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Dielectric and Impedance Spectroscopy of Barium Orthoniobate Ceramic

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Barium orthoniobate ($Ba_3Nb_2O_8$), a derivative of the perovskite family, was prepared using a high-temperature solid-state reaction technique (calcination temperature = 1425°C and sintering temperature = 1450°C for 4 h). Preliminary x-ray structural analysis with room-temperature x-ray diffraction data confirmed the formation of a single-phase compound with hexagonal crystal structure. Study of the microstructure of a gold-coated pellet by scanning electron microscopy (SEM) showed that the sample has well-defined grains that are distributed uniformly throughout the surface of the sample. Detailed studies showed that the dielectric parameters (ε_r and tan δ) of the compound at three different frequencies (10 kHz, 100 kHz, and 1000 kHz) are almost constant in the low-temperature region (from room temperature to about 200°C). An anomaly in the relative permittivity (ε_r) (~357°C) suggests the possible existence of a ferroelectric–paraelectric phase transition of diffuse type in the material. Detailed studies of impedance and related parameters show that the electrical properties of the material are strongly dependent on temperature, showing good correlation with its microstructure. The bulk resistance (evaluated from impedance studies) is found to decrease with increasing temperature. This shows that the material has negative temperature coefficient of resistance (NTCR), similar to that of semiconductors. Studies of electric modulus indicate the presence of a hopping conduction mechanism in the system with nonexponential-type conductivity relaxation. The nature of the variation of the direct-current (dc) conductivity with temperature confirms the Arrhenius and NTCR behavior in the material. The alternating-current (ac) conductivity spectra show a typical signature of an ionic conducting system and are found to obey Jonscher's universal power law.

Key words: Electroceramics, impedance analysis, bulk resistance, electric modulus analysis

INTRODUCTION

Since the discovery of ferroelectricity in Rochelle salt in 1921,[1] a large number of dielectric materials of different structural families have been studied for possible industrial applications. Out of the large number of ferroelectric compounds available today, barium titanate ($BaTiO_3$) of the perovskite family of ABO_3 type (A = mono-divalent, B = tri-hexavalent ions) has attracted much attention from researchers because of its unusual properties that are useful for devices. Some of the simple or complex oxides derived from the perovskite structure are structurally more stable at room temperature.[2,3] In the process of searching for new oxides (containing rare-earth ions), the calcium oxa-metallate family has been extensively studied.[4] Such orthometallates of alkaline-earth metals, with general formula $A_3B_2O_8$ or $A_3(BO_4)_2$ (A = divalent metal, B = pentavalent metal), e.g.,

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