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Fabrication and Enhanced Optical Properties of $\text{ZrO}_2/\text{PbO}_2$ -Nanostructures-Doped PVA for Optoelectronics Fields

Ahmed Hashim¹, Hamed Ibrahim², Batool Mohammed¹,
Eman Hammod Abdullah¹, and Aseel Hadi³

¹College of Education for Pure Sciences,
Department of Physics,
University of Babylon,
Hillah, Iraq

²Al-Zahraa University for Women,
Baghdad Road (opposite pole 70),
Kerbala, Iraq

³College of Materials Engineering,
Department of Ceramic and Building Materials,
University of Babylon,
Hillah, Iraq

This work aims to fabricate of the PVA– ZrO_2 – PbO_2 nanocomposites and to investigate the optical properties to utilize them in different optical and electronic fields. The optical properties of the PVA– ZrO_2 – PbO_2 nanocomposites are tested in wavelength range 200–800 nm. The results show that the PVA– ZrO_2 – PbO_2 nanocomposites have high absorption in UV region. The PVA absorbance is increased, while both the transmittance and the energy band gap are reduced with increasing ZrO_2 – PbO_2 -NPs' content. The obtained results show that the PVA– ZrO_2 – PbO_2 nanocomposites may be useful in different optoelectronics applications.

Метою цієї роботи є створення нанокompозитів PVA– ZrO_2 – PbO_2 та дослідження їх оптичних властивостей для використання в різних оптичних й електронних галузях. Оптичні властивості нанокompозитів PVA– ZrO_2 – PbO_2 було протестовано в діапазоні довжин хвиль 200–800 нм. Результати показали, що нанокompозити PVA– ZrO_2 – PbO_2 мають високе вбирання в УФ-діапазоні. Вбирання PVA збільшувалося, тоді як пропускання та ширина забороненої енергетичної зони зменшувалися зі збільшенням вмісту наночастинок ZrO_2 – PbO_2 . Одержані результати показали, що нанокompозити PVA– ZrO_2 – PbO_2 можуть бути корисними в різних оптоелектронних застосуваннях.

Key words: PVA, PbO_2 , ZrO_2 , nanocomposites, absorbance, energy gap.

Ключові слова: PVA, PbO₂, ZrO₂, наноккомпозити, вбирання, заборонена енергетична зона.

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1. INTRODUCTION

The optical characteristics of composite matters may be enhanced by adding of different semiconducting ceramics nanostructures into the matrix of polymer in order to make materials with required physical characteristics for optoelectronic and technological fields in the UV area [1]. A hybrid material consists of soluble polymers with inorganic component with excellent mechanical, optoelectronics and dielectric properties due to the combination of the organic and inorganic components, and it can be deposited as a thin film in different substrates. Therefore, the number of contributions in the development of hybrid composites based on polymers and nanoparticles with high permittivity, low cost, and easily tuneable properties, have become a hot topic in the research of materials [2]. Polyvinyl alcohol (PVA) has high tensile strength and flexibility, high oxygen and aroma barrier property. It also has estimable film forming, blending and adhesive properties. Visible light transmission is very strong. The role of PVA polymer composites in scientific fields is well recognized [3, 4]. The addition of nanostructures into the polymer leads to improving the optical, dielectric, structural, morphological, and electronic properties to utilize in different approaches like sensors [5–11], electronics and optoelectronics [12–27], energy storage [28–36]. The present work investigated the fabrication of PVA–ZrO₂–PbO₂ nanocomposites and exploring the optical properties to use in various optoelectronics applications.

2. MATERIALS AND METHODS

PVA–ZrO₂–PbO₂-nanocomposite films were prepared from both PVA as a matrix and ZrO₂–PbO₂ nanoparticles as an additive by using casting technique. The PVA–ZrO₂–PbO₂ nanocomposites were fabricated *via* dissolving of 1 gm of PVA in 30 ml of distilled water using magnetic stirrer to obtain solution that is more homogeneous. Then, ZrO₂–PbO₂ nanoparticles with contents of 2%, 4% and 6% were added to the PVA.

The optical properties of PVA–ZrO₂–PbO₂ nanocomposites were measured using the double-beam spectrophotometer (Shimadzu, UV-1800 Å) in wavelengths' range 200–800 nm. The coefficient of absorption (α) is calculated as $\alpha = 2.303A/t$, where A is the absorbance and t is the film thickness [37]. The energy gap is given as

$\alpha h\nu = C(h\nu - E_g)^r$, 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 [38].

3. RESULTS AND DISCUSSION

Figure 1 shows the behaviour optical absorbance of PVA- ZrO_2 - PbO_2 -nanocomposite films with photon wavelength. The absorption spectra increases as the ZrO_2 - PbO_2 -NPs' content rises. The rise in the absorbance with rising ZrO_2 - PbO_2 -NPs' content within the polymer medium reflected the rise of the defects' number in the host polymer medium.

The PVA- ZrO_2 - PbO_2 nanocomposites have high absorbance in the UV region due to the high energy of photons at these energies. The increase of absorbance for PVA- ZrO_2 - PbO_2 nanocomposites with increasing ZrO_2 - PbO_2 -NPs' content may be due to increase of number of charge carriers, which absorb and scatter the photons, leading to decrease in transmittance (Fig. 2). Figure 2 demonstrates the optical transmission spectra of PVA- ZrO_2 - PbO_2 nanocomposites. The optical transmission is reduced, when ZrO_2 - PbO_2 -NPs' content rise. This reduction in the transmission refers to the scattering processes raising the incident photons by denser NPs filling the polymer medium [39–51].

Figures 3 and 4 show the energy gap values of allowed and forbidden indirect transitions, respectively, for PVA- ZrO_2 - PbO_2 nanocomposites. The energy gap of PVA- ZrO_2 - PbO_2 nanocomposites is reduced, when the ZrO_2 - PbO_2 -NPs' content rises. This decrease indicates on the formation charge-transfer complexes due to the defects in the polymer medium. These defects create the localized levels in the energy gap. The formed levels lead to reducing the energy band gap, when the nanoparticles' content rises in the polymer matrix [52–65].

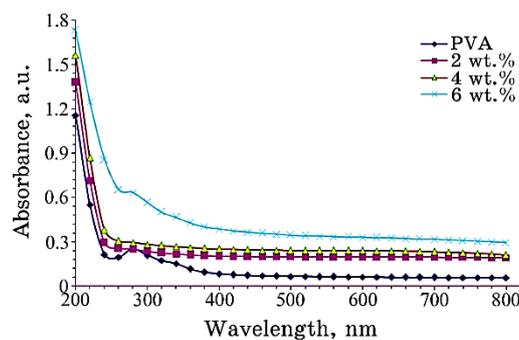


Fig. 1. Absorbance of PVA- ZrO_2 - PbO_2 nanocomposites with photon wavelength.

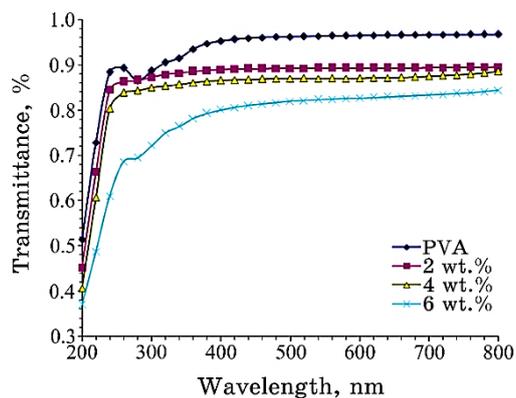


Fig. 2. Optical transmittance spectra of PVA-ZrO₂-PbO₂ nanocomposites.

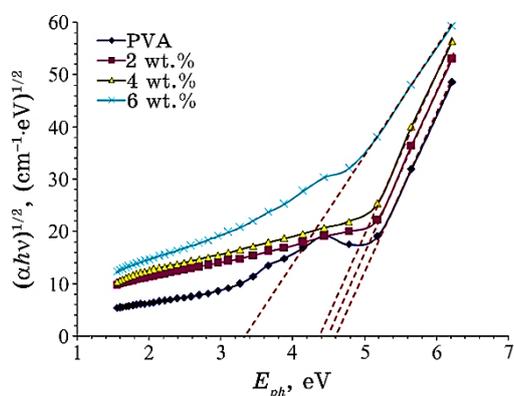


Fig. 3. Energy gap values of allowed indirect transitions for PVA-ZrO₂-PbO₂ nanocomposites.

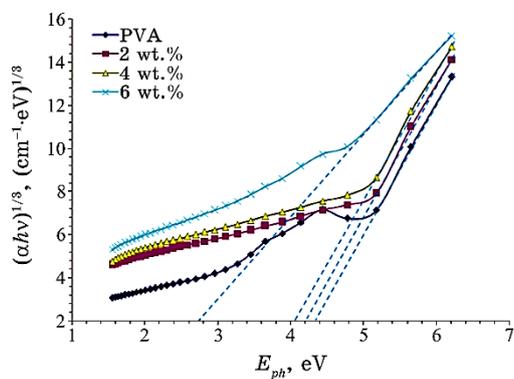


Fig. 4. Energy gap values of forbidden indirect transitions for PVA-ZrO₂-PbO₂ nanocomposites.

4. CONCLUSION

The present work includes fabrication of PVA–ZrO₂–PbO₂ nanocomposites and studying their optical properties to apply in the optical and electronic fields. The results indicated that the PVA–ZrO₂–PbO₂ nanocomposites have high absorption of photons at UV region. The optical transmittance and the energy band gap of PVA were reduced, while the absorbance was increased with increasing ZrO₂–PbO₂ NPs' content. The attained results demonstrated that the PVA–ZrO₂–PbO₂ nanocomposites might be useful in various optoelectronics fields.

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