Inverse tunnel magnetoresistance in Fe$_3$O$_4$/MgO/Fe epitaxial Magnetic tunnel junction

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【Introduction】Since the spin polarization of Fe$_3$O$_4$ is predicted as -100% theoretically, it is expected to obtain very large TMR ratio in the magnetic tunnel junction (MTJ) with Fe$_3$O$_4$ electrodes. However, the TMR ratio is still small value in previous research. It is considered that one possible cause is the insufficient understandings of the interface magnetism between Fe$_3$O$_4$ and barrier layer. In this study, we investigated epitaxial growth and interface state with various crystal orientations, and then fabricated MTJs using Fe$_3$O$_4$ electrode.

【Experiment】The films were epitaxially grown by MBE under ultra-high vacuum with the base pressure of $10^{-8}$ Pa. To investigate the crystal orientation dependence of epitaxial growth and interface states, NiO(5 nm)/Fe$_3$O$_4$ (60 nm)/MgO(2 nm) or AlOx(2 nm) was deposited on MgO(001), (110) and (111) substrates, respectively. We employed MgO and AlOx as barrier materials. The surface morphology was observed by RHEED and AFM, and the interface electronic states were investigated by XMCD. With respect to the TMR, the MTJs of MgO(001)/NiO(30 nm)/Fe$_3$O$_4$ (60 nm)/MgO (2 nm)/Fe(10 nm)/Au(30 nm) were fabricated and magnetoresistance was measured by two-probe method.

【Result】From the AFM measurements, the surface roughness of Fe$_3$O$_4$ (001), (110), (111) were estimated at 0.27nm, 1.30 nm and 1.96 nm, respectively. Since the Fe$_3$O$_4$(100) had the flattest surface, we fabricated the MTJs with Fe$_3$O$_4$ (001) electrode. The MTJs exhibited the TMR ratio of -9.6% at room temperature (290 K) and -56.6 % at 80K as shown in Fig.1. Regarding the temperature dependence, the TMR ratio increased monotonically up to -56.6% at 80 K with decreasing temperature (Fig.2). The XMCD spectra will be also discussed.

![Fig.1 MR curve of Fe$_3$O$_4$(001)/MgO/Fe MTJ measured at 80K.](image1)

![Fig.2 Temperature dependence for TMR ratio of Fe$_3$O$_4$(001)/MgO/Fe MTJ.](image2)