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Thickness and Annealing Temperature Dependences of [CoFe/Pt] Multilayers Exchange-Coupled by NiO Films.

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In the past most exchange bias investigations have been carried out in multilayers with in-plane magnetic anisotropy, however it has been recently shown that it is also possible to induce exchange bias in Pt/$Co_{0.9}Fe_{0.1}$, Co/Pt, and Co/Pd multilayers with a perpendicular anisotropy [1-3]. We studied antiferromagnetic layer thickness dependences of perpendicular magnetic anisotropy in the (CoFe/Pt) multilayers exchange-coupled by NiO pinning layers at the top and bottom interfaces, and the annealing temperature dependence of these samples was also investigated.

The NiO/$[CoFe/Pt]_N$ multilayers were deposited by dc and rf magnetron sputtering at room temperature on glass (Corning 7059) in a vacuum system with a base pressure of 1×10-6 Torr. The perpendicular magnetization hysteresis curves were obtained by the out-of-plane extraordinary Hall measurement. Magnetic force microscopy (MFM) has been used for the investigation of magnetic domains on thin films. The films were annealed up to 350 °C in a vacuum (<5×10^{-6} Torr) for 1 h under zero field.

The crystallographic structure of the bottom NiO sample was determined by x-ray diffraction (XRD) with Cu $K\alpha$ radiation (λ = 1.541 Å). The XRD patterns of the multilayers reveal a Pt (111) peak. The crystalline Pt(111) peak was reduced as increasing the Co thickness. As the thickness of the NiO layer was changed from 0 to 20 nm, the relative peak intensity of Pt (111) did not change. No peaks corresponding to other crystallographic orientations are observed.

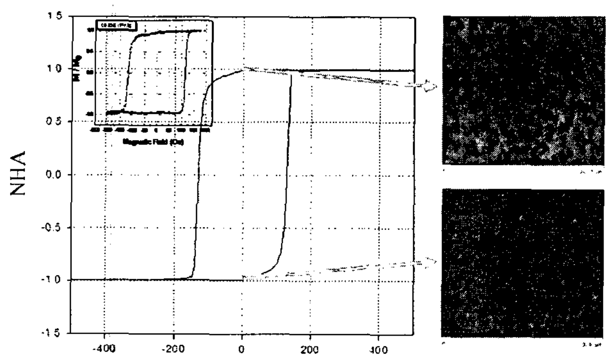

Figure 1: (a) NHA curve of NiO(5 nm)/[CoFe(1 nm)/Pt(1.25 nm)]5 multilayer. The insert shows the SMOKE magnetization curves of the multilayer. The field was applied perpendicular to the plane of the sample. (b) and (c) shows the MFM images of the sample. The scan size is 20 x 20μm^2.

Figure 1(a) shows the normalized hall amplitude (NHA) curve of NiO(5 nm)/[CoFe(1 nm)/Pt(1.25 nm)]5 multilayer. The insert shows the SMOKE magnetization curves of the multilayer. The NHA curves agreed with the values measured by a SMOKE. Both curves are fairly square, implying out-of-plane easy axes. The NHA curve does not show any shift, but does show the coercive field $Hc = 260$ Oe. Figure 1(b) and 1(c) show the MFM images of the sample. Both images show the magnetization states at remanent state (H= 0 Oe) after positive saturation (↑↑) and negative saturation (↓↓). In the ac-demagnetized state, the multilayers display a fine labyrinthine domain structure.

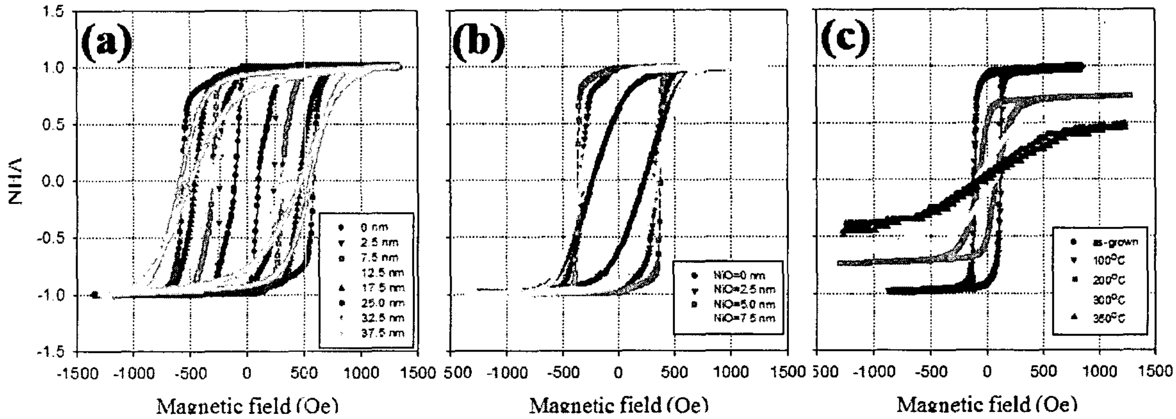

Figure 2: (a) NHA curves of NiO(0~37.5 nm)/[CoFe(1.25 nm)/Pt(1.25 nm)]3 multilayers, (b) NiO(7.5 nm)/CoFe(1.25 nm)/[Pt(1.25 nm)/CoFe(1.25 nm)]3/NiO(0~7.5 nm) multilayers as a function of thickness of top NiO layer and (c) NHA curves of NiO(5 nm)/[CoFe(0.75 nm)/Pt(1.25 nm)]5 multilayer as a function of the annealing temperature.

Figure 2(a) shows the NHA curves of NiO(0~37.5 nm)/[CoFe(1.25 nm)/Pt(1.25 nm)]3 multilayers as a function of thickness of bottom NiO layer. Figure 2(b) shows the NHA curves of NiO(7.5 nm)/CoFe(1.25 nm)/[Pt(1.25 nm)/CoFe(1.25 nm)]3/NiO(0~7.5 nm) multilayers as a function of thickness of top NiO layer. As bottom NiO thickness increases up to 37.5 nm, the perpendicular coercive field increases 200 Oe to 650 Oe. However the top NiO sample did not influence by the NiO thickness and its coercive field is less than that of bottom NiO sample. Figure 2(c) shows the NHA curves of NiO(5 nm)/[CoFe(0.75 nm)/Pt(1.25 nm)]5 multilayer as a function of the annealing temperature. As increasing an annealing temperature up to 350 °C, the bottom NiO sample was changed from perpendicular anisotropy to in-plane.

References

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