Preparation and the dielectric properties of magneto-electric capacitor: $(Cr, Fe)_2O_3$ thin films

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Introduction

Magneto-electronics with ME has been attractive as new generation non-volatile data storage because their magnetic or ferroelectric properties will be able to be controlled by an external electric or magnetic field. We are interested in a room temperature ME material: Cr_2O_3 as spintronics applications, which has extreme small induced magnetic moment by the ME effect. [1] In order to make efficient use of the magnetic moment, we proposed to use the Cr_2O_3 film as a gate insulator of Metal/Insulator/Si (MIS) capacitor with the floating gate (F.G.). [2] We predict the induced magnetic moment to affect the stored charge state in ultra-thin F.G. layer, electro-magnetically. Especially, if we could use the magnetic oxide having different magnetic quantum number from Cr_2O_3 as a F.G. layer, the Cr_2O_3 gate insulator should have to magneto-electrically couple with F.G. layer and the coupling will be unique. In this paper, we investigate the magnetic, dielectric and magneto-electric properties of Cr_2O_3 MIS capacitor inserting a Fe_2O_{3-x} layer.

Experimental Procedure

The MIS capacitors are prepared using radio-frequency (RF) magnetron sputtering method. The gas pressure during deposition was 8.0×10^{-1} Pa. The gas was used the mixture of Ar and O_2 and the ration was used Ar : O_2 = 16 : 1. The growth temperature was fixed at 400 °C. The first insulator layer: Cr_2O_3 (16 nm) is deposited on n-type Si (111) substrate cleaned using improved RCA methods. Then, a floating gate (F.G.) layer was deposited. The thickness of F.G, layer has been changed from 0 ~ 4 nm. The third layer (16 nm) was also deposited using same condition as the first layer. The magnetic properties of the sample were measured at room temperature using a Vibrating Sample Magnetometer (VSM). The structural analysis of the films was performed with an X-ray diffract meter (XRD) using Cu Kα radiation. The surface morphology was measured using Atomic Force Microscope (AFM). For I-V and C-V measurement, Au and Pt were used as a top and bottom electrode, respectively.

Results and Discussion

Structural analyses of the MIS capacitors with changing the F.G. layer thickness have been carried out using XRD patterns. Only Cr_2O_3 polycrystalline diffraction patterns were observed, because the thickness of the F.G. layer is too thin to detect the diffraction signal from the layer. Even with increasing the thickness of F.G. layer, any crystallinity and lattice constant changes of Cr_2O_3 matrix were not observed. These results should indicate the F.G. layer didn't diffuse into the Cr_2O_3 matrix. Fig. 1 shows C-V curves of the MIS capacitors with various F.G. layer thicknesses. All curves show counter clock wise trace with hysteresis window, which is indicated that the films have mobile ionic charges. With increasing the thickness of the F.G. layer, the value of flat band voltage is getting close to the theoretical one. These results indicated that the mobile ionic charges should exist in the Cr_2O_3 top gate or the interface between the Cr_2O_3 and F.G. layer. Since the relative permittivity of the Fe_2O_3 is higher than that of the Cr_2O_3, the even thin Fe_2O_3 film might work as a gate insulator. The mobile ionic charges may be due to the diffused iron or chromium because of the miscibility.

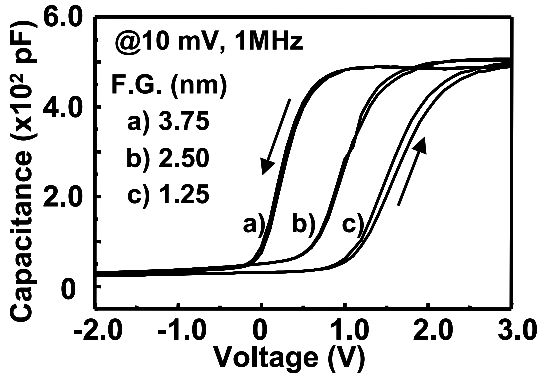
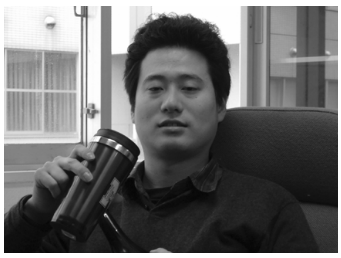


Fig.1 Floating gate layer thickness dependence of C-V characteristics of the MIS capacitors: floating gate thickness is a) 3.75 nm, b) 2.50 nm, c) 1.25 nm.

Biographical Sketch



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