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$FeOx-Al_2O_3$ Nanocomposite Tunnel Barriers For Magnetic Tunnel Junctions

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Introduction

Since large room temperature magnetoresistance was demonstrated, magnetic tunnel junctions have been actively studied. In order to ensure high magnetoresistance, the oxide tunnel barrier has to be extremely well controlled because the composition and structure of oxide tunnel barrier have a large influence on the spin polarized tunneling [1]. Normally including magnetic impurities in the tunnel barrier reduces the magnitude of the spin polarized tunneling due to spin flipping [1]; however, it was shown that Fe-doped Al_2O_3 tunnel barrier exhibited enhancement of tunnel magnetoresistance in spite of the presence of Fe in the oxide layer [2]. In this research, we fabricated $FeOx-Al_2O_3$-based tunnel barriers to study their physical properties and to test the possibility of using the oxide composite as a tunnel barrier.

Experimental Procedure

150 ~ 200 -Å- thick $FeOx-Al_2O_3$ thin films were deposited using reactive sputtering(O_2/Ar gas ratio was 1:14) at room temperature on a SiOx wafer. To obtain different Fe compositions, a number of Fe chips (Aldrich, 99.98%) were placed on the Al sputtering target in a mosaic pattern. Composition of the resulting thin films was verified using Auger Electron Spectroscopy and Energy Dispersive X-ray spectroscopy (EDS). Cu grids coated with evaporated carbon were placed on the wafer in order to check the uniformity of film composition using EDS. Thin film stacks were annealed at temperatures ranging from 300 °C to 500 °C under vacuum (10-5 torr) for 3 hours. Transmission electron microscope (TEM, 200 kV, JEOL2010) equipped with EDS was used to analyze the microstructure of the thin film. Magnetic hysteresis loops were measured using a vibrating sample magnetometer at room temperature.

Results and Discussion

$FeOx-Al_2O_3$ thin films were co-sputtered and their magnetic hysteresis loops are shown in Fig.1. As expected, increased amount of Fe during reactive-sputtering raised the saturation moment of the thin films. It is noted that in previous study by Jansen and Moodera, less than a monolayer of Fe was inserted between two Al layers so that magnetic properties of the barrier was not affected by the Fe inclusion. In our study, excess amount of Fe was deliberately introduced to form partially oxidized Fe clusters embedded in the Al_2O_3 tunnel barrier. Existence of the metallic Fe clusters was verified using X-ray photoelectron spectroscopy. Our future study includes the electron transport properties through the composite barrier as a function of Fe/FeOx. Transmission electron microscopy indicated that the structure of the composite film was nearly amorphous as can be seen from the electron diffraction pattern in Fig.2. High-resolution TEM of the thin film suggested that had a segregated structure showing localized two phase structure.

The thin films were also heat treated in a reducing atmosphere in order to form a granular alloy. Because of the difference in the Gibbs free energy of the two oxides, FeOx was preferentially reduced. Increased amount of Fe after the heat treatment was verified again by XPS. Because of the initial segregated structure of the oxide film, metallic Fe was surrounded by Al_2O_3 oxide, closely resembling a granular alloy in which a islands of magnetic materials are incorported in a non-magnetic medium. Indeed, our heat treated thin film also exhibited magnetoresistance whose value ranged from 1% to 5%.

Reference

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[2]. R. Jansen, J. S. Moodera, Appl.Phys. Lett., 75(1999) 400 ~ 402

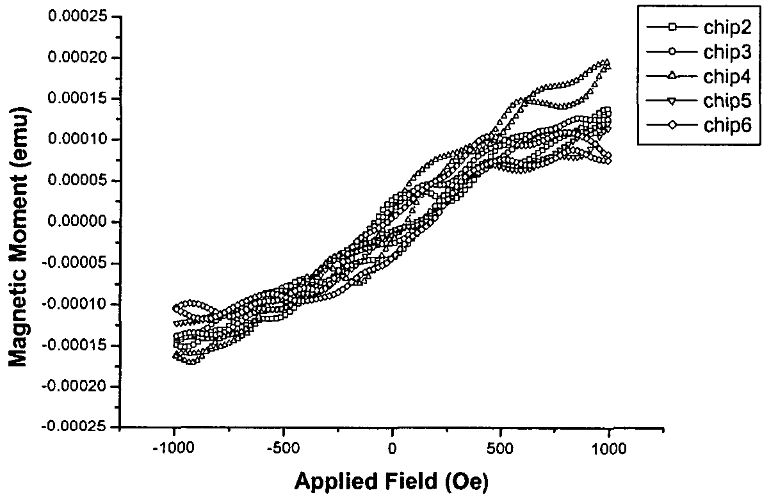

Fig. 1

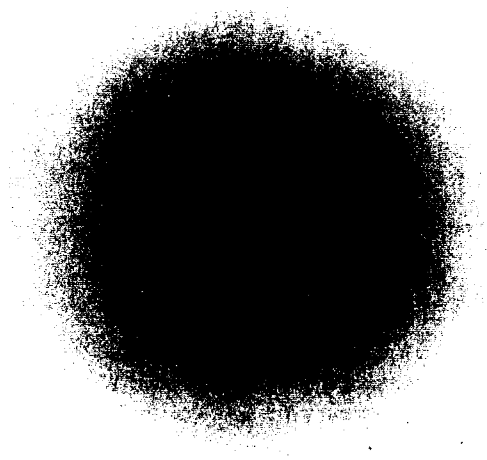

Fig. 2