

RESEARCH PAPER

Thickness Influence on the Optical Properties of (PMMA-PbO) Nanocomposites

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ABSTRACT

In all technological fields, nanotechnology is one of the most popular subjects of contemporary study and development. Polymer science and technology are included, and research in this field encompasses a wide range of problems. Because the key size scale for current devices is now less than 100 nanometers, this would encompass microelectronics (which may now be referred to as nanoelectronics). This paper includes the effect of thickness of the nano-composite (polymethyl methacrylate - lead oxide) on the optical properties and preparing (PMMA-Pbo) nanocomposite by adding 1wt% of lead oxide to PMMA that have been prepared at room temperature, by using the casting method. The thicknesses of the films were determined using an electronic digital device (Micrometer) and found to be (60,120, and 220) μm . FTIR and Optical properties of nanocomposite (PMMA-PbO) were examined. The absorbance, absorption coefficient, refractive index, extinction coefficient, real and imaginary parts of the dielectric constant of (PMMA-PbO) nanocomposites increased with increased film thickness, according to the experimental results. With increasing film thickness, the transmittance, and energy band gap decrease.

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INTRODUCTION

In all technological fields, nanotechnology is one of the most popular subjects of contemporary study and development. Polymer science and technology are included, and research in this field encompasses a wide range of problems. Because the key size scale for current devices is now less than 100 nanometers, this would encompass microelectronics (which may now be referred to as nanoelectronics) [1]. Nanotechnology contains manufacturing and nanocomposites applications that provide new techniques and trade opportunities for a variety of industries, including automotive, electronics, physical, chemical,

and systems, at scales ranging from single atoms or molecules to submicron dimensions. Nanotechnology is often regarded as the next manufacturing revolution [2]. The nanocomposites are composites with nanometer-scale dimensions ($1 \text{ nm} = 10^{-9} \text{ m}$) in at least one phase [3]. Nanocomposite materials have emerged as viable alternatives to micro composites and monolithic, but they come with their own set of hurdles in terms of elemental composition and stoichiometry control in the nanocluster phase. They are said to be the materials of the twenty-first century since they have design distinctiveness and property combinations not found in traditional composites.

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This property's general knowledge has yet to be achieved [4]. Synthetic and natural polymers, as well as nanomaterials, make up nano-composites. The latter refers to materials that have nanoscale dimensions or are made up of nanoscale building components [5]. The optical properties of polymers are important in the study of electronics transitions and their potential use as optical filters, amorphous and crystalline semiconductor architectures are often derived from the research of optical properties over broad frequency ranges [6,7]. Poly (methyl methacrylate) is one of the most well-known and oldest polymers [8]. Because of its appealing physical and optical qualities, it is a vital and intriguing polymer with a wide range of applications. [9]. (PMMA) has been successfully utilized to freeze enzymes, create micro-locked devices, precipitate minerals, and freeze proteins and DNA (in the form of microcellules) [10]. The TCOs (transparent conducting oxides) with the dielectric constant of ≈25.9 are PbOs (lead monoxides). Because of their low band gap, PbO has a lot of upside as a surface modification layer in polymer solar inverted cells of photovoltaics, whereas -PbOs can be used as such a layer to reduce work functions [11]. PbO has sparked a lot of interest because of its high electrochemical efficiency and stability in the medium of acid [12]. The optical properties considered in this study include: The equation is used to compute the coefficient of absorption (α): [13]

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

where t is the thickness, and A is the absorbance. The in-direct transitions models of nanocomposite provide the following results [14]:

$$\alpha h\nu = B(h\nu - E_g^{opt} \pm E_{ph})^r \tag{2}$$

Where $h\nu$ represents photon energy, B is constant, E_g represents optical energy band gap, $r = 2$ for allowed indirect transitions, and $r = 3$ for disallowed indirect transitions. When (-) phonons are absorbed, and when (+) phonons are emitted. The coefficient extinction (k) is computed using the next equation: [15]

$$K = \alpha\lambda/4\pi \tag{3}$$

The refractive index (n) of nanocomposites was calculated using the equation as follows: [16]

$$n = \sqrt{4R - \frac{k^2}{(R-1)^2} - \frac{R+1}{R-1}} \tag{4}$$

Where the coefficient of extinction is K , the reflectivity is R , and the refraction index is n . For (PMMA-PbO) nanocomposites, the equations are used to partition the dielectric constant (real and imaginary) sections of (ϵ_1, ϵ_2). [17]:

$$\epsilon_1 = n^2 - k^2 \tag{5}$$

$$\epsilon_2 = 2nk \tag{6}$$

MATERIALS AND METHODS

Materials

(PMMA) is a tough, and lightweight material. Its density is 1.2 g / cm^3 . It is less than half of the PMMA glass with high strength, high modulus of elasticity, and high surface hardness (scratch resistance), and if it is polymerized between the float glass panels, with a high surface sheen. it has a melting point of (160°C). The casting method is used to prepare films of Poly (Methyl Methacrylate) (PMMA) and (PbO) with different thicknesses. (PMMA-PbO) nanocomposites were prepared by dissolving PMMA in chloroform, with 1wt% of PbO nanoparticles. A magnetic stirrer was used to agitate the solution for 1 hour waiting for the polymer to be entirely dissolved then (PbO) was added to the polymer with 1wt%. The solution was poured into flat glass plate dishes, after drying in the air for seven days at room temperature, homogeneous films were produced. An electronic digital instrument was used to measure the thicknesses of the manufactured films (60, 120, and 220) μm . The samples' optical characteristics were determined using a double beam spectrophotometer, (Shimadzu, UV-18000A) in wavelength (190-400) nm.

RESULTS AND DISCUSSIONS

Fig. 1 shows the several peaks in FT-IR spectrums of (PMMA-PbO) nano-composites at concentrations 1wt% of (PbO), that fall within a range of ($4000 - 1000 \text{ cm}^{-1}$), Fig 1. (A, B, and C) described (PMMA-PbO) nanocomposite FTIR spectra, the (PMMA-PbO) nanocomposite a discrete band of bended and stretched vibration of a function group. The absorption band at 1720 cm^{-1} due to C=O stretching aldehydes, and the absorption band at 1143.49 cm^{-1} represents

C-O stretching vibration in PMMA [18]. At 747cm^{-1} C-H deformation vibration, at 2350cm^{-1} O-H stretch, and at 1717cm^{-1} C=O stretching vibration of carboxyl bond, the absorption band at 1240.18cm^{-1} represents C-C also from PMMA. The band at 1434.89cm^{-1} attributed to C-H bending . From the

FT-IR results, it can be detected that no chemical reaction occurs, but rather physical reactions or physical bonding [19].

Fig. 2 illustrates the absorption spectra of the substances under research with different thicknesses (60,120, and 220) μm in the range

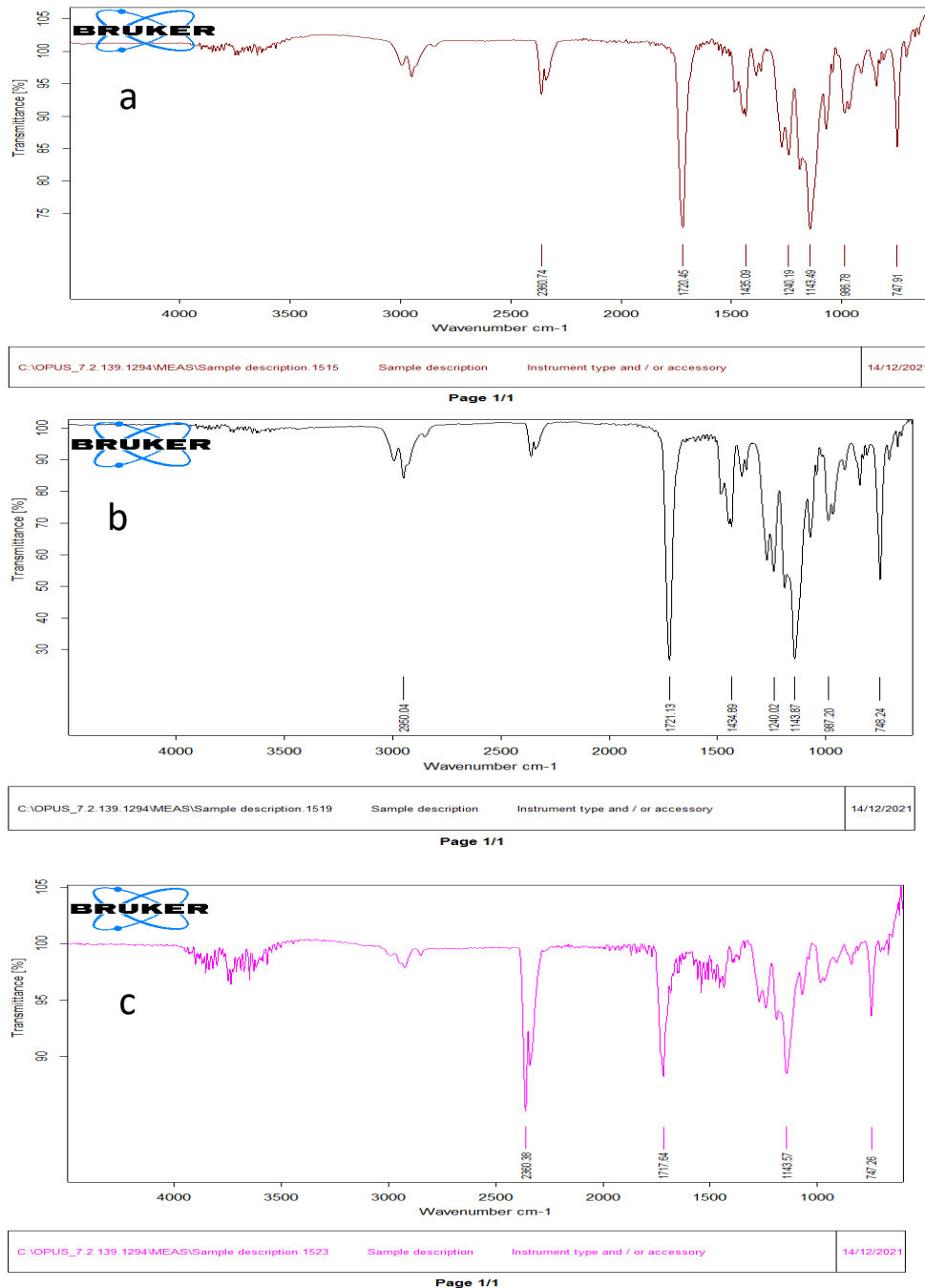


Fig. 1. Spectrum FTIR for (PMMA-PbO) Nano-Composites at 1wt% of PbO with different thickness (A=60, B=120, C=220) μm

(200–800) nm, which is a convenient spectral range. In the UV, all samples showed that the absorbance gradually decreases according to the increase in wavelength and for all films (PMMA-PbO), while the absorbance increases gradually with increasing the thickness of the film. This is because the incident light is absorbed by free electrons [20].

Fig. 3 shows the optical transmittance spectra of the samples with different thicknesses (60,120, and220) μm respectively under investigation in the range (200–800) nm which is the convenient

spectral region. In the ultraviolet, all samples showed that the transmittance gradually increases with the increase of the wavelength and for all films (PMMA-PbO), while the transmittance decreases gradually with increasing the thickness of the film, This behavior may be because of the increase in the absorbance and increase in film thickness which decreases the transmittance value [21].

The coefficient of absorption (α) is computed by using equation 1 where Fig. 4 shows the absorption coefficient of nanocomposites (PMMA-

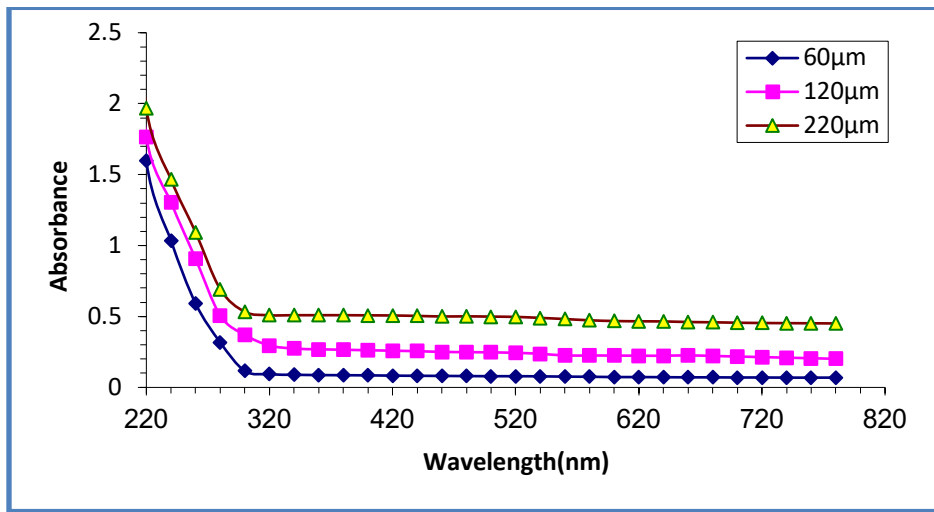


Fig. 2. The absorbance as a function of wavelength for (PMMA-PbO) sample with different thicknesses at 1wt% of PbO.

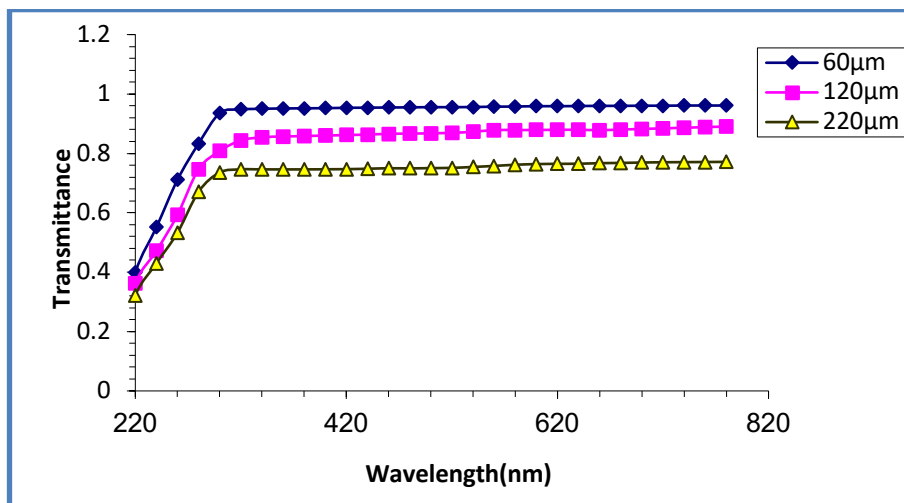


Fig. 3. The transmittance as a function of wavelength for (PMMA-PbO) sample with different thicknesses, at 1wt% of PbO.

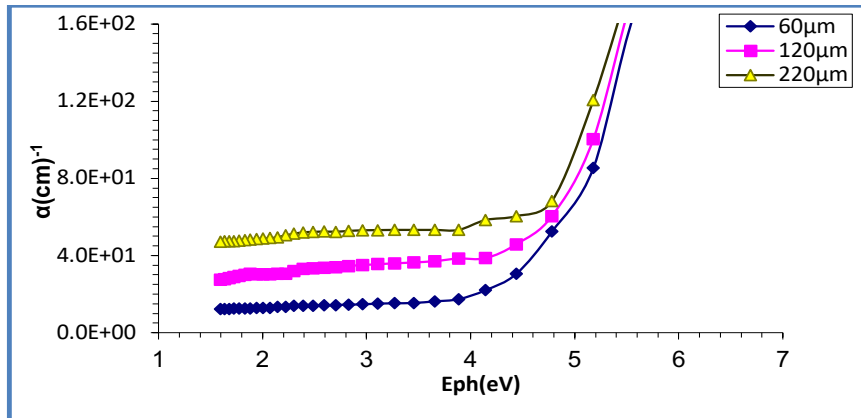


Fig. 4. The absorption coefficient versus photon energy for (PMMA-PbO) different thickness films at 1wt% of PbO.

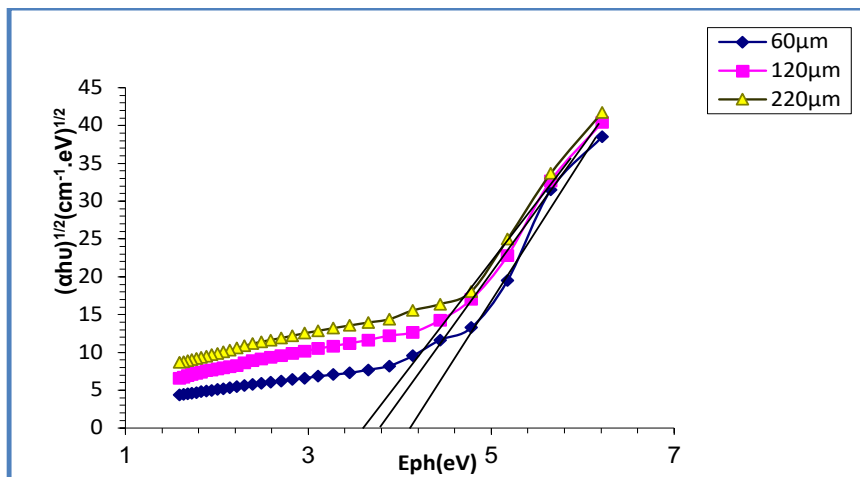


Fig. 5. Photon Energy versus Energy Gap for the Allowed Indirect Transition $(h\nu)^{1/2} (\text{cm}^{-1}.\text{eV})^{1/2}$ of PMMA-PbO Nanocomposites with different thicknesses at 1wt% of PbO.

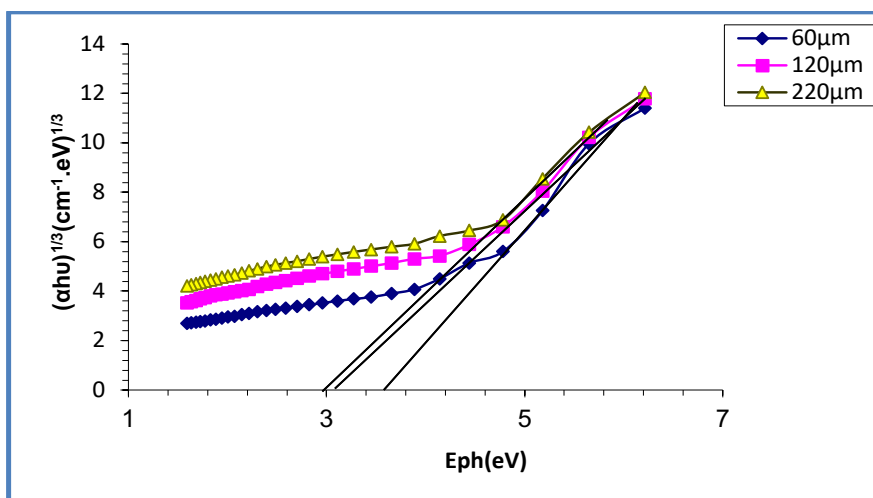


Fig. 6. Photon Energy versus Gap of Energy for the Forbidden Indirect Transition $(h\nu)^{1/3} (\text{cm}^{-1}.\text{eV})^{1/3}$ of (PMMA-PbO) Nanocomposites with different thicknesses.

PbO). The results presented that the coefficient of absorption changes depending on the frequency change. It depends on the energy of the photons. From the figure, we notice that the value of the absorption coefficient increases with the increase in the energy of the photon for all films (PMMA-PbO), The value of the absorption coefficient increases with the increasing thickness of the

film [22]. At low energies, was found to be the lowest, meaning that there were fewer options for electron transitions, because the input photon energies were inadequate to transport electrons from the valence bands to the conduction bands. The electron absorptions were stellar at high energies. The absorption coefficients were less than (10^4 cm^{-1}), indicating that indirect transitions

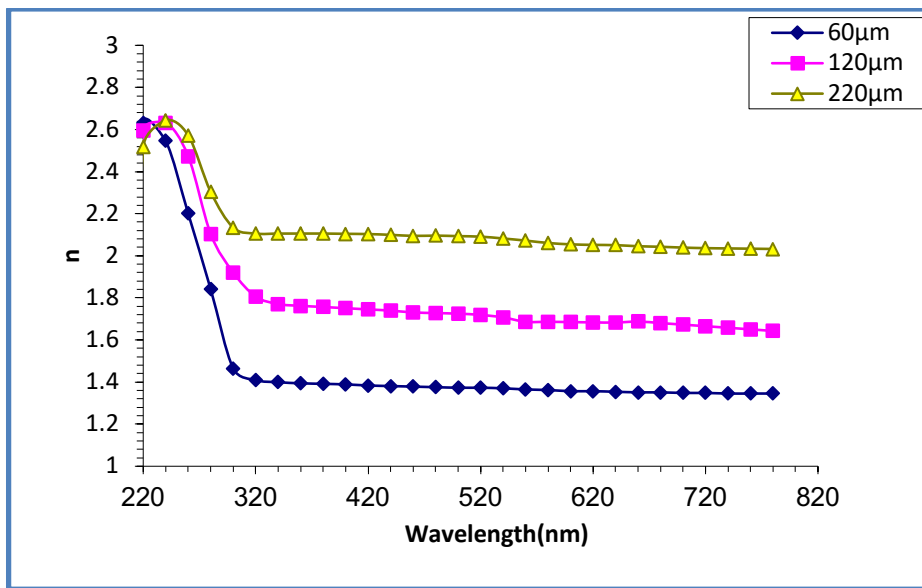


Fig. 7. Refractive index versus wavelength for (PMMA-PbO) different thickness films at 1wt% of PbO.

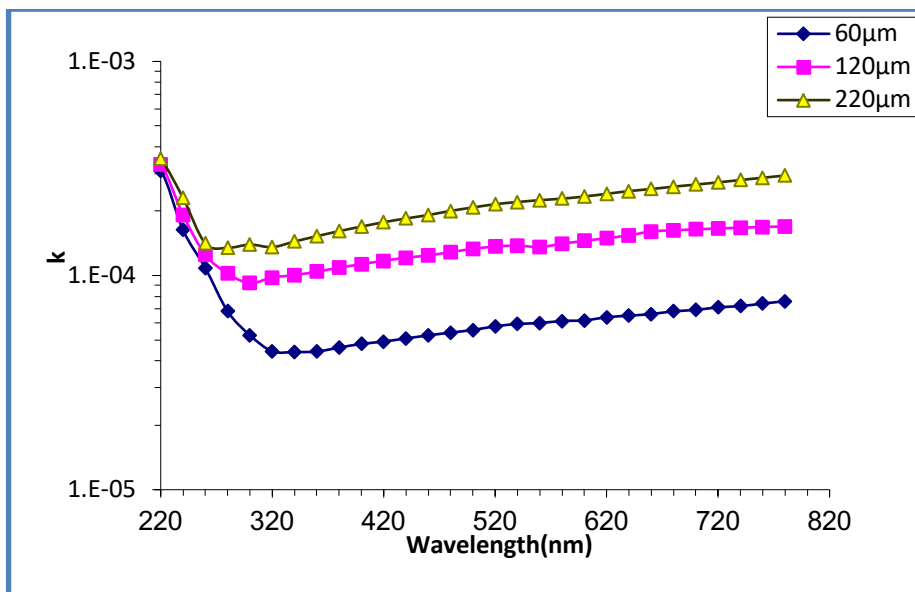


Fig. 8. Extinction coefficient versus wavelength for the (PMMA-PbO) different thickness films at 1wt% of PbO.

were a strong possibility. It's worth noting that the energy gap figures have shrunk significantly. This is due to localized level increases in the energy band gaps [23,24]. Figs. 5 and 6 illustrate the allowed and forbidden indirect optical energy gaps for (PMMA-PbO) nanocomposites films of different thicknesses, which were determined in general

from the intercepts of extrapolating linear parts of curves against photon energy ($h\nu$) at $(h\nu)^n = 0$ [25]. The indirect optical band gap for the (PMMA-PbO) films with different thicknesses was estimated to be about 4.19, 3.80, and 3.60 eV, the indirect allowable transition was determined as, while the indirect disallowed energy gap were obtained as

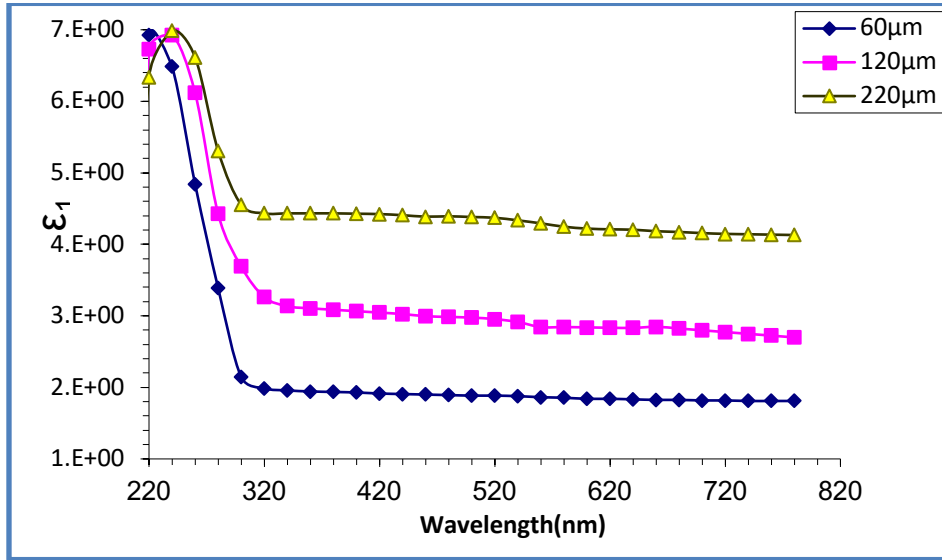


Fig. 9. Real part of dielectric constant versus wavelength for the (PMMA-PbO) different thickness films at 1wt% of PbO.

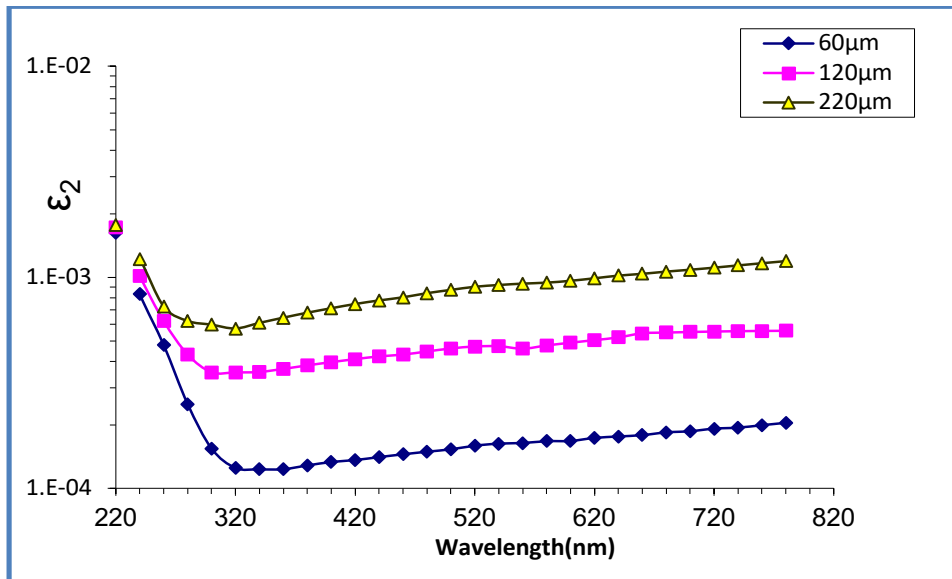


Fig. 10. Imaginary part of dielectric constant versus wavelength. for the (PMMA-PbO) different thickness film at 1wt% of PbO.

3.60, 3.20, and 3.0 eV with increased thickness, respectively. We observe a decrease in the energy gap with increasing thickness. This behavior is due to the increase in thickness leads to an increase in crystal defects and thus an increase in the energy levels between the valence and conduction bands and as a result the energy gap decreases with increased thickness.

Fig. 7 shows the refractive index versus the wavelength of different thicknesses. We can notice that the refractive index increases with increasing thickness [26]. where the refractive index is calculated from equation 7.

Equation 3 can be used to calculate the coefficients of extinction (k). For (PMMA-PbO) nanocomposites, the behavior of the extinction coefficients as a function of the wavelengths is illustrated in Fig.8. At visible and near-infrared wavelengths, (k) is the lowest value of low particles. However, according to equation 3, the extinction coefficients increased as the wavelengths increased this is due to an increase in absorption coefficients as the thickness of the film increases [27]. As the film thickness increases, these values for the films increases as shown in equation 3, absorption coefficients have a direct relationship with k . Figs. 9 and (10) illustrate the dependency of (ϵ_r) and (ϵ_i) values on wavelength. As the film thickness increases, these values for the films increase [28]. The real, and imaginary dielectric constants (ϵ_r , ϵ_i) for (PMMA-PbO) nanocomposites were used to compute from equations 5 and 6 respectively. The real, and imaginary parts of the dielectric constant have the same pattern curves, but the real part's values are greater than the imaginary part's.

CONCLUSION

1. The absorbance of (PMMA-PbO) nanocomposites increases with the increase of films thickness. Optical constants (absorptions coefficients, extinction coefficients, refractive index, real, and imaginary dielectrics constants) are increasing with the increase of the film's thickness. Therefore, these thicknesses can be used for composites (PMMA-PbO) to attenuate high-energy rays

2. The energy gaps for (PMMA-PbO) nanocomposites are decreased with the increase of films thickness.

3. Measurements (FTIR) indicate a physical bonding, not a chemical reaction.

4. A significant change was observed in most of the optical properties, especially the absorbance because the absorbance is a function of the thickness and its increase due to the increase in the thickness of the absorbent material and the decrease in both transmittance and reflectivity due to the increase in absorbance.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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