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Augmented Optical Properties of PVA/Ti/NiO Nanostructures for Photonics and Optical Applications

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The nanocomposites' films of metal/ceramics-doped polymers have huge applications in different modern industries. In this work, the Ti/NiO-nanoparticles-doped PVA is used to fabricate the PVA–Ti–NiO-nanocomposites' films. The optical properties of the PVA–Ti–NiO nanocomposites' films are studied. The results for optical properties illustrate that the PVA–Ti–NiO nanocomposites have elevated absorbance in ultraviolet region. The absorbance of PVA is raised, while the transmittance and energy band gap are decreased with rising Ti–NiO-nanoparticles' content. The results prove that the PVA–Ti–NiO-nanocomposites' films are appropriate for many nano- and optoelectronic fields.

Нанокомпозитні плівки з полімерів, леґованих металом і керамікою, мають широке застосування в різних сучасних галузях промисловости. У цій роботі було використано полівініловий спирт (ПВС), леґований наночастинками Ti/NiO, для одержання нанокомпозитних плівок ПВС–Ti–NiO. Було досліджено оптичні властивості нанокомпозитних плівок ПВС–Ti–NiO. Результати дослідження оптичних властивостей показали, що нанокомпозити ПВС–Ti–NiO характеризуються підвищеним вбиранням в ультрафіолетовому діяпазоні. Вбирання ПВС збільшувалося, тоді як пропускання та ширина забороненої енергетичної зони зменшувалися зі збільшенням вмісту наночастинок Ti/NiO. Остаточні результати довели, що нанокомпозитні плівки ПВС–Ti–NiO підходять для багатьох галузей нано- й оптоелектроніки.

Key words: PVA, Ti, NiO, nanocomposites, absorbance, transmittance, energy gap.

Ключові слова: полівініловий спирт, Ti, NiO, нанокомпозити, вбирання, пропускання, енергетична заборонена зона.

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1. INTRODUCTION

The production of novel polymeric nanocomposites have been widely studied by the current applications on nanosize inorganic fillers in the food packaging field, barrier applications, sensors, antimicrobial, conductive, coatings, antiballistic products and other materials. The characteristics and properties of the nanocomposites are influenced by the type of filler used as well as by the polymeric matrix. The applications encompass several areas such as electronic, medicine, military, aerospace, marine and vehicles [2]. Polyvinyl alcohol (PVA) is a biocompatible, biodegradable and non-toxic water-soluble polymer. This polymer is an excellent adhesive, has good organic solvent resistance and its resistance to oxygen passage is superior to that of any other known polymer. It is one of the few water-soluble semicrystalline polymers with good interfacial characteristics. It is widely used in the textile industry, in the packaging industry and in biomedical applications such as contact lenses, medication, orthopaedic materials, tissue engineering, and the manufacturing of artificial organs [2].

Transition metal oxides, such as nickel-oxide (NiO) nanoparticles, have recently received a lot of attention from researchers due to their low cost, stability, and optoelectronic characteristics. NiO is used in electrochemical capacitors, batteries, gas sensors, magnetic materials, and catalysis [3].

Titanium is an exceedingly attractive substance in the components to fabricate for a variety of fields ranging from implants of biomedical to automotive fuel injectors because of its lower density, elevated strength, superior resistance of corrosion and biocompatibility. The ratio of elevated strength and elevated corrosion resistance to weight make Ti and its alloys perfect substances for numerous fields [4].

The nanostructured materials and nanostructures-doped polymers have attractive properties to employ in various fields such as optical fields [5–12], sensors [13–19], thermal energy storage [20–28], *etc*. This work includes synthesis of PVA–Ti–NiO-nanocomposites' films and investigation of their optical properties to use in different photonic and electronic devices.

2. MATERIALS AND METHODS

The used materials in present work are PVA and Ti–NiO nanoparticles (NPs). Films of PVA–Ti–NiO nanocomposites were fabricated by pure PVA and PVA doped with Ti–NiO nanoparticles using casting technique. The pure PVA film was fabricated *via* dissolving of 1 gm of PVA in 30 ml of distilled water using magnetic stirrer to obtain solution that is more homogeneous. The PVA–Ti–NiO-nanocomposites' films were prepared by adding of Ti–NiO nanoparticles with contents of 1%, 2% and 3% to the PVA. The optical properties of PVA–Ti–NiO nanocomposites were tested using the double-beam spectrophotometer (Shimadzu, UV-1800Å) in wavelength 200–800 nm. The coefficient of absorption (α) was found as $\alpha = 2.303A/t$, where A is the absorbance and t is the film thickness [29]. The energy gap was determined as $\alpha h\nu = C\left(h\nu - E_g\right)^r$, where C is the constant, $h\nu$ is the photon energy, E_g is the energy gap, and $r = 2$ and 3 for allowed and forbidden indirect transitions [30].

3. RESULTS AND DISCUSSION

The performance of absorbance of PVA–Ti–NiO nanocomposites with photon wavelength is shown in Fig. 1. The PVA–Ti–NiO nanocomposites have high absorption within the UV-spectrum related to high energy of these photons. The optical absorption of PVA rises, when the Ti–NiO-NPs' ratio rises, that is due to increase in the

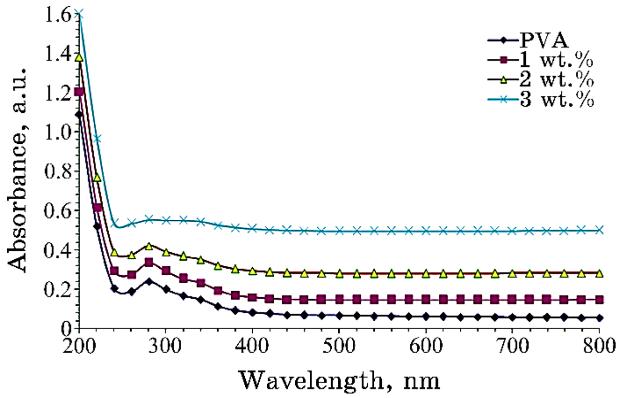

Fig. 1. Performance of absorbance for PVA–Ti–NiO nanocomposites with photon wavelength.

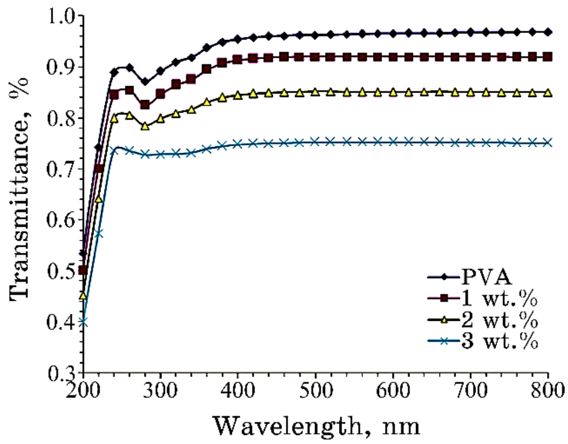

Fig. 2. Behaviour of transmittance for PVA–Ti–NiO nanocomposites with photon wavelength.

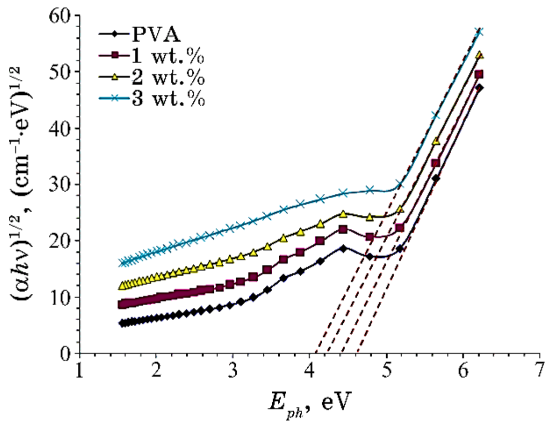

Fig. 3. Energy gap values of allowed indirect transition for PVA–Ti–NiO-nanocomposites' films.

density of charge carriers, which absorb the photons of incident light; hence, the optical transmission will be reduced as illustrated in Fig. 2. The nanostructures have high absorption and low transmission in the UV region that is related to the high energy of photons at these energies [31–44].

Figures 3 and 4 illustrate the energy gap of allowed and forbidden indirect transitions for PVA–Ti–NiO-nanocomposites' films, respectively. The E_g values for PVA are decreased with rising in the Ti–NiO-NPs' content due to the charges-complexes transfer between the functional groups of PVA and the Ti–NiO-NPs' atoms. The de-

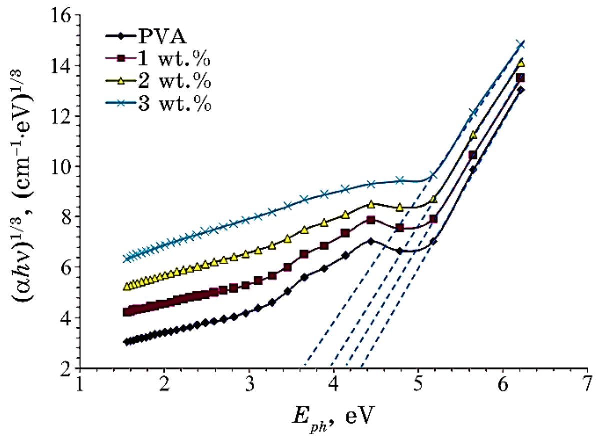

Fig. 4. Energy gap values of forbidden indirect transition for PVA–Ti–NiO-nanocomposites' films.

crease in the energy band gap values is suggested to rise with a disturbance degree producing the localized levels in the nanocomposites' structures that leads to reducing of the energy gap [45–57].

4. CONCLUSION

This study aims to prepare of PVA–Ti–NiO-nanocomposites' films. The optical properties of PVA–Ti–NiO-nanocomposites' films were studied. The results of optical properties showed that the PVA–Ti–NiO nanocomposites have high absorbance of UV-region photons. The absorbance of PVA was raised, while the transmittance and energy band gap were decreased with rising Ti–NiO-NPs' content. The results confirmed that the PVA–Ti–NiO-nanocomposites' films are suitable for numerous nano- and optoelectronic applications.

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