Bias voltage dependence of magnetic anisotropy for CoFe in CoFe/MgO/CoFe magnetic tunnel junctions

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Recently the electric-field effect on magnetic anisotropy for ultra-thin magnetic layer has been found in Au/Fe, $Fe_{80}Co_{20}$/MgO [1,2] and also magnetization switching by electric field has been demonstrated [3,4]. This switching technique is potentially advantageous to the spin-torque switching in terms of consumption power. However, the physical mechanism of electric field effect is not yet understood and should be clarified to apply to the commercial memory. Here we focus on the electric field effect on perpendicular magnetic anisotropy for (001) oriented CoFe ultrathin films with slightly Co rich composition. The (001)-oriented Fe or Fe-rich FeCo(B) have been used in many works [1-7], while there are few studies on (001)-oriented Co-rich CoFe ultrathin films.

The samples were fabricated using an ultrahigh-vacuum sputtering system with a based pressure of less than 1×10^{-7} Pa. The $Co_{60}Fe_{40}$(1.0)/Mg(0.4)/MgO(2.0)/$Co_{60}Fe_{40}$(3.0) multilayers (thickness in nm) were grown on MgO(001) single-crystal substrate with a 40 nm Cr buffer. The multilayer films were patterned into the junctions using a conventional UV photolithography and Ar ion milling process. The magnetic properties were measured using vibrating sample magnetometer (VSM) and polar magneto-optical Kerr effect (MOKE). Electrical resistance of devices was measured by a standard four probe method.

Figure 1 shows TMR curve at bias voltage of 1mV. The junction area of the device was 10×10 μm^2 and resistance-area product *RA* was about 60 kΩ μm^2. Resistance minima at about ±2.5 T corresponds to saturation of magnetizations for both electrodes. The slope between 2.0 to 1.2 T corresponds to the rotation of magnetization for top CoFe layer. Local maxima at around ±1.2 T reflect the field of saturation for bottom CoFe electrode. These behavior are consistent with the polar-MOKE measurement. The MR curve shows no hysteresis in the-above-mentioned field range, so that the magnetization for both electrodes uniformly rotates. The MR curve also shows the large peaks at about ±0.5 T with hysteresis, which may stem from domains formation with magnetic dipole coupling between CoFe electrodes. Figure 2 shows the normalized MR curves as a function of magnetic field at around 1.2 T with various bias currents. When the bias current is positive, electron accumulates at interface of MgO/top-CoFe electrode. The peak shift with varying bias current is clearly visible, which indicates that the saturation field of the bottom CoFe layer shifts with electric field applications. The saturation field H_s as a function of applied bias voltage linearly changes with bias voltage and its slope is estimated to dH_s / dV = -0.10 T/V. And also, The electric field effect coefficient (β) described as $\beta = d_{CoFe} d_{MgO} M_s (dH_s / dV)/2$ is estimated to be about -170 fJ/Vm. The sign of β is same as that in Au/Fe, $Fe_{80}Co_{20}$/MgO [1,2]. In addition, its absolute value is large and comparable to Ir/$(Fe_{85}Co_{15})_{80}B_{20}$/MgO [7].

Acknowledgements

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Reference:

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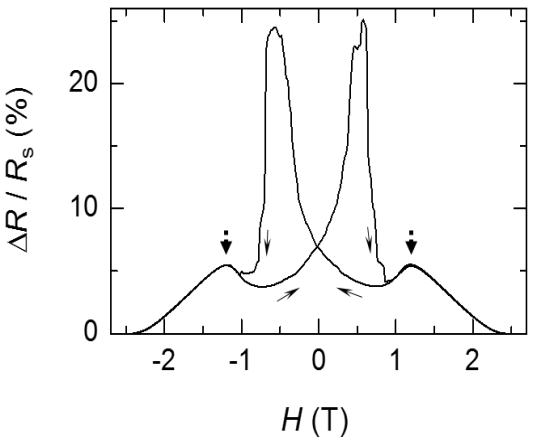

Fig. 1 MR curves for the unpatterned films and patterned MTJs of CoFe(1 nm)/MgO/CoFe(3 nm). Applied field direction is perpendicular to the film plane. Dashed arrows indicate the saturation field H_s.

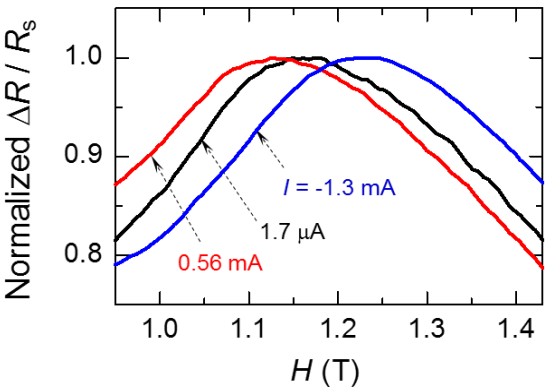

Fig. 2 Normalized TMR vs. magnetic field about saturation field H_s with different bias current.