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Fabrication and Dielectric Characteristics of PVA/SiO_2/$BaTiO_3$ Nanocomposites for Nanoelectronics Fields

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Nanocomposites' films of pure polyvinyl alcohol (PVA) and PVA doped with SiO_2/$BaTiO_3$ nanoparticles are fabricated using casting technique. The dielectric characteristics of PVA/SiO_2/$BaTiO_3$ nanocomposites are examined. The results show to enhance in dielectric properties, which include dielectric constant, dielectric loss and A.C. electrical conductivity of PVA with an increase in the SiO_2/$BaTiO_3$-nanoparticles' content. The dielectric constant and dielectric loss of PVA/SiO_2/$BaTiO_3$ nanocomposites are reduced, while the A.C. electrical conductivity is increased, with raising the frequency. Finally, the obtained results illustrate that PVA/SiO_2/$BaTiO_3$ nanocomposites may be useful in various electrical fields.

Плівки нанокомпозитів з чистого полівінілового спирту (ПВС) і ПВС, леґованого наночастинками SiO_2/$BaTiO_3$, виготовляються за допомогою ливарної техніки. Досліджено діелектричні характеристики нанокомпозитів ПВС/SiO_2/$BaTiO_3$. Одержані результати свідчать про підвищення діелектричних властивостей, які включають діелектричну проникність, діелектричні втрати та електропровідність змінного струму ПВС зі збільшенням вмісту наночастинок SiO_2/$BaTiO_3$. Діелектрична проникність і діелектричні втрати нанокомпозитів ПВС/SiO_2/$BaTiO_3$ зменшуються, а електропровідність змінного струму збільшується з підвищенням частоти. Нарешті, одержані результати ілюструють, що нанокомпозити ПВС/SiO_2/$BaTiO_3$ можуть бути корисними в різних електричних галузях.

Key words: polyvinyl alcohol, $BaTiO_3$, SiO_2, nanocomposites, dielectric properties, conductivity.

Ключові слова: полівініловий спирт, $BaTiO_3$, SiO_2, нанокомпозити, діелектричні властивості, електропровідність.

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1. INTRODUCTION

Nanoparticles-reinforced polymer composites with preferred characteristics are gaining significant attention among researchers for their potential application in a wide range of industrial sectors such as packaging, artificial biomedical implants, electrical devices, electronics, *etc.* Among them, functional polymer materials with high dielectric constant, low dielectric loss and flexibility are highly desirable in producing next-generation smart devices, such as decoupling capacitors, electric vehicles, solar photovoltaic generation plants, sensors and actuators, electromagnetic interference (EMI) shielding, switched-mode power supplies, *etc.* [1].

Modern electronics heighten the demand for adaptable, multipurpose, eco-friendly dielectric materials with superior properties. Historically, ceramics were used as dielectric materials; however, it possessed undesirable properties such as brittleness, processing difficulties, and low stability. Polymers have superior flexibility, processability, and lightweight, when compared to ceramics. In addition, they gained significant interest in science and technology during the last decade as a dielectric or interfacial layer between metals and semiconductors. Among the polymers biodegradable, nontoxic, and hydrophilic ones have specific research interest, as they can be applicable in bioelectronics [2].

Polyvinyl alcohol (PVA) is semi-crystalline, with low electrical conductivity. PVA has certain physical characteristics resultant from crystal amorphous interfacial effects. Its electrical characteristics may be modified to an exact requirement by the suitable doping substance addition [3].

Barium titanate ($BaTiO_3$), due to its high dielectric permittivity, ferroelectric properties and non-toxicity, is used in electronic and microwave devices, as an interlayer in ceramic capacitive structures, as a sensor, in portable energy storage systems, in supercapacitors, *etc.* [4].

Silica is an inorganic substance, which can be functional in a wider variety of fields. Silica is a stable substance and extensively employed in quantum devices, optoelectronics, biomaterials, environmental science and sensors [5].

The nanocomposites of polymers doped with nanoparticles (NPs) included huge applications in the optical, electronics, optoelectronics and sensors [6–32]. The present study objects to prepare of $PVA/SiO_2/BaTiO_3$ nanocomposites and studying their dielectric properties to use in various electrical fields.

2. MATERIALS AND METHODS

Films of PVA/SiO_2/$BaTiO_3$ nanocomposites were prepared using casting method. The pure PVA film was fabricated by dissolving of 1 gm in (30 ml) of distilled water. The SiO_2/$BaTiO_3$NPs were added to PVA solution with concentration 1:1 and various contents are 1.3, 2.6 and 3.9 wt.%. The dielectric properties measured in frequency ranged of 100 Hz–5 MHz by LCR meter type (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant, ε', is given by [33] $\varepsilon' = C_p/C_0$, where C_p is the capacitance and C_0 is the vacuum capacitor.

The dielectric loss, ε'', is calculated by [34] $\varepsilon'' = \varepsilon' D$, where D is the dispersion factor.

The A.C. conductivity is determined by [35] $\sigma_{A.C.} = w\varepsilon''\varepsilon_0$, where w is the angular frequency.

3. RESULTS AND DISCUSSION

Figures 1–4 demonstrate the variations of dielectric constant and dielectric loss with frequency and SiO_2/$BaTiO_3$ NPs content, respectively.

The dielectric constant and dielectric loss are decreased with frequency, while it rises with SiO_2/$BaTiO_3$ NPs content. These performances of dielectric constant and dielectric loss related to the high contribution of charge accumulation in the nanocomposites assigned to the effect of polarization effect.

The dielectric constant and dielectric loss are rise with raising

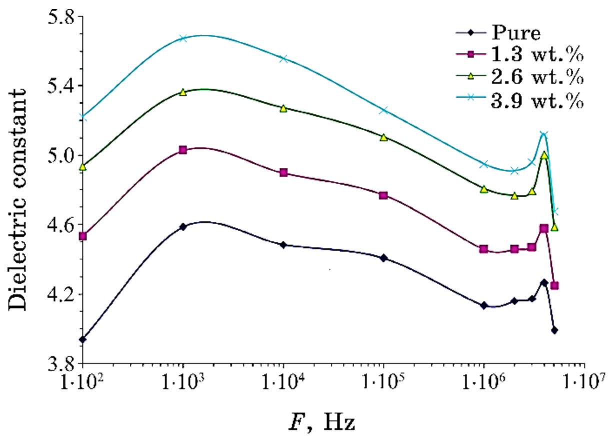

Fig. 1. Variation of dielectric constant for PVA/SiO_2/$BaTiO_3$ nanocomposites with frequency.

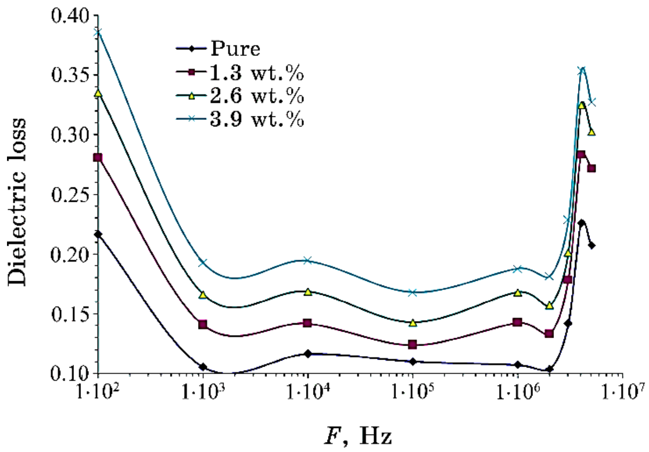

Fig. 2. Behaviour of dielectric loss for PVA/SiO_2/$BaTiO_3$ nanocomposites with frequency.

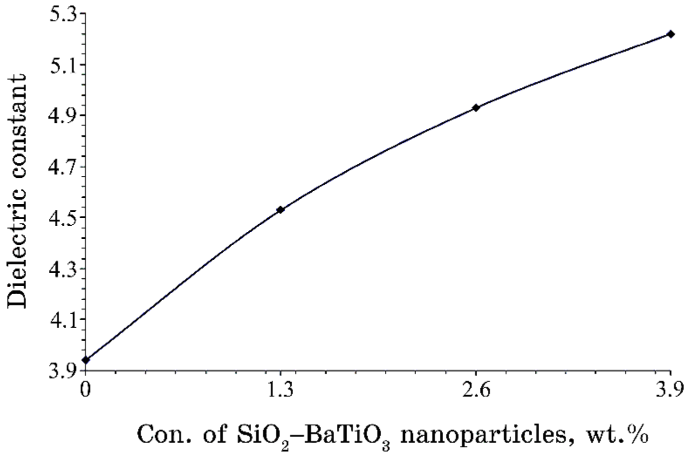

Fig. 3. Dielectric constant variation with SiO_2/$BaTiO_3$ NPs content.

the SiO_2/$BaTiO_3$ NPs content, which related to rise of charges carrier numbers [36–44].

Figures 5 and 6 illustrate the behaviour of A.C. conductivity for PVA/SiO_2/$BaTiO_3$ nanocomposites with frequency for varied contents of SiO_2/$BaTiO_3$ NPs. From these figures, the electrical conductivity rises with increasing the SiO_2/$BaTiO_3$ NPs concentration, where the distributed SiO_2/$BaTiO_3$ NPs in the polymer medium has increased the number of conductive pathways and increase in the charge-carriers' number.

The conductivity of PVA/SiO_2/$BaTiO_3$ nanocomposites increases

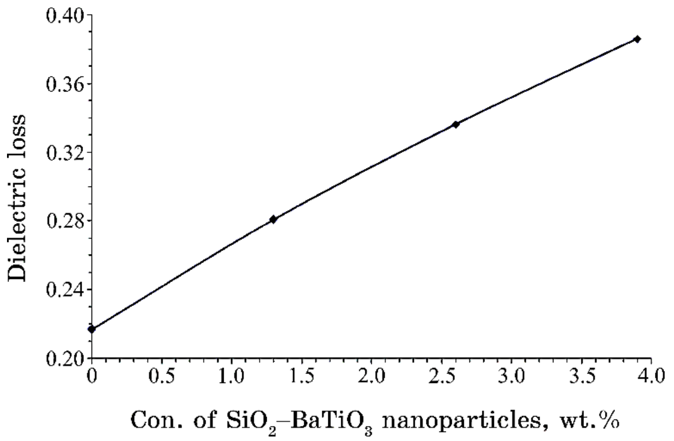

Fig. 4. Behaviour of dielectric loss with SiO_2–$BaTiO_3$ NPs content.

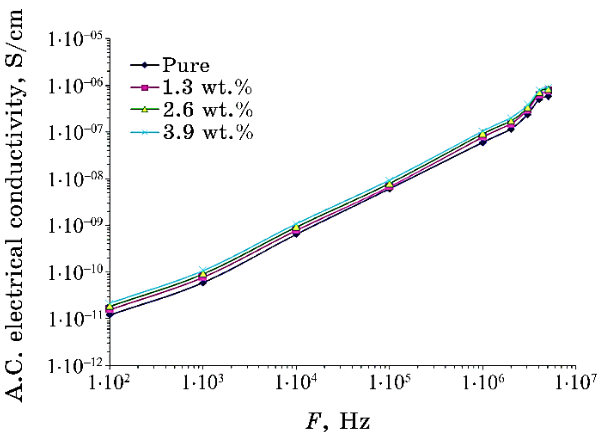

Fig. 5. Performance of A.C. conductivity for PVA/SiO_2/$BaTiO_3$ nanocomposites with frequency.

with increasing the frequency. The dependence of conductivity on the frequency is caused by the charge carriers' hopping in the localized levels [45–57].

4. CONCLUSIONS

The current study included fabrication of PVA/SiO_2/$BaTiO_3$ nanocomposites to use in different industrial applications. The results demonstrated that the dielectric properties, which include dielectric constant, dielectric loss and A.C. electrical conductivity of PVA, are enhances with increasing the SiO_2/$BaTiO_3$ NPs content. The die-

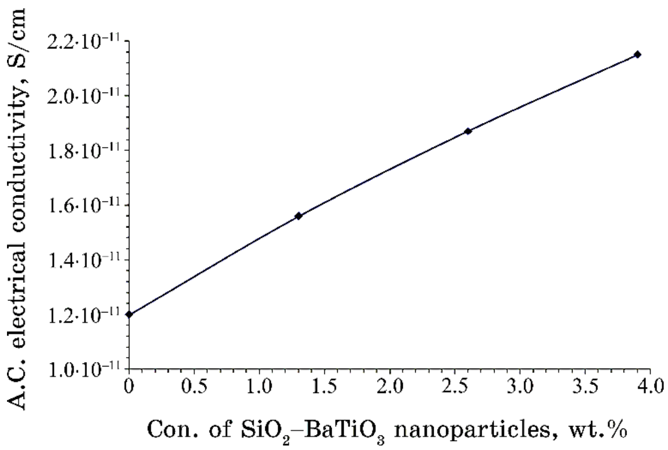

Fig. 6. Variation of A.C. conductivity with $SiO_2/BaTiO_3$ NPs content.

lectric constant and dielectric loss of $PVA/SiO_2/BaTiO_3$ nanocomposites are reduced, while the A.C. electrical conductivity is increased, with raising frequency. The obtained results showed that the $PVA/SiO_2/BaTiO_3$ nanocomposites could be suitable in different electrical fields.

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