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Biopolymers–Metal Oxide Nanocomposites as Coating Materials for Biomedical Applications

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Films made of polyvinylpyrrolidone–polyethylene oxide–lead oxide nanoparticles are investigated as coating materials for antibacterial applications as well as gamma- and x-rays' shielding with low cost, lightweight and high attenuation. Nanocomposites are prepared with different ratios of the blend and lead oxide. The structural and optical characterizations of such PVP–PEO–PbO_2 nanocomposites are investigated. The results indicate that the nanocomposites have higher absorbance in the UV region. The optical parameters of the PVP–PEO blend are changing as the PbO_2 content increases. The energy gap of the PVP–PEO blend decreases with increasing PbO_2 content.

Досліджено плівки з полівінілпіролідону, поліоксиетилену та наночастинок оксиду Плюмбуму як матеріяли покриття для антибактеріяльних застосувань і захисту від γ- та Рентґенових променів з низькою вартістю, легковагістю та високою угамівністю. Нанокомпозити готуються з різним співвідношенням суміші й оксиду Плюмбуму. Досліджено структурні й оптичні характеристики таких нанокомпозитів PVP–PEO–PbO_2. Результати показують, що нанокомпозити мають більш високу абсорбцію в УФ-області. Оптичні параметри суміші PVP–PEO змінюються зі збільшенням вмісту PbO_2. Енергетична щілина суміші PVP–PEO зменшується зі збільшенням вмісту PbO_2.

Key words: nanocomposites, blends, antibacterial activity, shielding, optical properties, γ-rays, x-rays.

Ключові слова: нанокомпозити, суміші, антибактеріяльна активність, екранування, оптичні властивості, γ-промені, Рентґенові промені.

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1. INTRODUCTION

Radiological protection is the knowledge and practice of protecting the environment and people from the ionizing radiation harmful effects. Ionizing radiation is commonly used in the medicine and industry, and can existent as important health hazard. The shielding efficiency is dependent on the radiation particles stopping power, which different with the shielding material used, energy and type of radiation [1, 2]. In the class of new materials, polymer nanocomposites have grabbed more attention due to their enhanced electrical, optical and magnetic properties. These materials possess increased modulus and flame resistance, and are capable to preclude oxidation and agglomeration. These enhancements in properties are due to interaction between nanoparticles and polymer matrix. Addition of nanoparticles into polymer matrix improves lifetime of nanoparticles, modifies the surface of nanoparticles by passivation defect states, provide low cost, ease of device fabrication and tuneable optical and electronic properties [3]. Various methods have been used to prepare nanocomposites. Thus, more concern has been related to the *in situ* fabrication of nanoparticles of inorganic materials in polymer to prepare new semiconductor characterization [4]. Polyvinylpyrrolidone is water soluble and polar solvents. It has good wetting characterization and easily forms films. These properties make it good material as a coating [5]. The effect of additive on properties of polymer deals with improvement the A.C. electrical properties [6–12], D.C. electrical properties [13–17], optical properties [18–21]. The nanocomposites' applications are quite promising in the many fields of sensors [22–24], antibacterial activity [25, 26], energy storage and release [27, 28].

2. MATERIALS AND METHODS

Nanocomposites' films of polyvinylpyrrolidone–polyethylene oxide–lead oxide nanoparticles as a coating materials for gamma and x-rays' shielding were fabricated by using the casting method where 0.5 gm of polymers with concentration of 66 wt.% PVP/34 wt.% PEO was dissolved in 20 ml of distilled water. The lead oxide added to the polymer solution with ratios 1.5, 3 and 4.5 wt.%. The optical characterization of PVP–PEO–PbO_2 nanocomposites was measured by spectrophotometer (UV-1800A, Shimadzu) at wavelength of photons from 220 nm to 820 nm.

Absorption coefficient α of nanocomposites is calculated by using [29]:

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

where A—absorbance, S—thickness. Energy gap is calculated by [30]:

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

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

Extinction coefficient k was determined using the equation [31]:

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

Refractive index n is given by [32]:

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

X is reflectance.

Dielectric constant parts (real ε_1 and imaginary ε_2 ones) are calculated as follow [33]:

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

The conductivity was calculated by using the equation [34]:

$$\sigma = \alpha nc / (4\pi). \tag{7}$$

3. RESULTS AND DISCUSSION

Figure 1 shows absorbance spectra variation with wavelength of PVP–PEO–PbO_2 nanocomposites.

The absorbance raises with the PbO_2 nanoparticles' concentration raising (as shown in Fig. 2) that is related to the free charge carriers absorbing the incident photons [35, 36].

The values of E_g for different PbO_2 concentrations of nanocomposite samples are shown in Fig. 3 for allowed indirect transitions. It is very clear from this figure that the PbO_2 concentration increase the energy gap decreases. The decrease of energy gap is due to the local cross-linking existence, which is occurred inside the phase of noncrystalline of composite [37].

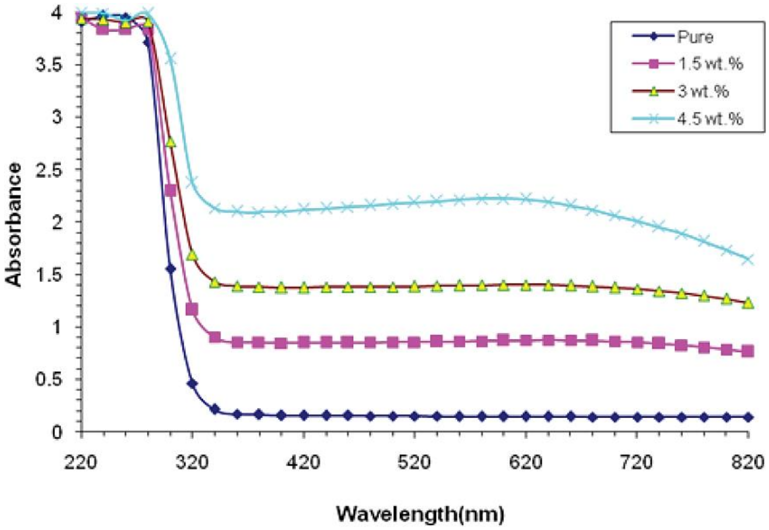

Fig. 1. Absorbance spectra with photon wavelength of nanocomposites.

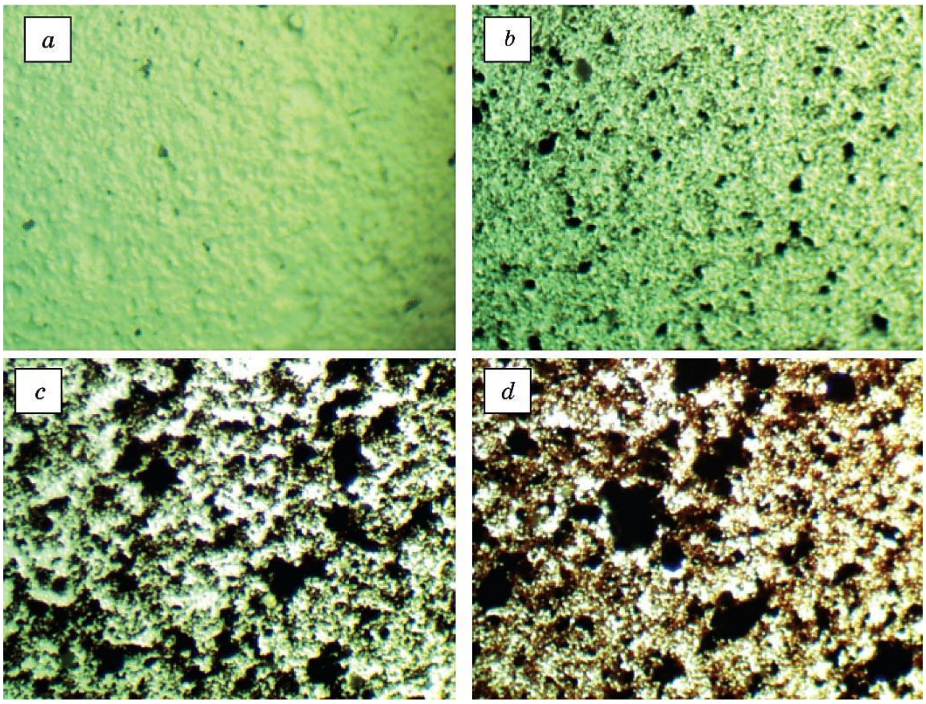

Fig. 2. Microscope images (×10): (*a*) pure; (*b*) 1.5 wt.% PbO_2; (*c*) 3 wt.% PbO_2; (*d*) 4.5 wt.% PbO_2.

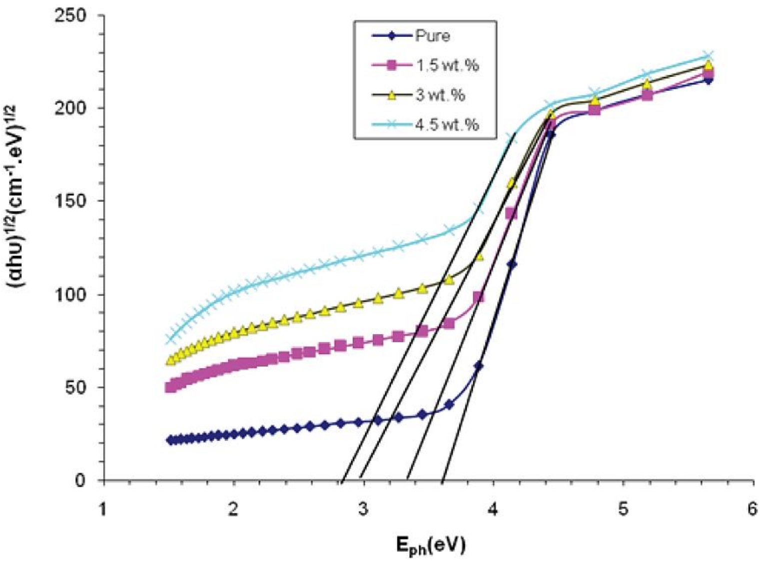

Fig. 3. Indirect energy gap of allowed transition for PVP–PEO–PbO_2 nanocomposites.

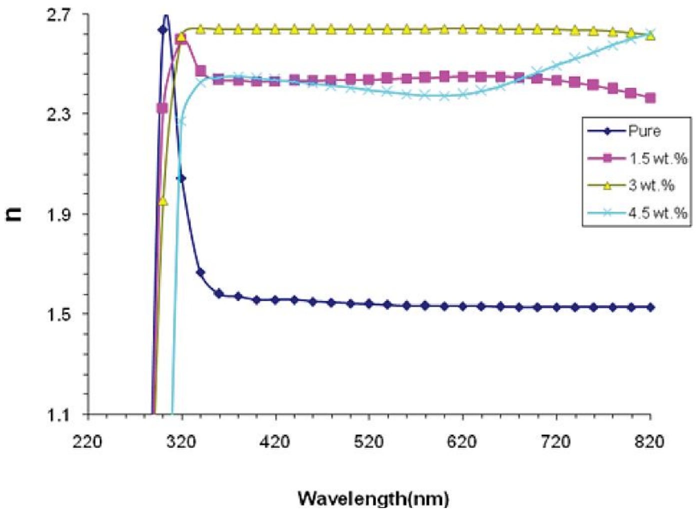

Fig. 4. Refractive index of PVP–PEO–PbO_2 nanocomposites with wavelength.

Figure 4 represents the behaviour of the refractive index with wavelength. Refractive index raises as the lead oxide content increase that is attributed to raise the packing density [38].

Figure 5 represents the real part of dielectric constant. The real

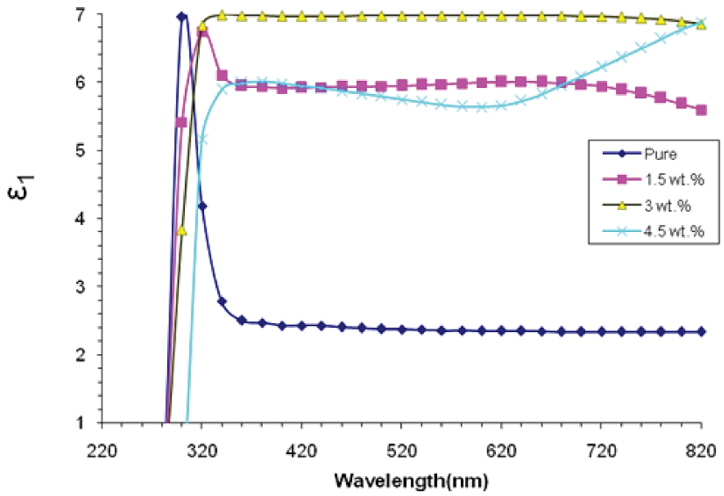

Fig. 5. Real part of dielectric constant *vs.* wavelength for nanocomposites.

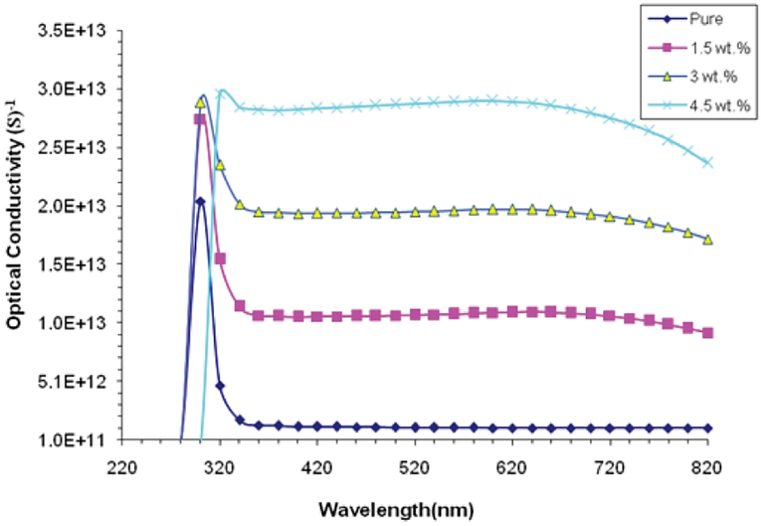

Fig. 6. Conductivity of nanocomposites with photon energy.

part increases with raising the PbO_2 content; this performance is due to increase of polarization, *i.e.*, the increase attributed to raising in charges [39].

Figure 6 shows the conductivity with photon energy. From this figure, the conductivity increases with the raise in weight percentages of PbO_2 nanoparticles. This performance is attributed to raising of refractive index and absorption coefficient [40, 41].

4. CONCLUSIONS

The polyvinylpyrrolidone–polyethylene oxide–lead oxide nanocomposites have higher absorption for high-energy photons; this behaviour makes it be used as coating materials with high attenuation and low cost. The optical parameters of PVP–PEO blend are increased with increase in PbO_2 content. Energy gap of blend decreases with increase in PbO_2 concentrations.

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