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The Properties of (PVA-CNTs) Nanocomposites

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Abstract

Nanocomposites are used in many industries such: solar cells, light emitting diodes, optoelectronic device, aircraft and cars. This paper is aimed to preparation of (PVA-CNTs) nanocomposites to using the new materials in many industries. Using the nanocomposites in these applications need to study the electrical, optical and mechanical properties which investigated in this paper. The samples of nanocomposites are prepared by using casting technique with different concentrations of carbon nanotubes. The optical properties of nanocomposites are measured in the wavelength range (200-800) nm. The results showed that the absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constant of nanocomposites are increasing with increase the carbon nanotubes concentrations. The D.C electrical properties of (PVA-CNTs) nanocomposites are studied in the range of temperature (from 50^0C to 80^0C). The results found the electrical conductivity is increased with increasing the carbon nanotubes concentration and temperature. The activation energy is decrease with increasing the weight percentages of carbon nanotubes. Also, the mechanical properties of (PVA-CNTs) are investigated. Results showed that velocity of ultrasonic wave**,** specific acoustic impedance, bulk modulus and compressibility change with increase the concentration of carbon nanotubes.

Keywords: Nanocomposites, optical, electrical, mechanical properties

Introduction

Carbon nanotubes (CNTs) are structures from the fullerene family which are created when a carbon honeycomb sheet rolls in itself to form a cylinder. Due to their outstanding physical properties, they have become a major topic of research in areas as diverse as material science, chemistry, electronics and recently in photonics. CNTs exhibit exceptional nonlinear optical properties which include nonlinear saturable absorption, ultrafast recovery time, high third-order optical nonlinearity, and broad bandwidth operation thus CNTs are rapidly becoming a key component in various photonic devices such as saturable absorbers used for noise suppression and as the intensity dependent component in passive mode-locked lasers [Martinez *et al.*, 2008]. In recent years, polymer–nanoparticle composite materials have attracted the interest of a number of researchers, due to their synergistic and hybrid properties derived from several components. Whether in solution or in bulk, these materials offer unique mechanical, electrical, optical and thermal properties. Such enhancements are induced by the physical presence of the nanoparticle and by the interaction of the polymer with the particle and the state of dispersion. One advantage of nanoparticles, as polymer additives appear to have is that compared to traditional additives, loading requirements are quite low. Micro sized particles used as reinforcing agents scatter light, thus reducing light transmittance and optical clarity. Efficient nanoparticle dispersion combined with good polymer–particle interfacial adhesion eliminates scattering and allows the exciting possibility of developing strong yet transparent films, coatings and membranes [Schmidt and Malwitz., 2003]. Electrical conduction in polymers has been studied aiming to understand the nature of the charge transport prevalent in these materials while the optical properties are aimed at achieving better reflection, antireflection, interference and polarization properties[Hamed *et al*., 2012]. If the band gaps of the materials were narrow, most of the incoming radiation would be absorbed by the electrons and be exited by the electrons from the valence band into the conduction band. If the materials, on the other hand, have wide energy band gap, the photon energy will be too weak and to cause any absorption and such materials would be seen as ineffective in converting the photon distribution to a narrow distribution. Only photons with energy greater than band gap of the materials will be absorbed. Photons of longer wavelength will pass through (i.e. be transmitted) having just sufficient energy to excite electrons [Ugwu , 2006].

Theoretical

The volume D.C electrical conductivity σ_v defined by [Ahmad *et al.*, 2007] :

$$\sigma_v = \frac{L}{RA} \quad \ldots\ldots\ldots (1)$$

Where:

A = guard electrode effective area.
R = volume resistance (Ohm).
L = average thickness of sample (cm).

In this model the electrodes have circular area $A = D^2\pi/4$ where D= 0.5 cm^2.

The activation energy was calculated using equation [Ramaiah and Raja,1999]:

$\sigma = \sigma_o \exp(-E_a/k_BT)$ ………..(2)

σ = electrical conductivity at T temperature
σ_0 = electrical conductivity at absolute zero of temperature
K_B = Boltzmann constant
E_a = Activation Energy

The absorbance (A) is defined as the ratio between absorbed light intensity (I_A) by material and the incident intensity of light (I_o) [Kurt and Demirelli, 2010]:

$A = I_A / I_o$ …………... (3)

The transmittance (T) is ratio between the intensity of the rays transmitting from the film (I) and the intensity of the incident rays on it (I_o) ($T = I/I_o$), and can be calculated by:

$T = \exp[-2.303A]$ ……….. (4)

And the reflectance (R) can be obtained from absorption and transmission spectra in accordance with the law of conservation of energy by the relation:

$R + T + A = 1$ ………… (5)

Absorption coefficient (α) is defined as the ability of a material to absorb the light of a given wavelength

$\alpha = 2.303A/t$ ..……. (6)

Where A: is the absorptance of the material t: the sample thickness in cm.

According to the generally accepted non-direct transition model for amorphous semiconductors proposed by [Bakauskas and Vinslovaite, 2003]:

$$\alpha h\upsilon = B(h\upsilon - E_g)^r \ldots\ldots\ldots\ldots(7)$$

Where B is a constant related to the properties of the valance band and conduction band, hυ is the photon energy , E_g is the optical energy band gap, r=2, or 3 for indirect allowed and indirect forbidden transition

The Refractive index (n), the index of refraction of a material is the ratio of the velocity of the light in vacuum to that of the specimen:

$R = ((n-1)^2 + k^2)/((n+1)^2 + k^2)$ …. (8)

When the ($k \rightarrow 0$)

$R = (n-1)^2/(n+1)^2$ ……… (9)

$n = (1+R^{1/2})/(1-R^{1/2})$ ……… (10)

The extinction coefficient (k) was calculated using the following equation:

$K = \alpha\lambda/4\pi$ ………… (11)

Dielectric constant is defined as the response of the material toward the incident electromagnetic field. The dielectric constant of compound (ε) is divided into two parts real (ε_1), and imaginary (ε_2).The real and imaginary parts of dielectric constant (ε_1 and ε_2) can be calculated by using equations:

$\varepsilon = \varepsilon_1 - i\,\varepsilon_2$ ……... (12)

$\varepsilon_1=n^2-k^2$ (real part) ……..... (13)

$\varepsilon_2=2nk$ (imaginary part) …… (14)

The velocity of ultrasonic wave (V) in nanocomposites by measured the pass time of the wave through the nanocomposites. The specific acoustic impedance calculated by using the following equation [Jarlath, 2008]:

$Z= \rho V$ ……..…..……….(15)

Where ρ is density of material

The compressibility of nanocomposites calculated by:

$K= (\rho V^2)^{-1}$ …………….(16)

The bulk modulus of (PVA-CNTs) nanocomposites was calculated by using the equation:

$B= \rho V^2$ …………….(17)

Experimental

The polyvinyl alcohol was dissolved in distill water by using magnetic stirrer in mixing process to get homogeneous solution. The weight percentages of CNTs are (0,1,2 and 3) wt.% were added and mixed for 10 minute to get more homogenous solution, after which solution was transferred to clean glass Petri dish of (5.5cm) in diameter placed on plate form. The dried film was then removed easily by using tweezers clamp. The composites (PVA-CNTs) were evaluated spectra photo metrically by using UV/160/Shimadzu spectrophotometer. The resistivity was measured over range of temperature from (30 to 80) ^{o}C using Keithly electrometer type (616C).

The ultrasound properties of nanocomposites are measured by using the ultrasonic velocity system measurement.

Results and Discussion

The Electrical Properties of (PVA-CNTs) Nanocomposites

Fig. 1: shows the variation of D.C electrical conductivity with concentration of carbon nanotubes at 50^0C. From the figure, we note the electrical conductivity of nanocomposites increases with increasing the concentration of CNTs where increase the weight percentages of carbon nanotubes create electrons join as carries charges in nanocomposites, consequently the electrical conductivity is increased [Sindhu *et al*., 2002].

Fig. 2: shows the variation of electrical conductivity with temperature of different concentrations of CNTs. The electrical conductivity of nanocomposites increases with the increase of the temperature where these nanocomposites have resistance of negative thermal coefficient, this behavior attributed to move the carbon nanotubes in composites with increasing the temperature, also the increase of temperature creates increasing of number of carries charges in nanocomposites [Prashantha1 *et al*., 2008].

The relationship of ln (conductivity) with inverse of temperature is shown in Fig.3 to calculate the activation energy.

The figure shows the activation energy is decreased with increasing of the concentration of CNTs which attributed to increase the local energy levels in the forbidden energy gap as shown in Fig. 4. [kontos *et al*., 2007]

The Optical Properties of (PVA-CNTs) Nanocomposites

The spectral of the absorbance of the (PVA-CNTs) nanocomposites with wavelength of different concentrations of carbon nanotubes is shown in Fig. 5. The absorbance of (PVA-CNTs) nanocomposites is large at high energy of incident light which due to absorption of polymer lies in high energy, also, the absorbance of nanocomposites increases with increasing the concentration of CNTs, this attribute to increase the electrons which join to absorption the light.

The variation of the absorption coefficient of the (PVA-CNTs) nanocomposites with incident photon energy of different concentrations of carbon nanotubes is shown in Fig.6. This figure shows the absorption coefficient of nanocomposites is increased with increasing of CNTs [Srivastava *et al*., 2008].

The increase of absorption coefficient with CNTs concentration attributed to increase the number of carries charges. The values of absorption coefficient is less than 10^4 cm^{-1}, this mean the (PVA-CNTs) nanocomposites have indirect energy band gap which is calculated by using Eq.7, as shown in Fig. 7 and Fig. 8 . The indirect transition depend on the value of (r) where r=2 for allowed indirect transition and r=3 for forbidden indirect transition. These figures show the energy band gap is decreased with increasing the carbon nanotubes concentration because increase the local level in forbidden energy band gap [Hellen *et al*., 2011].

Fig. 9: shows the variation of the extinction coefficient (k) of (PVA-CNTs) nanocomposites with the photon energy of different concentration of CNTs. The figure show the extinction coefficient increases with increasing of the CNTs concentration, this due to increase the number of carries charges.

The variation of the refractive index of (PVA-CNTs) nanocomposites with incident photon energy of different weight percentages of carbon nanotubes is shown in Fig. 10. From this figure we can see that the refractive index is increased with increase of the CNTs concentration which attributed to increase the scattering of incident photon [Canan *et al*., 2009].

The Fig. 11 and Fig. 12 show that the variation of real and imaginary parts of dielectric constants of nanocomposites respectively with energy photon of different concentration of carbon nanotubes. These figures show the real and imaginary parts of dielectric constants of (PVA-CNTs) nanocomposites are increased with increasing of the carbon nanotubes weight percentages which due to increase the absorption and scattering of incident photon with increasing of the CNTs concentration[Bakauskas and Vinslovaite, 2011].

The Ultrasound Properties of (PVA-CNTs) Nanocomposites

Figures (13, 14, 15 and 16) show the effect of CNTs concentration on the velocity of ultrasonic wave, specific acoustic impedance, compressibility and bulk modulus respectively. The figures show the velocity of ultrasonic wave through (PVA-CNTs) nanocomposites is increased with increasing the carbon nanotubes concentration which due to increase the density of nanocomposites with increase the CNTs concentration where it join as medium to travel the wave [Mahsan1 *et al*.,2009]. Hence, specific acoustic impedance and bulk modulus are increasing with increasing the carbon nanotubes concentration. While the compressibility is decreased with increasing the CNTs concentration [Wittawut *et al*.,2011].

Conclusions

1- The electrical conductivity of polyvinyl alcohol increases with increasing the concentration of CNTs and temperature.
2- The activation energy decreases with increasing of the concentration of CNTs.
3- The absorbance of polyvinyl alcohol increases with increasing of the CNTs concentration.
4- The optical constants are increasing with increasing of the weight percentages of CNTs.
5- The energy band gap increases with increasing of the CNTs concentration.
6- The velocity of ultrasonic wave**,** specific acoustic impedance and bulk modulus are increasing and compressibility decreases with increasing of the CNTs concentration.

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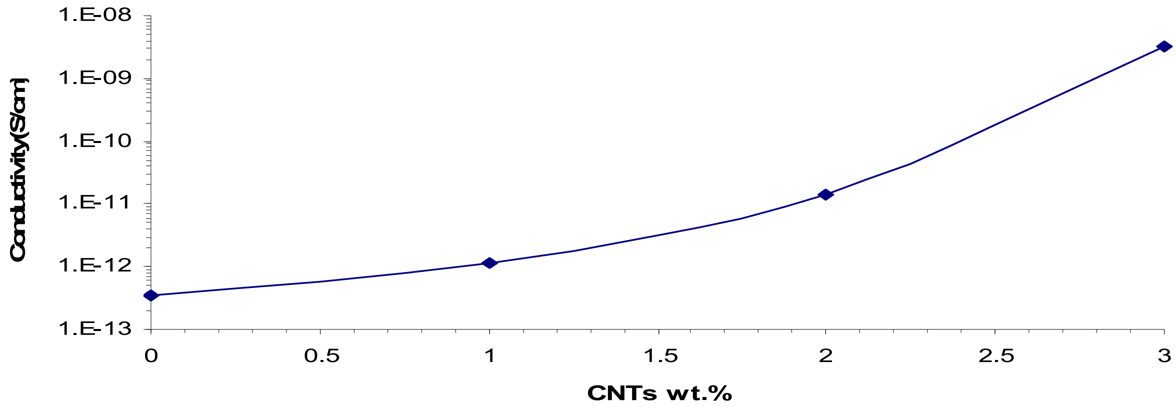

Fig.1
Variation of D.C electrical conductivity with CNTs wt.% of nanocomposite.

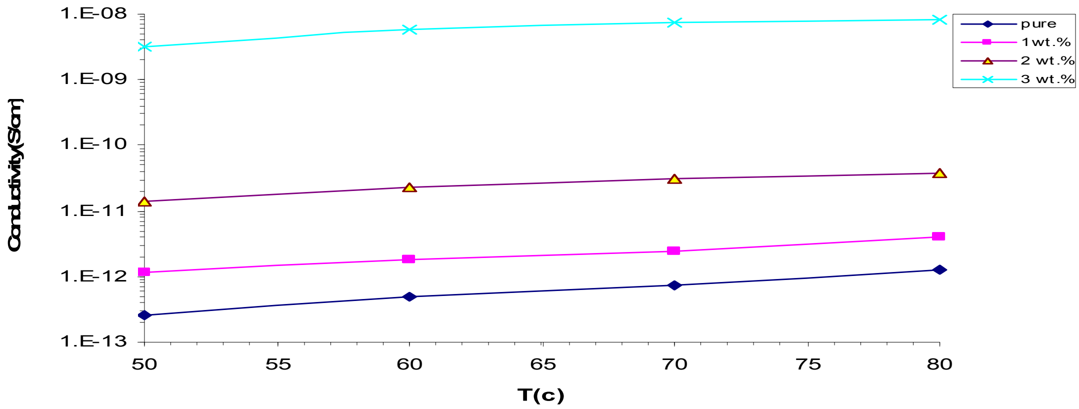

Fig.2
Variation of D.C electrical conductivity of nanocomposites with temperature

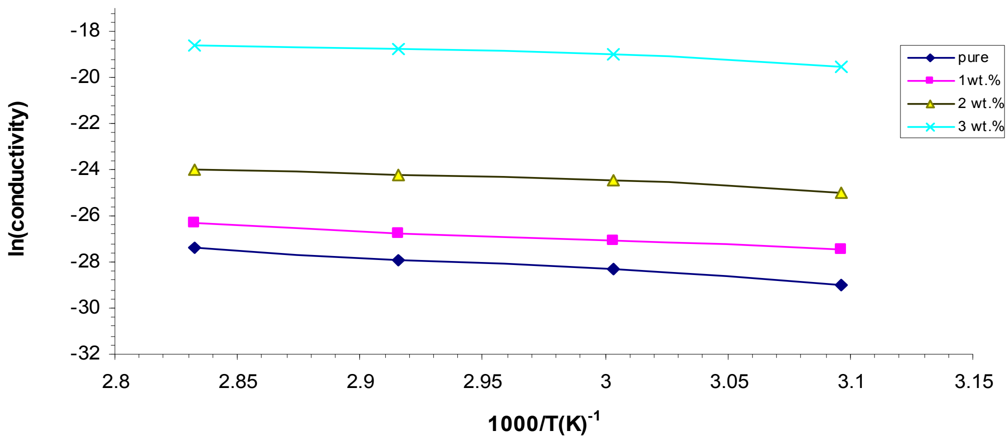

Fig.3
Variation of D.C electrical conductivity of nanocomposites with inverse of temperature

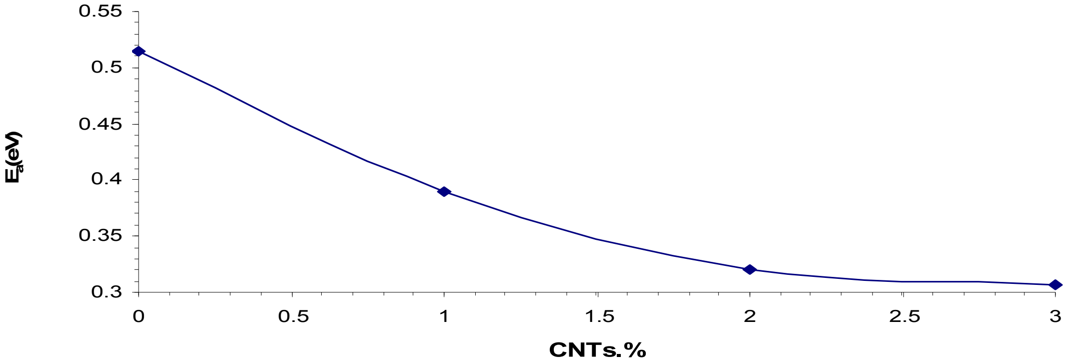

Fig.4
Variation of activation energy with CNTs wt.% of nancomposite

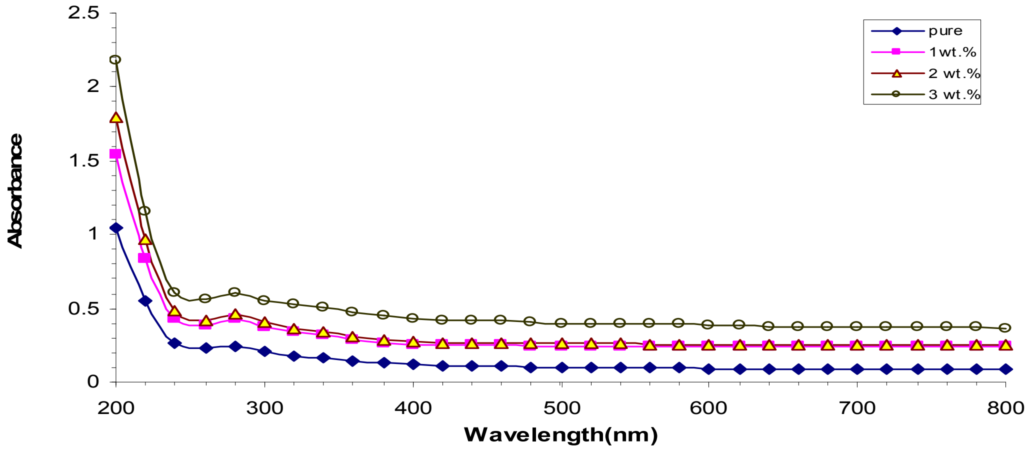

Fig.5
The variation of optical absorbance for (PVA-CNTs) nanocomposite with wavelength

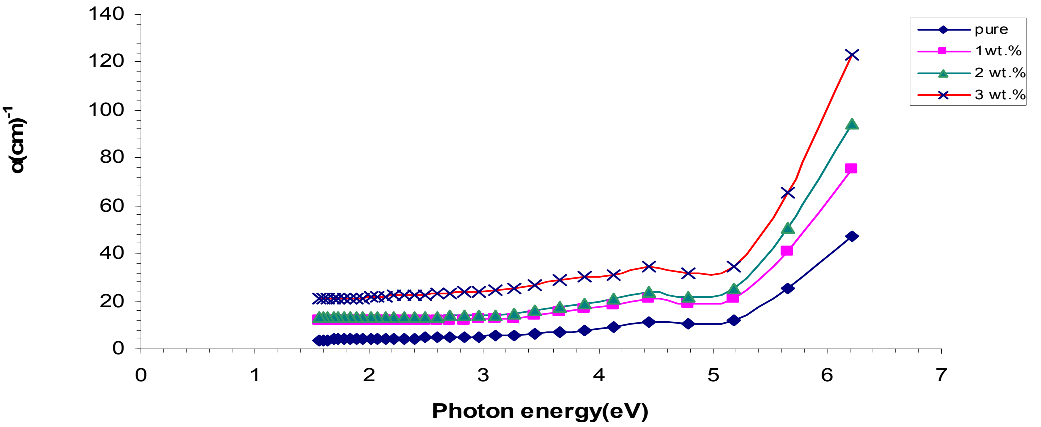

Fig.6
The absorption coefficient of (PVA-CNTs) nanocomposite with various photon energy

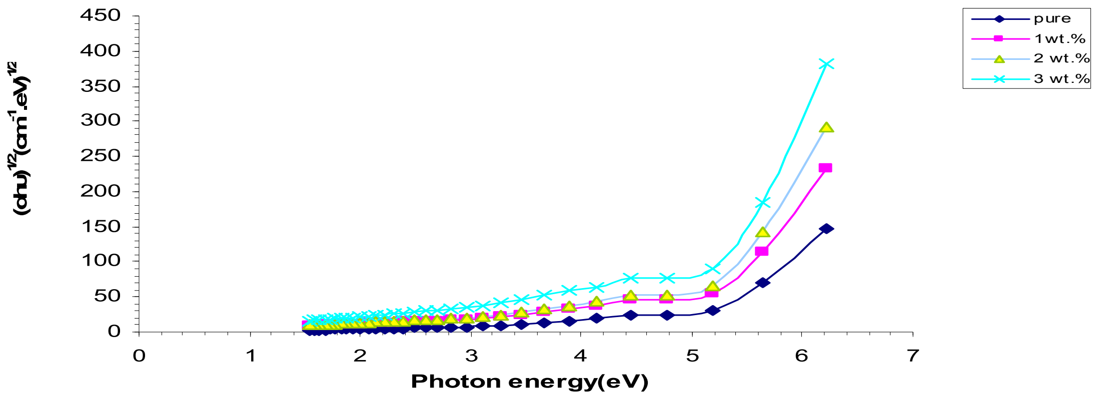

Fig.7
The relationship between $(\alpha h\upsilon)^{1/2}(cm^{-1}.eV)^{1/2}$ and photon energy of nanocomposites.

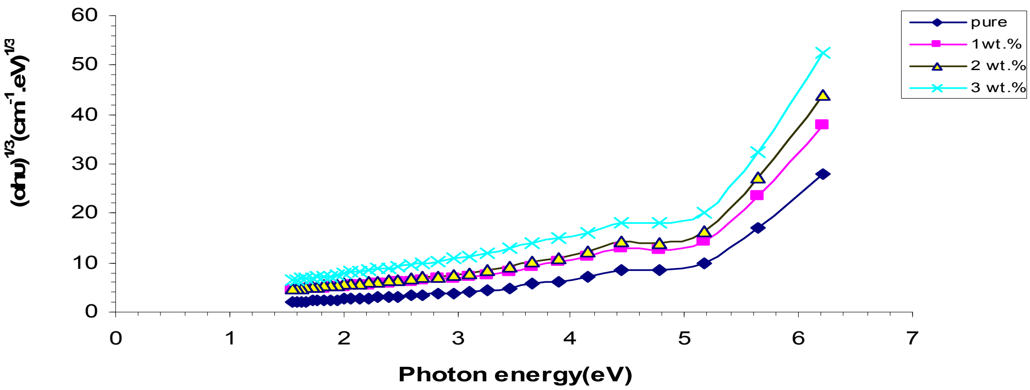

Fig.8
the relationship between $(\alpha h\upsilon)^{1/3}(cm^{-1}.eV)^{1/3}$ and photon energy of nanocomposites.

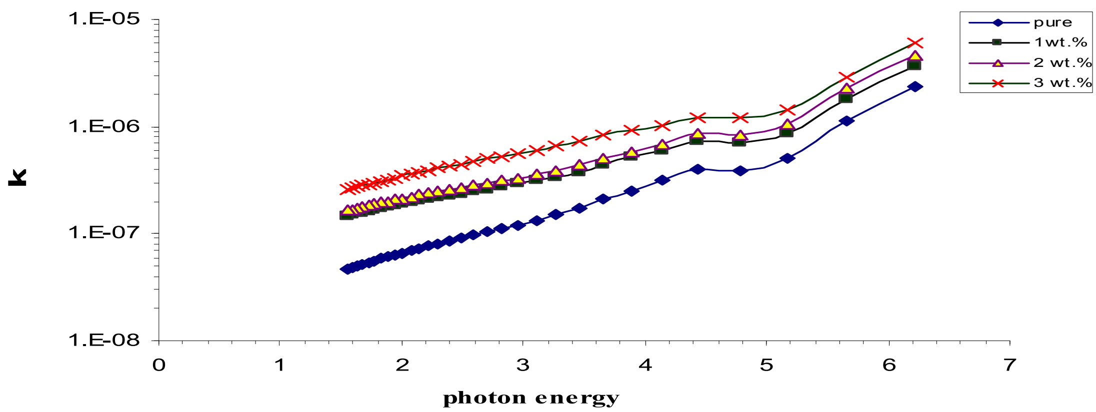

Fig.9
The extinction coefficient nanocomposite with various photon energy

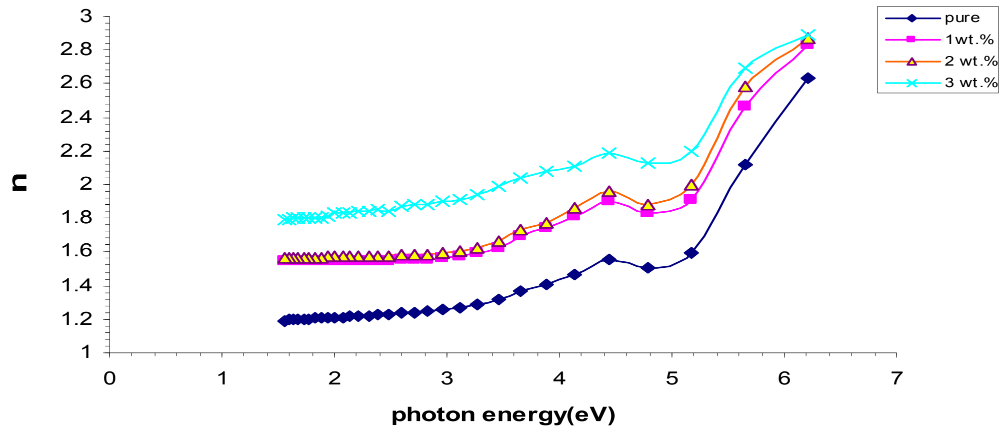

Fig.10
The relationship between refractive index of nanocomposite with photon energy

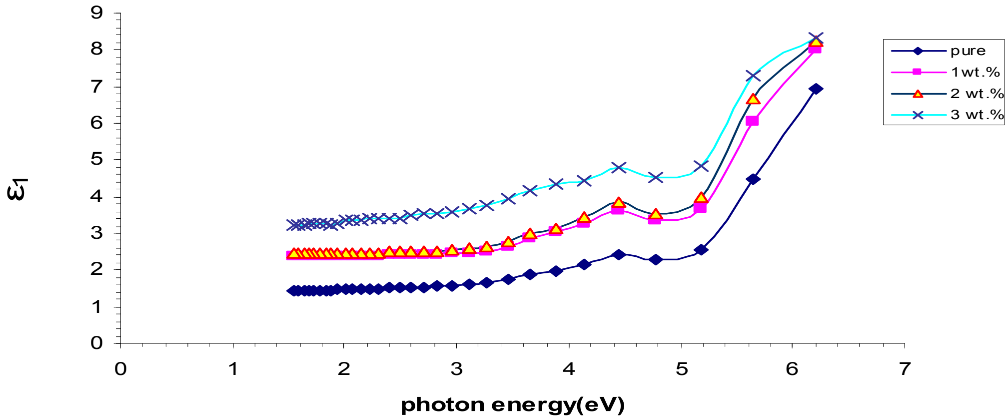

Fig.11
The variation of real part of dielectric constant nanocomposite with photon energy

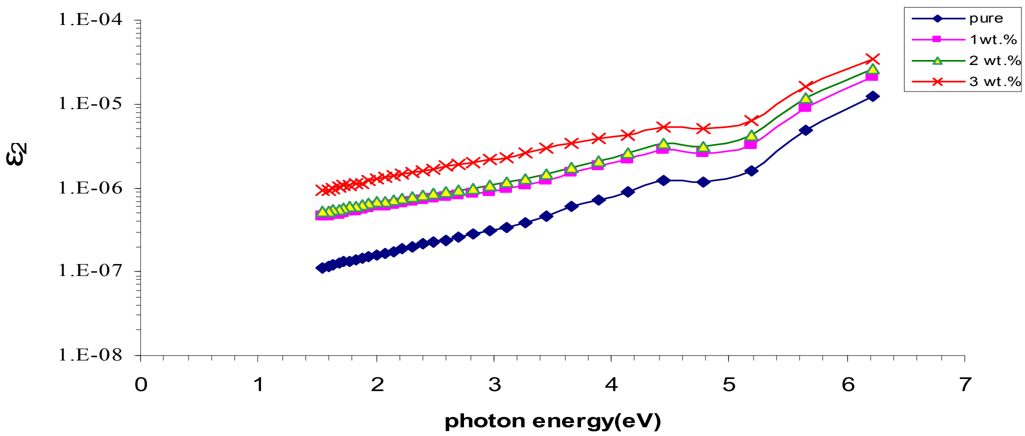

Fig.12
The variation of imaginary part of dielectric constant nanocomposite with photon energy

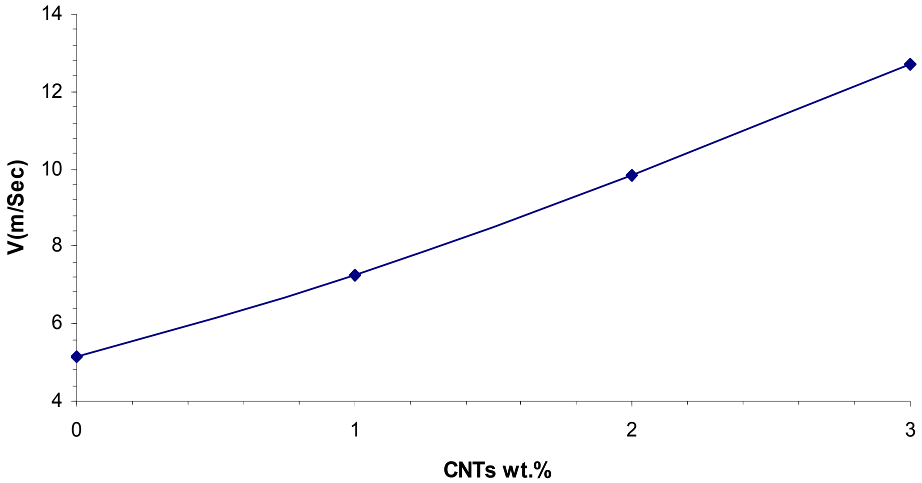

Fig. 13
Effect of CNTs concentration on the velocity of ultrasonic wave

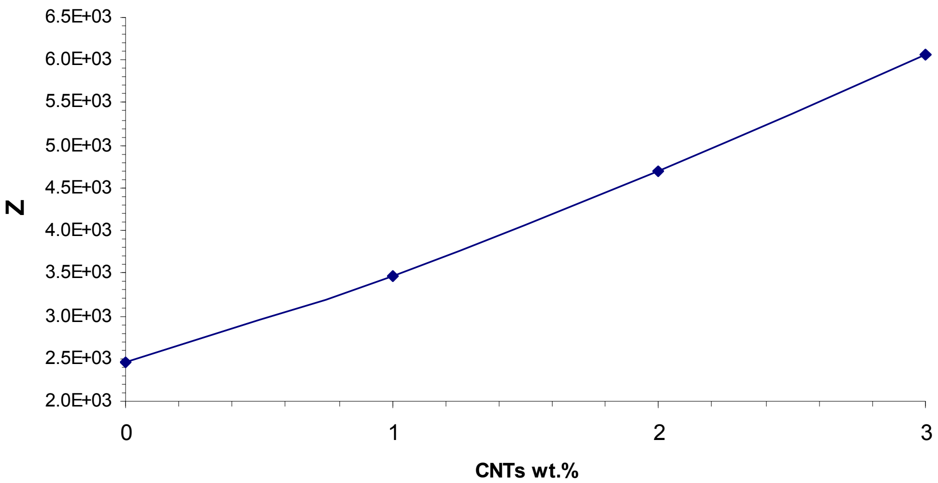

Fig. 14
Effect of CNTs concentration on the specific acoustic impedance

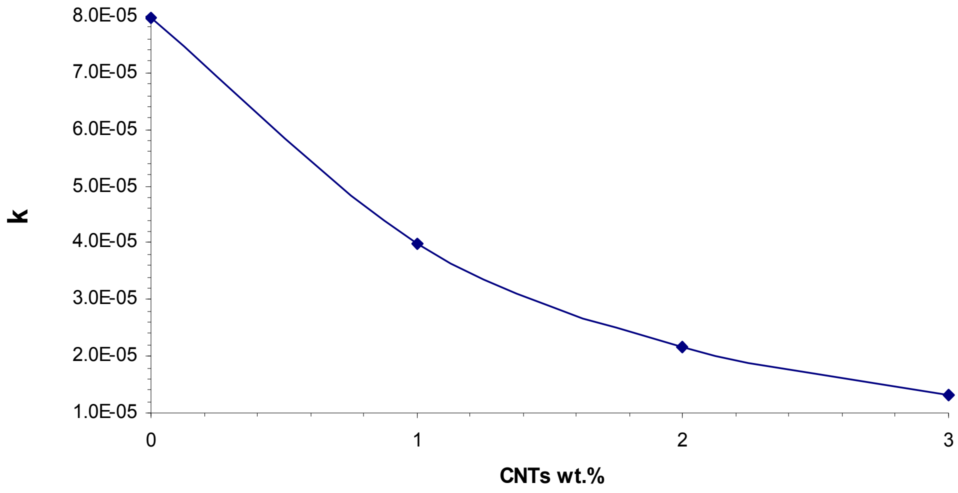

Fig. 15
Effect of CNTs concentration on the compressibility of nanocomposites

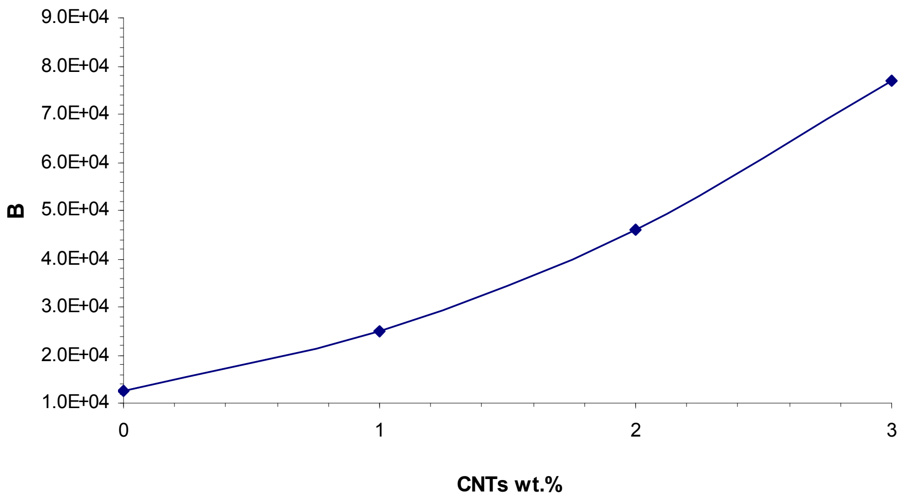

Fig. 16
Effect of CNTs concentration on the bulk modulus of nanocomposites