

PREPARATION AND CHARACTERIZATION OF THERMAL EVAPORATED BATIO₃ THIN FILMS**Sengodan, R¹. and B. Chandar Shekar^{2*}**¹Department of Physics, Kumaraguru College of Technology, Coimbatore.²Nanotechnology research lab, Dept. of Physics, Kongunadu Arts and Science College, Coimbatore.

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ABSTRACT

Thermal evaporated Barium titanate (BaTiO₃) thin films were prepared on to well cleaned glass substrates under the vacuum of 2 x10⁻⁵ torr, using 12A4 Hind Hivac coating unit from the BaTiO₃ nanoparticles synthesized by using wet chemical method. The thickness of the film was measured by Quartz crystal monitor. From X-ray analysis, it has been found that the deposited film was polycrystalline in nature. SEM analysis revealed that grains of various sizes having tetragonal shape were uniformly distributed throughout the surface of the film. The dependence of capacitance and loss factor on frequency and temperature were investigated and results are discussed.

Keywords: BATIO₃, Nanoparticles, X-ray analysis.

1. INTRODUCTION

BaTiO₃ thin films are very promising for a wide range of application such as high dielectric capacitors, insulating surface layer, non-volatile memories with low switching voltage, dynamic random access memory (DRAM), positive temperature coefficient of resistance (PTCR) thermistors, infrared sensors and electro-optics devices due to high dielectric constant, low dielectric loss, low leakage current and low temperature coefficient of dielectric constant. Due to the desirable properties and applications, over the last few decades, synthesis of BaTiO₃ nanoparticles and their thin film has attracted great attention. A detailed survey of the literature revealed that even though some work on dielectric properties of BaTiO₃ thin films prepared by sol - gel method (Maneeshya *et al.*, 2013; Hu *et al.*, 2003) , r.f. sputtering (Bhattacharya *et al.*, 1993), pulsed laser ablation (Yoon *et al.*, 1995) and metal-organic chemical vapour deposition (Tahan *et al.*, 1996). So far, there is no report on the preparation of thin films of BaTiO₃ on glass substrate by vacuum evaporation method. The present work deals with the characterization of thermal evaporated BaTiO₃ thin films.

2. EXPERIMENTAL*2.1. BaTiO₃ thin film preparation*

Using the conventional 12A4 Hind Hivac coating unit, pure (99.99%) aluminium was evaporated from a tungsten filament onto well-cleaned glass substrates through suitable masks to form the bottom electrode. Prepared BaTiO₃ nanoparticles were then evaporated from a molybdenum boat to form the middle dielectric

layer. An aluminium top electrode was deposited onto the dielectric through suitable masks to complete the aluminium-BaTiO₃-aluminium (Metal-Insulator-Metal) sandwich structure. A working pressure of 2 x10⁻⁵ torr was maintained in all the evaporation processes. For the structural and surface analysis, the BaTiO₃ films were deposited on pre cleaned glass substrates.

2.2. Measurements

Thickness of the prepared films was measured by using Quartz crystal monitor ("Hind Hivac" Digital Thickness Monitor Model-DTM- 101). The structural aspects of the films were analyzed, using X-ray diffractometer with filtered CuK α radiation ($\lambda = 1.5418 \text{ \AA}$). Measurements of series capacitance and the dissipation factor in the frequency range 12Hz- 100KHz were carried out at various temperatures (303-483 K) using digital LCR meter (LCR-819, GW instek, Good will Instrument company Ltd., Taiwan). The dielectric constant ϵ was evaluated from the capacitance data, known area and thickness of the dielectric films.

3. RESULTS AND DISCUSSION*3.1. EDS Analysis*

Energy dispersive spectrum (EDS) was carried out to identify the composition of the BaTiO₃ thin films prepared by thermal evaporation. Figures 1 shows the EDS spectrum of the BaTiO₃ thin film of thickness 160 nm. High intensity peaks corresponding to Ba and Ti elements were clearly noticed in the EDX pattern of the thin films. From the EDS analysis it was found that BaTiO₃ did not contain any impurities.

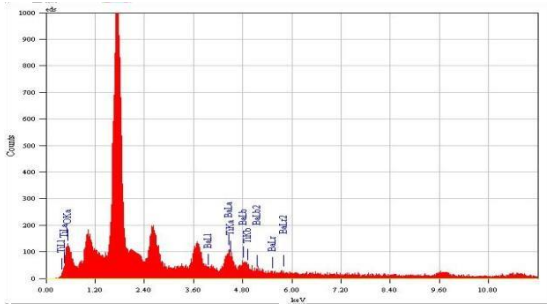


Fig. 1. EDS spectrum of the BaTiO₃ thin film of thickness 160 nm.

3.2. SEM analysis

Figure 2 shows the surface morphology of BaTiO₃ thin film of thickness 160 nm. No pits and pin holes were seen on the surface. Grains of various sizes having tetragonal shapes are uniformly distributed throughout the surface area.

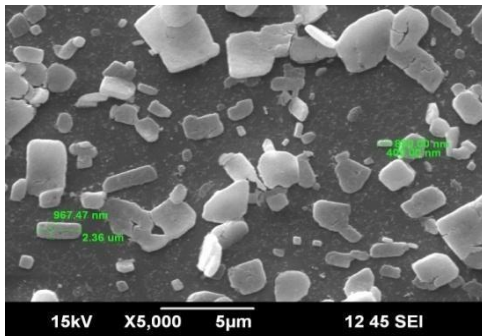


Fig. 2. Surface morphology of BaTiO₃ thin film of thickness 160 nm.

3.3. X- Ray diffraction analysis

Fig. 3 shows the X- ray diffraction pattern of the BaTiO₃ thin films of thickness 160 nm. The films were found to be polycrystalline with (001), (101), (111) and (200) orientation peaks arising at 2θ values of 22.2°, 31.4°, 36.7° and 43.8° respectively. The intensity of (101) peak was higher than (001), (111) and (200) peaks.

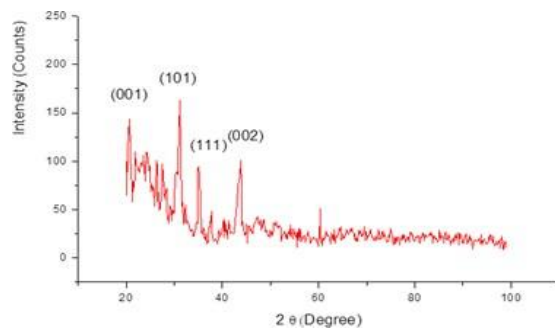


Fig. 3. XRD pattern of the BaTiO₃ thin films of thickness 160 nm.

3.4. Frequency effect

The variation of capacitance with frequency for a typical film of thickness 160 nm in the frequency range 12Hz - 100 kHz for different temperatures is shown in Fig. 4. The capacitance value decreases with increase of frequency for all temperature ranges studied. It increases with increase of temperature up to 398 K and then decreases with increase of temperatures. This reveals that phase transition from ferroelectric to paraelectric above 398 K and attain a constant value at higher frequency, which is a characteristics feature of the ferroelectric materials (Lines *et al.*, 1979). The decrease of capacitance (C) with increase of frequency is attributed to the trapping of charge carriers due to gap states density in the amorphous films (Budaguan *et al.*, 1998). The large increase in capacitance towards the low frequency region may be attributed to the blocking of charge carriers at the electrodes. Actually, the charge carriers present in the film migrate upon the application of the field and because of the impedance to their motion at electrodes resulted in space charge layer leads to a large increase in the capacitance at low frequencies. The observed decrease of capacitance with increasing frequency is also attributed to the increasing inability of the dipoles to orient themselves in a rapidly varying electric field and slow release of charge carriers from relatively deep traps. Increase of capacitance above room temperature is partly due to the expansion of the lattice and partly due to the excitation of charge carriers present at the imperfection sites (Chandar Shekar *et al.*, 1999; Beladakere *et al.*, 1992).

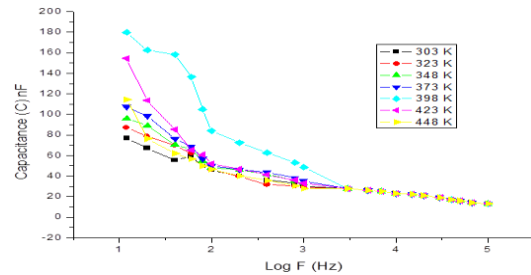


Fig. 4. The variation of capacitance with frequency of the BaTiO₃ thin films.

Fig. 5 shows the variation of dielectric constant with frequency for various temperatures. The dielectric constant values decreases with increase of frequency for all temperature ranges studied. It increases with increase of temperature up to 398 K and there after it decreases with the increase of temperature. It exhibit a similar trend as that of the capacitance. The increase of dielectric

constant with temperature was due to an increase of total polarization arising from dipoles and trapped charge carriers (Debye, 1929). It is seen that dielectric constant with frequency curve closely resemble those predicted by the Debye relaxation model for orientation polarization (Chandar Shekar *et al.*, 2004).

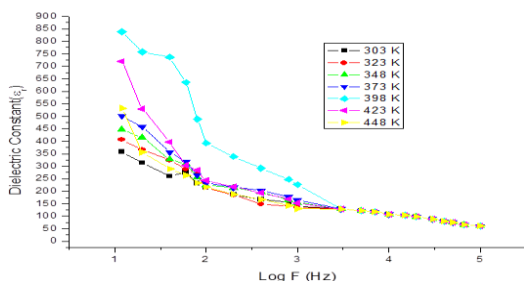


Fig. 5. Variation of dielectric constant with frequency of the BaTiO₃ thin film.

5. CONCLUSION

Thin films of few hundred nanometer thickness was prepared on well cleaned glass plate using thermal evaporation method. X-ray analysis showed that the deposited films were polycrystalline in nature. The capacitance is dependent both on temperature and frequency in the lower frequencies and at higher temperatures whereas it is independent of frequency at lower temperature and of high frequencies. The value of dielectric constant depends on frequency and temperature.

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