The fabrication of the magnetic tunnel junctions including spinel ferrite layers

Nozomi Takahashi¹, Tomohiro Kawai¹, Taro Nagahama² and Toshihiro Shimada²

¹ Graduate School of Chemical Sciences and Engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan
Phone: +81-11-706-7113 E-mail: nozomi86takahashi@ec.hokudai.ac.jp
² Graduate School of Engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628, Japan

Abstract
Spin torque transfer technique provides us the way to reverse the magnetization on very low power. In 2010, Slonczewski proposed that the spin current generated by spin wave in magnetic insulator reverses the magnetization effectively. To investigate the effect, the magnetic tunnel junctions with magnetic insulator layer are necessary. In this study, we fabricated the MTJs with CoFe2O4 spin current generating layer.

1. Introduction
In the spintronics research fields, MRAM and STT-RAM have attracted much attention because of its high functionality as non-volatile memory. In the devices, magnetic tunnel junctions (MTJs), that enable us to control the resistance by magnetic field, are the most important elements. The STT-RAM employs the spin torque transfer magnetization reversal to switch the magnetization on very low power. In 2010, Slonczewski proposed that the magnetization is reversed effectively by the spin current generated by spin wave in magnetic insulator, and he performed the theoretical calculation for the MTJs with CoFe2O4 layer. However, the MTJs with magnetic oxide insulator are not reported so far. The fabrication of such complex MTJs requires epitaxial growth technique for both of the MgO-MTJs and oxides layers. In this study, we fabricated the epitaxial MgO-MTJs with spinel ferrite oxide using reactive molecular beam epitaxy.

2. Experiments
We employed the reactive MBE method to fabricate the junctions because the oxide layers and MgO-MTJs have to be grown epitaxially. CoFe2O4 and Fe3O4 were used as magnetic oxide. Their lattice constant is about 0.84 nm, that is just twice of MgO. The surface morphology was confirmed by RHEED and AFM, respectively.

The films were patterned into 100 x 200 nm² devices with e-beam lithography, Ar ion milling and sputtering. The epitaxial growth and surface morphology were confirmed by RHEED and AFM, respectively.

3. Results and discussion
The non-magnetic layer (NM) in sample 1 played a role of the decoupling the MTJs and ferrite layer magnetically. To obtain the well-defined magnetic characteristics, the spinel ferrite layer should be epitaxially grown on the NM layers. To seek the appropriate NM material, we deposited the Fe/NM(Cr,Au,Pt)/CoFe2O4 and observed the surface morphology.

All the samples exhibited the epitaxial growth, however, insertion of Au layer between Fe and CoFe2O4 made the...
RHEED pattern very spotty, as shown in figure 1(a). For Cr and Pt, as shown in figure 1(b) and (c), the RHEED patterns were streak, meaning the CoFe2O4 layers had flat surfaces. On the other hands, in the AFM image, some bumps and pinholes were observed on the CoFe2O4 surface for Cr and Au insertion layers. From the viewpoint of the layer structure and epitaxial growth, Pt is a suitable material for the insertion layer. However, it should be noted that Pt has large spin-orbit interaction, which disturbs the spin transport in the NM layer. Therefore, we also prepared the sample (2) that has Fe3O4 layer as a bottom electrode because Cr insertion layer can be used.

After the structural investigation, the tunnel junctions of 100 x 200 nm were fabricated by e-beam lithography. In the case of sample (1), the MTJs showed a TMR effect of 70%. The TMR curve had high squareness, meaning the CoFe2O4 layer did not influence the Fe/MgO/Fe junctions magnetically.

4. Summary
We fabricated MTJs including spinel ferrite layers. From the RHEED and AFM observations, Pt is more appropriate for the insertion layer between Fe and ferrite layers than Cr and Au. The MTJ devices exhibited TMR effects of 70%.

Acknowledgements
We would like to express sincere thanks to Laboratory of nanoscale electron devices in Hokkaido Univ. for their enormous help on micro-fabrication.

References