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Synthesis and Study of Optical Properties of $(PMMA\text{-}CrCl_2)$ Composites

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Abstract In this paper, the optical properties of randomly mixed consisting of poly(methyl methacrylate) and Chromium chloride have been investigated. The samples of composites have been prepared by adding Chromium chloride to poly(methyl methacrylate) with different weight percentages from Chromium chloride with polymer and different thickness. Results showed that the absorbance increases with the increase of the concentration of $CrCl_2$. The absorption coefficient, extinction coefficient, refractive index and real and imaginary parts of dielectric constants are increasing with the increase of the $CrCl_2$ concentration. The energy band gap is decreased with the increase of the $CrCl_2$ concentration.

Keywords Poly(Methyl Methacrylate), Chromium Chloride, Optical Properties

1. Introduction

Polymeric composite materials are widely used in weight sensitive applications due to their high strength-to weight and stiffness-to-weight ratios compared with metallic materials. The weight and fuel savings offered by composite materials makes them attractive not only to the military, but also to the civilian aircraft, space, solar vehicles, and automobile industries. The physical properties of polymers may be affected by doping, the certain structural, optical, mechanical, electrical and magnetic properties of the selected polymer can be controllably modified owing to the type of the doping, concentration, and the way in which it penetrates and interacts with the chains of the polymer. Detailed studies of doped polymer with different dopant concentrations allow the possibility of choice of the desired properties[1].The study of the optical absorption spectra in solids provides essential information about the band structure and the energy gap in the crystalline and non-crystalline materials. Analysis of the absorption spectra in the lower energy part gives information about atomic vibrations while the higher energy part of the spectrum gives knowledge about the electronic states in the atom[2]. The main two types of optical transitions are direct and indirect transitions, both involve the interaction of an electromagnetic wave with the electron in valence band which may cross the forbidden gap to the conduction band[3]. Indirect transitions are possible only by phonon assisted transition. The value and shape of the mobility gap in the amorphous semiconductors depend on the preparation condition such as substrate temperature, annealing temperature, degree of impurity and defect of the material. Any variation in such parameters leads to a shift in the absorption edge towards higher or lower energy[4]. Ahmad et . al, [5] studied the optical constants of polymethyl methacrylate doped with methylene blue and methyl red with in the wavelength range(200-900) nm. They found that the optical constants change with increasing dopant concentrations,. The aim of this work is to study the effect of Chromium chloride concentration on the optical properties of $PMMA\text{-}CrCl_2$ composite.

2. Experiment

2.1 Materials

The materials used in this paper are poly(methyl methacrylate) and Chromium chloride.

2.2. Methods

The weight percentages of poly(methyl methacrylate) are (0,1,2 and 3)wt.%. The samples were prepared using casting technique thickness ranged between (200-430)µm. The transmission and absorption spectra of composites have been recording in the length range (200-800) nm using double-beam spectrophotometer (UV-210^{o}A shimedza)

3. Results and Discussion

Figure (1) shows the variation of the optical absorbance with the wavelength of the incident light of composites. From figure we can see the absorbance increases with increase of Chromium chloride concentration, this attributed to the high absorbance of Chromium chloride [6].

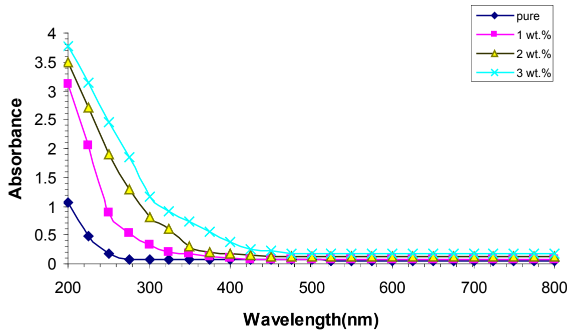

Figure 1. Variation of optical absorbance for (PMMA-$CrCl_2$) composite with wavelength

The variation of the absorption coefficient, α, as a function photon energy are presented in Fig. 2 . It was calculated from equation[6]:

$$\alpha = 2.303\frac{A}{d}. \qquad (1)$$

Where : A is absorbance and d is the thickness of sample

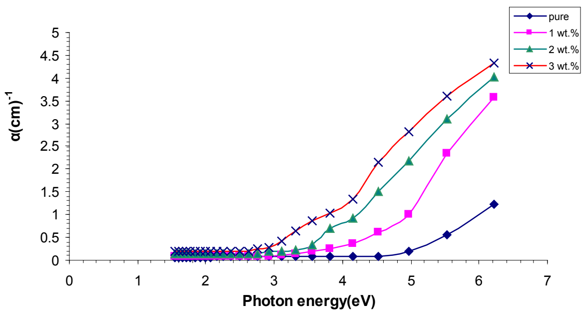

Figure 2. absorption coefficient for (PMMA-$CrCl_2$) composite with various photon energy

The values of the absorption coefficient are less than 10^4cm^{-1} in the investigation spectral range. The fundamental absorption, which corresponds to electron excitation from the valence band to conduction band, can be used to determine the nature and value of the optical band gap, *Eg*. The relation between the absorption coefficient, α, and the incident photon energy, hν, can be written as[2] :

$$(\alpha h\nu)^{n} = B(h\nu - Eg) \qquad \text{..............(2)}$$

where B is an constant depending on the transition probability and n is an index that characterizes the optical absorption process and is theoretically equal to 1/2,2, 1/3 or 2/3 for indirect allowed, direct allowed, indirect forbidden and direct forbidden transition, respectively. The usual method to calculate the band gap energy is to plot a graph between $(\alpha h\nu)^n$ and photon energy, hν, and find the value of the n which gives the best linear graph. This value of n decides the nature of the energy gap or transition involved. If an appropriate value of n is used to obtain linear plot, the value of *Eg* will be given by intercept on the hν-axis, the optical energy gap has been determined from the intercepts of extrapolations to zero with the photon energy axis $(\alpha h\nu)^n \to 0$ [7]as shown in figures (3,4).

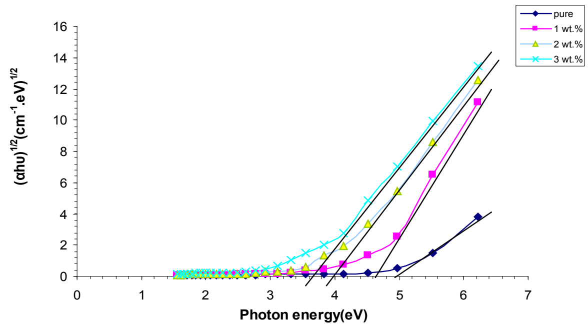

Figure 3. the relationship between $(\alpha h\upsilon)^{1/2}(cm^{-1}.eV)^{1/2}$ and photon energy of (PMMA-$CrCl_2$) composites.

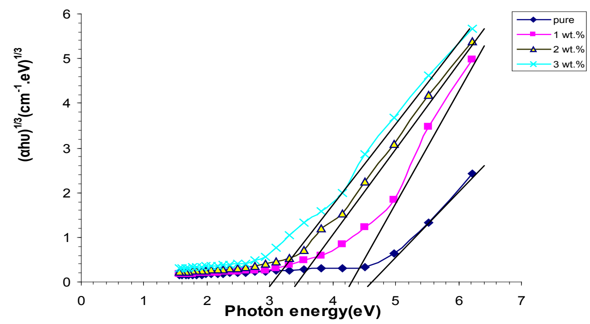

Figure 4. the relationship between $(\alpha h\upsilon)^{1/3}(cm^{-1}.eV)^{1/3}$ and photon energy of (PMMA-$CrCl_2$) composites.

From the figures, we can see that an increase of concentration of Chromium chloride in the system leads to an decrease in the optical band gap. The increase in band gap with decrease in concentration can be due to the decrease in cluster size of the parent solution. It is found that as the concentration of the chalcogenide decreases there is a red shift in band edge and a change in the slope of absorption spectra[2].

The attenuation coefficient (k) is directly proportional to the absorption coefficient(α)[8]:

$$k = \alpha\lambda/4\pi \qquad (3)$$

Where λ is the free space wavelength of light. The decrease in the extinction coefficient with an increase in wavelength shows that the fraction of light lost due to scattering [2]

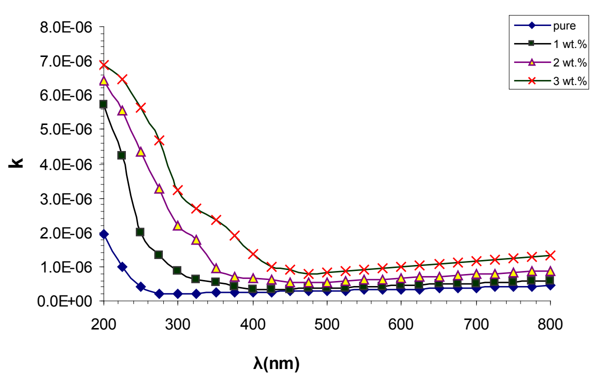

Figure 5. extinction coefficient for (PMMA -$CrCl_2$) composite with various photon energy

Figure(6) shows the variation of the refractive index ($n = \frac{1+\sqrt{R}}{1-\sqrt{R}}$ where R is reflectance) of composites a function of photon energy. It has been found that the value of refractive index increases with increasing the concentration of Chromium chloride which is a result of increasing the number of atomic refractions due to the increase of the linear polarizability in agreement with Lorentz - Lorentz formula[7].

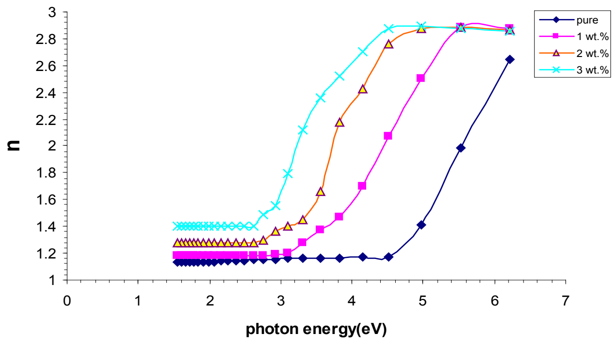

Figure 6. The relationship between refractive index for (PMMA -CrCl2) composite with photon energy

The calculation of real part and imaginary part of the dielectric constant provide information about the loss factor. Figures(7,8) show the variation of real and imaginary parts of dielectric constants ($\varepsilon_1 = n^2 - k^2$ and $\varepsilon_2 = 2nk$) of composites .It is concluded that the variation of ε_1 mainly depends on (n^2) because of small values of (k^2), while ε_2 mainly depends on the (k) values which are related to the variation of absorption coefficients[6]. The real part of the dielectric constant is associated with the term that shows how much it will slow down the speed of light in the material and the imaginary part shows how a dielectric absorbs energy from an electric field due to dipole motion[8].

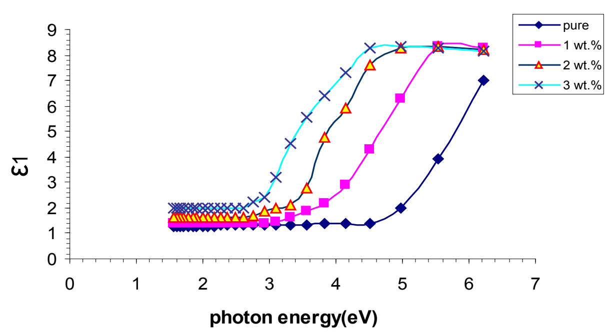

Figure 7. variation of real part of dielectric constant (PMMA -$CrCl_2$) composite with photon energy

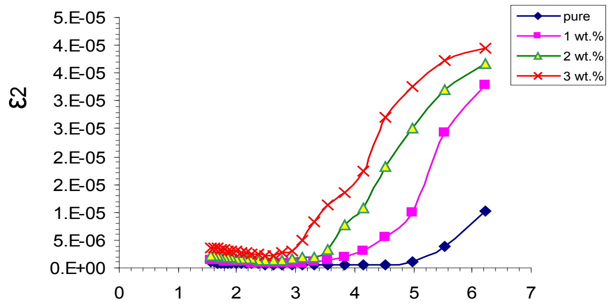

Figure 8. variation of maginary part of dielectric constant(PMMA -$CrCl_2$) composite with photon energy

4. Conclusions

The absorbance increases with the increase of the weight percentages of Chromium chloride

1. The absorption coefficient, extinction coefficient, refractive index and real and imaginary parts of dielectric constants are increasing with the increase of the weight percentages of Chromium chloride.
2. The indirect energy band gap decreases with the increase of the $CrCl_2$ concentration.

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