

Two relaxation mechanisms in $(\text{Sr}_{1-1.5x}\text{Bi}_x)\text{TiO}_3$ ($x:0.0067$)

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Abstract

The ceramic samples were prepared by the solid-state reaction. Detailed studies of the real and imaginary part of the dielectric constant of the compound as a function of temperature carried out at low temperatures. The measurements exhibit a ferroelectric phase transition at around 55 K for 10 Hz. Measurements of the real and imaginary part of the dielectric constant have been studied both as a function of frequency in mentioned temperature interval. The two different relaxations with non-Debye type were observed clearly at around the temperature of the dielectric constant maximum. The relaxation times were calculated from the Cole–Cole plot analysis. The dielectric relaxation behaviour has been described by means of Maxwell–Wagner model.

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1. Introduction

SrTiO_3 has been studying intensively experimentally, as well as theoretically since 1970's [1]. It is important for technological importance and also of interest from a more fundamental point of view [2]. SrTiO_3 shows many interesting properties, including quantum paraelectric properties, a structural phase transition, quantum ferroelectric behaviour and superconductivity [3]. It shows a permittivity peak at 107 K and the physical of this behavior is characterized as a ferroelectric phase transition [1]. The temperature dependence of the dielectric permittivity of SrTiO_3 follows Curie–Weiss law, with Curie temperature $T_c = 35.5$ K [4]. Pure SrTiO_3 is also quantum paraelectric material. Its low temperature dielectric constant, perpendicular to the c axis, increases to about 30,000 upon cooling and then remains temper-

ature independent below 3 K because of quantum fluctuations [5].

On the other hand, the dielectric studies carried out in Bi [3,6,7], Ce [6], Fe and La [2] doped SrTiO_3 because of attractive physical properties. For impurity doping studies in quantum paraelectric SrTiO_3 , the most common example is Bi doping. The temperature dependence of the real and imaginary parts of the permittivity for $x = 0.0067$ shows a wide peak at around 55 K at 10 Hz. and two permittivity peaks (at 18 K and 30 K) appear with further decreasing temperature [4]. On contrary to high content of Bi doping, SrTiO_3 reveals a wide and high dielectric peak and two dielectric peaks at very low temperatures [4,7]. The scientist focused on the analysis of the mechanism of the low temperature dielectric anomalies at 18 K and 30 K in Bi doped SrTiO_3 . However, no attempt has been made to determine dielectric relaxation properties at around 55 K.

In this paper, the results of the real and imaginary part of the dielectric measurements are presented and analyzed in the frequency range of 10 Hz–10 MHz at

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around the main dielectric peak Cole–Cole plots analysis has been used in order to explain the experimental data obtained.

2. Experimental procedure

The ceramics samples with composition $(\text{Sr}_{1-1.5x}\text{Bi}_x)\text{TiO}_3$ ($x:0.0067$) were prepared by solid-state reaction. The sample was gently polished, cleaned and covered with silver paste. The inter-electrode distance was 1 mm. Single cubic phase formation of the sample is confirmed by X-ray diffraction results. The real and imaginary part of the dielectric constant as a function of temperature were measured by using a HP 4192A impedance analyzer in a Helium cryostat system in the temperature range between 30 and 140 K. The temperature cooling rate was in the order of 1 K/min. The measurements carried out in the frequency range of 10 Hz–10 MHz. The system was fully computer controlled with a program written in Visual Borland Delphi programming language. This automatic measuring system was used to measure and record numerically the real and imaginary part of the dielectric constant.

3. Results and discussion

The temperature dependence of the real and imaginary part of the dielectric constant is shown in Figs. 1 and 2. The real part of the dielectric constant shows a broad maximum at around 55 K for 10 Hz. As frequency is increased, the maximum in the real part of the dielectric constant shifts towards higher temperatures and becomes broader. The value of maximum of the dielectric constant peak strongly decreases with increasing frequency.

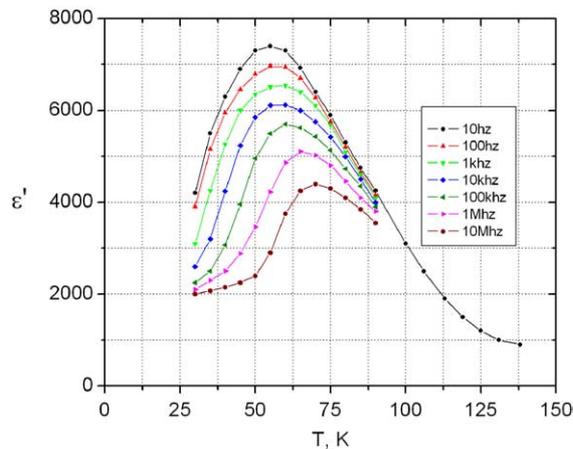


Fig. 1. Temperature dependence of the real part of the dielectric constant at different frequencies.

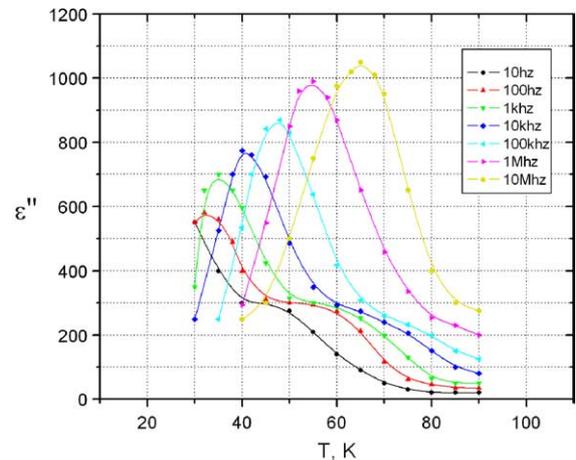


Fig. 2. Temperature dependence of the imaginary part of the dielectric constant at different frequencies.

Fig. 2 indicates that the magnitude of the imaginary part of the dielectric constant increases gradually with frequency in mentioned temperature region where the peaks occur. The shift of peaks towards higher temperature side with increasing frequency is consistent with a dielectric relaxation behavior.

In a number of perovskite ABO₃-type ferroelectrics, deviations from the Curie–Weiss behaviour have been reported [8]. In Bi doped SrTiO₃, the deviations from the Curie–Weiss behaviour have been detected. The notable characteristic of deviations is the fact that the transition temperature is not sharply defined and physical properties change rather gradually over a temperature range. This type of phase transition is named a diffuse phase transition [8]. The diffuse phase transition in ferroelectrics is characterized by extending the phase transition in a wide temperature interval around the temperature where the dielectric permittivity assumes its maximum value [9]. The experimental relative dielectric constant data can be successfully fitted by a semi-empirical equation of the form;

$$\frac{1}{\varepsilon} - \frac{1}{\varepsilon_{\max}} = \frac{(T - T_0)^\gamma}{A} \quad (1)$$

where ε_{\max} is the maximum of the real part of the dielectric permittivity, T_0 the temperature of maximum dielectric permittivity and γ the diffuseness parameter related to the peak broadening of the phase transition. In other words, γ indicates the degree of the DPT. For the present study, the value of γ (diffusivity) that was calculated from Fig. 3 was found to be 1.9 for 10 Hz. This value of γ confirmed the broad diffused phase transition in the studied sample.

Fig. 4 shows the schematic diagram of the frequency-dependent behavior of the dielectric relaxation in the imaginary part when only the relaxation time is chosen as a fitting parameter. This process well describes the

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