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Ultrathin Perpendicular RE-TM Films with Low Coercivity and Low Magnetization on the Application of STT-RAM

Lin-Xiu Ye[1], Ching-Ming Lee[1,2], Jhih-Wei Syu[1,3], Wen-Jaun Chen[1], and Te-ho Wu[1,2,3]*

[1]Taiwan SPIN Research Center, National Yunlin University of Science and Technology, Touliu, 64002, Taiwan

[2]Graduate School of materials science, National Yunlin University of Science and Technology, Touliu, 64002, Taiwan

[3]Graduate School of Optoelectronics, National Yunlin University of Science and Technology, Touliu, 64002, Taiwan

Recently there are a lot of studies on spin-transfer torque (STT) effect from fundamental physics to industrial applications, such as magneto-resistive random access memory (MRAM) and microwave oscillators. For real production of STT-RAM, the reduction of switching current less than 1 MA/cm^2 is a key issue. The possible solutions include the adoption of magnetic layers with low saturation magnetizations and reducing their thicknesses. In this study we present the magnetic properties of ultrathin Rear earth-Transition metal (RE-TM) perpendicular magnetic layers. The structures studied are Si/X/TbFeCo(3 or 6 nm)/X under various annealing temperatures, where X represents SiNx (10 nm) or Al (10~30 nm). Figure (1) shows the hysteresis loops of Si/X/TbFeCo(3 nm)/X structure with various capping and buffer layers. In this case, the thicknesses of SiN and Al are 10 nm. We found that the coercivity of TbFeCo film is much larger than other structures when using Al as capping and buffer layer. Influence on magnetic characteristics was more obvious when aluminum was used as under layer. Using Al as capping or buffer layer can improve perpendicular anisotropy for very thin TbFeCo magnetic films. In addition, the Al layer thickness will affect the coercivity, magnetization, and squareness. The hysteresis loops of the structures Al/TbFeCo(3 nm)/Al with various annealing temperature are shown in Figure (2). Fig.(2) shows that as annealing temperature increases, both the coercivity and magnetization decrease. Moerover, the loop squareness becomes better. Other results about the effect of Aluminum and magnetic layer thickness on magnetic properties with various annealing temperatures were also presented and meticulously discussed.

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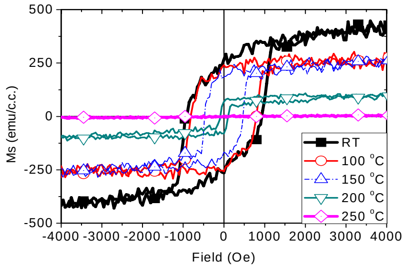
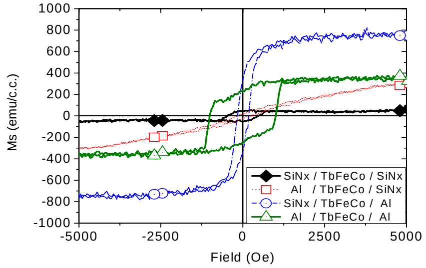


Figure(1)



Figure(2)

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MgO-based MTJs with Synthetic Free Layers

B. -C . Min[1], I. J. Shin[1], J. H. Lee[1], J. Langer[2], J. Wrona[2], B. Ocker[2], and K. -H. Shin[1]*

[1]Korea Institute of Science and Technology, Seoul 136-791, Korea

[2]Singulus Nano Deposition Technologies GmbH, D-63796 Kahl am Main, Germany

*Corresponding author: e-mail: kshin@kist.re.kr

The high switching current density in current induced magnetization switching devices is one of the most serious challenges on the road to the development of high density magnetic random access memories (MRAMs). Engineering the magnetic tunnel junction (MTJ) structure by using a synthetic free layer or by introducing an out-of-plane anisotropy has turned out to provide potential solutions for the reduction of the switching current density[1,2]. We have fabricated MgO-based MTJs with various synthetic free layers and those with layers having out-of-plane anisotropy, and investigated how their tunnel magenetoresistance (TMR) and critical switching current density (J_c) are influenced by the device structure. The MTJs are deposited by a Singulus NDT TIMARIS II sputtering cluster system, which allows us to secure the MTJ properties with high reproducibility. The MTJs are characterized by the current-in-plane-tunneling method as well as the four-terminal measurements using patterned MTJs with a cross-geometry structure. In the MTJs consisting of CoFeB/ MgO/ CoFeB/ nonmagnetic spacer / ferromagnet (CoFeB/ MgO/ CoFeB/ NM/ FM_2), we show that the TMR is dependent on the kind of materials used for NM and FM2, while the resistance area product in the low-resistance state remains constant. We illuminate how the TMR is affected by the structural and magnetic properties of the CoFeB/ NM/ FM_2 free layer. In the MTJs with a layer having out-of-plane anisotropy, we demonstrate that a proper device structure and suitable material selection present TMR higher than 100%. We discuss the consequences of the use of synthetic free layers and the out-of-plane anisotropy on the reduction of the J_c.

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