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Improved Dielectric Properties of PVA/PEG/TiN Nanocomposites for Electronics Applications

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The dielectric properties of polyvinyl alcohol/polyethylene glycol/TiN (PVA/PEG/TiN) nanocomposites are studied to use them in different electronic nanodevices. The PVA/PEG/TiN nanocomposites' films are synthesized by using the casting method. The dielectric properties of PVA/PEG/TiN nanocomposites are tested at frequency (f) ranged from 100 Hz to 5 MHz. The results demonstrate that the dielectric properties of fabricated nanocomposites (ε', ε'' and $\sigma_{A.C.}$) are improved with increase in the TiN-nanoparticles' concentration. Components (ε' and ε'') of complex dielectric constant are decreased, while the A.C. electrical conductivity ($\sigma_{A.C.}$) is increased with increase in the frequency. The results indicate that the PVA/PEG/TiN nanocomposites can be useful in different electronic nanodevices.

Вивчено діелектричні властивості нанокомпозитів полівініловий спирт/поліетиленгліколь/TiN (PVA/PEG/TiN) для використання їх у різних електронних нанопристроях. Плівки нанокомпозитів PVA/PEG/TiN синтезуються методом лиття. Діелектричні властивості нанокомпозитів PVA/PEG/TiN перевіряються на частоті (f) від 100 Гц до 5 МГц. Результати показують, що діелектричні властивості виготовлених нанокомпозитів (ε', ε'' і $\sigma_{A.C.}$) поліпшуються зі збільшенням концентрації TiN-наночастинок. Компоненти (ε' і ε'') комплексної діелектричної проникности зменшуються, тоді як електропровідність змінного струму ($\sigma_{A.C.}$) збільшується зі збільшенням частоти. Результати показують, що нанокомпозити PVA/PEG/TiN можуть бути корисні в різних електронних нанопристроях.

Key words: nanocomposites, TiN, blend, electrical conduction, nanoelectronic devices.

Ключові слова: нанокомпозити, TiN, суміш, електропровідність, наноелектронні пристрої.

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1. INTRODUCTION

In recent years, semiconductor nanoparticles (NPs) have been extensively studied due to their novel properties, which are greatly different from those of their bulk materials. Nowadays, semiconductor-polymer nanocomposites have attracted growing interest because these materials offer new performance by combining properties from both the semiconductor and the polymer matrix. The nanoparticles exhibit unique properties, due to quantum size effects and the large number of unsaturated surface atoms. The polymeric matrix provides additional qualities such as the processability, solubility and thermal stability of the systems [1]. Dielectrics with high permittivity are widely used in electronic industry. With the advancement of flexible electronics, high permittivity dielectric materials with excellent flexibility are in demand. As compared to conventional dielectrics like ceramics, polymers are widely being used as dielectric materials as polymers exhibit better properties, like relatively high electric breakdown field, processing ease, mechanical flexibility, *etc*. Moreover, their properties can be modified by incorporating inorganic materials into it [2].

Polyvinyl alcohol (PVA) anions are suitable bridging ligands for constructing network coordination polymers. PVA is a semicrystalline polymer and its crystalline index depends on the synthetic process and physical aging. It has gained increasing attention in the biomedical field due to bioinertness [3]. It has various properties such as glossy nature, adhesive and easy film forming ability. In PVA, presence of hydrogen bonding between hydroxyl groups is very important for its high water solubility and high crystal modulus. Normally, PVA is a poor electrical conductor it can become conductive, when it is added with other polymer. Polymer composites are the materials in which different systems are combined to achieve a system with improved functional properties such as physical, optical, thermal, and electrical properties. The improvement in these properties depends on the chemical nature of the nanomaterial and the way, in which it interacts with the polymer [4].

Polyethylene glycol (PEG) is a hydrophilic and non-toxic polymer, having tremendous properties like electron acceptor nature, biocompatibility, chain flexibility and a wide range of molecular weight. PEG is widely used to increase the ductility and flexibility of rigid polymers [5].

Transition metal nitrides form a wide range of refractory materials. Because of their high hardness and mechanical strength, they are used as abrasives and high-T structural components, and they provide protective coatings for metals and ceramics, including biocompatible surgical tools and implants [6].

This paper aims to prepare of PVA/PEG/TiN nanocomposites to use in different electronics nanodevices.

2. MATERIALS AND METHODS

Nanocomposites films of polyvinyl alcohol (PVA)/polyethylene glycol (PEG)/titanium nitride (TiN) were fabricated by casting method. The blend of PVA/PEG with ratio (81% PVA/19% PEG) was fabricated by dissolving of 1 gm in distilled water (30 ml). The titanium nitride NPs were added to the PVA/PEG with ratios 1.5%, 3%, and 4.5%. The dielectric characteristics of PVA/PEG/TiN films measured at $f = 100$ Hz to $5 \cdot 10^6$ Hz by LCR meter (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant, ε', of PVA/PEG/TiN films was determined in Ref. [7] as:

$$\varepsilon' = C_p d / (\varepsilon_0 A), \tag{1}$$

where C_p is capacitance of matter, d is thickness; A is defined in [cm^2].

The dielectric loss, ε'', was defined in Ref. [7] as:

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

where D represents the dispersion factor.

The A.C. electrical conductivity was given in Ref. [8]:

$$\sigma_{\text{A.C.}} = 2\pi f \varepsilon' D \varepsilon_0. \tag{3}$$

3. RESULTS AND DISCUSSION

Figures 1, 2 represent the variations of dielectric constant and dielectric loss of PVA/PEG/TiN nanocomposites with frequency respectively. The dielectric constant values reduce with incremental frequency, resulting in the dipole no longer being able to rotate

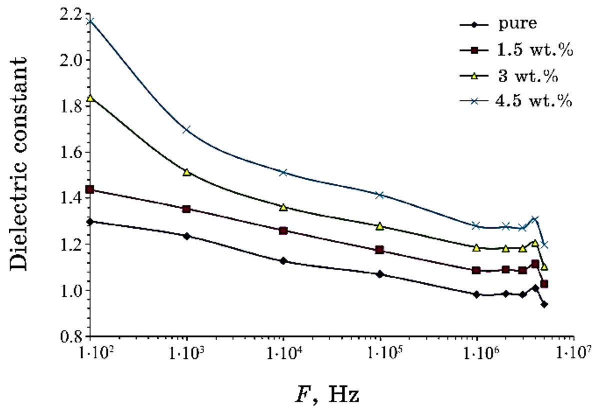

Fig. 1. Dielectric constant variation with frequency for the PVA/PEG/TiN nanocomposites.

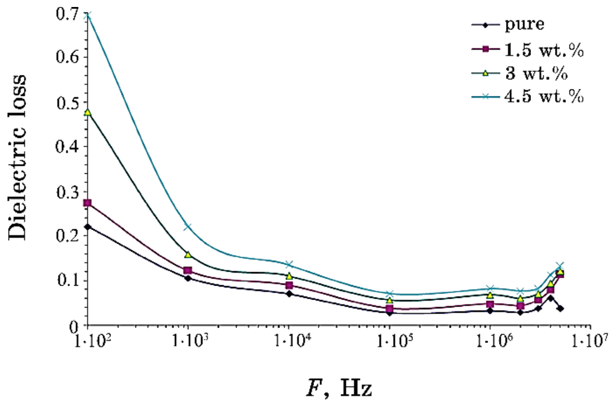

Fig. 2. Dielectric loss variation with frequency for the PVA/PEG/TiN nanocomposites.

properly and easily, such that its oscillation begins to lie after this field. The dielectric loss was found to be reduced as a function of frequency increase since the movement of ions considered as the main foundation of nanocomposite dielectric loss at lower frequencies. Consequently, the high dielectric loss value at lower frequency values designates the influence of ion jumping and the loss of ion movement conduction, and the loss of ion polarization [9–14].

Figures 3, 4 show the behaviours of dielectric constant and dielectric loss of PVA/PEG blend with concentration of TiN NPs respectively. As shown in these figures, the dielectric constant and dielectric loss are increased with increase in the TiN NPs content which are due to increase in the charge-carriers' numbers [15, 16].

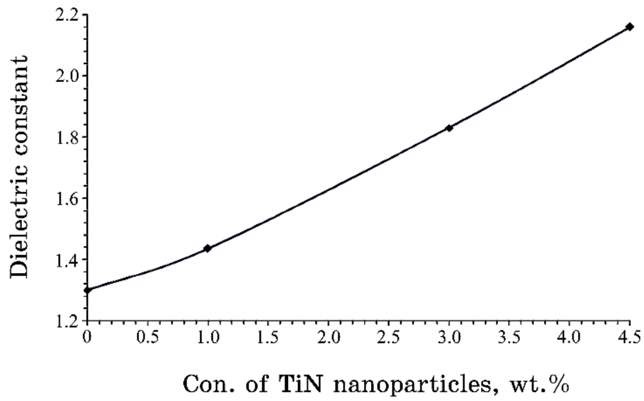

Fig. 3. Behaviour of dielectric constant of PVA/PEG blends with ratio of TiN NPs.

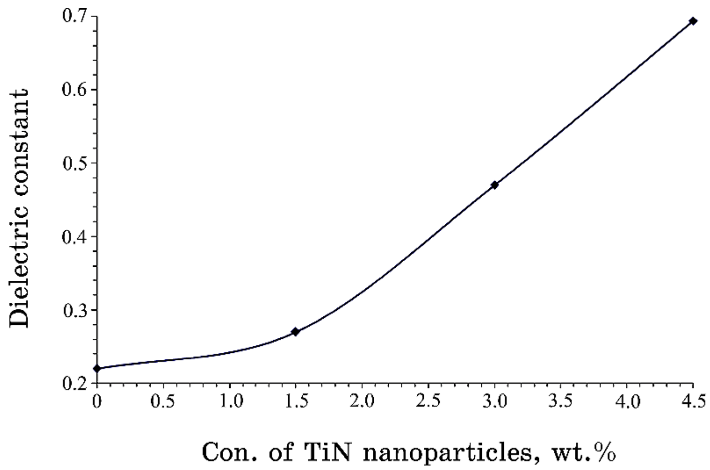

Fig. 4. Behaviour of dielectric loss of PVA/PEG blends with ratio of TiN NPs.

Figure 5 shows the variation of A.C. electrical conductivity of PVA/PEG/TiN nanocomposites with frequency. Generally, the number of charge carriers, which have high relaxation time due to higher energy barrier and respond in low frequency regime, might be less in number; hence, the conductivity is lower at lower frequencies. However, the number of charge carriers with low barrier heights is bigger and they respond easily with high frequency and showed higher conductivity at higher frequencies [17–20].

Figure 6 shows the effect of TiN-NPs' concentration on electrical conductivity of PVA/PEG blend. The electrical conductivity of

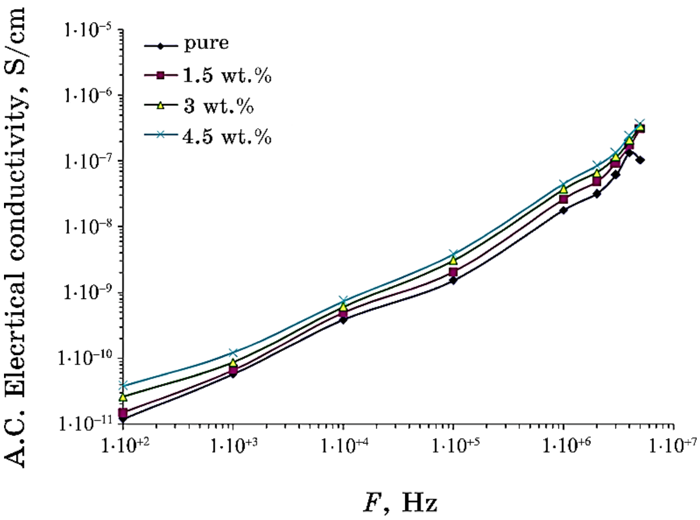

Fig. 5. Variation of A.C. electrical conductivity of PVA/PEG/TiN nanocomposites with frequency.

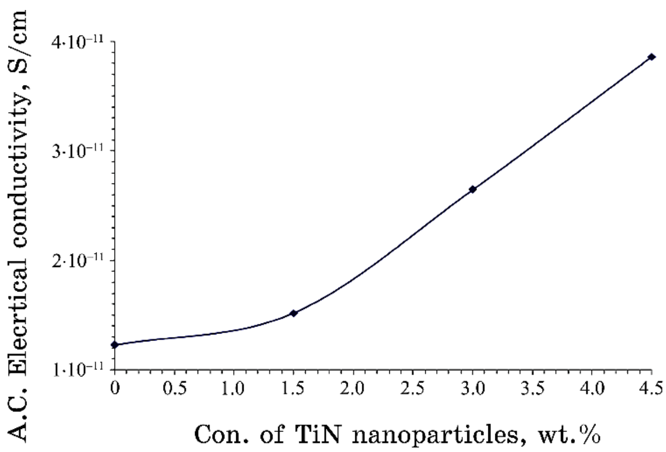

Fig. 6. Variation of A.C. electrical conductivity of PVA/PEG blends with TiN-NPs' ratio.

PVA/PEG blend increases with increase in the TiN NPs' concentration [wt.%] that is attributed to rise in the charge carriers and forming a network inside polymer blend [21–25].

4. CONCLUSIONS

In this work, the PVA/PEG/TiN nanocomposites were prepared by casting method. The A.C. electrical properties of PVA/PEG/TiN nanocomposites are investigated in frequency range from 100 Hz to 5 MHz. Results showed that the dielectric properties of PVA/PEG blend are improved with the increase in TiN-NPs' content. The dielectric constant and dielectric loss of PVA/PEG/TiN nanocomposites are reduced, while the A.C. electrical conductivity is increased with the increase in frequency.

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