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Evidence of non-debye behavior of $Pb_{0.76}Sm_{0.24}Ti_{0.76}Fe_{0.24}O_3$ ceramics by complex impedance spectroscopy

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ABSTRACT

The polycrystalline sample of $Pb_{0.76}Sm_{0.24}Ti_{0.76}Fe_{0.24}O_3$ was manufactured via solid state reaction technique. Impedance Spectroscopy mode is utilized to evaluate the electrical parameters of the prepared sample throughout the frequency range of (100 Hz-1 MHz) at selected temperature range from 300 °C – 400 °C. The presence of relaxation is mainly supported by the nyquist plots which suggests that grain boundaries are more conductive than grains. Temperature dependent non-debye behavior of relaxation is confirmed by the electric modulus study. Because of the conduction through the hopping mechanism in the proposed sample, the universal Jonscher's power law is best fit to experimental data. The activation energies are 0.44 eV, 0.56 eV, and 0.288 eV calculated from impedance, electric modulus, and conductivity are equivalent.

1. Introduction

The electrical, magnetic and magneto-electric capabilities of electroceramics particularly oxides can be improved by inducing pressure and high temperature [1–3]. The grains and grain borders in these ceramics have different electrical characteristics. As a result, studying the interaction between grains and grain boundaries has been increasingly popular in recent years [4]. In addition, an electrode serves as a link between electroceramics coupled to different systems. As a result, such materials with helpful qualities are in high demand these days. The charge in the region of bulk and grain boundaries of dielectrics may be studied using CIS (Complex Impedance Spectroscopy), which is a useful experimental instrument. The result emerges in semi circles when an ac signal is applied, indicating grain boundary effect and interfacial polarization. Real and imaginary parts refer to the electric behavior of materials that is affected by frequency and temperature [5]. As seen in the relationships below, it has been defined on the basis of complex impedance (Z^*), complex dielectric constant (ε^*), complex electric modulus (M^*), and tan δ [6].

$$\text{ComplexImpedance}, Z^* = Z' - jZ''$$

$$\text{Complexdielectricconstant}, \varepsilon^* = \varepsilon' - j\varepsilon'' \quad (1)$$

$$\text{Complex electric modulus}, \ M^* = M' + jM'' \quad (2)$$

$$\text{Also}, \tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (3)$$

Where Z',ε', M' and Z'', ε'', M'' denote the real and imaginary parts of the impedance, dielectric constant and electric modulus respectively and $j = \sqrt{(-1)}$.

Ferroelectric oxides with a perovskite structure ABO_3 have been developed to explore the fields of research and industrial applications. As a base material, lead titanate (PT) becomes an important ferroelectric substance that can be used to prepare hybrid perovskite multiferroics [7–9]. It possesses a high curie temperature (T_c) (~490 °C) and substantial dielectric constant as contrast to several other ferroelectrics, enabling a variety of uses in sensors, transducers, and memory devices accruing to its exceptional ferroelectric and electrical features [10,11]. Doping of rare earth elements in PT has been reported to modify its qualities, according to many sources. It's also been proven that substituting rare earth ions (Re^{3+}) at the A-site of PT materials reduces leakage current which is introduced by transition metal cations through proposing magnetic properties in the composition [12–15]. $SmFeO_3$ (SF) is a perovskite-structured having Pbnm space group and Neel temper-

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