

A Study the Effect of ZrO_3 on the Electrical and Mechanical Properties of (PMMA - Cr_2O_3)

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Abstract:

The polymers have many uses in industries. The addition of electrolytes to the polymers are produced a new materials use in many applications. Hence, in this paper study the effect of ZrO_3 on the electrical and mechanical properties of PMMA - Cr_2O_3 with concentrations (1, 5, 10, 15, 20) % gm/ mole at room temperature. ZrO_3 was added to polymer with amount weight of (0, 3, 6, 9, 12) wt% added to the polymer. The mechanical properties were measured by using ultrasound technique with frequency (26kHz), show that the relaxation amplitude, relaxation time, velocity, as well as bulk modulus of polymer are increasing with the increment of ZrO_3 weight percentages. The compressibility of PMMA - Cr_2O_3 decreases with the increment of ZrO_3 weight percentages. The electrical properties measurement of PMMA - Cr_2O_3 show that the electrical conductivity is increased with increment of ZrO_3 weight percentages and both of molar conductivity and degree of dissociation are decreased with increment of ZrO_3 weight percentages.

1. Introduction

The poly methyl methacrylate (PMMA) is very suitable as a polymer matrix for its excellent electrical and mechanical properties, simple synthesis and low cost. So the PMMA composite material was made by bulk polymerization **(M. Singla, 2009).** PMMA manufacturing is of great importance because the commercialization prospects for various syntheses that have been successfully accomplished under laboratory conditions typically depend on whether these syntheses can be scaled up to large apparatus. The product yield from the polymerization reaction may strongly depend on physical factors, which can also considerably affect the properties of the resulting polymer in many cases. Chemical kinetics focuses on quantitative characteristics of chemical reactions. the study deals with results of the effect of ZrO_3 on the electrical and mechanical properties of PMMA-Cr_2O_3 **(Rafah A. Nassif, 2010)**.

Cr_2O_3 is the main oxide of chromium. It is amphoteric and while it is insoluble in water, it will dissolve in acid. It is found in nature in the form of a rare mineral, eskolaite. It is used as a pigment, producing a dark green color **(Petrucci, Ralph H. 2007)**. In solid form, it is a dark red-orange granular complex. It is used in chrome-plating as a strong oxidizer, however, it is extremely toxic **(Whisnant, David, 2007)**.

The metal dioxide (ZrO_2), was identified as such in 1789 by the German chemist Martin Heinrich Klaproth in the reaction product obtained after heating some gems, and was used for a long time blended with rare earth oxides as pigment for ceramics. Although low-quality zirconia is used as an abrasive in huge quantities, tough, wear resistant, refractory zirconia ceramics are used to manufacture parts operating in aggressive environments, like extrusion dyes, etc. Zirconia blades are used to cut Kevlar, magnetic tapes (because of their reduced wear). High temperature ionic conductivity makes zirconia ceramics suitable as solid electrolytes in fuel cells and in oxygen sensors. Good chemical and dimensional **(C. Piconi, G. Maccauro, 1999)**

2. Theoretical Part

2-1 Mechanical Properties:

The ultra sonic wave's velocity in different media can be calculated from **(Abdul-Kareem J. Rashid, 2011)**

$$V = \sqrt{k/\rho} \qquad (1)$$

Hence k is an elastic modulus, ρ is medium density. Any sudden changing in the system made a new balancing case called relaxation processing, occurred during certain time called relaxation time can be calculated from **(Jabbar Hussein Ibrahim, 2009)** :

$$t = \frac{4\eta_s}{3\rho V^2} \qquad (2)$$

Hence η_s is suspension viscosity, the relaxation amplitude decreased with frequency increment which mean it depend on wave energy calculated from **(Zong fang Wu1 and Dong C. Liu, 2011)**:

$$D = \frac{\alpha}{f^2} \qquad (3)$$

Hence α is absorption coefficient, f is the linear frequency. The specific acoustic impedance can be calculated from:(**Josef and Herbert Krautkramer, 1990)**.

$$z = \rho V \qquad (4)$$

And the compressibility can be calculated from laplas equation :**(Jarth Mc-Hugh, 2008)**.

$$B = (\rho V^2)^{-1} \qquad (5)$$

Finally Bulk modulus is the inverse of the compressibility can be calculated from**: (Boutouyrie P, Briet M, 2009)**

$$k = B^{-1} = \rho V^2 \qquad (6)$$

2.2 Electrical Properties

2.2.1 Electrical Conductivity

The soluble materials particles consist from positive and negative fragments that directed under affect of the electrical field as chains, where the positive part of each particle toward cathode, while the negative part toward anode. The chemical structure of polymers has limited effecting in ions motions, where the polymers conductivity increased with the temperature increment as follows (**M. Serin,2003)**

$$X = Ae^{-\Delta u/RT} \qquad (7)$$

Where (A) is constant depends on $(A\alpha\frac{1}{T})$, (R) gas constant, (Δu) is internal energy. The conductivity basically depends on unbounded free ions with macroscopic molecules that did not participate in conductivity **(Al-Bermany,1995).**

2.2.2 Molar Conductivity

The molar conductivity can define as the ratio between the soluble conductivity to the molar soluble concentration (M. Admon, 1992) as follows

$$\Lambda = \frac{X}{C_m} \qquad (8)$$

2.2.3 Disintegration Degree

The soluble molecules of salts, acids, and basicity in water disintigrate to ions and the water interact with ions in unstable compounds **(A. Ashour, 2000)** as follows:

$$D.D = \Lambda / \Lambda_0 \qquad (9)$$

Where (Λ_0) is infinite molar conductivity in diluting, D.D can calculated by drawing the relationship between the square root of concentration $(\sqrt{C})$ and molar conductivity (Λ)

3. Experimental Work

The materials used in the research are PMMA - Cr_2O_3 with concentrations (1, 5, 10, 15, 20) % gm/ mole at room temperature as a matrix. Then ZrO_3 was added to polymer with amount weight of (0, 3, 6, 9, 12) wt% added to the matrix as a filler. The electrical properties mesurement have been taken by using digital device (alpha 800) made by (coortelond. Ltd. inpover English) contains two probes one of them for temperature measuring and other to measure electrical conductivity, at frequency (20 kHz). While the mechanical properties Were measured speed of ultrasound scattered through liquids using a technology pulse, consisting of a device manufactured by a company (PHYWE) German works VDC (220 V) and generates waves of ultrasound frequency constant (26kH),

4. Results and Discussion

Figure (1) shows electrical conductivity increasing of matrix (PMMA - Cr_2O_3) with concentration increment because of the increasing of ionization degree changing, where the focusing of electric field makes a charges rarefaction in polymer molecules (incongruous), which means appearing induced dipoles able to electrical conduction, the increasing of ions concentration and free electrons, so this makes increasing in electrical conductivity, this the reason of adding ZrO_3 as improver in conductivity to matrix **(S. H. Abood, K. H. Habeb, 2006).**

Figure (2) shows the decreasing in molar conductivity after adding ZrO_3 to the matrix because of electrostatic repulsion which interpret to decreasing in molecular bonding between the matrix and the filler (ZrO_3) which due to slowing ions motion **(Massoumeh F., 2006)**.

Figure (3) shows the decreasing in disintegration degree with concentration increment because of the advance surface area of ZrO_3 molecules adding to the matrix **(Maffezzoli, A. Tazia, 1999)**.

Figure (4) shows the increasing in the ultrasound velocity of the matrix as a resulting from the union of two types of molecules of matrix and ZrO_3, leading to the formation of large molecules (Macromolecular) within the solution polymer compatible ZrO_3, which is working on the transfer of mechanical waves from a source of disorder on the board of beams, which lead to increase speed in contrast to simple liquids or pure **(Khalida H. H.2004)**

Figure (5) shows the increasing in the values of the relaxation time with greater emphasis, by the addition of carbon black, and explains that the increased size of the chains of polymeric lead to increased internal friction among the layers of the liquid resulting from the dislocations and the effect of ultrasound, thus increasing the time required to re-excited molecule to its original **(K. Hassan, N. A. Hassan. 1993)**.

Figure (6) shows the relaxation amplitude which increased with the increasing of matrix concentration and the increase added ZrO_3 is due to the large distance traveled by the molecules during the process of stimulation **(Shaghayegh J. and Hamid M., 2005)**.

Figure (7) shows the decreasing in compressibility with the concentration increment the adding of ZrO_3 to the matrix is working to urge the particles to move from the natural state of balanced to the high energy state, which then become the structural composition of the liquid compressed, and lead the process of rearrangement of molecules adjacent to the building part of the absorption of energy, causing rapid decay of the wave **(Hiroyasu N., Tatsuro M. 2004)**.

Figure (8) shows the increasing of Bulk modulus with increasing the matrix concentration after adding ZrO_3 due to the adoption of the modulus of elasticity on the speed of ultrasound is mainly **(Shaghayegh J. and Hamid M., 2005).**

5. Conclusion

1 – The matrix (PMMA – Cr_2O_3) reinforced by ZrO_3 continuous change in physical properties with increasing concentration.

2 - Knowing the extent to which the synthetic rubber to survive external influences, which work to select the most appropriate concentration utilized in the industrial and engineering applications.

3 - The mixing of the matrix as a phase of reinforcement lead to improve the physical properties of a compound of polymer used in the electronics industries. This back to the reason of additive nature which considered a good strengthen factor and appropriate for the homogeneity of the polymer, which makes it cheap, colorless, odorless and nontoxic.

4 - Increasing in values of the physical properties of PMMA – Cr_2O_3 significantly with different wt. percent ZrO_3 because of the increased of kinetic energy of the ions in solution, in that way increasing the kinetic energy.

6. References

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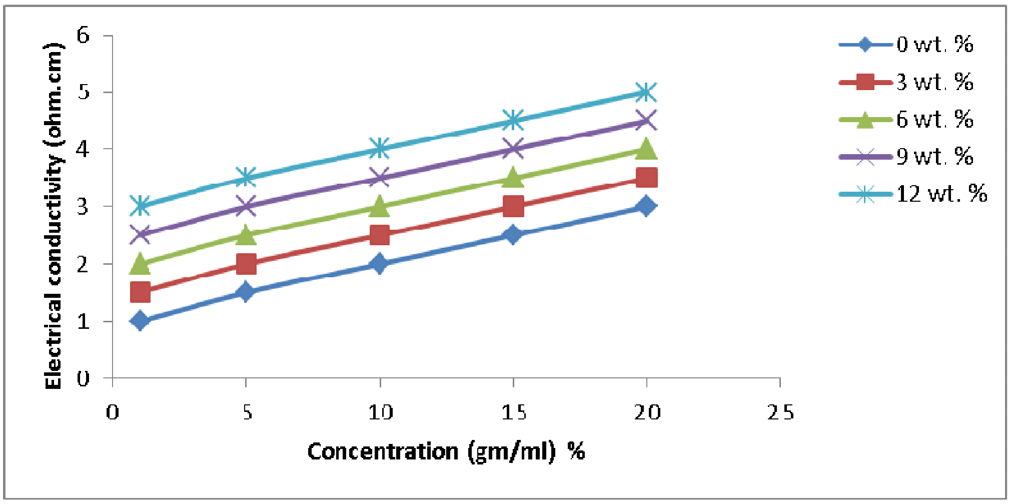

Figure (1) shows the electric conductivity vs. concentration

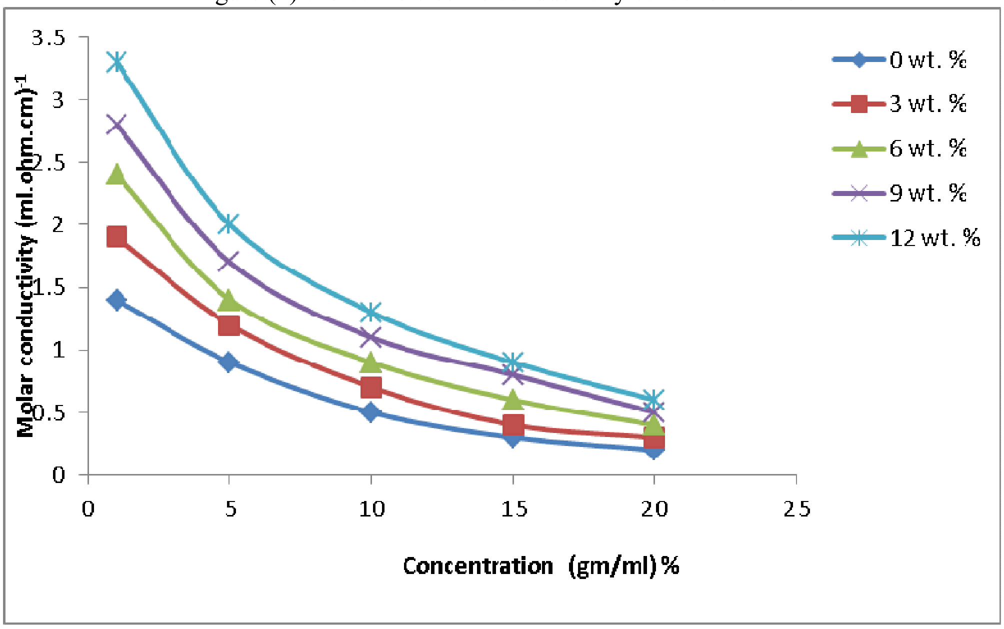

Figure (2) shows the molar conductivity vs. concentration

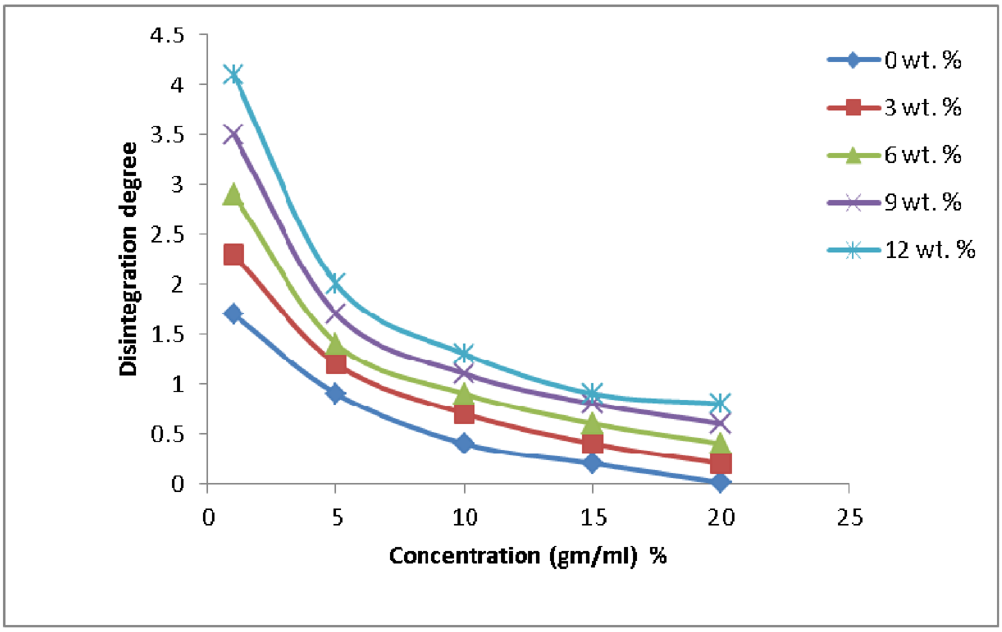

Figure (3) shows the disintegration degree vs. concentration

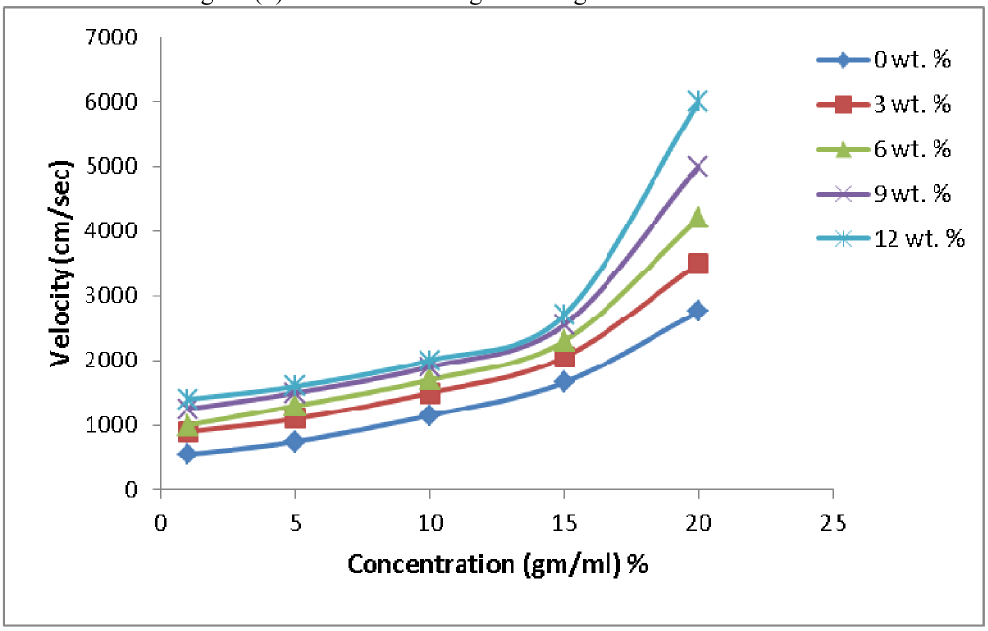

Figure (4) shows the ultra sound velocity vs. concentration

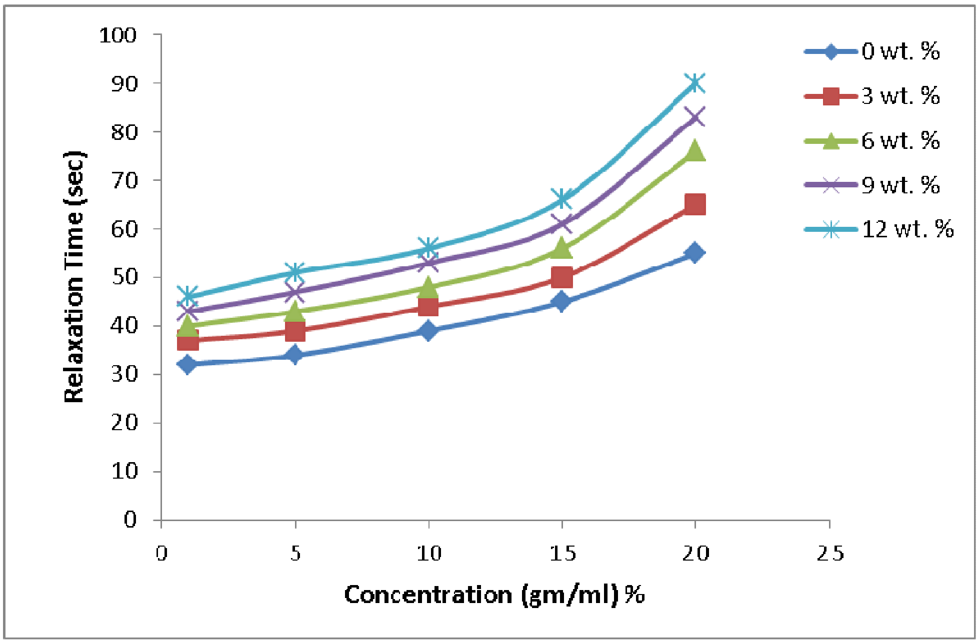

Figure (5) shows the relaxation time vs. concentration

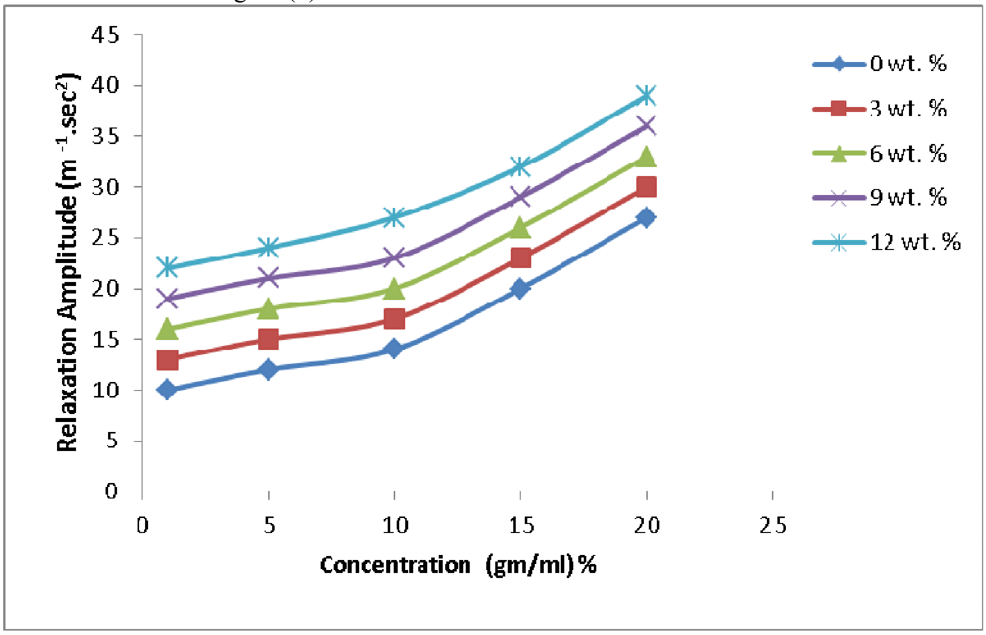

Figure (6) shows the relaxation amplitude vs. concentration

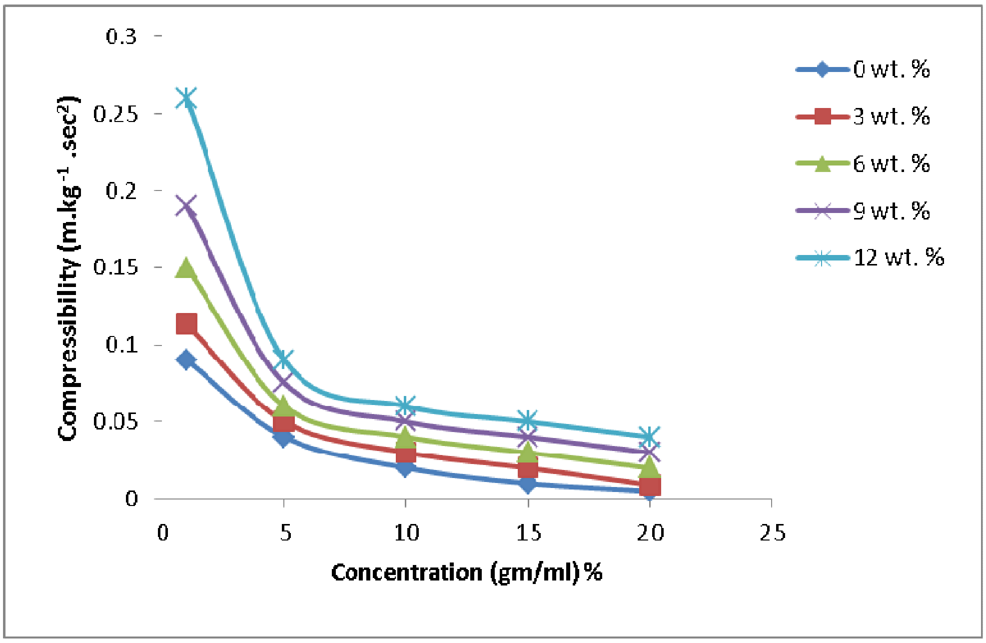

Figure (7) shows the compressibility vs. concentration

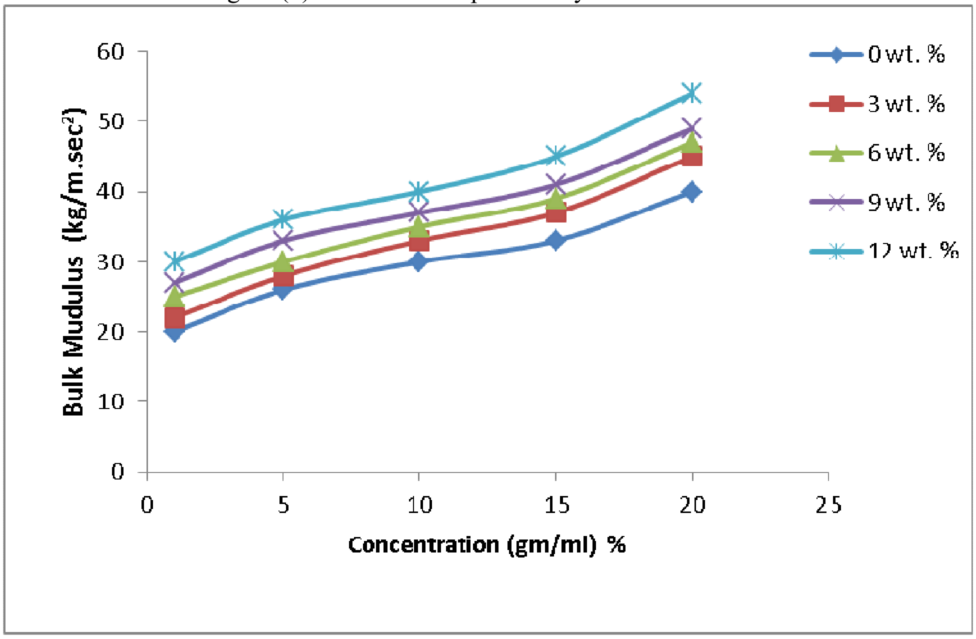

Figure (8) shows the bulk modulus vs. concentration