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Oscillation of Interlayer Exchange Coupling in $[Pt/CoFe]_4/[NiO(t)/[CoFe/Pt]_4$ Multilayers with Perpendicular Anisotropy

Jong-Gu Choi, Jin-Yong Lee, Mi-Sun Kim, Do-Guwn Hwang, Sang-Suk Lee
Sangji University, Dept. of Computer and Electronic Physics
Sun-Wook Kim, *Dankook University, Dept. of Physics*
Jang-Roh Rhee, *Sookmyung Women's University, Dept. of Physics*

Interlayer exchange coupling (IEC) that exists between antiferromagnetic (AFM) and ferromagnetic (FM) as a function of NiO thickness has been observed in $[Pt/CoFe]_4/[NiO(t)/[CoFe/Pt]_4$ multilayers with out-of plane anisotropy. The period of oscillation corresponds to ~2 monolayers of NiO. This existence of interlayer exchange coupling is possibly attributed to the antiferromagnetic ordering in NiO.

In this letter we have investigated the IEC at room temperature as a function of NiO thickness in glass/[Pt(12.5 Å)/CoFe(12 Å)]$_4$/[NiO(t)/[CoFe(12.5 Å)/Pt(12 Å)]$_4$ multilayers with an out-of-plane easy axis.

The samples were prepared by dc and rf magnetron sputtering from separated Pt, CoFe, and NiO targets at the deposition rates of 2.1, 2.0, and 0.12 Å/s, respectively, in 2~9 mTorr Ar pressure. The base pressure was 3×10^{-6} Torr. The thickness calibration was checked by grazing angle x-ray reflectivity after sample preparation, displaying an accuracy of ~10%. X-ray diffraction results show highly textured fcc(111) Pt and NiO

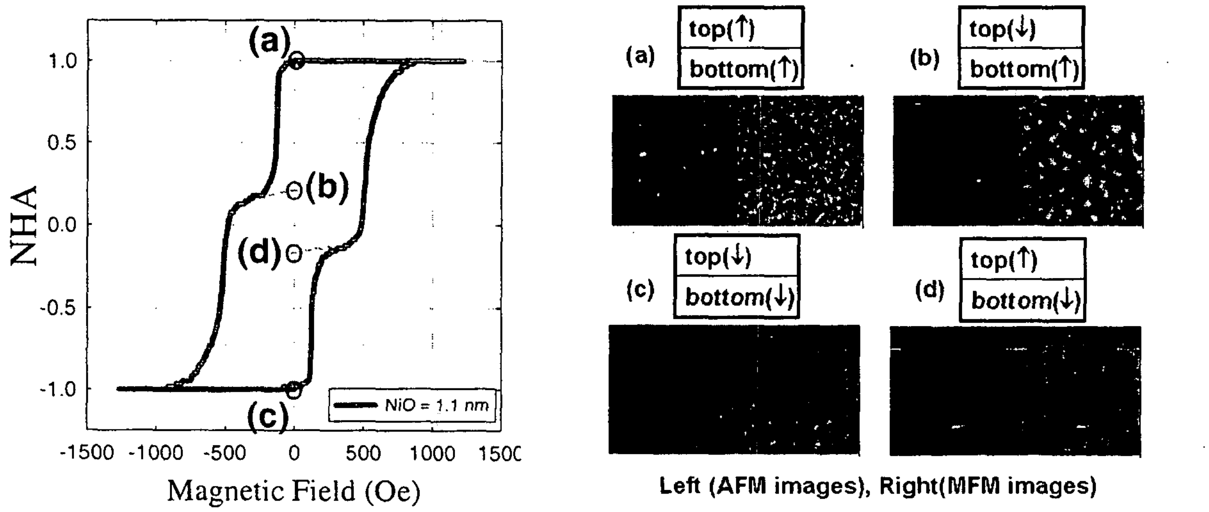

FIG. 1. The major anomalous Hall-voltage curve along the out-of-plane easy axis for sample. The magnetic force images at the four remanent states.

layers and hcp(100) CoFe layers. Hysteresis M-H loops have been measured by an anomalous Hall-voltage curves at room temperature (RT). Two figures in FIG. 1 depict the major Hall-voltage curve and MFM images at RT for of NiO thicknss of t = 11 Å. The symmetric shift does not result from the exchange biasing (EB) due to the antiferromagnetic NiO layer, because the EB disappears completely above 250 K. It can be unambigiously attributed only to IEC between the two multilayers across the thin NiO spacer. On other side, MFM imaging in Fig. 1 demonstrates the existence of 360° domain walls, identical to those observed in AF coupled Co/Ru/Co multilayers with perpendicular anisotropy.

Figure 2 shows claely that at RT the IEC oscillates between AF and FM coupling as a function of NiO thickness with a period of ~5 Å. This unexpexted oscillatory behavior is quite different from the nonoscillatory decay of IEC strength expexted by the models of Bruno [1,2] and Slonczewski [3] for nonmagnetic insulating spacers and from recent experimental observations of coupling across a nonmagnetic insulating MgO spacer [4]. This oscillatory behavior of the IEC as a function of NiO thickness is different from the oscillation in Fe/Cr multilayer as a function of Cr thickness. Even though Cr is an antiferromagnet, it is metallic. NiO is is an antiferromagnetic insulator, and the oscillatory IEC is very likely to originate from the antiferromagnetism of NiO spacers.

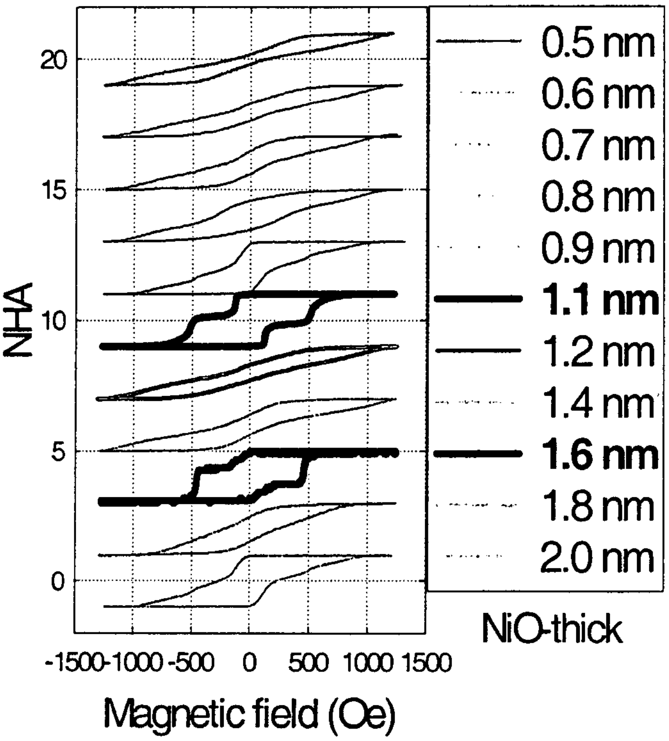

FIG. 2. Normalized Hall-voltage curves as a function of NiO thickness at room temperature. The bold line and thickness values show a period of two nonolayers of NiO.

References

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