# Dielectric and Raman Studies of modified Bismuth Ferrite

**Dr. Alok Shukla** - Assistant Professor, Department of Physics, NIT Mizoram, Aizawl (Mizoram).
**Email:** aloksnmr@rediffmail.com

**Abstract:** Using high-temperature solid-state reaction technique, polycrystalline sample of Bismuth Cobalt Titanium Ferrite (BCTF) ceramic has been synthesized. The dielectric analysis for both dielectric parameters, dielectric constant ($\varepsilon_r$) and tangent loss (tan δ), has been analysed at various temperature (RT – 723 K) and frequency (1 kHz – 1 MHz) ranges. However, no phase transition is observed for BCTF ceramic in the above experimental temperature range. Complex impedance spectroscopic studies of the compound were carried out in different experimental conditions for better understanding of relaxation process of the material.
**Key words:** Dielectric Constant, Tangent loss & Raman Spectroscopy.

## Introduction:

The main problems of Bismuth Ferrite compound are their high-leakage current density, high tangent loss, structural distortion etc., which affects the values of dielectric, ferroelectric, resistive properties and other parameters. It suffers, high-leakage current density attributed to the oxidation–reduction of Fe ions ($Fe^{+2} \rightarrow Fe^{+3} + e^-$), creating oxygen vacancies for charge compensation [1]. The above problems seriously limit its use for multifunctional devices. The physical properties of a material could be changed by the process of doping. In order to reduce the tangent loss, high leakage current density, remnant polarization, structural distortion and enhances the magnetic and ferroelectric properties, various dopants, substitutions and additives are added to $BiFeO_3$ [2-3] and/or fabricate composite/solid solution with suitable systems. In addition, Cobalt titanate ($CoTiO_3$) belongs to ilmenite structural family; is one of very interesting room temperature ferroelectric materials with excellent electrical properties. Keeping in this mind a composite consisting of $BiFeO_3$ and cobalt titanate, BCTF has been prepared.

## Method:

The calcined powder of the prepared material was cold pressed into circular disc-shaped pellets were prepared (10 mm diameter and 1-2 mm thickness). The prepared pellets were then sintered at an optimized temperature of 800 ºC for 6 h in air atmosphere. The capacitance, dielectric constant, loss tangent and other parameters were measured as a function of temperature (25-500 ºC) over a wide range of frequency (1 kHz -1 MHz) using a computer-interfaced phase sensitive meter (N4L PSM-1735) and a laboratory-fabricated sample holder. Raman scattering spectra were measured at room temperature using a Laser Micro Raman spectrometer (Bruker, Senterra).

## Analysis:

Fig.1 (a-b) shows the temperature dependence (RT-723 K) of the relative dielectric constant ($\varepsilon_r$) and corresponding loss tangent (tan δ) at various frequencies (1 kHz - 1 MHz) for BCTF sintered pellet. It is observed that, the dielectric dispersion curves possess strongly temperature and frequency dependent dielectric constant for BCTF sintered pellet. For all the frequencies, the relative dielectric constant increases linearly with rise in temperature but dielectric parameters ($\varepsilon_r$ and tan δ) decrease on increasing frequency, which is a general characteristic of dielectric materials [4]. The value of $\varepsilon_r$ increases with temperature and decrease with frequency. The increase of $\varepsilon_r$ with temperature may be due to the electron–phonon interaction [5]. The value of $\varepsilon_r$ at 20 kHz and 1 MHz at room temperature and 500 $^0$C are 266.35, 1367.34, 252.48 and 475.23 respectively. The increase in the value of $\varepsilon_r$ can be ascribed to the thermally activated transport of space charges. In addition, Fig. 1b shows the value of tan δ (calculated from Fig. 1b) at 20 kHz and 1 MHz at RT and 500 $^0$C are 0.049, 7.409, 0.011 and 0.675 respectively. However, no phase transition is observed in BCTF in the experimental temperature range of (RT–500 $^0$C). In addition, the value of dielectric loss (tan δ) increases smoothly initially but after the temperature increases, the loss increases sharply. The nature of variation of tan δ with temperature is same as that of $\varepsilon_r$ (i.e., the value of tan δ gradually increases on increasing temperature). Generally, tan δ has very high value in low-frequency and high-temperatures range in Fe-containing compounds which decrease rapidly with rise in frequency. Raman scattering spectra were measured at room temperature using a Laser Micro Raman spectrometer as shown in figure 2.

**Figures:**

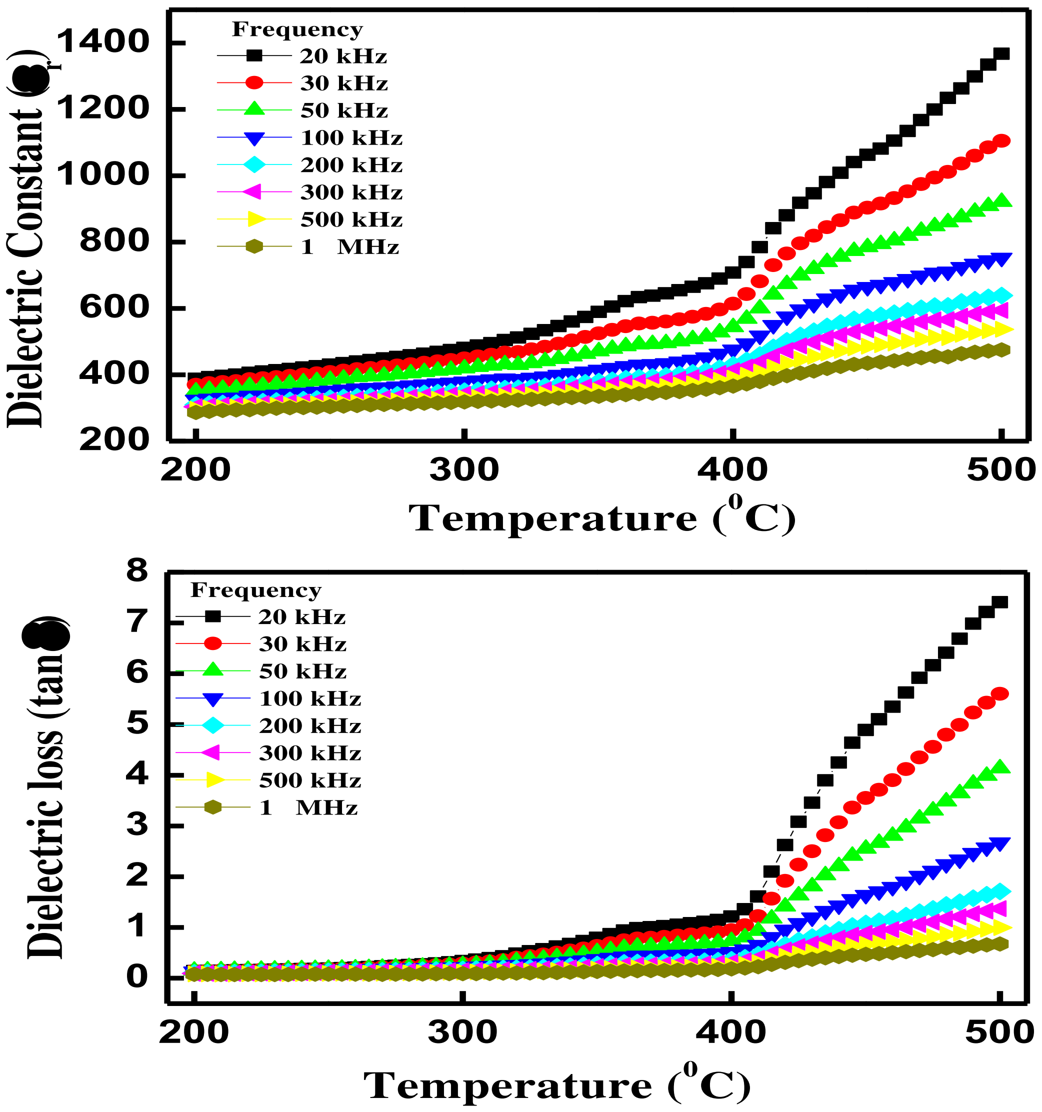


**Fig. 1(a, b): Variation of relative dielectric constant ($\varepsilon_r$) and dielectric loss (tan δ) for BCTF compound as a function of temperature at different frequencies.**

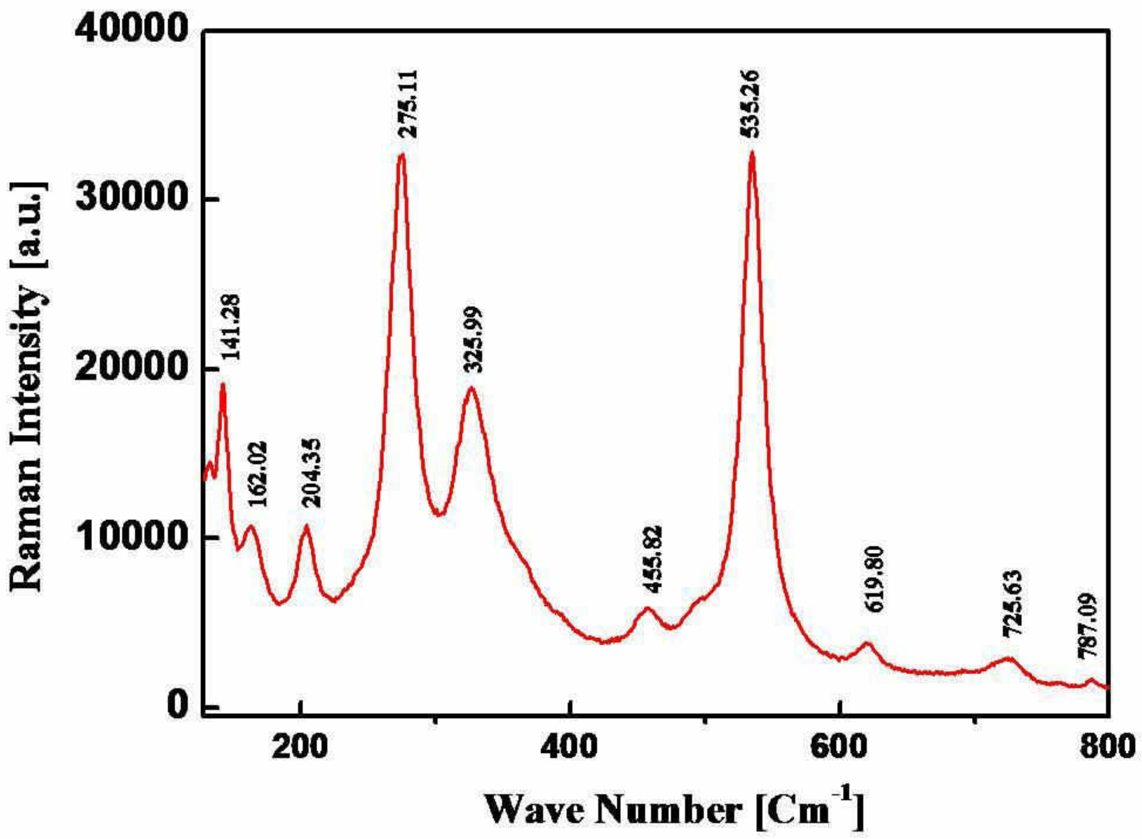


**Fig.2 Raman scattering measured at room temperature for BCTF compound.**

**Conclusion:**
The polycrystalline sample of BCTF was synthesized using a standard high temperature solid-state reaction technique. Dielectric study reveals that the both dielectric parameters increase with temperature whereas they decrease with frequency. The value of dielectric constant and tangent loss increases with increase in space charge polarization. It may be due to some defects in the material. Raman scattering spectra were measured at room temperature.

**References:**
1. Y.P. Wang, L. Zhou, M.F. Zhang, X.Y. Chen, J.M. Liu, Z.G. Liu, Appl. Phys. Lett. 84, 1731–1733 (2004)
2. B. F. Yu, M. Y. Li, J. Wang, L. Pei, D. Y. Guo and X. Z. Zhao, J. Phys. D: Appl. Phys.,41, 185401(2008).
3. Alok Shukla, Nitin Kumar, C. Behera, R.N.P Choudhary, J. Mater. Sci. Mater. Electron. doi: 10.1007/s10854-015-3877-3 (2015).
4. J. C. Anderson, Dielectrics (Chapman & Hall, London; 1964).
5. S. Pattanayak, R.N.P. Choudhary, P.R. Das, J. Mater Sci:Mater Electron 24, 2767-2771(2013).