Mg$_x$Al$_{1-x}$O$_y$ バリア層を有する Fe$_3$O$_4$ トンネル磁気抵抗素子の作製

Fabrication of Fe$_3$O$_4$ magnetic tunnel junctions with Mg$_x$Al$_{1-x}$O$_y$ barrier layer

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【Introduction】The Fe$_3$O$_4$ has been expected to be half metal, which have 100% spin polarization, from the ab initio calculations[1]. Many research groups investigated the magnetic tunnel junctions (MTJs) with Fe$_3$O$_4$ electrodes to obtain very high TMR, however, the reported values of TMR ratio were not so high; about 20%. Although the reason has not been clear, it could be attributed to the interface between Fe$_3$O$_4$ and tunnel barrier. So far, the MgO and amorphous AlO$_x$ were employed as tunnel barrier due to easy to fabricate the junctions. Since Fe$_3$O$_4$ has spinel structure, the difference of the crystal structure could disturb the spin transport in the MTJs. Recently, Sukegawa et al. developed the MTJs with MgAl$_2$O$_4$ tunnel barrier layers[2], which has spinel structure. In this study, we fabricated the Fe$_3$O$_4$-MTJ with Mg$_x$Al$_{1-x}$O$_y$ tunnel barrier and investigated the crystal structure and the magneto-transport characteristics.

【Experiments】Samples were fabricated by the reactive MBE system. The sample structures were MgO(100) / Fe$_3$O$_4$ / Mg$_x$Al$_{1-x}$O$_y$ / Fe / Au. The Mg$_x$Al$_{1-x}$O$_y$ layer was formed by reactive deposition at a $T_{sub}$ of 100°C in an O$_2$ atmosphere of $4 \times 10^{-4}$ Pa, and annealed at 150°C in vacuum. The epitaxial growth was observed by RHEED and crystal structure was investigated by STEM. The films were fabricated into MTJs of 10x10 by photolithography, ion milling and sputtering.

【Results】We fabricated the Mg$_x$Al$_{1-x}$O$_y$ of 30nm for various x and observed RHEED. x=0.5 exhibited streak pattern, meaning epitaxial growth, however, x=0.33 corresponding to MgAl$_2$O$_4$ spinel exhibited halo pattern which means the amorphous films. Fig.2 shows the cross sectional TEM image and FFT of Fe$_3$O$_4$ / Mg$_x$Al$_{1-x}$O$_y$ / Fe. Epitaxial growths were confirmed, which was consistent with RHEED pattern, and the spinel type structure of Mg$_x$Al$_{1-x}$O$_y$ was indicated by FFT image. As shown in Fig. 2, the MTJs shows nonlinear I-V characteristics, however, the TMR ratio was +3%, which was inconsistent with ab initio calculations.


Fig.1 STEM image and FTT of Fe$_3$O$_4$/Mg$_x$Al$_{1-x}$O$_y$/Fe.

Fig.2. I-V curves for MTJ with various thickness of barrier layers.