International Symposium of Research Students on Material Science and Engineering
December 20-22, 2004, Chennai, India
Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras

SYNTHESIS AND DIELECTRIC BEHAVIOR OF SOME Ti DOPED STRONTIUM STANNATE

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ABSTRACT

In the present investigation samples of $SrSn_{1-x}Ti_xO_3$ were prepared by solid-state ceramic route. X-ray diffraction studies confirm the formation of single phase cubic perovskite ($0 \leq x \leq 0.4$). Unit cell parameters have also been calculated for the samples. Dielectric constant and dielectric loss was measured as a function of temperature at a few selected frequencies in the temperature range 300 to 500K. It is observed that the dielectric constant varies slightly with doping of Ti.

Keywords: Strontium stannate; Dielectric behavior, Perovskite oxide

1. INTRODUCTION

Electronic materials with high dielectric constant, high Q- values and good stability of temperature coefficient of resonant frequency have been extensively studied because of their applications in discrete and multilayer capacitors (MLC), microwave telecommunication applications and low loss substrates for microwave integrated circuits[1]. Complex perovskite-related oxides have been of great importance since a number of materials exhibiting a wide range of unusual properties can be synthesized based on them. These include magnetic materials, superconductors, laser host materials and dielectric materials. The ability of simple perovskite structures ABO_3 to give rise to the intergrowth structures, oxygen deficient structures and ordered perovskite structures is well known. Dielectric oxides constitute a large proportion of materials, which have wide range of technological applications. There is an increasing demand on dielectric materials to surpass their present abilities to be of use in the fast changing world of electronics. At the root of all devices lie the bulk dielectric materials, on whose basic properties further progress may be made. In memory devices based on capacitive components, such as static and dynamic random access memories, the static dielectric constant of materials will ultimately decide the degree of miniaturization[2].

Barium stannate in doped and undoped form has been studied extensively e.g. $Ba_{1-x}La_xSn_{1-x}Co_xO_3$ exhibit interesting and useful characteristics[3]. On the other hand $CaSnO_3$ and $SrSnO_3$ in doped form have not been studied much. In this paper synthesis and dielectric behavior of the system $SrSn_{1-x}Ti_xO_3$ ($x \leq 0.40$) is being reported.

2. EXPERIMENTAL PROCEDURE

Compositions with $x \leq 0.40$ in the system $SrSn_{1-x}Ti_xO_3$ were prepared by the conventional solid-state ceramic route. Stoichiometric amount of $SrCO_3$, TiO_2 and SnO_2 all are of A.R. grade and purity $\geq$ 99% were used as starting materials. These were weighed accurately and mixed in an agate ball mill

for 6 hours using acetone as mixing medium. The mixed powder were dried and calcined at 1523K for 12 hours in a platinum crucible in air and were then compacted in the form of cylindrical discs of thickness 1-2 mm and diameter 10-11 mm at an optimum load of 70 KN. These pellets were kept at 773K for two hours to burn off the binder (2% poly vinyl alcohol (PVA) solution) and temperature was then raised to 1773K and held there for 12 hours. The formation of single phase was confirmed by powder X-ray diffraction (XRD) using Rigaku X-ray diffractometer employing Cu-K_α radiation with Ni filter. The density of samples was measured by Archimedes method. One pellet of each composition was polished and coated with Ag-Pd paint for dielectric measurement. Measurement of dielectric constant was done using Hioki 3532-50 LCR Hi-Tester in the temperature range 300-500K.

The samples were fractured. The fractured surfaces were coated with Au-Pd. The micrographs of the fractured surfaces were taken in JSM840 (JEOL) Scanning Electron Microscope at (12KV-15KV). The grain size is determined by linear intercept method.

3. RESULTS & DISCUSSION

3.1 X-RAY DIFFRACTION

Powder X-ray diffraction patterns for all the samples shown in Fig. 1, indicate the formation of single phase materials, as no XRD lines characteristic of constituent oxides were present in them. XRD data of all the samples are indexed on the basis of the cubic unit cell similar to $SrSnO_3$. Composition, crystal structure, lattice parameter, theoretical and experimental density along with percentage porosity are given in Table 1. From the Table it is observed that lattice parameter decreases with increase in Ti doping. This may be due to the smaller ionic radii of Ti^{4+} (0.605 Å) as compared to Sn^{4+} (0.69 Å).

3.2 SCANNING ELECTRON MICROSCOPY

Microstructural development in the system $SrSn_{1-x}Ti_xO_3$ sintered at 1500^0C for 12 hrs, as a function of Ti doping is shown in Fig. 2. Fig. 2(a) shows that the fine grain size is of the order of ≈2μm. For composition with x=0.3, it is observed that the grain growth is uniform and the size of the grains is of the order of 5μm. The densification for this composition is more in comparison to pure composition x=0(Table 1).

In order to make a capacitor component, the material is required to be essentially pore free, since pores would act as sink for the electrical charge carriers and would be the source of poor grain to grain connectivity[4]. From these SEM micrographs it can be seen that, doping of Ti at Sn site though reduces porosity yet the samples are not dense to be useful as a capacitor material.

3.3 DIELECTRIC BEHAVIOR

Plots for ε_r and D vs temperature at 10 KHz, 100 KHz and 1 MHz for various samples are shown in Fig.3 and Fig .4 respectively. Form these plots it is observed that both ε_r and D increases smoothly with increase in temperature for all the samples. It is observed that the dielectric constant increases with x. The increase in relative dielectric constant with temperature for various samples may be due to interfacial polarization. These materials are prepared by diffusion controlled solid state ceramic method. Because of limitations of this slow diffusion controlled thermochemical processes, these

materials will have microhetrogenities. These heterogeneities gives rise to interfacial polarization at the interfaces. Interfacial polarization increases with increasing temperature.

4. CONCLUSIONS

Solid solution forms for all the compositions investigated. Structure remains cubic similar to SrSnO3. Both dielectric constant and dielectric loss increases with increase in temperature. Dielectric constant increases with x. The increase in dielectric constant with temperature seems to be due to contribution from interfacial polarization.

ACKNOWLEDGEMENT

One of the authors is grateful to CSIR for providing financial support during the course of this work. Thanks are due to Prof. D.Pandey of School of Materials Science and Technology for providing XRD-facility.

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TABLES

Table.1 Composition, crystal structure, lattice parameter, theoretical density (T.D.), experimental density (E.D.) and percentage porosity for various samples in the system $SrSn_{1-x}Ti_xO_3$

Composition (x)	Crystal Structure	Lattice Parameter (Å)	T.D. (gm/cm^3)	E.D. (gm/cm^3)	Porosity %
0.00	Cubic	8.0312	6.54	5.35	15
0.30	Cubic	7.9573	6.14	5.55	9.1
0.40	Cubic	7.9434	5.98	5.44	9.6

FIGURES

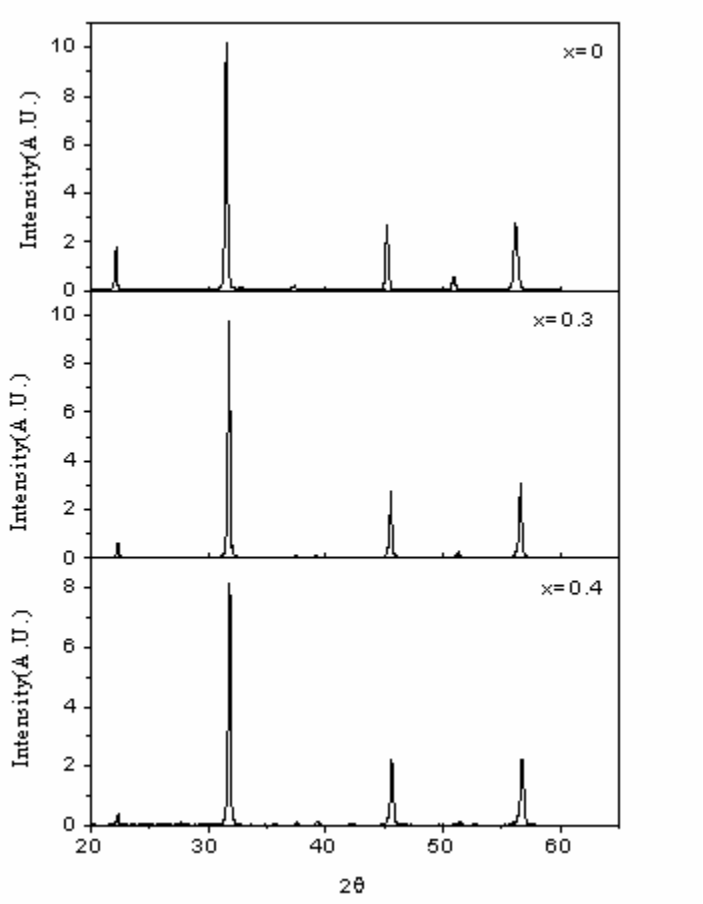
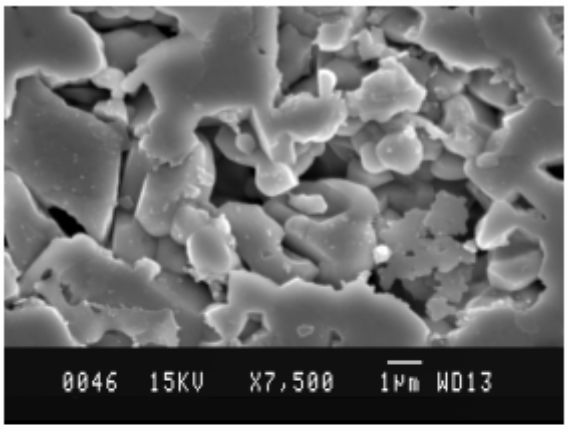
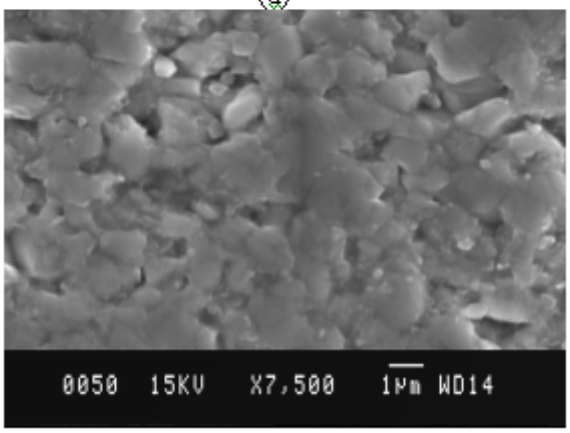


Fig.1 XRD patterns of the samples of the system $SrSn_{1-x}Ti_xO_3$ fired at 1500^0C



(a)



(b)

Fig.2 Scanning electron micrographs for the compositions (a) $SrSn_{0.7}Ti_{0.3}O_3$ (b) $SrSnO_3$

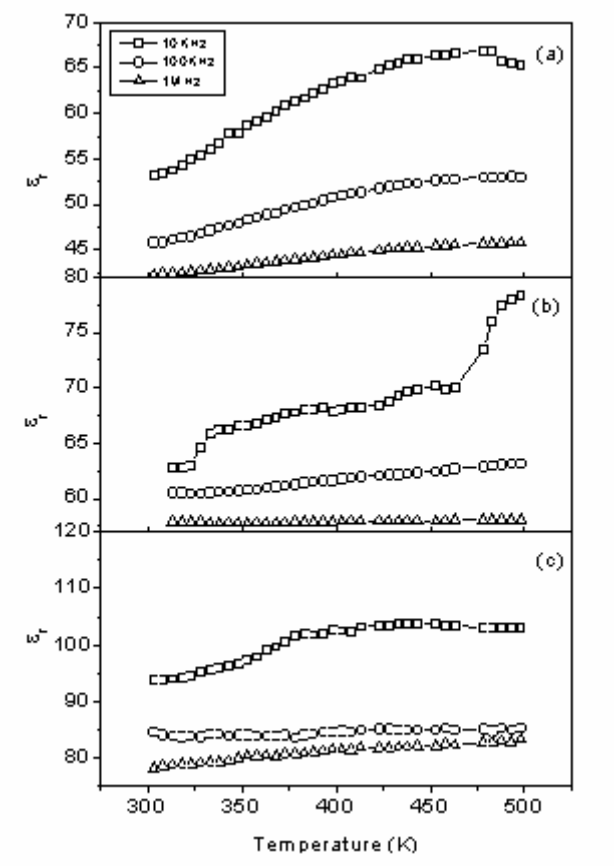


Fig.3 Variation of ε_r with temperature for $SrSn_{1-x}Ti_xO_3$ system at 10K, 100K and 1MHz for (a) x=0, (b) x=0.30 and (c) x=0.40

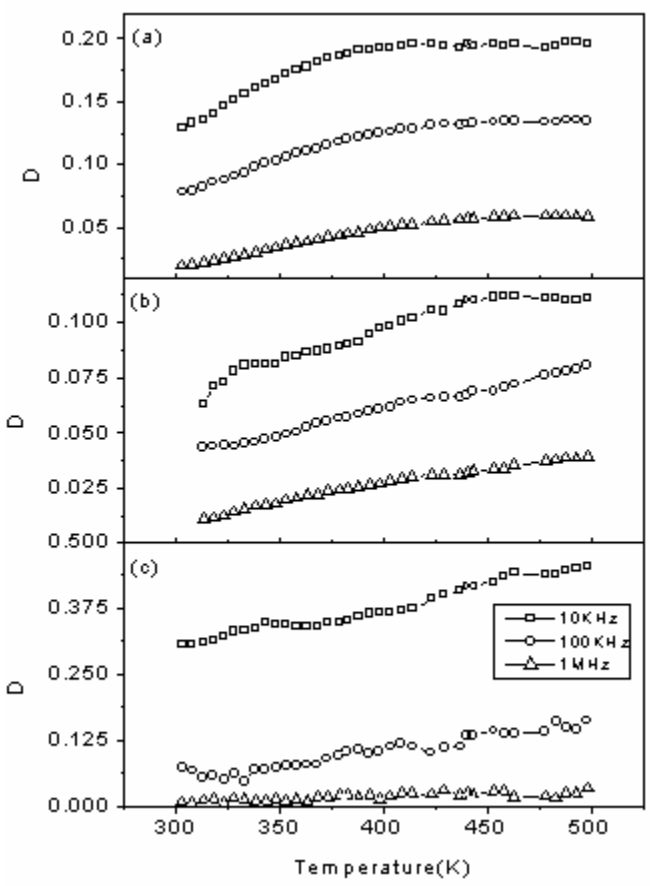


Fig.4 Variation of D with temperature for $SrSn_{1-x}Ti_xO_3$ system at 10K, 100K and 1MHz for (a) x=0, (b) x=0.3 and (c) x=0.4