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# Preparation and Characterization of PVA/$MnO_2$/$ZrO_2$ Nanocomposites for Electrical and Electronics Devices

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The PVA–$MnO_2$–$ZrO_2$ nanocomposites are prepared by using casting method with various concentrations of $MnO_2$–$ZrO_2$ nanoparticles (0%, 1%, 2%, and 3% wt.). The dielectric characteristics of the PVA–$MnO_2$–$ZrO_2$ nanocomposites are examined for use in different optoelectronic applications. The dielectric properties of nanocomposites demonstrate that dielectric constant, dielectric loss and A.C. electrical conductivity of PVA rise with rising in $MnO_2$–$ZrO_2$ nanoparticles' concentration. Both the dielectric constant and the dielectric loss of PVA–$MnO_2$–$ZrO_2$ nanocomposites decrease, while the A.C. electrical conductivity rises with rising in frequency. The results on dielectrical characteristics show that the PVA–$MnO_2$–$ZrO_2$ nanocomposites may be used for various electronics fields.

Нанокомпозити полівініловий спирт (ПВС)–$MnO_2$–$ZrO_2$ одержано методом лиття з різними концентраціями наночастинок $MnO_2$–$ZrO_2$ (0%, 1%, 2% і 3% за масою). Досліджено діелектричні характеристики нанокомпозитів ПВС–$MnO_2$–$ZrO_2$ для використання в різних оптоелектронних застосуваннях. Діелектричні властивості нанокомпозитів свідчать про те, що діелектрична проникність, діелектричні втрати та електропровідність змінного струму ПВС зростають зі зростанням концентрації наночастинок $MnO_2$–$ZrO_2$. Як діелектрична проникність, так і діелектричні втрати нанокомпозитів ПВС–$MnO_2$–$ZrO_2$ зменшуються, а електропровідність змінного струму зростає зі зростанням частоти. Результати стосовно діелектричних характеристик показують, що нанокомпозити ПВС–$MnO_2$–$ZrO_2$ можуть бути використані для різних галузей електроніки.

**Key words:** PVA, $MnO_2$–$ZrO_2$ nanoparticles, dielectric properties.

**Ключові слова:** ПВС, наночастинки $MnO_2$–$ZrO_2$, діелектричні властивості.

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## 1. INTRODUCTION

Composites can be defined as materials, which consist of two or more chemically and physically different components; it has several features as corrosion resistance, low weight, high fatigue strength, and faster assembly. They are extensively used as materials in making aircraft structures, electronic packaging to medical equipment, and space vehicle to home building. Composite materials having long-term durability for continuous purposes are desirable and cost-effective [1, 2]. There is much interest in the development of inexpensive composite polymers with an appropriate weight, appropriate electric conductivity and/or appropriate impact value for use [3]. The importance of polymers is mainly because polymers are still regarded as a cheap alternative material that is manufactured easily. The intensive use of polymer in broad use has led to the development of materials for specific applications namely composites polymers are flexible, can be easily processed at low temperatures and exhibit high dielectric-breakdown field mead (1961) [4, 5].

Polyvinyl alcohol (PVA) is an important polymer, relate to its chemical and physical features. This polymer may be a film, powder, and fibre forms [6]. PVA has a semi-crystalline nature due from the hydrogen bonds and the OH group role. Relating to its low protein adsorption properties, excellent water solubility and biocompatibility, PVA is usually employed in medical devices [7, 8]. It considered use of polymer polyvinyl alcohol with metal-oxide nanomaterials is a recent approach of researchers for removing toxic dyes from water bodies [9], where these polymers are used as matrix for semiconductor materials. The role of these polymers is to provide an interface for transfer of charge and obstruct leakage of ions in water among several polymers[10]. $MnO_2$ is attracting the interest of nanotechnology researchers due to its low toxicity. In both organic electrolytes and aqueous electrolytes, $MnO_2$ was employed as an electrocatalyst for oxygen generation and oxygen reduction. $MnO_2$ is ancient and promising material with unusual physical and chemical properties. Its derivatives have gotten a lot of attention, and they are employed in a lot of things like sensors, batteries, and electrochemical supercapacitors [11, 12]. $MnO_2$ is promising green matter has involved large interests in good quality of its excellent environmental compatibility, low cost, and broad structural diversity combined with especial chemical and physical characteristics. The important fields of $MnO_2$ nanoscale contain alkaline batteries, gas sensors, photocatalyst, electrochemical capacitors, and smart windows [13, 14]. $ZrO_2$ is a well-known material with extreme refractoriness, high mechanical strength and fracture toughness ,thermal insulation, wear and erosion resistance, chemical durability, and alkali resistance, which finds use in a variety of fields, in particular in constructional ceramics [15, 16].

## 2. EXPERIMENTAL PART

The nanocomposites PVA–$MnO_2$–$ZrO_2$ were prepared from mixing PVA at different concentrations with different concentrations of $MnO_2$ and $ZrO_2$ nanoparticles using the casting method, and different samples were obtained where the first sample consisted of PVA 100% by weight only without adding nanoparticles. The second sample was by mixing 99% of PVA with 0.1 of each of $MnO_2$–$ZrO_2$. Accordingly, the third sample was mixing 98% of PVA with 0.2 of each of $MnO_2$–$ZrO_2$, respectively, and the last sample was mixing 97% of PVA with 0.3 of each of $MnO_2$–$ZrO_2$, respectively. The mixtures were continuously stirred until homogeneous solutions were obtained. After pouring into different Petri dishes, the solutions were left to dry at room temperature to form films. The membranes were transferred to a dryer for continuous drying.

The dielectric constant ($\varepsilon'$) is calculated by Ref. [17] as

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

where $C_p$ is parallel capacitance and $C_0$ is vacuum capacitor.

The dielectric loss ($\varepsilon''$) is calculated by Refs. [18, 19] as

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

where $D$ is displacement. A.C. electrical conductivity is as follows:

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

where $\omega$ is the angular frequency.

## 3. RESULTS AND DISCUSSION

Figure 1 shows the effect of adding the $MnO_2$–$ZrO_2$ nanoparticles on the dielectric constant of PVA, the dielectric constant increases with increasing of the concentration of $MnO_2$–$ZrO_2$ nanoparticles; the reason for this increase is the formation of a clusters of $MnO_2$–

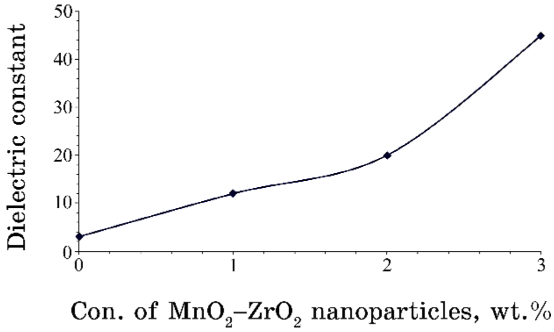


**Fig. 1.** Effect of $MnO_2$–$ZrO_2$ nanoparticles' concentration on dielectric constant for PVA.

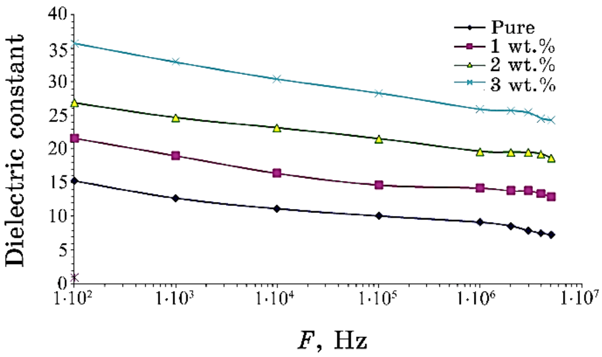


**Fig. 2.** Variation of dielectric constant for PVA–$MnO_2$–$ZrO_2$ nanocomposites with frequency.

$ZrO_2$ nanoparticles inside the nanocomposites at low concentrations of $MnO_2$–$ZrO_2$ nanoparticles; hence, the dielectric constant becomes low, and at high concentrations of $MnO_2$–$ZrO_2$ nanoparticles, a continuous network inside the nanocomposites is formed, and so, the value of dielectric constant increases with increasing of $MnO_2$–$ZrO_2$ nanoparticles' concentration [22–29].

The variation of dielectric constant of PVA–$MnO_2$–$ZrO_2$ nanocomposites with frequency $F$ are shown in Fig. 2; this figure shows that the dielectric constant of all nanocomposite samples decrease as the frequency of applied field increases. It can be due to the tendency of dipole in nanocomposite samples in order to orient themselves in the directions of the electrical fields applied and to decrease the polarization of the space charge to absolute polarization [30–37].

The dielectric loss of PVA–$MnO_2$–$ZrO_2$ nanocomposites increases as the concentration of $MnO_2$–$ZrO_2$ nanoparticles increases as shown

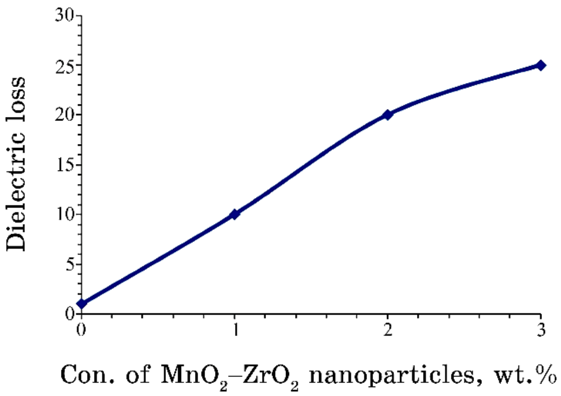


**Fig. 3.** Effect of $MnO_2$–$ZrO_2$ nanoparticles' concentration on dielectric loss for PVA.

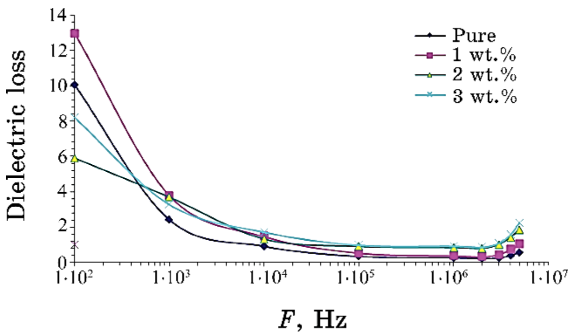


**Fig. 4.** Variation of dielectric loss for PVA–$MnO_2$–$ZrO_2$ nanocomposites with frequency.

in Fig. 3; this is related to the increase in the number of carriers of charge. When the concentration of nanoparticles exceeds a high ratio, the nanoparticles form a continuous network in the nanocomposites. These findings are identical to the previous investigator's results [38–40].

Figure 4 shows the dielectric loss as a function of frequency for PVA–$MnO_2$–$ZrO_2$ nanocomposites; this figure indicates that the dielectric loss of nanocomposites decreases with a rise in the frequency of the applied electric field. This behaviour is due to a decrease in the contribution of the space charge polarization, as well as the high value of the dielectric loss for PVA–$MnO_2$–$ZrO_2$ nanocomposites at low frequencies [41–44].

Figure 5 shows the variation of A.C. electrical conductivity of PVA–$MnO_2$–$ZrO_2$ nanocomposites; the A.C. conductivity slightly increases at low concentrations of $MnO_2$–$ZrO_2$ nanoparticles. The

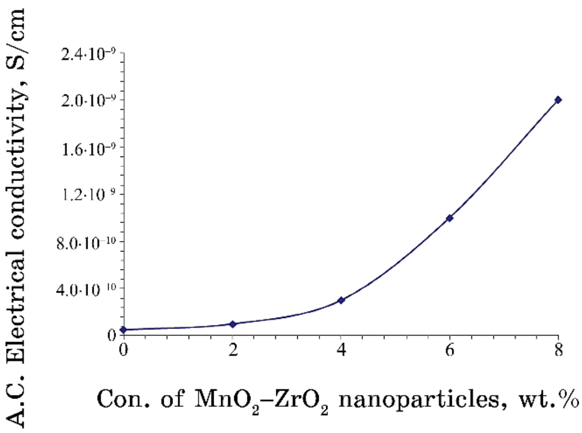


**Fig. 5.** Effect of $MnO_2$–$ZrO_2$ nanoparticles' concentration on A.C. electrical conductivity for PVA.

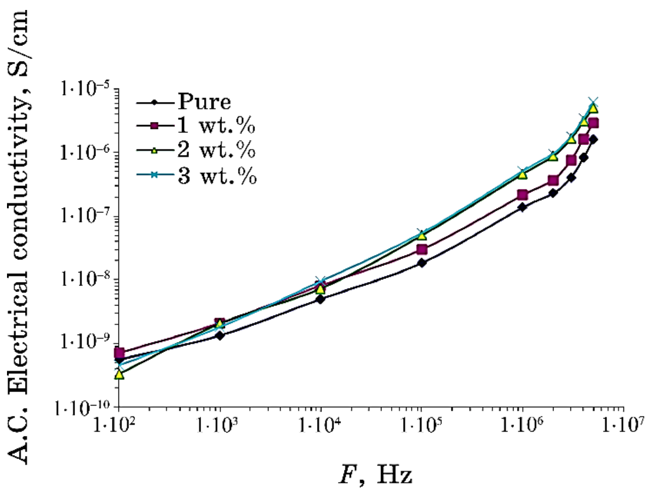


**Fig. 6.** Variation of A.C. electrical conductivity for PVA–$MnO_2$–$ZrO_2$ nanocomposites with frequency.

conductivity is increases with the increasing of the concentration of $MnO_2$–$ZrO_2$ nanoparticles, because of the increase of the charge carriers and the formation of a continuous network of $MnO_2$–$ZrO_2$ nanoparticles inside the nanocomposites [45–47].

Figure 6 shows the plot of the variation of A.C. electrical conductivity of PVA–$MnO_2$–$ZrO_2$ nanocomposites with frequency at room temperature. The A.C. electrical conductivity increases with increasing of frequency of electric field for all the samples of nanocomposites, where the frequency acts as a pumping force, pushing the charge carriers between the different conduction states [48, 49].

## 4. CONCLUSIONS

This work includes synthesis of PVA–$MnO_2$–$ZrO_2$ nanocomposite and studying the dielectric properties to use in different electrical applications. The results show that dielectric constant, dielectric loss and A.C. electrical conductivity increase as the content of $MnO_2$–$ZrO_2$ increases. The dielectric constant and dielectric loss reduce as the frequency rises, while the A.C. electrical conductivity increases. According to the findings, the PVA–$MnO_2$–$ZrO_2$ nanocomposites may be used in different optoelectronics applications.

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