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Preparation of ($PMMA-Y_2O_3$) Nanocomposites and Study their Optical Properties

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ABSTRACT

In this paper, the effect of yttrium oxide nanoparticles on the optical properties of polymethylmethacrylate has been investigated. The results show that the optical constants of ($PMMA-Y_2O_3$) nanocomposites are increasing with the increase of the yttrium oxide nanoparticles concentrations. The energy band gap of ($PMMA-Y_2O_3$) nanocomposites decreases with the increase of the yttrium oxide nanoparticles concentrations.

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INTRODUCTION

Nanostructured materials constitute one of the most propulsive fields of materials science and have received great attention due to their potential application in various fields.Therefore, the research activities on nanoscale particle synthesis and characterization have increased significantly in the last few years. Advanced applications require nanoparticles with narrow particle size distribution and defined particle shape[1]. Nanostructured materials promise fruitful development for applications in the aerospace sector due to their high strength, low density and thermal stability. These applications include equipping aircrafts, rockets, space stations and platforms for planetary or solar exploration. Nanotechnology has attracted the interest of numerous research groups around the world due to its potential for application in various industries[2]. Nanocomposites are a distinct form of composite materials, which involve embedding nano- or molecular domain-sized particles into organic polymer, metal or ceramic matrix materials. The intimate inclusion of nanoparticles in these matrices can greatly change the mechanical, electrical, optical or magnetic properties of these materials. The reason for this is that with such small inclusions, a large amount of interfacial phase material exists in the bulk of these nanocomposites [3]. Poly(methyl- methacrylate) (PMMA) is an important member in the family of polyacrylic and methacrylic esters. It has several desirable properties, including exceptional optical clarity, good weatherability, high strength, and excellent dimensional stability [4]. Polymethylmethacrylate (PMMA) is a versatile polymeric material that is well suited for many microelectronic applications. It is often preferred because of its moderate properties, easy handling and processing, and low cost. Its melting point it 160^oC. Also, Polymethylmethacrylate is one of the most versatile polymeric materials that are well suited for many applications in micro electric and electro-optics areas. This polymer offers low costs, process ability, possibility of functionalization, and are semiconductor nanoparticles, which simultaneously show a size-dependent band gap shift, high carrier mobility, and nonlinear optical properties [5].

Experimental Work:

Nanocomposites of ($PMMA-Y_2O_3$) films are prepared by using casting method. The yttrium oxide nanoparticles are added to polymer with different concentrations are (0, 1.5, 3, 4.5) wt.%. The optical properties of ($PMMA-Y_2O_3$) nanocomposites are measured by using UV/1800/ Shimadzu spectrophotometer in range of wavelength (200-800) nm.

Absorption coefficient (α) of ($PMMA-Y_2O_3$) nanocomposites is defined by following equation[6]:

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

Where A: is the absorbance and t: is the sample thickness.
The indirect transition for amorphous materials is[6]:

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$$\alpha h\upsilon = B(h\upsilon - E_g)^r \quad (2)$$

Where B is a constant, hυ is the photon energy , E_g is the optical energy band gap, r = 2 for allowed indirect transition and r = 3 for forbidden indirect transition.
The Refractive index (n) is given by following equation for ($PMMA-Y_2O_3$) nanocomposites [7]:

$$n= (1+R^{1/2})/ (1-R^{1/2}) \quad (3)$$

Where R is the reflectance.
The extinction coefficient (k) is calculated by the following equation[7]:

$$K=\alpha\lambda/4\pi \quad (4)$$

The dielectric constants (real(ε_1), and imaginary (ε_2)) are calculated by using equations[8]:

$$\varepsilon_1=n^2-k^2 \quad (5)$$

$$\varepsilon_2=2nk \quad (6)$$

RESULTS AND DISCUSSION

The variation of absorbance of ($PMMA-Y_2O_3$) nanocomposites with wavelength of different concentrations of additive nanoparticles is shown in figure 1.. The figure shows that the absorbance of polymer is increased with the increase the concentrations of nanoparticle, this is due to the nanoparticles absorb the incident light [9].

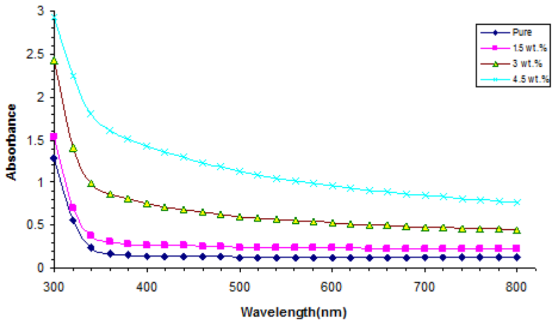

Fig. 1: variation of absorbance of ($PMMA-Y_2O_3$) nanocomposites with wavelength.

Figure 2: shows the variation of the absorption coefficient of nanocomposites with photon energy. From the figure, the absorption coefficient is increased with the increase of the concentrations of the yttrium oxide nanoparticles. The increase of absorption coefficient with yttrium oxide nanoparticles concentrations attributed to the increase of absorption of the light. The values of absorption coefficient is less than 10^4 cm^{-1}, this mean the ($PMMA-Y_2O_3$) nanocomposites have indirect energy band gap as shown in figure 3 for allowed indirect transition and figure 4 for forbidden indirect transition. The energy band gap of the ($PMMA-Y_2O_3$) nanocomposites decreases with the increase of the concentrations of yttrium oxide nanoparticles which attributed to the increase of the local levels in forbidden energy band gap[9].

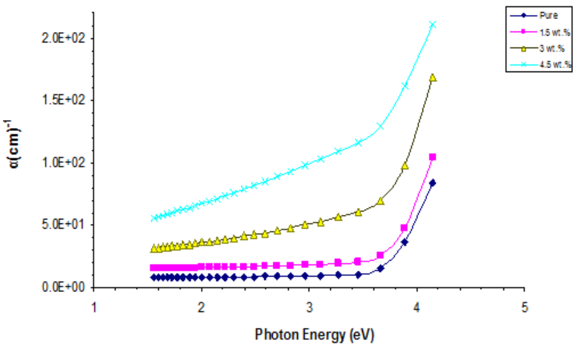

Fig. 2: variation of the absorption coefficient of nanocomposites with photon energy.

The variation of the extinction coefficient of ($PMMA-Y_2O_3$) nanocomposites with the wavelength is shown in figure 5. The figure shows the extinction coefficient of ($PMMA-Y_2O_3$) nanocomposites increases with the increase of the concentrations of yttrium oxide nanoparticles this is attributed to loss of energy because the reaction between the light and the molecules of the medium[10].

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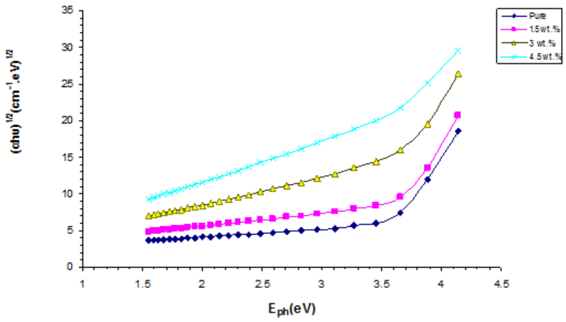

Fig. 3: The relationship between $(\alpha h\upsilon)^{1/2}(cm^{-1}.eV)^{1/2}$ and photon energy of nanocomposites.

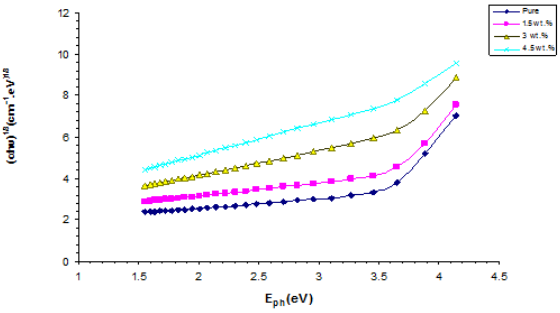

Fig. 4: The relationship between $(\alpha h\upsilon)^{1/3}(cm^{-1}.eV)^{1/3}$ and photon energy of nanocomposites.

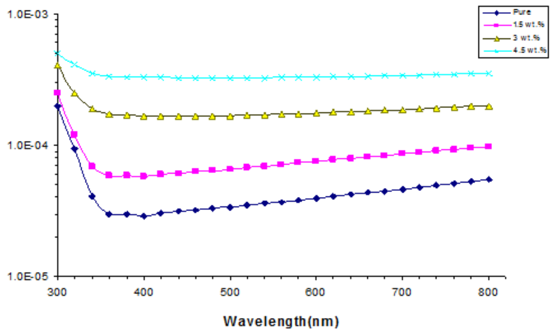

Fig. 5: variation of the extinction coefficient of ($PMMA-Y_2O_3$) nanocomposites with the wavelength.

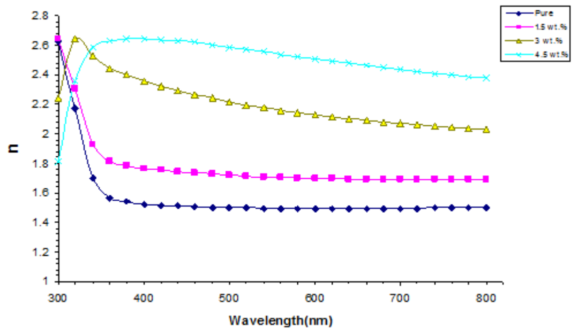

Fig. 6: The relationship between the refractive index of ($PMMA-Y_2O_3$) nanocomposites and wavelength.

The relationship between the refractive index of ($PMMA-Y_2O_3$) nanocomposites and wavelength is shown in figure 6. The figure shows that the refractive index of increases with the increase of the concentration of filler which is due to the increase the scattering of the light [10].

Figures 7 and 8 show the effect of yttrium oxide nanoparticles concentrations on the real and imaginary parts of dielectric constants of ($PMMA-Y_2O_3$) nanocomposites.

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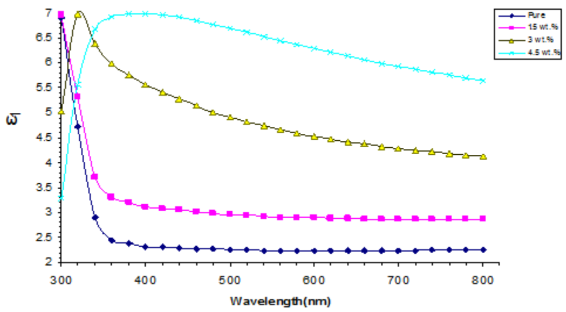

Fig. 7: Effect of yttrium oxide nanoparticles on real part of dielectric constant of nanocomposites.

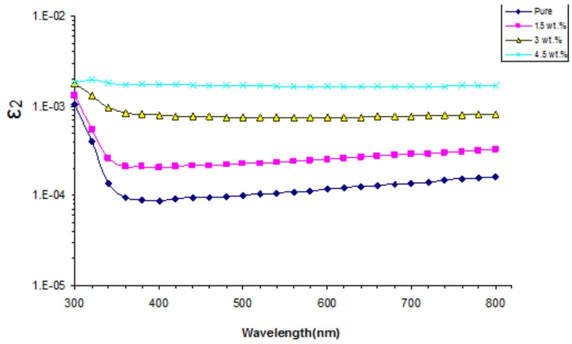

Fig. 8: Effect of yttrium oxide nanoparticles on imaginary part of dielectric constant of (PMMA-Y_2O_3) nanocomposites.

From the figures, the real and imaginary parts of dielectric constants of (PMMA-Y_2O_3) nanocomposites are increased with the increase of the concentrations of yttrium oxide nanoparticles, this is attributed to the increase of the absorption and scattering[11].

Conclusions:

1- The absorbance of (PMMA-Y_2O_3) nanocomposites increases with the increase of the concentrations of yttrium oxide nanoparticles.
2- The optical constants (absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constants) of (PMMA-Y_2O_3) nanocomposites are increasing with the increase of the concentrations of the yttrium oxide nanoparticles.
3- The energy band gap of (PMMA-Y_2O_3) nanocomposites decreases with the increase of the concentrations of the yttrium oxide nanoparticles.

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