Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2024, т. 22, № 4, сс. 883–891
https://doi.org/10.15407/nnn.22.04.883

PACS numbers: 78.20.Ci, 78.30.-j, 78.40.-q, 78.67.Sc, 81.07.Pr, 82.35.Np, 85.60.-q

Enhanced Optical Properties of PVA–CuO–Fe_2O_3 Nanocomposites for Optoelectronics Applications

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The current work aims to fabrication of nanocomposites' films of CuO–Fe_2O_3-nanoparticles'-doped PVA to apply in many optoelectronics applications. The PVA–CuO–Fe_2O_3 nanocomposites are prepared using casting method. The optical properties are tested at wavelength range from 200 nm to 800 nm. The results show that the absorbance and absorption coefficient of PVA is increased with increasing CuO–Fe_2O_3-nanoparticles' ratio. The transmittance and energy gap of PVA is reduced with increasing CuO–Fe_2O_3-nanoparticles' ratio. The obtained results confirm that the PVA–CuO–Fe_2O_3 nanocomposites can be important for optoelectronics fields.

Дану роботу спрямовано на виготовлення нанокомпозитних плівок з полівінілового спирту (ПВС), леґованих наночастинками CuO–Fe_2O_3 задля використання в багатьох застосуваннях оптоелектроніки. Нанокомпозити ПВС–CuO–Fe_2O_3 виготовлено методом лиття. Оптичні властивості перевіряли в діяпазоні довжин хвиль від 200 нм до 800 нм. Результати показують, що спектральна поглинальна здатність і коефіцієнт поглинання ПВС збільшуються зі збільшенням вмісту наночастинок CuO–Fe_2O_3. Коефіцієнт пропускання й енергетична щілина ПВС зменшуються зі збільшенням вмісту наночастинок CuO–Fe_2O_3. Одержані результати підтверджують, що нанокомпозити ПВС–CuO–Fe_2O_3 можуть бути важливими для галузей оптоелектроніки.

Key words: PVA–CuO–Fe_2O_3 nanocomposites, optical properties, energy gap, absorbance.

Ключові слова: нанокомпозити полівінілового спирту з наночастинками CuO–Fe_2O_3, оптичні властивості, заборонена зона енергій, поглинання.

(Received 18 August, 2023)

1. INTRODUCTION

Polymer composites and hybrids including inorganic components have sparked a lot of interest in various industrial applications due to their enhanced thermal, electrical, mechanical and photovoltaic properties [1]. Recently, optically transparent materials containing Fe_2O_3 are intensively investigated because of their novel properties and potential applications. Among the most attractive properties of the transparent materials containing Fe_2O_3 are those related to the magnetooptical effects and their scientific and industrial applications in many areas such as optical fibre sensors, optical isolators, information storage, magnetooptical switches, modulators, colour imaging, bioprocessing, catalysis, and ferrofluids. Hence, the interest in designing and preparing these composite materials with superior magnetic property and optical property continues to increase [2].

Metallic filler that was recently used as filler in polymeric nanocomposites, copper oxide CuO, has a monoclinic crystal structure with a good electrical conduction, which is related to their potential physical properties. Crystalline CuO nanoparticles (CuO NPs) have a relatively small energy-band gap, which allows them to be exploited for both photocatalytic and photovoltaic activities. Because of the physicochemical properties of the nanocomposites that include CuO NPs incorporated into them, such as their semiconducting characteristics, great chemical stability, low toxicity, and chemical and physical stability, copper oxide, has solidified its position as a significant substance in technology. Moreover, it has become a promising option for use in energy storage systems. In addition, supercapacitors, a supplementary device between batteries and regular capacitors, have received many attentions because of their advantageous properties [3].

Polyvinyl alcohol (PVA) is a polymer with carbon chain backbone attached with hydroxyl groups. These OH groups can be a source of hydrogen bonding and hence assist in the formation of polymer blends. PVA is non-toxic, water-soluble synthetic polymer, which is widely used in the polymer blends due to its good physical and chemical properties, excellent film forming characteristics, emulsifying capability, non-carcinogenic, biodegradable and biocompatible qualities. These unique characteristics enable it for its applicability in pharmaceutical fields, drug-coating agents, material for surgical structures and cosmetic industries [4]. The doping of micro- or nanomaterial into polymers leads to enhancing the dielectric and electrical properties [5–23], optical and electronic properties [24–33].

This study aims to fabricate the PVA–CuO–Fe_2O_3 nanocomposites to employ in many optoelectronics applications.

2. MATERIALS AND METHODS

Nanocomposites films of pure PVA and PVA doped with CuO–Fe_2O_3 NPs were prepared using casting method. The pure PVA film was prepared by dissolving 0.5 gm of PVA in 30 ml of distilled water using magnetic stirrer to mix the polymer for 1 hour to get more homogeneous solution. Then, CuO–Fe_2O_3 NPs were added to PVA solution with ratio 50% CuO:50% Fe_2O_3 and different contents of 1%, 2% and 3%.

The optical properties of PVA–CuO–Fe_2O_3-nanocomposites' films were tested using the double beam spectrophotometer (Shimadzu, UV-1800 Å) with range of wavelength from 200 nm to 800 nm. The absorption coefficient (α) was given by [34]:

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

where A refers to the absorbance, t represents the film thickness.

The energy gap was calculated by [35]:

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

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

3. RESULTS AND DISCUSSION

Figure 1 and Figure 2 demonstrate the variation of absorbance and transmittance spectra for PVA–CuO–Fe_2O_3 nanocomposites in the range of wavelength 200–800 nm. As shown in these figures, the absorbance reduces and transmittance increases with increasing of wavelength. There are peaks of absorption in the UV area, which related to electronic transitions between molecular orbitals and the spectra in this region due to conjugated bonds. The addition of CuO–Fe_2O_3 NPs into PVA leads to increasing the absorbance peaks intensity and reducing the transmission with shift in an edge of the absorption to the high wavelengths. The absorbance of polymer increases with increase in the nanoparticles content due to increase in the number of charges carriers [36–46].

Figure 3 shows the absorption coefficient variation for PVA–CuO–Fe_2O_3 nanocomposites with photon energy. The absorption coefficient of PVA increases with the increase in CuO–Fe_2O_3-NPs con-

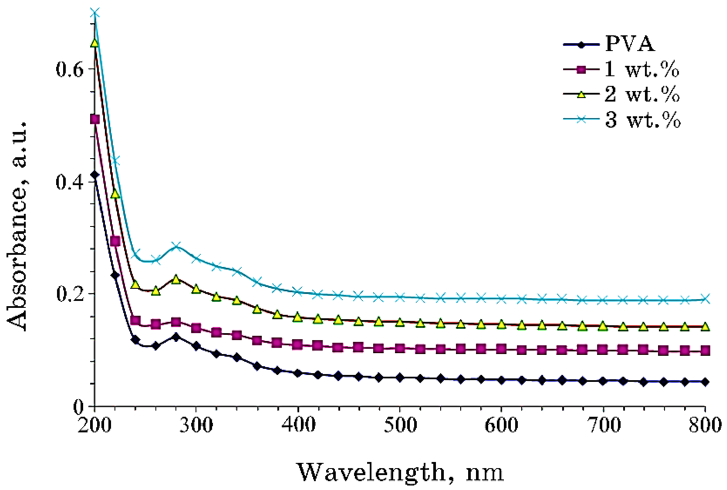

Fig. 1. Variation of absorbance spectrum for PVA–CuO–Fe_2O_3 nanocomposites with wavelength.

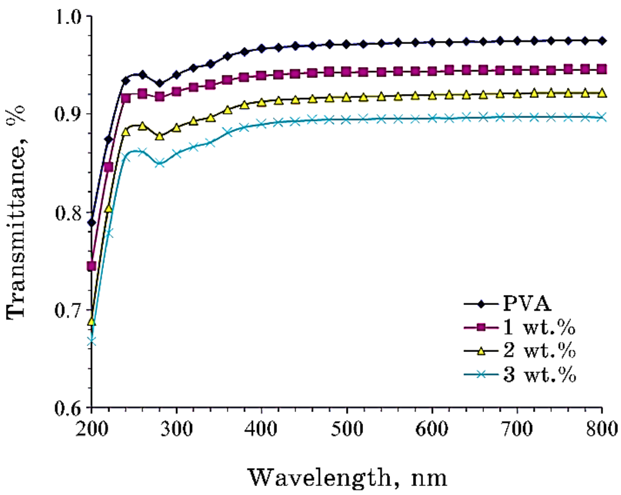

Fig. 2. Transmittance spectrum behaviour for PVA–CuO–Fe_2O_3 nanocomposites with wavelength.

tent that may be due to a larger absorption increment associated with the charge transfer transition.

The energy gaps of allowed and forbidden transitions for PVA–CuO–Fe_2O_3 nanocomposites are illustrated in Figs. 4 and 5. The energy gap values reduce with the raise in CuO–Fe_2O_3-NPs content that is due to the defects in the films. These defects produce the localized states in the energy gap. These values of energy gap may

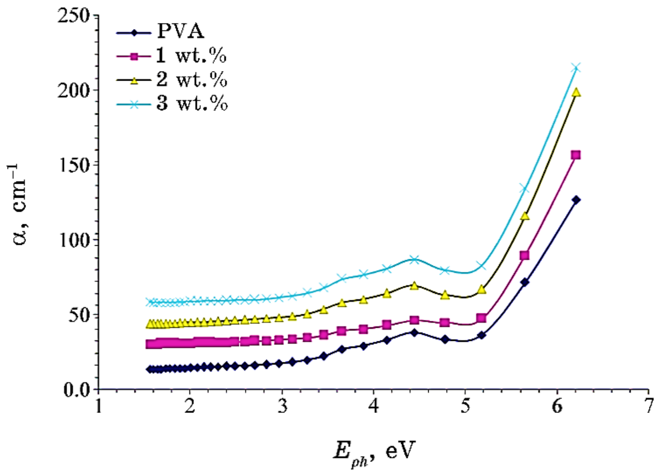

Fig. 3. Absorption coefficient variation for PVA–CuO–Fe_2O_3 nanocomposites with photon energy.

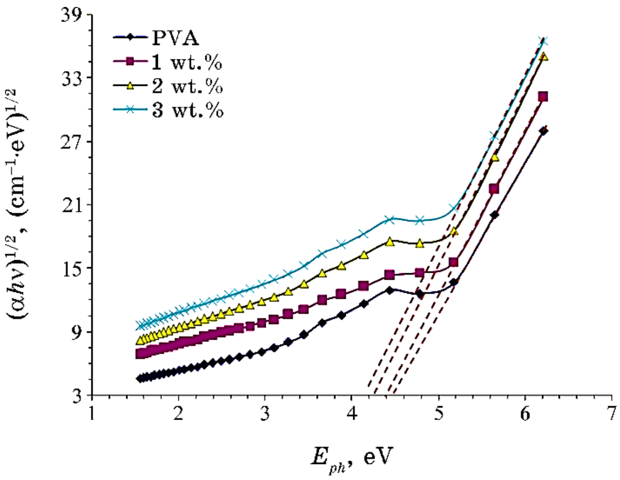

Fig. 4. Energy gap of allowed transition for PVA–CuO–Fe_2O_3 nanocomposites.

be related to the localized-states' generation between the HOMO and LUMO energy bands producing the lower energy transitions [36, 47–58].

4. CONCLUSIONS

This work involved synthesis of PVA–CuO–Fe_2O_3-nanocomposites'

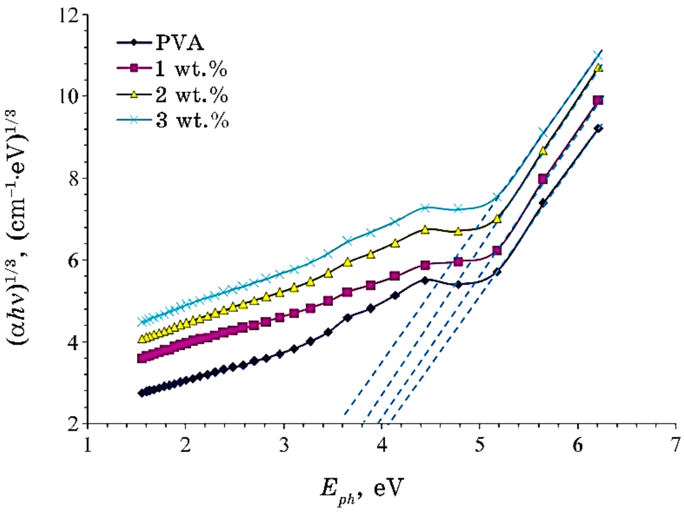

Fig. 5. Energy gap of forbidden transition for PVA–CuO–Fe_2O_3 nanocomposites.

films. The optical properties of PVA–CuO–Fe_2O_3 nanocomposites were examined. The results indicate that the optical properties of PVA are enhanced by adding of CuO–Fe_2O_3 NPs. The absorbance and absorption coefficient of PVA were increased with increasing CuO–Fe_2O_3-NPs ratio. The transmittance and energy gap of PVA were decreased with increasing CuO–Fe_2O_3-NPs ratio. The results on optical properties confirm that the PVA–CuO–Fe_2O_3 nanocomposites can be useful for optoelectronics applications.

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