Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 1148-1149

J-7-2

Electrical Properties of TiO/LaTiO/TiO Stacked Thin Films

Hikaru Hara[1], Masami Tanioku[2], Masaki Yamato[1] and Takamaro Kikkawa[1]

[1]Research Center for Nanodevices and Systems, Hiroshima University,
1-4-2 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8527, Japan
Phone: +81-82-424-6265 E-mail: hikaru-hara@hiroshima-u.ac.jp, kikkawa@sxsys.hiroshima-u.ac.jp
[2]Elpida Memory, Inc.,
7-10 Yoshikawakogyodanchi, Higashi-Hiroshima, Hiroshima 739-0198, Japan

1. Introduction

It becomes very difficult for dynamic random access memories (DRAM's) to keep sufficient capacitance per unit cell for refresh requirement and tolerance to noises, when the DRAM cell size has been shrunk. Therefore, high dielectric constant (High-*k*) materials become important to meet the requirements for sufficient capacitance in small area. Several candidates of high-*k* material, such as La_2O_3, HfO_2, TiO_2 and BST have been investigated to satisfy the requirements for both high dielectric constants and low leakage current due to wide energy bandgap. La_2O_3 and HfO_2 have wide bandgaps such as 5.5 eV and 6 eV respectively, but the dielectric constants are relatively low (~21 and ~27) [1-2]. On the other hand, TiO_2 and BST have higher dielectric constant, but the bandgaps are relatively narrow. In this study, LaTiO dielectric material which is expected to have both properties of La_2O_3 and TiO_2 are investigated. A TiO/LaTiO/TiO stacked structure is proposed and is proved to improve properties of LaTiO films.

2. Experimental

Silicon dioxide (SiO_2) layers were formed by thermal oxidation on Si(100) substrates. Metal-Insulator-Metal (MIM) capacitor was deposited on SiO_2/Si substrates as shown in Fig. 1. Platinum (Pt) was deposited by DC magnetron sputtering in Ar ambient. DC power was 50 W. The pressure was 1.0 Pa. Pt top electrodes were formed with screen mask of ϕ 1.55 mm. TiO and LaTiO thin films were deposited by RF magnetron sputtering by use of TiO_2 and $La_2Ti_2O_7$ targets, respectively. The gas mixture ratio of Ar and O_2 was Ar:O_2=1:1. The substrate temperature was 300°C. RF powers of sputtering for TiO and LaTiO were 150 W and 50 W, respectively. The post-deposition annealing in O_2 ambient was performed in the temperature range of 25 to 900°C.

3. Results and discussion

Figure 2 shows the annealing temperature dependence of single layer LaTiO X-ray diffraction (XRD) spectra. After 800-900°C annealing, a crystalline peak due to LaTiO was observed at 2θ~28°. The film remained amorphous up to 700°C annealing. Figure 3 shows dielectric constant and tanδ versus annealing temperature for LaTiO single layer films. Leakage current density versus electric field for LaTiO films as a parameter of annealing temperature is shown in Fig. 4. The film with no annealing had relatively large tanδ and large leakage current density for low electric field. The LaTiO films treated in 800-900°C had larger dielectric constant but larger leakage current density for high electric field. The 700°C annealed film had relatively lower tanδ and lower leakage current density. However, the leakage current of single layer LaTiO film increased as the physical thickness decreased so that the electric field for the leakage current of 1×10^{-8} A/cm^2 decreased abruptly with reducing the thickness as shown in Fig. 5. In order to overcome this problem, we designed TiO/LaTiO/TiO stacked structure and investigated its electrical properties.

Figure 6 shows measured voltage which was applied to the film at the current density of 1×10^{-8} A/cm^2 versus equivalent oxide thickness (EOT). Compared with single layer LaTiO films having the same EOT, TiO/LaTiO/TiO stacked films showed the larger voltage at J=1×10^{-8} A/cm^2, indicating that TiO/LaTiO/TiO stacked films could suppress leakage current at the same applied voltage. Figure 7 shows the dependence of tanδ on EOT for various film structures. Compared with single LaTiO films having the same EOT, TiO/LaTiO/TiO stacked films had lower tanδ. Figure 8 shows physical thickness of single LaTiO film versus deposition time. EOT of single LaTiO film versus deposition time is shown in Fig. 9. From these two slopes, the dielectric constant was calculated to be approximately 25. Dielectric constant versus physical thickness for LaTiO is shown in Fig.10. The dielectric constant of single LaTiO films decreased with decreasing physical thickness. On the other hand, the dielectric constant of TiO/LaTiO/TiO stacked films remained constant with decreasing physical thicknesses. The effect of TiO/LaTiO/TiO stacked structure on the suppression of leakage current is attributed to TiO layer which can suppress damaged layer formed by metal interdiffusion between Pt electrodes and LaTiO.

4. Conclusion

The properties of LaTiO thin films were investigated. 700°C annealing was found to be the optimum condition to realize lower leakage current and lower tanδ. Higher dielectric constant with lower leakage current and tanδ were obtained by TiO/LaTiO/TiO stacked film structure.

Reference

[1] E. Gerritsen *et al*., Solid-State Elec. 49 (2005) 1767-1775
[2] N.K. Park *et al*., Appl. Surf. Sci. 252 (2006) 8506-8509

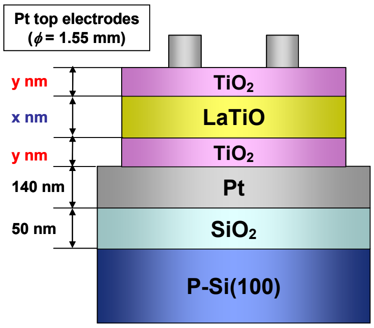

Fig. 1. Cross sectional diagram of TiO/LaTiO/TiO sample structure. Thickness is x and y changed from 0 to 1 nm and 3.5 to 54 nm, respectively.

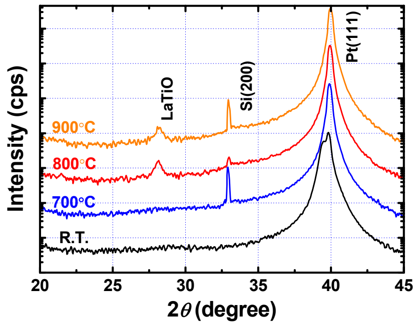

Fig. 2. Annealing temperature dependence of single layer LaTiO XRD spectra.

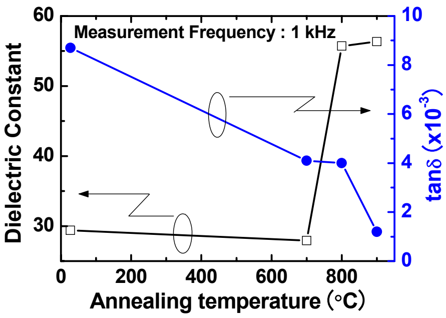

Fig. 3. Annealing temperature dependence of the dielectric constant and tanδ for single layer LaTiO films.

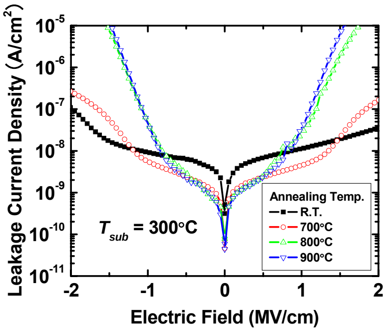

Fig. 4. Annealing temperature dependence of leakage current density versus electric field for single layer LaTiO films.

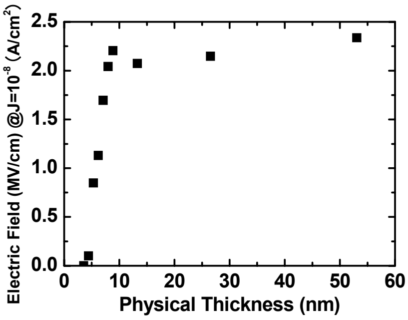

Fig. 5. Electric field at the current density of $J=10^{-8}$ A/cm^2 versus physical thickness for single layer LaTiO films.

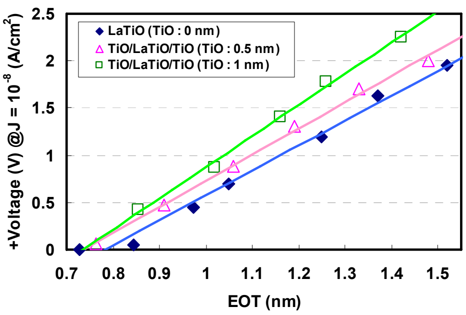

Fig. 6. Applied voltage at the current density of $J=10^{-8}$ A/cm^2 versus EOT for single layer and stacked LaTiO films.

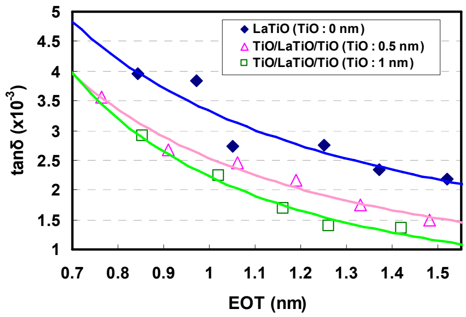

Fig. 7. Dependence of tanδ on EOT for various film structures.

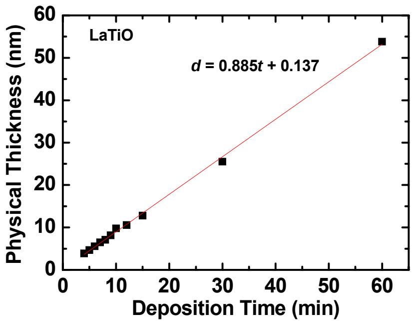

Fig. 8. Physical thickness of single LaTiO film versus deposition time.

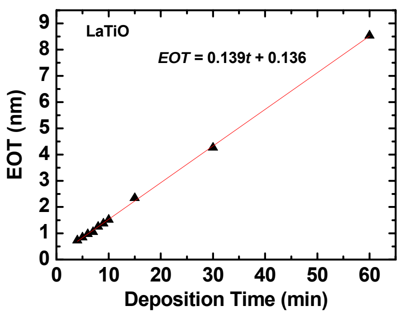

Fig. 9. EOT of single LaTiO film versus deposition time.

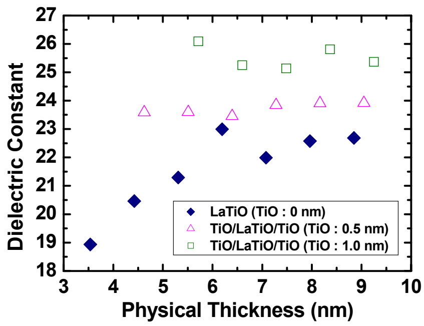

Fig. 10. Dielectric constant versus physical thickness for stacked and single layer structures of LaTiO.