FERROELECTRIC PARAMETERS OF NANOSIZED $BaTiO_3$ AT DIFFERENT ELECTRIC FIELDS

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Abstract

Ferroelectric parameters such as coercive field, maximum polarization and remnant polarization are measured for the $BaTiO_3$ nanoparticles which were synthesized by the sol-gel method. It was found that the reversal of the polarization is observed at and above the applied field of 4.941kV/cm. The maximum applied electric field value was 32.54kV/cm above which the electric breakdown may occur. The ferroelectric parameters were found to increase continuously with the applied electric field and reach to their maximum values and then fall. The observed value of the coercive field is found to be higher than the values of single crystals, whereas the values of the maximum polarization and remnant polarizations are smaller.

Keywords: Ferroelectrics, Nanoparticles, Hysteresis, Polarization.

1. Introduction

$BaTiO_3$ is the most extensively investigated perovskite type ferroelectric material. It was studied for its various properties like dielectric, ferroelectric, piezoelectric, optical, etc. The ferroelectric materials were characterized by the presence of spontaneous polarization i.e. non-zero value of electric dipole moment per unit volume, even in the absence of external electric field. The spontaneous polarization can be reversed by the application of suitable electric field and visualized by a hysteresis loop [1, 2]. The electric field at which half of the polarization gets reversed is termed as coercive field E_c, and the electric displacement at zero- field is termed as remnant polarization P_r. These parameters however can be influenced by the temperature, size of the crystal, domains, pressure, etc [2].

Recent studies show the properties of the material are greatly influenced by the size of the crystal, particularly when the size of the crystal is in the nano-range [3- 5]. Nanosized $BaTiO_3$ is therefore expected to show some significant variation in there ferroelectric parameters.

2. Review

There is a long back history of investigations on various aspects of the $BaTiO_3$. Being a most extensively investigated material to account the complete review of work on $BaTiO_3$ is not possible here. Since there is a long list of researchers, the brief review of $BaTiO_3$ only on significant work is given here. The ferroelectric properties of $BaTiO_3$ were first discovered by Hippel et al [6] and Wul and Goldman [7]. Later various properties subsequently were reported by many researchers [8-10]. Based on the $BaTiO_3$ many theoretical models of the ferroelectrics were also developed [11-14]. Recent studies show $BaTiO_3$ is still a material of interests of many researchers. For examples: Synthesis, structure and magnetic properties of $BaTiO_3$ nanoceramics were reported by Pazik et al [15]; Various synthesis methods of $BaTiO_3$ nanoceramics were reported by Chenung et al [16]; The effect of doping on structural and dielectric properties [17], Luminance properties [18], and the effect of temperature and time on properties [19] of $BaTiO_3$ nanoparticles were also reported.

3. Methods

The $BaTiO_3$ nanoparticles were prepared by the sol-gel method similar to procedure represented earlier [20]. The gel obtained by this method was then filtered and dried in an oven at 70^0C for overnight. It was then grounded and finally calcined at 750^0C for 3 hours to get nanosized $BaTiO_3$ powder. The phase and structure of the sample was determined by comparing XRD data pattern with JCPDS data. The size of the particles was determined by Scherrer's formula.

The synthesized calcined powder was mixed with few drops of 1 wt% solution of polyvinyl alcohol and isostatically pressed into pallets under pressure of 4-5 tons for 5 min. The pallets were sintered at 925^0C for 4 h, polished and coated with the silver paint and used for the hysteresis studies. The ferroelectric hysteresis loop parameters were measured by P-E hysteresis loop tracer (AUTOMATIC P-E LOOP TRACER, MARINE INDIA).

4. Results and Discussion

Fig. 1 shows the XRD pattern of as synthesized $BaTiO_3$ nanoparticles. The X-ray peak pattern matched with the JCPDS data (JCPDS file no.75-0462) and the tetragonal phase of $BaTiO_3$ is identified. The average size of particles calculated by Scherrer's formula using full width at half the maximum was found to be 80 nm.

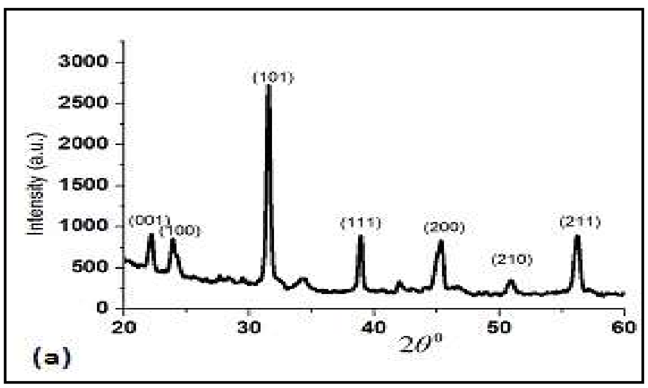

Figure1. X-ray diffraction peaks of $BaTiO_3$ nanoparticles

Hysteresis loops of BaTiO3 nanoparticles measured at various applied electric fields are shown in Fig. 2. The loops are observed only after the applied electric field increase to 4.941kV/ cm and above. This means the reversal of spontaneous polarization, in fact, domain switching is observed at and above the applied electric field of 4.941kV/cm. At this field the values of coercive field, maximum polarization and remnant polarization are 2.089kV/cm, 0.251μC/cm^2

and 0.112μC/cm² respectively. The highest values of these parameters are 24.812kV/cm, 2.760μC/cm² and 1.868μC/cm² respectively observed at an applied electric field of 32.022kV/cm. It was found that the applied electric is not increased above 32.54kV/cm, means the electric breakdown may occur afterwards.

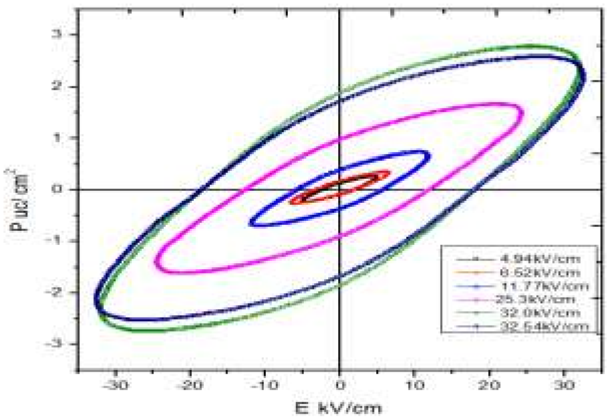

Figure 2. Hysteresis loops at different applied electric field of BaTiO3 nanoparticles.

The values of maximum polarization and remnant polarization are found to be much smaller while the value of coercive field is higher than the values reported for the single crystal [8]. This discrepancy can be attributed to the size of the particles.

The variation of coercive field against the applied electric field is shown in Fig. 3 and variations of maximum polarization and remnant polarization is shown in Fig.4.

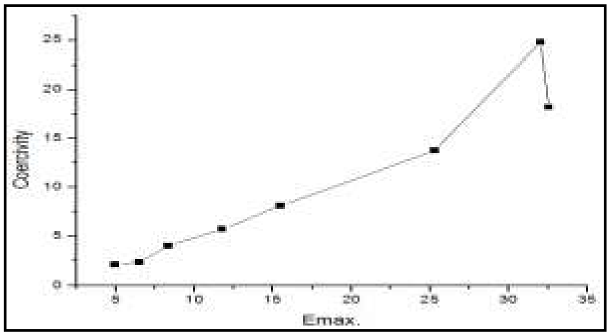

Figure 3. Variation of Coercive fields of $BaTiO_3$

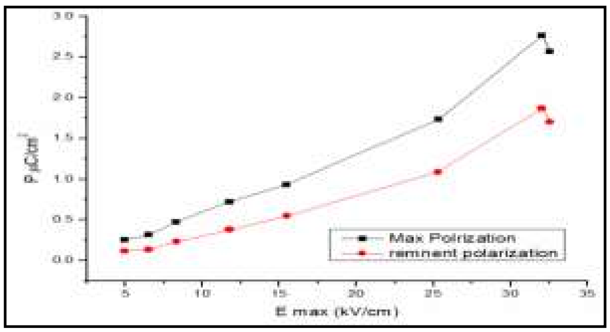

Figure 4. Variations of maximum and remnant polarizations against applied fields.

Figures 3 and 4 show that the values of coercive field, maximum polarization and remnant polarizations increase continuously with the applied field, reach to their maximum values and then show sign of fall, probably this is a sign of electric breakdown. `

5. Conclusion

The values of coercive field, maximum polarization and spontaneous polarization are measured for the nanosized $BaTiO_3$. These values are differing significantly from the values of single crystals. Variations of these parameters against applied electric fields are also studied.

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