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Enhanced dielectric properties of polyvinyl alcohol doped with ZrC Nanoparticles

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Abstract

In this paper, effect of ZrC nanoparticles on dielectric properties of polyvinyl alcohol has been investigated. The polymer nanocomposites films were fabricated by using casting method. The dielectric properties of prepared nanocomposites were recorded at frequency(f) ranged from100Hz to 5MHz. Results showed that the dielectric properties of polymer were enhanced with increase in the ZrC NPs ratio. The ε' and ε" were reduced while the σAC was rise with rise in the frequency.

Keywords: Conductivity; Nanocomposites; ZrC; Dielectric properties; Polymer

1. Introduction

Polymer nanocomposites materials have gotten a lot of consideration lately because of the expanded series of fields that these hybrid substances can be employed for. It is extensively documented that polymers materials, as dielectric substances, are excellent host medium for nanostructures, and that this is true for together metal and ceramic nanostructures. While doing so, these embedded particles within the polymer medium will also impact the physical characteristics of the host. Hybrid composites of polymer and ceramic, in exacting, are promising useful substances in a variety of disciplines, including optical, mechanical, electrical, antibacterial and thermal properties[1].Composite materials because of these diverse properties are successfully used in almost all areas of industry and science[2].Dielectrics with elevated permittivity are extensively employed in electronic industry. With the development of flexible electronics, elevated permittivity dielectric substances with exceptional flexibility are in demand. As compared to conventional dielectrics such as ceramics and polymers are extensively being employed as dielectric substances as polymers display better characteristics, like relatively elevated electric break downfield, processing simplicity, mechanical flexibility etc. Moreover, their characteristics may be modified by incorporating inorganic substances into it[3].PVA is a linear polymer that possesses good optical characteristics, biodegradability, biocompatibility, and nontoxicity, and consequently can be extensively utilized in a variety of field's water soluble, good optical transmission, noncorrosive and has excellent ability for film forming[4].PVA is a semicrystalline and its crystalline index depends on the synthetic method and physical aging[5].In PVA, hydrogen bonding presence between hydroxyl groups is extremely significant for its elevated water solubility and elevated crystal modulus. Normally PVA is a poor electrical conductivity it can become conductor when it is added with other polymer. Polymer composites are the substances in which different systems arecombined to achieve a system with enhanced functional characteristics like physical, thermal, optical and electrical characteristics. The development in these characteristics depends on the chemical nature of the nanostructure and the way in which it interacts with the polymer [6]. There are many studies on PVA as matrix with different additives [7-12]. This work deals with preparation and dielectric properties of ZrC/PVA nanocomposites.

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2. Material and methods

Films of polyvinyl alcohol (PVA)/zirconium carbide (ZrC) nanocomposites were prepared by using casting technique. The film of pure polyvinyl alcohol was fabricated by dissolving of 1 gm in (30 ml) distilled water. The nanocomposites films were prepared by adding different ratios (1.1%, 2.2%, and 3.3%) of ZrC NPs to the polymer solution. The dielectric properties of PVA/ZrC nanocomposites films measured by LCR meter (HIOKI 3532-50 LCR HI TESTER).The dielectric constant ($\acute{\varepsilon}$) is calculated by[13]:

$$\acute{\varepsilon} = C_p\, d / \varepsilon_o\, A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where, C_p is capacitance, thickness(d), A (in cm^2). Dielectric loss(ε'') is given by[14]:

$$\varepsilon'' = \acute{\varepsilon}\, D \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Wherever, D is the dispersion factor.The A.C conductivity is defined by[15]:

$$\sigma_{A.C} = 2\pi f\, \acute{\varepsilon}\, D\, \varepsilon_o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

3. Results and discussion

Figures 1 and 2 represent the variations of dielectric constant and dielectric loss of studied nanocomposites with frequency respectively. The dielectric constant and dielectric loss are reduced with increase in the frequency. This behavior related to decrease the effect of space charge polarization. The dielectric constant and dielectric loss of PVA are increased with increase in the ZrC NPs ratio which due to increase in the number of charges carriers[16-20].

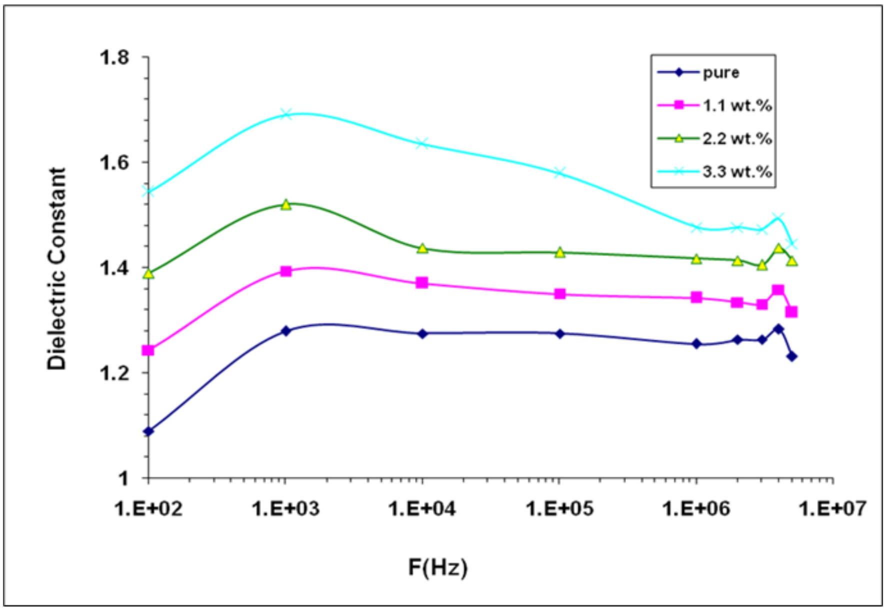

Figure 1 Variation of dielectric constant of PVA/ZrC nanocomposites with frequency

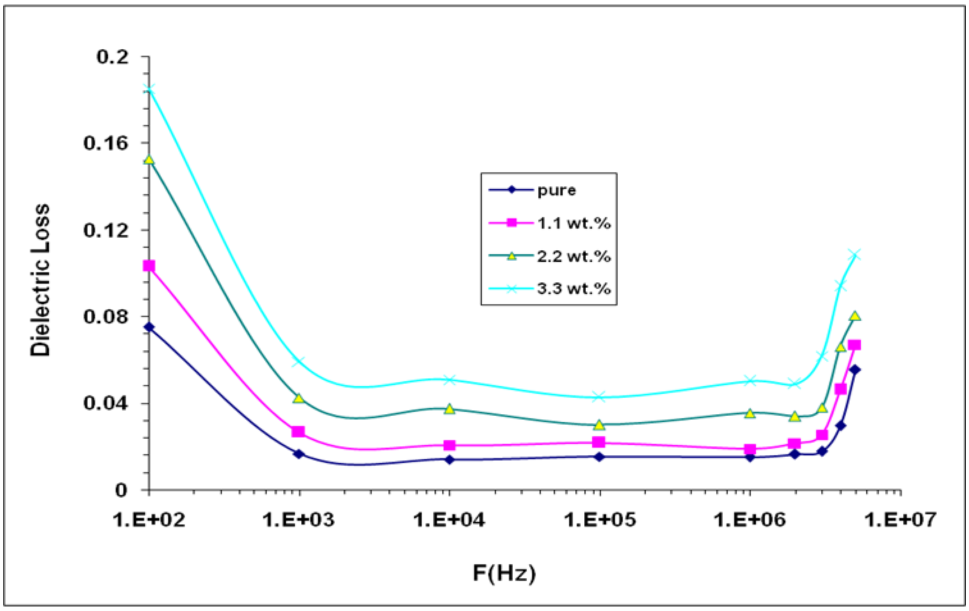

Figure 2 Variation of dielectric loss of PVA/ZrC nanocomposites with frequency

Figure 3 shows the behavior of A.C electrical conductivity of PVA/ZrC nanocomposites with frequency. As shown in this Figure, the conductivity increases with rise in the frequency. This behavior indicates that there may be charge carriers, which may be transported by hopping through the defect sites along the polymer chain. With rise in the ZrC NPs ratio, the A.C electrical conductivity of PVA increases which due to increase in the charges carriers numbers[21-24].

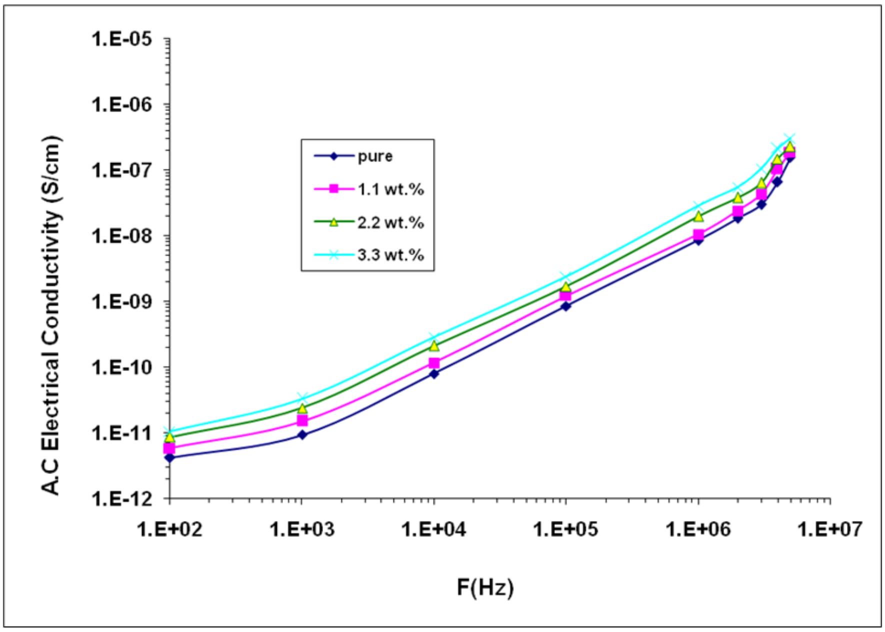

Figure 3 Behavior of A.C electrical conductivity of PVA/ZrC nanocomposites with frequency

4. Conclusion

This work includes fabrication of PVA/ZrC nanocomposites using casting method. The dielectric properties of PVA/ZrC nanocomposites were studied at frequency ranged from100Hz to 5MHz. Results demonstrated that the dielectric properties of PVA were enhanced with increase in the ZrC NPs ratio. The ε' and ε" were reduced while the σ_{AC} was rise with rise in the frequency.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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