Composition Dependence of the Critical Current Density and Thermal Stability of MgO Magnetic Tunnel Junctions with a CoFeB Single Free Layer.

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1. Introduction

A large thermal stability and small switching current are major prerequisites for the spin- transfer-torque magnetoresistive memory (STT-MRAM) technologies [1]. The two parameters are influenced by the properties of magnetic tunnel junctions, for example, in-plane and perpendicular spin transfer torque efficiency, interface and bulk magnetic anisotropy, and magnetostatic interactions, which are closely associated with the composition of the free layer. In this study, we have investigated the composition dependence of the critical current density and thermal stability of MgO magnetic tunnel junctions (MTJs) with a CoFeB single free layer.

2. Experiments

We have prepared MgO MTJs with varying the CoFeB free layer composition, Fe-rich (MTJ_1), equi-composition (MTJ_2), and Co-rich ones (MTJ_3). The MTJ stacks, consisting of substrate/ buffer/ CoFe/ Ru/ CoFeB/ MgO/ $Co_xFe_{80-x}B_{20}$ (x= 20, 40, 60)/ capping layer, were deposited using an ultra high vacuum DC/RF magnetron sputtering system. The films were patterned into elliptical-shaped MTJs of 150 nm x 50 nm size using electron beam lithography and Ar ion milling.

3. Results

The tunnel magnetoresistance (TMR) of MTJ_1, MTJ_2, and MTJ_3 having a 1.7-nm-thick free layer is, respectively, 120%, 145%, and 132% at room temperature. The switching phase diagrams (SPD), where Hc is measured as a function of bias voltage or current, shows that the current induced magnetization switching (CIMS) are influenced by the free layer composition.

In order to obtain the intrinsic thermal stability (*Δ0*) and the critical switching current (*Ico*), we have measured the time-dependent probability of CIMS under external magnetic fields. Employing the thermal activation model with the Stoner-Wohlfarth field dependence and a linear current dependence of magnetization switching, we have obtained the *Δ0* and Ico of MTJs [2-7].

For the P-to-AP switching, the *Δ0* of the MTJ_1, MTJ_2, and MTJ_3 is respectively, 30.5, 35.3, and 24.1, and the corresponding Ico is, respectively, -0.73, -0.89, and -0.72 mA. For the AP-to-P switching, the *Δ0* of the MTJ_1, MTJ_2, and MTJ_3 is, respectively, 41.6, 39.3, and 24.1, and the corresponding Ico is, respectively, 0.38, 0.52, and 0.63 mA. In summary, The Fe-rich composition gives rise to a largest figure of merit, *Δ0/Ico*, whereas the Co-rich composition presents smallest *Δ0/Ico.*

4. Conclusion

We find that the composition of free layer influences the critical current density and thermal stability of MgO magnetic tunnel junctions (MTJs) with a CoFeB single free layer. Especially, the Ico for the AP-to-P switching is greatly influenced by the free layer composition. In terms of the figure of merit, it is likely that the Fe-rich free layer is a suitable choice for the free layer. A further investigation is required to clarify the relation between the composition of the free layer and critical factors for CIMS, for example, the perpendicular spin transfer torque and interface magnetic anisotropy.

5. References

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