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Structural, Thermal, and Rheological Characteristics of PMMA Polymer Doped with ZnO Nanoparticles

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Abstract

Four samples of Poly (methyl methacrylate) (PMMA)dissolved in acetone, (1gm of PMMA and 100ml of acetone) were prepared. Structural, thermal, and rheological characteristics were studied, and zinc oxide nanoparticles (ZnONPs) with concentrations (0.5,1,1.5) wt% were added to PMMA polymer. Structural characteristics after adding different percentages of ZnONPs to PMMA/acetone are found, and the results showed the appearance of new bonds because interaction of ZnONPs with PMMA/acetone. In thermal characteristics, the thermal conductivity values of PMMA/acetone after adding ZnONPs increase with increasing concentrations of ZnONPs. The thermal resistance values of PMMA /acetone decrease with increasing concentration of ZnONPs. In rheological characteristics, the viscosity measurement of PMMA/acetone after adding ZnONPs increases with increasing amounts of ZnONPs. When measuring the density of the PMMA /acetone and comparing it with the density values when adding ZnONPs, we notice a small increase.

Keywords:

PMMA, ZnONPs, thermal resistivity, thermal conductivity, density, viscosity, FTIR.

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Introduction

Polymers are very useful in the diversity of electronic strategy applications because of their many useful qualities, which contain low cost, and high resistance. PMMA is famous as an acrylic polymer, It is used in the manufacture of plates (Siddaiah et al., 2018). PMMA polymer is used in environmentally stable outdoor fields such as beauty and art because it is a hydrophobic polymer (Daabool & Hussein, 2022; Ali, 2021) Poly (methyl methacrylate) (PMMA) is characterized by its dimensional stability and high resistance to weathering. The light absorption of PMMA polymer is low due to the high transparency in the visible region. It also has a low refractive index and is easy to manufacture. (Raghuram, 2024) (PMMA) abbreviates nucleic acids via ionic interactions (Das et al., 2025). Nanoparticles resist harsh conditions and remain stable in the presence of alkalis or acids. Nanoparticles have poor scratch resistance (Saxena & Menon, 2024). Nanoparticles have good matrix performance, so their structure can be enhanced (Mano et al., 2004; Prasath et al., 2024). Carbonaceous materials are usually considered the most Excellent nanofillers, making an important in the development of the materials (Raghuram, 2024; Swaroop et al., 2016). Metal oxides production a very important role in numerous aspects for example material science (Hegazy & El-Agamy, 2021). Many methods to make NPs for example chemical vapor deposition (Zia & Zomaya, 2011). ZnONPs has found extensive spread interest because of its many properties. For example. It has excellent thermal stability (Hegazy & El-Agamy, 2021). ZnONPs are used in numerous applications for example solar cells (Hegazy & El-Agamy, 2021). ZnO nanoparticles have a propensity to agglomerate, which leads to prevention the of antibacterial activities (Jeyaraj et al., 2024).

Experimental work

Materials

Poly (methyl methacrylate) (PMMA), Acetone solvent is a purity equal to 99.5%, a colorless solvent, nano ZnO with purity equal to 99.8%, shape spherical and diameter in the range (20-30) nm.

Preparation of PMMA/acetone and addition of ZnONPs

PMMA / acetone was prepared via the addition of 1g PMMA powder in 100 ml acetone solvent, also mixing PMMA/acetone via using a stirrer device for 30 minutes at $25C^{\circ}$, As shown in the equations below (1-2) (Al-rammahi & Alshimaysawe, 2025; Ali Hasan et al., 2024).

$$C_x = \frac{n_x}{v} \quad (1)$$

$$n_x = \frac{m}{Mw} \quad (2)$$

Where C_x: explains concentration measured in (mol/L),n_x :explains the number of mole:s, v explains the volume of solvent measured in (litter), m: explains the mass of PMMA measured in (g), and Mw: explains the molecular weight measured in (g/L), Then adding(0.5,1,1.5) Wt% ZnONPs with using a stirrer device during 1h at$25C^{\circ}$.

Results and discussion

Structural characteristics

FTIR examination for the purpose of determining the chemical composition of materials by measuring their absorption of infrared radiation, the range of wave number (450 to 4050)cm^{-1}, and the broad peak of PMMA/acetone equal to 3417.86cm^{-1}(Skoog et al., 2012). After adding different percentages of ZnONPs to PMMA/acetone, the results showed the appearance of new bonds because interaction of ZnONPs with PMMA/acetone (Attia & Abd El-kader, 2013). This spectroscopy Shows the formation of numerous new bonds (Kadim et al., 2024). Figure (1) Explains the effect of adding ZnONPs on FTIR examination of PMMA/acetone.

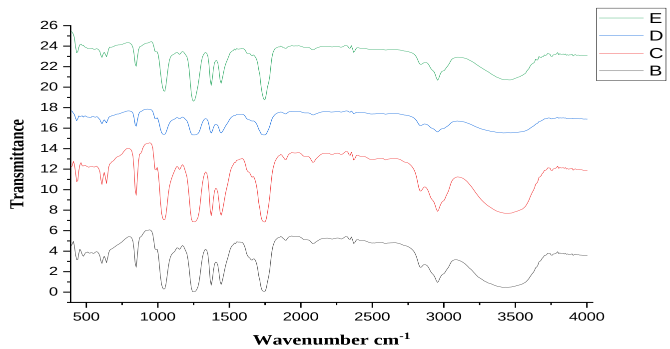

Figure 1. The effect of adding ZnONPs on FTIR examination of PMMA/acetone

In Figure 1 (B) Explains the transmittance and wavenumber at PMMA/ZnONPs 0wt%, (C) Explains the transmittance and wavenumber at PMMA/ZnONPs0.5wt%, (D) Explains the transmittance and wavenumber at PMMA/ZnONPs1wt% and (E) Explains the transmittance and wavenumber atPMMA/ZnONPs 1.5wt%.

Thermal properties

The thermal conductivity and Thermal resistivity values are prepared as shown in Table (1), The thermal conductivity values of PMMA /acetone after adding ZnONPs increase with increasing concentrations of ZnONPs (Turko et al., 2016; Farhan et al., 2017) Figure (2) Explains the effect of adding ZnONPs on thermal conductivity of PMMA/acetone. The thermal resistance values of PMMA /acetone decrease with increasing concentration of ZnONPs (Turko et al., 2016; Abraham et al., 2016; Ruan et al., 2024). Figure (3) Explains the effect of adding ZnONPs on the thermal resistance of PMMA/acetone.

Table 1. The relationship between concentrations of ZnONPs and the thermal conductivity and Thermal resistivity values.

Concentration of ZnONPs	**Thermal conductivity (K$\frac{W}{m.k}$)) of PMMA/acetone**	**Thermal resistivity (ρ)($\frac{C^{\circ}.cm}{W}$)of PMMA/acetone**
0.0wt%	0.482	207.5
0.5wt	0.901	138.7
1wt	1.02	111.0
1.5wt	1.097	91.17

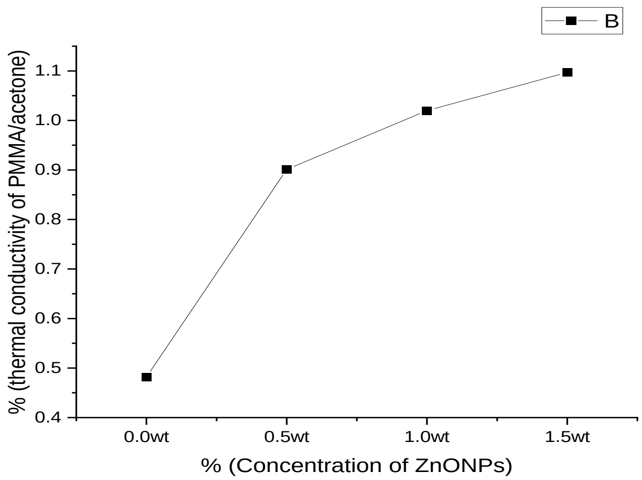

Figure 2. The effect of adding ZnONPs on the thermal conductivity of PMMA/acetone

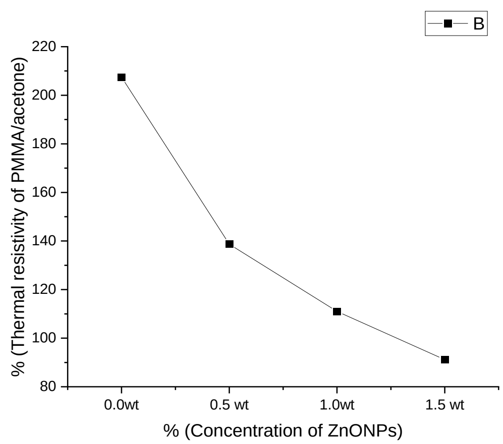

Figure 3. The effect of adding ZnONPs on the thermal resistance of PMMA/acetone

The rheological properties

The viscosity and the density values are prepared as shown in Table (2), The viscosity values of PMMA polymer after adding ZnO NPs increase with increasing concentrations of ZnO NPs (Demir et al., 2006). Figure (4) Explains The effect of adding ZnONPs on the viscosity of PMMA/acetone. When measuring the density of the PMMA polymer and comparing it with the density values when adding ZnONPs, we notice a small increase (Rudolf et al., 2020; Dizon et al., 2018). Figure (5) Explains the effect of adding ZnONPs on the density of PMMA/acetone.

Table 2. The relationship between concentrations of ZnONPs and viscosity and the density values.

Concentration of ZnONPs	**Viscosity (CP) (of PMMA/acetone**	**Density (g/cm^3) of PMMA/acetone**
0.0wt%	18.1	0.858
0.5wt%	22.9	0.872
1wt%	24	0.896
1.5wt%	25.2	0.897

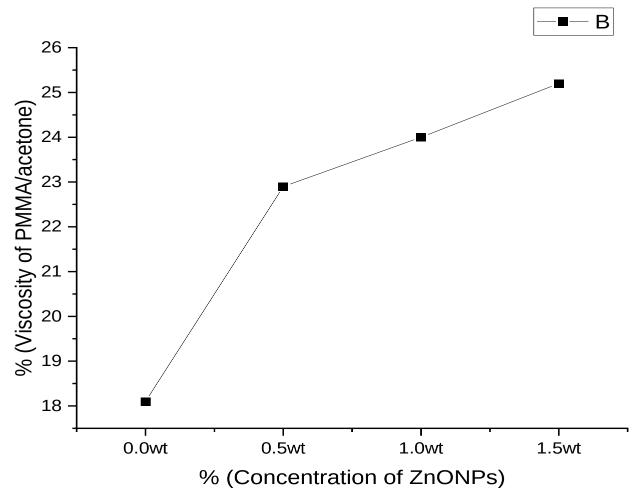

Figure 4. The effect of adding ZnONPs on the viscosity of PMMA/acetone

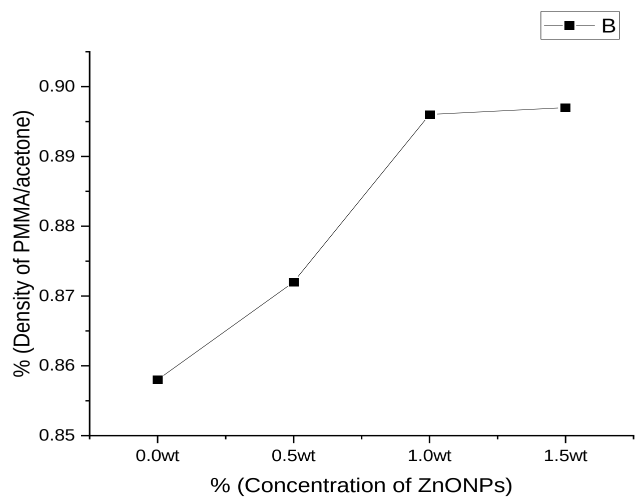

Figure 5. The effect of adding ZnONPs on the density of PMMA/acetone

Conclusion

FTIR examination showed that adding ZnONPs to PMMA polymer causes the appearance of new bonds, indicating the presence of an interaction between PMMA polymer and ZnONPs, The thermal conductivity values of PMMA polymer solution after adding ZnONPs increase with increasing concentrations of ZnONPs. The thermal resistance values of PMMA polymer solution decrease with increasing concentration of ZnONPs. The viscosity measurement of PMMA / acetone after adding ZnONPs Increases with increasing amounts of ZnONPs. When measuring the density of the PMMA polymer solution and comparing it with the density values when adding ZnONPs, we notice a small increase.

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Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

References

Abraham, A., Soloman, P. A., & Rejini, V. O. (2016). Preparation of chitosan-polyvinyl alcohol blends and studies on thermal and mechanical properties. *Procedia Technology*, *24*, 741-748. https://doi.org/10.1016/j.protcy.2016.05.206

Ali Hasan, H. M., Mjali, H. H., & Owaiz, M. H. (2024). Effect of Zinc Oxide Nanoparticles and Structural Properties of PVA/PMMA Composite Films. *Journal of Kufa-Physics*, *16*(2). 10.31257/2018/JKP/2024/v16.i02.16787

Ali, N. A. (2021). Zinc oxide on Polymethyl Methacrylate prepared by Pulsed Laser Deposition in Artistic and Aesthetic application. *Egyptian Journal of Chemistry*, *64*(9), 4791-4795. https://doi.org/10.21608/ejchem.2021.49047.3003

Al-rammahi, G. G., & Alshimaysawe, U. A. (2025). Diagnosis and Pathogenesis of Fungi F. Oxysporum and R. Solani Associated with Tomato Seed Rot and Seedlings Death in Najaf. *Natural and Engineering Sciences*, *10*(1), 176-187.

Attia, G., & Abd El-kader, M. F. H. (2013). Structural, optical and thermal characterization of PVA/2HEC polyblend films. *International Journal of Electrochemical Science*, *8*(4), 5672-5687. https://doi.org/10.1016/S1452-3981(23)14714-6

Daabool, F. S., & Hussein, F. H. (2022). Synthesis; characterization and photocatalytic activity studying of TiO_2. *International Academic Journal of Science and Engineering,* *9*(1), 18–25. https://doi.org/10.9756/IAJSE/V9I1/IAJSE0903

Das, A., Ghosh, S., Bisal, P., & Pramanik, N. (2025). Doxorubicin (DOX) modified zinc oxide (ZnO) nanocomposite encapsulated with polymethyl methacrylate (PMMA) biopolymer for effective cancer treatment. *Results in Surfaces and Interfaces*, *18*, 100389. https://doi.org/10.1016/j.rsurfi.2024.100389

Demir, M. M., Memesa, M., Castignolles, P., & Wegner, G. (2006). PMMA/zinc oxide nanocomposites prepared by in-situ bulk polymerization. *Macromolecular Rapid Communications*, *27*(10), 763-770. https://doi.org/10.1002/marc.200500870

Dizon, J. R. C., Espera Jr, A. H., Chen, Q., & Advincula, R. C. (2018). Mechanical characterization of 3D-printed polymers. *Additive manufacturing*, *20*, 44-67. https://doi.org/10.1016/j.addma.2017.12.002

Farhan, F. K., Al-Ramadhan, Z., & Abd-Al Hussein, W. A. (2017). Thermal Properties of UPE-PMMA Blend Reinforced by ZnO Nanoparticles. *European Journal of Engineering and Technology Research*, *2*(7), 45-47.

Hegazy, M. A., & El-Agamy, H. H. (2021). ICMMS-2: Synthesis and Characterization of ZnO Nanoparticles in Presence of Triethanolamine (TEA) as Surfactant Via Sol-Gel. *Egyptian Journal of Chemistry*, *64*(3), 1207-1212. https://doi.org/10.21608/ejchem.2021.55874.3189

Jeyaraj, A., Sakthivel, P., Saravanakumar, K., Arivalagan, A. R., Karthik, V., & Thirumurugan, A. (2024). Thermal and rheological behavior of aluminium-doped zinc oxide nanofluids: Experimental study and application of artificial neural network model. *Hybrid Advances*, *7*, 100329. https://doi.org/10.1016/j.hybadv.2024.100329

Kadim, A. M., Abass, K. H., Abdali, K., & Musa, S. J. (2024). Effect of loading corn starch nanoparticles on the morphological, optical, and dielectric behaviors of PVA/PMMA/PAAm polymer blend for optoelectronic and antibacterial applications. *Nano Biomed Eng*, *16*(1), 119-127. https://doi.org/10.26599/NBE.2024.9290049

Mano, V., Ribeiro E Silva, M. E. S., Barbani, N., & Giusti, P. (2004). Binary blends based on poly (N-isopropylacrylamide): Miscibility studies with PVA, PVP, and PAA. *Journal of applied polymer science*, *92*(2), 743-748. https://doi.org/10.1002/app.20027

Prasath, M., Sampath, P. S., Saravanan, C., Gokul, R., & Prakash, J. H. (2024). Experimental Study on Optimizing the Fused Deposition Modeling PARAMETERS for Polyethylene Terephthalate Glycol Material Using Taguchi Method. *Archives for Technical Sciences/Arhiv za Tehnicke Nauke*, (31). https://doi.org/10.70102/afts.2024.1631.025

Raghuram, G. (2024). Synthesis and Characterization of Novel Nanoparticles for Targeted Cancer Therapy. *Clinical Journal for Medicine, Health and Pharmacy*, *2*(4), 21-30.

Ruan, S., Zhao, Y., Chen, R., Ma, J., Guan, Y., Ma, J., & Ren, L. (2024). Effect of zinc oxide/graphene oxide nanocomposites on the cytotoxicity, antibacterial and mechanical properties of polymethyl methacrylate. *BMC Oral Health*, *24*(1), 1013. https://doi.org/10.1186/s12903-024-04754-0

Rudolf, R., Popović, D., Tomić, S., Bobovnik, R., Lazić, V., Majerič, P., ... & Čolić, M. (2020). Microstructure characterisation and identification of the mechanical and functional properties of a new PMMA-ZnO composite. *Materials*, *13*(12), 2717. https://doi.org/10.3390/ma13122717

Saxena, A., & Menon, K. (2024). Recent Patterns in the Usage of Nanomaterials and Nanofiltration Models for Pollutant Removal in Wastewater Treatment. *Engineering Perspectives in Filtration and Separation*, 14-20.

Siddaiah, T., Ojha, P., Kumar, N. O. G. V. R., & Ramu, C. (2018). Structural, optical and thermal characterizations of PVA/MAA: EA polyblend films. *Materials Research*, *21*(5), e20170987. https://doi.org/10.1590/1980-5373-MR-2017-0987

Skoog, D., West, J., Crouch, S., & Holler, C. (2012). Fundamentals of analytical chemistry, *United States, Wadsworth Publishing Co.*

Swaroop, K., Francis, S., Somashekarappa, HM. (2016). Gamma irradiation synthesis of Ag/PVA hydrogels and its antibacterial activity Materials today: Proceedings. 3(6):1792-1798. https://doi.org/10.1016/j.matpr.2016.04.076

Turko, B. I., Kapustianyk, V. B., Rudyk, V. P., & Rudyk, Y. V. (2016). Thermal conductivity of zinc oxide micro-and nanocomposites.

Zia, T. A., & Zomaya, A.Y. (2011). A Lightweight Security Framework for Wireless Sensor Networks. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *2*(3), 53-73.