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The effect of ferromagnetic oxide formation in spin dependent tunnel junction

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1. Introduction

To make spin dependent tunnel junctions, many solutions have been introduced but the metal(Al) deposition followed by oxidation step is the most popular method that having been used. The oxidation step can be divided by two methods, one is plasma oxidation and the other is natural oxidation. In the case of plasma oxidation the oxygen species are so reactive to make ferromagnetic oxide easily. There are many arguments on the contribution of ferromagnetic oxide relating the TMR ratio[1]. So we analyzed the interface to confirm the contribution of ferromagnetic oxide to the MR ratio. And when the bottom ferromagnetic layer is Co there may be formation of the CoOx which have antiferromagnetic properties. This material's Neel Temperature is 293K[2]. But even when we measure the magnetic properties of our junctions we could see the increase of Co layer's coercivity. We report about this phenomenon.

2. Experiments

We fabricated the Junction which consisted of Glass/Co(10nm)/Al(variable)- oxidation/Co(3nm)/Ni81Fe19(14nm) with RF and DC magnetron sputtering machine. For the Al layer deposition, the power was 30W, pressure was 5 mTorr and the target to substrate distance was 10 cm. In oxidation step the power was 20W and the pressure was 15mTorr with O_2/Ar ratio of 3:1. We varied the Al deposition time and oxidation time to check the resistance and TMR ratio change

3. Results and discussion

The variation of TMR % and resistance value, varying the oxidation time, are shown in fig.1 and fig.2. It is easy to guess that junctions in the every left side of the peak value have the unoxidized Al and junctions on the right side of the peak value have the oxidized ferromagnetic layer[3]. We varied the Al layer thickness from 1.5 nm to 2.5 nm. In case of the junction with the 2.5 nm Al and oxidation for 120 sec we could get the highest TMR% (16.5 %) and we directly see the image of this junction by TEM(Transmission Electron Microscope) in fig.3 and we confirmed the oxide layer is continuous and the thickness of the barrier was 3.5 nm. The interface between the Co and AlOx layer is flat and easy to define but that between the AlOx and intermediate Co layer is relatively rough and hard to define. That may be due to the roughening of Al layer after oxidation.

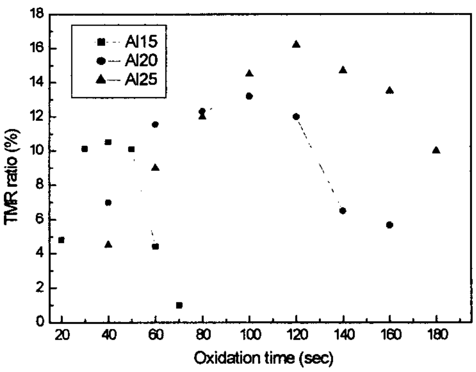

Fig.1 TMR ratio variation with oxidation time

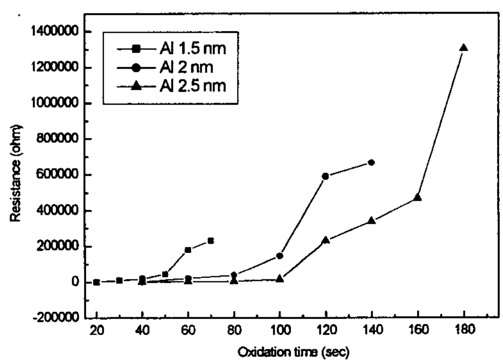

Fig.2 Resistance variation with oxidation time

In fig. 2 we can see that junction with thinner Al layer have higher resistance in the same oxidation condition. And in detail, in junction with 1.5 nm of Al layer the increase of the resistance is very steep and this value reach to 200 kilo-ohm just by oxidation for 60 sec. To the contrast, the increase of resistance is not that steep in the junction with 2nm of Al, until the oxidation time is 100 sec. And, in 1.5 nm Al junction, the TMR ratio is decreased sharply as the oxidation time is above 50 sec, which means that the bottom Co layer is oxidized rapidly. Similarly, in 2 nm Al junction the TMR ratio is maximum when the oxidation time is 100 sec and above 100sec the TMR ratio start to decrease as the resistance go up steeply. In 2.5 nm Al junction, similar resistance and MR ratio feature are also shown. The increase of_the resistance is not fast, when the junction is in the left side of peak value of the TMR ratio curve, but when the oxidation time exceed the peak value of the TMR ratio, the increase of the resistance is faster than the left side case.

4. Conclusion.

We showed the variation of the TMR ratio and resistance value varying the Al layer thickness and the oxidation time. And Resistance and TMR ratio is related and discussed. The slightly oxidized junctions have highest TMR ratio in each Al layer thickness. And the oxidation time range is getting broad as the Al thickness is increased for the AlOx have passivation ability. And the coercivity of Co layer is increased as the oxidation time is increased. This may be due to exchange coupling between the Co layer and CoOx layer or(and) the local CoOx formation in the Co layer to reduce the interacton between the Co clusters.

Reference

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