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LEAKAGE CURRENT BEHAVIOR OF Al/$Ba_{0.5}Sr_{0.5}TiO_3$/Pt THIN FILM CAPACITOR

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ABSTRACT

$Ba_{0.5}Sr_{0.5}TiO_3$ ferroelectric ceramic thin film is prepared via sol-gel technique and fabricated as Al/BST/Pt capacitor. The leakage current mechanism has been studied under positive bias using semiconductor parameter analyzer. The results show that the leakage current is Ohmic conduction at low applied electric field, space charge limited conduction at higher applied field, and it is Schottky emission for all applied electric field regions. The leakage current density increases from 3.63×10^{-8} to 7.66×10^{-8} A/cm as the electric field increases from 2.39×10^{4} V/cm up to 3.91×10^{4} V/cm, these values quite low compared to the values reported in the literature for the same value of applied field. Furthermore, the breakdown strength of BST thin film has been discussed; the results show that it has high breakdown strength.

Keywords: $BaTiO_3$; current density; breakdown strength;

INTRODUCTION

Electroceramic thin films with high dielectric constants have attracted much attention for practical use in the capacitors of giga-bit DRAMs, since using high dielectric constant materials can reduce the area of the storage capacitor and simplify the cell structure [1]. Barium strontium titanate (BST) is considered one of the most promising materials for extra-thin film capacitors since it has high dielectric constant and low dielectric loss at room temperature.

One of the most important characteristics of the BST thin films is the leakage current behavior, since it provides information about the charge transport mechanisms [2]. Meanwhile leakage current directly affects the charge storage performance of the material in high density capacitor applications. To reduce the leakage current, the mechanism must be studied. The conduction mechanism of the current through the ferroelectrics thin films has been often explained by the Ohmic conduction, space charge limited conduction, Schottky and Poole–Frenkel emission [3, 4]. Some studies have reported that the leakage current mechanism of BST thin films on platinum showed Schottky emission [2, 5].

In this study, $Ba_{0.5}Sr_{0.5}TiO_3$ (BST50) thin film is fabricated as Al/BST/Pt capacitor, the

leakage current has been investigated under positive dc bias voltage range. The conduction mechanism such as Ohmic conduction, space charge limited conduction and Schottky emission at the film-electrodes barrier have been investigated.

EXPERIMENTAL DETAILS

$Ba_{0.5}Sr_{0.5}TiO_3$ or BST50 solid solution is prepared using sol-gel method. Barium acetate, strontium acetate and titanium (IV) isopropoxide are used as starting materials. Specific amounts of barium acetate and strontium are dissolved in 10 ml heated acetic acid at 80°C under stirring until a clear and transparent solution is obtained. Stoichiometric amount of titanium (IV) isopropoxide is added into 2-Methoxyethanol to form a separate solution at room temperature. The Ba-Sr solution is added to the prepared Ti solution, in drops. The final mixture is stirred at 500 rpm for two hours.

BST50 thin film is deposited on $Pt/SiO_2/Si$ substrate via spin-coater at 5000 rpm for 20 s, followed by baking at 200 °C for 20 min, and then the sample is inserted into annealing furnace and heated at 500 °C for 30 min, finally, it is annealed at 800 °C for 1h in O_2 atmosphere. For leakage current measurement, dots of Al are deposited on top of the film as top electrode using shadow mask. The leakage current density versus electric field (J-E) measurement is performed using a semiconductor parameter analyzer.

RESULTS AND DISCUSSION

Figure 1 shows typical graph of leakage current density as a function of applied electric field for BST50 thin film, 160 nm in thickness, at room temperatures, and applied field from zero up to 435 KV/cm. The current density increases gradually at electric field up to 2.5×10^5 V/cm approximately. At higher applied electric field region, the current density increased exponentially. The dc leakage current density increases from 3.63×10^{-8} to 7.66×10^{-8} A/cm as the electric field increases from 2.39×10^4 V/cm to 3.91×10^4 V/cm. These values are quite lower than the values reported in literature for same applied electric field [6].

The breakdown strength defined as an electric field at which the current density reaches 10^{-3} A/cm through the capacitor, is above 3.01×10^5 V/cm [6]. It is observed from Figure 1 that the current density does not reach this value as the electric field reaches up to 4.35×10^5, which indicates that BST50 thin film has low leakage current density and high breakdown strength, indicating excellent dielectric properties for BST50 film and it is suitable for developing microelectronic devices.

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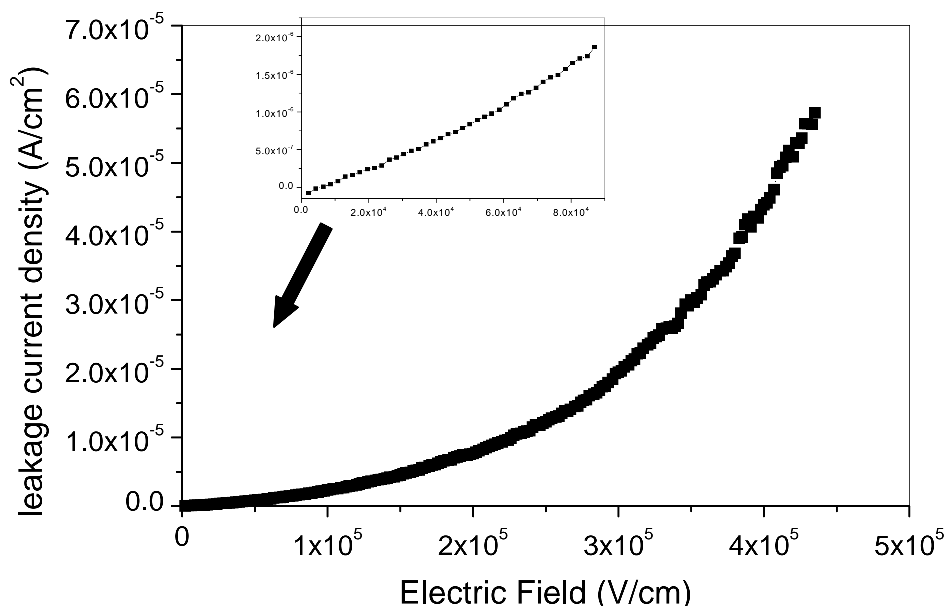

Figure 1: The leakage current density (J) as a function of applied electric field (E) of BST50 film under positive bias. The inserted graph represents the ohmic conduction region

Ohmic Conduction

The inserted graph in Figure 1 shows the leakage current density at low electric field region, where the applied electric field less than 8.7×10^4 V/cm. The graph shows that the current density changes linearly with the applied field, this indicates that the Ohmic conduction in this region dominant.

Space Charge Limited Current (SCLC)

The conduction mechanism based on space charge limited (SCL) emission predicts that J–E characteristics for MFM capacitor system fit polynomially [8]. Figure 2 shows the fitted data for BST50 thin film at applied electric field more than 8.7×10^4 V/cm. The data for the BST50 film can be fitted well with the modified Langmuir–Child law that is, $J(E) = a + bE + cE^2 + dE^3$. The solid line in Figure 2 is the best fitted curve where the coefficients a, b, c, and d are -5.03×10^{-6} A/cm^2, 1.06×10^{-10} A/cm.V, -4.64×10^{-16} A/V^2 and 1.3×10^{-21} Acm/V^{-3}, respectively.

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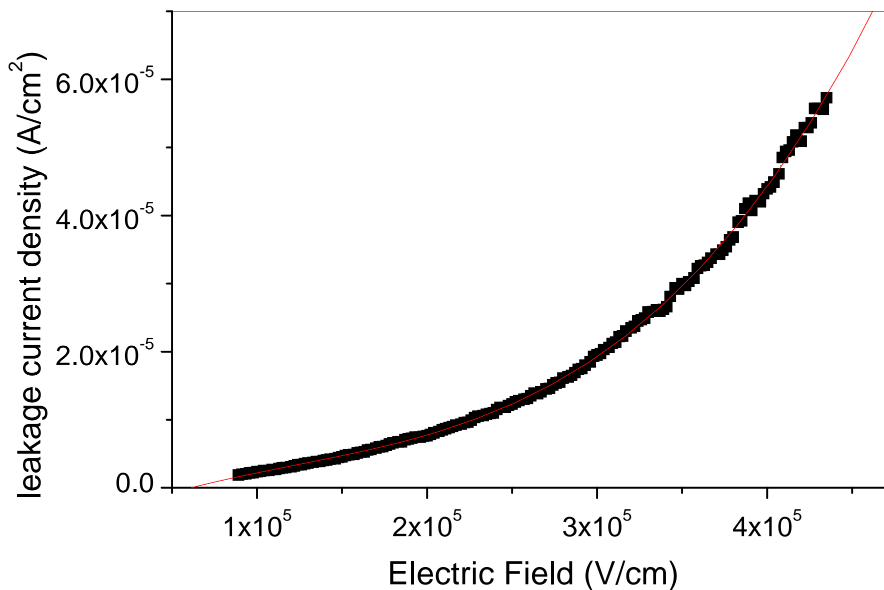

Figure 2: The polynomial curve fitting of J-$E^{1/2}$ according to modified Langmuir–Child law

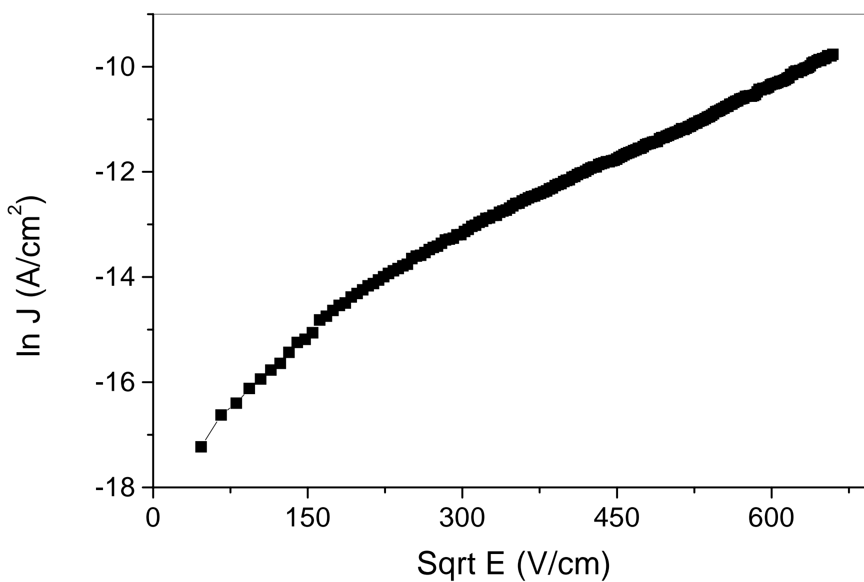

Figure 3: Schottky plots of the square root of applied electric field ($E^{1/2}$) versus the logarithm of leakage current density (ln J) under positive bias

Schottky Emission

According to schottky theory the leakage current density is proportional to square root of the applied field ($E^{1/2}$). The ln J- $E^{1/2}$ data are plotted in Figure 3, the graph shows two linear regimes: at applied field up to 4.13 $\times 10^4$ with slope about 1.4 and the region where the applied field more than 4.13 $\times 10^4$ which has slope about 1. Both of the regions show very good agreement with Schottky theory, this implies that the Schottky mechanism is dominant for all applied field values.

CONCLUSION

For $Ba_{0.5}Sr_{0.5}TiO_3$ (BST50) thin film deposited via sol-gel technique as Al/BST/Pt capacitor, the leakage current is Ohmic conduction at low applied electric field, space charge limited conduction at medium and high applied electric field, and it is Schottky emission for all applied field regions. Furthermore, the leakage current density increases from 3.63×10^{-8} to 7.66×10^{-8} A/cm as the electric field increases from 2.39×10^4 V/cm to 3.91×10^4 V/cm, this values quit low comparing to the value reported in the literature for the same value of applied field. On the other hand, BST50 thin film shows high breakdown strength.

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