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Ferroelectric Properties of Seeded SBT Thin Films on the LZO/Si Sturcture

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Abstract : We fabricated seeded $SrBi_2Ta_2O_9$ (SBT) thin films using seeding technique on the $LaZrO_x$ (LZO)/Si structure. To evaluate the ferroelectric properties of seeded SBT thin films, we investigated the crystalline phase, the surface morphology, the capacitance-voltage (C-V) curve and the current density-voltage (J-V) curve of seeded films and then compared with the physical and electrical properties of unseeded films. As the result of that, the characteristics of seeded and unseeded films have a slight difference. Therefore, the ferroelectric properties of seeded SBT thin films are not necessarily superior than unseeded films.

Key Words : FRAM, MFIS, $Sr_{0.9}Bi_{2.1}Ta_2O_9$, $LaZrO_x$

1. Introduction

In the past years ferroelectric random access memories (FeRAM) with a metal-ferroelectric-insulator-semiconductor (MFIS) as the next-generation non-volatile memory have been extensively researched because of its low-power and high speed operation, and small memory cell size [1]. In particular, the ferroelectric-gate field-effect transistors (Fe-FETs) with a single-transistor (1-T) memory cell have promising advantages of the high-density integration and the non-destructive read-out operation [2]. The various ferroelectric materials such as $Pb(Zr,Ti)O_3$ (PZT), $Pb_5Ge_3O_{11}$ (PGO), $SrBi_2Ta_2O_9$ (SBT) and $(Bi,La)_4Ti_3O_{12}$ (BLT), have been widely investigated as a ferroelectric layer in MFIS structures[3-6]. Among them, SBT with bismuth layer structured perovskites is one of the most promising candidates for 1-T type FeRAM. Because the SBT film shows good characteristics such as high fatigue endurance, little imprint, long retention and low leakage current [7]. However, this compound presents lower values of the remanent polarization (Pr) when compared to other materials such as PZT. To improve that, some methods have been proposed as follows: rapid thermal annealing, bismuth excess, non-stoichiometric compositions, laser irradiation and seeding techniques [8-10].

In this work, we formed the SBT films using a seeding technique on the LZO/Si structure, and then evaluated the ferroelectric properties of it comparing with the unseeded films.

2. Experiments

For the fabrication of Au/SBT/LZO/Si MFIS structure, we prepared the LZO solution of 0.1 M concentration and the SBT solution of 0.3M concentration, respectively.

To fabricate the LZO/Si structure, we spin-coated the LZO solution on a p-type Si(100) wafer at 4000 rpm for 25 seconds. The coated LZO film was annealed at 750 ℃ for 30 minutes in O_2 ambient by rapid thermal annealing (RTA).

To fabricate SBT thin films, the SBT solution was also spin-coated on the LZO/Si structure at 3000rpm for 20 seconds. The coated films were dried at 250 ℃ for 10 minutes on hot-plate to remove organic materials. These processes were repeated for 6 times in order to have the desired thickness. For the formation of seeded thin films, after the first layer is coated, the film was dried and then annealed to crystallize at 800 ℃ for 30 minutes in O_2 ambient by RTA. Subsequently, the coating-drying cycles (5 times) were carried out on this crystallized film as in the case of unseeded film. All films were finally crystallized at 800 ℃ for 30 minutes in O_2 ambient by RTA. For electrical measurements, Au electrodes were formed onto the samples using shadow mask by thermal evaporation.

The physical and electrical properties of seeded and unseeded SBT thin films on the LZO/Si structure were measured by atomic force microscopy (AFM) and x-ray diffraction (XRD) measurement, HP 4280A capacitance-meter and HP 4155C precision semiconductor parameter analyzer, respectively.

3. Results and Discussion

Fig. 1 shows the AFM images seeded and unseeded SBT thin films on the LZO/Si structure. The measured area was $2\times2\mu m^2$. The surface roughness of seeded and unseeded SBT thin films were about 12.355nm and 11.373nm, respectively. The measured values are indicated that it is a little bit rough surface morphology and the difference is a slight.

According to the XRD patterns of Fig. 2, the seeded film was crystallized in a polycrystalline phase with a highly preferred (115) orientation as in the case of unseeded film.

Fig. 3 shows a typical capacitance-voltage(C-V) characteristic for seeded and unseed SBT films. As shown in the figure, the values of memory window width for seeded and unseeded sample were about 0.81V and 0.76V at bias sweep voltage ±5V, respectively. The difference is negligible. Also, the accumulation capacitance of both samples have a slight difference.

As shown Fig. 4, leakage current densities for seeded film and unseeded film were about 6.7×10^{-8} A/cm^2 and 1.6×10^{-7} A/cm^2 at 10V, respectively. These rusults indicate that the leakage current density was slightly improved by seed layer.

4. Conclusions

We fabricated Au/SBT/LZO/Si MFIS structure with seeded SBT thin films by a sol-gel method and then evaluated the ferroelectric properties of seeded SBT thin films comparing with unseeded SBT thin films. Considering all experimental results, we found that the characteristic of seeded SBT thin films is not superior than unseeded films.

Acknowledgments

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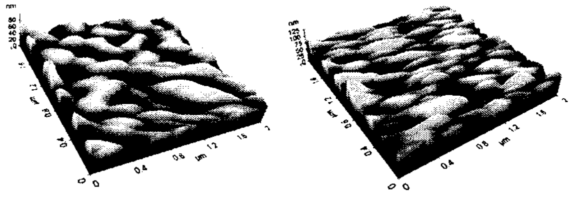


(a) (b)

Fig. 1 AFM image of unseeded (a) and seeded (b) SBT thin films on LZO/Si structure

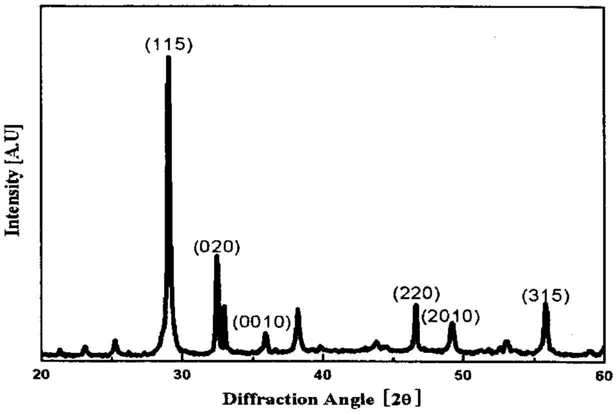
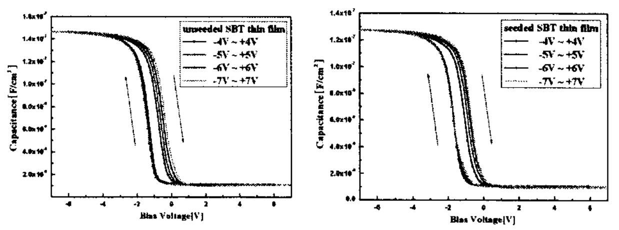


Fig. 2 X-ray diffraction pattern of seeded SBT film on LZO/Si structure



(a) (b)

Fig. 3 Capacitance-voltage characteristics of unseeded (a) and seeded (b) SBT thin films on LZO/Si sturcture

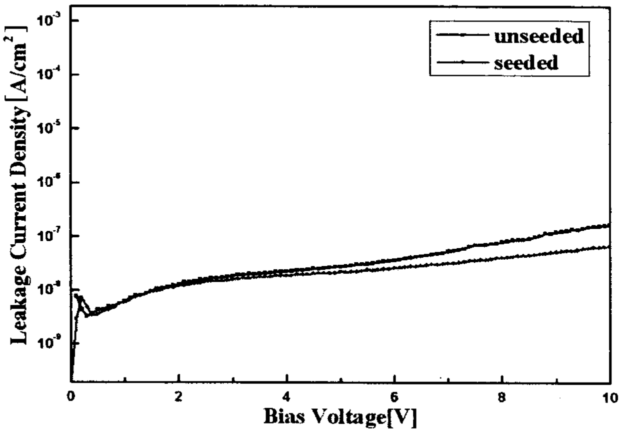


Fig. 4 Leakage current densities of seeded and unseeded SBT thin films on LZO/Si structure