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# A Review on Enhancement of Dielectric Loss and Constant of Bifeo$_3$ and Different Type of Polymer Composites

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***Abstract***
*Polymer composite materials with better dielectric qualities have garnered a lot of interest for use in advanced electronic devices due to their affordability, ease of processing, and potential for energy storage. Because of its multiferroic nature—which includes both ferroelectric and antiferromagnetic properties—bismuth ferrite ($BiFeO_3$ ) has become a promising candidate among other ceramic fillers. However, the direct application of $BiFeO_3$ is limited due to it's low breakdown strength, poor manufacturability, and high dielectric loss. To get around these problems, scientists have looked into adding $BiFeO_3$ to polymer matrices like poly(methyl methacrylate) (PMMA) and poly(vinylidene fluoride) (PVDF) to make polymer–ceramic composites that perform better as dielectrics. To guarantee uniform distribution of $BiFeO_3$ particles in the polymer matrix, surface-modifying agents and optimized dispersion techniques have been used.The structural, dielectric, and processing difficulties of $BiFeO_3$ -based polymer composites are covered in this review, along with new developments in their manufacturing processes and possible uses in memory devices, gate dielectrics, and telecom miniaturized capacitors.*
***Keywords:*** *Dielectric loss, $BiFeO_3$, polymer composites, Dielectric Properties, PMMA*

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## I. Introduction

Polymer composite materials with good dielectric qualities have found immense utilities in technological, electrical and electronics sectors due to their economic and ease of handling. [1–5]. Examining dielectric characteristics and nature of polymer-ceramic composites now is more expedient and insightful using parameters like capacitance, dielectric loss, dielectric constant and electrical conductivity as a function of frequency [6,7]. Polymer–ceramic composite materials are essential for applications in advanced electronics, such as integrated circuit memory and gate dielectrics [8], small capacitors for telecommunication , and so on. Numerous ternary oxides, including $YMnO_3$, $BaTi_2O_4$, $LuFe_2O_4$, $BiMnO_3$, and $BiFeO_3$(BFO), have been proposed as potential candidates during the last ten years [9]. It is commonly known that multiferroics exhibit both ferromagnetism and ferroelectricity simultaneously. $BiFeO_3$ has exhibited excellent G-type antiferromagnetic and simultaneous ferroelectric properties as a multiferroic compounds. Characteristics that are higher than room temperature. Ceramics, on the other hand, have a high dielectric constant because of their high polarization, but their low breakdown strength, poor manufacturing quality, and high dielectric loss limit their use.However, the difficulty in preparing pure $BiFeO_3$ is the primary cause of the scant information regarding the size dependence of the physical properties of the multiferroic material like $BiFeO_3$. Impurity phases can readily arise during the $BiFeO_3$ synthesis. One major issue with the use of BFO is highly volatile Bi-ions. Polymers such as poly-(methyl methacrylate) (PMMA), poly-(vinylidene fluoride) (PVDF), polypropylene (PP), etc., are in focus mainly to reduce the loss and to produce composites with greater flexibility. Polymers like polyethylene (PE) have high electrical breakdown strength for energy storage and harvesting however, possess high dielectric loss and a low dielectric constant .Thus, new composites with low loss and a high dielectric constant can be shaped by fusing the qualities of ceramics and polymers. In the meantime, the high surface energy of ceramic particles makes it challenging to disperse them evenly throughout the polymer matrix, which causes agglomeration and phase separation from the matrix and reduces the flexibility and breakdown strength of the composites. The electric and dielectric characteristics of the composite are adversely affected by the inhomogeneity. Numerous efforts have been put thus far to enhance the ceramic particle dispersion within polymer matrices.[10].

## II. Structure And Properties Of Polymer And Bismuth Ferrite

### 2.1 Polymer

A macromolecule made up of numerous repeating subunits is called a polymer. In polymers, the repeating units are referred to as monomers. Hydrocarbons, hydrogens, and carbon compounds combine to form various general classes of polymers. The backbone of the polymer is made up of long chains of carbon atoms that are precisely joined to one another. Some of its distinctive physical characteristics are thoughtness, viscoelasticity, and a propensity to form glasses and semicrystalline structures rather than crystals. In addition to having a low dielectric constant (<10) and high dielectric loss values, polymers have a high electrical breakdown strength for energy storage applications. The chemical makeup of the polymeric repeating unit is important in determining the distinctive dynamic mechanical and dielectric properties of polymers. The dielectric losses reach their maximum at the frequency where the dielectric constant curve has its point of inflection; the dispersion region attains lower frequencies as the temperature decreases; and the dielectric constant value decreases over a narrow frequency region as frequency increases.[11]

### 2.2 Bismuth ferrite($BiFeO_3$)

One of the more promising multiferroic compounds is bismuth ferrite, an inorganic compound with a rhombohedralperovskite structure. Chemical processes, solid-state synthesis, and other methods can be used to prepare bismuth ferrite. The simultaneous presence of ferromagnetism and ferroelectricity in multiferroics is well known .$BiFeO_3$, exhibits ferroelectric (TC ≈ 830°C) and G-type antiferromagnetic (TN ≈ 370°C) characteristics at room temperature. Their large polarization gives them a high dielectric constant, but their low breakdown strength, poor manufacturing quality, and high dielectric loss limit their use primarily because of the challenge in purifying the BiFeO3. When $BiFeO_3$ is synthesized, phase formation kinetics in the $Bi_2O_3$-$Fe_2O_3$ system can readily cause the development of impurity phases like $Bi_{25}FeO_{40}$ and $Bi_2Fe_4O_9$. BFO has significant issues for the applications owing to the high leakage current caused by highly volatile Bi-ions, which play a crucial act in lowering down the remnant polarization.

### 2.3 Dielectric Properties Of Composite

Here, they fabricated a homogeneous ceramic-filled polymer composite in which PMMA serves as polymer matrix, BFO as ceramic filler and BFO particles are surface-modified by 2-aminoethanesulfonic acid layer. The composite prepared showed a maximum dielectric constant of 147 and comparatively suppressed loss values (< 1) at 100 Hz.

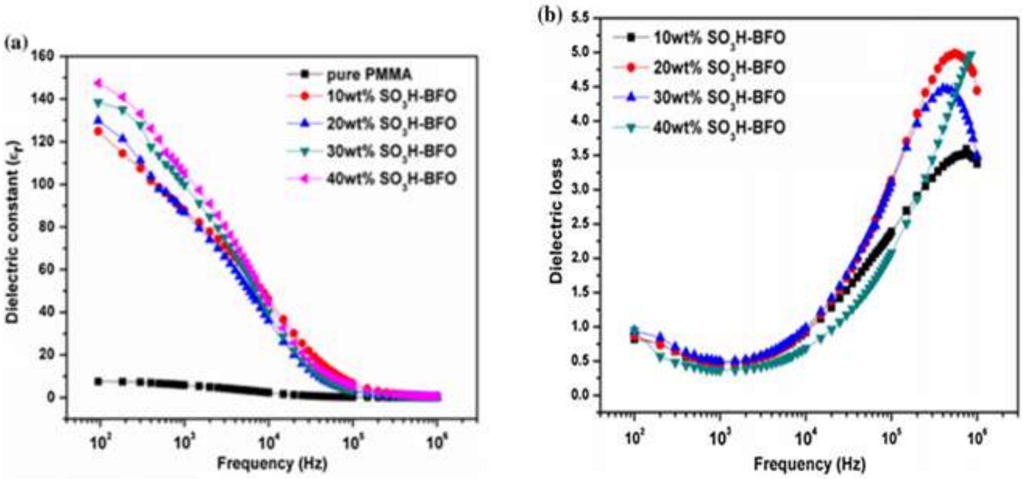


**Fig. 1. Frequency dependence of (a) dielectric constant and (b) dielectric loss of $SO_3H$-modified BFO-PMMA composites at room temperature.**

A BFO-filled composite film is fabricated by solvent casting with poly(methyl methacrylate) as the polymer matrix. The BFO surfaces are hydroxylated by hydrogen peroxide, an appropriate hydroxylating agent. The dielectric analysis of the composites shows that the surface-modified one differs from the unmodified onePMMA–(BFO-OH) composites exhibit an enhanced dielectric constant with low dielectric loss..[12]

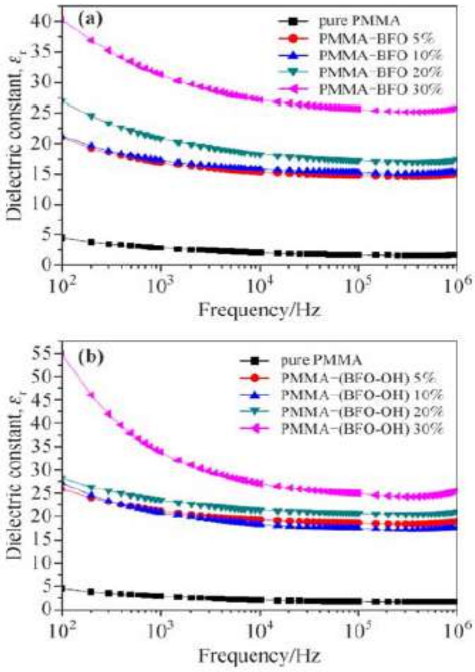


**Fig. 2. Dielectric constants of (a) PMMA–BFO and (b) PMMA–(BFO-OH) composite films with various concentrations of BFO and BFO-OH @ wide ranges of frequencies.**

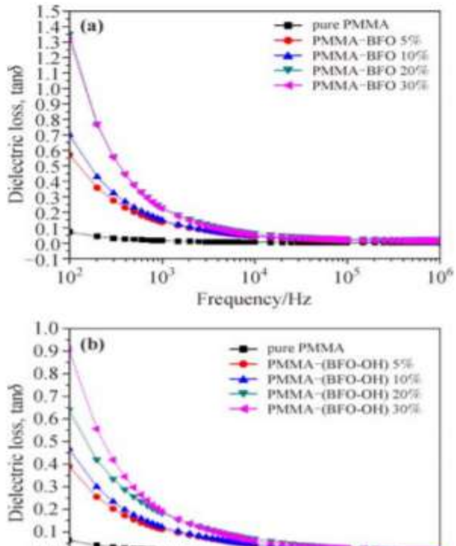


**Fig. 3. Dielectric loss of (a) PMMA-BFO and (b) PMMA-(BFO-OH) composite films with various concentrations of BFO and BFO-OH @ wide ranges of frequencies**

## III. Summary

The major issues for the applications of BFO can be eliminated by mixing various kinds of polymer to it. Numerous various works had been conducted to overcome all these issues by synthesizing BFO on polymer matrixes .in some cases, some surface modifying agents are also incorporated for homogenous dispersion. In brief all the bismuth ferrite based polymeric composite can be successfully synthesized by various methods, The occurrence of both BFO and Polymer peaks in the nanocomposite suggested the formation of both polymer as well as ceramic phases. The agglomeration of particles was found to increase with the rise in the loading percentage of BFO particles. The dielectric characteristics of the nanocompositesi.e the dielectric constant and dielectric loss are improving after the composite synthesis. Dielectric constant value greatly enhances with the rise in loading percentage of BFO compared to virgin polymer. polymer–ceramic composite materials are very significant components for applications in advanced electronic device for examples, gate dielectrics and memory for integrated circuits and miniaturized capacitors for telecommunication and so on.

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