Chemistry and Materials Research www.iiste.org
ISSN 2224- 3224 (Print) ISSN 2225- 0956 (Online)
Vol 1, No.1, 2011

Preparation PVA/TiO_2 composite and study some acoustic properties by ultrasound.

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Abstract

The PVA/TiO_2 composite polymer membranes were prepared by a sol-Gel casting method, the weight of PVA is constant (1gm) while the TiO_2 powder ratios were (0.01, 0.02, 0.03, 0.04, 0.05) gm. In order to evaluate the mechanical properties of PVA/TiO_2 composite the ultrasonic measurements were performed at the samples , these properties are ultrasonic velocity, compressibility, acoustic impedance, relaxation time, bulk modulus, shear viscosity and density were analyzed at different frequencies (25,30,35,40) KHz , another acoustic mechanical properties were measured and calculated at a same time such as the ultrasonic wave amplitude before and after absorption by composite were showed on oscilloscope ,then we calculated absorption coefficient and transmittance. It was found that the frequency effect on the ultrasonic velocity except the first concentration (1gmPVA) stay constant and the material properties also shows that (20 KHz) frequency has the best results for other frequencies under search, results also shows that adding TiO_2 enhances PVA polymer and the composite became good membrane foe reflecting ultrasound waves.

Keywords: composite polymer; ultrasound technique; mechanical properties; sol-gel method.

1. Introduction

Ultrasonic technique is one of the basic non-destructive methods for evaluation of materials and structures. A significant part of every ultrasonic inspection is the way in which the ultrasonic energy is transferred between the transducer and tested object. Different types of commercial liquids and gels are used as a coupling medium. Sometimes the use of a liquid or gel is undesirable because it may contaminate or penetrate into the material being tested leading to reduction of mechanical properties or corrosion (Bogomil *et. al*. 2006). Ultrasonic technique is good method for studying the structural changes associated with the information of mixture assist in the study of molecular interaction between two species; some of mechanical properties of different polymers were carried by some workers using ultrasonic technique (B. Boro 2009).The absorption of ultrasound in polymer systems is governed by local modes of motion and cooperative because of the existence of strong intermolecular interaction within the polymer. The breakage of chemical bonds is due to cavitations into the medium. Cavitations are the formation and violent collapse of small bubbles. This leads to shearing forces of sufficient magnitude to cause the rupture of chemical bonds (Jayanta 2004). The effects of various parameters like ultrasound intensity, frequency of ultrasonic waves and polymer concentration have been investigated (Jayanta 2004 & Andre 2003). Ultrasonic velocity measurements are relatively simple to make in bulk solids and can be related to the various elastic modules, especially for isotropic solids. For these bulk solids the sound speed may be weakly related to the crush or abrasion strength of the material, as the sound transmission depends on both the properties of the particles and their configuration, care must be taken to understand the preparation of the sample for measurement. This includes shaking steps to consolidate the powder and prepare as uniform as possible configuration of the powders at measurement (P.J. Coghill and P. Giang 2011). Composites have good potential for various industrial fields because of their excellent properties such as high hardness, high melting point, low density, low coefficient of thermal expansion, high thermal conductivity, good chemical stability and improved mechanical properties such as higher specific strength, better wear resistance and specific modulus (Shu, K.M. and G. C. Tu, 2002 & Canan and Ayşe 2009).

2. Experimental:

2.1 Sample Preparation:

PVA (Gerhard Buchman -Germany) with assay (99.8 %) and TiO_2 with assay (99.7%) and M.W. (81.38) were used as received without further purification. The PVA/TiO_2 composite membranes were prepared by a sol-Gel casting method, the appropriate weight of PVA is constant (1gm) was dissolved in (25ml) of distilled water under stirring and heat (70◦C) for (1 hour) then leave the PVA solution for

(15min) to get could at room temperature, then the TiO_2 powder was added slowly to the PVA solution with stirring with weights (0.01, 0.02, 0.03 0.04 0.05) gm. The resulting solution was stirred continuously until the solution mixture became a homogeneous viscous appearance at room temperature for (30 min.). The PVA/TiO_2 composite polymer membranes are obtained by leaving the mixture solution in a petre dish at room temperature for 2 weeks and then the composites samples were cut in the circle shape with (4cm) diameter and the density of the samples were measured by the weight method.

2.2 Ultrasonic measurements:

Ultrasonic measurements were made with variable frequencies (f=25,30,35,40 KHz) using pulse technique of sender-receiver type (SV-DH-7A/SVX-7 velocity of sound instrument) .The receiver quartz crystal mounted on a digital vernier scale of slow motion, the receiver crystal could be displaced parallel to sender and the samples were put between sender and receiver. The sender and receiver pulses (waves) were displaced as two traces of cathode ray oscilloscope, and the digital delay time of received pulses were recorded with respect to the thickness of the samples. The pulses height on oscilloscope (CH1) represents incident ultrasonic wave's amplitude (A_0) and the pulses height on oscilloscope (CH2) represents the receiver ultrasonic wave's amplitude (A) after passing the composite.

2.3 Theoretical calculation:

The absorption coefficient (α) was calculated from Lambert – Beer law (Zong fang *et. al.* 2011):

$$A/A_0 = e^{(-\alpha x)} \ldots\ldots (1)$$

Where (A_0)is the initially amplitude of the ultrasonic waves,(A) is the wave amplitude after absorption and (x) is the thickness of the sample, the transmittance (T) is the fraction of incident wave at a specified wavelength that passes through a sample was calculated from the following equation (Dipak 2001):

$$T = I / Io \ldots\ldots\ldots (2)$$

Where (I_0) is the initially intensity of the ultrasonic waves and (I) is the received intensity. The ultrasonic wave velocity was calculated using the following equation (Abdul-Kareem and Burak.2011):

$$v = x / t \ldots\ldots (3)$$

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

Attenuation is generally proportional to the square of sound frequency so the relaxation amplitude (D) was calculated from the following equation (Josef and Herbert1990):

$$D = \alpha / f^2 \ldots\ldots\ldots (4)$$

The wavelength (λ) can change only when the speed of the wave changes inside the samples we can calculate it by the equation (David *et al.2002*):

$$\lambda = v / f \ldots\ldots\ldots (5)$$

Bulk modulus (B) of a composite 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 where (ρ) is the density (Al-Bermany E.2004):

$$B = \rho v^2 \ldots\ldots\ldots (6)$$

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 (Hassina *et. al.* 2009):

$$\beta = (\rho v^2)^{-1} \ldots\ldots\ldots (7)$$

The acoustic impedance of a medium (Z), it was calculated by equation (Jarth 2008):

$$Z = \rho v \ldots\ldots\ldots (8)$$

On the basis that all solids flow to a small extent in response to small shear stress, some researchers have contended that substances known as amorphous solids, such as glass and many polymers may be considered to have viscosity. This has led some to the view that solids are simply "liquids" with a very high viscosity; the viscosity (η_s) of the samples was measured by using the equation (Al-Bermany K.J. 2009):

$$\eta_s = 3 \alpha \rho v^3 / 8 \pi^2 f^2 \ldots\ldots\ldots (9)$$

The relaxation time (τ) was calculated from the equation (Herbert 1985):

$$\tau = 4\,\eta_s / 3\rho\, v^2 \ldots\ldots\ldots (10)$$

3. Result and discussions:

In our study we try to enhance some of PVA mechanical properties by adding different TiO_2 concentrations. Result show that the density is decreasing when adding TiO_2, since TiO_2molecules fills the vacancies between polymer macromolecules chains that randomly coiled in distilled water (Abdul-Kareem *et. al.* (2011) & Subhi *et. al.* 1990) and the polymer macromolecules are heavier than TiO_2, so the density decreasing as show in fig.(1).Since the density decreasing ultrasonic velocity decreasing also when increasing TiO_2 and the composite of (0.5 gm TiO_2) has the lower value of velocity as shown in fig.(2) .Bulk modulus reducing when adding TiO_2since these molecules restricted polymer macromolecules by filling the vacancies and forming new conformations and configurations in the composite and reducing bulk modulus agree with equation (6) which indicate that bulk modulus must decreasing when velocity decreasing. Specific acoustic impedance is decreasing when increasing TiO_2, the concentration (0.5 gm TiO_2) shown in gig.(4) has lower value ,since TiO_2 and polymer macromolecules come close together when passing ultrasonic waves, as a result the specific impedance decreasing this agree with equation (8).The compressibility is increasing when adding TiO_2, the concentration (0.5 gm TiO_2) has the higher compressibility value as shown in fig.(5) as we discussed above that bulk modulus decreasing so compressibility must increasing that means TiO_2 molecules forming network formation as a result of entanglement interaction between the two types of molecules ,polymer macromolecules and TiO_2 molecules (Tomasz *et. al.* 2010).The transmittance is decreasing when TiO_2 increasing as shown in fig. (6) Since the compressibility increasing, so transmittance must decrease as result of adding TiO_2 molecules. Absorption coefficient of the composite is decreasing with increasing TiO_2 and (0.5 gm TiO_2) has lower absorption coefficient as shown in fig. (7), this could be attributed that the attenuation of ultrasonic waves depend on viscosity, thermal conductivity, scattering and intermolecular interactions, the thermal conductivity was known to be negligible (Tomasz *et. al.* 2010 & E.Foled *et. al.* 1988) Therefore intermolecular processes and scattering were assumed to be responsible for reducing acoustic absorption coefficient. The relaxation time is decreasing when TiO_2 and (0.5 gm TiO_2) is lower than other concentrations, this attributed that we saw absorption coefficient decreasing so reducing the number of molecules as a result of degradation by ultrasonic waves, this lead to reducing relaxation time for molecules to be stated their positions (Al-Bermany E. 2004). The viscosity is decreasing by increasing TiO_2 as shown in fig. (10) ,this attributed that hydrogen bonding of water attached to oxygen sites then lead to salvation sheaths and increase the size of molecules so TiO_2 molecules between new macromolecules lead to reduce its viscosity (Andre 2003). Relaxation amplitude is decreasing with increasing TiO_2 as shown in fig. (11) , since polymer molecules swelling water and increase its size , adding TiO_2 molecules made macromolecules to be restricted and the free radical obtained as a result of degradation (E.Foled *et. al.* 1988) resist molecules to back to their positions with mall amplitude.

4. Conclusion

1. Ultrasonic waves made degradation to the polymer chains then affect the velocity.
2. Adding TiO_2 enhances this composite to become good reflected medium for ultrasonic and can be applied on air plane surface and so on that reflected radar waves or sonar surface.
3. Adding TiO_2 made composite not good absorber for ultrasonic waves.
4. The composite can be applies in echo or sonar instrument.
5. Adding TiO_2 made composite hard because its compressibility increasing.
6. The composite can applied in echo or sonar instrument.

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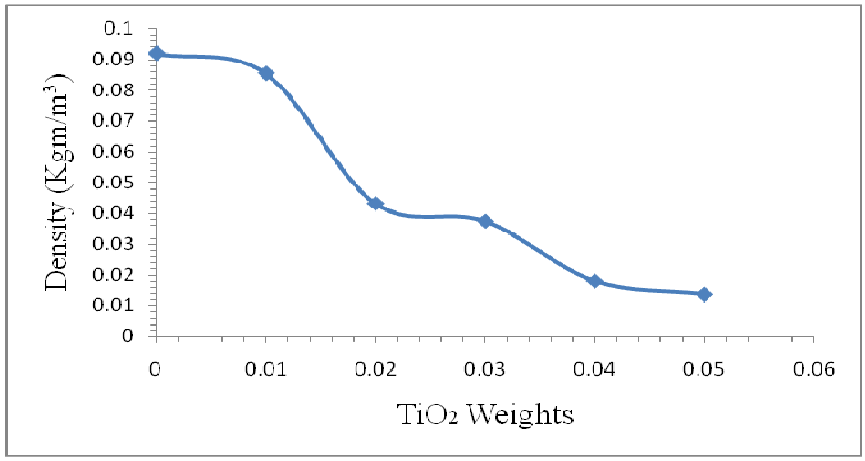

Fig. (1) The density due to the TiO2 Weights

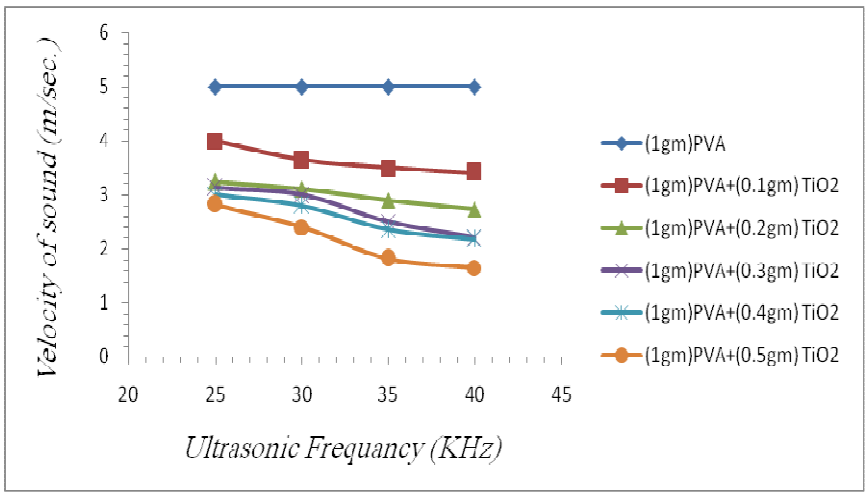

Fig. (2) The velocity of sound due to the ultrasonic frequency

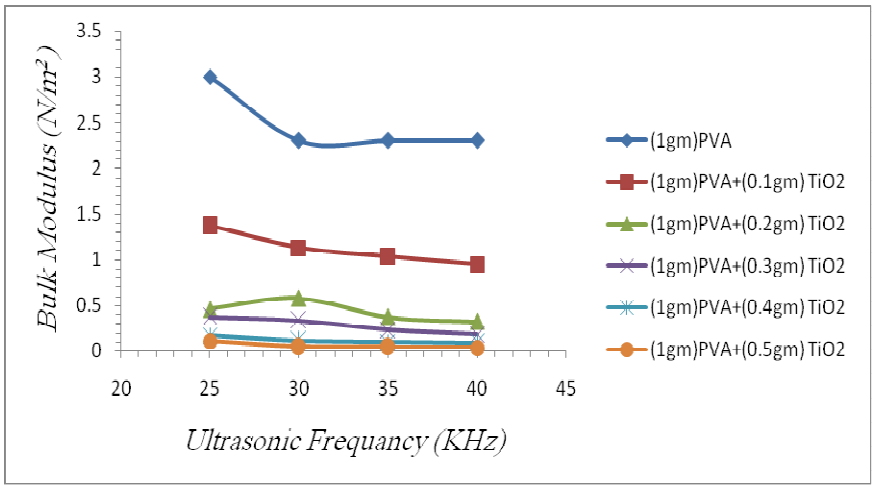

Fig. (3) The bulk modulus due to the ultrasonic frequency

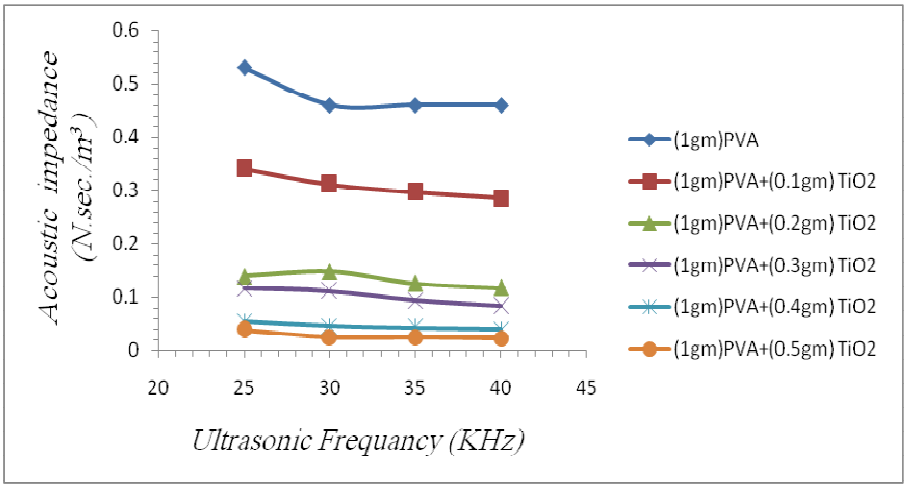

Fig. (4) The acoustic impedance due to the ultrasonic frequency

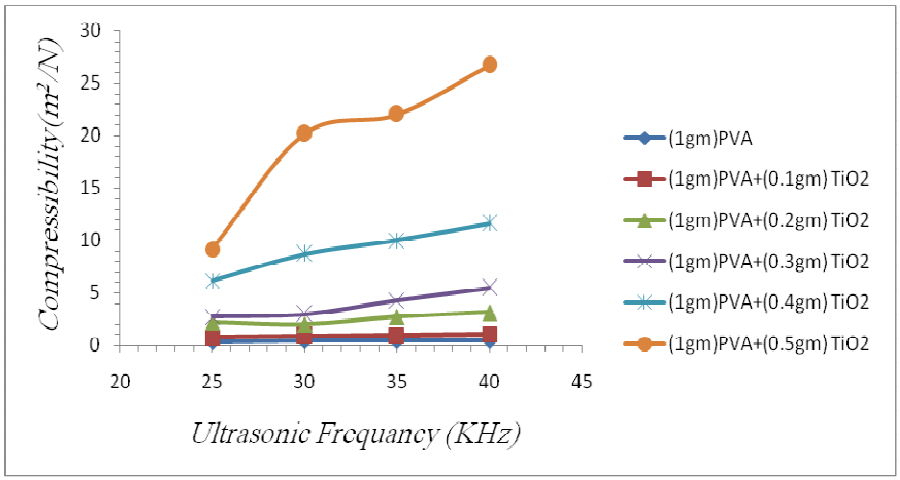

Fig. (5) The compressibility due to the ultrasonic frequency

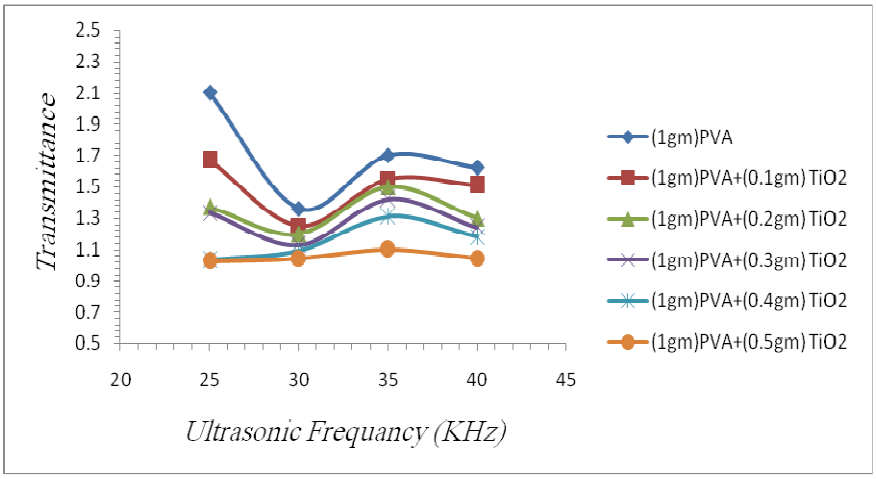

Fig. (6) The transmittance due to the ultrasonic frequency

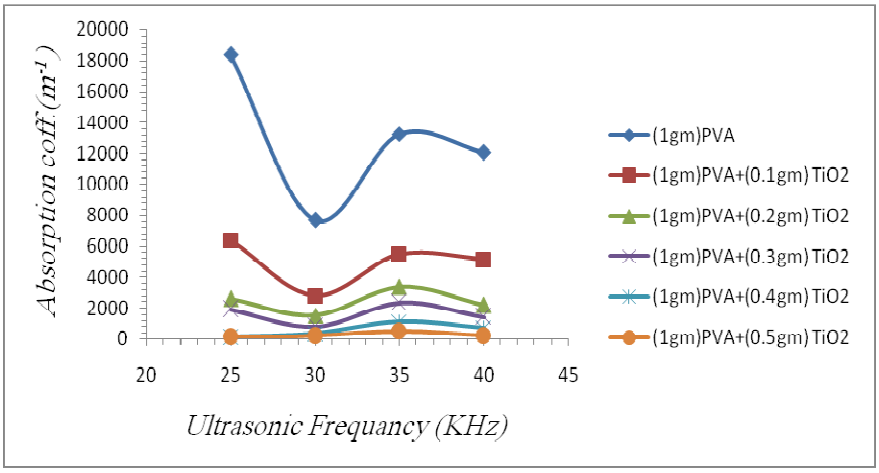

Fig. (7) The absorption coefficient due to the ultrasonic frequency

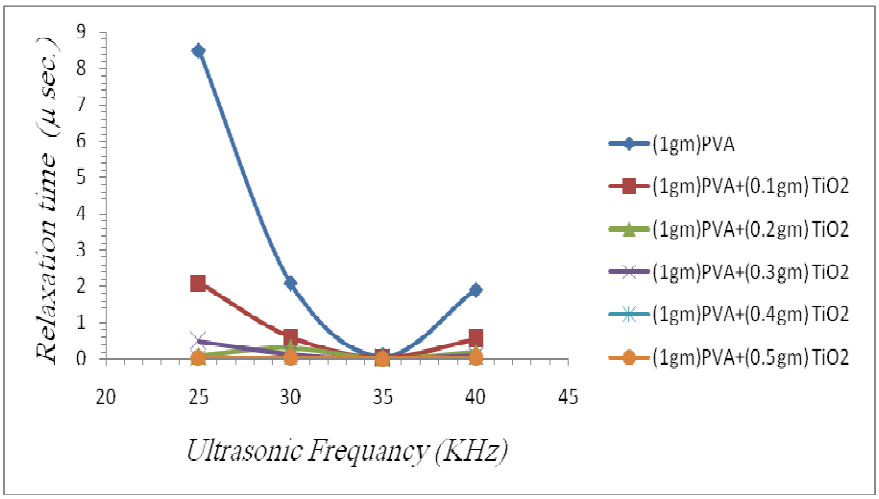

Fig. (8) The relaxation time due to the ultrasonic frequency

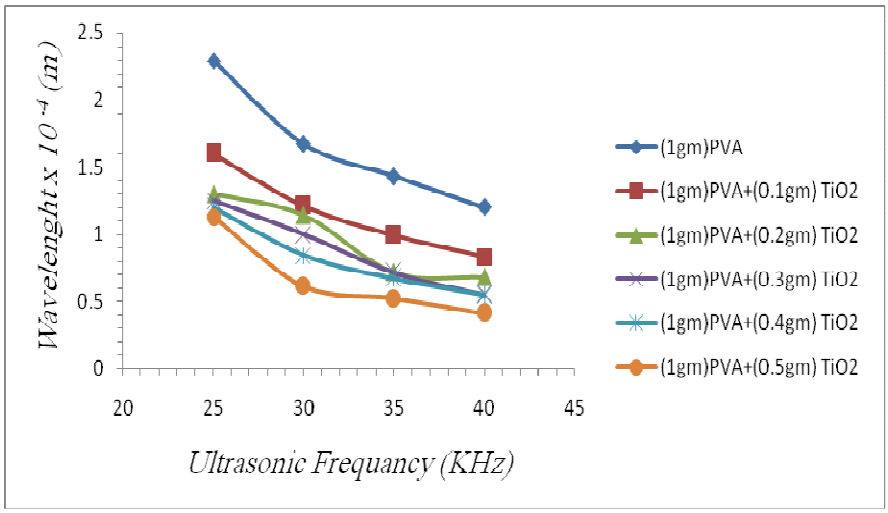

Fig. (9) The wavelength due to the ultrasonic frequency

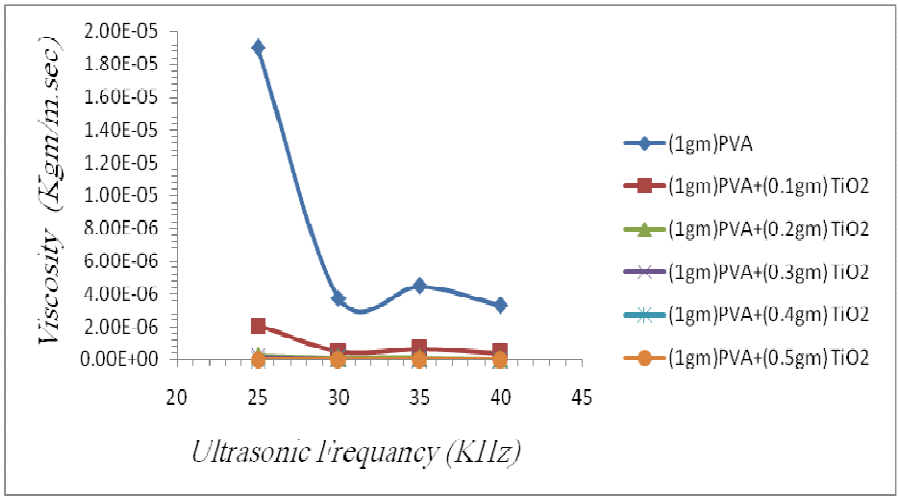

Fig. (10) The viscosity due to the ultrasonic frequency

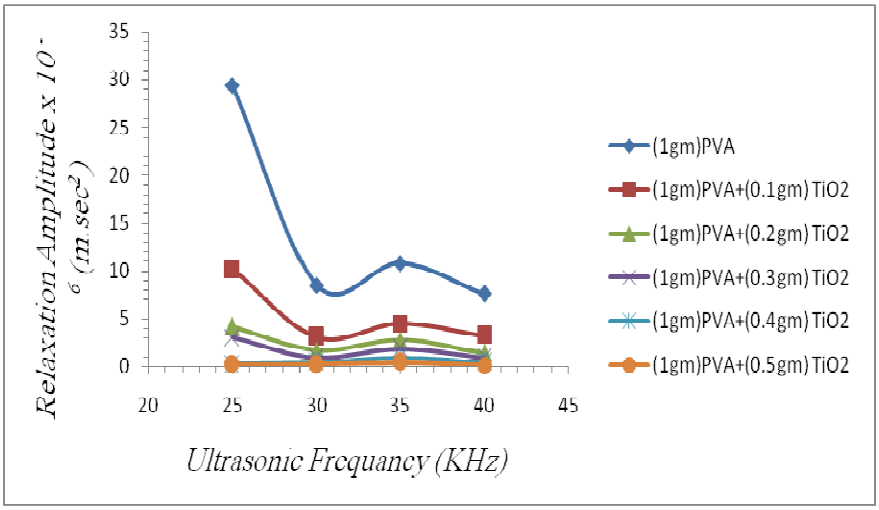

Fig. (11) The relaxation amplitude due to the ultrasonic frequency