Critical Current Density and Thermal Stability with Asymmetric CoFeB/Ru/CoFeB Synthetic Free Layers

Tae Young Lee[1,2], Chiyui Ahn[1], Byoung-Chul Min[1]*, Boram Jeong[2], Soo Young Jang[2],
Sang-Ho Lim[2], Jürgen Langer[3], Berthold Ocker[3], Wolfram Maass[3],
Seung-Young Park[4], Younghun Jo[4] and Kyung-Ho Shin[1]
[1]Korea Institute of Science and Technology, Seoul 136-791, Korea
[2]Korea University, Seoul 136-713, Korea
[3]Singulus Technologies Ag, D-63796 Kahl am Main, Germany
[4]Korea Basic Science Institute, Daejeon 305-333, Korea
*e-mail : min@kist.re.kr

1. Introduction

Reduction of critical curret density (J_c) for magnetization switching while maintaining a high thermal stability factor (Δ_0) is an important issue in spin-transfer devices such as magnetoresistive random access memory (MRAM). According to the previous works[1,2], the MgO-based magnetic tunnel junctions (MTJs) with synthetic ferrimagnetic (SyF) free layers can provide a lower J_c and higher Δ_0 than those with a single free layer. In this work, we investigate the dependence of J_c and Δ_0 on the magnetic configuration of the SyF free layers in MTJs with asymmetric SyF free layers.

2. Experiment details

The samples, MgO-based MTJ cells, are prepared with a $Co_{60}Fe_{20}B_{20}(2)/Ru(0.8)/Co_{60}Fe_{20}B_{20}(t)$(in nm) SyF free layer with varying thickness of the second CoFeB layer (t). In the SyF free layer, the thickness of the second CoFeB layer is varied from 1 nm to 2.8 nm, and the magnetizations of two CoFeB layers are anti-ferromagnetically coupled by a thin Ru layer. The samples are patterned into nanopillars of elliptical shape with a size of 120 nm × 80 nm using electron-beam lithography and ion-beam etching. The samples are annealed at 270℃ with an in-plane applied magnetic field of 4 kOe.

3. Results and discussion

We find that the second CoFeB layer significantly affects the magnetic configuration of the SyF free layer, and thereby influences the J_c of MTJs. The results show a tunnel magnetoresistance (TMR) of about 90%, independent of the second CoFeB layer thickness, but the shape of the TMR curves strongly depends on the second CoFeB layer thickness as shown in Figs. 1 (a) – (c). Also, we use Julliere's model[3] to calculate the angle between the pinned layer and the first free layer. The result clearly shows the parallel, anti-parallel, and spin-flop state of the SyF free layer depending on the applied magnetic field as shown Fig. 1. (d). Fig. 2 shows the measured J_c in current-induced magnetization switching and Δ_0 of the samples. As we increase the thickness of the second CoFeB layer, we observed that the switching field and the J_c also increased correspondingly. We used the switching probability analysis based on a single-layer energy model[2] to evaluate the Δ_0. This analysis shows that the Δ_0 and the intrinsic critical current density (I_{C0}) do not have a simple relationship with the thickness of the second CoFeB layer. This result implies that the switching model based on a single-layer energy profile fails to explain the switching of the SyF structure.

This work is supported by the KIST institutional program, by the KRCF DRC program, and by the MEST/NRF Grant (No.2010–0019103).

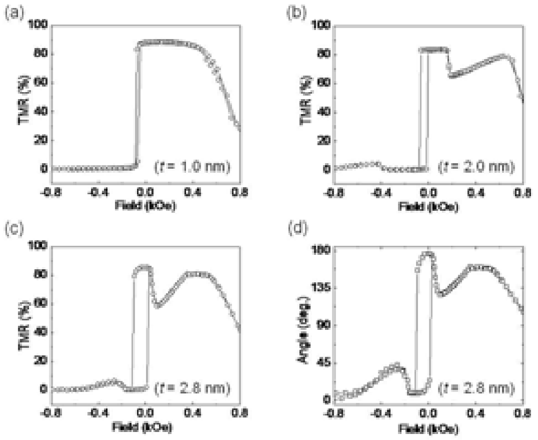

Fig. 1. Tunnel magnetoresistance curve with the second CoFeB thickness of (a) 1.0 nm, (b) 2.0 nm, and (c) 2.8 nm, (d) the angle between the pinned layer and the first free layer of (c) as a function of the applied magnetic field.

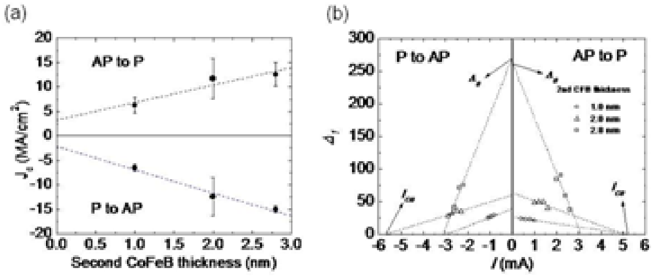

Fig. 2. (a) The critical current dencity (J_c) versus the second CoFeB thickness and (b) the thermal stability factor ($\triangle_0$) and the intrinsic critical current density (I_{C0}) with the various thickness of the second CoFeB layers.

4. References

[1] J. Hayakawa *et al.*, Jpn. J. Appl. Phys. **45**, L1057 (2006).

[2] S. Yakata *et al.*, Appl. Phys. Lett. **95**, 242504 (2009).

[3] M. Julliere., Phys. Lett. A. **54**, 225 (1975).