S-5

QUENCHING OF TUNNELING MAGNETORESISTANCE IN MAGNETIC TUNNEL JUNCTIONS

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The report on large tunneling magnetoresistance (TMR) at room temperature in magnetic tunnel junctions (MTJ), composed of two ferromagnetic electrodes separated by a thin insulating barrier, has ignite the intensive research both from scientific and technological points of view. A simple model proposed by Juliere has explained the observed TMR surprisingly well, where the TMR is expressed in terms of the spin polarization P of the ferromagnetic electrodes. After that report, theoretical and experimental studies of the temperature dependence of TMR ratio have been conducted to investigate the transport mechanism of spin dependent tunneling in MTJ. In this work, we describe the characteristic transport feature of MTJ whose tunnel barrier is formed by relatively high-power plasma oxidation, and investigate the effects of annealing in MTJ.

Bottom exchange biased magnetic tunnel junctions with the layer stacks of 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) (from bottom to top) were fabricated *in-situ* on a thermally oxidized Si(100) wafer by a 6-target DC magnetron sputter system with a base pressure better than 5×10^{-8} Torr. The tunnel barrier (Al_2O_3) was formed by plasma oxidation of 1.6 nm thick Al in a separated load-lock chamber, by applying relatively high DC bias (-150W) to Al target in pure oxygen of 20 mTorr. The cross geometry junctions were fabricated by photolithography and ion beam etching process. Four point probe method was used for characterization in the temperature range of 2 ~ 300 K and magnetic field up to 1 Tesla in Quantum Design PPMS (Physical property measurement system). A series of samples were heat treated by the rapid thermal annealing (RTA) method for 10 sec at the each annealing temperatures of 250, 300, and 400 ℃. Another series of samples were fabricated with different oxidation time.

This series of junctions shows abnormal junction behavior, particularly in the temperature dependence of junction conductance and TMR. In order to treat the abnormal *TMR-T* dependence qualatatively, we investigate the effects of oxidation time and annealing temperature. Annealing enhances TMR and reduces junction resistance, and changes the transport behavior. Figure 1 shows the temperature dependece of TMR for annealed samples with various oxidation time. The solid circles represent the TMR of junction oxidized for 17 sec, and the triangles, the open circles, and the squares are for junctions oxidized for 20, 23, and 26 sec, respectively. The 17 sec-oxidized sample shows typical junction behavior, *i. e.* TMR decreases monotonically with increasing temperature. However, the other junctions show 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[1]. At low temperatures, the junction has a longer oxidation time exhibits lower TMR value and shows abruptly decresed conductance.

We characterize these transport feature qualitatively based on the tunneling mechanism via magnetic impurities which can cause spin-flip scattering at barrier interface or in the barrier.

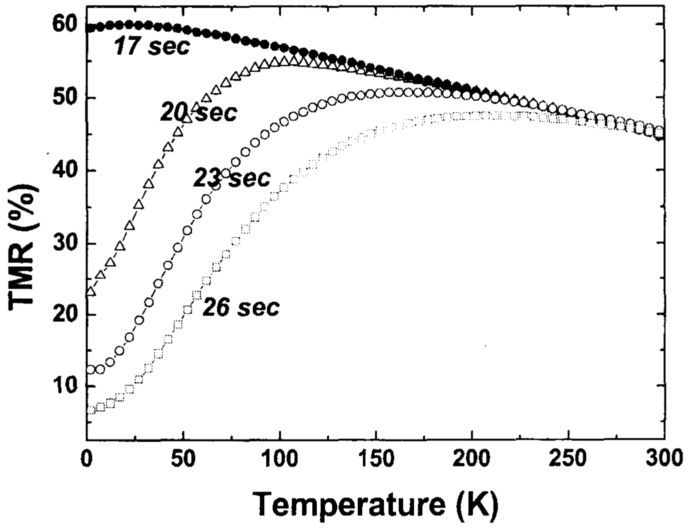

Fig. 1. The temperature dependence of TMR for annealed MTJs with various oxidaition time.

References

[1] C. H. Shang, J. Nowak, R. Jansen, and J. S. Moodera, Phys. Rev. B **58**, R2917 (1998)