Development of Spontaneous Polarization of Epitaxial Iron-Excess Gallium Ferrite Thin Films

S. H. Oh[1]*, R. H. Shin[1,2], J. H. Lee[1,2], W. Jo[1†] , C.Lefevre[3],
F. Roulland[3], A. Thomasson[3], C. Meny[3], and N. Viart[3]

[1]Department of Physics, Ewha Womans University, Seoul, Korea

[2]CNRS-EWHA International Research Center, Ewha Womans University, Seoul, Korea

[3]Institute of Physics and Chemistry of Materials of Strasbourg, UMR 7504 University of Strasbourg-CNRS, Strasbourg, 67043, France

† wmjo@ewha.ac.kr

1. Abstract

Iron-excess gallium ferrite, $Ga_{0.6}Fe_{1.4}O_3$ (GFO), is known to have room-temperature ferromagnetic phases and potentially exhibit ferroelectricity as well [1]. But, leaky polarization-electric field (PE) hysteresis curves of the GFO thin film are hurdle to prove its spontaneous polarization, in other words, ferroelecticity. One of the reasons that the GFO films have leaky PE hysteresis loop is carrier hopping between Fe^{2+} and Fe^{3+} sites due to oxygen deficiency. We focus on reducing conducting current by substituting divalent cations at Fe^{2+} sites. GFO thin films were grown epitaxially along *b*-axis normal to $SrRuO_3/SrTiO_3$ (111) substrates by pulsed laser deposition. Current density of the ion-substituted GFO thin films was reduced by 10^3 or more. Ferroelectric properties of the ion-substituted GFO thin films were measured using macroscopic and microscopic schemes. In particular, local ferroelectric properties of the GFO thin films were exhibited and their remnant polarization and piezoelectric d33 coefficient were obtained.

2. Experiment

GFO thin films were deposited on $SrRuO_3/SrTiO_3$ (111) substrate by pulsed laser deposition at 750℃ using a KrF excimer laser (λ=248 nm) with a 5 Hz repetition rate and a fluence of 3 J/cm^2. By controling concentration of the substituted ions, change of conducting current density was examined using a HP4145B semiconductor parameter analyzer. In addition, surface and ferroelectric properties of the GFO thin films were measured using scanning probe microscopy and piezoresponse force microscopy which is useful to obtain local polarization-electric field hysteresis curves.

3. Result and discussion

Preferential b-axis oriented growth of the ion-substituted GFO thin films was investigated by x-ray diffraction patterns. We measured I-V characteristics of the ion-substituted GFO thin film, which show a drastic decrease. Furthermore, we measured the temperature dependence of the I-V curves over a range of temperature from 300K to 400K. I-V curves were fitted on Schottky thermionic emission or Poole Frankel thermionic emission models. PE curves of the lowest conducting current GFO thin films were measured by microscopic and macroscopic schemes. Local PE curves using piezoresponce force microscopy (PFM) tool showed the potential ferroelectricity reversal of the ion-substituted GFO thin films by controlling conducting current.

4. Conclusion

The epitaxial GFO thin films were deposited with different concentration of the substituted ions. structure and electrical characteristics showed a clue of ferroelectric properties at room temperature.

5. Reference

[1] M. Trassin, N. Viart, G. Versini, S. Barre, G. Pourroy, J. Lee, W. Jo, K. Dumesnil, C. Dufour and S. Robert, J. Mater. Chem, 19, 8876-8880 (2009)