Perpendicular magnetic tunnel junctions with cubic GaN barrier

D. Kumar[1], K. Suzuki[2,1], H. Kwon[2,1], N. Kamata[2,1], and S. Mizukami[1,3]

[1]WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan.
[2]Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan.
[3]Center for Science and Innovation in Spintronics, Tohoku University, Sendai 980-8577, Japan.
E-mail: kumar.deepak.e3@tohoku.ac.jp

Magnetic tunnel junctions (MTJs) exhibit tunneling magnetoresistance (TMR) effects, which are applied for HDD reading head, memory, sensors, etc. Current standard materials are FeCoB and MgO, whereas various materials are being explored for advanced technology of MTJ devices [1-4]. One of the demands is new barrier material exhibiting both large TMR and low resistance [3,4], and a good candidate would be cubic wide-bandgap oxide semiconductors crystallizing on (001) planes of magnetic films [3-5]. In this study, we explore metastable cubic nitride widegap semiconductor c-GaN (001) with a bandgap of approximately 3 eV as a tunnel barrier for out-of-plane magnetized MTJs.

The MTJ stacks were deposited on single crystal MgO(100) substrate using an ultrahigh-vacuum magnetron sputtering system with a base pressure below 5×10^{-7} Pa. The stacking structures was substrate/Cr(40)/MnGa(50)/Mg(0.4)/CoMnFe(1.2)/Mg(0.4)/MgO(0.6)/GaN(1)/MgO(0.6)/CoFeB(1.2)/Ta(3)/Ru(5) (thickness is in nm). We also prepared a similar stack with a single 2.0-nm-thick MgO barrier instead of MgO/GaN/MgO for comparison, as already reported elsewhere [6]. The MTJ device fabrication was performed using standard optical lithography with Ar ion etching. The MTJs were annealed in a vacuum furnace with different annealing temperatures (T_a). Transport measurements were carried out using the standard four-probe method at 300K.

Figure 1 shows hysteresis loops for the TMR effect in p-MTJ, which were measured after the annealing at T_a =300°C. We observed perpendicular magnetization for the top CoFeB layer, indicating that large perpendicular magnetic anisotropy is maintained even in the presence of the GaN layer. The maximum TMR ratio of ~47% and ~110% were observed with and without the GaN layer, respectively. We also observed that the resistance area product ($R_P A$) of 8.2×10^3 Ωμm^2 and 1.3×10^4 Ωμm^2 of p-MTJ at T_a =300°C with and without GaN layer, respectively, possibly due to a reduced barrier height. In the presentation, we will discuss more details with a comparison of the data obtained in-plane magnetized MTJs with GaN layers having different thicknesses

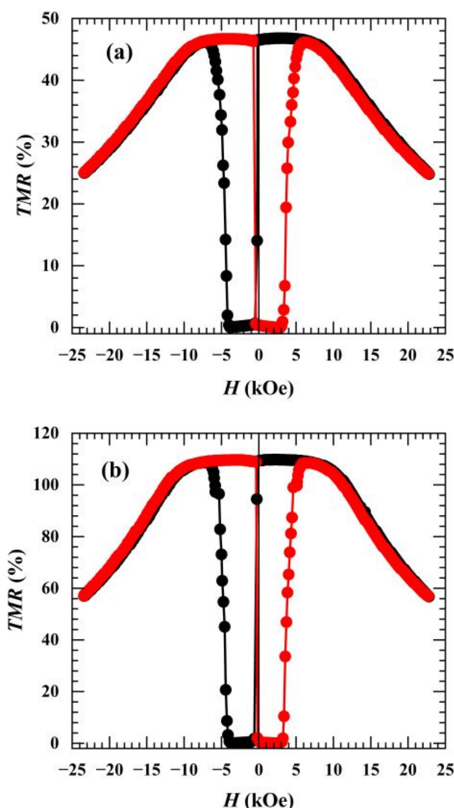

Fig. 1 TMR hysteresis loops in p-MTJ as the function of magnetic field for (a) with and (b) without GaN barrier at T_a = 300°C.

This work is partially supported by KAKENHI (21H05000), CREST(JPMJCR17J5), and X-NICS of MEXT (JPJ011438). H. K. thanks to GP-spin at Tohoku University

References

1. T. Ichinose et al., J. Alloy. Compound. **960,** 170757 (2023).
2. D. Kumar et al., STAM, **25**(1), 2421746, (2024)
3. H. Sukegawa et al., Appl. Phys. Lett. **110,** 122404 (2017).
4. S. Mertens et al., Appl. Phys. Lett. **118,** 172402 (2021).
5. Y. Xie et al., Appl. Phys. Lett. **69,** 334 (1996).
6. D. Kumar et al., AIP Advances (accepted).