An effect of electric field on a cone angle at an easy-cone state in CoFeB/MgO stack investigated by ferromagnetic resonance

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Magnetization reversal by spin-transfer torque (STT) is of importance for non-volatile memory applications using magnetic tunnel junctions. Recently, the free layer with an easy-cone state, which can be obtained when the first- and second-order magnetic anisotropy energy constants satisfy a certain condition, is attracting much attention for improving the STT-induced reversal efficiency [1-2]. In this study, we investigate an effect of the electric field E on the cone angle at the easy-cone state in Ta/ CoFeB/ MgO system using ferromagnetic resonance (FMR) to elucidate the variation in the intrinsic critical current under application of voltage.

Stack, from substrate side, Ta (5 nm)/ Ru (10 nm)/ Ta (5 nm)/ $Co_{0.2}Fe_{0.6}B_{0.2}$ (1.6 nm)/ MgO (2 nm)/ Al_2O_3 (5 nm) is deposited on thermally oxidized Si substrate by sputtering, followed by annealing at 300°C for 1 h under perpendicular magnetic field of 0.4 T. The stack is processed into 1 mmϕ circular mesa. Insulator Al_2O_3 (32 nm) is deposited by atomic layer deposition to cover the device, and top electrode Cr (3 nm) /Au (50 nm) are formed by evaporation and lift-off technique.

We evaluate anisotropy fields H_{K1}^{eff} and H_{K2} by FMR using TE_{011} cavity with 9 GHz microwave at temperature T varied from 4 K to 300 K [3]. We first study temperature dependence of H_{K1}^{eff} and H_{K2} in an absence of electric field. Both H_{K1}^{eff} and H_{K2} increase with decreasing temperature. As a result, below 200 K, the easy-cone state is observed. We then study the electric field dependence of H_{K1}^{eff} and H_{K2} as a function of T. At all the measured T, H_{K1}^{eff} varies by application of E while H_{K2} is virtually constant, which is consistent with previous reports [3,4]. Due to the difference in the dependence of anisotropy field on electric field, the cone angle is modulated by E (~10 degrees with E = 0.1 V/nm), which manifests itself in the magnetic field angle dependence of resonance field as a function of E. The present result indicates that the intrinsic critical current with the easy-cone state is modulated by the electric field through variation of the cone angle.

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