An Experimental Study on Electrical Behaviour of $(Pb_{1-x}Sn_x)TiO_3$(x=0.10,0.20,0.30) Ceramics

Mitra Mani Subedi

Department of physics, Prithvi Narayan Campus, Pokhara

subedimitramani@yahoo.com

Abstract

$(Pb_{1-x}Sn_x)TiO_3$(x=0.10,0.20,0.30)(PST) powders are synthesized using the conventional dry route in a mixture of $PbCO_3$,$SnCl_2.2H_2O$ and TiO_2.The samples are sintered at 1050°C to achieve about 95% of theoretical density. It is observed that PST sample reveals dielectric anomaly around 190°C for x=0.10,180°C for x=0.20 and no anomaly is observed for x=0.30which confirms the ferroelectric behaviour of PST 10 %,PST 20% and PST 30 % as paraelectric. The peak value of the real part of dielectric constant is higher during cooling mode than that for heating mode as per simple Landau theory argument, which gives the thermal hysteresis of 10°C for PST 10% ,5°C for 20%.This observation confirms the first order nature of the ferroelectric to paraelectric transition and tending towards second order. The feature of PST has great applications such as capacitors, temperature sensors as well as humidity and gas sensors. So, it is recommended to extend further study.

1. Introduction

Scientists as well as many researchers have been interested in the field of ceramics materials because of their broad field of applications. Electronic ceramics are very useful in device fabrications. The electronic ceramics such as Barium titanate ($BaTiO_3$), Lead titanate ($PbTiO_3$), Lead zirconate ($PbZrO_3$) with perovskite structure show ferroelectric and ant ferroelectric behaviors which are being used in many applications in electronics and optics. A large number of applications of ceramics also exploit properties that are an indirect consequence of ferroelectricity and antiferroelectricity such as dielectric, piezoelectric, electrostrictive, pyroelectric and electro-optic properties.

2. Experimental

In the present work, we have synthesized $(Pb_{1-x}Sn_x)TiO_3$ at temperatures<800°C using the dry route involving the reaction between TiO_3 and $(Pb_{1-x}Sn_x)CO_3$.The pellets formed by this dry route method are used for the study of various characteristics.The Hioki (3532-50) LCR Hi-Tester is used to study the relaxor and dielectric properties of the sample.

3. Results and discussion

3.1 Ferroelectric to paraelectric transition

Variation of real part of dielectric constant with temperature at frequency 100 kHz during heating and cooling mode separately for (i)PST 10 %(ii)PST 20%(iii)PST 30% samples.

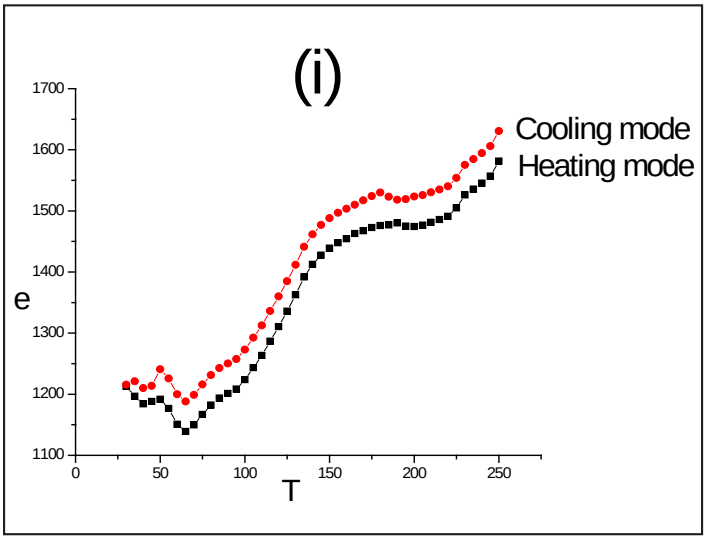
Fig.1 (i,ii,iii) depict the variation of real part of dielectric constant with temperature during heating and cooling of samples for PST 10%, 20% and 30% respectively. We have observed data for heating and cooling cycles at frequency 100 KHz and in the temperature range from room temperature to 250°C.

The ferroelectric to paraelectric phase transition occurs at temperature 190°C for PST 10 %, 180°C for PST 20 % during heating mode. But in case of PST 30 % we cannot draw any significant conclusion. The paraelectric to ferroelectric phase transitions for PST 10 % is 180°C, for PST 20 % is 175°C during cooling mode. The peak values of dielectric constants for heating mode are 1480.1 for PST 10 % and1530.69 for PST 20 %.

The dielectric data for PST 10 % at 100 KHz first decreases then after a certain temperature it starts increasing up to the transition temperature 180°C then again it starts increasing. It may be due to anomalous dispersion effect in which dielectric data increases with the increase of temperature. The anomalous dispersion effect is observed in the sample above certain temperature if polar modes of the dipoles are present effect at certain frequency [3]. The transition temperature of PST 20 % is lower than that of PST 10 % indicating the conversion of ferroelectric tetragonal phase towards cubic paraelectric phase. The dielectric data in such case should decrease in PST 20%. But due to high density of PST 20 %, the dielectric data also becomes higher in comparison to that of PST 10%. In the case of PST 30%, no dielectric anomalies are observed. It is because the sample has paraelectric cubic phase even at room temperature. Similar results are also observed in cooling modes as shown in the figures.

3.2 Thermal hysteresis

Fig. 2(i, ii, iii) depict the variation of real part of dielectric constant for both heating and cooling modes at frequency 100 KHz. The thermal hysteresis is obtained from the difference between the transition temperatures during heating and cooling modes i.e. (T^H_C - T^C_C) gives the value of hysteresis. The values of thermal hysteresis observed for PST 10 % sample is 10°C, PST (20%) sample is 5°C.



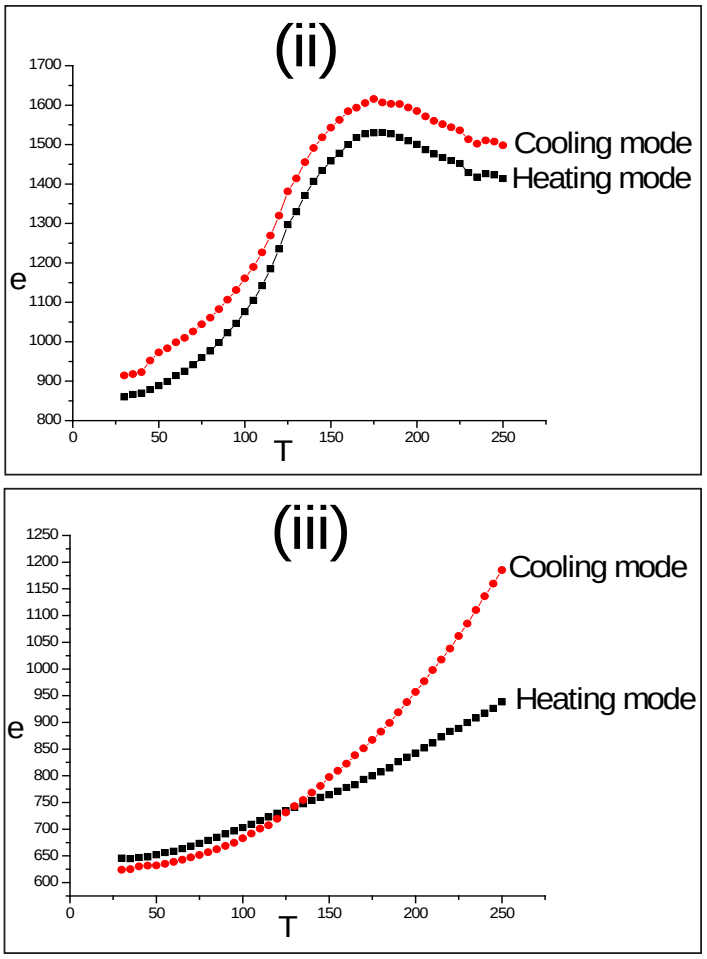


Fig.2: Variation of real part of dielectric constant with temperature (°C) at frequency 100 KHz during heating and cooling modes in same graph for (i)PST 10 % (ii)PST 20 % (iii)PST 30 % samples.

This shows that the value of hysteresis decreases with increasing stannous (Sn^{2+}) content in PST sample. The decrease in thermal hysteresis indicates the change of first order phase transition towards second order phase transition.

The value of dielectric constant at peak temperature in cooling cycle is greater than that in heating cycle. Simple Landau theory arguments suggest that the dielectric anomaly during the cooling mode should be more pronounced than heating mode. For our samples the difference in the values of dielectric constant for heating and cooling cycles are 49.08 for PST (10%),85.79 for PST (20%) .These values also support the Landau theory arguments. Table shows the values of real part of dielectric constant (e) for

PST 10 % and PST 20 %.

Sample	Heating mode(e)	Cooling mode(e)
PST 10 %	1480.1	1529.18
PST 20 %	1530.69	1616.48

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