RB02

Transient Repairing Annealing on Patterned CoFeB-based Magnetic Tunnel Junctions

K. M. Wu[1], C. H. Huang[1], M. J. Kao[2], M. J. Tsai[2], J. C. Wu1, and L. Horng*,[1]
[1]Department of Physics and Taiwan SPIN Research Center, National Changhua University of Education, Changhua, Taiwan
[2]Industrial Technology Research Institute, Hsinchu, Taiwan
*Corresponding author: wuncp@yahoo.com.tw, Phone: +886-4-7232105ext3340, Fax: +886-4-7211153

A drawback in microfabrication process is that certain damages, such as: edge stress, irregular domain structure, and blocking contact will occur in magnetic tunnel junctions (MTJs). The irregular domain structure may arise during etching process, giving rise to uncertain magnetization reversal that makes MTJ cell difficult to achieve reliable and repeatable switching. The blocking contact between capping layer of MTJ and top leads increases the surrounding resistance of device, decreasing the effective signal output that leads to lower recording densityof application. Therefore, appointing a thermal treatment after fabrication processes to improve the faults as described above is required. In this study, the transient annealing effect on the switching behavior of microstructured $Co_{60}Fe_{20}B_{20}$-based magnetic tunnel junctions has been studied through magnetoresistacne measurements. Elliptical shape of devices with long/short axis of 4/2 micrometers was patterned out of sheet film stack of: seed layer (20)/ PtMn (15)/ CoFeB (3)/ Al (0.7)-oxide/ CoFeB (2)/ capping layer (48) (thickness unit in nanometers) after a conventional long time field cooling annealing. The transient annealing was then executed by sample loading into a furnace with pre-set temperatures ranging from 100 to 400°C for only 5 minutes in the absence of any external magnetic field. The vortex-like reverse of free layer in as-etched MTJ evidently changes to single-domain-like reverser after 200~250°C transient annealing. The magnetoresistance was found to increase with increasing annealing temperatures up to 250°C and then decrease at higher annealing temperatures. In addition, the magnetoresistance ratio of around 35%, similar to that of as-fabricated devices, sustains up to annealing temperature of 350°C.

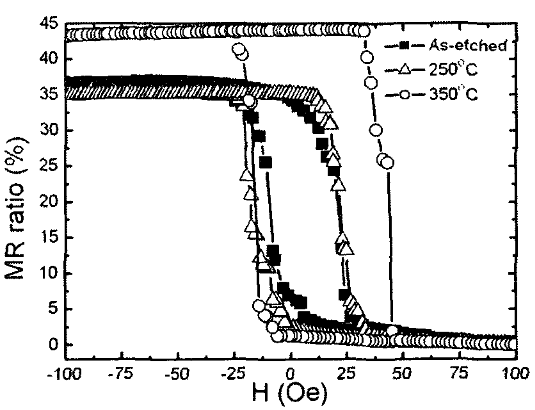

Fig. 1. MR loops of CoFeB-based MTJs after different transient annealing temperatures.

REFERENCES
[1] F. Li, R. Sharif, L. Jiang, X. Zhang, X. Han, Y. Wang, and Z. Zhang, J. Appl. Phys. **98**, 113710 (2005).

RB03

Effect of Nb Concentration on the Microstructure of Al and the Magnetoresistive Properties of the Magnetic Tunnel Junction with a Nb-Doped Al-Oxide Barrier

Sung Min Park, Ha Chang Chung, and Seong-Rae Lee*
Division of Materials Science and Engineering, Korea University, Seoul 136-701, Korea
*Corresponding author: kumetsrl@korea.ac.kr, Phone: +82 2 3290 3270, Fax: +82 2 928 3584

Modified Al oxide barriers have been studied for high stable and low resistance magnetic tunnel junction (MTJ) device applications [1-2]. Recently, we developed the low resistance MTJ using the Ti-alloyed Al-oxide barrier, which has reduced band-gap of AlOx caused by the formation of extra bands [1]. In addition, we reported a MTJ with a Zr-alloyed Al oxide barrier which showed excellent thermal and electrical stability [1]. We studied the composition dependence of TMR behavior of MTJ with Nb-doped Al-oxide barrier and microstructural evolution of Nb-Al alloy films. Also we analyzed electrical stability and thermal stability of MTJs with Nb-doped Al-oxide barrier. A MTJ consisting of Ta 5/CoFe 17/IrMn 7.5/CoFe 5/Al-Nb1.6 + oxidation/CoFe 5/Ta 5 (in nanometers) was prepared by a rf magnetron sputtering under typical base pressure below 5×10^{-7} Torr. An Al composite target with Nb chips was used to get Nb-Al alloy of the desired composition. Junctions were patterned by using a set of metal shadow mask with $100\times100\ \mu m^2$ opening.

As the Nb concentration increases, the TMR ratio increased and reached a maximum 38.5% at 9.26 at. % Nb. The grain size decreases rapidly and the microstructure becomes a dense, fine equiaxed-type structure. Above 9.26 at.% Nb concentration, grain size increases and TMR ratio reduced. Resistance of the MTJ decreased systematically from 1200 Ω to *220 Ω as the Nb concentration increased because effective barrier height lowered. Effective barrier height decreased from* 1.62 eV to 0.847 eV as the Nb concentration increased. Theoretical calculations [2] predicted and x-ray absorption spectroscopy (XAS) analysis [3] confirmed that the localized *d* states formation reduced the band gap of Nb-doped alumina. Therefore, we speculated that the reduction of junction resistance of the MTJ with Nb-doped Al-oxide barrier was due to Nb d states formation in the band gap. The breakdown voltage (V_B) variation of the MTJ as a function of the Nb concentration in the AlO_x barrier is shown in Figure. 2. V_B increased as Nb concentration increased and reached a maximum *1.16V at 9.26 at.* % Nb in the annealed state. The high $V_B$signified that the junction has a high-quality tunnel barrier, pinhole-free with few defects. The composition dependence of the V_B behavior of MTJs with a NbAl-oxide barrier was closely related to the structural changes in the NbAl alloy films. These structural improvements [1] enhanced the TMR ratio, electrical and thermal stability, and increased breakdown voltagewith Nb-doped Al-oxide barrier.

REFERENCES
[1] J.-O. Song, S.-R. Lee, and H.-J. Shin, Appl. Phys. Lett., **86**, 252501 (2005) S. -R. Lee, C. M. Choi, and Y. K. Kim, Appl. Phys. Lett., **83**, 317 (2003); C. M. Choi and S. -R. Lee, IEEE Trans. Mag. 40, 2281 (2004)
[2] M. Haverty, A. Kawamoto, K. Cho, and R. Dutton, Appl. Phys. Lett., **80**, 2669 (2002)
[3] R. Jung, J. -C. Lee, Y. -W. So, T. -W. Noh, S. -J. Oh, J., -C. Lee, and H. -J. Shin, Appl. Phys. Lett. **83**, 5226 (2003)