Australian Journal of Basic and Applied Sciences, 8(17) November 2014, Pages: 1-9

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Enhancement of Structural and Mechanical Properties for (PVA-PAAm) By Adding Titanium Nanoparticles

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ARTICLE INFO

Article history:
Received 19 August 2014
Received in revised form
19 September 2014
Accepted 29 September 2014
Available online 6 November 2014

Keywords:
structural, mechanical, nanocomposites, titanium nanoparticles, morphology.

ABSTRACT

The aim of this paper, preparation of (PVA-PAAm-Ti) nanocomposites and study their structural and mechanical properties to use it in many applications. The nanocomposites was tested by different methods such as Fourier transformation infrared ray (FTIR) and optical microscope. The mechanical properties were measured by using ultrasonic waves system with different frequency of (25,30, 35, 40, 45 and 50) KHz. The mechanical properties were calculated such as: velocity of ultrasonic waves, absorption coefficient of ultrasonic waves, compressibility and bulk modulus. The results (FTIR) show that increasing of the value of the absorbance of (PVA-PAAm-Ti) nanocomposites with increases of concentration of titanium nanoparticles. The morphology of the nanocomposites was studied using optical microscope, which showed grain distribution at surface morphology and grain aggregates increases with increasing of titanium nanoparticles. There results show that the mechanical properties for (PVA-PAAm-Ti) nanocomposites were increases with increasing of concentration of titanium nanoparticles except compressibility decreased under effect addition.

To Cite This Article: Majeed Ali Habeeb, Enhancement of Structural and Mechanical Properties For (PVA-PAAm) By Adding Titanium Nanoparticles. ***Aust. J. Basic & Appl. Sci.,*** *8(17): 1-9, 2014*

INTRODUCTION

Polymers are widely used in electrical and electronic applications. In early works, polymers have been used as insulators because of their high resistivity and dielectric properties. Polymer-based insulators are used in electrical equipment to separate electrical conductors without passing current through themselves. The insulator applications of polymers include printed circuit boards, wire encapsulants, corrosion protective electronic devices, and cable sheathing materials. Polymers have several advantages, such as easy processing, low cost, flexibility, high strength, and good mechanical properties. In the microelectronic fabrication industry, polymers are used in the photolithography process (Alias, 2013). 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. Microsized 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, 2003). There is a continued interest in conducting polymers due to their properties like easy fabrication, low cost, leak proof, biodegradability, and good storage capacity. Conducting polymers find application in the development of advanced high energy electrochemical devices for example, batteries, fuel cells, electrochemical display devices, and photo electrochemical cells. The development of conducting polymers involves several approaches: (i) dry solid state polymers, (ii) gel/plasticizer polymer, and (iii) composite polymer (Nanda Prakash, 2013). The applications of nanocomposites are quite promising in the fields of microelectronic packaging, optical integrated circuits, automobiles, drug delivery, sensors, injection molded products, membranes, packaging materials, aerospace, coatings, adhesives, fire-retardants, medical devices, consumer goods, etc (Wasan Al-Taa'y, 2014). The development of polymer based nanocomposites with antimicrobial activity offers interesting possibilities because the polymer matrix can be varied in order to fulfill not only specific technological requirements but also

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nanostructures with size- and shape dependent properties that can be exploited (Ricardo, 2013). The conducting polymers are a new group of synthetic polymers which combines the chemical and mechanical properties of polymers with the electronic properties of metals and semiconductors. Nowadays, conducting polymers have several applications in different areas such as microwave absorption, electronic displays, corrosion protection coating, electrochemical batteries, super capacitors, sensors, and electrodes (Khairy, 2014). This paper deals with the effect of titanium nanopaticles on structural and mechanical properties of (PVA- PAAm) nanocomposites.

Theoretical:

The density defined as mass per unit volume and in this study the volume is fixed so the density is increasing with the concentration**.** The ultrasonic wave velocity (v) was calculated using the following equation (Abdul-Kareem Jawad Rashid, 2009):

$$v = x / t \tag{1}$$

Where (t) is time that the waves need to cross the samples (digital obtained from the instrument).

The conversion of the sound energy to other forms of energy is absorption. In this way, the strength of an ultrasonic signal reduces as it propagates through a given material (Gasni, 2012). If imagines us a thin slice from the center perpendicular to the line of wave propagation and the thickness of amount (dx) and is located just (x) of in the case of the original point of the fact that the uniform attenuation loss relative to the energy unit length can be found from the following relationship (Hornowski, 2010):

$$\frac{dE}{E} = -2\,\alpha dx \tag{2}$$

Where (E) represents the energy density of the primary wave,(α) the absorption coefficient of the medium. That the intensity of the sound waves (I) is directly proportional to the energy density, so we have the following (Hornowski, 2010):

$$\frac{dI}{I_o} = -2\,\alpha dx \tag{3}$$

Applying the boundary conditions ($I=I_o$) when ($x = 0$) and when the integration of the equation we get (Martinez, 2011):

$$I = I_o \exp(-2\alpha x) \tag{4}$$

As the intensity is proportional to the square of the amplitude (Martinez, 2011):

$$A_2 = A_1 \exp(-\alpha x) \tag{5}$$

The rearrangement of the last equation we get (Martinez, 2011):

$$\alpha = -1/x \ln (A_2/A_1) \ (m^{-1}) \tag{6}$$

(A_1)amplitude primary of the ultrasonic wave of the fallen,(A_2) amplitude decreasing on the distance (x) result absorption by article.

Transmittance (T) is given by (Martinez, 2011):

$$T = A_2/A_1 \tag{7}$$

The acoustic impedance of a medium (Z), it was calculated by equation (Abdul-Kareem, 2009):

$$Z = \rho\, v \tag{8}$$

Bulk modulus (B) is the substance's resistance to uniform compression, it is defined as the pressure increase needed to decrease the volume; it was calculated by Laplace equation (Burak Yahya, 2011):

$$B = \rho\, v^2 \tag{9}$$

Compressibility (β) is a measure of the relative volume change of a fluid or solid as a response to a pressure (or mean stress) change, it was calculated by the following equation (Burak Yahya, 2011):

$$\beta = (\rho\, v^2)^{-1} \tag{10}$$

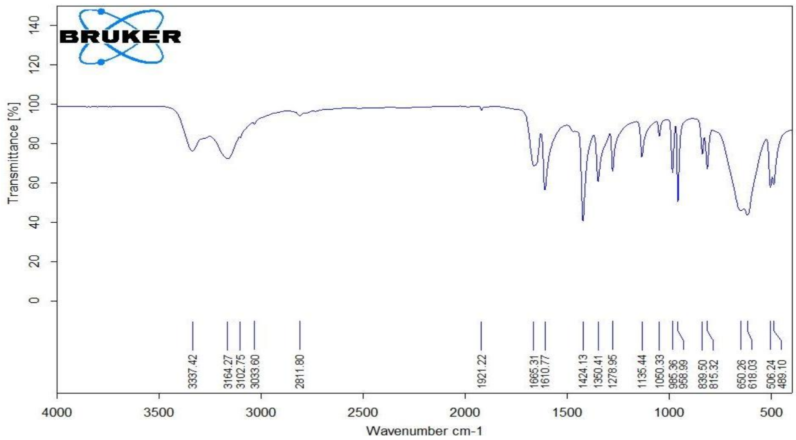
MATERIALS AND METHODS

The (PVA-PAAm-Ti) nanocomposites were prepared by the melting (0.9)g of PVA with (0.1)g of PAAm in (30) ml of distilled water and by using magnetic stirrer to mix the materials to obtain more homogeneous solution at temperature 90^0C , then wait for the solution to be cold. The casting method was used to preparation the samples in the template (Petri dishit has diameter 5cm) and then left to dry mixture for five days , then taken from the template quietly to conducting the necessary tests, by using electronic digital device(Micro meter to measure thickness. The titanium nanoparticles were added with the weight percentages of additives are (2, 4, and 6) wt.% . The samples of nanocomposites were examined by using the optical microscope, which is supplied from Olympus name (ToupView) type(Nikon- 73346).. FTIR spectra were recorded by FTIR (Bruker company, German origin, type vertex -70) Fourier transformation infrared ray in the wave number range (400 –

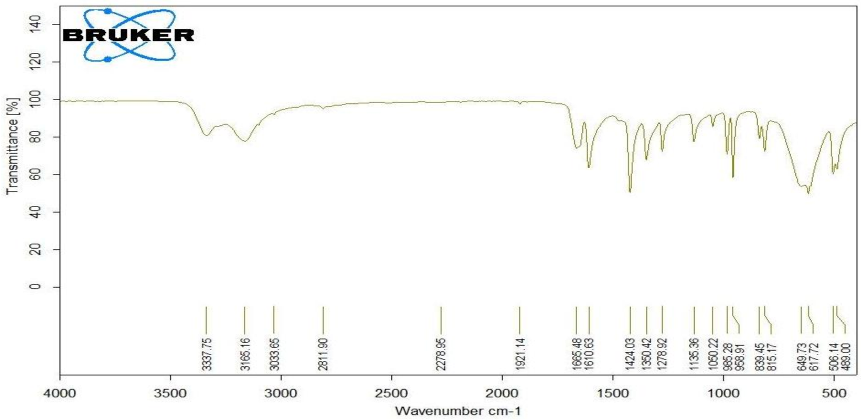
4000)cm^{-1}. The mechanical properties were measured by using ultrasonic waves system with different frequency of (25,30, 35, 40, 45 and 50) KHz.

RESULTS AND DISCUSSIONS

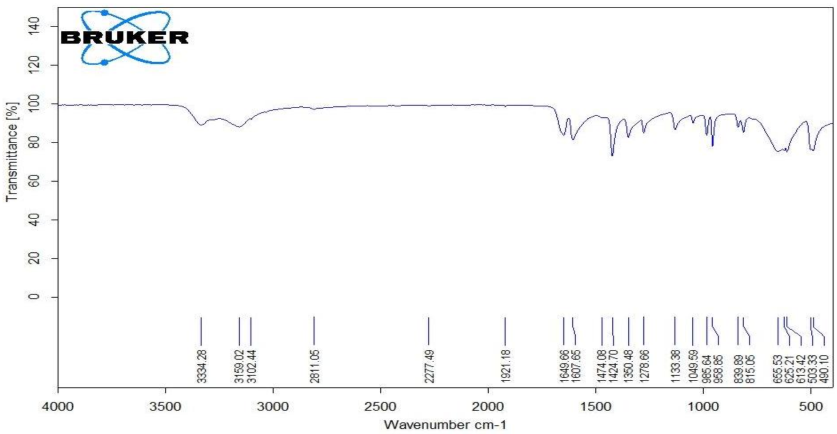
To analyze the interactions of atoms or ions in nanocomposites used FTIR spectroscopy. The FTIR spectra of (PVA-PAAm-Ti) nanocomposites in the wave number range (400-4000) cm^{-1}. Figure (1, A,B,C and D) shows that the FTIR spectra of (PVA-PAAm-Ti) nanocomposites , we can see, a strong broad band at 3500–3200 cm^{-1} attributed to O–H stretching frequency indicating the presence of hydroxyl groups. FTIR spectra shows broad and strong bands at 3337 cm^{-1} due to O–H stretching vibration of hydroxyl groups and 3164 cm^{-1} attributed to C–H stretching vibration. A weak band at 1921 cm^{-1}, which attributed to the combination frequency of C=C. The bands at 1665 cm^{-1} and 1610 cm^{-1}corresponds to an acetyl C=O group. The strong band at 1424-1135 cm^{-1} is attributed to the stretching mode of C-H and C-O groups. (Ragab, 2011)



A



B



C

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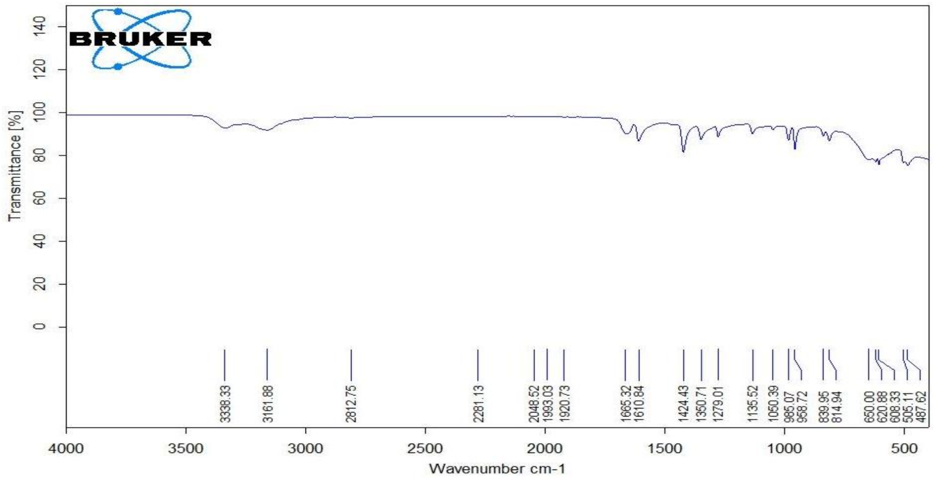
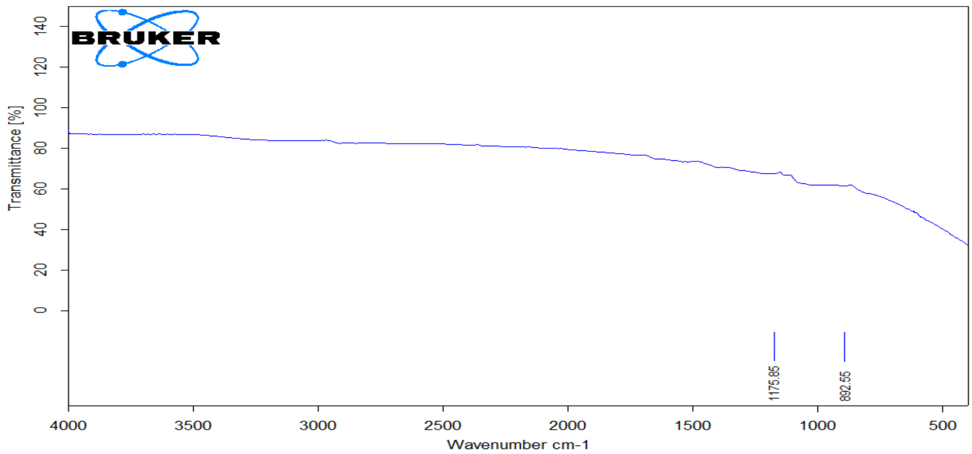
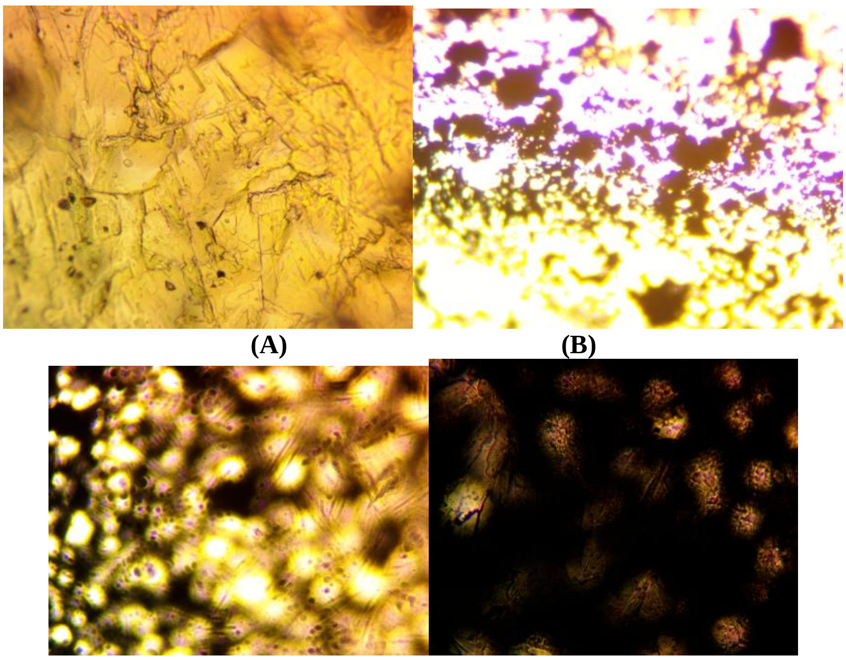


D



E

Fig. 1: FTIR spectra for (PVA-PAAm-Ti) nanocomposites, pure(PVA-PAAm), B- 3 wt.% Ti nanoparticles, C- 6 wt.% Ti nanoparticles, D- 12 wt.% Ti nanoparticles, E- 16wt.% Ti nanoparticles.



(A) **(B)**

(C) **(D)**

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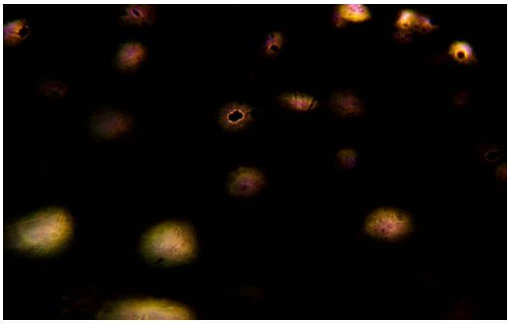

(E)

Fig. 2: Photomicrographs (x10) for (PVA-PAAm-Ti) nanocomposites: (A) for (PVA-PAAm), (B) for 3 wt.% Ti nanoparticles, (C) for 6 wt.% Ti nanoparticles, (D) for 9 wt.% Ti nanoparticles, (E) for12 wt.% Ti nanoparticles.

Figure. 3 show that the variation of velocity of ultrasonic waves for (PVA-PAAm-Ti) nanocomposites with concentration of titanium nanoparticles. From the figure, velocity of ultrasonic waves decreases with the increase of titanium nanoparticles concentrations, this attributed to the interaction causing association between polymer and titanium nanoparticles where titanium nanoparticles do as medium to travel the waves where the nanoparticles form a continuous network inside nanocomposite (Al-Bermany, 2004; Formageau, 2003), as shown in figure. 2.

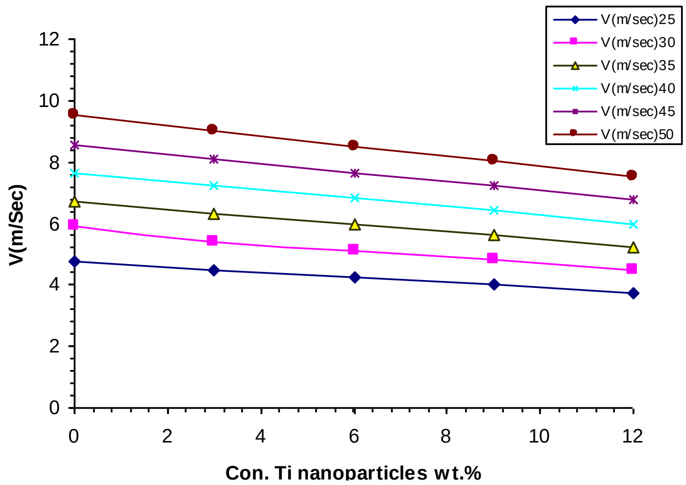

Fig. 3: Variation of ultrasonic velocity for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles.

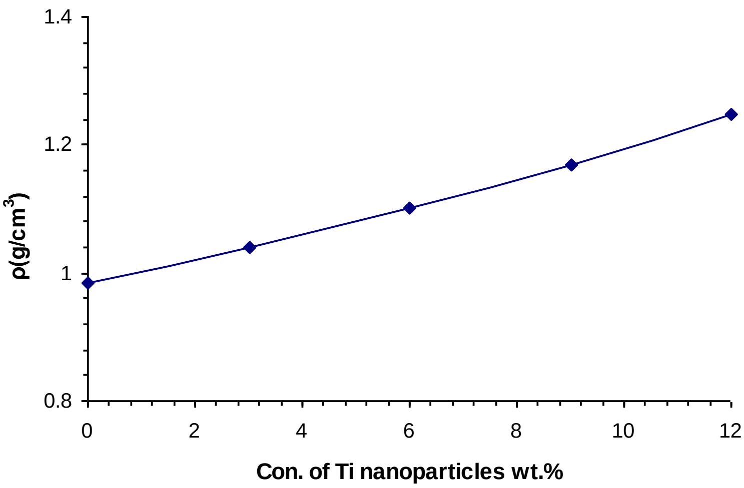

Fig. 4: Variation of density with the concentration of titanium nanoparticles.

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Figure. 4 shows that the effect of titanium nanoparticles concentration on the density of (PVA-PAAm-Ti) nanocomposites. The density increases with the increasing of titanium nanoparticles concentration which attributed to the tight interaction between the titanium nanoparticles and polymer molecules which as shown in figure 2.

Figure. 5 shows the variation of the absorption coefficient for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles. From this figure the absorption coefficient increases with the concentration of titanium nanoparticles, this attributed to the attenuation of the ultrasonic waves determines mainly by the shape, size, and particles distribution. The attenuation attributed to the friction and heat exchange between the particles and the surrounding medium as well as to the decay of the acoustic wave in the forward direction due to scattering by the particles (Hornowski, 2010). As an ultrasound beam penetrates a medium, energy is removed from the beam by absorption, scattering, and reflection. As with x rays, the term attenuation refers to any mechanism that removes energy from the ultrasound beam. Ultrasound is “absorbed” by the medium if part of the beams energy is converted into other forms of energy, such as an increase in the random motion of molecules. Ultrasound is “reflected” if there is an orderly deflection of all or part of the beam. If part of an ultrasound beam changes direction in a less orderly fashion, the event is usually described as “scatter” (William, 2002).

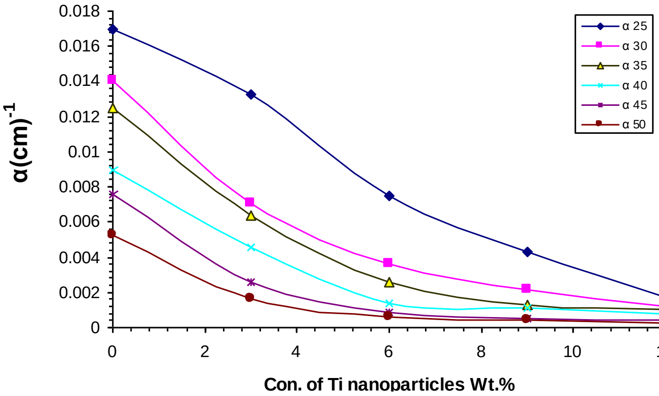

Fig. 5: Variation of absorption coefficient for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles.

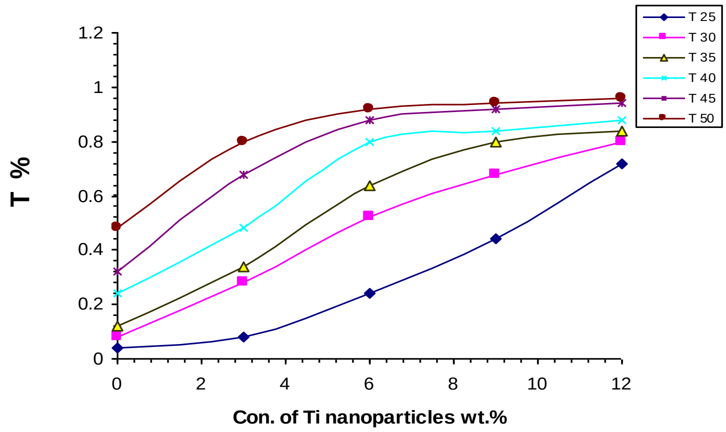

Fig. 6: Variation of transmittance for (PVA-PAAm-Ti) nanocomposites versus the concentration of titanium Nanoparticles.

The relationship between the transmittance for (PVA-PAAm-Ti) nanocomposites and concentration of titanium nanoparticles is shown in figure. 6. The transmittance decreases with the increasing of titanium nanoparticles concentration, this behavior attributed to fills the vacancies between PVA-PAAm chains and restricted these chains, soultrasonic waves faces a strong resistance to follow through the composites (Abdul-Kareem, 2011; Burak Yahya Kadem, 2011). Also, the transmittance for (PVA-PAAm-Ti) nanocomposites decreases with frequency, this due to high frequency results more degradation that introduces un tie chains .Ultrasonic wave transfer as compression and rarefaction, the un tie chains ply an important role of dumping the propagation of ultrasonic wave which is decreases transmittance (Abdul-Kareem, 2011).

The variation of acoustic impedance for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles is shown in figure. 7. From the figure, the acoustic impedance for (PVA-PAAm-Ti) nanocomposites is decreasing with the concentration of titanium nanoparticles, this is same behavior of ultrasonic velocity because its more effective than density which has small variation with respect to velocity variation (Al-ani, 1992; Abdul Kareem, 2013). The increase of concentration of titanium nanoparticles attributed to arrangements of the of titanium nanoparticles network is occurs, by breaking chains bonds. It was probably that clusters grew and contacted with each other in the nanocomposites resulting in a gradual change from small of titanium nanoparticles clusters to larger clusters with stronger hydrogen bonds (Wiggens, 1986). The acoustic impedance decreases with the frequency because of the (PVA-PAAm) polymers chains degradation which combined with high frequency, this degradation is resisting the transferring of the ultrasonic wave and gave the composite good acoustic impedance (Abdul-Kareem, 2011).

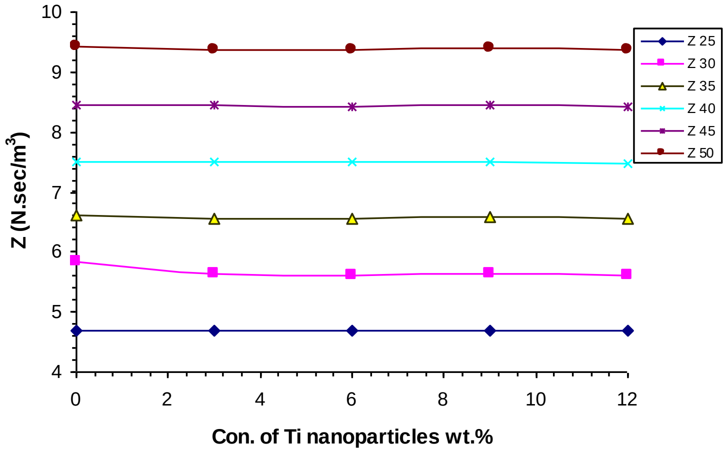

Fig. 7: Variation of acoustic impedance for (PVA-PAAM-Ti) nanocomposites versus the concentration of titanium nanoparticles.

The variation of Bulk modulus for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles is shown in figure 8. The Bulk modulus is decreasing with the increase of concentration of titanium nanoparticles this behavior attributed to the fact that titanium nanoparticles make entanglement interaction to the (PVA-PAAm) chains forming a network (Pradeep Rohatgi, 2009). The low concentration of titanium nanoparticles means more vacancies that coiling polymers chains randomly to be close each other giving the composite higher Bulk modulus (Wiggens, 1986). The compressibility (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles is shown in figure 9. The compressibility increases with the increasing titanium nanoparticles concentration which attributed to made polymers chains are adjacent to each other which change conformation and configuration of these molecules producing more compression for these molecules (Curi, 2006; Hasun, S.K., 1989).

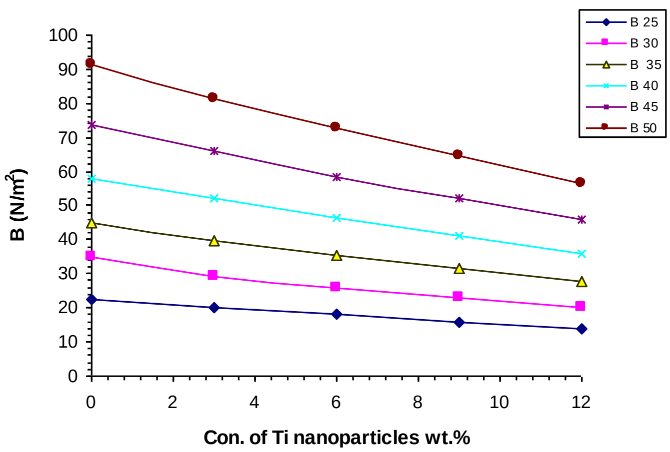

Fig. 8: Variation of Bulk Modulus for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles

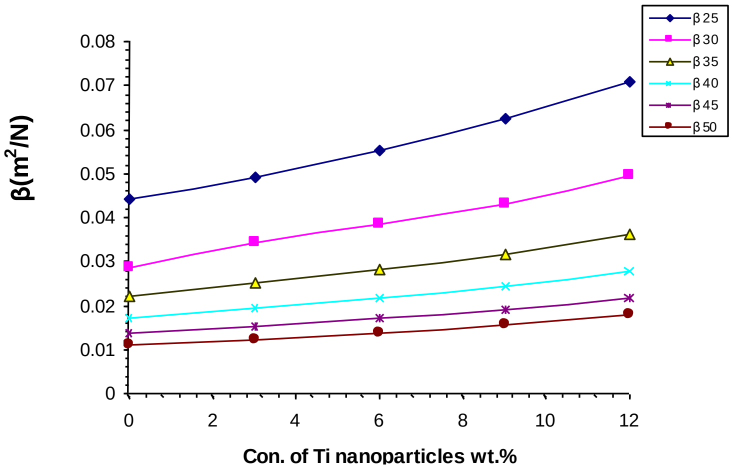

Fig. 9: Variation of Compressibility for (PVA-PAAm-Ti) nanocomposites with the concentration of titanium nanoparticles.

Conclusions:

1. The velocity of ultrasonic wave for (PVA-PAAm-Ti) nanocomposites increases with increasing of concentration of titanium nanoparticles.
2. The density and absorption coefficient for (PVA-PAAm-Ti) nanocomposites are increasing with the increase of concentration of titanium nanoparticles.
3. The transmittance for (PVA-PAAm-Ti) nanocomposites decreases with increase of concentration of titanium nanoparticles.
4. The specific acoustic impedance and Bulk modulus for (PVA-PAAm-Ti) nanocomposites are increasing with increase of concentration of titanium nanoparticles.
5. The compressibility for (PVA-PAAm-Ti) nanocomposites decreases with increasing of concentration of titanium nanoparticles.

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