Volume 1 No.5, November 2011 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

Study of Some Mechanical Properties of PVA/TiO_2 Composite by Ultrasonic Technique

Burak Yahya Kadem
University of Babylon /college of science/Physics department

ABSTRACT

The PVA/TiO2 composite polymer membranes were prepared by a sol-Gel casting method, the weight of PVA is constant (1gm) while the TiO2 powder ratios were (0.01, 0.02, 0.03, 0.04, 0.05) gm. In order to evaluate the mechanical properties of PVA/TiO2 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 measured using oscilloscope ,then we calculated absorption coefficient and transmittance. It was found that there is significant relationship between ultrasonic velocity and material properties also results show that adding TiO2 effect on the absorption of the ultrasonic waves inside the composites samples.

Keywords: *composite polymer, ultrasound technique, mechanical properties, sol-gel method*

I. 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 the 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. [1] 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 [2]. 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. Ultrasonic attenuation measurements are a standard method used to assess the effects of material degradation [3]. 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 [4]. Many researchers have investigated the ultrasonic degradation of polymers, as summarized by Price [4]. The effects of various parameters like ultrasound intensity, frequency of ultrasonic waves and polymer concentration have been investigated [4, 5]. PVA is a water-soluble synthetic polymer, due to the characteristics of easy preparation, good biodegradability, excellent chemical resistance, and good mechanical properties, PVA has been used on many biomaterial applications [6], 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 [7,8].

II. EXPERIMENTAL

Sample Preparation

PVA (Gerhard Buchman -Germany) with assay (99.8 %) and TiO2 with assay (99.7%) and M.W. (81.38) were used as received without further purification. The PVA/TiO2 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 TiO2 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/TiO2 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.

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 received ultrasonic wave's amplitude (A) after passing the composite.

Theoretical calculation

The absorption coefficient (α) was calculated from Lambert – Beer law [9]:

$$A/A_0 = e\,(-\alpha x) \ldots\ldots (1)$$

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 the composite was calculated from the following equation where (Io) is the initial ultrasonic intensity and (I) the received intensity [10]:

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

The ultrasonic wave velocity was calculated using the following equation [11]:

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

Where (t) is time that the waves need to cross the samples. Attenuation is generally proportional to the square of sound frequency so the relaxation amplitude (D) was calculated from the following equation [12]:

$$D = \alpha / f2 \ldots\ldots\ldots (4)$$

The wavelength (λ) can change only when the speed of the wave changes inside the samples we calculated it by the equation [13]:

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

Bulk modulus (B) of a composite is the substance's resistance to uniform compression, it was calculated by Laplace equation where (ρ) is the density [14]:

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

Compressibility (β) was calculated by the following equation [15]:

$$\beta = (\rho\, v2)\text{-}1 \ldots\ldots\ldots (7)$$

The acoustic impedance of a medium (Z) was calculated by equation [16]:

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

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 (ηs) of the samples was measured by using the equation [17, 18]:

$$\eta s = 3\ \alpha\ \rho\ v3/\ 8\ \pi 2\ f2 \ldots\ldots\ldots (9)$$

The relaxation time (τ) was calculated from the equation [19]:

$$\tau = 4\ \eta s\ /3\rho\ v2 \ldots\ldots\ldots (10)$$

III. RESULTS AND DISCUSSIONS

The density are decreasing with adding TiO2as shown in (fig.1) since density defined as a mass per unit volume and when adding the TiO2its molecules occupied the vacancies between polymer macromolecules displaying PVA molecules from their position which are heavier than TiO2 molecules so density reducing when TiO2increasing [6] ultrasonic velocity was calculated for different TiO2 concentrations that added to PVA polymer as shown in (fig.2), the velocity are decreasing with the increasing of TiO2 concentration; since TiO2 molecules filled the vacancies of the polymer chains that randomly coiled and give composite good tensile strength that increasing the impedance against velocity so reducing the later slightly. Figure also shows that the velocity are decreasing when frequency increasing since higher value of frequency make degradation to the chains that decreasing tie chains which reduces the velocity [20] this behavior same to that obtained by [2] for other polymers used the same technique. Bulk modulus are decreasing with the increase of TiO2 as shown in (fig.3) this attributed to the fact that TiO2 molecules make entanglement interaction to the polymer chains and network formation [21], The specific acoustic impedance are decreasing with concentration increasing as shown in (fig.4); this attributed when the concentration increasing there are rearrangements of the polymer network by breaking chains bonds [22]. The compressibility shown in (fig.5) are increasing with increasing concentration (this behavior same to that given by [23, 24] for other polymers) this attributed to the ultrasonic waves propagation made polymer chains to be each close together ,this change conformation and configuration of these molecules so there are more compression happen of these molecules[25]. The transmittance are decreasing with increasing TiO2 as shown in (fig.6) this attributed that when adding TiO2 to PVA solutions these molecules fills the vacancies between polymer chains and restricted these chains in fixed volume so when ultrasonic passes through composite it faces strong resistance to follow so TiO2 has good property for reflecting ultrasonic waves. The absorption coefficient is decreasing as shown in (fig.7) this could be attributed to the changes in the particle size distribution function of the three types of molecules that formed the composite; the TiO2 intermolecular processes were assumed to be responsible for reducing acoustic attenuation then reducing the relaxation time for the composite molecules to be stated in their positions as shown in (fig.8) [26]. The wavelength are decreasing with concentration increase as shown in (fig.9), since there are increasing in concentration so the molecules come close together and there are more transmittance according to compressibility and rarefaction of more propagation against these molecules [22]. Share viscosity is decreasing with concentration increase as shown in (fig.10) this is attributed to the changes in the particle size distribution function [27]. Relaxation amplitude are decreasing with concentration as shown in (fig.11) this attributed to the polymer molecules are swelling water and increase its size and these molecules restricted and the free radicals obtained as a result of degradation by ultrasonic [20] .

IV. CONCLUSION

1. The velocity decreases with increasing TiO_2 weights in the samples because of the degradation to the polymer chains.
2. The vacancies between the polymer macromolecules were filled with TiO_2 molecules that restricted these macromolecules
3. The attenuation of the ultrasonic wave in composite is determined mainly by the size,

and molecules distribution in the composite.

4. The results show that the lower frequency is more beneficial for composite regeneration. This is because the lower acoustic frequency will lead to more uniform energy distribution.
5. Since ultrasonic absorption decreasing so this composite is good medium for transferring ultrasonic waves.
6. This study shows there is strong intermolecular interaction which is responsible for increasing compressibility of composite when adding TiO_2 this lead to reduce the absorption coefficient.
7. The composite can be applied in echo or sonar instruments.

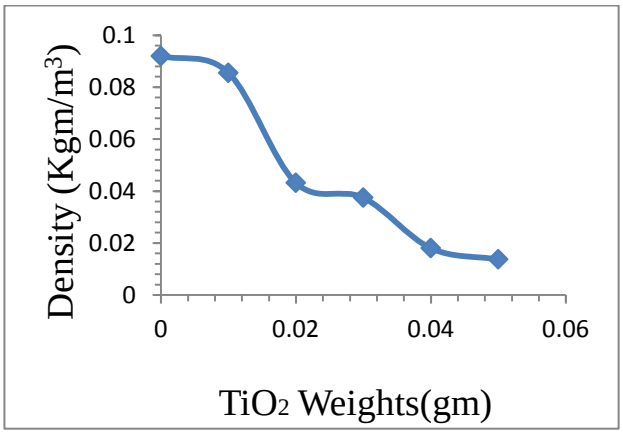

Fig. (1) The density due to the TiO2 Weights

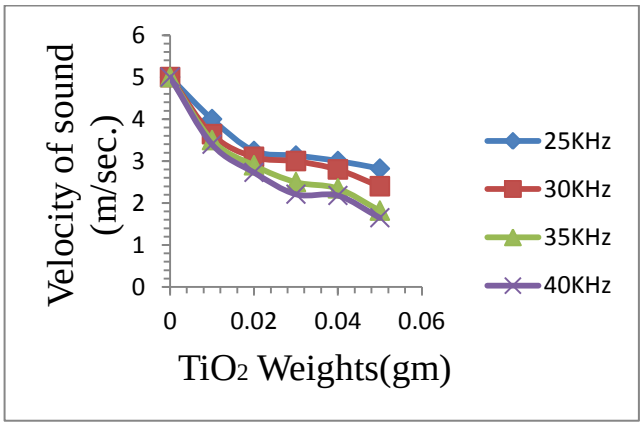

Fig. (2) The velocity of sound due to the TiO2 Weights

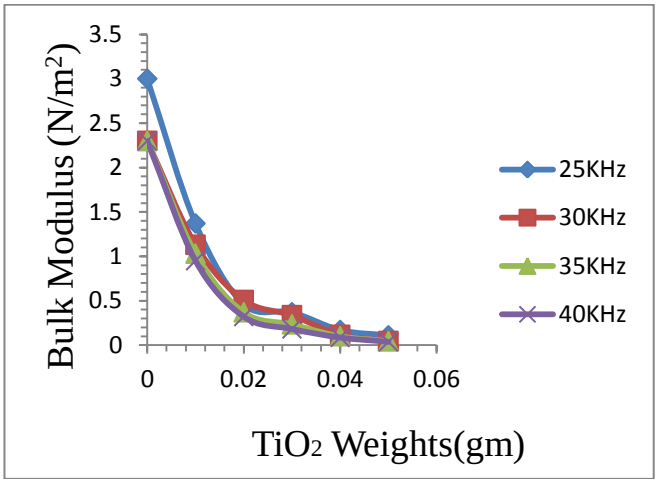

Fig (3) The bulk modulus due to the TiO2 Weights

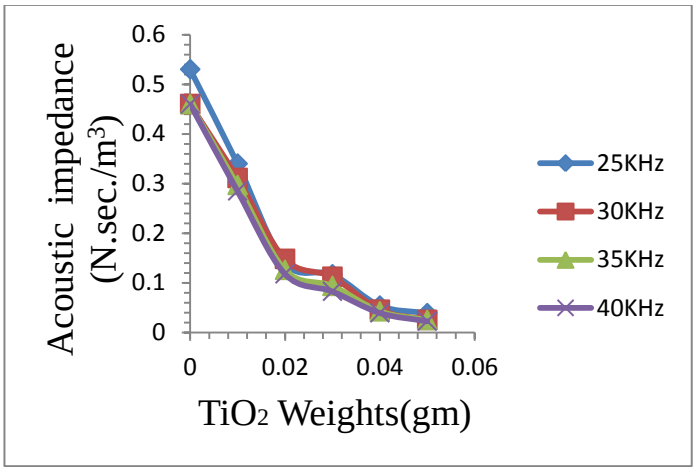

Fig. (4) The acoustic impedance due to the TiO2 Weights

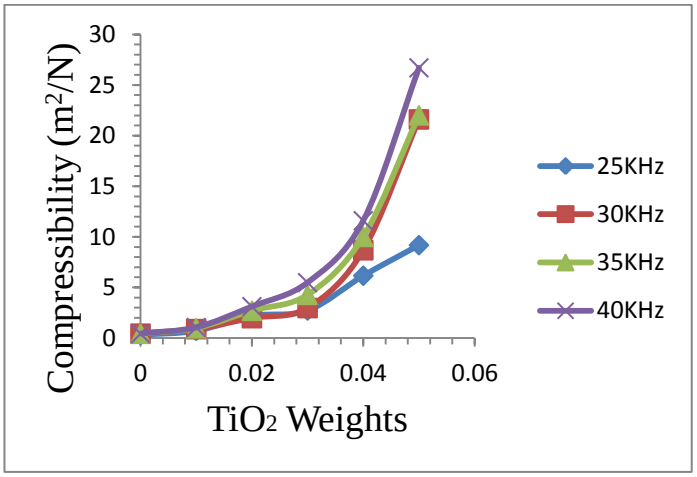

Fig. (5) The compressibility due to the TiO2 Weights

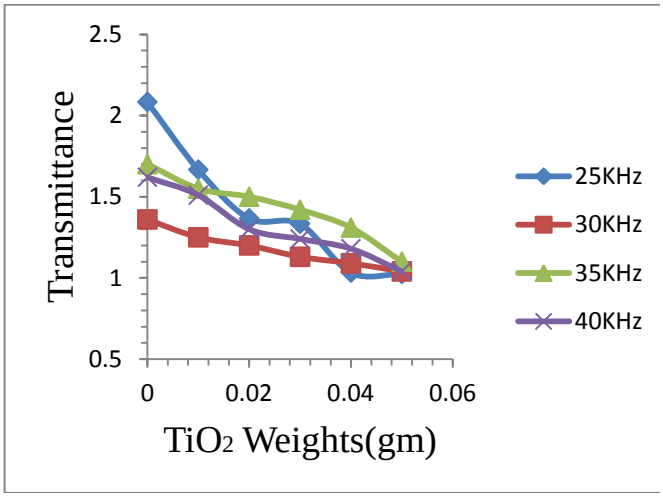

Fig. (6) The transmittance due to the TiO2 Weights

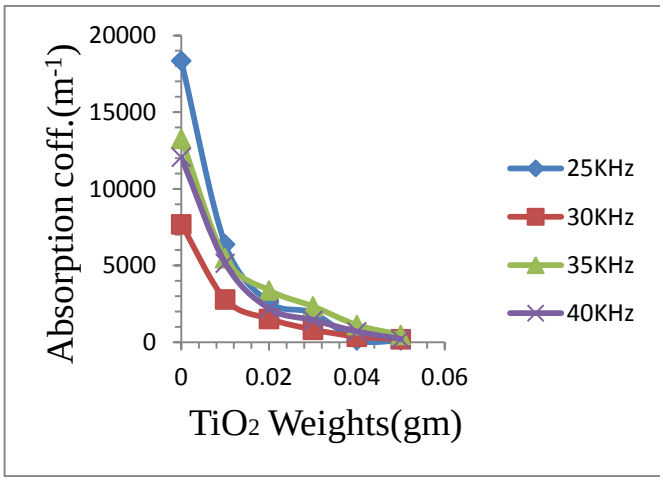

Fig. (7) The absorption coff. due to the TiO2 Weights

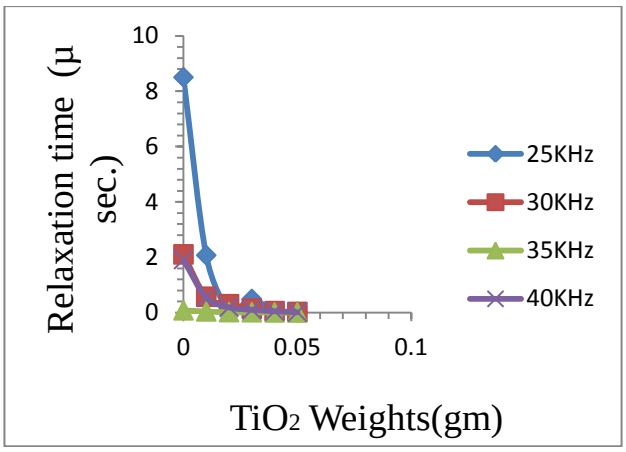

Fig. (8) The relaxation time due to the TiO2 Weights

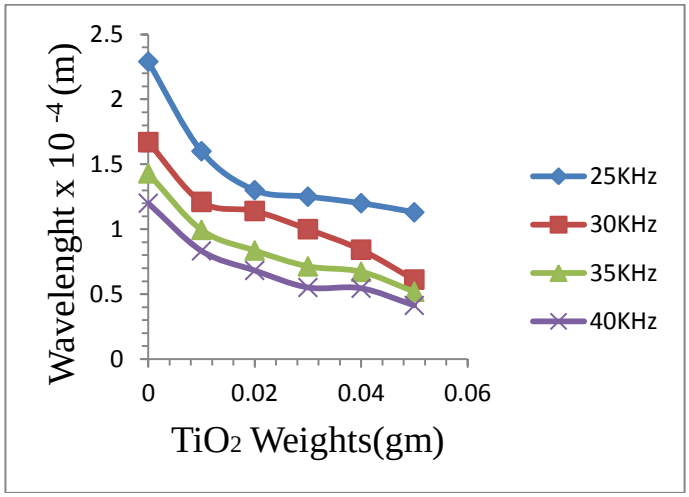

Fig. (9) The wavelength due to the TiO2 Weights

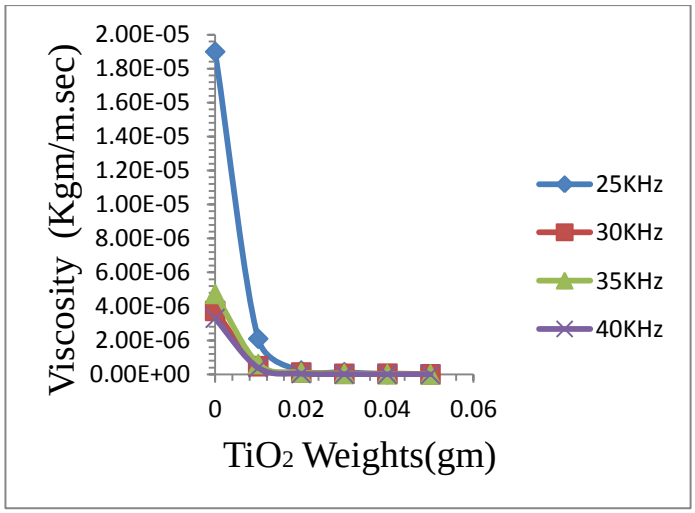

Fig. (10) The viscosity due to the TiO2 Weights

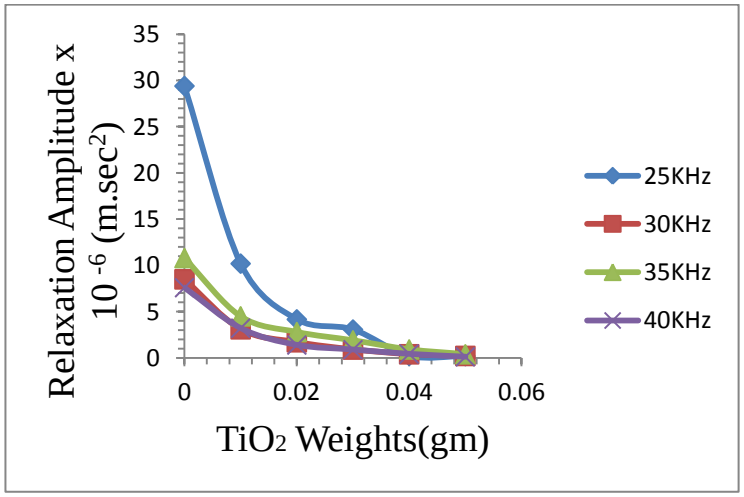

Fig. (11) The relaxation amplitude due to the TiO2 Weights

REFERENCES

[1] Bogomil YOCHEV, Svetoslav KUTZAROV, Damyan GANCHEV, Krasimir STAYKOV(2006)" Investigation of Ultrasonic Properties of Hydrophilic Polymers for Dry-coupled Inspection", ECNDT - We.1.6.5

[2] B. Boro Djordjevic , the 10th International Conference of the Slovenian Societyfor Non- Destructive Testing, Ljubljana, Slovenia, 47-57 ,(2009)

[3] Nondestructive Testing, ASTM Standard E664-93, Vol. 03.03, Easton, MD, 1994), pp.264-266

[4] Jayanta Chakraborty, Jayashri Sarkar, Ravi Kumar and Giridhar Madras, "Ultrasonic Degradation of Polybutadiene and Isotactic Polypropylene", Polymer Degradation and Stability, 85 (2004) 555-558.

[5] Andre M.Striegel, "Influence of Chain Architecture on the Mechanochemical Degradation of Macromolecules", J.Biochem.Biophys.Methods, 56 (2003) 117-139

[6] Abed Al-Kareem J. , Burak Yahya K., Lamis F.N., study of some mechanical properties of PVA/ZnO composites byultrasonic waves , accepted and to be published in Babylon university Journal (2012),Vol.20,No.6

[7] Shu, K.M., G. C. Tu,, Materials Science and Engineering 236-247(2002)

[8] Canan AKSU CANBAY and Ayşe AYDOGDU, Turkish Jo. Sci.&Tech. Volume 4, No 2, 121-126.(2009)

[9] J. D. J. Ingle and S. R. Crouch, Spectrochemical Analysis, Prentice Hall, N.J. (1988).

[10] Dipak Basu , Dictionary of pure and applied physics, CRC Press, (2001).

[11] Boutouyrie P, Briet M, Collin C, Vermeersch S, Pannier B Artery Research,3(1): 3–8(2009).

[12] Krautkramer, Josef and Herbert, "Ultrasonic testing of materials" 4th edition, Springer. (1990).

[13] David C. Cassidy, Gerald James Holton, Floyd James Rutherford Understanding physics. Birkhäuser. pp. 339,(2002).

[14] Cohen, Marvin ", Phys. Rev. B 32: 7988–7991(1985).

[15] Callen, Herbert B. Thermodynamics and an Introduction to Thermo statistics (2nd Ed.).New York: John Wiley & Sons. (1985).

[16] Jarth Mc-Hugh, a thesis PhD Bundesanstalt für Materialforschung und - prüfung (BAM),(2008).

[17] Kumagai, Naoichi; Sadao Sasajima, Hidebumi Ito, Journal of the Society of Materials Science*)* Japan) (Japan Energy Society) 27 (293): 157–161(2008).

[18] A. K. Al-Bermany, journal of college of education Vo.2, no.384.(2009)

[19] Curi E. Companha S, "Marco mol. Sci."A431, 4, (2006).

[20] E.Foled, M.Iring and F.tudds"degradation of HDPE and LLDPE in closed mixing chamber", polymer Bulletin J.(1988)Vol20, no.1 (89-96).

[21] Pradeep K. Rohatgi, Takuya Matsunaga and Nikhil Gupta," Compressive and ultrasonic properties of polyester/fly ash Composites", J Mater Sic, (2009) 44:1485–1493.

[22] Wiggens P.M. and Van Ryn R.T. "the solvent properties of water in desalination membrane", Journal of Macromolecules Sci.-Chem.(1986), A23, 875-905.

[23] Al-Bermany K.J. "Enhancement of mechanical properties using gamma radiation for HEC polymer" , Journal of college of Education ,Babylon university (2010),vol.1,no.5.

[24] A. K. Al-Bermany,"Enhancement of electrical and optical properties for carboxyl methyl cellulose and it's industrial applications", journal of college of education (2009) Vo.2, no.384.

[25] Hasun S.K. ,"Ultrasonic study and visco-relaxation of PVA", British polymer Journal, (1989) vol.21, 333-338.

[26] Formageau J., Brusseau E. Vary D., Gimenez G. and Chartre P." characterization of PVA cryogen for intravascular ultrasound elasticity imaging", IEEE transactions on ultrasonic ferroelectrics and frequency control,(2003), Vol.50,issue 10 pp(1318-1324).

[27] Tomasz Hornowski, Arkadiusz Józefczak ,Andrzej Skumiel and Mikołaj Łabowski ," Effect of Poly(Ethylene Glycol) Coating on the Acoustic Properties of Biocompatible Magnetic Fluid", Int J Thermo phys. , (2010), 31:70–76.