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Examining the Structural Characteristics and Antibacterial Efficiency of MgO pure Nanoparticles

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ABSTRACT

This work examines the structural and antibacterial characteristics of sol-gel-synthesized pure magnesium oxide (MgO) nanoparticles for medicinal applications. A bandgap of 4.95 eV was found in UV-Vis and fluorescence spectroscopy of optical characteristics, including fluorescence absorption. XRD investigation validated the cubic crystal structure of MgO nanoparticles with a 13-nm crystallite size. Nanoparticles were biocompatible with human peripheral blood mononuclear cells and showed no cytotoxicity. Agar diffusion was used to test antibacterial activity against Gram-negative bacterium Escherichia coli (E. coli). A 13-mm zone of inhibition showed great antibacterial activity. MgO nanoparticles have antibacterial activity, making them a promising biomedical and antibacterial candidate. This study also reveals how nanoparticle size and surface area determine antibacterial activity, suggesting they might combat bacterial infections despite antimicrobial resistance.

Keywords: Medical applications, NPs, E. coli, zone of inhibition, antibacterial activity

INTRODUCTION

Antibiotic-resistant bacteria imperil global health, requiring innovative bacterial infection therapies. Nanotechnology, especially nanomaterials, may solve this. The large surface area to volume ratio and higher reactivity of nanoparticles make them effective against germs. Due to their capacity to destroy bacterial cell walls and produce ROS, magnesium oxide (MgO) nanoparticles are of interest.

Biocompatible, non-toxic, and eco-friendly MgO nanoparticles are suitable for wound healing and medicine administration. Many investigations have demonstrated MgO nanoparticles destroy Gram-positive and Gram-negative bacteria. Researchers have explored doping or enhancing manufacturing techniques to increase antibacterial efficacy and usage. Sol-gel-synthesised pure MgO nanoparticles are examined for structural and antibacterial characteristics. The sol-gel technique regulates nanoparticle size and form and is inexpensive. In this work, MgO nanoparticles' bandgap, fluorescence, and antibacterial activity against E. coli, a commonly studied Gram-negative bacterium, are evaluated. This study links the structural properties and antibacterial activity of MgO nanoparticles, suggesting their relevance in treating bacterial infections.

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METERIALS AND METHODS

SYNTHESIS OF MgO NPs

Synthesis of sol-gel MgO NPs. Analytical-grade reagents, such as $MgCl_2•6H_2O$ and $C_6H_8O_7$, were acquired from Sigma-Aldrich and utilized without purification. Citric acid was added to a 100 mL solution of $MgCl_2•6H_2O$ in distilled water as a chelating agent. Heat to 80 °C removed superfluous water from the mixture. The solution formed a thick gel with magnetic stirring. After drying at 120 °C to eliminate moisture, the gel was calcined at 500 °C for 3 hours to yield pure MgO nanoparticles. Sol-gel-synthesised MgO nanoparticles have good dispersion and crystalline shapes, making them promising candidates for antibacterial and medicinal applications.

As shown in Fig. 1, the synthesis method requires dissolving $MgCl_2$ and citric acid in distilled water, then heating to 80°C to eliminate moisture. After stirring to create a gel, the mixture is dried at 120°C and calcined at 500°C to produce magnesium oxide nanoparticles.

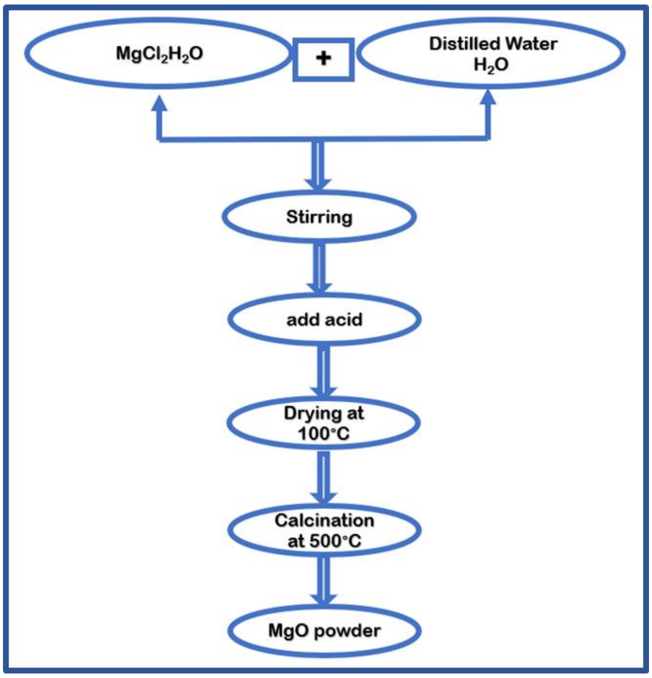

Fig. 1. MgO NPs preparation

CHARACTERIZATION

X-ray diffraction (XRD) confirmed the crystal structure and estimated particle size, UV-Vis and fluorescence spectroscopy examined optical properties, and agar diffusion assessed antibacterial activity of the synthesized nanoparticles. To determine biocompatibility for biomedical applications, human peripheral blood mononuclear cells were tested for nanoparticle cytotoxicity. The antibacterial capabilities were evaluated against Gram-negative bacterium Escherichia coli (E. coli), which causes illnesse.

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RESULTS AND DISCUSSION

XRD PATTERN OF MgO NANOPARTICLES

XRD measurement revealed MgO nanoparticles' crystalline structure. Pure MgO nanoparticles' XRD pattern showed face-centered cubic (FCC) structural peaks. The cubic phase of MgO is shown by the diffraction peaks at 37.007°, 42.857°, 68.307°, 74.457°, and 78.557°, which correspond to the (111), (200), (220), (311), and (222) crystal planes. The diffraction pattern showed significant nanoparticle crystallinity.

From the peak in the (200) plane, Scherrer's equation estimated the nanoparticles' average crystallite size. The computed crystallite size was 13 nm, showing nanoparticles are nanoscale, which supports their improved antibacterial activities. Sharp and well-defined XRD peaks indicated extremely crystalline nanoparticles.

The large surface area and reactivity of MgO nanoparticles allow them to interact with bacterial cells, increasing their antibacterial efficacy. XRD examination validated the fabrication of pure MgO nanoparticles with a well-defined crystalline structure, making them appropriate for antibacterial and biological applications (see Fig. 2).

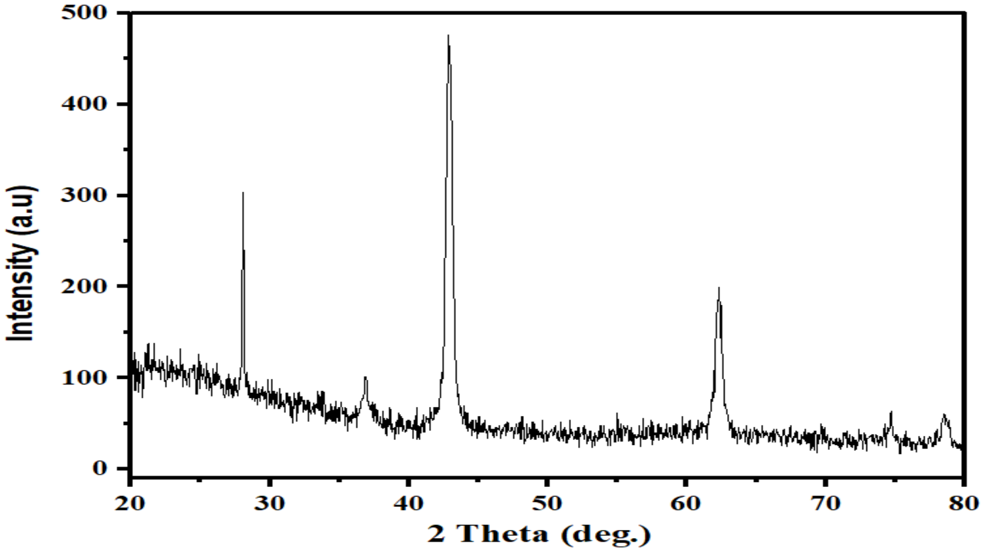

Fig. 2. MgO XRD diffractograms

Scherer's approach in Eq. 1 determined the average size of pure and doped nanoparticles from the (200) XRD peak [15].

$$D_{SC}=\frac{0,9*\lambda}{\beta*cos\theta} \quad (1)$$

where particle size (Dave), full width at half maximum (FWHM), Bragg angle of (200) peak (θ), and wavelength (λ) are the factors. Table 1 shows that MgO averages 18 nm and MgO averages 13 nm.

Table 1. MgO XRD parameters

2Theata	FWHM	hkl	d-Spacing (A)	Crystallite size (nm)
42.9113	0.53460	200	2.10591	13.8304

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Antibacterial activity of MgO nanoparticles depends on their structure. MgO nanoparticles interact well with bacteria due to their high surface area to volume ratio. varied synthesis methods produce varied MgO nanoparticle morphologies and efficiency. Spherical, rod-shaped, or flower-like MgO nanoparticles are typical. Their antibacterial efficacy depends on particle size. Researchers found that smaller particle sizes had more surface area and reactivity, making them more antimicrobial.

OPTICAL PROPERTIES

UV-Vis spectroscopy was used to evaluate magnesium oxide (MgO) nanoparticle absorption throughout 190–1100 nm. This spectral range helps observe UV and visible areas, revealing materials' electronic transitions and optical properties.

MgO nanoparticles' UV-Vis absorption spectra showed different absorption peaks, usually in the UV region, due to electronic transitions from the valence band to the conduction band. The broad bandgap of MgO, roughly 4.95 eV for bulk MgO, explains its UV absorption, especially below 400 nm. However, particle size, morphology, and surface flaws may affect nanoparticle absorption, which may change the bandgap somewhat compared to bulk material.

Quantum size effects affect UV absorption spectra, which alter somewhat depending on MgO nanoparticle size. Due to the higher bandgap energy caused by smaller particles, the absorption edge typically shifts blue.

UV-Vis spectra may also be used to compute nanoparticle optical bandgap (E_g) using the Tauc plot approach, which assumes a straight transition model. This data is useful for photocatalysis, sensors, and antimicrobial coatings, where optical characteristics are crucial to performance.

Fig. 3 shows MgO nanostructures with energy band gaps (E_g) calculated using mathematical formulae (2). Equations are underneath:

$$(\alpha h\nu) = B\,(h\nu - Eg)^2 \qquad (2)$$

For Eq. 2, Eg represents the optical bandgap, hv represents photon energy, B is an invariable, and α measures absorption.

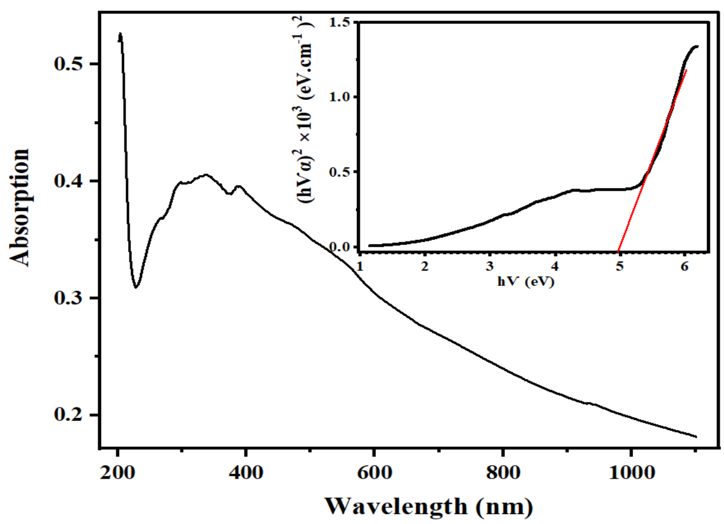

Fig. 3. MgO pure NPs absorption curve and $(\alpha h\nu)^2$ versus (hν)

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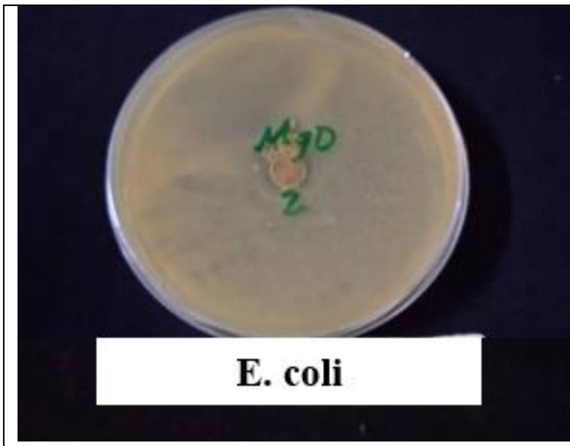
ANTIBACTERIAL PERFORMANCE

Agar diffusion was used to test the produced MgO nanoparticles' antibacterial activity. E. coli, a Gram-negative bacteria, was selected for this investigation because of its role in healthcare-associated illnesses. E. coli was put onto agar plates and MgO nanoparticles were added. For nanoparticle antibacterial effectiveness, the zone of inhibition (ZOI) width was assessed after 24 hours at 37°C. A ZOI of 13 mm surrounding nanoparticle-loaded wells indicated considerable antibacterial action.

MgO NPs attacking bacterial cells generate reactive oxygen species (ROS) when they interact with cell membranes. Microorganisms die when ROS destroy proteins, lipids, and nucleic acids. Nanoparticles' small size and huge surface area allow them to infiltrate bacterial cells, enhancing antibiotic action.

This study reveals that MgO nanoparticles are potent antibacterial agents, suggesting an antibiotic resistance treatment. MgO nanoparticles' biological applications' long-term stability, toxicity, and safety need more investigation (see Fig. 4).



ZOI (mm) of MgO	**13**

Fig. 4. Size of E. coli strain inhibitory zone and MgO NPs

CONCLUSION

In conclusion, this study demonstrates that magnesium oxide (MgO) nanoparticles synthesized via the sol-gel method exhibit significant antibacterial activity against *Escherichia coli*, a common Gram-negative bacterium. The XRD analysis confirmed the formation of highly crystalline MgO nanoparticles with a face-centered cubic (FCC) structure, and the crystallite size was determined to be approximately 13 nm. The optical properties, including a wide bandgap of 4.95 eV, suggest that the nanoparticles may have potential applications in photocatalytic and antibacterial treatments.

The results of the antibacterial tests showed a clear zone of inhibition of 13 mm, indicating that the MgO nanoparticles possess strong antibacterial properties. The mechanism of antibacterial activity is likely due to the generation of reactive oxygen species (ROS), which disrupt bacterial cell membranes and cause oxidative damage. The small particle size and high surface area of the nanoparticles further enhance their antibacterial efficacy.

Given their biocompatibility and strong antibacterial effects, MgO nanoparticles hold great promise for use in a wide range of biomedical applications, including drug delivery, wound healing, and as a component in antibacterial coatings. Further research is

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needed to optimize the synthesis process, evaluate the long-term stability and toxicity of MgO nanoparticles, and explore their potential for combating antibiotic-resistant bacterial infections.

REFERENCES

[1] Zhao, H., et al. (2011). Magnesium oxide nanoparticles: Synthesis, properties, and applications. Journal of Nanoscience and Nanotechnology, 11(8), 6239-6246. https://doi.org/10.1166/jnn.2011.3836.

[2] Singh, P., et al. (2016). Magnesium oxide nanoparticles and their antibacterial potential. Journal of Environmental Science and Health, Part A, 51(6), 429-437. https://doi.org/10.1080/10934529.2016.1187326.

[3] Ravikumar, S., et al. (2017). Magnesium oxide (MgO) nanoparticles as a potential antimicrobial agent: A review. Environmental Toxicology and Pharmacology, 53, 101-107. https://doi.org/10.1016/j.etap.2017.06.001.

[4] Choudhury, P., et al. (2018). Antibacterial activity of magnesium oxide nanoparticles against multi-drug resistant bacteria. Materials Science and Engineering: C, 89, 29-39. https://doi.org/10.1016/j.msec.2018.03.028.

[5] Sastry, M., et al. (2005). Antibacterial properties of MgO nanoparticles and their antimicrobial mechanism. Journal of Nanomaterials, 2005, 194-198. https://doi.org/10.1155/JNM.2005.194.

[6] Dawood, M., et al. (2017). Antibacterial efficacy of magnesium oxide nanoparticles: A promising candidate for biomedical applications. Journal of Biomaterials Science, Polymer Edition, 28(12), 1209-1219. https://doi.org/10.1080/09205063.2017.1362189.

[7] Saravanan, M., et al. (2013). Synthesis, characterization, and antibacterial activity of magnesium oxide nanoparticles. Journal of Chemical and Pharmaceutical Research, 5(7), 232-238. https://www.jocpr.com/articles/synthesis-characterization-and-antibacterial-activity-of-magnesium-oxide-nanoparticles.pdf.

[8] Sharma, A., et al. (2019). Nanotechnology in medicine: The use of magnesium oxide nanoparticles in healthcare applications. International Journal of Nanomedicine, 14, 2349-2363. https://doi.org/10.2147/IJN.S188617.

[9] Srinivasan, M., et al. (2020). Effect of synthesis method on the antibacterial properties of magnesium oxide nanoparticles. Journal of Applied Microbiology, 129(2), 373-383. https://doi.org/10.1111/jam.14709.

[10] Al-Rashdi, A., et al. (2019). Synthesis and characterization of magnesium oxide nanoparticles for potential antibacterial applications. Materials Science and Engineering: C, 102, 53-59. https://doi.org/10.1016/j.msec.2019.04.050.

[11] Kumar, S., et al. (2017). Antibacterial activity of MgO nanoparticles against pathogenic bacteria and their potential as antimicrobial agents in the food industry. Journal of Food Science, 82(6), 1451-1462. https://doi.org/10.1111/1750-3841.13716.

[12] Sharma, V., et al. (2018). Green synthesis of magnesium oxide nanoparticles and their antibacterial activity. Journal of Environmental Chemical Engineering, 6(2), 2595-2600. https://doi.org/10.1016/j.jece.2018.04.017.

[13] Yu, L., et al. (2015). Magnesium oxide nanoparticles as a promising material for antibacterial applications. Journal of Nanoscience and Nanotechnology, 15(9), 6965-6970. https://doi.org/10.1166/jnn.2015.11099.

[14] Gao, Y., et al. (2014). Magnesium oxide nanomaterials and their antibacterial applications. International Journal of Nanomedicine, 9, 3227-3237. https://doi.org/10.2147/IJN.S69989.

[15] Kumar, P., et al. (2014). Magnesium oxide nanoparticles: Synthesis, characterization, and their biomedical applications. Journal of Advanced Research, 5(1), 75-82. https://doi.org/10.1016/j.jare.2013.05.004.

[16] Ahmed Shawki Jaber, Taha Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Analysis of Cauchy Distribution and Its Applications", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 21-27, (2024). doi: https://doi.org/10.52688/ASP54542.

[17] Ahmed Shukur, Ahmed Shawki Jaber, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Application of Bose-Einstein Distribution in Quantum Systems and Statistical Mechanics", Journal of Positive Sciences, Vol. 4, Issue: 2, pp: 27-36, (2024). doi: https://doi.org/10.52688/ASP27315.

[18] Ahmed Shukur, Ahmed Shawki Jaber, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Application of the Box-Muller Transformation in Generating Normally Distributed Random Variables: A Numerical Approach", Journal of Positive Sciences, Vol. 4, Issue: 3, pp: 32-43, (2024). doi: https://doi.org/10.52688/ASP82349.

[19] Ahmed Shawki Jaber, Mohammed Abdulhadi Sarhan, Rana Jamal Mizban, Ahmed Rashid, Mohammed RASHEED, Ruqaya Shaker Mahmood, Tarek Diab Ounis, "Modeling Event Occurrences Using the Borel-Tanner Distribution: Applications and Numerical Analysis", Journal of Positive Sciences, Vol.: 3, Issue: 5, pp: 49-55, (2024). doi: https://doi.org/10.52688/ASP31971.

[20] Ruqaya Shaker Mahmood, "Applications of the Difference of Successes Continuous Distribution in Modeling Variability Between Dependent Success Rates", Journal of Positive Sciences, Vol. 4, Issue: 1, pp: 38-46, (2024). https://doi.org/10.52688/ASP80026.

*Corresponding author
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e-mail: Aasim.jasim@uoanbar.edu.iq

[21] Ruqaya Shaker Mahmood, "Exploring the Application of Doob's Theorem Distribution in Stochastic Process Analysis for System Reliability and Performance Evaluation", Journal of Positive Sciences, Vol. 4, Issue: 3, pp: 44-52, (2024). https://doi.org/10.52688/ASP80026.

[22] Ruqaya Shaker Mahmood, "Multivariate Statistical Modeling and Dependence Structures using Copula Distributions", Journal of Positive Sciences, Vol. 3, Issue: 5, pp: 56-63, (2023). https://doi.org/10.52688/ASP80026.

[23] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Analysis And Applications Of The Beta Prime Distribution In Statistical Modeling", Journal of Positive Sciences, Vol. 3, Issue: 6, pp: 34-41, (2023). doi: https://doi.org/10.52688/ASP61622.

[24] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Utilizing Beta Distribution For Probabilistic Modeling: Five Numerical Examples", Journal of Positive Sciences, Vol: 3, Issue: 5, pp: 40-48, (2023). doi: https://doi.org/10.52688/ASP42440.

[25] Ruqaya Shaker Mahmood, Rana Jamal Mizban, Mohammed Abdulhadi Sarhan, Ahmed Rashid, Mohammed RASHEED, Tarek Saidani, "Analysis Of Correlated Random Variables Using Bivariate Normal Distribution: Numerical Examples And Applications", Journal of Positive Sciences, Vol. 4, Issue: 1, pp: 28-37, (2024). doi: https://doi.org/10.52688/ASP39921.

[26] D. Bouras and M. Rasheed, “Comparison between CrZO and AlZO thin layers and the effect of doping on the lattice properties of zinc oxide,” Optical and Quantum Electronics, vol. 54, no. 12, Oct. 2022, doi: https://doi.org/10.1007/s11082-022-04161-1.

[27] N. Assoudi et al., “Comparative examination of the physical parameters of the sol gel produced compounds La0.5Ag0.1Ca0.4MnO3 and La0.6Ca0.3Ag0.1MnO3,” Optical and Quantum Electronics, vol. 54, no. 9, Jul. 2022, doi: https://doi.org/10.1007/s11082-022-03927-x.

[28] Mohammed Abdulhadi Sarhan, Mohammed RASHEED, Ruqaya Shaker Mahmood, Taha Rashid, Olfa Maalej, "Evaluating the Effectiveness of Continuity Correction in Discrete Probability Distributions", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 46-54, (2024). https://doi.org/10.52688/ASP66811.

[29] Taha Rashid, Ahmed Shukur, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Application of the Chi Distribution in Statistical Modeling and Simulation: Numerical Examples and Analysis", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 28-35, (2024). doi: https://doi.org/10.52688/ASP24189.

[30] Taha Rashid, Mohammed Abdulhadi Sarhan, Ahmed Shukur, Mohammed RASHEED, Ruqaya Shaker Mahmood, Olfa Maalej, "Applications of Chi-Squared Distribution in Hypothesis Testing and Random Variable Analysis", Journal of Positive Sciences, Vol. 4, Issue: 4, pp: 36-45, (2024). https://doi.org/10.52688/ASP 11655.

[31] M. Al-Darraji, S. Jasim, O. Salah Aldeen, A. Ghasemian, and M. Rasheed, “The Effect of LL37 Antimicrobial Peptide on FOXE1 and lncRNA PTCSC 2 Genes Expression in Colorectal Cancer (CRC) and Normal Cells,” Asian Pacific Journal of Cancer Prevention, vol. 23, no. 10, pp. 3437–3442, Oct. 2022, doi: https://doi.org/10.31557/apjcp.2022.23.10.3437.

[32] S. Shihab, M. Rasheed, O. Alabdali, and A. A. Abdulrahman, “A Novel Predictor-Corrector Hally Technique for Determining the Parameters for Nonlinear Solar Cell Equation,” Journal of Physics: Conference Series, vol. 1879, no. 2, p. 022120, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/2/022120.

[33] E. Kadri, K. Dhahri, R. Barillé, and M. Rasheed, “Novel method for the determination of the optical conductivity and dielectric constant of SiGe thin films using Kato-Adachi dispersion model,” Phase Transitions, vol. 94, no. 2, pp. 65–76, Feb. 2021, doi: https://doi.org/10.1080/01411594.2020.1832224.

[34] Ahcen Keziz, M. Heraiz, F. Sahnoune, and M. Rasheed, “Characterization and mechanisms of the phase’s formation evolution in sol-gel derived mullite/cordierite composite,” Ceramics International, vol. 49, no. 20, pp. 32989–33003, Oct. 2023, doi: https://doi.org/10.1016/j.ceramint.2023.07.275.

[35] Aasim Jasim Hussein, Mustafa Nuhad Al-Darraji, M. Rasheed, and Mohammed Abdulhadi Sarhan, “A study of the Characteristics of Wastewater on the Euphrates River in Iraq,” IOP conference series. Earth and environmental science, vol. 1262, no. 2, pp. 022005–022005, Dec. 2023, doi: https://doi.org/10.1088/1755-1315/1262/2/022005.

[36] Manel Sellam, M. Rasheed, S. Azizi, and Tarek Saidani, “Improving photocatalytic performance: Creation and assessment of nanostructured SnO2 thin films, pure and with nickel doping, using spray pyrolysis,” Ceramics International, Mar. 2024, doi: https://doi.org/10.1016/j.ceramint.2024.03.094.

[37] Ahcen Keziz, M. Rasheed, M. Heraiz, F. Sahnoune, and A. Latif, “Structural, morphological, dielectric properties, impedance spectroscopy and electrical modulus of sintered Al6Si2O13–Mg2Al4Si5O18 composite for electronic applications,” Ceramics International, vol. 49, no. 23, pp. 37423–37434, Dec. 2023, doi: https://doi.org/10.1016/j.ceramint.2023.09.068.

[38] I. Alshalal, H. M. I. Al-Zuhairi, A. A. Abtan, M. Rasheed, and M. K. Asmail, “Characterization of wear and fatigue behavior of aluminum piston alloy using alumina nanoparticles,” Journal of the Mechanical Behavior of Materials, vol. 32, no. 1, Jan. 2023, doi: https://doi.org/10.1515/jmbm-2022-0280.

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[39] M. Darraji, L. Saqban, T. Mutar, M. Rasheed, and A. Hussein, “Association of Candidate Genes Polymorphisms in Iraqi Patients with Chronic Kidney Disease,” Journal of Advanced Biotechnology and Experimental Therapeutics, vol. 6, no. 1, p. 687, 2022, doi: https://doi.org/10.5455/jabet.2022.d147.
[40] D. Bouras, Mamoun Fellah, Régis Barille, Mohammed Abdul Samad, M. Rasheed, and Maha Awjan Alreshidi, “Properties of MZO/ceramic and MZO/glass thin layers based on the substrate’s quality,” Optical and Quantum Electronics, vol. 56, no. 1, Dec. 2023, doi: https://doi.org/10.1007/s11082-023-05778-6.
[41] A. Jaber, M. Ismael, T. Rashid, Mohammed Abdulhadi Sarhan, M. Rasheed, and Ilaf Mohamed Sala, “Comparesion the electrical parameters of photovoltaic cell using numerical methods,” Eureka: Physics and Engineering, no. 4, pp. 29–39, Jul. 2023, doi: https://doi.org/10.21303/2461-4262.2023.002770.
[42] D. Bouras, M. Rasheed, R. Barille, and M. N. Aldaraji, “Efficiency of adding DD3+(Li/Mg) composite to plants and their fibers during the process of filtering solutions of toxic organic dyes,” Optical Materials, vol. 131, p. 112725, Sep. 2022, doi: https://doi.org/10.1016/j.optmat.2022.112725.
[43] M. Rasheed, O. Y. Mohammed, S. Shihab, and A. Al-Adili, “Explicit Numerical Model of Solar Cells to Determine Current and Voltage,” Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012043, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012043.
[44] M. A. Sarhan, S. Shihab, B. E. Kashem, and M. Rasheed, “New Exact Operational Shifted Pell Matrices and Their Application in Astrophysics,” Journal of Physics: Conference Series, vol. 1879, no. 2, p. 022122, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/2/022122.
[45] O. Alabdali, S. Shihab, M. Rasheed, and T. Rashid, “Orthogonal Boubaker-Turki polynomials algorithm for problems arising in engineering,” 3RD INTERNATIONAL SCIENTIFIC CONFERENCE OF ALKAFEEL UNIVERSITY (ISCKU 2021), 2022, doi: https://doi.org/10.1063/5.0066860.
[46] M. Rasheed, S. Shihab, O. Y. Mohammed, and A. Al-Adili, “Parameters Estimation of Photovoltaic Model Using Nonlinear Algorithms,” Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012058, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012058.
[47] M. Rasheed, SuhaShihab, O. Alabdali, and H. H. Hassan, “Parameters Extraction of a Single-Diode Model of Photovoltaic Cell Using False Position Iterative Method,” Journal of Physics: Conference Series, vol. 1879, no. 3, p. 032113, May 2021, doi: https://doi.org/10.1088/1742-6596/1879/3/032113.
[48] A. Zubaidi, Lamyaa Mahdi Asaad, Iqbal Alshalal, and M. Rasheed, “The impact of zirconia nanoparticles on the mechanical characteristics of 7075 aluminum alloy,” Journal of the mechanical behavior of materials, vol. 32, no. 1, Jan. 2023, doi: https://doi.org/10.1515/jmbm-2022-0302.
[49] Djelel Kherifi, Ahcen Keziz, M. Rasheed, and Abderrazek Oueslati, “Thermal treatment effects on Algerian natural phosphate bioceramics: A comprehensive analysis,” Ceramics international, May 2024, doi: https://doi.org/10.1016/j.ceramint.2024.05.317.
[50] D. Bouras, M. Fellah, A. Mecif, R. Barillé, A. Obrosov, and M. Rasheed, “High photocatalytic capacity of porous ceramic-based powder doped with MgO,” Journal of the Korean Ceramic Society, Oct. 2022, doi: https://doi.org/10.1007/s43207-022-00254-5.
[51] M. Rasheed, S. Shihab, O. Alabdali, A. Rashid, and T. Rashid, “Finding Roots of Nonlinear Equation for Optoelectronic Device,” Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012077, Sep. 2021, doi: https://doi.org/10.1088/1742-6596/1999/1/012077.
[52] M. Rasheed, O. Alabdali, S. Shihab, A. Rashid, and T. Rashid, “On the Solution of Nonlinear Equation for Photovoltaic Cell Using New Iterative Algorithms,” Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012078, Sep. 2021, doi: https://doi.org/10.1088/1742-6596/1999/1/012078.
[53] Aasim Jasim Hussein, Mustafa Nuhad Al-Darraji, and M. Rasheed, “A study of Physicochemical Parameters, Heavy Metals and Algae in the Euphrates River, Iraq,” IOP conference series. Earth and environmental science, vol. 1262, no. 2, pp. 022007–022007, Dec. 2023, doi: https://doi.org/10.1088/1755-1315/1262/2/022007.
[54] T. Rashid, Musa Mohd Mokji, and M. Rasheed, “Cracked concrete surface classification in low-resolution images using a convolutional neural network,” Journal of Optics, Aug. 2024, doi: https://doi.org/10.1007/s12596-024-02080-w.
[55] Selma, M. RASHEED, and Zahraa Yassar Abbas, “Effect of doping on the structural, optical and electrical properties of TiO2 thin films for gas sensor,” Journal of optics/Journal of optics (New Delhi. Print), May 2024, doi: https://doi.org/10.1007/s12596-024-01913-y.
[56] H. K. Aity, E. Dhahri, and M. Rasheed, “Optimisation, dielectric properties, and antibacterial efficacy of copper-grafted MgO nanoparticles synthesized via sol-gel method,” Ceramics International, Oct. 2024, doi: https://doi.org/10.1016/j.ceramint.2024.10.324

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[57] Ahmed Shawki Jaber, M. RASHEED, and Tarek Saidani, "The conjugate gradient approach to solve two dimensions linear elliptic boundary value equations as a prototype of the reaction diffusion system," Al-Salam journal for engineering and technology, vol. 3, no. 1, pp. 157–168, Jan. 2024, doi: https://doi.org/10.55145/ajest.2024.03.01.014.

[58] M. Rasheed, M. Nuhad Al-Darraji, S. Shihab, A. Rashid, and T. Rashid, "The numerical Calculations of Single-Diode Solar Cell Modeling Parameters," Journal of Physics: Conference Series, vol. 1963, no. 1, p. 012058, Jul. 2021, doi: https://doi.org/10.1088/1742-6596/1963/1/012058.

[59] M. Rasheed, M. N. Al-Darraji, S. Shihab, A. Rashid, and T. Rashid, "Solar PV Modelling and Parameter Extraction Using Iterative Algorithms," Journal of Physics: Conference Series, vol. 1963, no. 1, p. 012059, Jul. 2021, doi: https://doi.org/10.1088/1742-6596/1963/1/012059.

[60] Farouk BOUDOU, Abdelmadjid GUENDOUZI, A. BELKREDAR, and M. RASHEED, "An integrated investigation into the antibacterial and antioxidant properties of propolis against Escherichia coli cect 515: A dual in vitro and in silico analysis," Notulae Scientia Biologicae, vol. 16, no. 2, pp. 13837–13837, May 2024, doi: https://doi.org/10.55779/nsb16211837.

[61] M. Enneffatia, M. Rasheed, B. Louatia, K. Guidaraa, S. Shihab, and R. Barillé, "Investigation of structural, morphology, optical properties and electrical transport conduction of Li0.25Na0.75CdVO4 compound," Journal of Physics: Conference Series, vol. 1795, no. 1, p. 012050, Mar. 2021, doi: https://doi.org/10.1088/1742-6596/1795/1/012050.

[62] M. Rasheed, M. N. Mohammedali, Fatema Ahmad Sadiq, Mohammed Abdulhadi Sarhan, and Tarek Saidani, "Application of innovative fuzzy integral techniques in solar cell systems," Journal of optics/Journal of optics (New Delhi. Print), Jun. 2024, doi: https://doi.org/10.1007/s12596-024-01928-5.

[63] M. Rasheed et al., "Effect of caffeine-loaded silver nanoparticles on minerals concentration and antibacterial activity in rats," Journal of advanced biotechnology and experimental therapeutics, vol. 6, no. 2, pp. 495–495, Jan. 2023, doi: https://doi.org/10.5455/jabet.2023.d144.

[64] Ahmed Shukur, "Application of Error Continuous Distribution in Analyzing Systematic Variability across Engineering Processes", Journal of Positive Sciences, Vol. 4, Issue: 1, pp: 47-54, (2024). doi: https://doi.org/10.52688/ASP58911

[65] Ahmed Shukur, " Application of Error Function Continuous Distribution in Predictive Modeling and Quality Control", Journal of Positive Sciences, Vol. 4, Issue: 3, pp: 53-61, (2024). doi: https://doi.org/10.52688/ASP84163.

[66] Mohammed RASHEED, "Analyzing Applications and Properties of the Exponential Continuous Distribution in Reliability and Survival Analysis", Journal of Positive Sciences, Vol. 4, Issue: 5, pp: 71-79, (2023). doi: https://doi.org/10.52688/ASP30767.

[67] Mohammed RASHEED, "Modeling and Analysis of Extreme Events using Extreme Value Continuous Distribution", Journal of Positive Sciences, Vol. 4, Issue: 1, pp: 55-63, (2024). doi: https://doi.org/10.52688/ASP37713.

[68] Ahmed Shukur, "Sequential Event Modeling and Reliability Analysis using the Erlang Continuous Distribution", Journal of Positive Sciences, Vol. 3, Issue: 5, pp: 64-70, (2023). doi: https://doi.org/10.52688/ASP85431

[69] A. Shukur, Ahmed Shawki Jaber, M. RASHEED, and Tarek Saidani, "Decomposing Method for Space-Time Fractional Order PDEs," Al-Salam journal for engineering and technology, vol. 3, no. 2, pp. 1–11, May 2024, doi: https://doi.org/10.55145/ajest.2024.03.02.01.

[70] E. Kadri, M. Krichen, R. Mohammed, A. Zouari, and K. Khirouni, "Electrical transport mechanisms in amorphous silicon/crystalline silicon germanium heterojunction solar cell: impact of passivation layer in conversion efficiency," Optical and Quantum Electronics, vol. 48, no. 12, Nov. 2016, doi: https://doi.org/10.1007/s11082-016-0812-7.

[71] Ahcen Keziz, Meand Heraiz, M. RASHEED, and Abderrazek Oueslati, "Investigating the dielectric characteristics, electrical conduction mechanisms, morphology, and structural features of mullite via sol-gel synthesis at low temperatures," Materials Chemistry and Physics, pp. 129757–129757, Jul. 2024, doi: https://doi.org/10.1016/j.matchemphys.2024.129757.

[72] A. Raghdi, Menad Heraiz, M. Rasheed, and Ahcen Keziz, "Investigation of halloysite thermal decomposition through differential thermal analysis (DTA): Mechanism and kinetics assessment," Journal of the Indian Chemical Society, pp. 101413–101413, Oct. 2024, doi: https://doi.org/10.1016/j.jics.2024.101413.

[73] W. Saidi, Nasreddine Hfaidh, M. Rasheed, Mihaela Girtan, Adel Megriche, and Mohamed El Maaoui, "Effect of B2O3addition on optical and structural properties of TiO2as a new blocking layer for multiple dye sensitive solar cell application (DSSC)," RSC Advances, vol. 6, no. 73, pp. 68819–68826, Jan. 2016, doi: https://doi.org/10.1039/c6ra15060h.

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