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Low Temperature Properties of Exchange-biased Magnetic Tunnel Junction

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Abstract

Low temperature diagnosis was performed as a probe for the integrity of MTJ(Magnetic tunnel junction) process which is optimised for the given plasma oxidation condition. TMR ratio increased slowly with decreasing temperature than that expected from spin wave exitation theory[1]. Junction resistance (RJ) does not follow $T^{-1/2}$ law below 200 K, indicating another conduction path besides spin polarized tunneling is involved at low temperature. Temperature dependence of conductance dip and bias dependence of TMR with temperature are discussed, from which the quality of tunnel barrier and its formation process can be inferred.

Introduction

In MTJ, oxide growth of tunnel barrier is most crucial part of fabrication, which brings poor controllability and reproducibility. Typically, the oxide growth process is optimized with the room temperature TMR and junction resistance as indicators. However, only room temperature TMR cannot explain the whole property of high quality tunnel barrier. For this purpose, we present low temperature transport porperties of our bottom exchange-biased ferromagnetic tunnel (Ta(5nm)/NiFe(6nm)/FeMn(8nm)/CoFe(4nm)/Al-AlO(16nm)/CoFe(2nm)/NiFe(10nm)/Ta(5nm)) which shows moderate room temperature TMR of 20 %. The temperature dependence of TMR, RJ and conductance dip provide a robust of information on barrier quality. Within this experimental frame, we discuss the critical issues of barrier quality such as overoxidation, the presence of impurities and FM/I interface sharpness.

Experimental

Bottom exchange biased MTJ was deposited in-situ using dc magnetron sputtering on Si(100)/SiO2 substrate under base pressure of about 4×10^{-8} Torr or better . The Al-oxide layer was formed by dc plasma oxidation in 20mTorr oxygen for 20 sec-1min. Junction of $10\times10\mu m^2$ to $50\times50\mu m^2$ was fabricated using a conventional photolithography and ion-beam etching methods. Four-point-probe method was used for measuring MR ratio, and ac current modulation technique was used to obtain dynamic conductance and inelastic electron tunneling spectra. All measurements were conducted from 77K to room temperature under magnetic field swept up to 600 Oe.

Result and Discussion

Figure 1 shows that the dynamic conductance of MTJ with parallel (P) and antiparallel (AP) magnetization alignment at room temperature and 77 K. The increase of TMR with lower temperature is much slugish (only 14 % increase from 16 % at RT to 19 % at 77 K) compared to that expected by spin wave excitation (hot electron) theory[1,2]. To investigate the origin of such slow increase of TMR, R_J and extra conductance ($\Delta G(0)$) of MTJ are plotted in Figure 2 as a function of temperature. Here, $\Delta G(0) = G(0) - G^*(0)$, where G(0) is extrapolated conductance at $V = 0$ using Brinkman's formular[3] and $G^*(0)$ is a conductance dip (see Figure 1). R_J obeys $T^{-1/2}$ law down to 200 K, however, they increase much slowly below the temperature, indicating the extra conducation path in addition to quantum mechanical tunneling is present, which may be thermally activated process.

Likewise, $\Delta G(0)$ decreases with increasing temperature, which clearly manifest that it is not inelastic tunnel type. Tentatively, the presence of antiferromagnetic and semiconductive CoO or FeO_x at FM/I interface, which may undergo phase transformation at 200 K is proposed.

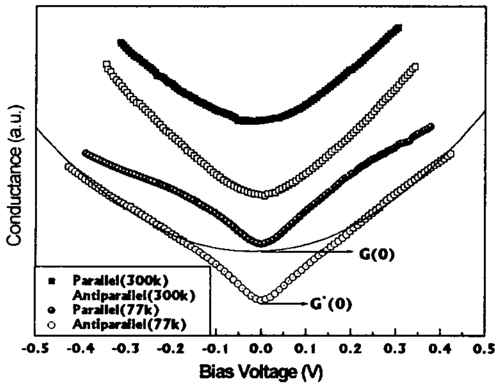

Fig. 1. the dynamic conductance of MT with parallel (P) and antiparallel (AP magnetization alignment at roo temperature and 77 K.

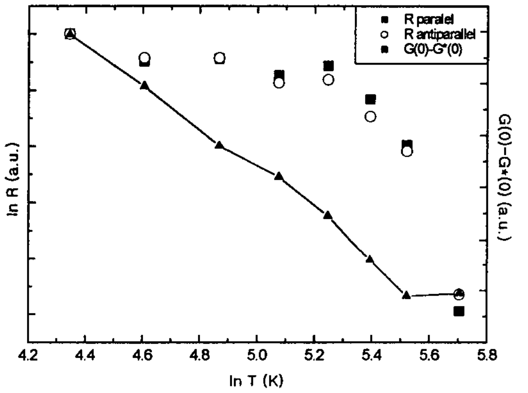

Fig. 2. R_J and extra conductance ($\Delta G(0)$ of MTJ as a function of temperature.

References

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