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Investigating the A.C. Electrical Properties of PVA/PEG/CeO_2 Nanocomposites for Dielectric Applications

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Films of PVA/PEG/CeO_2 nanocomposites are fabricated to be used in different electronic applications. The A.C. electrical properties of PVA/PEG/CeO_2 nanocomposites are studied. The dielectric properties are examined at frequencies from 100 Hz to 5 MHz. The experimental results indicate that the A.C. electrical properties of PVA/PEG/CeO_2 nanocomposites are enhanced with increase in the CeO_2 nanoparticles' content. The dielectric parameters are changed with rise in the frequency.

Плівки нанокомпозитів PVA/PEG/CeO_2 (полівініловий спирт–поліетиленгліколь–наночастинки CeO_2) виготовляються для використання в різних електронних застосуваннях. Вивчено електричні властивості нанокомпозитів PVA/PEG/CeO_2. Діелектричні властивості досліджуються на частотах від 100 Гц до 5 МГц. Експериментальні результати показують, що електричні властивості нанокомпозитів PVA/PEG/CeO_2 підвищуються зі збільшенням вмісту наночастинок CeO_2. Параметри діелектрика змінюються з підвищенням частоти.

Key words: PVA/PEG, CeO_2 nanoparticles, nanocomposites, electrical properties, conductivity.

Ключові слова: полівініловий спирт/поліетиленгліколь, наночастинки CeO_2, нанокомпозити, електричні властивості, провідність.

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1. INTRODUCTION

Polymer composites are polymers containing modifiers that are utilized as passive and active layers in optoelectronic devices, such as solar cells, light-emitting diodes (LED), optical waveguides materials, and photochromic materials [1].

Polyvinyl alcohol (PVA) is a synthetic, non-toxic biocompatible, semi-crystalline polymer having good transparency, high dielectric strength, and fast charge transfer at electrode–electrolyte interface. Due to its excellent optical and physical properties, PVA is successfully used in a wide range of industrial field [2]. PVA being a hydrophilic–organic polymer has fascinated the interest of materials scientists due to its variety of applications in food packaging, humidity sensors, thin-film transistors, fuel cells, and so on [3]. Moreover, PVA has a carbon-chain backbone with hydroxyl group that is a source of hydrogen bonding to improve the development of polymer complexes.

Furthermore, polyethylene glycol (PEG) has significant features such as superb water solubility, being good protein adsorption resistance and low toxicity; therefore, it is used in several applications such as a coating material for biotechnical applications [4].

CeO_2 is one of the most attractive rare-earth metal oxides. It has several applications in the field of corrosion prevention, electrochemical cells, electromagnetic shielding, thermal coatings, optical and photoelectrical properties. Mostly, the rare-earth elements exist in trivalent state, but cerium exists in both trivalent (+3) state and tetravalent (+4) one. Because of its ability to alter oxidation state, it has the several applications such as catalytic converters and solid oxide fuel cells. In addition, CeO_2 has a great attention because of its unique features like nontoxicity, biocompatibility, oxygen storage capability, optical and thermal properties, which have significant applications in solar cells, gas sensors and biosensors [5].

This paper deals with preparation of PVA/PEG/CeO_2 nanocomposites for films to be employed in different electronic applications.

2. MATERIALS AND METHODS

Films PVA/PEG/CeO_2 nanocomposites were synthesized by using casting technique. The PVA/PEG blend was prepared with concentrations of 81 wt.% PVA and 19 wt.% PEG by dissolving of 1 gm of polymers in distilled water (30 ml). The CeO_2 nanoparticles (NPs) were added to the polymer blend with contents of 1.5 wt.%, 3 wt.%, and 4.5 wt.%. The A.C. electrical properties of PVA/PEG/CeO_2 nanocomposites were measured within the frequency range 100 Hz–$5\cdot10^6$ Hz by LCR meter (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant (ε') of nanocomposite films was calculated by [6]:

$$\varepsilon' = C_p d/\varepsilon_0, \quad (1)$$

where C_p is matter capacitance, d is the thickness, A is the area (in cm^2).

Dielectric loss (ε'') was determined by [6]:

$$\varepsilon'' = \varepsilon' D, \quad (2)$$

where D is the dispersion factor.

The A.C. electrical conductivity was found by [7]:

$$\sigma_{A.C.} = \omega\varepsilon' D\varepsilon_0. \quad (3)$$

3. RESULTS AND DISCUSSION

Figures 1–4 show the variations of dielectric constant and dielectric loss of PVA/PEG/CeO_2 nanocomposites with frequency and CeO_2 NPs' concentration, respectively.

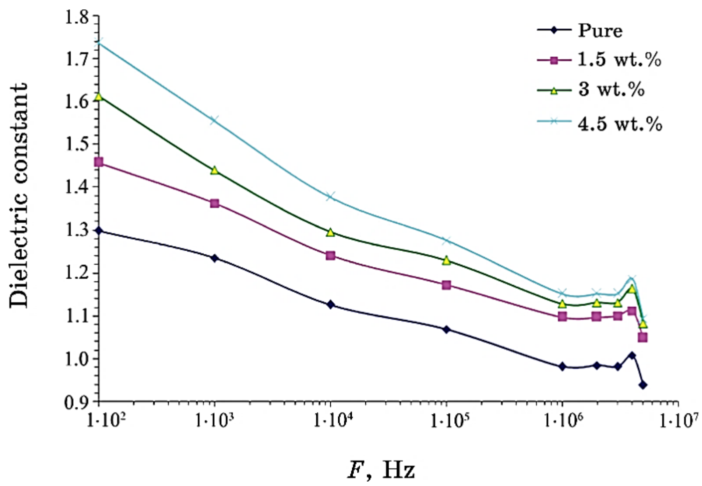

Fig. 1. Variation of dielectric constant of PVA/PEG/CeO_2 nanocomposites with frequency.

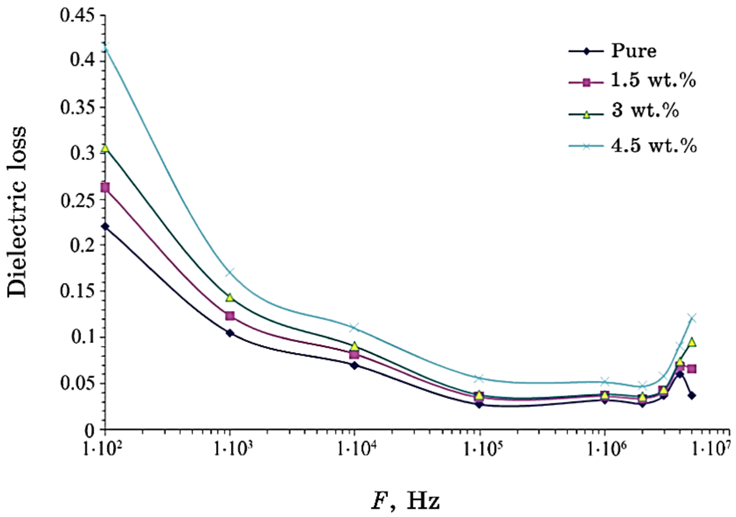

Fig. 2. Variation of dielectric loss of PVA/PEG/CeO_2 nanocomposites with frequency.

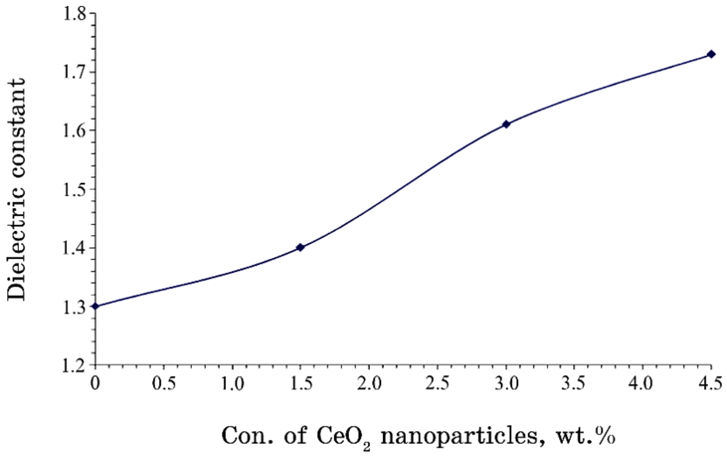

Fig. 3. Variation of dielectric constant of PVA/PEG blend with CeO_2 NPs' concentration.

The dielectric constant and dielectric loss are decreased with increase in the frequency. This is because the effect of space charge polarization has decreased. Because of the charge accumulated due to the polarization of the PVA/PEG/3 wt.% CeO_2 NPs' interfaces, more charges are generated, resulting in an increase in the number of charge carriers accumulated at the sample–electrode interface [8–14].

Figure 5 and Figure 6 represent the behaviour of A.C. electrical conductivity for PVA/PEG/CeO_2 nanocomposites with frequency and CeO_2 NPs' concentration, respectively. The conductivity increases with increase in frequency as well as CeO_2 NPs' concentration. This increase is attributed to the formation of excess charge carriers developed in the polymer matrix [15–24].

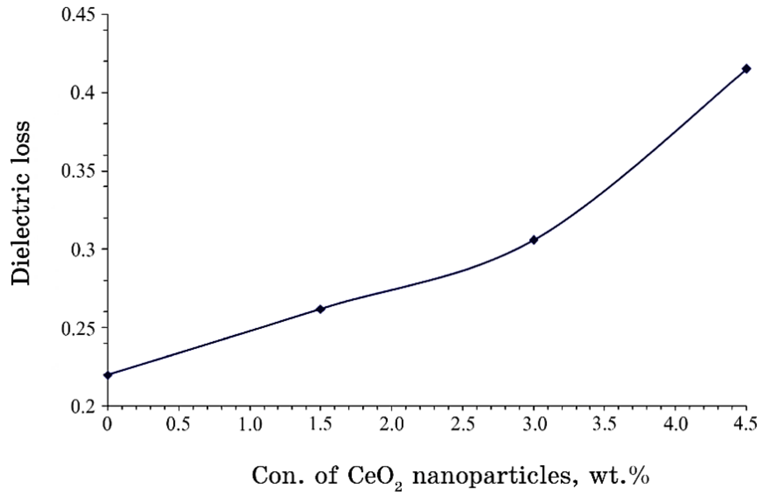

Fig. 4. Variation of dielectric loss of PVA/PEG blend with CeO_2 NPs' concentration.

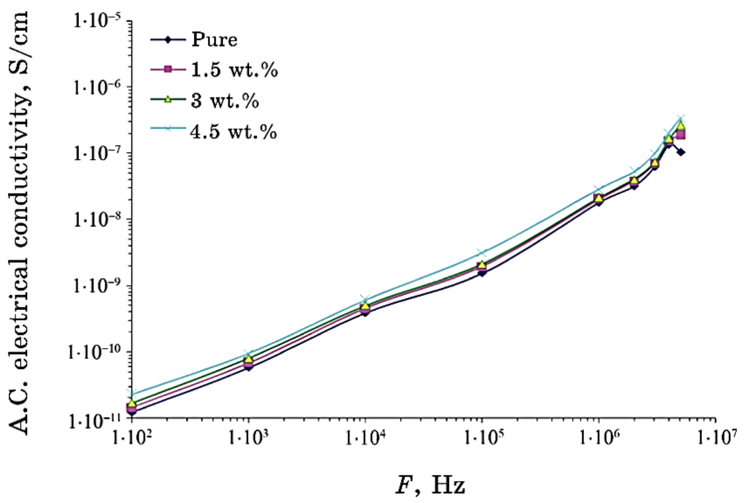

Fig. 5. Behaviour of A.C. electrical conductivity for PVA/PEG/CeO_2 nanocomposites with frequency.

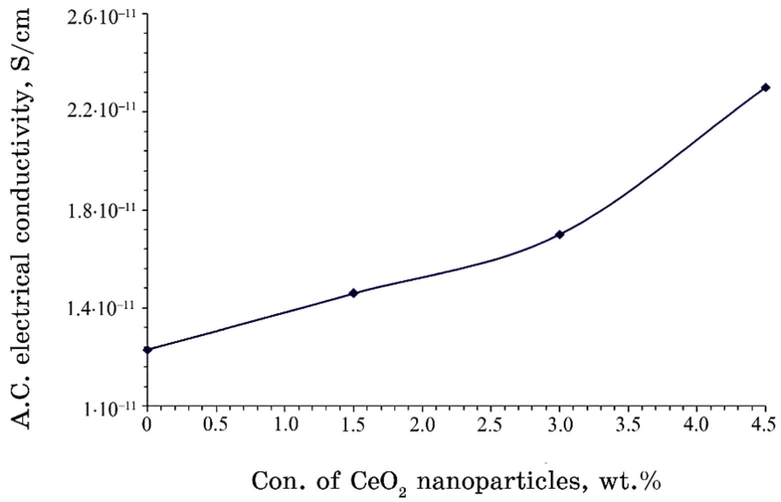

Fig. 6. Behaviour of A.C. electrical conductivity for PVA/PEG blend with CeO_2 NPs' concentration.

4. CONCLUSIONS

The current work includes studying the dielectric characteristics of PVA/PEG/CeO_2 nanocomposites to use for various electrical devices. The results indicated to enhance the dielectric properties of PVA/PEG with adding of the CeO_2 NPs' concentration. The dielectric constant, dielectric loss and A.C. electrical conductivity are changed with the increase in frequency.

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