D-14

Inverse Giant Magnetoresistance and Exchange Bias in spin valves with FeMn Antiferromagnetic Layers

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1. Introduction

Giant magnetoresistance (GMR)[1] have been widely studied in an enormous number of magnetic multilayers and spin-valves because of its important applications in magnetic storage devices. It is well established that GMR is due to spin dependent scattering[2] of the conduction electrons in the bulk or at the interface of the ferromagnetic layers. In normal GMR, the resistivity is larger for antiparallel alignments of magnetizations than the parallel alignments where the GMR ratio is positive. In inverse GMR effect, however, the resistivity for the antiparallel alignment of magnetization is smaller than the parallel alignments where the GMR ratio is negative. The IGMR has been observed in many multilayers and spin-valves[3-4] but this is the first time the inverse giant magnetoresistance is observed in the unpatterned spin-valve like FeCr/Cu/Co and NiFeCr/Cu/Co systems. In this work, the role of crystalline anisotropies is reported. These experiments give strong evidence that FeMn antiferromagnetic layer can be used to enhance the IGMR in case that magnetization of magnetic layers is in plane.

2. Experimental

Device fabrication begins with sputter deposition of Si/ SiO2/ $Fe_{1-x}Cr_xt_{FeCr}$/ Cu4/ Cot_{Co}/ Ru5, Si/ SiO2/ $Fe_{1-x}Cr_xt_{FeCr}$/ Cu4/ Cot_{Co}/ FeMn11/ Ru5, Si/ SiO2 /$NiFe_{1-x}Cr_xt_{NiFeCr}$/ Cu4/ Cot_{Co}/ Ru5 and Si/ SiO2/ $NiFe_{1-x}Cr_xt_{NiFeCr}$/ Cu4/ Cot_{Co}/ FeMn8/ Ru5 (thicknesses in nm) on Si substrates. Where concentrations of Cr, x, is range from 10 to 40%. The alloy layers were made by sputtering from pure targets of the Fe and NiFe metal in which small chips of Cr are embedded. The thickness of FeCr and NiFeCr layers range from 1 to 9nm. The relatively large thickness of the Cu spacer layers, 4nm, was chosen to prevent exchange interactions between the magnetic layers.

3. Results and discussion

The MR curves of Fe/Cu/Co and $Fe_{1-x}Cr_x$/Cu/Co are shown in Fig. 1a and Fig. 1b. While the GMR of Fe/Cu/Co (Fig. 1a), is normal, the GMR of $Fe_{1-x}Cr_x$/Cu/Co is inverse, as being seen in Fig. 1b. Fig. 2 shows the IGMR decreases when Cr concentration increases and the minimum IGMR value, -0.45%, can be observed with Cr concentration, x, is 35%, afterward, the IGMR ratio increases when the Cr concentration is higher than 35%. It is clearly that the inverse MR is mainly due to a bulk scattering process.

The IGMR ratio decreases lightly with increasing of the FeCr thickness. That means the inverse GMR also comes from interface scattering.

For the NiFeCr case, IGMR effect cannot be observed in wide range of Cr concentrations. The IGMR ratio increases when the Cr concentration large than 10%. Magnetization of two magnetic layers in FeCr/Cu/Co systems is not in plane. It is different

from NiFeCr/Cu/Co systems, where their magnetization is well aligned in plane. That is the reason why when we apply FeMn as a pinning layer, the effects observed are very different (Fig. 3a and Fig. 3b.).

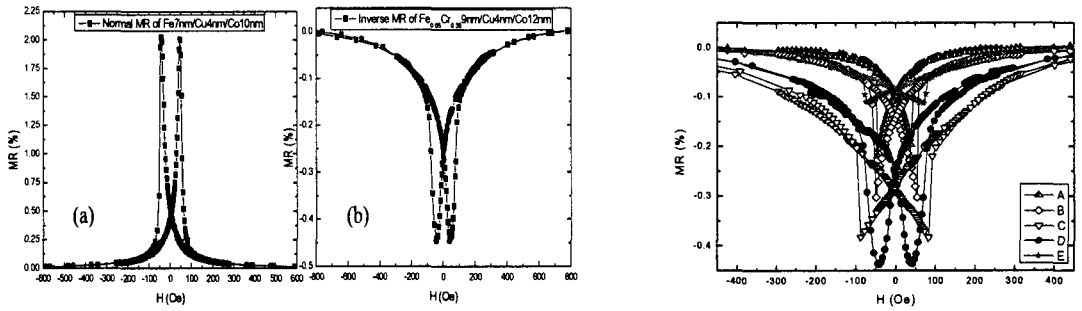

Fig. 1. Magnetoresistance curves of (a) Fe7nm/ Cu4nm/ Co10nm and (b) Fe0.65Cr0.359nm/ Cu4nm/ Co12nm (Left)

Fig. 2. Magnetoresistance curves of Fe1-xCrx7nm/ Cu4nm/ Co10nm. A-x=0.1, B-x=0.2, C-x=0.3, D-x=0.35, and E-x=0.4 (right)

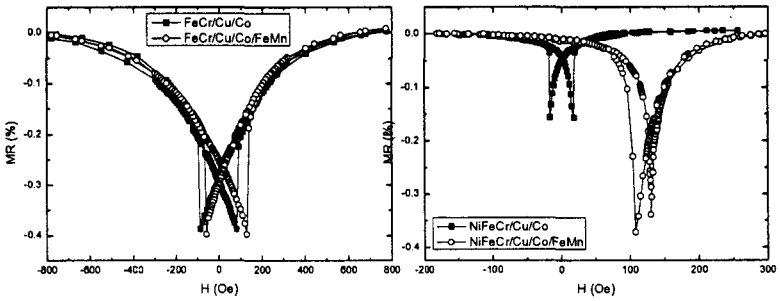

Fig. 3. Magnetoresistance curves of (a) FeCr7nm/ Cu4nm/ Co10nm, FeCr7nm/ Cu4nm/ Co10nm/ FeMn11nm and (b) NiFeCr6nm/ Cu4nm/ Co6nm, NiFe6nm/ Cu4nm/ Co6nm/ FeMn8nm.

4. Conclusion

Inverse CIP-GMR has been clearlyobserved in simple spin valves, FeCr/Cu/Co NiFeCr/Cu/Co. Alloys of Fe and NiFe with Cr have an effect on the spin scattering process, leading to an inversion of the spin scattering coefficients (α_{Fe}, $\alpha_{NiFe}>1$ and α_{FeCr}, $\alpha_{NiFeCr}<1$). The magnetization of FeCr is out of plane, meanwhile, the magnetization of NiFeCr is in plane. The difference of crystalline anisotropies of FeCr/Cu/Co and NiFeCr/Cu/Co systems leads to the enhancement of IGMR ratio of NiFeCr/Cu/Co system when we apply FeMn, but not such thing for FeCr/Cu/Co system. We believe the introduction of the pinned ferromagnetic layer is a promising approach for the enhancement of the IGMR effect.

5. Reference

[1]M. N. Baibich, J .M. Broto, A. Fert, F. Nguyen Van Dau, F. Petroff, P. Etienne, A. Friederich, and J. Chazelas, Phys. Rev. Lett. 61, 2472 (1988)

[2]S. S. P. Parkin, Phys. Rev. Lett. 71, 1641 (1993)

[3]J.-P.Renard, P. Bruno, R. Mégy, B. Brartenlia, P. Beauvillain, C. Chappert, C. Dupas, E. Kolb, M. Mulloy, P. Veillet, and E. Vélu, Phys. Rev. B 51, 12 821, 1995

[4]M. AlHajDarwish, A. Fert, W. P. Pratt, Jr. and J. Bass, J. Appl. Phys. 95, 6771, 2004