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Augmented Optical Properties of PVA–Fe_2O_3–In_2O_3 Nanocomposites for Optoelectronics Fields

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This work objects to synthesize of PVA–Fe_2O_3–In_2O_3 nanocomposites and investigating their optical characteristics to employ in various photonics and optics fields. The optical characteristics of PVA–Fe_2O_3–In_2O_3 nanocomposites are measured with wavelength ranged from UV to NIR spectra. The experimental results show that the absorbance and absorption coefficient of PVA are enhanced, when the Fe_2O_3–In_2O_3-nanoparticles' content is increased. The transmittance and energy gap of pure polymer are reduced, when the Fe_2O_3–In_2O_3-nanoparticles' content is raised. Finally, optical-properties' results illustrate that the PVA–Fe_2O_3–In_2O_3 nanocomposites may be considered as potential materials for optical devices.

Цю роботу спрямовано на синтезу нанокомпозитів ПВА–Fe_2O_3–In_2O_3 та дослідження їхніх оптичних характеристик для використання в різних областях фотоніки й оптики. Оптичні характеристики нанокомпозитів ПВА–Fe_2O_3–In_2O_3 виміряно в діяпазоні довжин хвиль від УФ- до близьких ІЧ-спектрів. Експериментальні результати показують, що спектральна поглинальна здатність і коефіцієнт поглинання ПВА зростають зі збільшенням вмісту наночастинок Fe_2O_3–In_2O_3. Коефіцієнт пропускання й енергетична щілина чистого полімеру зменшуються зі збільшенням вмісту наночастинок Fe_2O_3–In_2O_3. Нарешті, результати стосовно оптичних властивостей ілюструють, що нанокомпозити ПВА–Fe_2O_3–In_2O_3 можна розглядати як потенційні матеріяли для розробки оптичних пристроїв.

Key words: PVA–Fe_2O_3–In_2O_3 nanocomposites, absorbance, transmittance, energy gap.

Ключові слова: нанокомпозити ПВА–Fe_2O_3–In_2O_3, поглинальна здатність, пропускання, енергетична щілина.

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1. INTRODUCTION

Polymers have become important materials, in recent decades, in various research fields. This is as a result of their attractive characteristics, including flexibility, eco-friendliness, processing simplicity at low temperatures, and inexpensive cost. Moreover, there are fundamental technological applications of the energy-conversion processing of polymers such as solar cells, photovoltaics, and biosensors [1].

PVA is a well-known man-made green polymer with good mechanical strength, flexibility, transparency, film-forming ability, water solubility, biodegradability, and nontoxicity. They are widely used in the preparation of polymer nanocomposite, biomedical applications, and packaging applications [2].

The most versatile metal oxide nanostructure groups of semiconductor nanostructures stand out as one of the most diverse and most probably richest class of materials due to their extensive structural, physical and chemical properties and functionalities. In these times, metal oxides have been at the heart of many dramatic advances in the materials science. The ferrous oxide has four crystallographic phases, namely, hematite (α-Fe_2O_3) antiferromagnetic, maghemite (γ-Fe_2O_3) ferromagnetic, β-Fe_2O_3 and ε-Fe_2O_3. The thermodynamics stable hematite phase of Fe_2O_3 is a functional semiconductor ($E_g = 2.1$ eV), which is environmentally friendly, nontoxic and important in various field. It has been the widely investigated material due to its various applications in the field of photocatalyst, pigments, gas sensors, solar cells, electrochemical sensor and lithium ion batteries *etc.* [3].

Indium oxide In_2O_3 is an important n-type semiconductor. It has a wide band gap of approximately 3.6 eV, shows high transparency in the visible region and excellent electrical conductivity. Semiconductor nanomaterials with a wide band gap have potential applications in nonlinear optics and optoelectronics. It has fascinating properties such as strong interaction between certain poisonous gas molecules and its surfaces. These properties make In_2O_3 as a remarkable material for a variety of applications such as solar cells, liquid crystal displays, architectural glasses, gas sensors, flat panel display, and in photocatalytic conversions. To widen the technological applications of In_2O_3, investigations were made to synthesize them in different forms such as nanotubes, nanobelts, nanowires and nanoparticles [4]. The composite material of micro- or nanoadditive doped polymers causes to improve the electronic and optical properties [5–15], electrical and dielectric properties [16–36].

This paper aims to fabrication of PVA–Fe_2O_3–In_2O_3 nanocomposites and studying the optical characteristics to utilize in various photonics and optics fields.

2. MATERIALS AND METHODS

Films of PVA and PVA–Fe_2O_3–In_2O_3 nanocomposites were fabricated using casting process. The film of PVA was fabricated by dissolving of 0.5 gm of PVA in 30 ml of distilled water using magnetic stirrer to mix the PVA for 1 hour to get more homogeneous solution. The Fe_2O_3–In_2O_3 nanoparticles (NPs) were added to PVA solution with concentration 50% Fe_2O_3:50% In_2O_3 and various ratios of 1%, 2% and 3%. The optical characteristics of PVA–Fe_2O_3–In_2O_3 nanocomposites were examined using the double beam spectrophotometer (UV-1800 Å, Shimadzu) at wavelength range from 200 nm to 800 nm. The absorption coefficient (α) was given by [37]:

$$\alpha = 2.303A/d, \tag{1}$$

where A is the absorbance and d is the film thickness.

The energy gap was found by [38]:

$$\alpha h\nu = B\left(h\nu - E_g\right)^r, \tag{2}$$

where B 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.

3. RESULTS AND DISCUSSION

Figures 1 and 2 demonstrate the behaviours of optical absorbance and transmittance spectra of PVA–Fe_2O_3–In_2O_3 nanocomposites with photon wavelength. As observed from these figures, the absorbance of PVA increases while transmittance reduces as the Fe_2O_3–In_2O_3 NPs content rises. The rise in the absorption reflected the rise of the defects number in the host polymer medium. The increase of absorbance peak and reduce of transmittance with rising of Fe_2O_3–In_2O_3 NPs content may be related to increase of numbers of charges carriers.

The absorbance is high at UV region and reduces with rising of wavelength. The optical transmission reduces when Fe_2O_3–In_2O_3 NPs content rises. This reduction in the transmission is due the scatter-

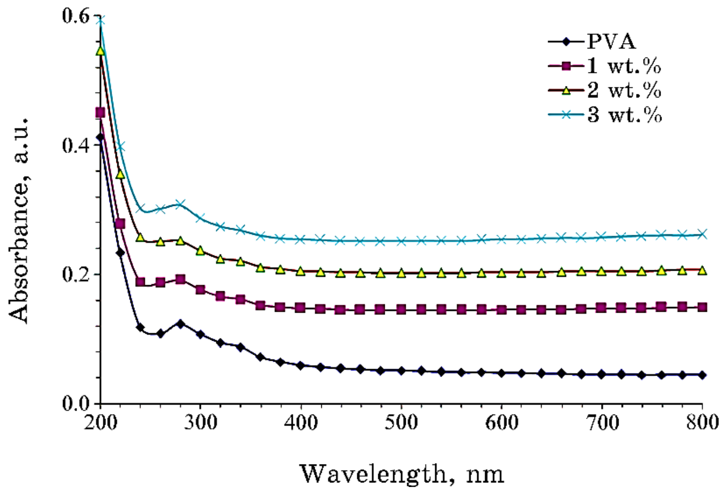

Fig. 1. Behaviour of optical absorbance spectrum of PVA–Fe_2O_3–In_2O_3 nanocomposites with photon wavelength.

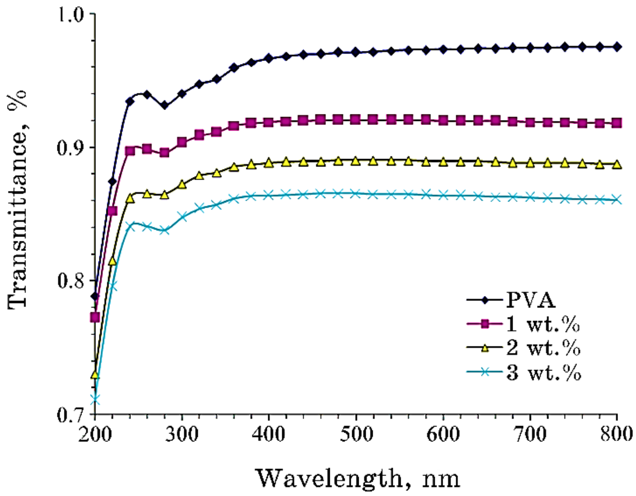

Fig. 2. Transmittance spectrum performance of PVA–Fe_2O_3–In_2O_3 nanocomposites with photon wavelength.

ing processes rising of the incident photons by denser NPs filling the polymeric medium [39–51].

Figure 3 illustrates the absorption coefficient behaviour of PVA–Fe_2O_3–In_2O_3 nanocomposites with photon energy. The increase in the Fe_2O_3–In_2O_3 NPs content causes to increase in the absorption coefficient values. The values of α are $< 10^4$ cm^{-1} and show to indirect transition.

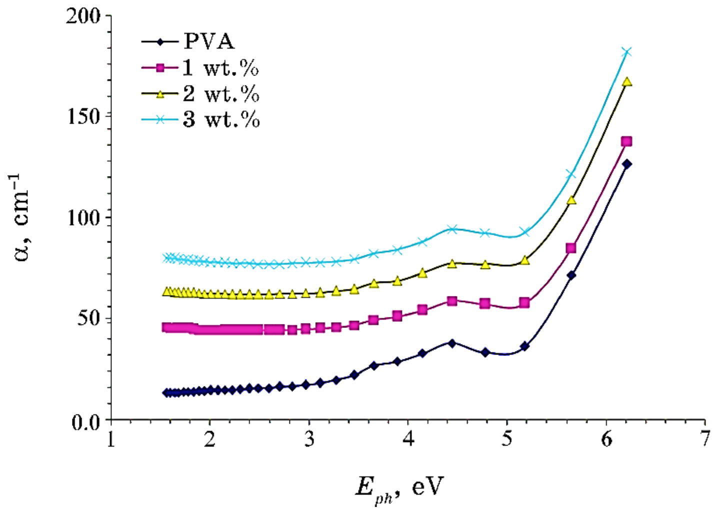

Fig. 3. Absorption coefficient behaviour of PVA–Fe_2O_3–In_2O_3 nanocomposites with photon energy.

Figures 4 and 5 show the energy gaps of allowed and forbidden indirect transitions for PVA–Fe_2O_3–In_2O_3 nanocomposites respectively. The energy-gap values of PVA are reduced with increasing in the Fe_2O_3–In_2O_3 NPs content due to the charges transfer complexes formation between the functional groups PVA and the Fe_2O_3–In_2O_3 NPs atoms. The embedded Fe_2O_3–In_2O_3 NPs form a middle band amid the PVA structure and therefore reduce the energy gap of nanocomposites films. The decrease in the band-gap energy values is suggested to rise with a disturbance degree to produce the localized level in the nanocomposites structures lead to reduce of the energy gap [52–60].

4. CONCLUSIONS

The present work comprised preparation of PVA–Fe_2O_3–In_2O_3 nanocomposites and studying the optical properties to utilize in a variety of photonics and optics applications.

The results illustrated the optical properties of PVA are improved with increasing Fe_2O_3–In_2O_3 NPs content.

The absorbance and absorption coefficient of PVA are increased when the Fe_2O_3–In_2O_3 NPs content rises.

The transmittance and energy gap of PVA are reduced when the Fe_2O_3–In_2O_3 NPs content rises.

The results of optical properties indicate to the PVA–Fe_2O_3–In_2O_3 nanocomposites may be considered as promising materials for opti-

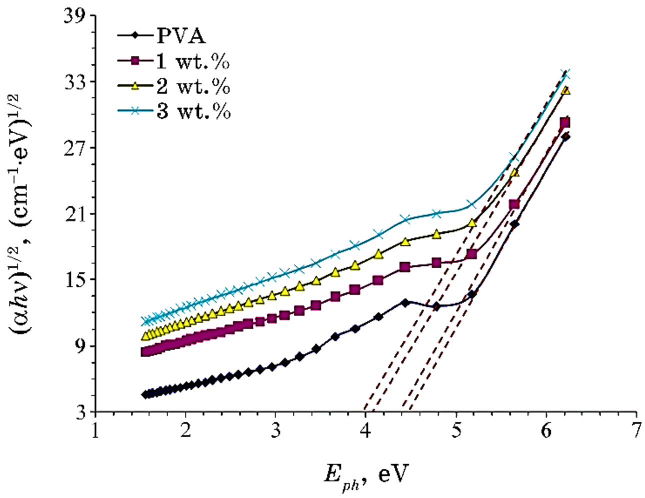

Fig. 4. Energy gaps of allowed indirect transition for PVA–Fe_2O_3–In_2O_3 nanocomposites.

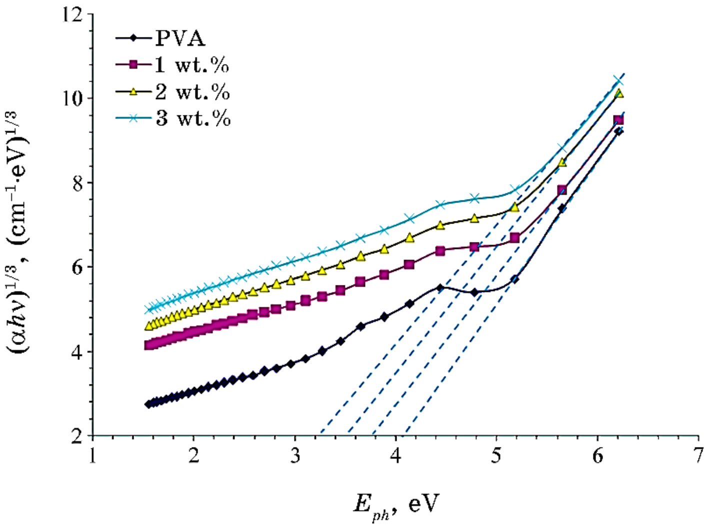

Fig. 5. Energy gaps of forbidden indirect transition for PVA–Fe_2O_3–In_2O_3 nanocomposites.

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