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Preparation and Exploring the Dielectric Properties of PVA/PbO_2/ZrO_2 Nanocomposites for Electrical and Electronic Applications

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The present study explores the fabrication of new PVA–PbO_2–ZrO_2 nanocomposites to utilize in different electrical and electronics applications. The dielectric properties of PVA–PbO_2–ZrO_2 nanocomposites are tested in frequency range between 100 Hz and 2 MHz. The results illustrate that the dielectric parameters, namely, dielectric constant, dielectric loss, and electrical conductivity, of PVA are increased with rising PbO_2–ZrO_2-nanoparticles' content. The dielectric constant and dielectric loss of PVA–PbO_2–ZrO_2 nanocomposites are decreased, while the electrical conductivity is increased with increasing frequency. The achieved results of dielectric properties indicate that the PVA–PbO_2–ZrO_2 nanocomposites are potential materials to use in different electrical and electronics fields.

Це дослідження стосується виготовлення нових нанокомпозитів ПВС–PbO_2–ZrO_2 для використання у різних електротехнічних та електронних галузях. Діелектричні властивості нанокомпозитів ПВС–PbO_2–ZrO_2 було випробувано в діяпазоні частот від 100 Гц до 2 МГц. Результати показали, що діелектричні параметри, а саме, діелектрична проникність, діелектричні втрати та електропровідність ПВС збільшувалися зі збільшенням вмісту наночастинок PbO_2–ZrO_2. Діелектрична проникність і діелектричні втрати нанокомпозитів ПВС–PbO_2–ZrO_2 зменшувалися, тоді як електропровідність зростала зі збільшенням частоти. Одержані результати дослідження діелектричних властивостей вказують на те, що нанокомпозити ПВС–PbO_2–ZrO_2 є потенційними матеріялами для використання в різних електротехнічних та електронних галузях.

Key words: PVA, ZrO_2, PbO_2, nanocomposites, dielectric properties, conductivity.

Ключові слова: полівініловий спирт (ПВС), ZrO_2, PbO_2, нанокомпозити, діелектричні властивості, провідність.

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1. INTRODUCTION

Polymer composites are polymers contain of modifiers, which are used as passive and also active layers in optoelectronic devices, such as optical-waveguide materials, light-emitting diodes (LED), solar cells, and photochromic materials. In this regard, seeking low-cost photovoltaic substances and minimum energy consumption during the industrialized process is becoming increasingly demanding. To achieve this stage of demand, blending certain fillers with a number of functional polymers (*i.e.*, polar polymers) at the atomic level of interaction has been carried out. For example, using the earlier mentioned methodology, a promising class of inorganic–organic nanostructured (NS) materials, *i.e.*, polymer nanocomposites (PNCs) with exceptional mechanical strength can be obtained [1]. Flexible composite materials have been receiving a great deal of attention in optical-energy applications due to their remarkable electrical, thermal, mechanical, dielectric, and optical properties *versus* the other traditional materials. Currently, polymer composites are of high interest in different energy applications because of their pliable characteristics and their easy to use. Huge attention has been given to reveal the optical properties of polymers and to potentiate their implementations in optical-energy applications [2]. 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. Moreover, 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, non-toxic, and hydrophilic ones have specific research interest, as they can be applicable in bioelectronics [3]. Polyvinyl alcohol (PVA) has drawn the researchers' attention because of its physical and chemical properties. PVA is a biocompatible, non-toxic, and chemically stable compound. It has been used for a wide variety of applications, including biomedicine, water filtration, and food packaging. It has a hydrophilic character, which can provide a suitable mechanism for its chemical interaction with the environment and, thus, ensure sufficient bioactivity. It has a semi-crystalline nature, arising from the position of hydrogen bonds and the OH groups. PVA has good charge-storage capacity, high dielectric strength, and filling-dependent electrical and optical properties [4]. The nanostructures of inorganic–organic and inorganic–inorganic hybrid systems involved many applications in different fields included thermal energy storage [5–13], radiation shielding and bioenvironmental fields [14–18], and electronics and optoelectronics [19–34].

This work deals with fabrication of new PVA–PbO_2–ZrO_2 nanocomposites to use them in various electrical and electronics applications.

2. MATERIALS AND METHODS

The films of PVA–PbO_2–ZrO_2 nanocomposites have been prepared with different contents of polymer and nanoparticles (NPs) using casting method. The PVA film was fabricated *via* dissolving of 1 gm of PVA in 30 ml of distilled water. The PbO_2–ZrO_2 NPs were added to the PVA with concentration of 1:1 and different weight percentages are of 2, 4 and 6 wt.%. The dielectric properties of PVA–PbO_2–ZrO_2 nanocomposites were tested in frequency ranged from 100 Hz to 2 MHz by LCR meter type (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant, ε', is defined by Ref. [35] as follows:

$$\varepsilon' = \frac{C_p}{C_0}, \tag{1}$$

where C_p is the matter capacitance and C_0 is the vacuum capacitor.

The dielectric loss, ε'', is determined by Ref. [36] as

$$\varepsilon'' = \varepsilon' D, \tag{2}$$

where D represents the dispersion factor.

The A.C. conductivity is given by Ref. [37] as follows:

$$\sigma_{\text{A.C.}} = \omega \varepsilon'' \varepsilon_0, \tag{3}$$

where ω is the angular frequency.

3. RESULTS AND DISCUSSION

Figures 1 and 2 illustrate the behaviours of dielectric constant and dielectric loss for PVA–PbO_2–ZrO_2 nanocomposites with frequency, respectively. At low frequencies, the dielectric-constant values for PVA–PbO_2–ZrO_2 nanocomposites are high. This is because of a large number of charges accumulated on the surface area of the polymer electrode, *i.e.*, interfacial polarization and induced dipoles. Fur-

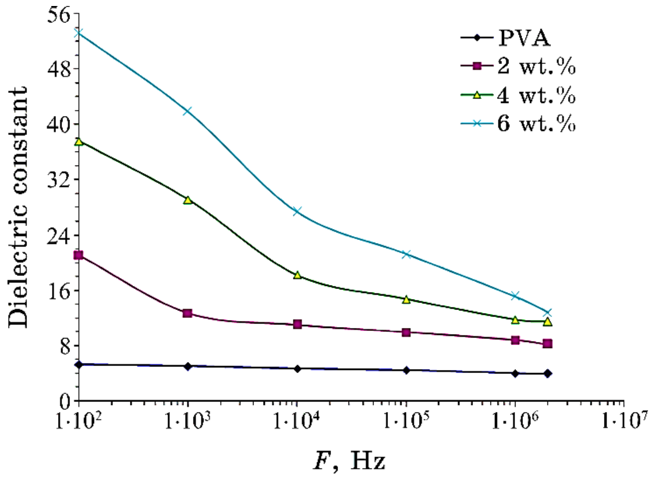

Fig. 1. Dielectric constant behaviour for PVA–PbO_2–ZrO_2 nanocomposites with frequency.

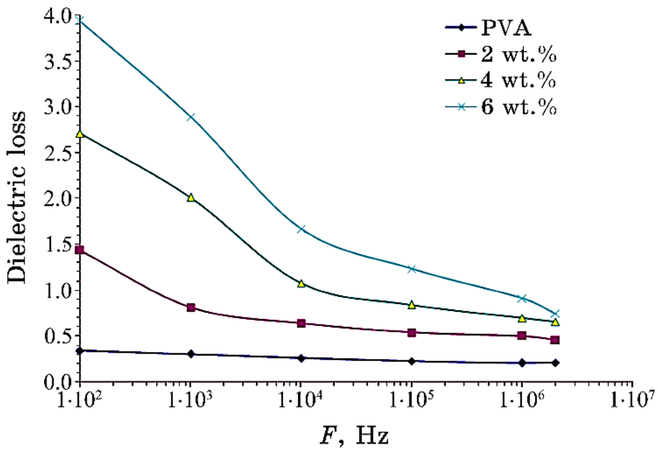

Fig. 2. Performance of dielectric loss for PVA–PbO_2–ZrO_2 nanocomposites with frequency.

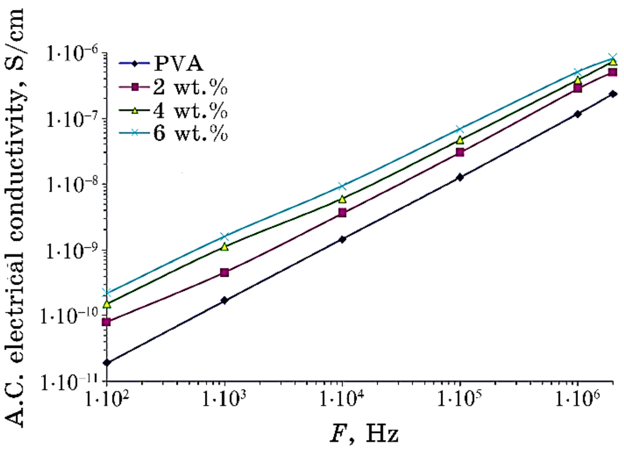

Fig. 3. Variation of electrical conductivity for PVA–PbO_2–ZrO_2 nanocomposites with frequency for different content of PbO_2–ZrO_2 nanoparticles.

thermore, at high frequency, electrons and atoms exhibit displacement polarization, while interfacial and orientation polarizations are restricted, resulting in a low charge on the film surface. In addition, the dielectric loss has high values at low frequency that is due to the polarization effect. The dielectric constant and dielectric loss of PVA are increased with rising PbO_2–ZrO_2-nanoparticles' concentration. These results may be attributed to the increase charge-carrier density [38–56].

Figure 3 confirms the variation of electrical conductivity for PVA–PbO_2–ZrO_2 nanocomposites with frequency for different contents of PbO_2–ZrO_2 nanoparticles. The electrical conductivity is increased with increasing frequency and PbO_2–ZrO_2-nanoparticles' content. The increase with the increase in PbO_2–ZrO_2 content is obvious because of the increase in charge carriers. The electrical conductivity also rises at higher frequencies because of the short-range intrawell hopping of charge carriers between localized states [57–67].

4. CONCLUSIONS

This work investigates the study of dielectric properties of PVA–PbO_2–ZrO_2 nanocomposites to exploit in various electrical and electronics fields. The results demonstrated that the dielectric constant, dielectric loss, and electrical conductivity of PVA are enhanced with increasing PbO_2–ZrO_2 NPs' content. The ε' is increased by 90% with rising PbO_2–ZrO_2-NPs' content to 6% at 100 Hz. The dielectric constant and dielectric loss of PVA–PbO_2–ZrO_2 nanocomposites are reduced, while the electrical conductivity is raised with increasing frequency. The final results of dielectric properties indicated that the PVA–PbO_2–ZrO_2 nanocomposites are functional nanomaterials to utilize in various electrical and electronics applications.

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