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The fabrication of the magnetic tunnel junctions including spinel ferrite layers

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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 impotant 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 structure of the MTJs were as follows.

(1) MgO(100)/MgO 20 nm/Fe 50 nm/MgO 2 nm/CoFe 5 nm/NM(Au,Cr,Pt) 3 nm/CFO 5 nm/Cr/Au

(2) MgO(100)/MgO 20 nm/TiN 50 nm/Fe3O4 50 nm/Cr 5 nm/Fe 3 nm/MgO 2 nm/Fe 50 nm/Au.

The CoFe2O4 and Fe3O4 are evaporated by e-beam in an atmosphere of atomic oxygen generated by ECR oxygen source. The partial pressure and substrate temperature during the oxidation process were kept at 4 x 10^{-4} Pa and 570K. The films were patterned into 100 x 200 nm^2 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

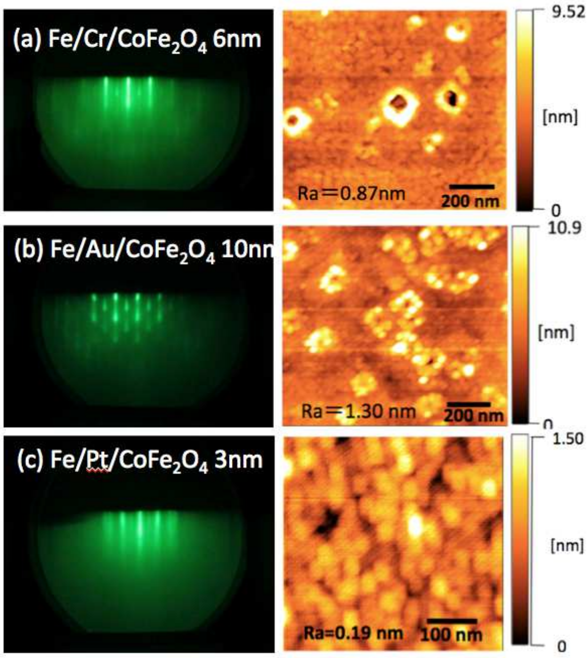

Fig.1 The RHEED patterns and AFM images of CoFe2O4 surfaces with various insertion layers.
(a)MgO(100)/Fe/Cr/CoFe2O4,
(b)MgO(100)/Fe/Au/CoFe2O4, and
(c) MgO(100)/Fe/Pt/CoFe2O4.

RHEED pattern very spotty, as shown in figure 1(a). For Cr and Pt, as shown in figure1(b) and (c), the RHEED patterns were streak, meaning the $CoFe_2O_4$ layers had flat surfaces. On the other hands, in the AFM image, some bumps and pinholes were observed on the $CoFe_2O_4$ 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 Fe_3O_4 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 $CoFe_2O_4$ layer did not influence the Fe/MgO/Fe junctions magnetically.

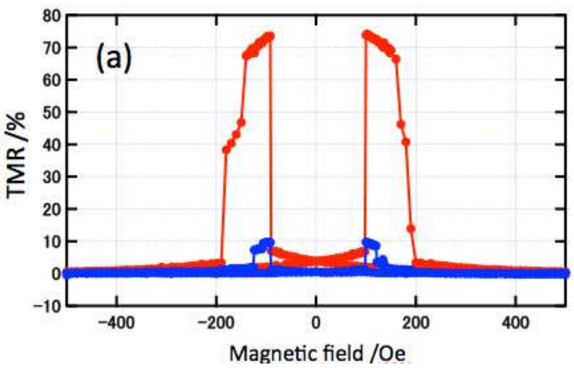

Fig.2 The tunnel magnetoresistance effect of MgO(100) / MgO20 nm/ Fe 50nm/ MgO 2nm/ CoFe 5 nm/ NM(Au,Cr,Pt) 3 nm/ CFO 5 nm/Cr/Au . The TMR was measured at room temperature in the bias voltage of 10 mV.

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 %.

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