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Synthesis and Improved Dielectric Properties of PVA/PVP/TaC Nanocomposites for Electronics Nanodevices

Ahmed Hashim[1], Aseel Hadi[2], and Noor Al-Huda Al-Aaraji[3]

[1]*College of Education for Pure Sciences,*
Department of Physics,
University of Babylon,
Hillah, Iraq
[2]*College of Materials Engineering,*
Department of Ceramic and Building Materials,
University of Babylon,
Hillah, Iraq
[3]*Department of Medical Physics,*
Al-Mustaqbal University College,
Babylon, Iraq

In present work, the PVA/PVP/TaC nanocomposites' films are synthesized to employ in various electronics nanodevices. The A.C. electrical properties of PVA/PVP/TaC nanocomposites are studied within the frequency range from 100 Hz to 5 MHz. The results show that dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PVP blend increase with rising of the TaC nanoparticles' ratio. Both the dielectric constant and the dielectric loss of PVA/PVP/TaC nanocomposites decrease, while the A.C. electrical conductivity increases with an increase in the TaC nanoparticles' ratio. Finally, the results on A.C. electrical properties indicate that the PVA/PVP/TaC nanocomposites may be useful for various electronics fields.

У даній роботі синтезуються плівки нанокомпозитів полівініловий спирт (ПВС)/полівінілпірролідон (ПВП)/TaC для використання в різних електронних нанопристроях. Досліджено електричні властивості нанокомпозитів ПВС/ПВП/TaC за змінного струму в діяпазоні частот від 100 Гц до 5 МГц. Результати показують, що діелектрична проникність, діелектричні втрати та електропровідність змінного струму суміші ПВС/ПВП зростають зі збільшенням співвідношення наночастинок TaC. Як діелектрична проникність, так і діелектричні втрати нанокомпозитів ПВС/ПВП/TaC зменшуються, тоді як електропровідність змінного струму зростає зі збільшенням співвідношення наночастинок TaC. Нарешті, результати щодо електричних властивостей змінного струму вказують на те, що нанокомпозити ПВС/ПВП/TaC можуть бути корисними для різних галузей електроніки.

Key words: PVA/PVP, TaC, nanocomposites, dielectric properties, conductivity.

Ключові слова: полівініловий спирт/полівінілпірролідон, TaC, нанокомпозити, діелектричні властивості, провідність.

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1. INTRODUCTION

In the last decade, polymer composites have been paying exclusive attention due to their potential role in a variety of disciplines. Polymers have gained this level of concern because of their attractive features like flexibility, abundance, and cost savings. Moreover, the ability to modify their properties qualifies them effectively to serve in many applications. This goal can be achieved by either blending several homopolymers or filling them with specific materials to match specific uses. These applications comprise optoelectronics, light emitting diodes (LEDs), photovoltaics, shielding, energy storage, bio and medical ones [1].

Polymer composites as sustainable materials are utilized in wide ranges of applications in the prospect of their ample variety of chemical compositions, room temperature characteristics, applicability, their probable reusability together with the facility of construction and economy. Among this class of materials, polymer nanocomposites have gained considerable focus due to the increasing demand for more slender weight and exorbitantly performing substances, especially in automobile, aerospace, and defence research [2].

Polyvinyl alcohol (PVA) gained widespread attention, as it is water soluble, nontoxic, non-carcinogenic, biodegradable, biocompatible and optically transparent with high charge storage ability, and it has wonderful film-forming attributes. Due to the abundant hydroxyl groups, it is capable of resisting agglomerations with nanofillers and thus facilitates uniform dispersion of nanofillers in its matrix, and this is the key factor for the improved properties of the nanocomposites. PVA, being soluble in water, can be easily fabricated in an eco-friendly manner. The PVA-based nanocomposites can be exploited for electric applications by selecting suitable nanofillers. From the literature, it is also evident that PVA has a pivotal role in fuel cells, coating materials, optoelectronic devices, adhesives, fuel cells, transparent electrode materials, *etc*. These applications stimulate an interest in improving the mechanical, thermal and dielectric properties of PVA. The properties of the PVA can be modified by the incorporation of various nanofillers into it [3].

Polyvinyl pyrrolidone (PVP) has a high polar group, low toxicity, biodegradable and amorphous nature with good film properties. It has two interactive site N atom and C=O group. It acts as a protecting agent with other surfaces of inorganic compounds [4].

Tantalum carbide, TaC, demonstrates huge individual characteristics like very elevated melting point, elevated hardness, high elastic modulus, elevated density, and excellent chemical stability [5].

There are many studies on properties of polymers doped with different materials to employ in various applications like sensors [6, 7], optical, electronics and optoelectronics [8–23], antibacterial [24–26] and bioenvironmental and radiation shielding [27–33].

This work aims to prepare of PVA/PVP/TaC nanocomposites and studying their A.C. electrical properties to use in different electronics nanodevices.

2. MATERIALS AND METHODS

The nanocomposites have been prepared from polyvinyl alcohol (PVA) and polyvinyl pyrrolidone (PVP) doped with tantalum carbide nanoparticles (TaC NPs) by using casting technique.

The PVA/PVP film was synthesized by dissolving 0.5 gm of PVA/PVP with ratio 2:1 in the distilled water (20 ml). The TaC NPs were added to PVA/PVP blend with concentrations of 1, 2 and 3 wt.%.

The dielectric properties were measured in frequency ranged from 100 Hz to 5 MHz by LCR meter type (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant ε' of material is given by Ref. [34] as

$$\varepsilon' = C_p/C_0, \quad (1)$$

where C_p is capacitance and C_0 is vacuum capacitor.

The dielectric loss ε'' is defined by Ref. [35] as

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

where D is the dispersion factor.

The A.C. electrical conductivity is determined by Ref. [36] as

$$\sigma_{\text{A.C.}} = 2\pi f \varepsilon'' \varepsilon_0, \quad (3)$$

where $\omega = 2\pi f$ is the angular frequency.

3. RESULTS AND DISCUSSION

Figures 1 and 2 show the variation of dielectric constant and dielectric loss of PVA/PVP/TaC nanocomposites with frequency for different concentrations of TaC nanoparticles.

From these figures, the dielectric constant and dielectric loss decrease with an increased frequency in the low-frequency region. This is possibly due to the polarization effects of the electrode-

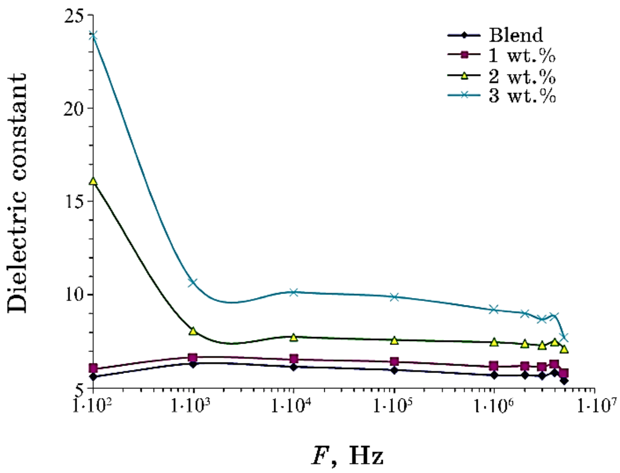

Fig. 1. Variation of dielectric constant for PVA/PVP/TaC nanocomposites with frequency.

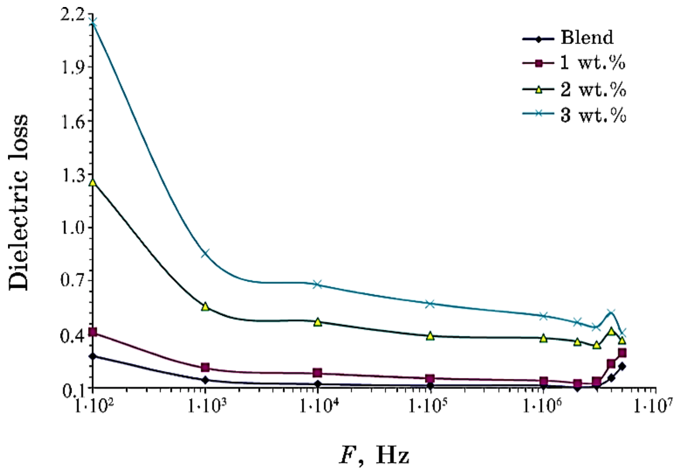

Fig. 2. Variation of dielectric loss for PVA/PVP/TaC nanocomposites with frequency.

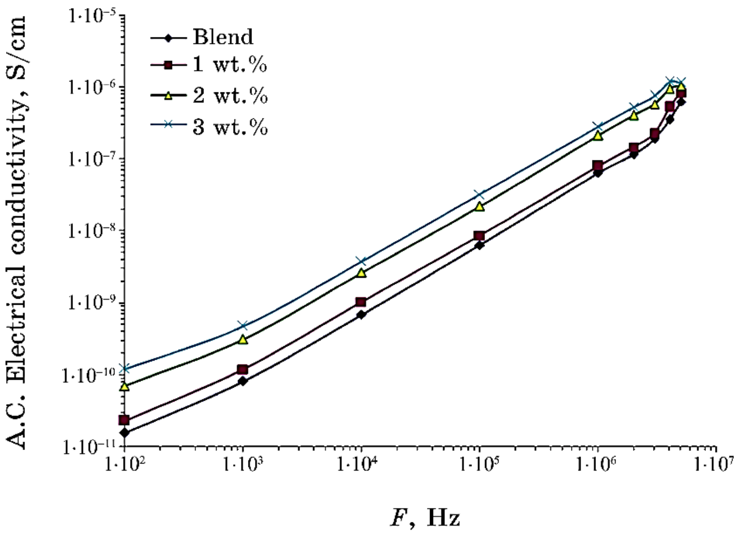

Fig. 3. Behaviour of A.C. electrical conductivity for PVA/PVP/TaC nanocomposites with frequency.

electrolyte interface [37]. The dielectric constant and dielectric loss of PVA/PVP blend are increased with an increase in the TaC nanoparticles' concentration; this is due to the due to raise the charge carriers' density in polymer medium [38].

Figure 3 represents the behaviour of A.C. electrical conductivity for PVA/PVP/TaC nanocomposites with frequency. As shown in this figure, the A.C. electrical conductivity of PVA/PVP/TaC nanocomposites increases with increasing of the frequency that is related to the effect of polarization and mechanism of hopping [39]. The A.C. electrical conductivity of PVA/PVP blend increases with increase in the TaC nanoparticles concentrations; this behaviour due to the increase in the charge carrier density in the polymer matrix and the space charge polarization contribution [40].

4. CONCLUSIONS

This study includes work on preparation of PVA/PVP/TaC nanocomposites' films to use in different electronics nanodevices. The A.C. electrical properties of PVA/PVP/TaC nanocomposites were tested at frequency range (from 100 Hz to 5 MHz). The results showed that dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PVP blend increased with an increase in the TaC NPs' content. The dielectric constant and dielectric loss of PVA/PVP/TaC nanocomposites decreased, while the A.C. electrical conductivity increased with increasing of the TaC NPs' content. The results indicate that the PVA/PVP/TaC nanocomposites may be useful for various electronics fields.

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