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Silver NPs Reinforced the Structural and Mechanical Properties of PVA-PAAm-PEG Nanocomposites

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Abstract. Three distinct polymers were used as model polymers in this study: poly (vinyl alcohol) (PVA), polyacrylamide (PAM), and poly (ethylene glycol) (PEG). These polymers were employed to make nanocomposites films utilizing solution and dry casting techniques with varied loading ratios of Silver nanopowders (AgNPs) of (0.1, 0.2, and 0.4 wt. percent). The films were of varying thicknesses (950 nm). The diffusion of NPs among the gaps of polymer mix particles was determined using optical microscopy (OM). The polymers and Silver nanopowders (AgNPs) created an important interfacial contact, as evidenced by Fourier-transform infrared spectra. In nanocomposites, the most functional group of polymer and nanoparticle. Using the ultrasound technique (U/S), the mechanical characteristics of each film were measured and estimated. The velocity of the U/S wave was calculated using the frequency (40 kHz) of the film thickness (950 nm). Except for compressibility, mechanical characteristics improved as the number of Ag NPs increased. Doping with AgNPs had a considerable impact on the U/S coefficients. The resulting blend gels demonstrate these new nanocomposites as potential materials for a wide range of applications, and they were used in medical applications instead of U/S sonar and echo gel.

Keywords: PAAm, Ag, nanopowders, blends, and U/S Properties.

INTRODUCTION

Polyvinyl alcohol (PVA) is one of the foremost polymers that soluble in water and associated with vinyl resin with a structure [CH3CHOH (CH2-CHOH)]n (1,2). PVA has many relative molecular mass ranges in viscosity (3) with several features that make it promising materials most used within the coatings, (2,4) ultrasound absorption, anti-scattering of ultrasound wave in sonar and echo devices, cosmetics, anti-bacterial applications, and other industrial applications (5,6). Polyacrylamide (PAAm) is additionally (WSP), features a wide range of medical and industrial applications such as water treatments, manufacture of paper, recovery of oil, and electrophoresis gels (7,8). The applications are often useful as a result of mechanical properties of vulnerable lastingness of the weak resistance to pressure and deficiency of lengthening (7,9). Moreover, PAAmfeatures a great ability to fool water and produce gel-like distinguishing, which makes an honest filter for forming gel polymer electrolyte (9).

The polymers are investigated with different forms such as the casting, sol-gel, drop-casting and theroticl methods (10–13). PEG or polyethylene oxide (PEO) from the polyether chemical class features major applications in flocculants in water treatment, manufacture of papers, mining, oil recapture, absorbents and electrophoresis gels (1,14,15). Poly (ethylene oxide) (PEO) is a polar semi-crystalline polymer that can be liquid or solid. It has a very

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hydrophilic nature, and its lubricating and water retention capabilities are excellent (16,17). Both organic and aqueous solutions of PEO with high hydration and flexibility are regarded effective solubilizers [1]. Furthermore, PEO does not exhibit toxicity, antigenicity, or immunogenicity (16). PEO's characteristics make it a versatile polymer with a wide range of applications, including polymer electrolyte (16), biomedical (16), pharmaceutical (16), and other uses (18). Other major applications include batteries, cell applications (19), supercapacitor (20), and polymer-drug conjugates (15), as well as PEO being utilized as a billboard polymer. Meanwhile, the most significant disadvantage of PEO is the solid polymer electrolytes' poor ionic conductivity. This is due to the comparatively weak interfacial connection, as well as the mechanical properties of the material (14). The nanoscale filler company might improve the mechanical, thermal, electrical, and magnetic properties of the polymer within the matrix without sacrificing optical clarity (18,21).

In the present work, the (PVA-PAAm-PEG). Ag NCs have been synthesised by casting method with different weight percentages of (Ag) nanoparticles. The structural and optical properties of pure and composite materials are studied. The structural properties include optical microscopy and FTIR study. The structure and molecular interaction of ultrasonic (U/S) waves in pure liquids and their additives (composites or blends) has piqued researchers' interest. The U/S investigations are necessary for understanding the liquid theory of matter. Because the U/S velocity of a polymer reflects its nature, the scientist is worried with reviewing polymer solutions. Nanoparticles are usually added to polymers as a composite to reinforce their qualities, although each nano-type is different depending on the surface treatment and method utilized (22,23).

The EXPERIMENTAL part

The NCs polymer films were contagious by blending of PVA that was equipped by the (DIDACTIC) company with (18000 Dalton Mw and assay purity 99 %), PAAm was equipped by (BDH) with Mw over (5000000 Dalton and purity 99.9%) and PEG from (Reagent World) with (6000 Dalton Mw and purity 99.8%) with varying doping percentages from Ag NPs that was equipped by (Sky Spring Nanomaterials, Inc.) with grain size about (20-30 nm) and assay purity (99.95%) at (60 mL) of distilled water in a glass beaker by a magnetic stirrer. The blending process was continued for (40 min.) to getting on a homogenous mixture at (55 ^{o}C). The Adding weights were (0.1, 0.2, and 0.4)wt.% respectively, as shown in Table (1), then the mixture cast in (5 cm diameter petri dish) leave for a week to drying. By micrometer, the thickness of the sample was measured in the range of about (700-800 nm). The optical microscope, FTIR, and U/S device that used to study the structural and U/S properties respectively. Figure (1) and Table 1 summarized the preparation of samples.

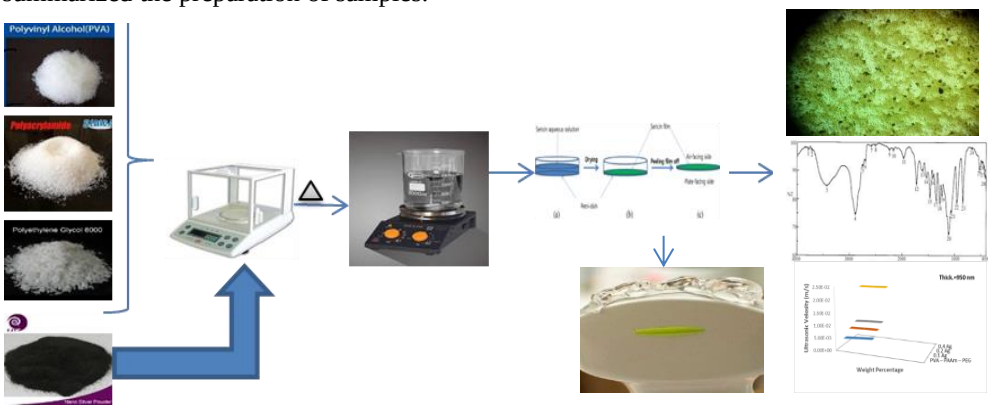

FIGURE 1. Scheme of preparation samples.

TABLE 1. Summarize the preparation PVA-PAAm-PEG and PVA-PAAm-PEG /Ag.

Sample No.	Concentration (wt. %)			
1	**PVA**	**PAAm**	**PEG**	**Ag NPs**
2	0.600	0.200	0.200	0.00
3	0.594	0.198	0.198	0.01
4	0.588	0.196	0.196	0.02
5	0.576	0.192	0.192	0.04

RESULTS AND DISCUSSIONS

Figure (2) represents the optical microscopy (OM) images of (PVA-PAAm-PEG) blends and PVA-PAAm-PEG/ Ag nanocomposites at (100X) magnification. Figure (2-A) shows the polymer blends that had a smooth surface and homogenous dissolving. The (B, C, and D) in the same figure show the fine diffusion and dispersion of Ag NPs within the blend polymers in the nanocomposites. The dispersion of NPs on blend were often clearly appeared good with fine homogeneous within the sample, also no aggregation of nanoparticle presented that is related to the interaction among polymers and Ag NPs, which is the large surface area to the volume ratio. These findings matched the other finding when using the nanofiller to reinforce the polymer (14,24).

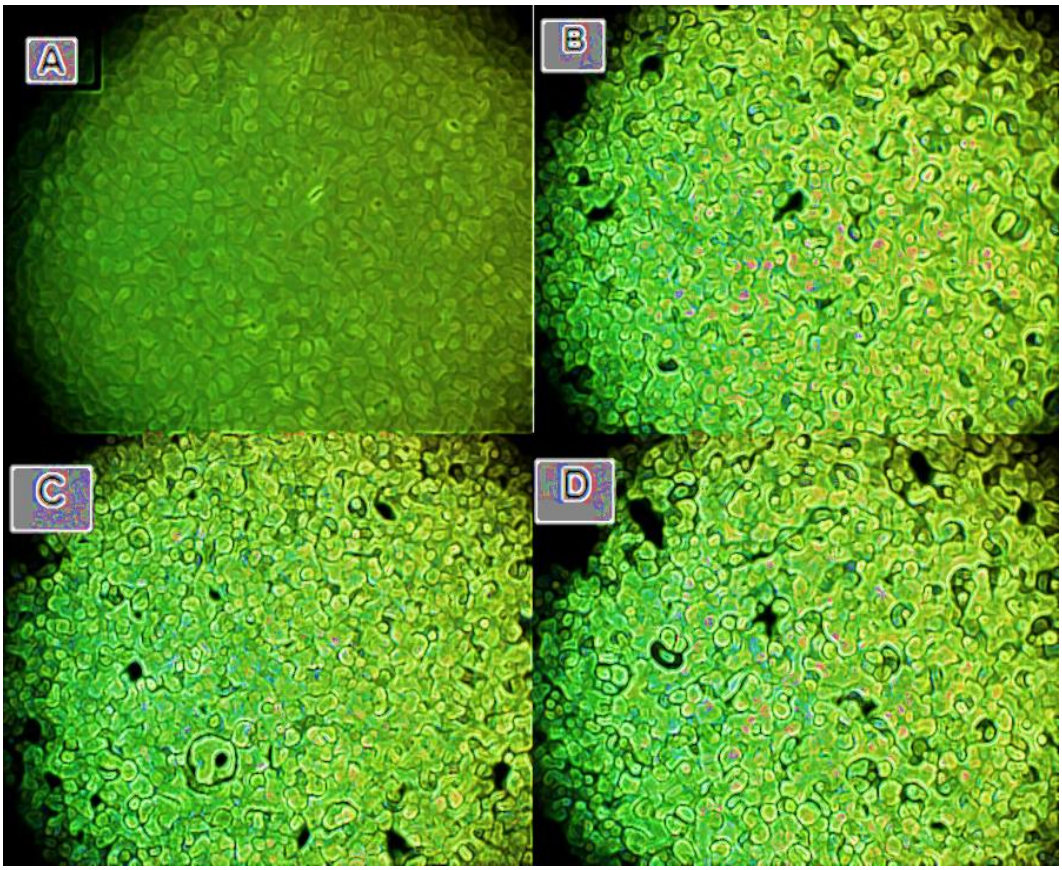

FIGURE 2. Photomicrographs with magnification (100X) of the NCs: A) PVA-PAAm-PEG, B) PVA-PAAm-PEG:0.01wt.% Ag NPs, C) PVA-PAAm-PEG:0.02wt.% Ag NPs, and D) PVA-PAAm-PEG:0.04wt.% Ag NPs nanocomposites.

Figure (3-A) represents the Fourier transform infrared spectrum (FTIR) of pure (PVA-PAAm-PEG). Figure (3-B) shows that (FTIR) of (PVA-PAAm-PEG) with (0.04 wt.%) for Ag NPs within the (1000-4000 cm^{-1}) wave factor optical range. From the Fig., it can be notest the functional groups that appeared for all polymers and nanoparticles. The peak at (3274.27 cm^{-1}) related to alcohol/phenol O-H stretch bond, while (1242.31 cm^{-1}) refer to C-O stretching bond, the aromatic C-H bond appears in (695.68 cm^{-1}), finally, C-O stretching related to primary alcohol appears in the (1085.39 cm^{-1}) wave factor rang. The functional group presented a strong interfacial interaction of polymers and nanoparticles. Additionally, when comparing these two figures, we see that the shifting of wave factor is less than (10 cm^{-1}), which means no chemical interaction happens between the basis and Ag additive.

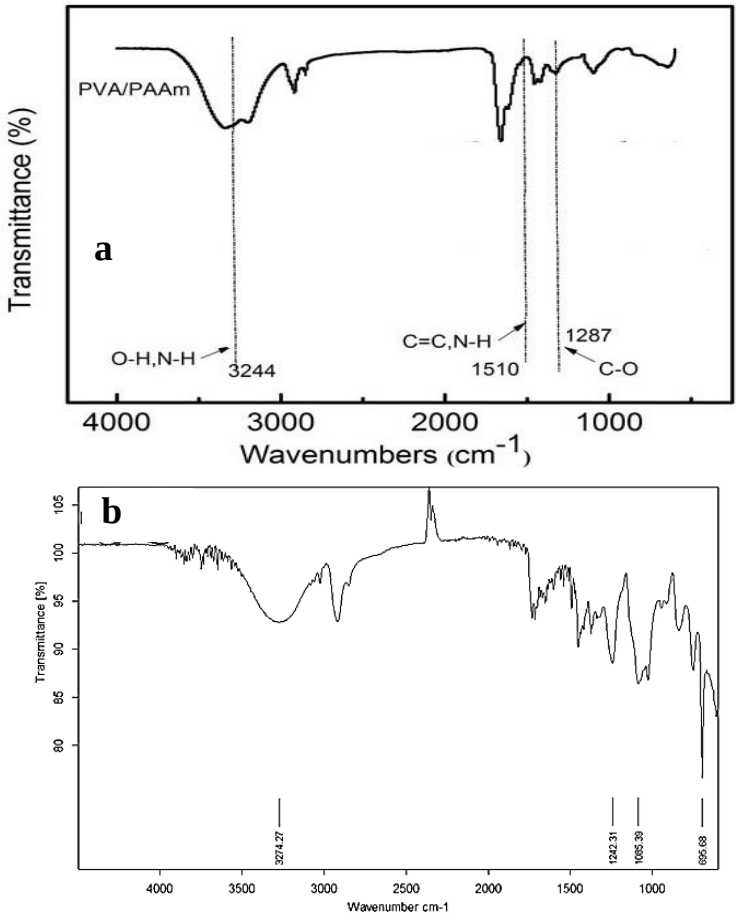

FIGURE 3. FTIR spectrum of (a): Pure (PVA-PAAm-PEG) (25), (b) (PVA-PAAm-PEG):0.04 wt. % Ag NCs.

The (SV-DH-7A/SVX-7) instrument is used to make practical U/S measurements at (41 kHz) frequency. The U/S waves are applied to the sample being tested, which is located between the sender and the receiver. A digital oscilloscope instrument receives U/S pulses, which are converted by the receiver into electrical pulses. The (+Ve) peak in the first channel represents the incident U/S wave or initial amplitude (Ao), and thus the (-Ve) part in the second channel corresponds to the receiver amplitude (A).

The density of composite films and gels was measured at RT. Figure (4) represents the densities of all solutions increased, because of the gels form across linked formulation among the molecules of (PVA-PAAm-PEG) and Ag NPs that occupied the spaces between (PVA-PAAm-PEG) molecules, furthermore, the density increased with increasing of the loading ratio of Ag NPs weight percentage (26).

The transmittance of U/S wave (T) has been computed by (27–29):

$$T = I / Io \quad (1)$$

From Figure (5), it was noticed that the ultrasound wave velocity of (PVA-PAAm-PEG) increased with the increase of Ag NPs weight percentage, and computed by (30,31):

$$V = x / t \quad (2)$$

This behavior is similar to that seen in the composite (PVA-PAAm-PEG) and Ag NPs. When waves propagate, they cause the flow of molecules between vacancies in the lattice during compression and return to their original location during rarefaction, but when the waves propagate, they cause the flow of molecules between vacancies in the lattice to flow between vacancies in the lattice to flow between vacancies in the lattice to flow between vacancies in the lattice to flow between vacancies in the lattice. Because U/S waves promote contact between (PVA-PAAm-PEG) and Ag NPs molecules, the velocity directly correlates with concentration before and after the addition of Ag NPs. This is consistent with the literature (30).

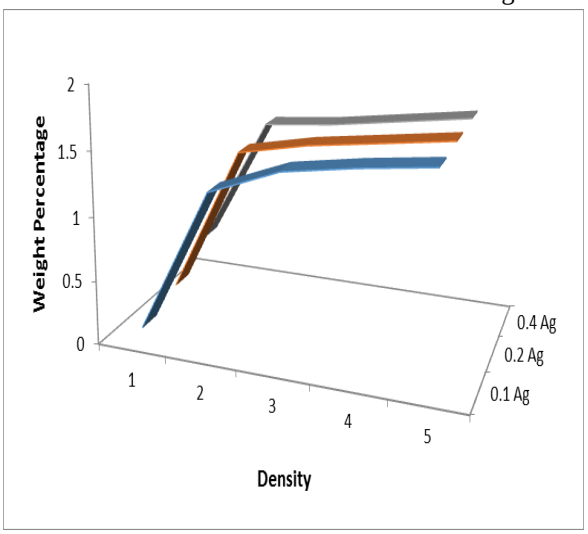

FIGURE 4. The ratio of Ag vs. the density.

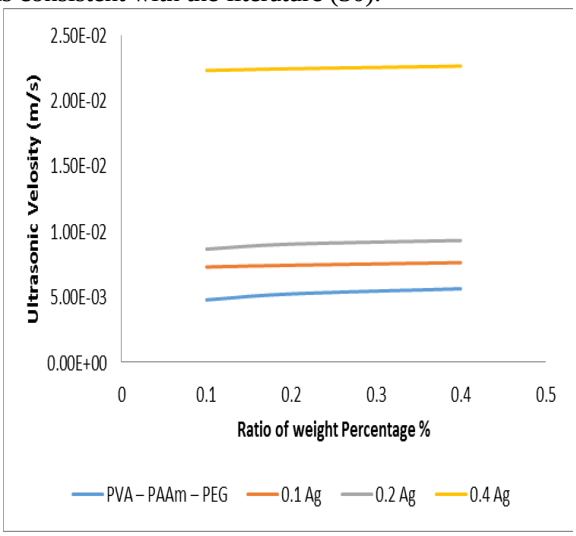

FIGURE 5. Ultrasonic velocity vs. the ratio of Ag.

Figures (6 and 7) show the relaxation time and relaxation amplitude also increased with the increasing of the Ag loading ratio of weight percentage according to theoretical equation (24,32):

$$D = \alpha / f^2 \quad (3)$$

The increasing of (PVA-PAAm-PEG) and Ag NPs chains led to an increase in the fraction between the composition layers that tested by a moment of inertia factor (32). The compressibility of (PVA-PAAm-PEG) and Ag NPs were calculated by Laplacian equation (33,34):

$$\beta = (\rho\, v2)^{-1} \quad (4)$$

Young modulus (K) computed by (31,35):

$$K = \rho\, v^{2} \quad (5)$$

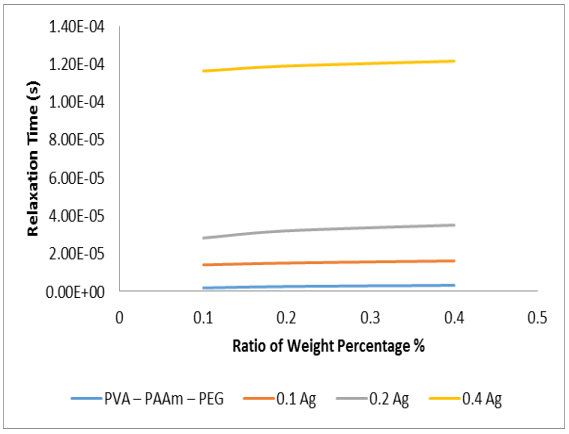

FIGURE 6. Relaxation time vs. the ratio of Ag.

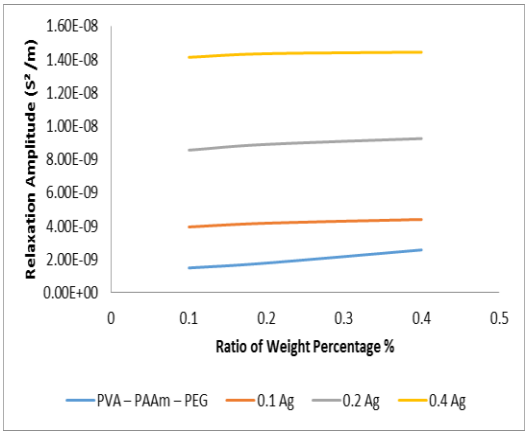

FIGURE 7. Relaxation amplitude vs. the ratio of Ag.

The results in Figure (8) show that as the amount of Ag NPs increased, the compressibility of (PVA-PAAm-PEG) decreased. This was due to the propagation of U/S waves causing a random polymer chain conformation, as well as the U/S wave compression causing a reduction in the elasticity of the composition due to the reinforcement of the Ag NPs (36). Furthermore, the U/S wave's velocity was inversely proportional to its wavelength. The bulk modulus increases as the concentration of Ag NPs rises, as shown in Figure (9). Figure (10) shows the particular acoustic impedance (Z), which increased as the number of Ag NPs increased, according to the theoretical equation (14,37):

$$Z = \rho v \qquad (6)$$

The U/S absorption coefficient computed by the law of Lambert-Beer (36,38):

$$A/A_o = e\,(-\alpha x) \qquad (7)$$

Figure (11) shows the direct influence of reinforcement the Ag led to improve the absorption of the absorption coefficient also that could relate to the U/S absorption coefficient depends on the weight percentage (36,39–41).

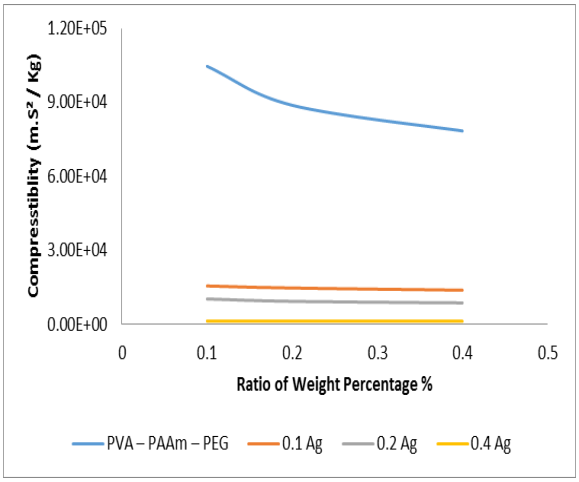

FIGURE 8. Compressibility vs. the ratio of Ag.

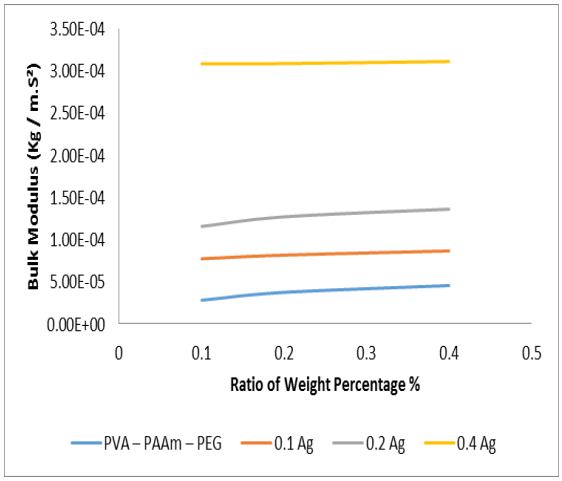

FIGURE 9. Bulk modulus vs. the ratio of Ag.

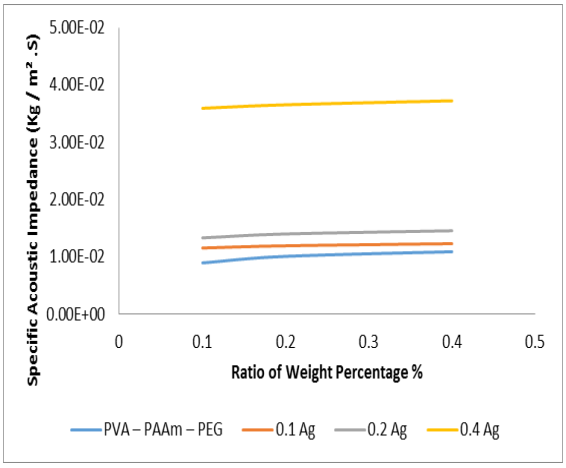

FIGURE 10. SAE vs. the ratio of Ag.

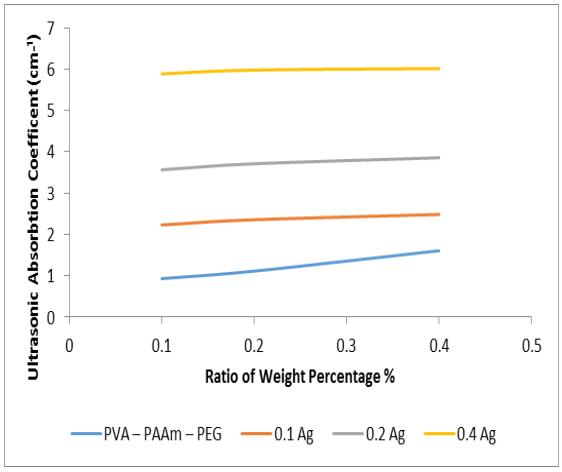

FIGURE 11. U/S absorption coefficient vs. the ratio of Ag.

The results showed that most of the physical properties were affected by the contribution of the loading ratio of Ag weight percentages in the samples. Most of the results were improved in comparison with a sample without Ag. Where the addition of nanosilver increased the density and viscosity additionally to significantly improve the U/S velocity and the ultrasonic absorption coefficient of the polymer-based Ag NPs. Furthermore, Ag NPs led to a decrease in compressive values of the prepared films. The viscosity increased up to 107 %. Moreover, it was found that the best ratio of Ag NPs percentage weight was (0.04 wt. %), which exposed the best mechanical results. The mechanical properties are enhanced by the addition of Ag NPs and this appears in U/S velocity and bulk modulus.

Therefore the Ag NPs presented a notable effect on the samples. These finding much the result of other investigations study the influence of nanoparticles on the polymer properties (14,23,24,31,34,42). The samples was test as U/S sonar and echo gel as a medical application and presented a good appsorption of the ultrasound waves. These samples are promising and lead to exhibit new materials have more tolerable to environmental conditions and can be useful in the external environment, so it can be used in various industrial applications.

CONCLUSIONS

(PVA-PAAm-PEG) blend films were successfully prepared to apply the solution-casting technique to prepare samples with a thickness of (950 nm). The Ag NPs diffuse inside the polymer blend increased presence as an important key role to enhance the mechanical properties in this study. (PVA-PAAm-PEG) blend films were a good medium for absorbing the U/S wave. The blend solutions were succeeded to be an anti- scattering medium instead of sonar and echo gel because of ease of preparation, cheapness, the harm of skin, conduct to electricity, and local production.

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REFERENCES

1. Mark JE. Polymer Data Handbook. 2nd ed. New York, USA: Oxford University Press, Inc; 1999.
2. Kadhim MA, Al-Bermany E. New fabricated PMMA-PVA/graphene oxide nanocomposites: Structure, optical properties and application. Journal of Composite Materials. 2021;(DOI:10.1177/0021998321995912).
3. Alipoori S, Mazinani S, Hamed S, Sharif F. Review of PVA-based gel polymer electrolytes in flexible solid-state supercapacitors : Opportunities and challenges. Journal of Energy Storage. 2020;27(101072):1–23.
4. Wang H, Li M, Zheng Y, Gu T. Function Synergy of Cross-Linked Cationic PVA Polymer to AMPS-Type Fluid Loss Additive Used for Cement-Based Material. International Journal of Polymer Science. 2020;2020(5968318):1–15.
5. Suganthi S, Vignesh S, Kalyana Sundar J, Raj V. Fabrication of PVA polymer films with improved antibacterial activity by fine-tuning via organic acids for food packaging applications. Applied Water Science [Internet]. 2020;10(4):1–11. Available from: https://doi.org/10.1007/s13201-020-1162-y
6. Rashid A-KJ, Jawad ED, Kadem BY. A Study of Some Mechanical Properties of Iraqi Palm Fiber-PVA Composite by Ultrasonic. European Journal of Scientific Research. 2011;61(2):203–9.
7. Mahmudi N, Syla N, Aliaj F. Swelling and Mechanical Properties of Polyacrylamide Based Hydrogels Prepared by Radiation Induced Polymerization. Journal of Engineering and Applied Sciences. 2018;13(17):7205–9.
8. Jawad ED, Khudhair SHSH, Ali HNHN. A thermodynamic study of adsorption of some days on Iraqi Bentoniet modified clay. European Journal of Scientific Research. 2011;60(1):63–70.
9. Chang A, Babhadiashar N, Barrett-catton E, Asuri P. Role of Nanoparticle – Polymer Interactions on the Development of Double-Network Hydrogel Nanocomposites with High Mechanical Strength. Polymer. 2020;12(470):1–9.
10. Guan Y, Wang L, Cui L, Shen X, Gao W, Meng J, et al. Preparation and rheological investigation of tough PAAm hydrogel by adding branched polyethyleneimine. Journal of Applied Polymer Science. 2019;137(14):48541.
11. Kadhim MA, Al-Bermany E. Structural and DC-electrical properties of novel PMMA-PVA nanocomposites reinforced with graphene nanosheets. IOP Conference Series: Materials Science and Engineering PAPER. 2021;1067(012120):1–14.
12. Al-Owaedi OA, Khalil TT, Karim SA, Said MH, Al-Bermany E, Taha DN. The promising barrier: Theoretical investigation. Systematic Reviews in Pharmacy. 2020;11(5):110–5.
13. Al-Khalaf AKH, Abdali K, Mousa AO, Zghair MA. Preparation and structural properties of liquid crystalline materials and its transition metals complexes. Asian Journal of Chemistry. 2019;31(2):393–5.
14. Al-Bermany E, Qais D, Al-Rubaye S. Graphene Effect on the Mechanical Properties of Poly (Ethylene Oxide)/ Graphene Oxide Nanocomposites Using Ultrasound Technique. Journal of Physics: Conference Series. 2019

Jul;1234(012011):1–12.
15. Abdali K, Lamis F, Abdmuslem A, Abdulazeez O, Abdulazeez A. Enhancing Some Physical Properties of Cosmetic Face Powders. Journal of Global Pharma Technology. 2018;10(3):75–8.
16. J. A-K, Ali M, Abdali K. Study the Optical Properties of (PEG-Cellulose Derivatives) Polymer Blends and Prepared New Tire Package. Research and Reviews in Polymer J. 2015;6(2):048–59.
17. Al-Bermany E, Chen B. Preparation and characterisation of poly(ethylene glycol)-adsorbed graphene oxide nanosheets. Polymer International. 2021;70(3):341–51.
18. Abdelamir AI, Al-Bermany E, Hashim FS. Enhance the Optical Properties of the Synthesis PEG/Graphene-Based Nanocomposite films using GO nanosheets. Journal of Physics: Conference Series. 2019 Sep;1294(022029):1–13.
19. Al-zuhairi A, Abdali K. Shear viscosity dependence on concentration of (polyethylene oxide - xanthan) pseudo plasticity polymer collide. Innovaciencia Journal. 2018;6(1):1–7.
20. Abdulridha AR, Al-Bermany E, Hashim FS, Alkhayatt AHO. Synthesis and characterization and pelletization pressure effect on the properties of Bi1.7Pb0.3Sr2W0.2 Ca2Cu3 O10+δ superconductor system. Intermetallics. 2020;127(106967):1–8.
21. Rong MZ, Zhang MQ, Ruan WH. Surface modification of nanoscale fillers for improving properties of polymer nanocomposites : a review. Materials Science and Technology. 2006;22(7):787–96.
22. Khan II, Saeed K, Khan II. Nanoparticles : Properties , applications and toxicities. Arabian Journal of Chemistry [Internet]. 2019;12(7):908–31. Available from: https://doi.org/10.1016/j.arabjc.2017.05.011
23. Abdul M, Al-bermany E. Enhance the Electrical Properties of the Novel Fabricated PMMA-PVA/ Graphene Based Nanocomposites. Journal of Green Engineering. 2020;10(7):3465–83.
24. Al-nesrawya SH, Mohseenb MJ, Al-Bermany E. Reinforcement the Mechanical Properties of (NR50/SBRs50/ OSP) Composites with Oyster Shell Powder and Carbon Black. IOP Conference Series: Materials Science and Engineering. 2020;871(012060):012060, 1–11.
25. Wu Y, Yu C, Xing M, Wang L, Guan G. Surface modification of polyvinyl alcohol (PVA)/ polyacrylamide (PAAm) hydrogels with polydopamine and REDV for improved applicability. Journal of Biomedical Materials Research. 2019;108(1):1–11.
26. Abdali K. Acoustical Properties of (Chitin/nano-TiO2) Bio Polymer Composite Gel. Journal of University of Babylon, Pure and Applied Sciences,. 2017;25(5):1762–6.
27. Li RI, Kolesnikov AA, Kiba MR. Parameters of Ultrasonic Dispersion of Polymer-Composite Solutions. Polymer Science. 2017;10(2):185–8.
28. Al-Bermany A-KJ, Hashim FS, Al-Bermany E. Enhancement the mechanical properties of a product porcelain by a ceramic additives using ultrasonic technique. Chemistry and Materials Research. 2012;2(6):2225–956.
29. Al-Zuhairi AJ, Allw AS, Obaid KA, Rasool SR, Mousa AO. Synthesis of hyperbranched polymers and study of its optical properties. Journal of Engineering and Applied Sciences. 2017;12(Specialissue6):7800–4.
30. Upmanyu A, Singh DP. Ultrasonic Studies of Molecular Interactions in Polymer Solution of the Polyisobutylene (PIB) and Benzene. Acta Acustica united with Acustica. 2014;100:434–9.
31. Abdelamir AI, Al-Bermany E, Hashim FS. Important factors affecting the microstructure and mechanical properties of PEG/GO-based nanographene composites fabricated applying assembly-acoustic method. AIP Conference Proceedings. 2020;2213(020110):020110, 1–13.
32. Khelladi H, Daridon JL, Djelouah H. Measurements under High Pressure of Ultrasonic Wave Velocity in Glycerol. IEEE International Ultrasonics Symposium Proceedings. 2009;nternation:1567–70.
33. Rao DN, Krishnaiah A, Naidu PR. Excess thermodynamic liquid (ethylenediamine aromatic hydrocarbon) properties of. Journal of Chemical Thermodynamics. 1981;13:677–82.
34. Abdullah SS, Abdul M, Al-bermany E. Graphene-Reinforced the Structure and Mechanical Properties of New PMMA-PVA Hybrid Nanocomposites. IOP Conference Series: Materials Science and Engineering PAPER. 2021;1094(012138):1–15.
35. Ravichandran S, Ramanathan K. Ultrasonic Investigations of MnSO4, NiSO4, and CuSO4 in PVA Solution at 303 K. Rasayan journal chemistry. 2010;3(2):375–84.
36. Wu Z, Liu DC, Zongfang Wu and Dong C.Lin, Wu Z, Liu DC. Method of improved scatterer size estimation without attenuation known a priori. IEEE. 2010;8(10):1–4.
37. Nikam PS, Hasan M. Ultrasonic velocity and apparent molar compressibility of trichloroacetic acid in aqueous ethanol. Asian Journal of Chemistry. 1993;5(2):319–321.
38. Hashim R, Hashim FS, Al-bermany E. Enhance the Optical Properties of the Synthesis PS- PMMA blend using ZnO/ Fe2O3 nanoparticles. Test Engineering and Management. 2020;83(March-April):21939–50.

39. Abdali Obaid K, Rasool SR, Jassim Al-Zuhairi A. Mechanical Ultrasonic Properties of (Poly(Methylene Oxide)-TiO 2) Polymer Composite Gel . Journal of Engineering and Applied Sciences. 2019;14(3):6002–5.
40. Al-Abbas SS, Ghazi RA, Al-shammari AK, Aldulaimi NR, Abdulridha AR, Al-Nesrawy SH, et al. Influence of the polymer molecular weights on the electrical properties of Poly(vinyl alcohol) – Poly(ethylene glycols)/Graphene oxide nanocomposites. Materials Today: Proceedings. 2021; (https://doi.org/10.1016/j.matpr.2020.12.565).
41. Karrar Abd Ali Al-Ogaili. Enhancement of Some Physical Properties of Polyethylene Glycol by Adding Some Polymeric Cellulose Derivatives and its Applications. Thesis. University of Babylon; 2015.
42. Al-Bermany E. Polymer/Graphene Oxide Nanocomposites: Surface Adsorption and Interfaces. Doctoral dissertation, University of Sheffield; 2017.