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Study the Rheological and Mechanical Properties of PVA/$CuCl_2$ by Ultrasonic

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Abstract

Some of physical properties of polyvinyl alcohol dissolves in distilled water had been studied before and after adding different weights of copper (II) chloride ($CuCl_2$), the Rheological properties shows that the densities variation are intangible and shear viscosity are responsible for reducing velocity, bulk modulus and transmittance the absorption coefficient of ultrasonic waves and relaxation amplitude are increasing with adding copper (II) chloride because there will be more molecules in solution and this lead to more attenuation against wave propagation

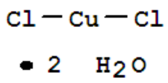
Keywords: PVA solution, mechanical properties, rheological properties, ultrasound technique.

1. Introduction

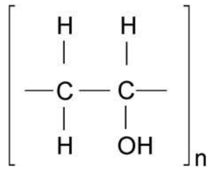
PVA is a water-soluble synthetic polymer, due to the characteristics of easy preparation, good biodegradability, excellent chemical resistance, and good mechanical properties, polyvinyl alcohol is used mainly as a solution in water but its solubility in water depends on its degree of polymerization and degree of hydrolysis of its precursor (poly vinyl acetate), In PVA solutions in water, very complicated and strong physical interactions between solvent and polymer would be present.

The rheological properties of the PVA solutions are affected by effectiveness of the physical bonding solvent systems the physical state of water is very important to rheological responses because free water forms hydro-gel structure (Song and Byoung 2004) solvent effects might therefore be expected to influence the ultrasonic relation behavior, the absorption of ultrasonic in liquid polymer systems is governed by local modes of motion and cooperative whole molecule movement because of the strong intermolecular interaction within the polymer it should be possible to observe cooperative motion in the ultrasonic range (Jayanta *et. al.* 2004).

Polyvinyl alcohol has high tensile strength and flexibility, as well as high oxygen and aroma barrier properties. However these properties are dependent on humidity, in other words, with higher humidity more water is absorbed, the water which acts as a plasticizer, will then reduce its tensile strength, but increase its elongation and tear strength. PVA is fully degradable and dissolves quickly. (Fromageau *et. al.* 2003). Acoustic relaxation measurements on other polymers have been reported by several workers (Hasun S.K. 1989, Tomasz *et. al.* 2010, Hassun,S.K. and Rahman,K.1990, Khalida 2004), 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 (Al-Bermany E.2004, B. Boro 2009). Aqueous solution prepared from copper (II) chloride contains a range of copper (II) complexes depending on concentration, temperature and the presence of additional chloride ions (Greenwood and Earnshaw 1997,).



(Fig. 1) The molecular structure of $CuCl_{2}.2H_2O$



(Fig. 2) The molecular structure of PVA.

2. Experimental

2.1 Preparation of Solutions:

The solution was prepared by soluble (0.5 gm PVA) in (400 ml) distilled water under stirring at 80^{o}C for (1 hour) the resulting solution was stirred continuously until the solution mixture became a homogeneous, the copper (II) chloride weights were (0.01, 0.02, 0.03, 0.04, 0.05) gm added to the PVA solution to study the addition affect on some of the rheological and mechanical properties.

2.2 Ultrasonic measurements:

Ultrasonic measurements were made by pulse technique of sender-receiver type (SV-DH-7A/SVX-7 velocity of sound instrument) with different frequencies (25, 30,35,40,45 and 50 kHz) in our study the frequency fixed at (25 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_0) and the pulses height on oscilloscope (CH2) represents the receiver ultrasonic wave's amplitude (A).

3. Results and Discussion

The densities of the solutions (ρ) were determined by density bottle method, the change in densities is almost intangible when we add copper (II) chloride as shown in (Fig.3) their viscosities measured before and after adding copper chloride for all samples using Ostwald viscometer with accuracy of ± 1.05%, the method of measurement has been described by (Al-Bermany E.2004), elsewhere the shear viscosity were determined before and after the adding of copper (II) chloride by the following equation (Illiger *et. al.* 2008, Subhi *et. al.*1990) ($\eta_s/\eta_o = t\,\rho/t_o\,\rho_o$) where ($\eta_s$) is the solution viscosity, (ρ_o) and (η_o) are the distilled water density and viscosity respectively, the shear viscosity is increasing with adding copper (II) chloride as shown in (Fig.4) since the viscosity describes a fluid's internal resistance between molecules so when we add the copper (II) chloride there will be more molecules, the additional forces between molecules leads to an additional contribution to the shear stress and this lead to reduce velocity as shown in (Fig.3), the associated state of water in the solvent systems had a significant effect on the physical properties of PVA solutions such as rheological responses and molecular relaxation behavior (Song and Byoung 2004).
Ultrasonic wave velocity (v) shown in (Fig.5) was calculated using the following equation (Boutouyrie *et.*

al. 2009) ($v = x / t$) where (t) is the time that the waves need to cross the samples (digital obtained from the instrument), the velocity is decreasing this because structural or volume relaxation it occurs in associated liquids such as polymers, a liquid when at rest has a lattice structure similar to that possessed by solid when waves are propagated through it, the resultant periodic changes of wave pressure causes molecules to flow into vacancies in the lattice during compression phase and to return to their original positions in the lattice during rarefaction, because of this and because of viscosity the ratio of the change in pressure to the fractional volume compression is decrease with adding copper (II) chloride, this called the bulk modulus of the material (B) as shown in (Fig.6) and it is calculated by Laplace equation ($B = \rho v^2$) (Abdul-Kareem *et.al* .2011). (Fig.7) shows the solutions compressibility (K) which is calculated from this equation (R. Palani and S. Kalavathy 2011) ($K = 1/ \rho v^2$) the compressibility appears to be increasing with increase in copper (II) chloride molecules, this behavior indicates significant interaction between solute and solvent molecules due to which the structural arrangement in the neighborhoods of constituent solutes is considerably affected. The transmittance (T) is the fraction of incident wave at a specified wavelength that passes through the sample was calculated from the following equation (Dipak Basu 2001) ($T = I / I_o$) where (I_o) is the initially intensity of the ultrasonic waves and (I) is the received intensity, it is decreasing with adding copper (II) chloride as shown in (Fig.8) this attributed that the polymer molecules absorbed the sound waves according to Lambert-Beer Law (Ingle and Crouch 1988) ($A/A_0 = e^{-\alpha x}$) where (α) is the absorption coefficient, (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 and because the viscosity increasing the absorption coefficient is increasing as shown in (Fig.9) which is biased on concentration (Dipak Basu 2001, Ingle and Crouch 1988), this attributed to the fact that when adding copper (II) chloride there will be more molecules in solution this lead to more attenuation against wave propagation, 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 (Tomasz *et. al.* 2010) so there will be increasing in absorption and this lead to increase the relaxation amplitude as shown in (Fig.10), the Attenuation is generally proportional to the square of sound frequency, the relaxation amplitude (D) was calculated from the following equation ($D = \alpha / f^2$) (Josef and Herbert 1990) where (f) is the ultrasonic frequency and this 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 (Boutouyrie *et.al.* 2009, Josef and Herbert 1990) so viscosity is responsible for the increase of relaxation amplitude for this reason absorption coefficient commonly known as visco –absorption.

1. Conclusion

This study shows that intermolecular processes and the associated state of water in the solvent systems had a significant effect on the physical properties of PVA solutions such as rheological responses and molecular relaxation behavior, and indicating increase in the size of molecules in bath of ultrasonic waves, when concentration increases there will be complexes molecules formed in the solution by the effect of peroxide and roots that rebounded to formations between polymer chains when adding copper chloride, the affect of adding copper chloride on densities is intangible so the viscosities of solutions which were increasing are responsible for reducing velocity of ultrasound then reducing the bulk modulus and transmittance, this lead to increase the absorption coefficient with adding copper chloride because molecules absorbed the sound waves according to Lambert-Beer Law then increase the relaxation amplitude.

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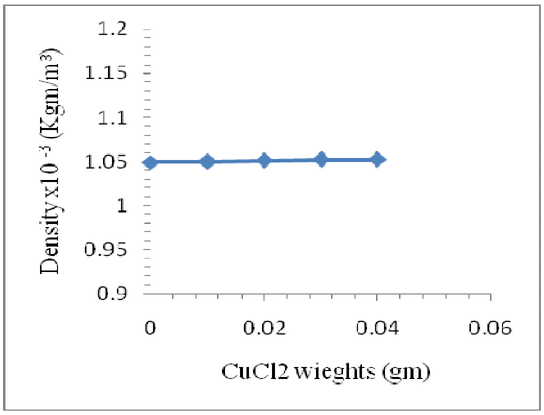
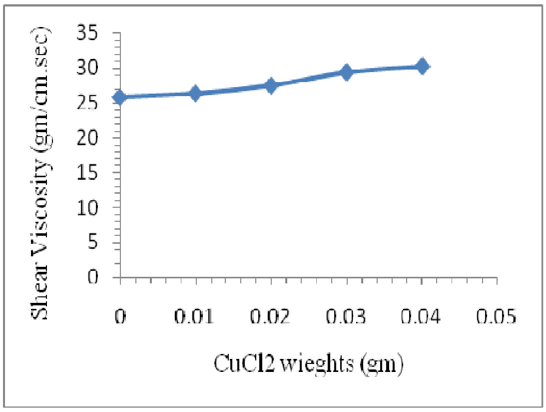
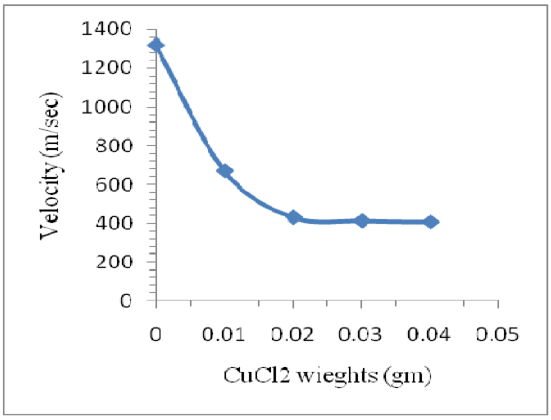


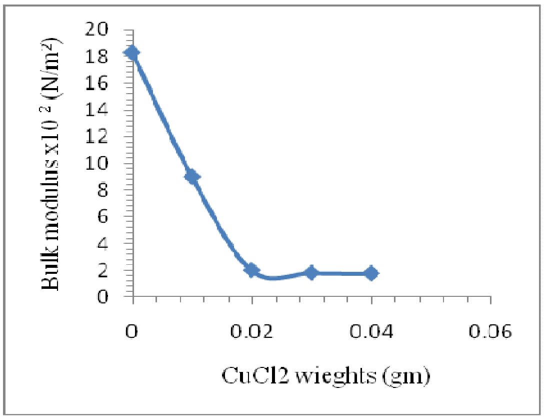
(Fig.3) Density due to$CuCl_2$ addition



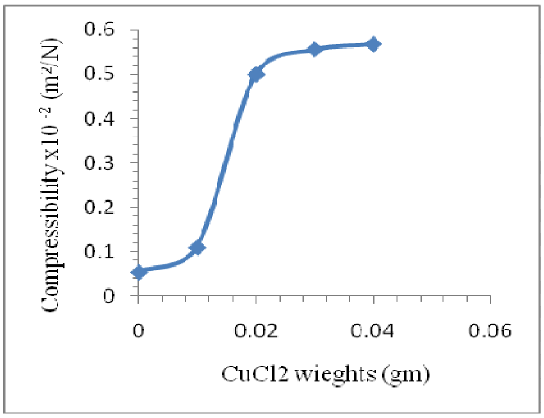
(Fig.4) Shear viscoscity due to concentration



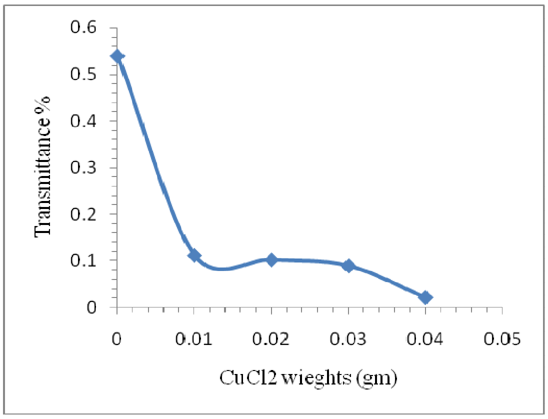
(Fig.5) Ultrasonic velocity due to concentration



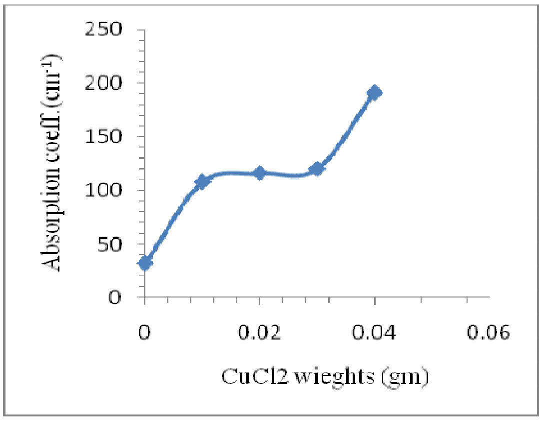
(Fig.6) Bulk modules due to concentration



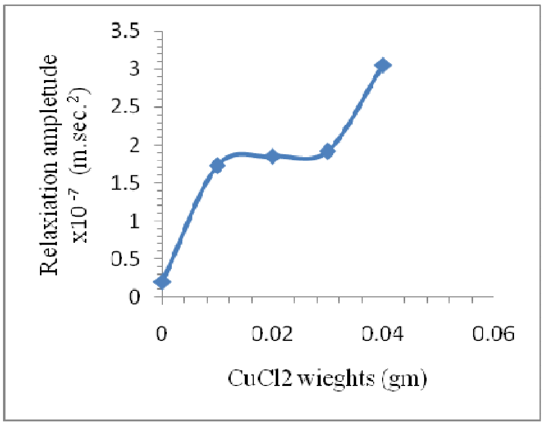
(Fig.7) Compressibility due to concentration



(Fig.8) Transmittance due to concentration



(Fig.9) Absorption coefficient due to concentration



(Fig.10) Relaxation amplitude due to concentration