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Study the Mechanical Properties of (PVA/Si) Composite Prepared by Casting Method

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ABSTRACT

The PVA/Si composite was prepared by casting method, the weight of PVA is constant (1gm) while the Si powder were (0.02, 0.04, 0.06, 0.08) gm, the densities of the samples were measured in the weight method. In order to evaluate the mechanical properties of PVA/Si composite the ultrasonic measurements were performed at the samples , these properties are ultrasonic velocity, compressibility, acoustic impedance and bulk modulus, absorption coefficient, the relaxation amplitude and transmittance were analyzed at different frequencies (25 and 30) kHz. It was found that there is significant relationship between ultrasonic velocity and density on the material mechanical properties.

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Key words: Mechanical Properties, Polyvinyl alcohol, Composite, Casting Method.

INTRODUCTION

The sol-gel casting method is widely used in the preparation processes for inorganic/organic composites. The advantages of the sol-gel method are that the synthesis process is done at room temperature and organic polymer can be introduced at the initial stage in which the particles of solution kept in the homogeneous dispersed state[1]. 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 [2]. Silicon is the eighth most common element in the universe by mass, but very rarely occurs as the pure free element in nature. It is most widely distributed in dusts, sands, planetoids, and planets as various forms of silicon dioxide (silica) or silicates. Over 90% of the Earth's crust is composed of silicate minerals, making silicon the second most abundant element in the earth's crust (about 28% by mass) after oxygen [3].

The study of composite materials, i.e., mixtures consisting of at least two phases of different chemical compositions, has been of great interest from both fundamental and practical standpoints, the macroscopic physical properties of such materials can be combined so as to produce materials with a desired average response [4]. 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 [5].

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[6] .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 [7].

The effects of various parameters like ultrasound intensity, frequency of ultrasonic waves and polymer concentration have been investigated [8,9]. 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[10].

EXPERIMENTAL

Materials

Polyvinyl Alcohol was purchase from Panreac-Spain with density (1.3 gm/ cm^3) and assay 99.9%, the silicon powder purchase from Merck-Germany with density (2.329 gm/ cm^3) and assay 99.8 %. The double distilled water was used in all sample preparation.

Preparation of Samples

The PVA/Si composite membranes were prepared by sol-gel casting method, the appropriate weight of PVA was dissolved in (20ml) of distilled water under stirring and heat (80æ%C) for (1 hour) then the Si powder was added to each sample, the resulting solution was stirred continuously until the solution mixture became a homogeneous viscous appearance at room temperature, the PVA/Si composites membranes are obtained by leaving the mixture solution in a petre dish at room temperature for 4 weeks. The densities of the samples were measured by the weight method for all the samples.

Measurements

Ultrasonic measurements were made by pulse technique of sender-receiver type (SV-DH-7A/SVX-7 velocity of sound instrument – Korea), the measurements were made at two different frequencies (f = 25 and 30 KHz), the receiver quartz crystal mounted on a digital vernier scale of slow motion, the receiver crystal could be displaced parallel to the 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 (t) of receiver pulses were recorded with respect to the thickness of the samples (x).

The pulses height on oscilloscope (CH1) represents incident ultrasonic wave's amplitude (A_o) and the pulses height on oscilloscope (CH2) represents the receiver ultrasonic wave's amplitude (A).

Theoretical calculation:

The ultrasound wave velocity (v) was calculated using the following equation (1) [11]:

$$V = \frac{x}{t}. \qquad ...(1)$$

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 Laplace equation (2) Where (ρ) is the density[12]:

$$\beta = \frac{1}{\rho v^2} \qquad ...(2)$$

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 the following equation (3)[13,14]:

$$B = \rho v^2 \qquad ...(3)$$

The acoustic impedance of a medium (Z) was calculated by the following equation (4) [15]:

$$Z = \rho v \qquad ...(4)$$

Using Lambert – Beer law the absorption coefficient (á) calculated by the equation (5)[16]:

$$\frac{A}{A_O} = e^{-\alpha x}. \qquad ...(5)$$

$$D = \frac{\alpha}{f^2} \quad ...(6)$$

Attenuation is generally proportional to the square of sound frequency (f) so the relaxation amplitude (D) was calculated from the following equation (6) [17]:

RESULTS AND DISCUSSION

In our study we try to make a membrane with good mechanical properties so we used the ultrasonic waves to evaluate these properties with two different frequencies (25 and 30 kHz).

PVA were used as matrix and silicon powder was used as filler to have a PVA/Si membrane, the densities were calculated by the weight method and Fig. (1) Shows the densities were decreased with increasing Silicon addition to PVA because the thickness of the samples were decrease and the density is define as the weight per volume so whenever the thickness increase the volume increase and the density decrease.

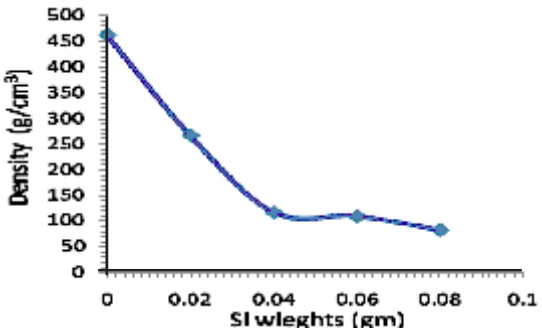

Fig.1 The density of the samples due to Si addition

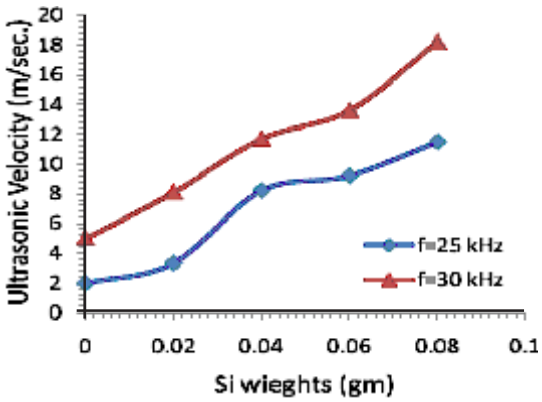

Fig.2 The ultrasonic velocity of the samples due to Si addition

Fig. (2) shows that the ultrasonic velocity of the samples increasing with Silicon addition this could be attributed to the reducing in density and the formation of the three molecules in the composite (polymer, water and Si) molecules, the polymer with high molecular weight made a matrix and the matrix vacancies were filled with silicon molecules and made the composite transfer the ultrasound waves, the frequency 30kHz has higher value of velocity in the composites this because the wave energy is increasing with frequency and increase the entanglement interaction of the molecules so increasing the velocity [18], this lead to increase the acoustic impedance of the membrane as shown in Fig. (3) and could attributed to the rearrangements of the

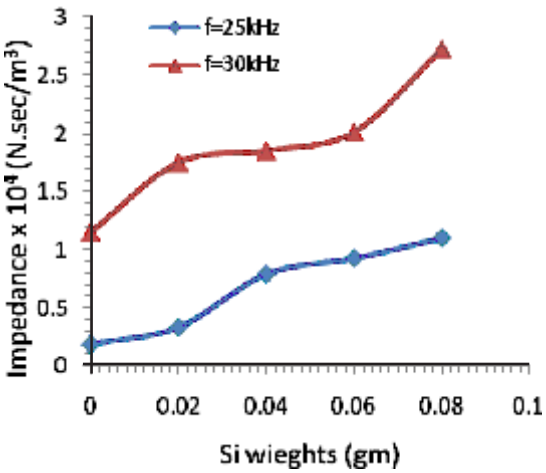

Fig.3 The Impedance of the samples due to Si addition

polymer network by breaking chains bonds, it was probably that water clusters grew and came into contact with hydrophobic regions of the membranes resulting in a gradual change from small mobile silicon clusters to larger clusters with stronger hydrogen bonds, Fig. (3) Also shows that at higher

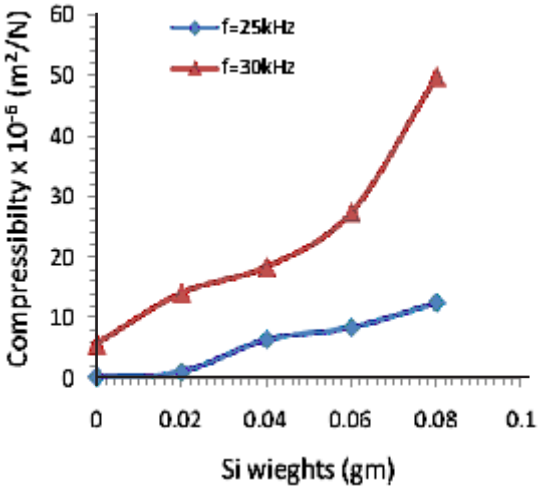

Fig.4 The Compressibility of the samples due to Si addition

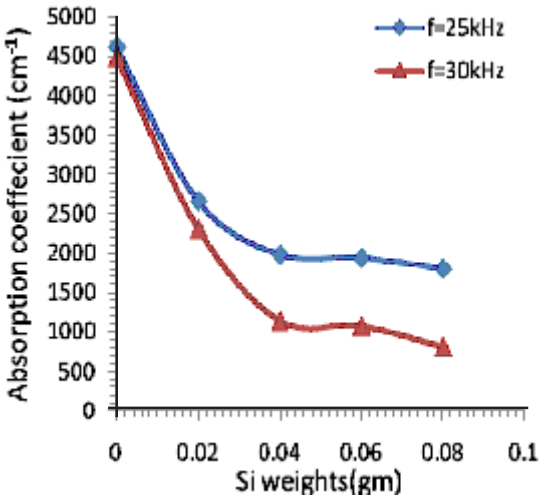

Fig.6 The Absorption coeffeicent of the samples due to Si addition

frequencies there are higher specific acoustic impedance since there are more degradation[19].

Fig. (4) Shows that the compressibility of the membrane increase with Silicon addition that means silicon molecules forming network formation as a result of entanglement interaction between the two types of molecules, polymer macromolecules and Silicon molecules [20]

Fig. (5) shows that the bulk modulus decreasing with Silicon addition and this could be attributed to the amount of contraction is governed by the compressibility, which is dependent on the intermolecular forces and because of the compressibility is inversely related to the bulk modulus by means of equations (2and 3) so there are decreasing in bulk modulus[12].

Fig.(5) shows that at lower Silicon addition there are higher bulk modulus values since decreasing Silicon addition means there are more vacancies that make polymer chains that randomly coiled have higher bulk modulus[19] .

Fig. (6) shows that the absorption coefficient of the membrane is decreasing with Silicon addition and this because the molecules will be close and restricted together, this lead to low vibration for these molecules so there is reducing

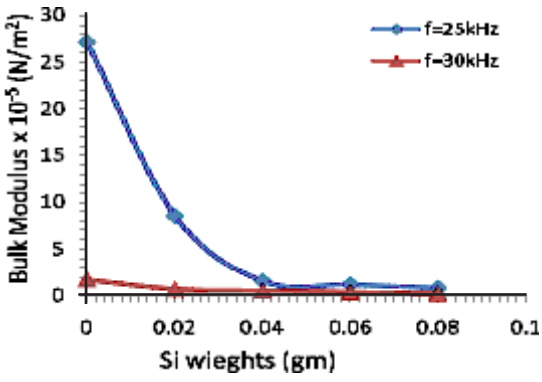

Fig.5 The Bulk modulus of the samples due to Si addition

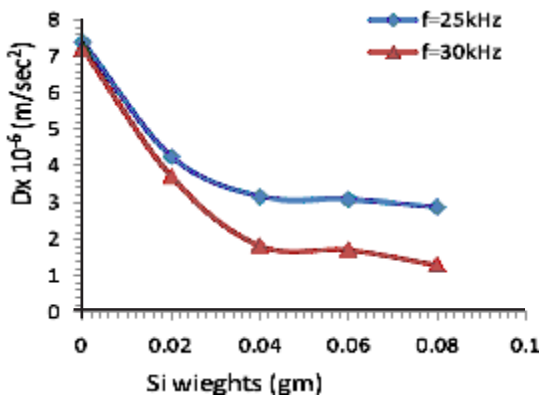

Fig.7 The Relaxation amplitude of the samples due to Si addition

in absorption, in other hand the attenuation can be 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[20] this will lead to decrease the relaxation amplitude as shown in Fig.(7), the Attenuation is generally proportional to the square of ultrasonic frequency, the relaxation amplitude decreasing with Silicon addition and could be attributed to the fact that ultrasonic energy depends on viscosity thermal conductivity, scattering and intermolecular processes , thermal conductivity and scattering effects are known to be negligible[11] so intermolecular processes is responsible for the increase of relaxation amplitude for this reason absorption coefficient commonly known as visco – absorption.

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CONCLUSION

The densities of the samples decreasing with Si addition, this decreasing responsible for increasing the ultrasonic velocity which made the composite good media to transfer ultrasound waves; in other hand both density and velocity are affected on the mechanical properties under search.

The attenuation of the ultrasound waves decreasing with Si addition and it related to density decreasing.

The ultrasound frequency affected directly on these mechanical properties since the frequency means the energy of the waves which made the Si molecules filled the vacancies in the PVA matrix .

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