Dielectric Relaxation and Magnetodielectric Responses in $Bi_5Ti_3FeO_{15}/Bi_2Fe_4O_9$ Composites

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Abstract. We investigate the dielectric relaxation and magnetodielectric (MD) properties of the (1-x)$Bi_5Ti_3FeO_{15}$/(x)$Bi_2Fe_4O_9$ (x = 0.0 and 0.3) composites. The sample is prepared by the sol-gel method to study its physical properties. The existence of mixed phases in the composite is assured by the Rietveld refinement of the XRD pattern. The dielectric data at different frequencies reveals the dispersive behavior of the pure cum composite samples. The ε′ vs. temperature reveals the appearance of relaxation behavior around 170 K in the composite. The frequency variation of the ε″ study excludes the Maxwell-Wagner origin of the dielectric relaxation. Further, the modified Curie-Weiss law analyzes the relaxor nature of the composite. The magnetic field-dependent MD% shows the maximum strength in the highly dielectric dispersive region. The maximum strength of MD effect ~0.2% is found in composite at 300 K.

INTRODUCTION

Magnetodielectric (MD) materials whose dielectric characteristics are regulated by the external magnetic field capture the great attention of future device fabrications. The MD materials are rare to be found due to the mutually exclusive behavior of the electronic origin of spontaneous magnetic and electric dipolar ordering. Recently, the MD effect has been explored in spin spiral $TbMnO_3$ and CuO far below room temperature (RT) and in charge ordered system of $LuFe_2O_4$ [1]. MD property exists well below RT for most materials, restricting their practical applications. Despite the above limitations, MD materials are also focused due to their applications in the field of antenna, micro-sensors, high-density storage media, and transducers [2]. Hence, the scientific community is concentrating on exploring suitable materials showing MD coupling near RT. Multiferroic material with inherent magnetic and electric properties is relevant in this context. MD coupling is explored in both the single and composite materials. But the weak strength of the MD coupling in single-phase material limits their technological application. So, the fabrication of composite materials may improve the required MD coupling and widen its application. Based on the above purpose, we have focused on composite sample preparation by adding the ferroelectric and ferromagnetic phases. In this quest, the composite of $Bi_5Ti_3FeO_{15}/Bi_2Fe_4O_9$ is of particular interest. The $Bi_5Ti_3FeO_{15}$ (BTFO) compound belongs to the Aurivillius compound with the general chemical formula $Bi_{n+1}Ti_3Fe_{n-3}O_{3n+3}$, where n represents the number of the perovskite layer. Aurivillius BTFO is an exciting material with the simultaneous presence of ferroelectric (Tc ~730 °C) and weak magnetic properties in the single phase [3]. The second compound, $Bi_2Fe_4O_9$ (BFO), exhibits unique spin frustration with an antiferromagnetic ordering at ~260 K [4]. These characteristics of both BTFO and BFO may facilitate the physical properties of the composite. Therefore, this report investigates the dielectric and MD behavior of pure and composite samples.

EXPERIMENTAL DETAILS

The synthesis of (1-x)$Bi_5Ti_3FeO_{15}$/(x)$Bi_2Fe_4O_9$ (x = 0.0 and 0.3) composites were prepared by two successive steps. In the first step, pristine powder of BTFO and BFO was prepared using the sol-gel auto combustion method.

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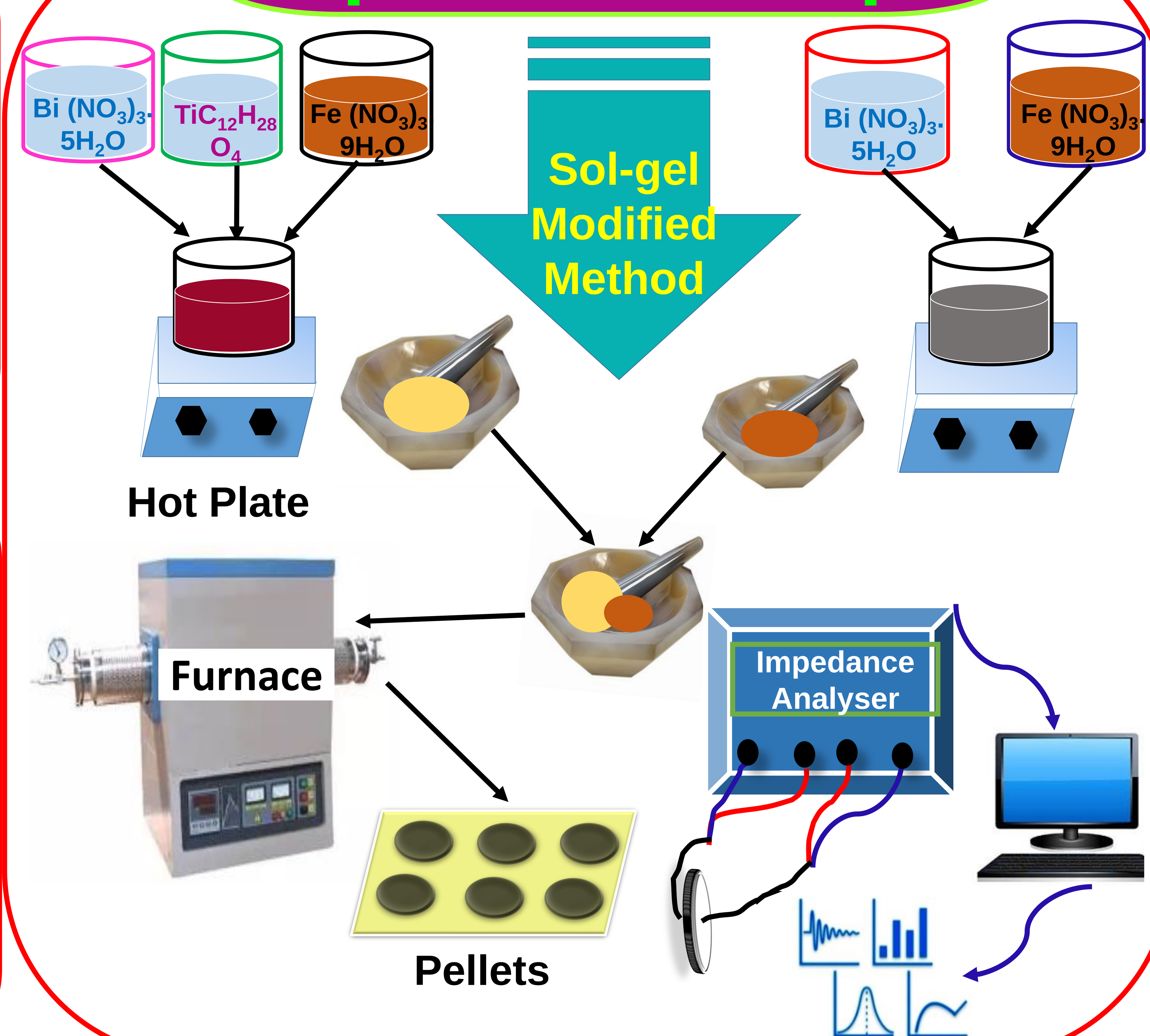
Abstract

- ✓ Composite (1-x)BTFO-(x)BFO (x= 0.0 and 0.3) is synthesized by sol-gel modified technique.
- ✓ Existence of mixed phases (*$A2_1am$ and Pbam*) in the composite is verified from the Rietveld analysis.
- ✓ Dielectric data at different frequencies reveals the dispersive nature of samples.
- ✓ Frequency variation of Ɛ″ study excludes the Maxwell-Wagner originated dielectric relaxation.
- ✓ Modified Curie-Weiss law analyzes the relaxor nature of composite.
- ✓ Magnetic-field-dependent MD% shows the maximum strength at highly dispersive region and found to be ~0.2% at 300 K.

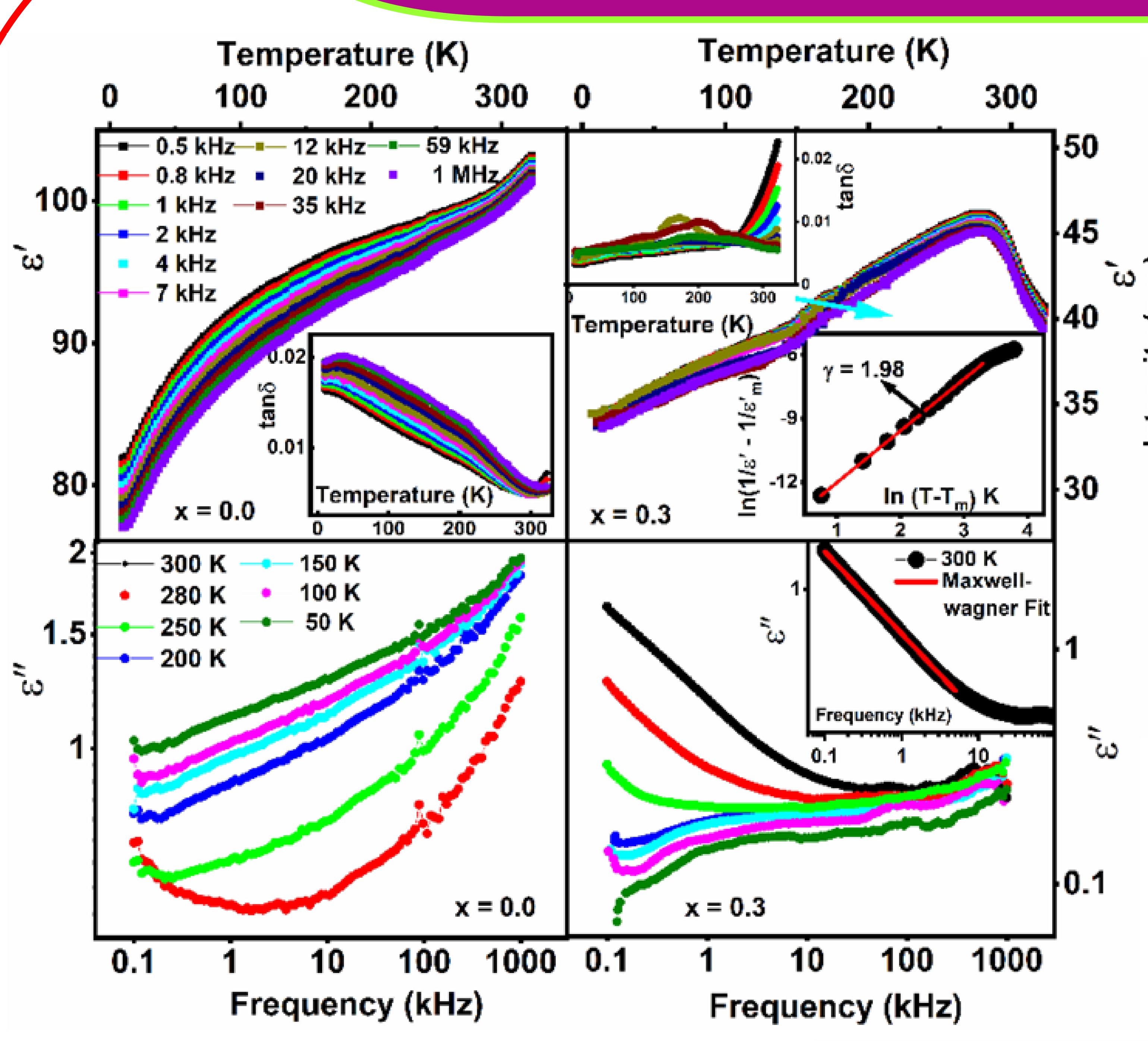
Introduction

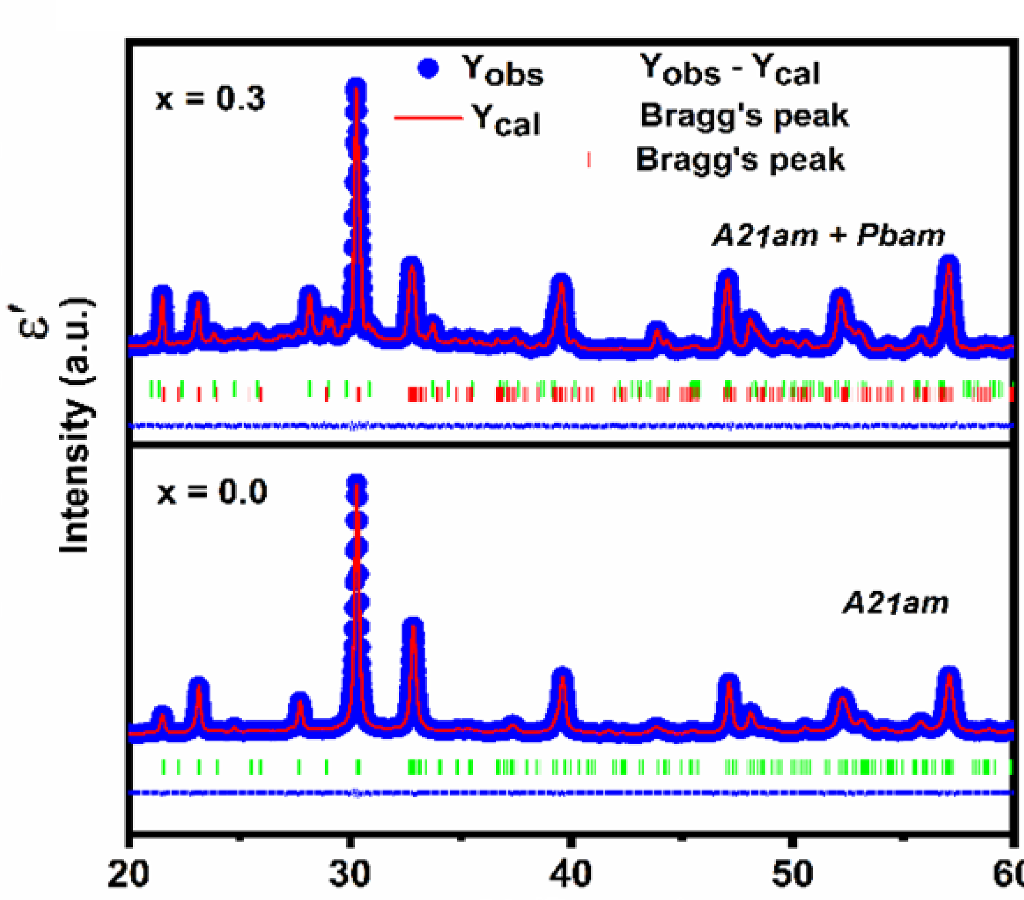
- ❑ Magnetodielectric (MD) materials are focused due to the various application such as antenna, micro-sensor, high-density storage media, and transducers.
- ❑ The weak strength of the MD coupling in the single-phase material limits the technological applications.
- ❑ Composite fabrication may provide a potential path to improve the MD coupling and widen its application.
- ❑ In this quest, Aurivillius $Bi_5Ti_3FeO_{15}$ (BTFO) is an exciting ferroelectric material (T_c ~ 730°C) and weak magnetic behavior in single-phase form.
- ❑ For magnetic purposes, the $Bi_2Fe_4O_9$ (BFO) is considered due to unique spin frustrated antiferromagnetic T_N~ 260 K.

Experimental Technique



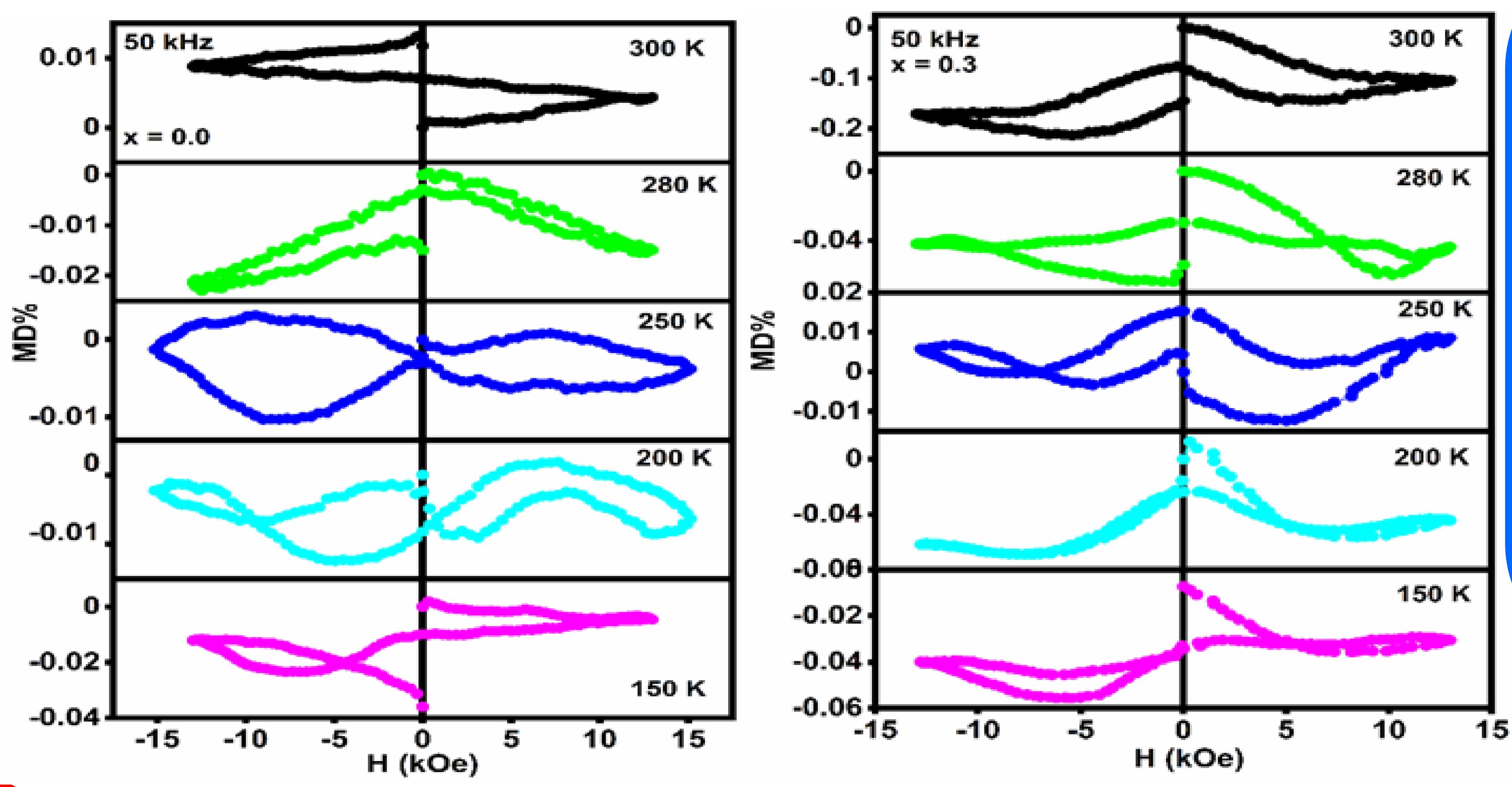
Results and Discussion





❖ $$\frac{1}{\varepsilon'} - \frac{1}{\varepsilon'_m} = \frac{(T-T_m)^{\gamma}}{C}$$

❖ $$\mathrm{MD}\ (\%) = \left[\frac{\varepsilon(H,T)}{\varepsilon(0,T)} - 1\right] \times 100$$



- ➢ Maxwell-Wagner relaxation is present in the 300 K to 250 K low-frequency region of composite.
- ➢ Value of γ = 1.98 close to the value of relaxor ferroelectric (γ = 2).
- ➢ Maximum MD% (~0.17%) at 150 K and ~0.2% at 300 K is observed in pure and composite.

Summary

- ➢ The composites (1-x)BTFO-(*x*)BFO (*x*= 0.0 and 0.3) are synthesized via the sol-gel modified method.
- ➢ The Rietveld refinement of XRD data confirms the dual-phase formation.
- ➢ Temperature-dependent Ɛ′ exhibits relaxation behavior at 170 K.
- ➢ Frequency-dependent Ɛ″ analysis reveals that the Maxwell-Wagner relaxation cannot be the origin of the dielectric relaxation in composite.
- ➢ Maximum strength of the MD% in pure cum composite is observed at the highly dispersive region.

References

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Acknowledgement

We would like to acknowledge UGC-DAE Consortium for Scientific Research, Mumbai (Sanction No. CRS-M-187, 225) for funding.