Thermal stability of magnetic tunnel junctions with FeOx doped tunnel barrier

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Magnetic tunnel junctions were fabricated with tunnel barriers in the middle of which a thin film of Fe was inserted to study the effect of FeOx doping on the magneto-electron transport properties of the junction. After oxidizing the 8Å-thick Al film in O2 plasma, 0~8Å-thick Fe was deposited. Then another 8Å-thick Al layer was deposited and oxidized. The overall junction structure consistered of Ta/Fe(40Å)/Al(8Å)-oxide/Fe(0~8Å)/Al(8Å)oxide/ Fe(40Å)/ IrMn (100Å)/CoFe(40Å)/Ta. Without the Fe interlayer, no tunneling magneto-resistance (TMR) was measured probably due to the excessively thick oxide tunnel barrier whose thickness was ~25Å as confirmed by transmission electron microscopy. When the Fe interlayer inserted, the TMR ratio of 15.0% was obtained only for the junction with 2Å-thick Fe film. With thicker Fe films, no TMR effect was detected. Enhancement of TMR effect by a factor of 1.25 by Fe-doped Al2O3 barriers was previously reported; however, the enhancement was limited to the 0.5% ~ 1Å thick Fe layers[1]. In our case, the 2Å-thick film produced a TMR ratio of 15.0% even though the oxide barrier was apparently low-quality to generate the TMR effect. X-ray photoelectron spectroscopy provided tentative evidence that the Fe layer exists in an oxide form. The reason for the enhancement is not clear although it was suggested that presence of half-metallic Fe3O4 and reduction of defects in the amorphous oxide structure by Fe could be responsible for the TMR improvement [1]. In addition to the improved TMR effect, the thermal stability of the junction was also considerably enhanced by the doping. The annealed junction showed an initial rise in TMR ration (24.1% at 250°C); however, maintained the TMR ratio of 14.0% even after annealing at 350°C at which most ordinary junctions would fail. Although the Fe-doped eventually failed beyond 375%, auger electron spectroscopy indicated that there was no appreciable interdiffusion among the thin films. We demonstrated that inclusion of a thin film of Fe within the oxide tunnel barrier can greatly improve the quality of the barrier as well as the thermal stability of the junction.

[1] R. Jansen, J.S. Moodera, Appl. Phys. Lett. 75(3), 400(1999)