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Gamma- and X-Rays' Shielding of New Nanomaterials for Biomedical Applications

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Shields for biomedical applications to attenuate the gamma- and x-rays are fabricated from PVA, PEG and lead oxide nanocomposites with low cost, lightweight, high corrosion resistance, and high attenuation. Structural and optical characterizations of PVA–PEG–PbO_2 nanomaterials are investigated. Results show that the PVA–PEG–PbO_2 nanomaterials have high absorbance for high-energy radiations. The optical characteristics of blend are changed with the increase in PbO_2 nanoparticles' content.

Захисні щитки для біомедичних застосувань задля послаблення γ- і Рентґенових променів виготовляються з нанокомпозитів полівініловий спирт–поліетиленгліколь–оксид Плюмбуму з низькою вартістю, легковагістю, високою корозійною стійкістю та високою угамівністю. Досліджено структурні та оптичні характеристики наноматеріялів ПВС–ПЕГ–PbO_2. Результати показують, що наноматеріяли ПВС–ПЕГ–PbO_2 мають високу спектральну абсорбційну здатність щодо високоенергетичних випромінень. Оптичні характеристики суміші змінюються зі збільшенням вмісту наночастинок PbO_2.

Key words: polymer blend, lead oxide, radiations, optical properties, attenuation.

Ключові слова: полімерна суміш, оксид Плюмбуму, випромінення, оптичні властивості, загасання.

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1. INTRODUCTION

Gamma- and x-rays' radiation particularly are a most important worry for outside experience as a result of its high penetrating control and effects of domestic special on the humans. The x-rays and gamma rays may be causing the cancer, sterility, DNA mutations when the doses are accumulated. With the increased using of radioactive materials in industry and medicine, shielding is a main concern in order to keep both equipment and humans. For example, lead is as the commonly used shielding material for the gamma rays and x-rays. Many papers efforts were prepared to manufacturing more professional shielding can be used for attenuating gamma with easily portable, lightweight, flexible and cost effective. Polymer composites or nanocomposites are an appropriated applicant to solve the conventional shields' problems [1].

Now, researchers are enhancing the medical radiation shielding prepared using novel materials that can replace the lead, which is causes human poisoning and heavy [2].

The possibility of interaction of gamma rays per unit of length its linear attenuation coefficient. The reducing of beam power results from the arrangement of absorption of photon and deflection. Thus, mass attenuation coefficient changed with absorber nature [3].

The nanotechnology is a mainly special approach, ranging from new expansions of typical physics of device to accurately novel fields to improving novel materials have sizes on the nanometer scale. Polymers have stability after chemical and physical doping with high mechanical properties [4].

Because of its high charge storage capacity, high flexibility and its good dielectric strength, polyvinyl alcohol (PVA) has been incorporated into many applications of industry. PVA is a semicrystalline polymer, and it plays a main role in the biomedical applications due to its good chemical resistance, simple preparation, and excellent biodegrade ability. The carbon chain backbone of PVA with hydroxyl groups provides a hydrogen-bonding source to improve the creation of polymer complexes [5].

The study of nanocomposites' field increases to enhance its D.C. electrical, dielectric, and thermal properties to use them in a variety of applications [6–18].

2. MATERIALS AND METHODS

Shields for gamma- and x-rays were fabricated by using polymer blend polyvinyl alcohol–polyethylene glycol with lead oxide nanoparticles. The films prepared using the casting method where 1 gm of polymer with concentration 78 wt.% PVA/22 wt.% PEG dissolve in water (20 ml) at 1 hour by magnetic stirrer. The PbO_2 added to the solution with ratios of 2 wt.%, 4 wt.%, 6 wt.%. Optical characterizations of nanomaterial are tested by spectrophotometer (UV-1800A, Shimadzu) in 200–800 nm of wavelength.

Absorption coefficient α was calculated by using [19–22]:

$$\alpha = 2.303A/t; \tag{1}$$

A represents the absorbance, *t*—thickness. Energy band gap was calculated by the equation [23–25]:

$$\alpha h\nu = Y(h\nu - E_g)^d, \tag{2}$$

Y represents a constant, $h\nu$ represents the photon energy, E_g—energy gap; $d = 2$ and $d = 3$ correspond to allowed and forbidden indirect transitions, respectively.

Extinction coefficient *k* is given by using the equation [26–28]:

$$k = \alpha\lambda/(4\pi). \tag{3}$$

Refractive index *n* is defined by [29]:

$$n = (1 + X^{1/2})/(1 - X^{1/2}); \tag{4}$$

X is reflectance.

The real dielectric constant and imaginary one (ε_1 and ε_2) are given by [30]:

$$\varepsilon_1 = n^2 - k^2,\ \varepsilon_2 = 2nk. \tag{5}$$

The optical conductivity is defined by using the equation [31, 32]:

$$\sigma = \alpha nc / (4\pi). \tag{6}$$

3. RESULTS AND DISCUSSION

Figure 1 shows UV spectrum of PVA–PEG–PbO_2 nanomaterials. Absorption spectra of PVA–PEG and PVA–PEG doped with PbO_2 nanoparticles are limited in high photon energy region.

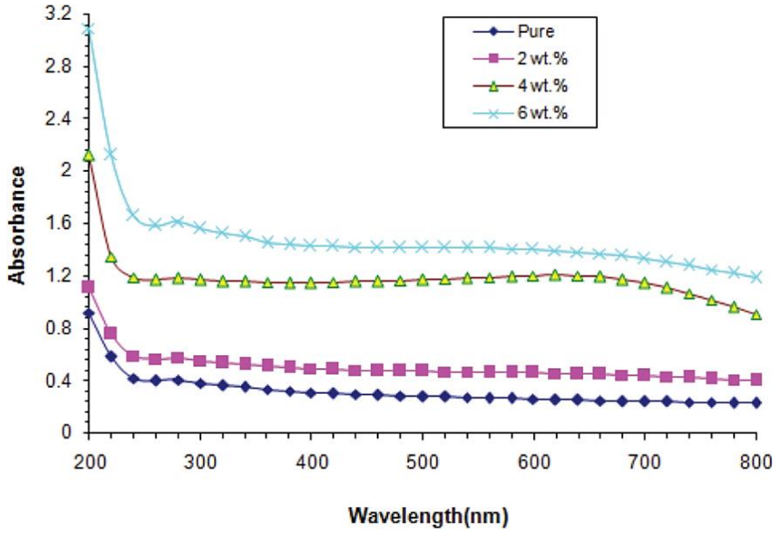

Fig. 1. UV spectra of PVA–PEG–PbO_2 nanocomposites.

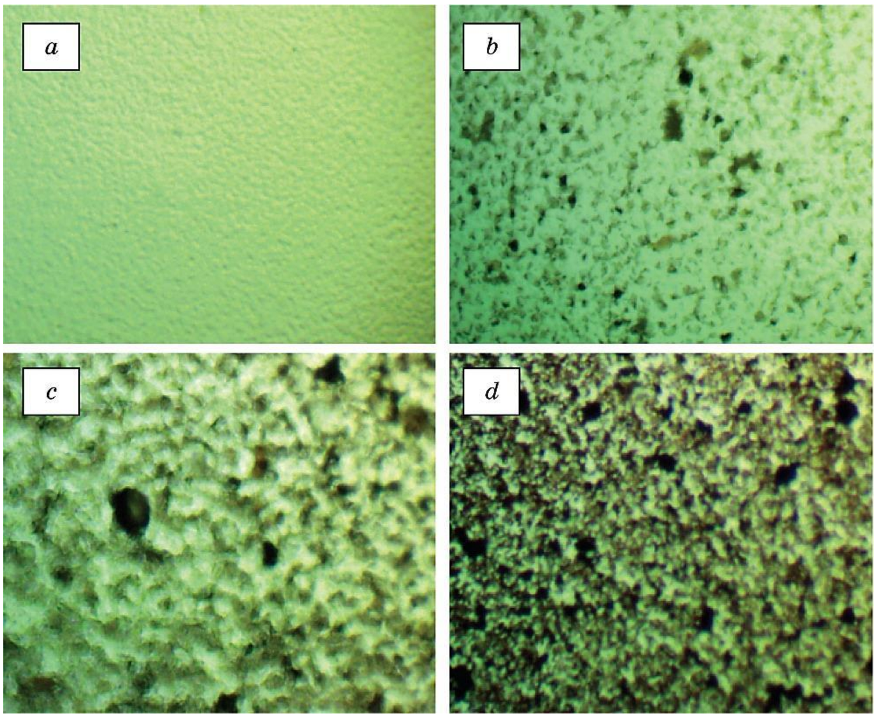

Fig. 2. Photomicroscope images (×10): (*a*) blend; (*b*) 2 wt.% PbO_2; (*c*) 4 wt.% PbO_2; (*d*) 6 wt.% PbO_2.

The absorbance of blend increases with increasing PbO_2 ratios. The increase in absorbance attributed to increase in charge carriers number [33–39] with increasing PbO_2 ratios shown in Fig. 2.

Figure 3 explains the effect of PbO_2 nanoparticles on energy gap for allowed indirect transitions. The E_g decreases with increasing PbO_2 content related to raising localized levels [40].

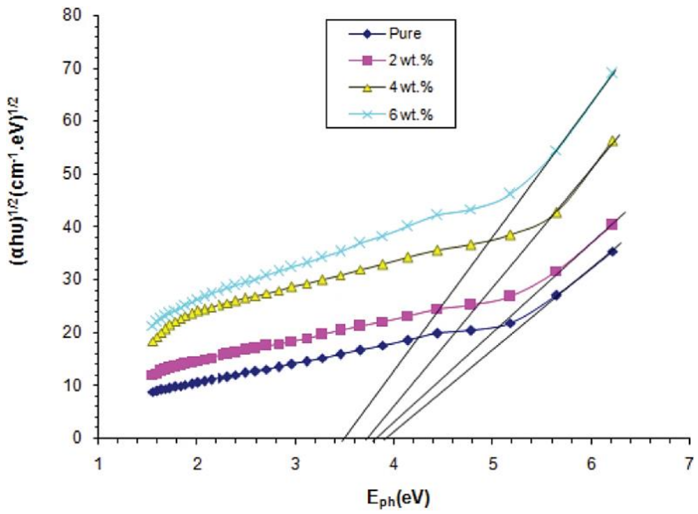

Fig. 3. Effect of PbO_2 nanoparticles' ratio on energy gap for allowed indirect transitions.

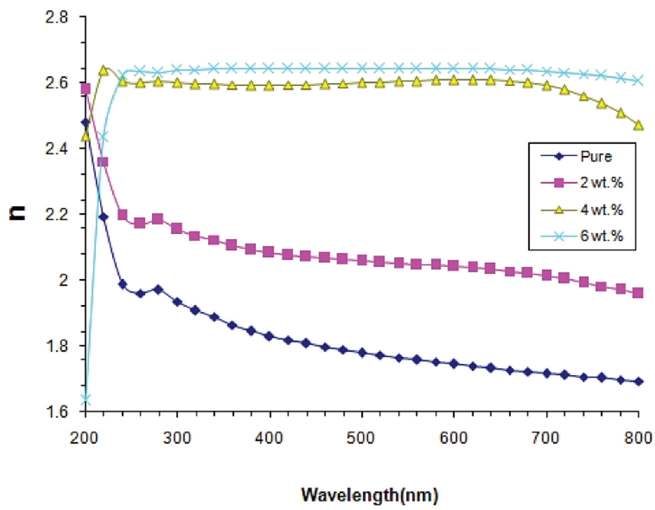

Fig. 4. Variation of refractive index of PVA–PEG–PbO_2 nanomaterials with wavelength.

Figure 4 explains the refractive index variation of nanomaterials with wavelength. The values of n increases as PbO_2 content raises attributing to the density increase [41].

Figure 5 explains the real dielectric constant of PVA–PEG–PbO_2 nanomaterials as a function of the wavelength of photons. The real

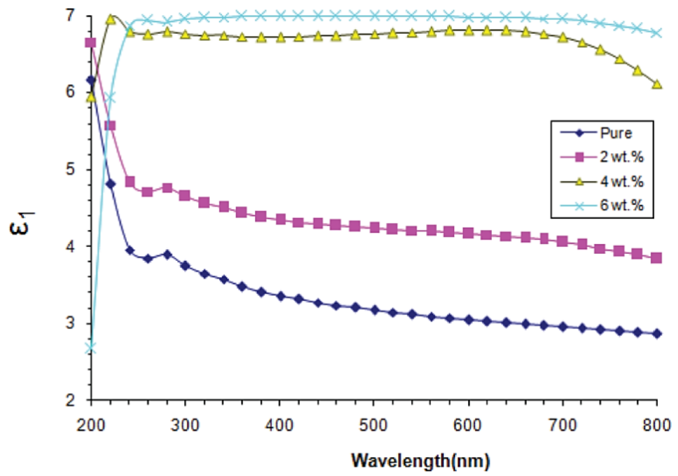

Fig. 5. Real dielectric constant of PVA–PEG–PbO_2 nanocomposites as a function of the photon wavelength.

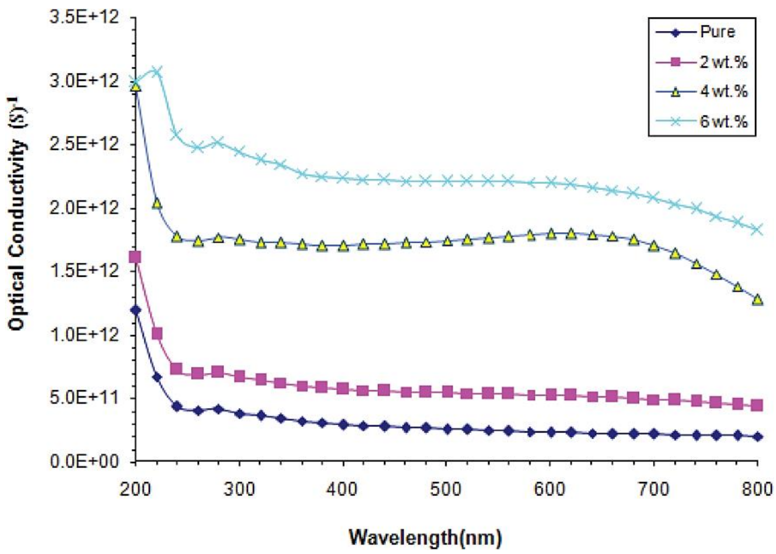

Fig. 6. Optical conductivity variation of PVA–PEG–PbO_2 nanomaterials with wavelength.

part raises as PbO_2 content increases that may be related to the increase in values of n and k [42].

Figure 6 explains the optical conductivity variation with wavelength. Optical conductivity decreases as wavelength is increasing that is related to high absorbance of samples in low-wavelength region [43–48].

4. CONCLUSION

Absorbance of blend raises with raising PbO_2 nanoparticles' ratios. The PVA–PEG–PbO_2 nanocomposites have higher absorbance for high photons' energies, which is make them used as shields for high energies.

The energy gap of PVA–PEG blend reduces with increasing PbO_2 nanoparticles' ratios.

The optical parameters of PVA–PEG blend are increased with raising PbO_2 nanoparticles' ratio.

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