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Improving the Structural and Optical Properties of PVP Doped with TiN Nanoparticles for Industrial and Bioenvironmental Applications

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Films of PVP doped with TiN nanoparticles are fabricated. The structure and optical characteristics are studied to apply the nanocomposites for industrial and bioenvironmental applications like humidity sensors, diodes, antibacterial coating, biosensors and UV-shielding. The results show that the optical characteristics are enhancing with the rising in TiN nanoparticles' ratio. The results indicate that the PVP/TiN nanocomposites may be used in various biomedical and bioenvironmental fields.

Виготовляються плівки полівінілпіролідону (ПВП), леґовані наночастинками TiN. Структура й оптичні характеристики вивчаються для використання нанокомпозитів у промислових і біосередовищних застосуваннях, таких як датчики вологости, діоди, антибактеріяльне покриття, біосенсори й УФ-екранування. Результати показують, що оптичні характеристики посилюються зі зростанням співвідношення наночастинок TiN. Результати вказують на те, що нанокомпозити ПВП/TiN можуть використовуватися в різних біомедичних і біосередовищних полях.

Key words: nanocomposite, biopolymer, TiN, biomedical field, optical properties.

Ключові слова: нанокомпозит, біополімер, TiN, біомедичне поле, оптичні властивості.

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1. INTRODUCTION

Bionanocomposites are well known as a new type of advanced materials. In these materials, the matrix of polymer, which contains polymers (synthetic or natural ones) or biomolecules, is believed the biological origin, while nanosize materials are considered as materials of value added. Novel nanocomposites characteristics may be get by successfully connected parent constituents' characteristics in an individual matter. These matters are various as mutually materials similar to pure natural polymers and inorganic nanoparticles (NPs) with several electronic, optical, and optoelectronic characteristics and widely used in optical fields like light-emitting diodes' lenses, optical switches, optical waveguides, and nonlinear optical devices. The nanocomposites include drawn much consideration related to their attractive optical characteristics, which are distinctive from the single polymers. The joint of inorganic NPs and organic polymer mutually display unexpected characteristics and improves the optical characteristics for nanocomposites, which very much vary from that of conventional matters [1].

Titanium nitride is a ceramic material with large hardness (of 2000 kg/mm^2), elevated temperature of decomposition (of 2949°C), defect structure (deviation from stoichiometry); it has superconductivity, and at room temperature, chemical stability. TiN is mostly employed as a coating to improve other materials [2].

Polyvinylpyrrolidone (PVP) is soluble in water and additional polar solvents. PVP is a hygroscopic powder; it easily obtains wet related to moisture absorbance in the atmosphere, during winter and rain seasons. The pyrrolidone group chooses to complex with several inorganic salts resulting in surface passivation and fine dispersion for the composites [3]. PVP has particular attention among the polymers related to its excellent stability with respect to environmental influence, appropriate electrical conductivity, and easy processability. The reactive pyrrolidone group (PVP) easily forms complexes with many inorganic salts, synthetic or natural functional polymers, biomolecules and biomacromolecules [4]. This work aims to prepare PVP/TiN nanocomposites to use them in biomedical and bioenvironmental fields.

2. MATERIALS AND METHODS

PVP–TiN nanocomposites were prepared by casting technique on glass slides. The solution of biopolymer was prepared by dissolving of 0.5 gm of PVP in distilled water (15 ml). Then, the TiN NPs were added to biopolymer solution with ratios of 1%, 2%, 3%. The optical characteristics were tested in wavelength range from 300 nm to 900 nm, using spectrophotometer (UV/1800/Shimadzu). Absorption coefficient is given [5] as follows:

$$\alpha = 2.303A/t, \quad (1)$$

where A—absorbance, t—sample thickness. The energy gap is determined [6] as follows:

$$\alpha h\nu = B(h\nu - E_g)^r, \quad (2)$$

where B—constant; $h\nu$—photon energy; E_g—energy gap; $r = 3$ for forbidden indirect transition, and $r = 2$ for allowed indirect transition. The optical conductivity/σop could be calculated as follows [7]:

$$\sigma_{op} = \frac{\alpha nc}{4\pi}. \quad (3)$$

3. RESULTS AND DISCUSSION

Figures 1 and 2 represent the absorbance and transmittance spectrums' variations for the PVP/TiN nanocomposites with wavelength. The absorbance of biopolymer rises with the rise in TiN NPs' content that is due to the rise in a number of charge carriers (as shown in Fig. 3) in PVP matrix; hence, the transmission will be decrease as exposed in Fig. 2.

The increase of absorbance in UV spectra and improving the absorption with the rise in TiN NPs make it be used in various fields like photovoltaic cell, transistors, solar cell, antibacterial coating

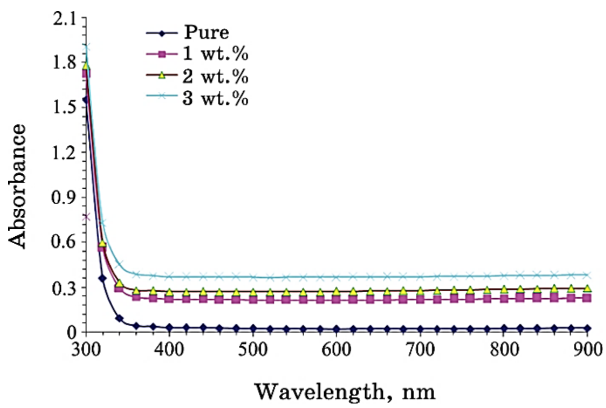

Fig. 1. Absorbance-spectrum variation for the PVP/TiN nanocomposites with wavelength.

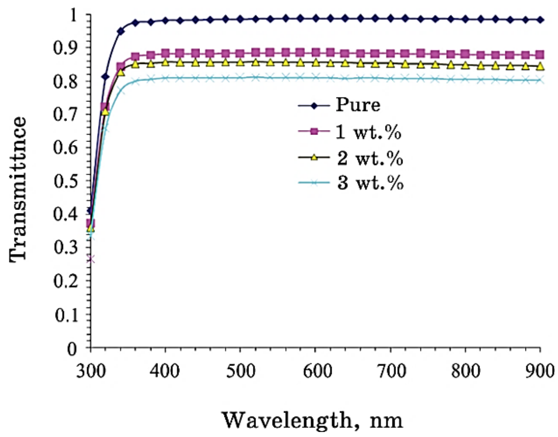

Fig. 2. Transmittance-spectrum variation for the PVP/TiN nanocomposites with wavelength.

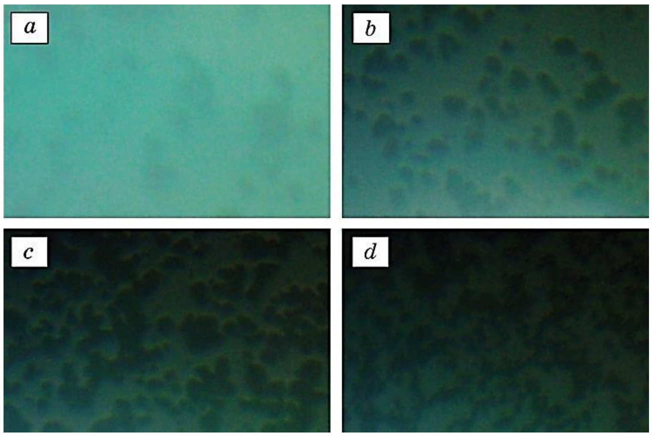

Fig. 3. Microscope images (×10): (*a*) PVP; (*b*) with 1 wt.% TiN; (*c*) with 2 wt.% TiN; (*d*) with 3 wt.% TiN.

and other modern applications. The behaviour of PVP/TiN nanocomposites with wavelength is consistent with Refs. [8–11].

The absorption-coefficient variation for the PVP/TiN nanocomposites with energy of photon is shown in Fig. 4. Absorption coefficient of biopolymer rises with rising of the TiN NPs' ratio that is related to the increase of the number of charge carriers [12] and manifests the energy-gap nature.

From the α values, the energy gap corresponds indirectly to allowed and forbidden transitions, as shown in Figs. 5 and 6, respectively.

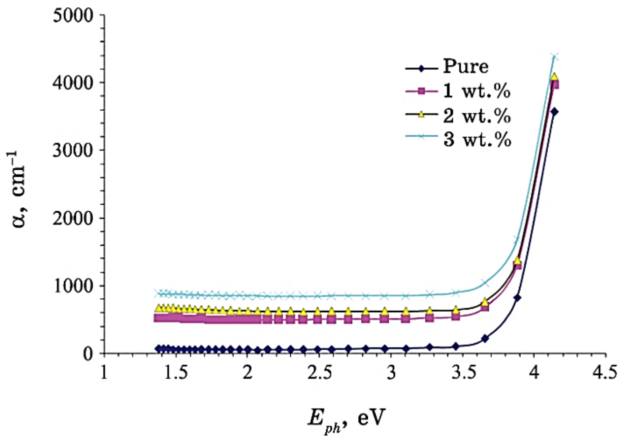

Fig. 4. Absorption-coefficient variation for the PVP/TiN nanocomposites with energy of photon.

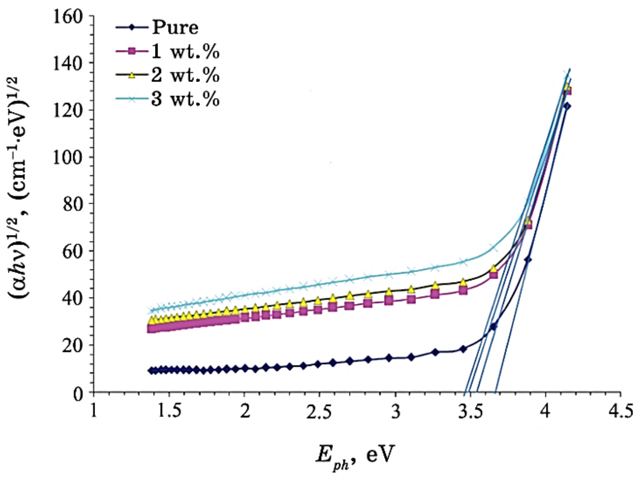

Fig. 5. Energy gap for the PVP/TiN nanocomposites (allowed transition).

The energy gap for both transitions (allowed and forbidden ones) is reduced with the rise in TiN NPs' content that is related to the creation of localized levels in the optical band gap [13, 14].

The optical-conductivity variation for the PVP biopolymer and TiN NPs-doped PVP with wavelength is shown in Fig. 7. The optical conductivity rises with raising the doping ratio and photon energy.

This behaviour due to the rise in TiN NPs increases the contribution of electron transitions between the conduction and valence bands as a result of rising localized-levels' density in the energy

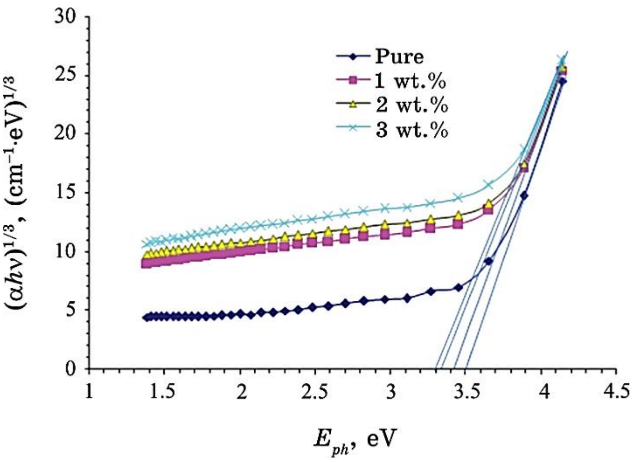

Fig. 6. Energy gap for the PVP/TiN nanocomposites (forbidden transition).

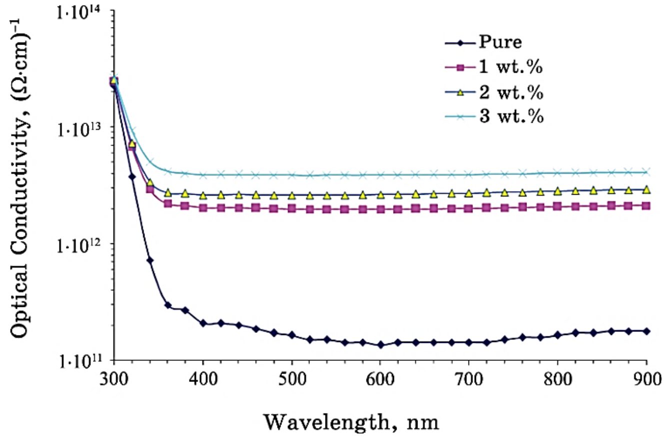

Fig. 7. Optical-conductivity variation for the PVP/TiN nanocomposites with wavelength.

gap that leads to both the energy-gap reduction and the rise of the absorption [15–18].

4. CONCLUSIONS

The present work includes synthesis of PVP/TiN nanocomposites and testing their structure and optical characteristics to be used in biomedical and bioenvironmental fields.

The results show the improving the structure and optical characteristics of biopolymer with rise in TiN NPs' ratio.

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