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Synthesis and Improved Dielectric Properties of PVP/TiN/Si_3N_4 Nanocomposites

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Nanocomposites of PVP/TiN/Si_3N_4 films are prepared with different concentrations to utilize in many industrial fields. The dielectric properties of PVP/TiN/Si_3N_4 nanocomposites are examined in the frequency range from 100 Hz to 5 MHz. The experimental results demonstrate that the dielectric constant, dielectric loss and electrical conductivity of PVP/TiN/Si_3N_4 nanocomposites increase with increasing concentration. In addition, the dielectric constant and dielectric loss of PVP/TiN/Si_3N_4 nanocomposites are reduced, while the conductivity is increased with rising frequency. Finally, the obtained results indicate that the PVP/TiN/Si_3N_4 nanocomposites can be considered as new nanomaterials to use in different electronics fields.

Нанокомпозити плівок полівінілпіролідон/TiN/Si_3N_4 було виготовлено з різними концентраціями для використання в багатьох галузях промисловости. Досліджено діелектричні властивості нанокомпозитів полівінілпіролідон/TiN/Si_3N_4 у діяпазоні частот від 100 Гц до 5 МГц. Експериментальні результати показали, що діелектрична проникність, діелектричні втрати й електропровідність нанокомпозитів полівінілпіролідон/TiN/Si_3N_4 зростають із збільшенням концентрації. Крім того, діелектрична проникність і діелектричні втрати нанокомпозитів полівінілпіролідон/TiN/Si_3N_4 зменшилися, а провідність зросла зі збільшенням частоти. Нарешті, одержані результати показали, що нанокомпозити полівінілпіролідон/TiN/Si_3N_4 можна розглядати як нові наноматеріяли для використання в різних областях електроніки.

Key words: TiN/Si_3N_4, dielectric properties, polyvinylpyrrolidone, elec-

tronics fields, nanocomposites.

Ключові слова: TiN/Si_3N_4, діелектричні властивості, полівінілпіролідон, електричні поля, нанокомпозити.

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1. INTRODUCTION

Polymer composites are a class of materials with prominent physicochemical properties, where a polymer acts as the matrix and micro-, macro-, or nanomaterials as the filler. Researchers have reported that nanofillers (*e.g.*, carbon nanotubes or nanosemiconductors) can improve some features of polymers, such as their electrical conductivity and mechanical behaviour. Accordingly, polymer nanocomposites (PNCs) are interesting for the industry due to their enhanced properties and have been receiving applications in fields such as environmental remediation, energy storage, and biomedicine [1].

Polymers have been widely used in various applications due to outstanding properties such as their low cost, stability, easy fabrication, *etc*.

The advantages of polymer matrix composites include their low cost and straightforward fabrication processes. Furthermore, polymer composites can be used as the primary material to create lightweight, flexible electronics, which is advantageous considering consumer demand [2].

Polyvinylpyrrolidone (PVP) has a good stable environment, easy processing, and moderate electric conductivity. It has a wide range of applications such as electrochemical devices (batteries, displays) [3].

Silicon nitride (Si_3N_4) is amid the mainly significant ceramic materials for elevated-temperature fields because of its combination of mechanical properties at room and elevated temperatures, resistance to oxidation, low thermal expansion coefficient, and low density compared of refractory metals [4].

Titanium nitride (TiN) shows excellent chemical resistance, superior electrical conductivity, and good adhesion with most materials [5].

The nanocomposites consisting of nanostructure doped with different materials have numerous applications in different fields like optical fields [6–15], energy storage [16–18], sensors [19–20], electronics and optoelectronics [21–35], antibacterial [36–41], radiation shielding and bioenvironmental [42–47].

The present work objects to prepare the $PVP/TiN/Si_3N_4$ nanocomposites' films to employ in many industrial applications.

2. MATERIALS AND METHODS

The used nanomaterials in this work are TiN and Si_3N_4 nanoparticles (NPs) as filler and PVP as matrix. The films of PVP/TiN/Si_3N_4 nanocomposites were prepared using casting process with various concentrations of 12.5 gm/L, 25 gm/L, and 50 gm/L with ratio of TiN/Si_3N_4 NPs (6 wt.%) and content of 50% TiN and 50% Si_3N_4. The dielectric properties of PVP/TiN/Si_3N_4 nanocomposites' films were examined at frequency ranged from 100 Hz to 5 MHz using LCR meter (HIOKI 3532-50 LCR HI TESTER). The dielectric constant (ε′) is found by [48] as follows:

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

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

Dielectric loss (ε″) is calculated by [49] as follows:

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

where D is the dispersion factor. The A.C. electrical conductivity is given by [50]:

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

4. RESULTS AND DISCUSSION

Figures 1–4 demonstrate the difference in the dielectric constant and dielectric loss with frequency and concentration for PVP/TiN/Si_3N_4 nanocomposites' films, respectively.

The dielectric constant and dielectric loss rise with increasing concentration; this behaviour is due to rise in number of charges' carriers. The high values of dielectric constant and dielectric loss at lower frequencies were assigned to the availability of enough time for the dipoles to interact with the fields before it changes, while the values of dielectric constant and dielectric loss decrease at higher frequencies due to the shorter time available to them [51–65].

The electrical conductivity performance with concentration and frequency for PVP/TiN/Si_3N_4 nanocomposites are shown in Figs. 5 and 6, respectively. The electrical conductivity increases with an increase in the concentration and frequency. The rise of electrical conductivity as the concentration increases due to increase in the charge-carriers' numbers. The frequency-dependent conductivity is caused by the hopping of electrons in the localized states near the Fermi level and due to the excitation of charge carriers to the

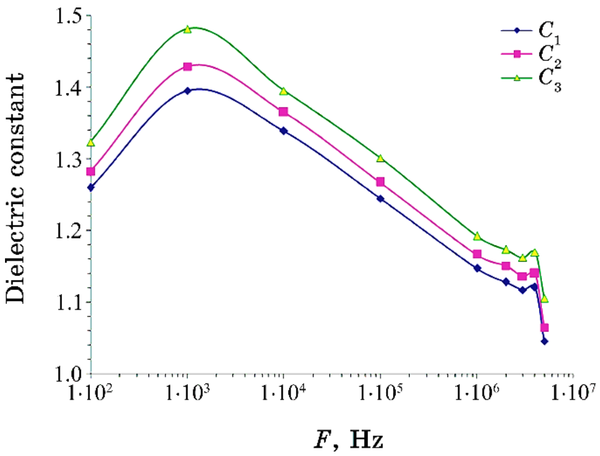

Fig. 1. Difference in the dielectric constant with frequency for PVP/TiN/Si_3N_4 nanocomposites.

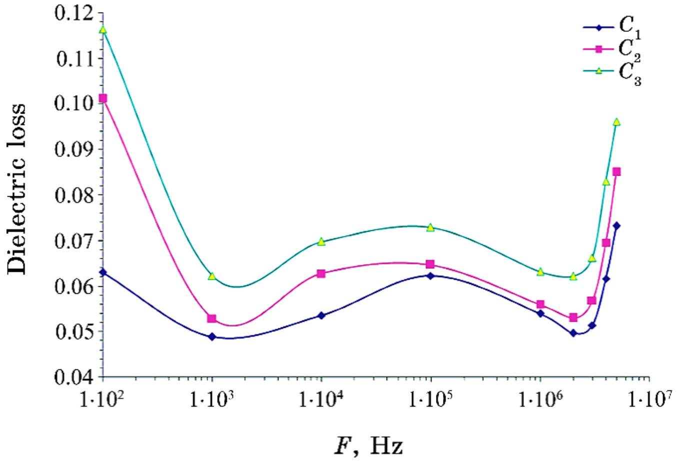

Fig. 2. Variation of dielectric loss with frequency for PVP/TiN/Si_3N_4 nanocomposites.

states in the conduction band [66–70].

5. CONCLUSIONS

This work includes fabrication of PVP/TiN/Si_3N_4 nanocomposites' films with various concentrations to utilize in different industrial applications.

The dielectric properties of PVP/TiN/Si_3N_4 nanocomposites were

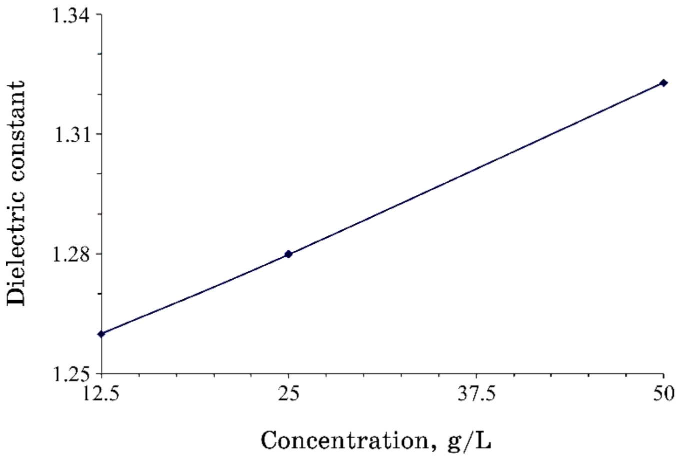

Fig. 3. Dielectric constant variation with concentration for PVP/TiN/Si_3N_4 nanocomposites.

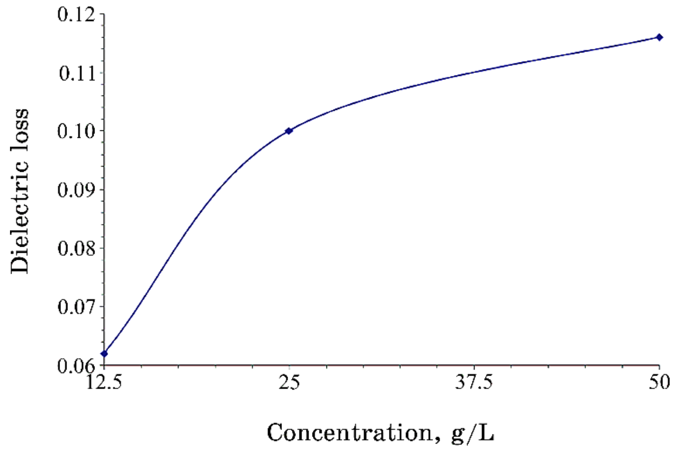

Fig. 4. Performance of dielectric loss with concentration for PVP/TiN/Si_3N_4 nanocomposites.

examined in the frequency range of 100 Hz–5 MHz. The results showed that the dielectric constant, dielectric loss and electrical conductivity of PVP/TiN/Si_3N_4 nanocomposites are increased with increasing concentration. The dielectric constant and dielectric loss of PVP/TiN/Si_3N_4 nanocomposites are reduced, while the conductivity is increased with rising frequency.

The results illustrate that the PVP/TiN/Si_3N_4 nanocomposites may be considered as new nanomaterials to employ in various electronics applications.

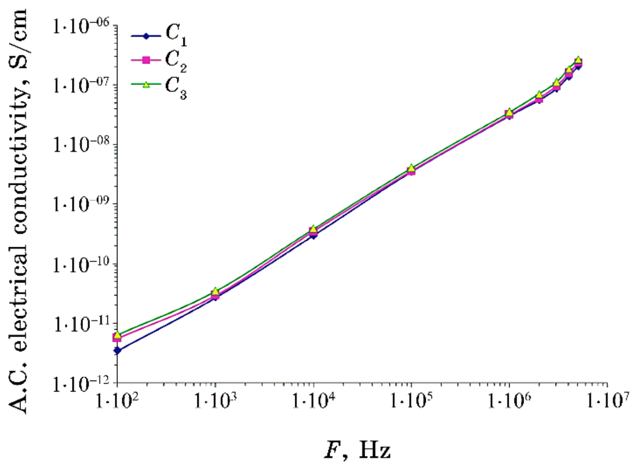

Fig. 5. Electrical conductivity performance with frequency for PVP/TiN/Si_3N_4 nanocomposites.

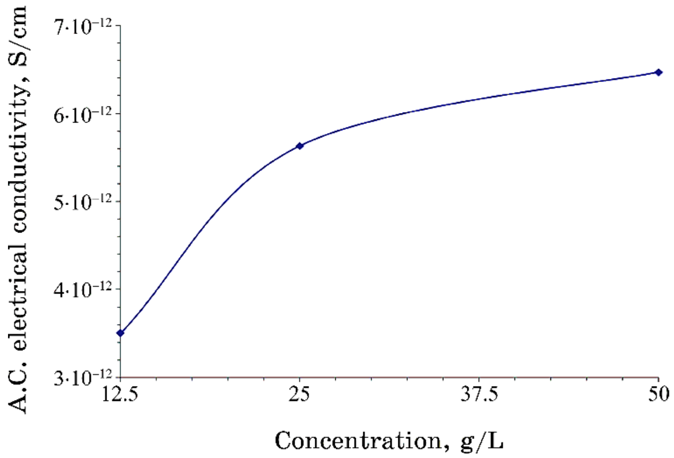

Fig. 6. Variation of electrical conductivity with concentration for PVP/TiN/Si_3N_4 nanocomposites.

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