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Temperature dependence of magnetoresistance for tunnel junctions with high-power plasma-oxidized barriers : Effects of annealing

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I. INTRODUCTION

It is well known that appropriate annealing enhances tunneling magnetoresistance (TMR) at room temperature,[1] but the effect of annealing on the temperature dependence of TMR is not much studied. Since annealing process improves the quality of interface between the ferromagnetic metal and barrier layer (Al_2O_3), it is supposed that better quality of junctions, at least the effects of fewer impurities as a result of annealing, should be reflected on the temperature dependence of TMR. In this work, the effects of annealing on the temperature dependence of TMR is investigated experimentally, and it is found that *Tmax*, the temperature where the maximum TMR value is observed, decreases with annealing.

II. EXPERIMENTS AND RESULTS

The magnetic tunnel junctions (MTJs) were deposited on thermally oxidized Si substrates by using 6-gun DC magnetron sputtering system. The structure is SiO_2/Ta(5 nm)/NiFe(6 nm)/FeMn(8 nm) /CoFe(4 nm)/Al_2O_3(1.6 nm)/CoFe(2 nm)/NiFe(10 nm)/Ta(5 nm). The base pressure was better than 5×10^{-8} Torr and the growing pressure was about 2×10^{-3} Torr. The Al_2O_3 was formed by oxidizing 1.6 nm Al layer with oxygen plasma of 150W for 20 sec. The $50 \times 50 \mu m^2$ junctions were patterned by using optical lithography and Ar^+ beam milling. A series of samples were heat treated by the rapid thermal annealing (RTA) method for 10 sec at the each annealing temperatures(T_A) of 250, 300, and 400℃.

Figure 1 shows the temperature dependence of TMR for samples annealed at different temperatures. The solid circles represent the TMR of as-grown junction, and the triangles, the open circles, and the squares are for junctions annealed at 250, 300, and 400℃, respectively. The TMR improved significantly by annealing at 250 and 300℃, but

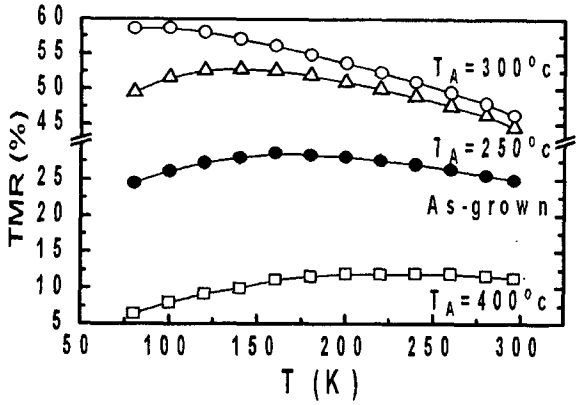

Fig. 1. Temperature dependence of TMR for junctions annealed at different temperatures.

deteriorated severely when annealed at 400℃. The optimal temperature for the RTA method is about 300℃. At this annealing temperature, TMR value reaches to 48 % measured at room temperature and 59 % at 80 K. It is known that the TMR usually decreases monotonically with increasing temperature due to the decrease of the polarization. However, our samples show a novel temperature dependence of TMR. It is notable that the TMR increases as a function of temperature in a certain range. This is in contrast to the temperature dependence of TMR observed by others.[2] As grown, the TMR increases with increasing temperatures from 80 K to 160 K and decreases thereafter. For the junction annealed at 250℃, the highest TMR is observed at 140 K. When annealed at 300℃, the temperature dependence is similar to those observed by others, but still the TMR measured at 100 K is slightly larger than that measured at 80 K.

III. DISCUSSIONS AND CONCLUSIONS

We investigated the effects of annealing on the temperature dependence of TMR. The highest TMR value was observed at 160 K for the as-grown junction. When junctions are annealed at 250 and 300℃, the temperature where the maximum TMR is observed shifts to 140 K and 100 K, respectively. This behavior is attributed to the oxidation of the bottom ferromagnetic layer. The increase of TMR as a function of temperature in a certain range is explained phenomenologically with spin-dependent transfer rates of electrons through the barrier.

REFERENCES

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