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Structural and dielectric properties of $KBa_5TiNb_9O_{30}$ ferroelectrics

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Abstract : Potassium barium titanium niobate (hereafter PBTN) having composition $KBa_5TiNb_9O_{30}$ has been synthesized by high temperature solid-state reaction technique. Room temperature X-ray diffraction (XRD) studies of the compound show that it has a tetragonal structure with lattice parameters $a = b = 12.43$ Å and $c = 4.10$ Å. Measurement of dielectric constant from liquid nitrogen temperature to 400°C suggests that the material is ferroelectric at room temperature and transforms into a paraelectric phase at around 290°C

Keywords : Tetragonal structure, dielectric constant, ferroelectric material

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Potassium barium titanium niobate ($KBa_5TiNb_9O_{30}$) belongs to a ferroelectric oxide family of tungsten-bronze (TB) structure [1] of general formula $AB_5TiNb_9O_{30}$ (A = Na, K and B = Sr, Ba). The tungsten-bronze (TB) structure consists of a complex array of distorted BO_6 octahedra sharing corners in such a way that the different types of interstices (A_1, A_2, B_1, B_2 and C) are available for cation substitution [2]. The polar axis of most of the members of TB family is normally c-axis. A wide variety and range of compounds of tungsten-bronze (TB) type has been studied. Some niobates with TB structure such as barium sodium niobate and potassium lanthanum niobates [3] are quite attractive and interesting owing to their wide industrial applications. Studies of structural and dielectric properties of some ferroelectric oxides of TB structure [4,5] have been reported. The electrical conductivity measurements of a few compounds [6] also confirm the occurrence of offset near the transition temperature.

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A literature survey reveals that even though the compound has been suggested to be ferroelectric, no systematic X-ray and detailed dielectric studies have yet been reported. We, therefore, present in this paper preliminary structural and detailed electrical (dielectric constant (ϵ) and loss (tan δ)) properties of the PBTN compound.

The polycrystalline samples of PBTN were prepared by a standard high-temperature solid-state reaction technique from the raw materials : TiO_2 (99 % s.d. fine chem Pvt. Ltd.), Nb_2O_5 (99.9 % SMP), K_2CO_3 (99.9 % SM Chemicals) and $BaCO_3$ (M/s Ultra Pure LOBA CHEMIE) in a suitable proportion. These oxides and corbonates were thoroughly mixed in an agate-mortar in alcohol for 10 h and dried. The dried powders were calcined in a crucible at 1050°C for 25 h. The process of calcination and mixing was repeated till the final homogeneous powder of PBTN was obtained. The formation and quality of the compound were checked with X-ray diffraction technique. Some of cylindrical pellets (of diameter 10.3 mm and thickness 2.3 mm) were made under the isostatic pressure (6×10^7 Kg/cm^2) using a hydraulic press. The pellets were then sintered in air atmosphere at 1100°C for 10 h. After polishing and grinding, both the flat surfaces of some pellets .were electroded with air drying silver paints for electrical measurements.

The X-ray diffractograms of the PBTN pellet samples were taken with CuK_α radiation (λ = 1.5418 Å) in a wide 2θ range ($20° \leq 2\theta \leq 70°$) with Philips powder diffractometer (PW 1710 Holland).

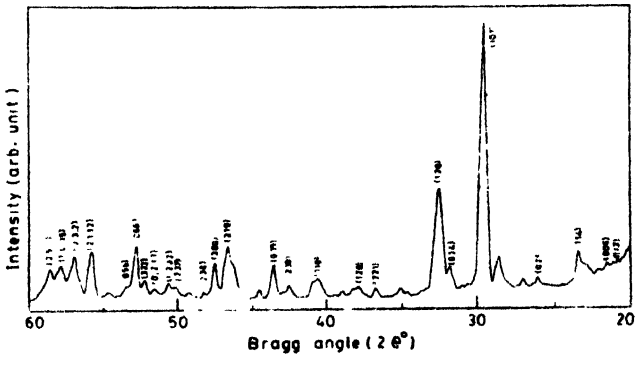

Figure 1. X-ray diffractogram of PBTN pellet sample.

The dielectric permittivity (ε') and loss (tan δ) were obtained on the sintered and electroded pellet samples as functions of frequencies (500 Hz to 10 KHz) and temperature (liquid nitrogen to 400°C) using G R 1620 capacitance measuring assembly. The reliability of the data was checked by repeating the experiments with different instruments (LCR-High tester, Hioki 5530, Japan) in the same physical conditions.

Following the data given in Landolt-Bornstein tables [7], all the prominent peaks in Figure 1 were indexed using tetragonal unit cells. A good agreement between the observed and calculated d-values suggests that the choice of unit cells is correct and the corresponding lattice parameters are $a = b = 12.43$ Å and $c = 4.10$ Å.

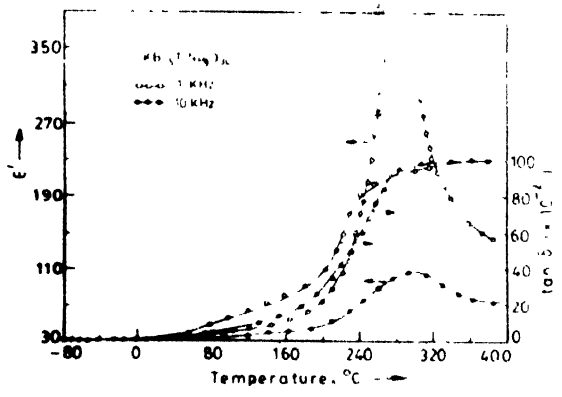

Figure 2. Variation of dielectric permittivity (ε') and dielectric loss (tan δ) with temperature at two frequencies 1 kHz and 10 kHz.

Figure 2 shows that the variation of dielectric permittivity (ε') and dielectric loss (tan δ) with temperature at two frequencies 1 kHz and 10 kHz. It is evident from this figure that the dielectric permittivity increases gradually above room temperature and becomes maximum around 290°C. The dielectric loss on the other hand increases up to about 290°C and then levels off. The reason for levelling off may be due to increased ac conductivity of the sample. The peak in the dielectric permittivity (ε') around 290°C is indicative of ferroelectric phase transition.

It is thus concluded that PBTN is tetragonal at room temperature and it may possess ferroelectric property with a ferroelectric phase transition temperature of 290°C which is quite high as compared to other members of the family.

Acknowledgment

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