

"Dielectric Properties of Polymers: Understanding the Role of Molecular Structure"

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Abstract

Polymers typically serve as dielectrics. Due to the distinct chemical composition of polymer fastens, semiconducting frameworks can be produced, which can then be doped appropriately in the strong state to produce frameworks with high electric conductivity, like polyacetylenes. These interesting substances are unstable, though, when left in their native state. Ceramic polymer composites have been investigated for their applicability as implanted capacitor materials because they combine the handling capabilities of polymers with the ideal dielectric properties of earthenware production. In this work, the dielectric properties of the burnt (BaTiO₃)- polymer (Epoxy) synthesis as a component of clay molecule size at a 40% volume percent earthenware stacking are studied. These clay polymer composites become more dielectrically consistent as the powder size decreases. Based on the results, it can be concluded that clay polymer composites have a low dielectric loss at 1 MHz, a high protective obstruction, a high breakdown voltage, and a high dielectric steady when combined with BaTiO₃ powder.

Keywords: *Dielectric Properties, Polymers, Understanding, Molecular Structure*

1. Introduction

Many polymers have a few metal-like characteristics. Due to their high strength, adaptability, frictional resistance, durability, and other qualities, as well as their ease of preparation, handling, and thinness, these polymers have long since replaced metals in a variety of applications. Just recently have polymers acquired electrical conductivity, the primary feature of metals. Many academic and contemporary centres have worked to produce polymers that exhibit excellent electrical conductivity. Since one would desire to manage things like movies or strands using important advancements in the plastics industry, the question's relevance is obvious. The arrangement and characteristics of macromolecular materials with semiconducting capabilities are the result of numerous scientific and physicist investigations. who's cited in this for instance, despite the abundance of fundamental knowledge acquired, it is generally accepted that concepts

addressing the connection between molecular constitution and the actual structure of macromolecular solids have not yet fully matured. Macromolecules with a drawn-out 11-electron framework were combined in the hopes that the delocalization of the electrons would lead to a high centralization of free charge transporters. Polymer 11-fortified frameworks speculatively observed poor conductivity was attributed to a number of things, including chain closures and 11-holding cracks. It is currently known that polymers with polyconjugate structures in the main chain are covers in the ground state and that illumination only offers a small number of free transporters based on exciton: development the warm excitation of an electron from the valence band into conduction boycott and is essentially prohibited. The continuous study of semiconducting and leading polymers is motivated by strong-state and semiconductor physical science.

Information about the electrical and optical qualities was uncovered in the structure of theories of stage changes from semiconductor-peak to metal, silicon, which after doping with givers or acceptors can be turned into a leading state. Another relationship must be highlighted in respect to the shapeless semiconductors that change their electrical behaviour after doping. Basically, inadequately leading hazy polymers (including coverings) can be converted into highly intriguing photocon — experts by using the proper molecular doping. In light of the aforementioned observations, doping polymeric frameworks is a crucial way to change their electrical properties and make formless photo transmitters or semi translucent high molecular weight photoconductors.

Since their most famous publication by Zhu and associates, dipolar glass polymers have inspired the creation of various innovative polymer dielectrics with high dielectric constants and slightly low misfortune factors. The theory of the polarization interaction of these materials, mainly regulated by the orientational instrument, has been related to their exceptional dielectric properties. In contrast to other systems (like ionic and interfacial) that rely on the presence of ionic species, whose dispersion increases the material's dissipative person and affects its truly essential protecting property, this component achieves a high captivated state while maintaining a somewhat low dissemination conduct. Researchers can now learn more thanks to the many papers that consolidate and clarify the physical science and physics behind this class of materials.

The unexpected rise in reports regarding dipolar glass polymers in recent times has fuelled curiosity in new all-polymer dielectric materials. But among all of these polymers, those from the family of polymethacrylates are thought to be the most well-known kinds. The above-mentioned work focused on how the dipolar arrangement influenced both their dielectric conduct and their primary and warm properties, and included a total correlation between the two types of polymethacrylates at the theoretical and experimental levels. These dipolar glass polymers, however, were produced in the two trials via conventional extreme polymerization, which resulted in materials with excellent dispersity's but low repeatability in terms of molecular loads. Without a doubt, by following the steps indicated by Wei et al., our team has successfully replicated the polymerization of PSO2MA at two distinct times (our work being one of them), obtaining different results for the aforementioned constraints on each occasion. In this context and while considering the high-level status of the polymer science with respect to controlled polymerization processes, it is intriguing to think about the potential implications that variations in molecular loads and scattering values could have on the dielectric conduct of these polymers.

2. Literature Review

Ferroelectric and no ferroelectric polymers' dielectric characteristics are studied by Cheng et al. Their dielectric properties, polarization processes, and frequency dependence are contrasted in the study. The authors offer helpful insights into the elements determining dielectric behaviour in these various types of polymers by investigating the molecular structure and physical characteristics.

Madbouly and Radwan concentrate on the cross-linked polyethylene's (XLPE) electrical conductivity and dielectric relaxation. The study examines the impact of cross-linking on dielectric characteristics and how it influences electrical behaviour and relaxation processes. To comprehend the mechanisms driving dielectric relaxation in XLPE, the authors examine the molecular structure and intermolecular interactions.

The dielectric characteristics of polyether-polyurethane block copolymers are studied by Fainleib et al. The main topic of the study is how morphology and polyether content affect dielectric behaviour. The scientists shed light on the importance of polyether content and morphology in

shaping the electrical characteristics of these block copolymers by modifying the molecular structure and examining the effects on dielectric properties.

The dielectric characteristics of carbon nanotube-polymer composites are studied by Kuzhir et al. The investigation of the impact of carbon nanotube concentration, alignment, and length on the dielectric behaviour combines simulations and experiments. The scientists provided insight into the function of nanofillers in changing the dielectric characteristics of polymer composites by examining the interaction between the polymer matrix and carbon nanotubes.

Dielectric spectroscopy of polymers in the presence of C60 fullerene is the main topic of Mabrouk and Al-Ghamdi's research. The study looks into how C60 affects the relaxation behaviour and dielectric characteristics of polymers. The authors learn more about the alteration of dielectric behaviour and electrical response in polymer-C60 systems by examining the interaction between C60 and polymers.

3. Dielectric Polarization in Composite Materials Made of Polymers

It is crucial to comprehend the many forms of polarization at the start of the dielectric steady or how to adjust the dielectric consistency of polymers. As shown in Fig. 1, every polarization has a dielectric misfortune (ϵ'') top associated with it at a specific repetition. The majority of the time, the molar polarization and the k characteristics increase with the number of polarization types used. However, keep in mind that depending on the material's structure, even more perplexing recurrence situations may be observed. Through certain power controls, the dielectric constant scales in such systems with repetition. The lack of specific patterns and the breadth of the response really reflect the dispersion of trademark sizes in densely interconnected networks. The following focuses on the usage of various polarizations for fitting the dielectric consistent.

Table 1: Interfacial, orientational, ionic, and electronic polarization in a polymer having a real (ϵ') and imaginary (ϵ'') component of the dielectric constant as a function of frequency

	ϵ'	ϵ''
kHz	0.5	0.4
MHz	0.3	0.2
GHz	0.8	0.1
THz	0.1	0.5
1000 THz	0.6	0.2

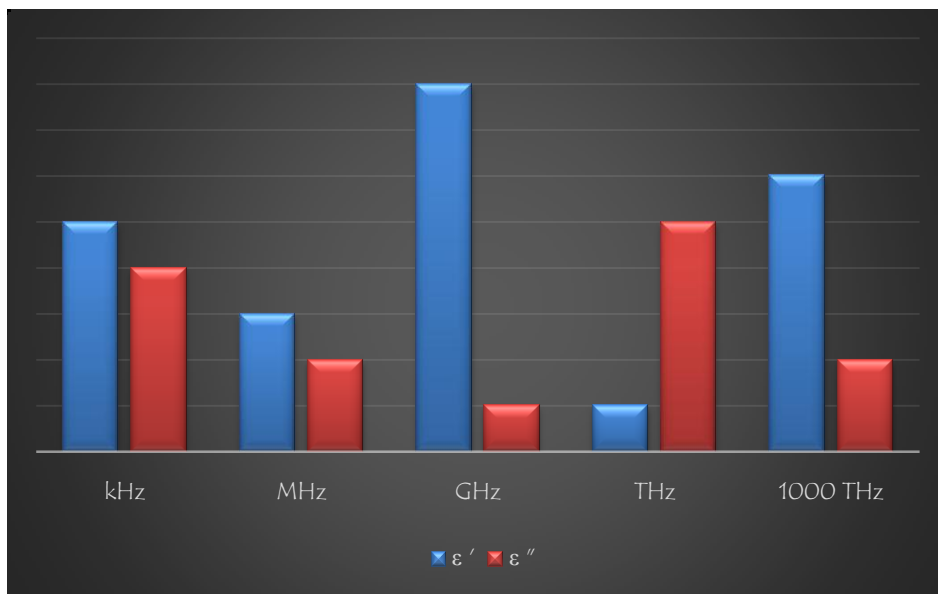


Figure 1: Interfacial, orientational, ionic, and electronic polarization in a polymer having a real (ϵ') and imaginary (ϵ'') component of the dielectric constant as a function of frequency

The reorientation of nanoparticles, dipolar moieties connected to polymers, or exceptionally robust molecular dipole moments are all examples of orientational polarization in connection to polymer composites. Dipolar unwinding normally happens between 0.1 to 10⁷ Hz, depending on the repetition, temperature, and shape of the dipoles (glasslike or shapeless). In fact, by carefully controlling the thickness and structure of dipoles, it is possible to produce dipolar glass,

ferroelectric, and wound or ferroelectric polymers that display various levels of dielectric consistency and dielectric misfortunes.

Ionic polarization brings to mind the actual method of particle condensation in polymer materials. Based on this polarization, polymeric electrolytes can be utilized to enhance the capacitive display of door dielectrics for natural field impact semiconductors. An electric double layer functions as the primary working system at the intersection of the polymer electrolyte and terminal. Despite having a huge amount of energy storage capacity, polymer electrolytes are inappropriate for film capacitors because of a serious defect, namely the significant dielectric loss caused by the movement of particle species over a long distance. Excessive dielectric losses harm the sensible suitability of typical polymer dielectrics because of the enormous energy waste and high administrative risk. Ionic polarization should be prevented for common polymeric dielectrics by minimizing the centralization of debasement particles during polymerization operations.

Electronic polarization and the delocalization of electrons in natural polymers are connected by a remotely applied electric field. It should be emphasized that the infrared and optical frequencies are where the dielectric disadvantages of electronic polarization occur, as opposed to the lower frequencies, which is advantageous for the applications that have already been explored. For innovative dielectric polymers, Si, Ge, and Sn are frequently recommended in substitution of C in order to adjust the dielectric steady from electronic polarization. In spite of this, mixing such inorganic polymers is very difficult.

Maxwell-Wagner-Sillars (MWS) interfacial polarization in heterogeneous frameworks is connected to redesign of interfacial charges, such electrons and openings accumulating at interfaces. It can be found in many kinds of multicomponent dielectric structures, including nanocomposites comprised of highly polarizable directed nanofillers or semi-transparent polymers (precious stone nebulous connecting points may result in MWS impact). As demonstrated by MWS impact (where is the conductivity and is the dielectric consistency), when a flow stream traverses the two-material points of interaction, charges may build at the site of interaction between the two dielectric materials with different unwinding times. From this vantage point, the large disparity in conductivity or dielectric constant between the filler and polymer framework (for ceramic nanoparticles) is extremely desired for interfacial polarization

and bears the cost of a high dielectric constant. The polymer grid at the molecular surface will, in any event, experience a rise in the electric field as a result of such a significant variation. The extremely inhomogeneous electric fields that are associated with the field increase frequently either enhance the local risk of dielectric disappointment or cause the release to overflow. Thus, a crucial test for employing interfacial polarization is to find compromises that consider high-k, high breakdown strength, and low misfortunes in a single nanocomposite material.

4. Experimental Procedures

4.1. Materials

4.1.1. Polymers

The polymer framework was KDP-550MC65 (EEW: 650, Kukdo Synthetics Inc., Korea), a commercial halogen-free epoxy pitch modified to phosphate epoxy. Me-THPA (Kukdo Synthetics Inc., Korea) and benzyl triethylammonium (BTEAC) were used as a relieving specialist and impetus. As a dispersant, phosphate ether (Disper BYK-110, BYK Cemie, and USA) was used to evenly scatter BaTiO₃ granules within the epoxy. Additionally, an evening out specialist (BYK310, BYK Cemie, USA) was used to lessen the epoxy sap's surface stress. As a dissolvable, methylketol-ketone (MEK) and toluene were combined.

4.1.2. BaTiO₃ powder

The following powders, produced by Sakai Substance Industry Co., Ltd., were used in the current investigation: BT-02, BT-03, BT-04, and BT-05. These powders, according to the manufacturer, have intermediate molecular sizes of 200, 300, 400, and 500 nm. The two powders' respective Ba/Ti nuclear proportions were around 0.998 and 1.000.

4.1.3. Sample preparation

The exploratory process for producing ceramic polymer composite movies is shown in Figure 2. The remaining natural dissolve able was then removed by projecting a thin layer of this ceramic polymer blended composite by a specialized edge on a copper substrate and drying at around 100°C for 10 min in a stove. By using the X-beam diffraction (XRD) technique and CuK radiation to describe the BaTiO₃ powders, and by using a filtering electron magnifying apparatus

to examine the surface morphology of the film composites. The deliberate film thickness and capacitance were used to determine the dielectric constants of the burned composite films.

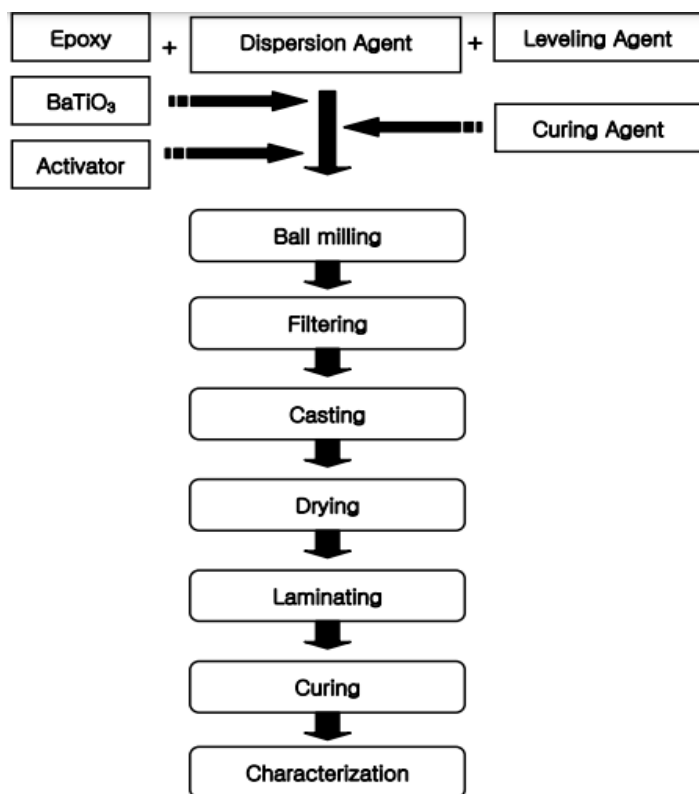


Figure 2: Flowchart for the investigational process.

5. Results and Discussion

SEM images of the morphologies of BaTiO₃ powders with 200, 300, 400, and 500 nm mean molecule sizes, separately, are shown in Figures 3(a), (b), (c), and (d). The particles' BET surface area ranged from 2.3 to 5.6 m²/g.

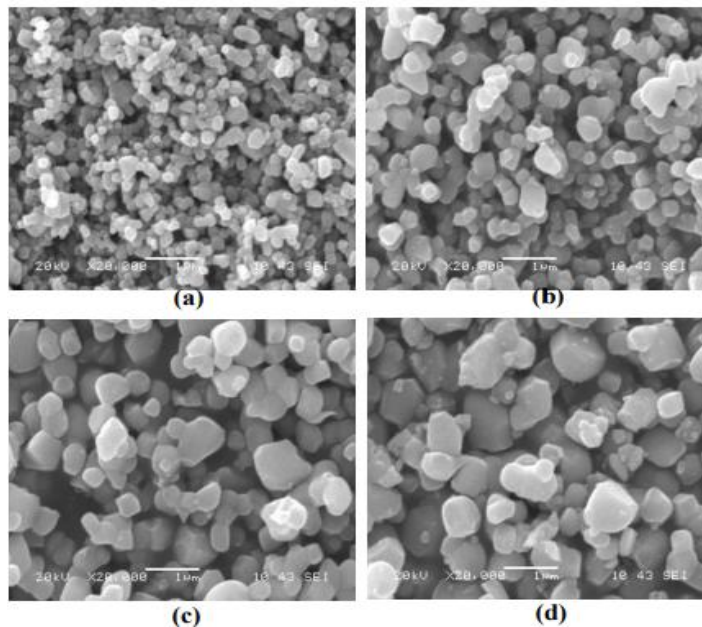


Figure 3: Powders of BaTiO₃ as seen by SEM. 1) BT-02, 2) BT-03, 3) BT-04, and 4) BT-05.

The dielectric constants of the BaTiO₃/epoxy composites are depicted in Figure 4 as a function of the BaTiO₃ molecule size. When BaTiO₃ molecules were smaller than 400 nm, the dielectric constant decreased in direct proportion to the increase in molecule size. This pattern's argument is that better particles with larger surface areas would facilitate improved molecule-to-molecule interaction, hence increasing the pressing thickness. The enhanced polarization resulting from the dipole connection may also be upgraded in solidly packed particles. The electrical transition lines between the two anodes will be coordinated in order to follow the example's path with the least amount of resistance. Due to the decreased ratio of polymer to ceramic over the path with the lowest impedance, the agglomeration of the particles would consequently result in reduced impedance. The agglomerated particles would be able to enter a larger electrical motion as a result of this impact than the non-agglomerated particles.

Table 2: the BaTiO₃/epoxy composites' dielectric constants in relation to BaTiO₃ particle size.

	BaTiO ₃ Type
BT02	40
BT03	30
BT04	50
BT05	20

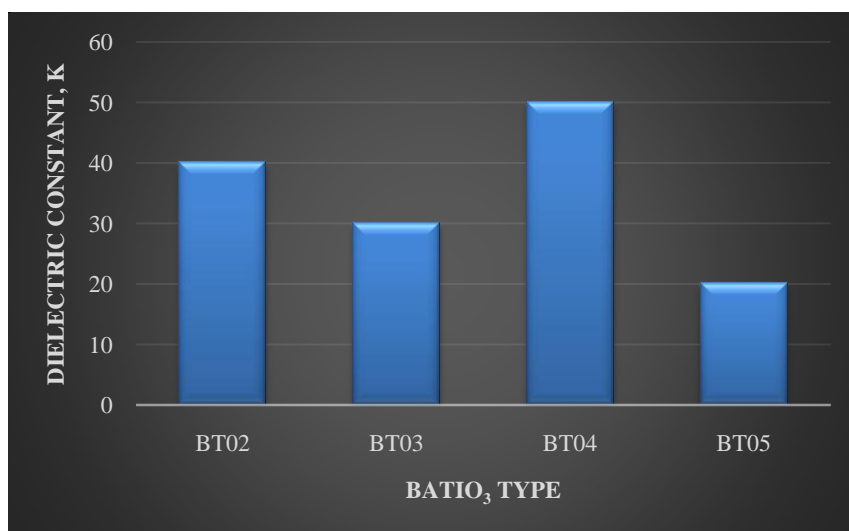


Figure 4: the BaTiO₃/epoxy composites' dielectric constants in relation to BaTiO₃ particle size.

Figure 5 depicts the fluctuation of the protection opposition in polymer-earthenware composites as a function of the BaTiO₃ molecule size. A 15-um thick polymer-clay composite sheet has a protective obstruction of about 1x10¹² ohm at the applied voltage of 100 V. With increasing BaTiO₃ molecule size, the protective barrier in polymer-ceramic composites became less significant. The better particles can cover the spaces left by the coarser particles as the molecule size decreases, causing the powder pressing thickness to increase even more.

Table 3: A relationship between insulation resistance and BaTiO₃ particle size was found in polymer-ceramic composites.

	BaTiO ₃ Type
BT02	50
BT03	20
BT04	40
BT05	30

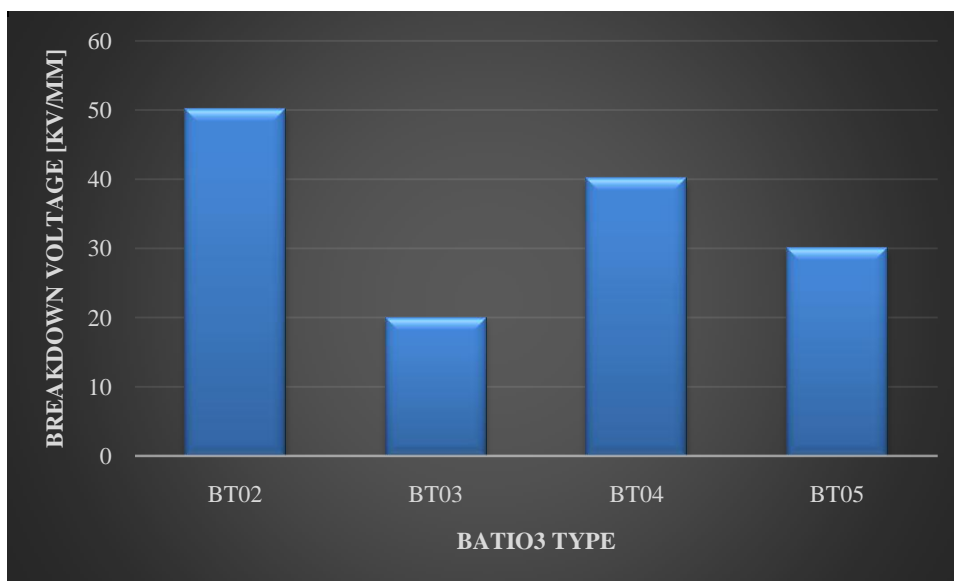


Figure 5: A relationship between insulation resistance and BaTiO₃ particle size was found in polymer-ceramic composites.

It is acknowledged that the BT-03's interaction capability exceeds that of the BT-02. This result demonstrates the possibility of additional polymer-artistic composite film development given the fire d's dispersed location throughout the polymer network.

6. Conclusion

The examination of all of our research in the field of molecular and transparent CT structure doped polymers is not intended to be complete by the discussion above. Leading frameworks can be produced by combining several glass-like CT structures and polymeric networks. TCNQ salts containing aromatic rings or aliphatic chains in the primary chain, as well as sulphur atoms, can solidify to create a polymeric grid that arranges conductive routes. In many ways, their characteristics mimic those listed above. Using typical intense polymerization and Pontoon, sulfone and nitrile-containing polymethacrylates were effectively created, producing materials with distinctly different molecular loads and dispersity's. the dielectric properties of ceramic polymer composites used to create implanted capacitors are determined by their tetragonal structure and predicted molecular composition. greater particles may have greater molecule-to-molecule interaction for further developing the dielectric constant, dielectric misfortune, and protective opposition if they have a higher surface area to volume ratio. While improving the electric characteristics, agglomerated powder also has an impact on capacitance resistance. Earthenware powder should then be widely dispersed within the polymer network to increase handling capability.

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