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Antiferromagnetically Exchange-coupled Reference Layer in Perpendicular Magnetic Tunnel Junctions

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The antiferromagnetic (AF) interlayer exchange coupling is widely used for constituting synthetic pinned layers and synthetic free layers in magnetic tunnel junctions (MTJs) [1]-[4]. Here we demonstrate the AF exchange coupling in out-of-plane direction, and use it in the reference layer of perpendicular MTJs.

The perpendicular MTJs are prepared by magnetron sputtering and standard lithography. The MTJs consist of Si/SiO_2 (300)/ Ta(5)/ Ru(20)/ $Co_{72}Pt_{28}$(8)/ Co(0.2)/ Ru(0.8)/ Co(0.2)/ Co40Fe40B20(0.6~0.8)/ MgO(2)/ CoFeB(1)/ Pt(2) (parenthetical units are in nanometers). The tunnel magnetoresistance (TMR) of patterned MTJs with cross junction geometry is measured by four probe method.

The perpendicular magnetic anisotropy (PMA) of top electrode is achieved using a CoFeB layer sandwiched by MgO and Pt layers, which are annealed above 300℃ [5]. The coercivity of the top electrode is less than 100 Oe. In order to obtain a PMA in bottom electrode, hcp $Co_{72}Pt_{28}$ alloy is co-sputtered using Co and Pt targets [6]. The coercivity of this material is higher than 1000 Oe, and suitable for a reference layer. The AF exchange coupling is made between the hcp $Co_{72}Pt_{28}$ and CoFeB in the bottom electrode consisting of $Co_{72}Pt_{28}$/ Co/ Ru/ Co/ CoFeB. In order to increase the AF exchange coupling strength, 0.2-nm-thick Co layer is inserted at both interfaces of the Ru layer.

Alternating gradient magnetometer (AGM) is used to characterize the AF exchange coupling strength of Ta(5)/ $Co_{72}Pt_{28}$(2)/ Co(0.2)/ Ru(0.4~1.2)/ Co(0.2)/ CoFeB(2)/ Ta(5) [7]. After annealing at 300℃, the maximum AF coupling strength of this stack, 0.34 erg/cm^2, was observed at the Ru thickness of 0.8 nm (Fig. 1). With this coupling strength, it is expected that, for a complete AF coupling with the PMA $Co_{72}Pt_{28}$ layer, the thickness of CoFeB layer should be less than 1 nm.

After investigating the magnetic configuration of the coupled $Co_{72}Pt_{28}$/ Co/ Ru/ Co/ CoFeB layers, we measured the TMR properties of MTJ stacks annealed at 300℃ with varying the bottom CoFeB thickness. As shown in Fig. 2, the MTJs show a nominal negative TMR within the applied field of 6000 Oe, which reveals that there is an AF exchange coupling between the $Co_{72}Pt_{28}$(8) and CoFeB(0.6~0.8) in the bottom electrode. A high resistance is observed when the magnetization of ($Co_{72}Pt_{28}$, bottom CoFeB, top CoFeB) layers are in (up, down, up) or (down, up, down) configuration, while a low resistance is observed when the magnetization of those layers are in (up, down, down) or (down, up, up) configuration.

With a 0.6-nm-thick CoFeB bottom electrode, the resistance of the (up, down, up) or (down, up, down) configuration remains constant as we increase the external magnetic field up to 6000 Oe. This means that a complete AF coupling is maintained even at the external field of 6000 Oe. By contrast, with the CoFeB thickness of 0.8 nm, the resistances of the (up, down, up) or (down, up, down) configuration starts to decrease as we increase the external field. This means that the $Co_{72}Pt_{28}$ and bottom CoFeB layers are in a tilted magnetic configuration. This result shows that the magnetic configuration is very sensitive to the thickness of the bottom CoFeB layer, and the critical thickness for a complete AF configuration is about 0.6~0.8 nm.

We have shown that antiferromagnetic exchange coupling in out-of-plane direction can be realized in perpendicular magnetic tunnel junctions. This result can be used to engineer the perpendicular magnetic tunnel junctions to obtain desired properties.

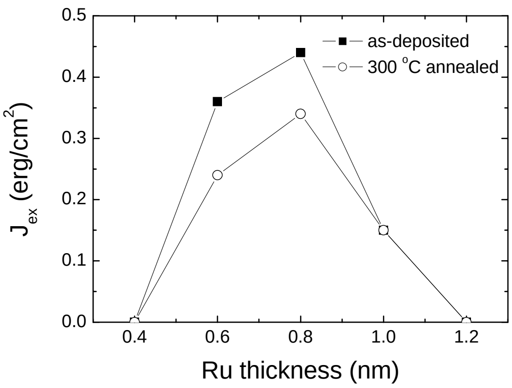

Fig. 1. AF exchange coupling strength of Ta(5)/ $Co_{72}Pt_{28}$(2)/Co(0.2)/Ru(0.4~1.2)/Co(0.2)/CoFeB(2)/Ta(5).

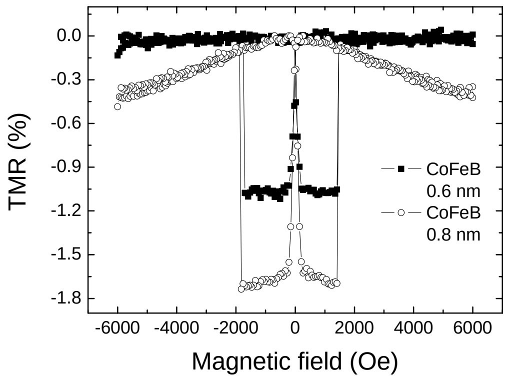

Fig. 2. TMR result of 300℃ annealed Ta(5)/Ru(20)/ $Co_{72}Pt_{28}$(8)/Co(0.2)/Ru(0.8)/Co(0.2)/CoFeB(0.6~0.8)/ MgO(2)/CoFeB(1)/Pt(2).

Reference

[1] S. S. P. Parkin et al, Phys. Rev. Lett., 64, 2304 (1990).
[2] Y. M. Lee et al, Appl. Phys. Lett., 89, 042506 (2006).
[3] R. C. Sousa et al, J. Appl. Phys., 91, 7700 2002).
[4] T. Nozaki et al, J. Appl. Phys., 95, 3745 (2004).
[5] L. E. Nistor et al, Appl. Phys. Lett., 94, 012512 (2009).
[6] T. Shimatsu et al, J. Appl. Phys., 99, 08G908 (2006).
[7] B. Heinrich et al, Phys. Rev. B, 44, 9348 (1991).