some of these experimental studies show the value of the exchange bias (H_E) oscillates with increasing of the metal thickness. This oscillatory exchange bias means there is an uncompensated magnetic moment (m_{AF}) in the AFM layer at the interfaces.

We theoretically determinate the m_{AF} in the AFM layer by calculating the H_E in the NiFe(100Å)/Cu/NiO(100Å) trilayer system[8]. For simplicity, we assumed that the FM anisotropy axis, AFM anisotropy axis, and the applied field are in the same direction, but the $\vec{m}_{AF}$ and the cooling field are along the opposite direction. The energy per unit area in the FM/M/AFM system can then be written as

$$\epsilon(t) = K_F t_F \sin^2 \theta - H M_F t_F \cos \theta + \epsilon_{ic}(t) \quad (1)$$

where t is the thickness of M, K_F is the anisotropy of the FM layer, M_F is the saturation magnetization of the FM, t_F is the thickness of the FM layer, H is the applied field, and θ is the angle between $\vec{M}_F$ and anisotropy axis. The first term in Eq. 1 accounts for the effect of the FM anisotropy, the second term is the Zeeman energy. Minimizing the energy with respect to θ , the displacement of hysteresis loop is found to be

$$H_E = \left\{ \frac{2\pi}{t} + \frac{J^2 m_F^2}{4\pi^2 \hbar^2} \left[\frac{2k_F t \cos 2k_F t - \sin 2k_F t}{(2k_F t)^2} - \int_{2k_F t}^{\infty} \frac{\sin y}{y} dy \right] + \frac{J^2 m_F^2 k_B^2}{12\hbar^6 k_F^2} \left(\int_{2k_F t}^{\infty} \frac{\sin x}{x} dx \right) T^2 \right\} \times \frac{m_{AF}(T)}{A}$$

where J and $m_{AF}(T)$ are our fitting parameter. It is worth to noted that $m_{AF}(T)$ means the temperature dependence of the uncompensated moment in the interface of the AFM layer. Fig.1 shows the results for the Eq.2, and we find that the behaviors of the H_E are similar to the experimental results [8]. Fig.2 shows the uncompensated m_{AF} in the AFM interface varies with increasing temperature by considering the interlayer exchange coupling between the FM layer and the AFM layer through the M spacer. In summary, we have determined the m_{AF} at AFM interface in FM/M/AFM trilayer system. And the experimentally observed is in good agreement with the calculated results.

Fig.1 The H_E value as a function of M thickness at different temperature.

Fig.2 Temperature dependence of the m_{AF} in the FM/F/AFM trilayer system.

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