



# P-E characterization and tunability of $(\text{Ba}_{0.6}\text{Sr}_{0.4})(\text{Zr}_{1-x}\text{Ti}_x)\text{O}_3$ ( $x=0.4, 0.5$ & $0.65$ ) modified dielectric ceramics

Chandrashekhar M. Tavade  
Bheemanna Khandre Institute  
of Technology  
Bhalki, Karnataka, India

Nagbasavanna Sharanappa  
Dept. of PG Studies & Research in Materials  
Science  
Gulbarga University, Gulbarga, Karnataka, India

R. L. Raibagkar  
Dept. of PG Studies & Research in Materials  
Science  
Gulbarga University, Gulbarga, Karnataka, India  
rlraibagkar@rediffmail.com

**Abstract:** In this Paper, we study the ferroelectric properties of modified dielectric BSZT ceramics. The remnant polarization ( $P_r$ ) is increases for  $x=0.4$  and  $x=0.5$  trends to larger in grain size, the  $P_r$  is decreases for  $x=0.65$  leads to smaller in grain size. Coercive field ( $E_c$ ) was determined for  $x=0.4, 0.5$  and  $0.65$  in  $(\text{Ba}_{0.6}\text{Sr}_{0.4})(\text{Zr}_{1-x}\text{Ti}_x)\text{O}_3$ . In all samples, the value of positive coercive field is larger than the negative coercive field. Tunability is found to be 98.63%, 99.50%, 96.09% for  $x=0.4, 0.5, 0.65$ , respectively.

**Index Terms:** Ferroelectric, BSZT, Hysteresis, Coercive field, Tunability.

## 1. INTRODUCTION

Barium Titanate (BT) is most commonly used ferroelectric material because of its excellent dielectric properties such as high dielectric constant and low tangent loss [1-3]. To improve the properties of BT, suitable materials such as Sr, Pb, and Ca, etc. were added [4,5]. Among these additive material Sr is most widely used due to its lower Curie temperature and ability to increase dielectric constant at room temperature of the BT material. On contrary, the Zr substitution on Ti site is found to decrease the Curie temperature and also improves the characteristics of the dielectric ceramics [6,7]. Therefore, by adding both Sr and Zr to the BT leads to the modified dielectric material, viz., barium strontium zirconium titanate (BSZT). Keeping this in view,

BSZT is synthesized by solid state reaction method and the effect of electric field on polarization was undertaken [8].

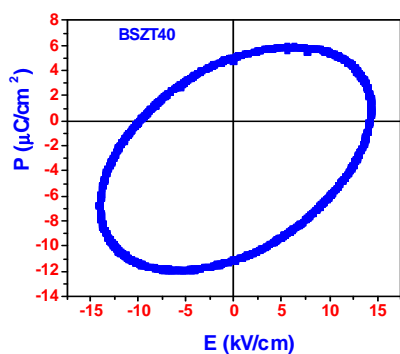
In this paper, we report the P-E and tunability characteristics of  $(\text{Ba}_{0.6}\text{Sr}_{0.4})(\text{Zr}_{1-x}\text{Ti}_x)\text{O}_3$  ceramics with  $x=0.4, 0.5$  &  $0.65$ .

## 2. EXPERIMENTAL ANALYSIS

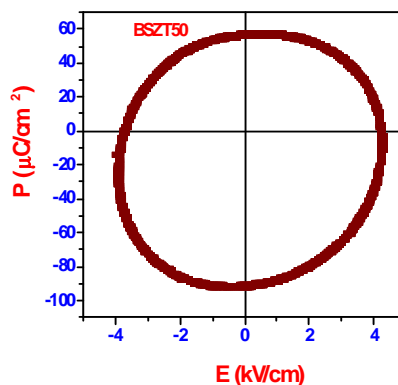
The  $(\text{Ba}_{0.6}\text{Sr}_{0.4})(\text{Zr}_{1-x}\text{Ti}_x)\text{O}_3$  (BSZT) dielectric ceramics were prepared using solid state reaction technique. The lattice parameters were calculated based on XRD patterns [8]. For the determination of ferroelectric properties, samples were coated with silver paste followed by firing at  $400^\circ\text{C}$  for half an hour to ensure good ohmic contacts. P-E characteristics were recorded for the samples having dimensions thickness = 1.1 mm, area =  $15.61\text{mm}^2$  and automated using a Sawyer-Tower circuit with  $C=4.7\mu\text{F}$ ,  $R=10\text{K}\Omega$ , with maximum field up to  $10\text{KV/cm}$ , field calibration factor ( $\text{kV/cm/V}$ )  $\approx 1.86\text{E-}02$ , polarization calibration factor ( $\mu\text{C/cm}^2\text{V}$ )  $\approx 7.28\text{E-}02$  to trace the P-E loop.

## 3. RESULTS AND DISCUSSION

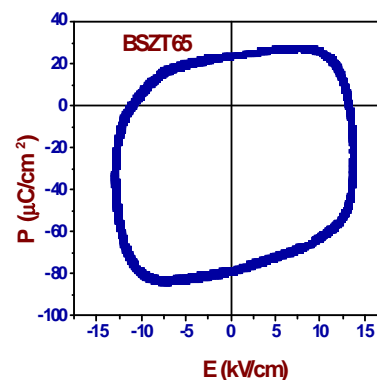
The relationship between polarization and electric field determines the ferroelectric properties of the material and is characterized by a hysteresis loop.



(a)



(b)



(c)



Figure 1. P-E Characterization of BSZT samples of (a) BSZT40, (b) BSZT50, (c) BSZT65.

From figures 1 (a,b,c), it is seen that the domain structure on average remains the same, while domain walls may move on a small scale by bending, jumps and local switching. We, thus make an implicit assumption that domain-wall displacement is the main source of the dielectric, hysteresis and shows non-switching condition of the ceramics [9]. The values of coercive field ( $E_c$ ), remnant polarization ( $P_r$ ), spontaneous polarization ( $P_s$ ) were determined from P-E loop. It is found that the trend of  $P_r$  is same as that of average grain

size [10]. Further, it can be seen that the positive  $E_c$  value is higher than the negative  $E_c$  value. This is attributed to some internal bias due to different electrode interface [11]. It is also observed that  $P_r$  and  $P_s$  value increases as  $x$  changes from 0.4 to 0.5. Such increase is attributed to larger grain size with Ti modifications and  $P_r$  value decreases for  $x=0.65$ , which leads to smaller grain size with Ti modification [10]. Figure 2 (a,b,c) depicts the tunability of BSZT ceramic samples.

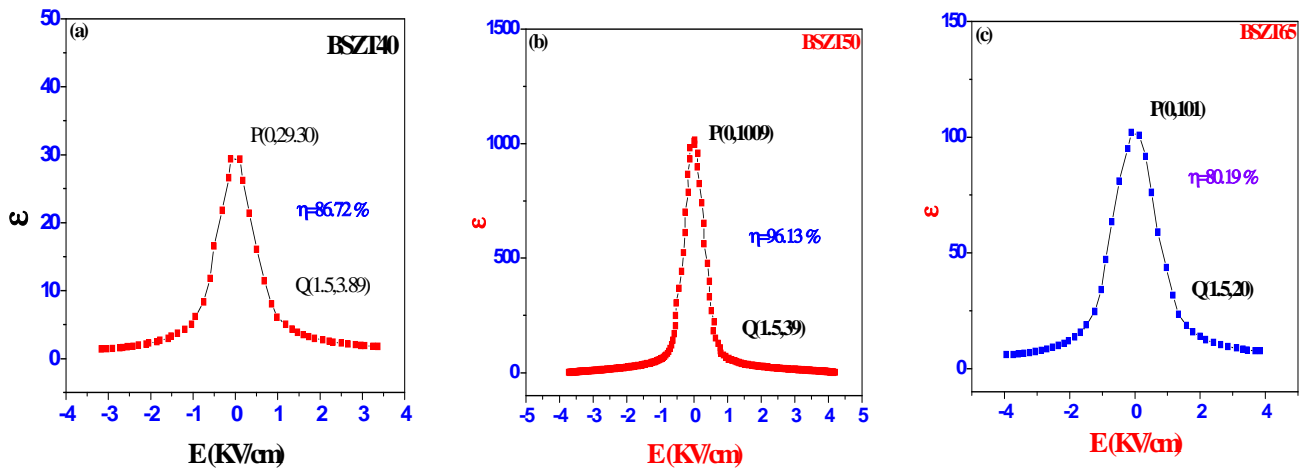


Figure 2. Tunability characteristics of BSZT ceramics of (a) BSZT40, (b) BSZT50, (c) BSZT65

The field and polarization are related by [5],

$$P = \chi E$$

where  $\chi$  is dielectric susceptibility. This shows that polarization is directly proportional to dielectric constant at constant electric field. Then, the tunability of the samples may be obtained from the formula,

$$\text{Relative tunability} =$$

$$\frac{\epsilon(E_0) - \epsilon(E_{\max})}{\epsilon(E_0)} \times 100$$

where  $E_0$  is field at 0 KV/cm and  $E_{\max}$  is field at 2.5 KV/cm.

Table 1: Tunability of BSZT ceramics

Samples	P at E=0 KV/cm	P at E=2.5 KV/cm	Relative tunability
BSZT40	0227	03.10	98.63
BSZT50	2870	29.50	99.50
BSZT65	0364	14.20	96.09

From the table 1, it is observed that the % of tunability increases from  $x=0.4$  to  $x=0.5$ , and decreases from  $x=0.5$  to  $x=0.65$ , at room temperature.

#### 4. CONCLUSIONS

It is observed that the positive coercive field is higher than the negative coercive field. The remnant polarization increases with increase in Ti concentration from  $x=0.4$  to  $0.5$  and it decreases for  $x=0.65$ . Such increase in remnant polarization attributes to larger grain size of the sample and decrease in  $P_r$  leads to smaller grain size with Ti modification. The tunability is found to grain size dependent.

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