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Optical Properties of PVA–Cr_2O_3–Sb_2O_3 Nanocomposites for Optoelectronics Fields

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This study aims to prepare the PVA–Cr_2O_3–Sb_2O_3 nanocomposites to utilize them in many optoelectronics fields. The optical properties of PVA–Cr_2O_3–Sb_2O_3 nanocomposites are investigated in photon wavelengths from 200 nm to 800 nm. The experimental results illustrate that the absorbance (A) and absorption coefficient (α) of PVA are increased, while the transmittance (T) and energy band gap (E_g) are decreased with increasing of the Cr_2O_3–Sb_2O_3-nanoparticles' content. The obtained results display that the PVA–Cr_2O_3–Sb_2O_3 nanocomposites might be appropriate to use in different optoelectronics applications.

Це дослідження спрямоване на приготування нанокомпозитів полівініловий спирт (ПВС)–Cr_2O_3–Sb_2O_3 для використання в багатьох галузях оптоелектроніки. Досліджено оптичні властивості нанокомпозитів ПВС–Cr_2O_3–Sb_2O_3 в довжинах хвиль фотонів від 200 нм до 800 нм. Експериментальні результати показали, що поглинання (A) та коефіцієнт поглинання (α) ПВС збільшувалися, тоді як коефіцієнт пропускання (T) і ширина забороненої зони (E_g) зменшувалися зі збільшенням вмісту наночастинок Cr_2O_3–Sb_2O_3. Одержані результати показали, що нанокомпозити ПВС–Cr_2O_3–Sb_2O_3 можуть бути доречними для використання в різних оптоелектронних застосуваннях.

Key words: nanocomposites, polyvinyl alcohol, Cr_2O_3–Sb_2O_3, energy gap, absorbance.

Ключові слова: нанокомпозити, полівініловий спирт, Cr_2O_3–Sb_2O_3, енергетична щілина, абсорбція.

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1. INTRODUCTION

In the last decade, several flexible and stretchable type organic polymer matrices and inorganic nanomaterials based hybrid polymer nanocomposites (HPNCs) were prepared with state-of-the-art and characterized to confirm their uses as multifunctional promising materials in advances of polymer engineering and technology based lightweight, cost-effective, and miniaturized electronic devices. Most of the HPNCs were characterized for confirmation of their appropriately controllable morphological, nanostructural, thermal, mechanical, dielectric, electrical, and optical properties in order to meet tremendously increased industrial demand [1].

Usually, flexible electronic devices take advantage of the mechanical properties of conventional plastics and the semiconductor properties of conjugated polymers. Many polymers exhibit high flexibility, low density, and transparency. Some of them are biocompatible and biodegradable and, therefore, are the dominant materials in flexible electronics [2]. Recent research has demonstrated the benefits of using inorganic nanofillers in preparing polymeric nanocomposites. For example, integrating semiconductor materials as nanofillers doped onto polymer membranes has attracted critical attention due to their potential applications in optics and electronics. The high miscibility of these materials on polymeric membranes explains the complexity of their interaction, although it is important to note that adding nanofillers to the polymer matrix can alter the properties of the polymer itself [3].

Chromium oxide (Cr_2O_3) attracted a lot of interest as a wide-band-gap material ($E_g \cong 3$ eV). Indeed, Cr_2O_3 is a transition-metal-oxide semiconductor belonging to the rhombohedral crystal system. Otoh, Cr_2O_3 has particular photoresponse properties, ensuring a good detection within the long and large optical range [4]. Sb_2O_3 was acknowledged as playing several critical roles: reorienting the active lubricating component, providing a mechanically hard surface to support and isolate a thin layer of the active lubricant, preventing crack growth, and serving as an oxidation barrier [5]. Polyvinyl alcohol (PVA) is a biocompatible, fully biodegradable and non-toxic water-soluble polymer. It has gained increasing attention for biomedical applications. PVA-based nanocomposites combine the properties of both additives and polymers. Adding specified nanoparticles (NPs) into the PVA matrix could modify its properties to be suitable for a particular application. These nanocomposites have several applications in the medical and engineering technologies because of their electron transport, mechanical and optical properties [6]. The nanocomposites involved enhanced characteristics to apply in a variety of fields such as radiation shielding and bioenvironmental [7–12], optical fields [13–22], energy storage [23–25], electronics and optoelectronics [26–43], antibacterial [44–50], sensors [51, 52], *etc*.

Here, synthesis of PVA–Cr_2O_3–Sb_2O_3 nanocomposites and the optical properties are studied to use in many optoelectronics fields.

2. MATERIALS AND METHODS

The PVA–Cr_2O_3–Sb_2O_3 nanocomposites films were synthesized using casting method. The pure polymer film was fabricated by dissolving of 0.5 gm PVA in 30 ml of distilled water by using magnetic stirrer to mix the polymer for 1 hour to obtain more homogeneous solution. The Cr_2O_3 and Sb_2O_3 nanoparticles were added to PVA of constant concentration 1:1 with ratios of 2.2%, 4.4% and 6.6%. The optical properties of PVA–Cr_2O_3–Sb_2O_3 nanocomposites films were measured at wavelength ranged from 200 nm to 800 nm using the double beam spectrophotometer (Shimadzu, UV-1800A). The absorption coefficient (α) is found by [53] as follows:

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

where A is the absorbance and t is the film thickness. The energy gap is given by [54] as follows:

$$ah\nu = C\left(h\nu - E_g\right)^m, \quad (2)$$

where C is the constant; $h\nu$ represents the photon energy; E_g indicates to the energy gap, and $m = 2$ and 3 for the allowed and forbidden indirect transitions, respectively.

3. RESULTS AND DISCUSSION

Figures 1 and 2 display the variations of absorbance and transmittance spectra of PVA–Cr_2O_3–Sb_2O_3 nanocomposites with wavelength. The PVA–Cr_2O_3–Sb_2O_3 nanocomposites include high absorbance values and low transmittance values for UV spectra, which related to the electrons excitation at these energies. The absorbance reduces while the transmittance increases with increasing of the photon wavelength. The absorbance values of PVA increases with rising of the Cr_2O_3–Sb_2O_3-NPs' ratio, which can be related to the absorption and scattering of photons by nanoparticles. The absorbance of PVA

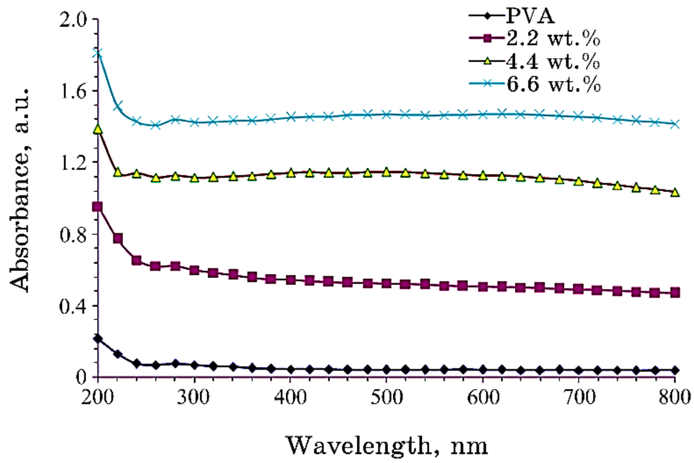

Fig. 1. Variation of absorbance for PVA–Cr_2O_3–Sb_2O_3 nanocomposites with wavelength.

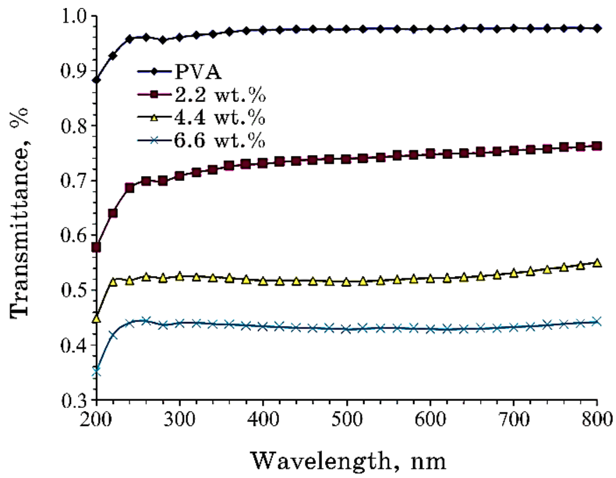

Fig. 2. Transmittance behaviour for PVA–Cr_2O_3–Sb_2O_3 nanocomposites with wavelength.

rises, while the transmittance is reduced with increasing of Cr_2O_3–Sb_2O_3-NPs' ratios, which is due to enhance in the number of charges carriers [55–65].

The behaviour of absorption coefficient for PVA–Cr_2O_3–Sb_2O_3 nanocomposites with energy of photon is shown in Fig. 3. The absorption coefficient for PVA–Cr_2O_3–Sb_2O_3 nanocomposites increases with photon energy and Cr_2O_3–Sb_2O_3-NPs' ratio.

Figures 4 and 5 demonstrate the allowed and forbidden indirect

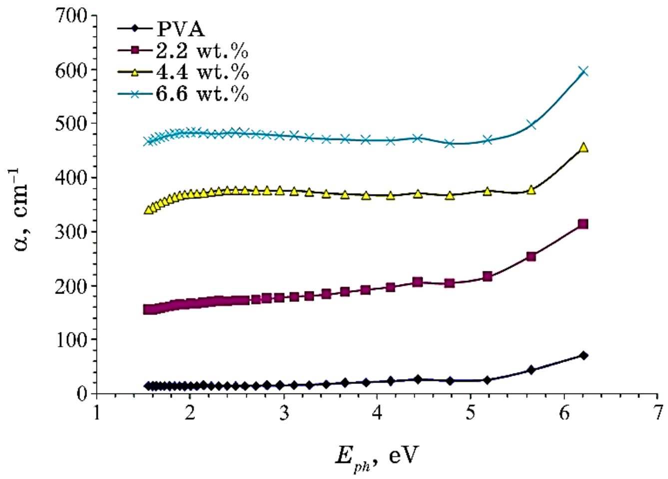

Fig. 3. Absorption coefficient behaviour for PVA–Cr_2O_3–Sb_2O_3 nanocomposites with photon energy.

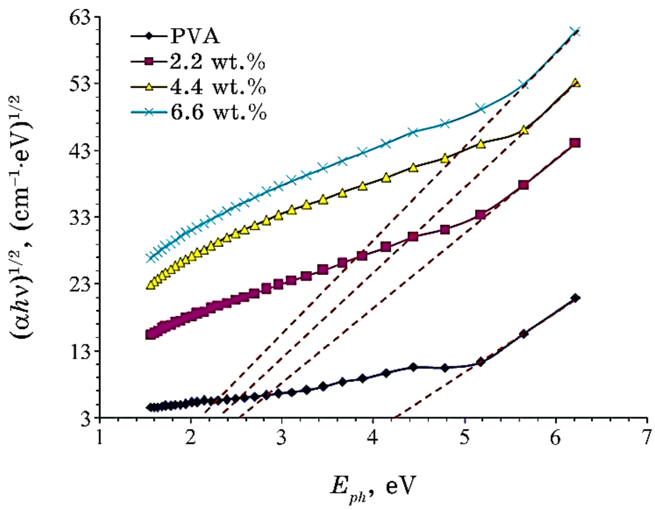

Fig. 4. Allowed indirect energy gap for PVA–Cr_2O_3–Sb_2O_3 nanocomposites.

energy gap for PVA–Cr_2O_3–Sb_2O_3 nanocomposites, respectively. The energy-gap values for PVA are reduced with increasing Cr_2O_3–Sb_2O_3-NPs' ratio that relates to the complex creation of charges' transfer along with the PVA functional groups and Cr_2O_3–Sb_2O_3-NPs' atoms. The embedded Cr_2O_3–Sb_2O_3 NPs create a centre band among the PVA structure causing the decrease of energy gap for nanocomposites.

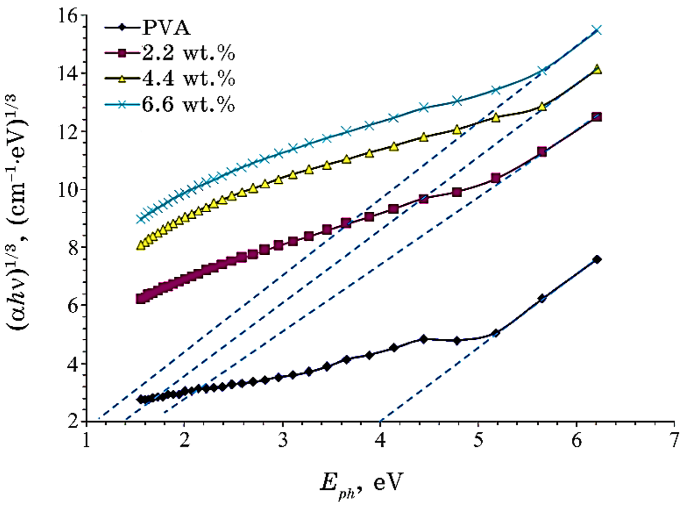

Fig. 5. Forbidden indirect energy gap for PVA–Cr_2O_3–Sb_2O_3 nanocomposites.

The reducing of energy gap is proposed to increase the localized levels in the nanocomposite structures [66–70].

4. CONCLUSIONS

The current study comprised fabrication of PVA–Cr_2O_3–Sb_2O_3 nanocomposites to utilize them in numerous optoelectronics applications. The results showed that the absorbance and absorption coefficient of PVA are increased with increasing of the Cr_2O_3–Sb_2O_3-NPs' content, while the transmittance and energy band gap are decreased with increasing of the Cr_2O_3–Sb_2O_3 content. The final results indicated that the PVA–Cr_2O_3–Sb_2O_3 nanocomposites may be useful for various optoelectronics fields.

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