Suresh Gyan Vihar University Journal of Engineering & Technology
(An International Bi-Annual Journal)
Vol. 1, Issue 1, 2015, pp 38-41
ISSN: 2395-0196

CHARACTERIZATION OF BLT THIN FILM PREPARED BY SOL-GEL TECHNIQUE

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Abstract: $Bi_{3.25}La_{0.75}Ti_3O_{12}$ (BLT) thin film was prepared on Pt (111)/TiO_2/SiO_2/Si (100) substrate by the Sol gel spin coating technique at annealing temperature of 600^0 C and annealing time of 2 hours. Various characteristics have been discussed in this paper which is suitable to make FRAM.

Keywords: Perovskite thin film, ferroelectric, Sol gel technique, FRAM, polarization, annealing time, FRAM

INTRODUCTION

Memories can be divided into two broad categories, volatile and non-volatile. Volatile memories are the memories in which the data is lost when the power is removed from the electronic system. These memories are expensive and very fast in read and write access [1]. On the other hand, non-volatile memory retains the data even when the electric power is interrupted [2].

Ferroelectric random access memory (FRAM) has features consistent with a RAM technology, but it is non-volatile like ROM technology. FRAM is a RAM-based device that uses the ferroelectric effect for the storage mechanism [3-5]. The writing speed of FRAMs is 1000 times faster and they consume lower power ($1/1000^{th}$ power) than EEPROMs.

FRAM is a type of non volatile read/write random access semiconductor memory. FRAM has similar applications to EEPROM, but can be written much faster. The ferroelectric film of the memory cell capacitor is made of PZT, PLZT or SBT, and permitting high storage density [6].

At present, the ferroelectric materials suitable for these devices like PZT (Lead Zirconium Titanate) system, SBT(Strontium Bismuth Tentalate), BLT(Bismuth Lanthanum Titanate), BT(Barium Titanate), are studied with a great deal of interest [7]. Sol-gel technique, which is a versatile solution process for making thin films, is used to deposit thin films of BLT [8-9].

EXPERIMENTAL PROCEEDURE

A. Sol Preparation

25 ml of $Bi_{3.25}\ La_{0.75}\ Ti_3\ O_{12}$ precursor solution of 0.1 M molarity was prepared. To prepare sol 4.7294gm of Bi $(NO_3)_3.5H_2O$ was dissolved in 25 ml of acetic acid at 140^0C and the net volume was reduced to 12.5 ml. 0.8119gm of La $(NO_3)_3.6H_2O$ was dissolved in 25 ml of 2-Methoxy ethanol at 160^0C .Volume was reduced to 12.5 ml. Both the solutions were mixed at room temperature and 2.2324ml of Ti -(isopropoxide) was added. Sol was stabilized with 2 ml of acetyl acetone. 10% wt of Bi $(NO_3)_{3}.5H_2O$ and 10%wt of Ti- (isopropoxide) was added to compensate for possible Bi loss during high temperature process.

B. Film Deposition

BLT films were prepared on cleaned Pt (111)/TiO_2/SiO_2/Si (100) substrate. The precursor solution was spin coated on substrate at rotational speed of 5000 rpm for 45 sec. The baked films were spin coated several times to yield desired thickness of 350 nm. For each coating films were dried at 110^0C for 5 min and after each two coating films were fired at 400^0C for 20 min. All coated BLT films were annealed at about 600^0C in air 2hours.

RESULTS AND DISCUSSIONS

A. Phase Analysis

BLT thin films were prepared on cleaned Pt (111)/TiO_2/SiO_2/Si (100) substrate. These films were annealed at about 600^0C in air for 2 hours. Fig.

1 shows XRD pattern. No secondary phase was observed which shows that the prepared sample is crystalline.

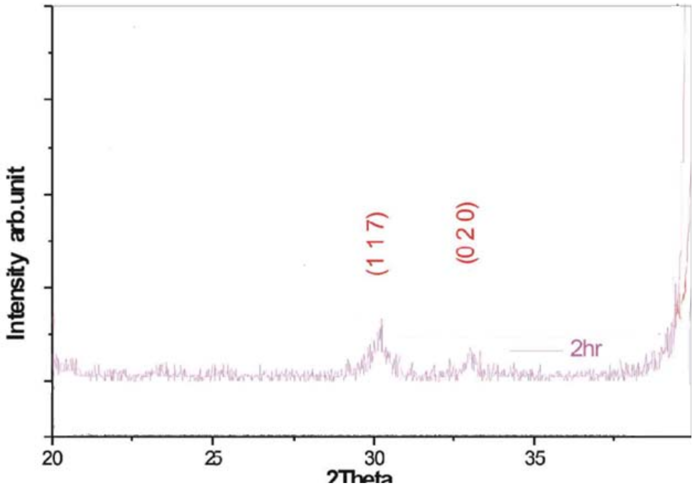

Fig.1: X-Ray Diffraction Comparison of BLTF1, BLTF2 And BLTF3 Films As Deposited Film

B. Field Induced Polarization

The polarization was found to increase with increasing applied field for prepared film. P-E hysteresis loop was measured against 200 kV/cm applied field at 100 Hz is shown in fig.2.

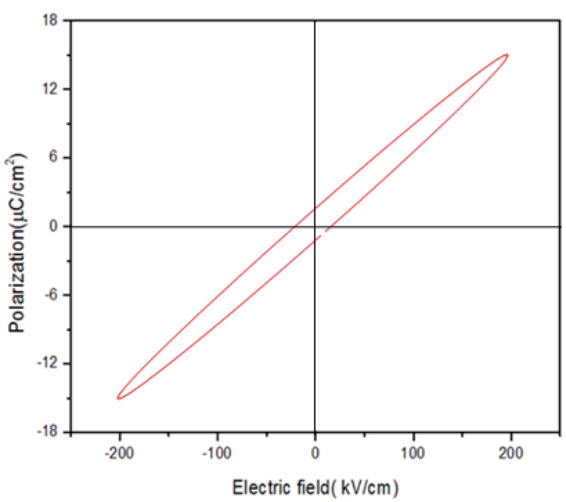

Fig.2: Applied Field Dependence of P-E Hysteresis at 200 kv/Cm

The P_r was found to increase more steeply with increasing the applied field. The P_r value was ~2.6 µC/cm² for test sample. The P_{sat} value was found to increase linearly with increasing field. E_c value was found to increase with the applied field. The polarization values in sample film are not saturated up to the applied field as high as ~200 kV/cm. It is clear that thin film can sustain much higher applied field which is because of the low probability of finding a defect under the electrode in thin films.

Frequency dependent P-E hysteresis loop is shown in fig.3. A P-E loop was recorded at room temperature when the field 200 kV/cm was applied at different frequencies. The prepared film showed frequency dispersion which may be due to the presence of high space charge polarization in film.

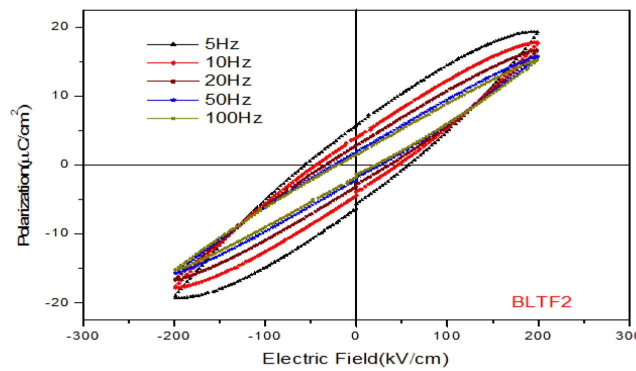

Fig. 3: Frequency dependence P-E hysteresis curve for BLTF2 at 200KV/cm

Fig.4 shows P_r, E_c and P_{sat} values against frequency for sample. It should be noticed that these values decrease exponentially with increasing frequencies.

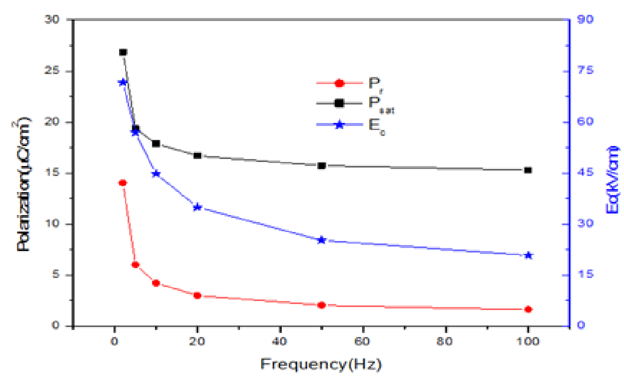

Fig. 4: Comparison of P_r, P_{sat} & E_c at 200 KV/cm with frequency

C. Leakage Current

Time dependent leakage current density was measured at different field for prepared sample as shown in fig. 5. The soak time and measurement time was 1 ms. The leakage current density was found to decrease exponentially for film at low DC-field (up to ~ 100 kV/cm). An increase in time dependent current density at higher field is because of the removal of traps at the domain boundary and losses due to the movement of the domain boundaries under at very high DC-field.

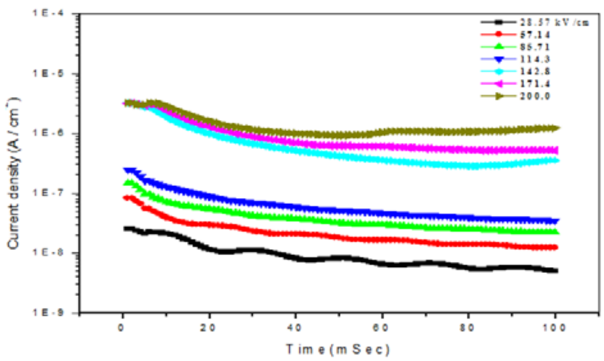

Fig.5: Time dependent leakage current at different field of BLTF2

D. I-V characteristics

I-V characteristic has been obtained for the prepared sample for a triangle field profile. The leakage current density has been found to increase exponentially with increasing field film as shown in fig. 6. A sudden increase in the current density can be seen for prepared thin film which is due to trap charges. This trap charges may be near to the domain boundary, which are pinning these boundaries. The traps are deep for this film, which is consistent with the field at which charges are escaping from these traps for film. When the DC-field was decreased from ~200 kV/cm to 0 kV/cm for film, it is observed that the boundary is pinned again at lower field. The enclosed loop confirms the ferroelectric behaviour of the film. A small enclosed area was observed for BLTF1 film, which is due to the presence of shallow traps.

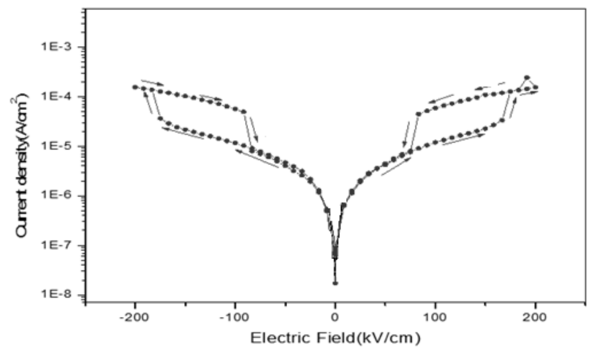

Fig. 6: Comparison of IV characteristics of BLTF1 & BLTF2

E. Microstructure

Fig. 7 shows the microstructure of the top surface of the prepared thin film. The average grain size was in nm range.

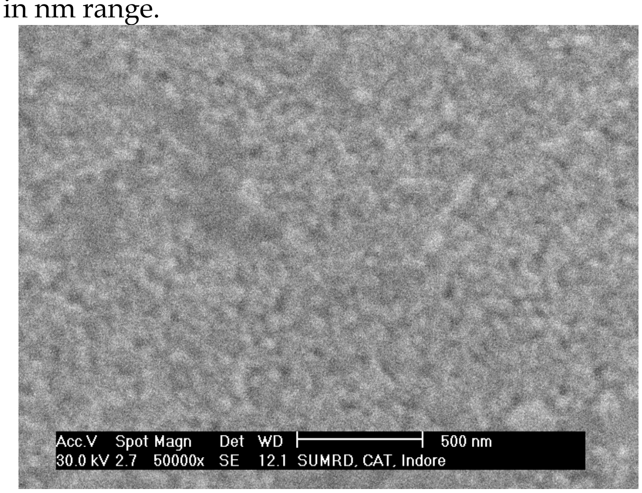

Fig.7: Microstructure of BLT thin film annealed at 600^0 C for 2hr

CONCLUSION

This study clearly shows that the BLT film prepared at annealing temperature at at 600°C for 2 hours exhibits crystalline phase , good ferroelectric properties, low leakage current density , good IV characteristics. SEM result shows that thin film is order of 350 nm which is suitable to make FRAM for various applications.

ACKNOWLEDGEMENT

This paper is based upon work supported by the Raja Ramanna Centre for Advanced Technology, Indore, India. Authors acknowledge the support of Mrs. Rachna Selvamani, scientific officer, Ramanna Centre for Advanced Technology, Indore for his support at various stage of this work.

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