

Antibacterial Improvement of Disease-Protective Face Masks Using Gold Nanoparticles

Farah Sadeq Khesro¹, Hanaa Shuker Mahmood²

¹Department of Physics, College of Pure Science Ibn Al-Haitham, University Of Baghdad

Email: Farah.Sadek1204a@ihcoedu.uobaghdad.edu.iq

Abstract

In this work, the antibacterial effectiveness of face masks made from polypropylene, against *Candida albicans* and *Pseudomonas aeruginosa* pathogenic was improved by soaking in gold nanoparticles suspension prepared by a one-step precipitation method. The fabricated nanoparticles at different concentrations were characterized by UV-visible absorption and showed a broad surface Plasmon band at around 520 nm. The FE-SEM images showed the polypropylene fibres highly attached with the spherical AuNPs of diameters around 25 nm over the surfaces of the soaked fibres. The Fourier Transform Infrared Spectroscopy (FTIR) of pure and treated face masks in AuNPs conform to the characteristics bands for the polypropylene bands. There are some differences in the FTIR patterns for samples containing AuNPs by decreasing band intensities and broadening the peaks by increasing the AuNPs concentration, resulting from the band formation between Au and methylene group in PP. The prepared AuNPs suspension showed decent antibacterial activity against *Candida albicans*. The antibacterial test showed improvement in the antibacterial of the mask samples soaked in AuNPs suspension against *C.albicans* and *P.aeruginosa* pathogenic.

Keywords: Au NPs, antibacterial, precipitation method.

INTRODUCTION

With the increased demand for face masks after the Coronavirus pandemic, it is vital to investigate the feasibility of drafting criteria for commercial face masks. One of the most significant things that recent studies have focused on is the effectiveness of masks as antibacterial against pathogenic microorganisms [1]. Some pathogenic bacteria are resistant to conventional treatments, which led researchers to use nanomaterials as an effective alternative against bacteria [2]. Nanomaterials have been employed to construct new generation masks with the greatest influence on filtration effectiveness, antibacterial efficiency, and comfort [3]. Silver is a popular nanomaterial as antibacterial effect against a wide variety of microorganisms [4]. Furthermore, gold nanoparticles (Au NPs) with chemical, optical, and surface engineering properties have attracted much research and applications in biology and medicine for diagnostic and therapeutic uses. These include cancer cells imaging, drugs delivery, and phototherapy [5].

Polypropylene (PP) fibers are the standard material in the manufacture of face masks and are used in various industries [6].

Various methods for the generation of nanomaterials were revealed in the literature such as sol-gel [7], solid state reaction, [8] laser ablation [9], and chemical precipitation methods [10].

This work is aimed to improve the antibacterial properties of commercial masks by using gold nanoparticles prepared by the precipitation method.

Experimental

Materials

Gold chloride trihydrate ($\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$) of 99.9 % purity (Merck) as precursor and sodium tricitate (PubChem), which act as both stabilizing and reducing agent.

Address for correspondence: Farah Sadeq Khesro,
College of Pure Science Ibn Al-Haitham, University Of Baghdad, Iraq
Email: Farah.Sadek1204a@ihcoedu.uobaghdad.edu.iq

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: pnrjournal@gmail.com

How to cite this article: Farah Sadeq Khesro, Hanaa Shuker Mahmood, Antibacterial Improvement of Disease-Protective Face Masks Using Gold Nanoparticles, J PHARM NEGATIVE RESULTS 2022;13:172-177.

Access this article online

Quick Response Code:



Website:
www.pnrjournal.com

DOI:
10.47750/pnr.2022.13.03.027

AuNPs Preparation

0.005 gm of gold chloride salt dissolved in 50 ml DW and 0.5 gm of sodium triacetate dissolved in 50 ml DW. The gold salt solution was heated to boiling point then the reducing solution was added gradually to the solution until the solution converted to red colour.

Characterization

The optical characteristics of the AuNPs was scanned by UV-visible absorbance (type SP-8001) at different dilution concentration. The nanostructure of the pure mask textile and that soaked in AuNPs were examined by field emission scanning electron microscopy (FE-SEM). The structural properties of the chemical band were examined by FTIR using (Thermo Scientific Nicolet N10 FTIR Spectrometer). Finally, the arranged AuNPs' antimicrobial was evaluated against *Candida albicans* by mixing the NPs with broth during the preparation process of the agar. The soaked mask in AuNPs suspension were evaluated against *Pseudomonas aeruginosa* and *Candida albicans* inhibition zone around the sample attached to the agar surface.

Results and discussions

The suspensions of the prepared AuNPs were diluted with DW at different concentrations (75%, 50% and 25%) of the prepared solution and examined by UV-Visible Absorption spectroscopy after sonication for 5 min. Figure 1 displays the absorbance curves of the AuNPs suspension in distilled water prepared at different concentrations. All patterns show surface plasmon broadband around 520 nm, which is the known surface plasmon resonance band for AuNPs [11] due to interaction between the electric field of electromagnetic wave with confined electrons within the nanoparticles at a specific frequency [12]. These peaks confirmed the nano size of the Au particles. It is increased in intensity as a result of increasing the AuNPs concentration. Also, increasing the gold concentration causes a red-shift corresponding to variation in Plasmon resonance. This may be due to growing the nanoparticle size nanoparticles which causes the change of its resonance frequency. This result agrees with that of Compagnini et al. [13]. Table 1 displays the wavelength values of Plasmon resonance peak. These absorbance peaks can use as a selective tunable irradiation absorbance peak.

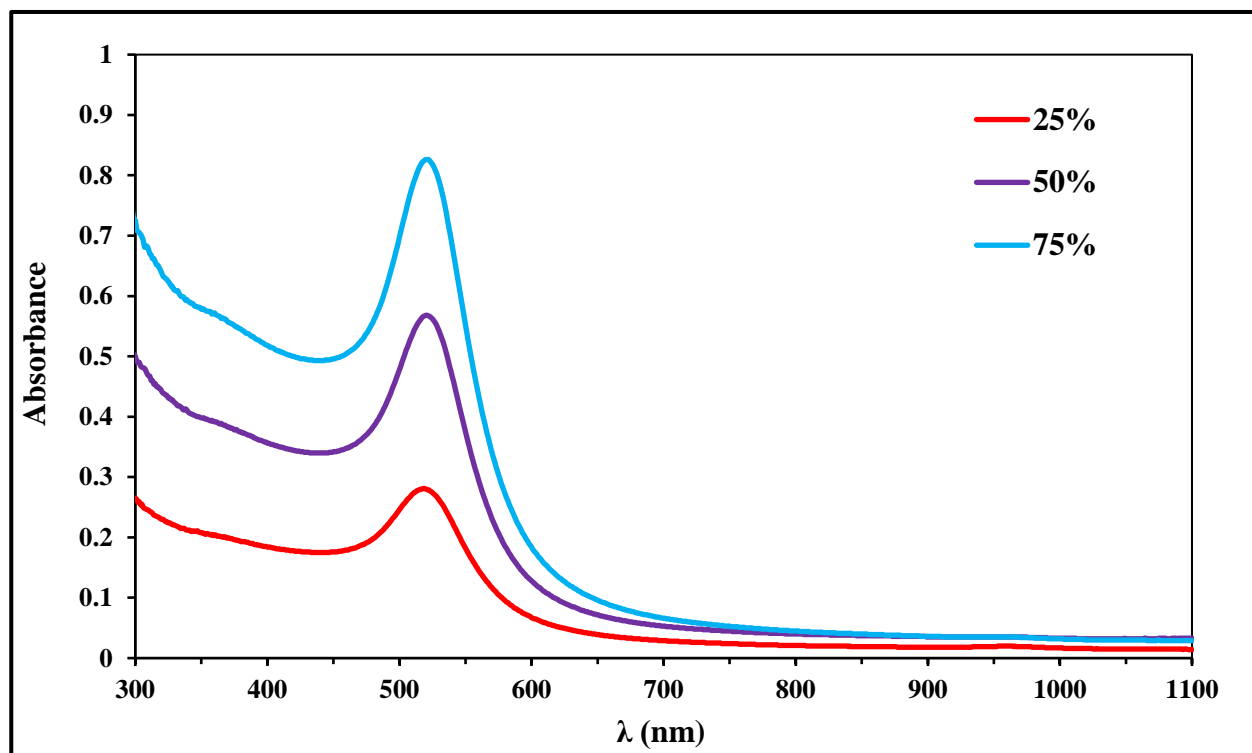


Figure 1: UV-visible absorbance for AuNPs suspended in water at different concentrations

Table 1: Plasmon resonance peaks for AuNPs suspended in water at different concentrations

Au concentration	wavelength (nm)	Absorbance
25%	519	0.281
50%	521	0.568
75%	522	0.826

Figure 2 illustrates the field emission microscope images at different magnification powers for the mask textile soaked in AuNPs suspension. The low magnification images show clearly the PP fibres with diameters around 24 μm. There is no appearance difference in the textile feature after treatment with Au NPs, but the highest magnification power images of 200 kX show spherical attached nanoparticles of diameters around 25 nm for the AuNPs highly secured over the surfaces of the fibres.

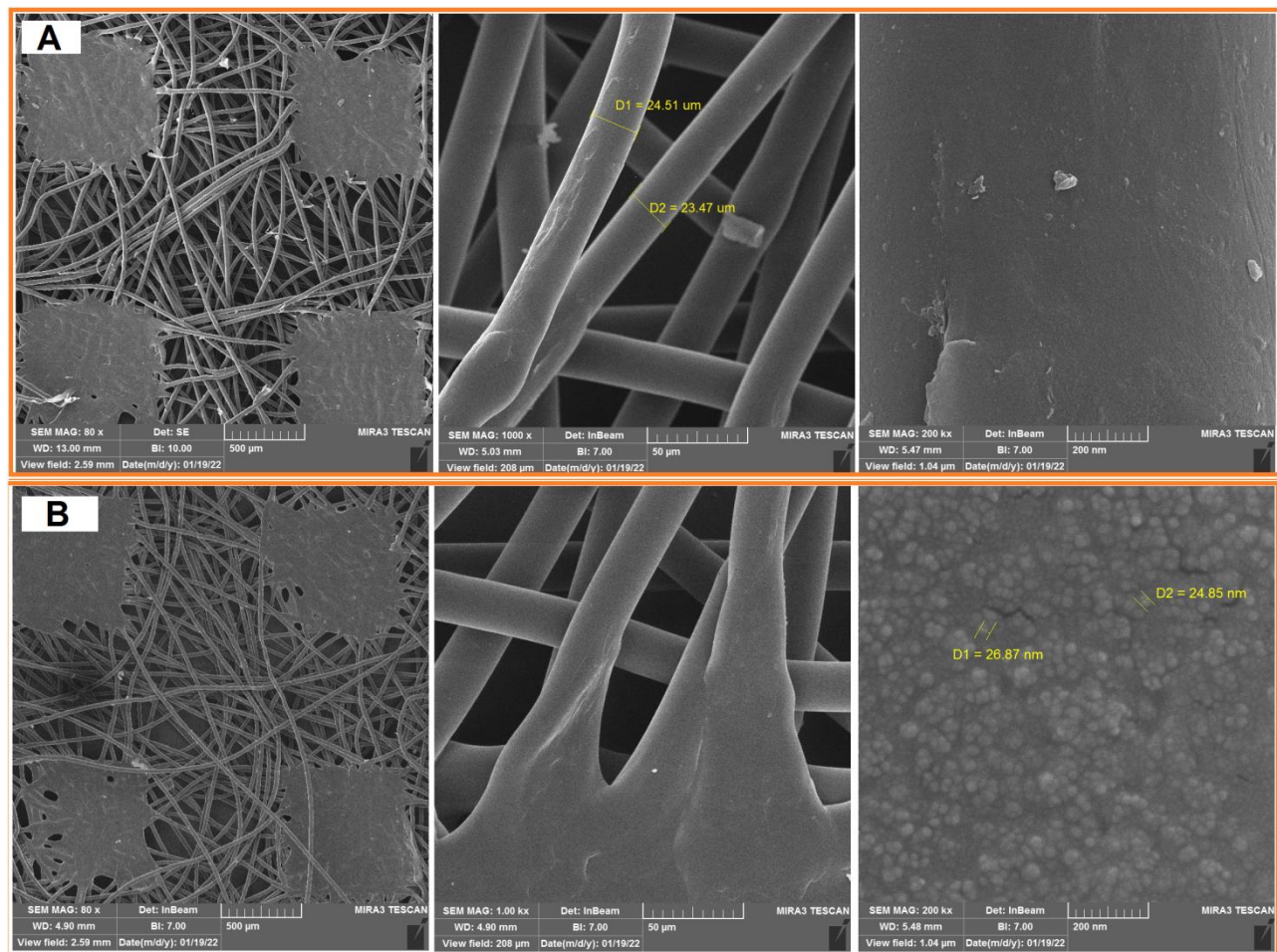


Figure 2: FE-SEM images at different magnifications for pure mask textile (A) and soaked samples with AuNPs suspension.

FTIR spectroscopy is a tool to identify the variation present in organic and inorganic compounds bands in the sample. Depending on the infrared absorption frequency range 400–4000 cm^{-1} , the specific molecular groups prevailing in a sample, the interaction bands between components of blends and the variation in these bands are determined. Figure 3 illustrates the FTIR curves of the free mask and that soaked with AuNPs suspension at different concentrations. All patterns show the characteristics bands for the polypropylene, which is the base substances for manufacturing of many types of surgical masks. For the pure sample, the broad band at about 3438 cm^{-1} is consistent with the hydroxyl group. The bands at 2976 and 2889 cm^{-1} corresponding to the asymmetric and symmetric stretching vibrations of the methylene group (CH_2), respectively [14]. The absorption peaks of deformation vibrations of the plane methylene group arise at 1463 cm^{-1} and 1374 cm^{-1} . Small band at 1523 for the $\text{C}=\text{O}$, while the bands appeared at 768, 619, and 517 cm^{-1} corresponding to the terminal unsaturated CH_2 groups [15]. The soaked face mask containing Au-NPs were nearly conforming to the pure PP spectra. The effect of incorporation the nanoparticles on the vibrations bands was recognized in terms of a decrease in some intensities of bands, broadening of the peaks with increasing the AuNPs concentration, which results from the formation of band

between Au and methylene group in PP. In these interactions, the band around 2875 and 2950 cm^{-1} increases gradually in their intensities and reduced in its energy with the increase of AuNPs concentration. In addition, increasing the AuNPs cause an increase in the broadening of the band located at 1450 cm^{-1} . These variations in spectra confirm the interaction of AuNPs with the PP fibers [16]. Table 2 displays the FTIR bands of pure mask and decorated samples with AuNPs at different concentrations.

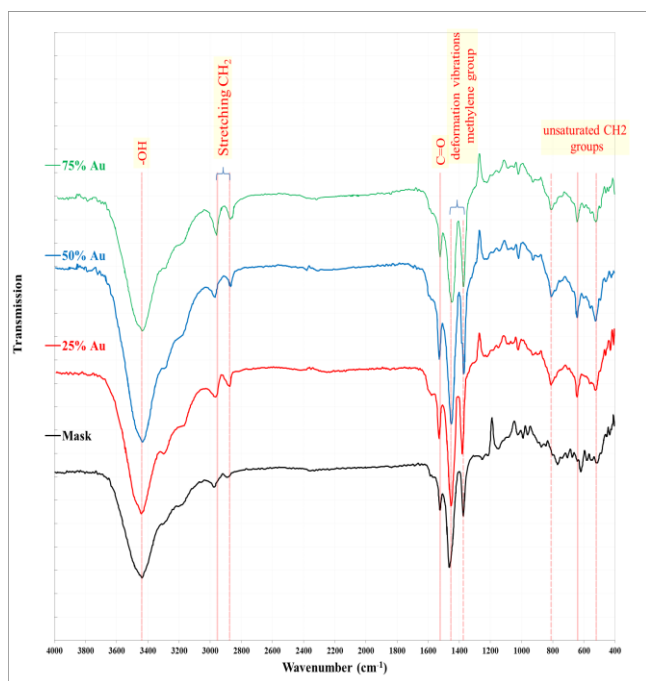


Figure 3: The FTIR curves of nano- free mask sample and that soaked with AuNPs at different concentrations.

Table 2: The FTIR bands of pure mask and decorated samples with AuNPs at different concentrations.

Band Type	Pure	25% Au NPs	50% Au NPs	75% Au NPs
O-H	3438.12	3444.79	3438.12	3438.12
C-H₂ stretch	2976.19	2967.30	2967.30	2956.20
	2889.57	2876.25	2871.37	2869.81
C=O	1523.75	1530.41	1528.19	1523.75
Deformation vibrations methylene group	1463.79	1452.68	1452.68	1448.24
	1374.95	1381.62	1370.51	1372.73
Terminal unsaturated CH₂	768.66	810.86	808.64	808.64
	619.86	644.29	642.07	639.85
	517.71	524.37	524.37	522.15

Figure 4 displays the antibacterial test of Au NPs, mixed as 1 to 4 ratio of the created suspension with the broth during the preparation process of the agar, against *C. albicans* comparing with the control agar without NPs. The nanoparticle free sample shows the bacteria's complete growth over the agar surface after incubation of 24 hours at 37 °C, while no growth over the agar contains Au NPs. The antibacterial mechanism of AuNPs is chiefly by altering cell membrane permeability by declining its metabolic activities; and by inhibiting the ribosome subunit for tRNA binding, causing a failure of the biological process. Furthermore, the AuNPs do not produce any ROS reason of their low toxicity against mammalian cells [17], [18].

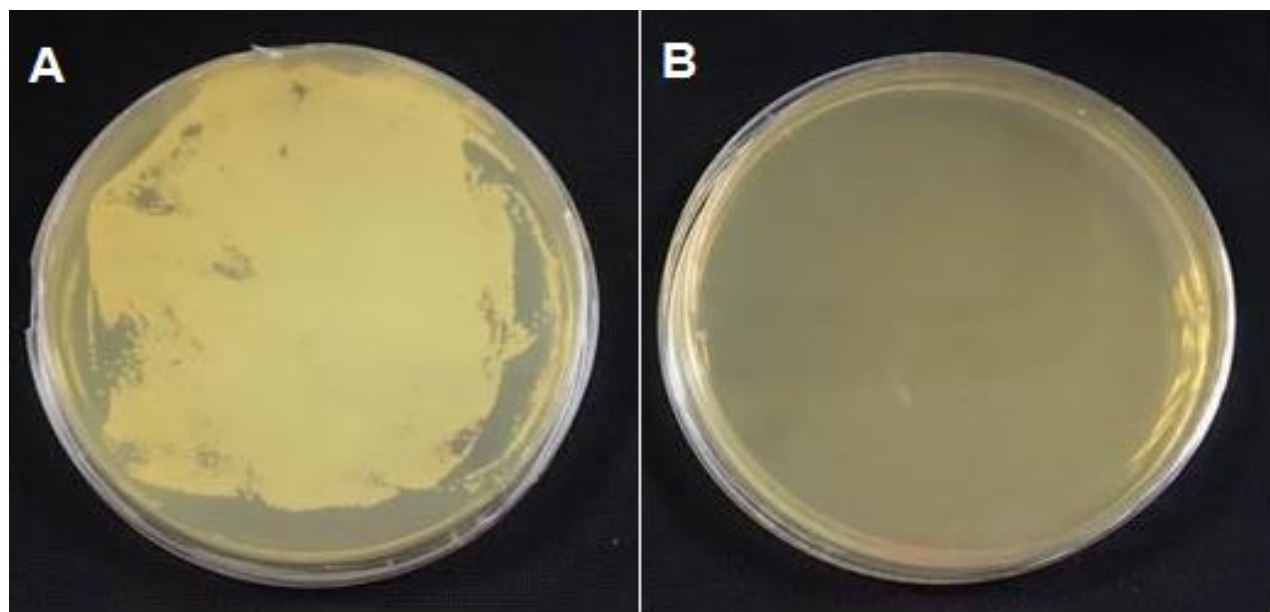


Figure 4: Antibacterial test of AuNPs against Candida (A) the agar without NPs (B) the agar mixed with Au NPs.

Figure 5 illustrates the antibacterial activity test of the mask samples soaked in AuNPs suspension against *C. albicans* and *P. aeruginosa* pathogenic attached to the agar surface compared with nano-free samples. The figure shows a good activity of the samples against both types of bacteria. Still, the activity was more effective against *Pseudomonas aeruginosa* bacteria, which shows an inhibition zone diameter of about 3.5 cm, while the killing zone of *Candida*

albicans bacteria is 1.5 cm. The difference in the effectiveness of killing is due to difference nature of the two species and the different nature of their cell wall [19].

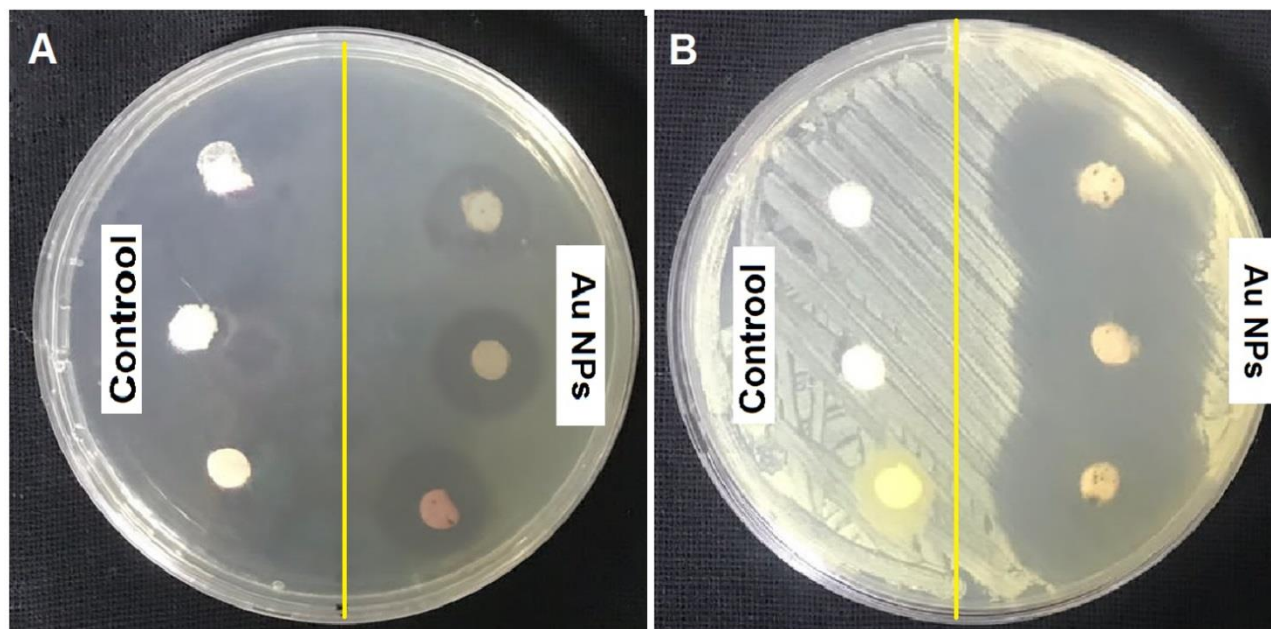


Figure 5: Antibacterial activity test of the mask samples soaked in AuNPs suspension against (A) *Candida albicans* and (B) *Pseudomonas aeruginosa* pathogenic

Conclusions

The antibacterial efficiency of face masks was significantly improved by gold nanoparticles synthesized by a simple precipitation method against highly resistant pathogenic *C. albicans* and *P. aeruginosa*. The FE-SEM images showed the highly attached AuNPs to the surfaces of polypropylene fibres. In addition, the FTIR test indicates the linking of AuNPs with the polymer chain. This method can be adopted to enhance the antibacterial of the disease-protective face masks, and for periods throughout the day, it prevents the growth of pathogenic bacteria on them.

REFERENCES

- [1] K. Stokes, R. Peltrini, U. Bracale, M. Trombetta, L. Pecchia, and F. Basoli, "Enhanced Medical and Community Face Masks with Antimicrobial Properties: A Systematic Review," *J. Clin. Med.*, vol. 10, no. 18, p. 4066, Sep. 2021, doi: 10.3390/jcm10184066.
- [2] S. Alwash and T. M. Al-saadi, "Assessment of the Mint-Copper Nanoparticles Treatment to Control the Infection of *Saprolegniasis* in *Cyprinus carpio* L.," in *Annals of R.S.C.B.*, 2021, vol. 25, no. 4, pp. 16010 – 16019.
- [3] M. A. Shah, B. M. Pirzada, G. Price, A. L. Shibiru, and A. Qurashi, "Applications of nanotechnology in smart textile industry: A critical review," *J. Adv. Res.*, Jan. 2022, doi: 10.1016/j.jare.2022.01.008.
- [4] M. Jeyaraj, G. Sathishkumar, and G. Sivanandhan, "Biogenic silver nanoparticles for cancer treatment: An experimental report," *Colloids Surfaces B Biointerfaces*, vol. 106, pp. 86–92, 2013, doi: 10.1016/j.colsurfb.2013.01.027.
- [5] F. Kong, J. Zhang, R. Li, and Z. Wang, "Unique roles of gold nanoparticles in drug delivery, targeting and imaging applications," *Molecules*, vol. 22, pp. 1–7, 2017, doi: 10.3390/molecules22091445.
- [6] P. A. Jeemol, S. Mathew, and C. P. R. Nair, "Maleimide end- capped polyether telechelics as novel toughening agents for unsaturated polyester resin," *J. Polym. Res.*, vol. 27, no. 10, p. 300, Oct. 2020, doi: 10.1007/s10965-020-02197-z.
- [7] S. H. Mahdie, "Preparation of unsaturated polyester/nano ceramic composite and study electric, thermal and mechanical properties," *Iraqi J. Phys.*, vol. 15, no. 35 SE - Articles, pp. 188–201, Oct. 2018, doi: 10.30723/ijp.v15i35.67.
- [8] M. A. Thejeel and S. Mahdi, "Preparation and investigation of the structural and mechanical properties of Nanobiomaterial zirconolite," *Solid State Technol.*, vol. 63, pp. 1949–1961, 2020.
- [9] N. Rajput, "Methods Of Preparation of Nanoparticles – A Review," *Int. J. Adv. Eng. Technol.*, vol. 7, no. 4, pp. 1806–1811, 2015, doi: 10.1016/j.jare.2015.02.007.
- [10] S. Ansar, S. Chakraborty, and C. Kitchens, "pH-Responsive Mercaptoundecanoic Acid Functionalized Gold Nanoparticles and Applications in Catalysis," *Nanomaterials*, vol. 8, no. 5, p. 339, May 2018, doi: 10.3390/nano8050339.
- [11] S. Link, C. Burda, Z. L. Wang, and M. A. El-Sayed, "Electron dynamics in gold and gold–silver alloy nanoparticles: The influence of a nonequilibrium electron distribution and the size dependence of the electron–phonon relaxation," *J. Chem. Phys.*, vol. 111, no. 3, pp. 1255–1264, 1999, doi: 10.1063/1.479310.
- [12] D.-H. Chen and C.-J. Chen, "Formation and characterization of Au–Ag bimetallic nanoparticles in water-in-oil microemulsions," *J. Mater. Chem.*, vol. 12, no. 5, pp. 1557–1562, 2002, doi: 10.1039/b110749f.
- [13] G. Compagnini, E. Messina, O. Puglisi, R. S. Cataliotti, and V. Nicolosi, "Spectroscopic evidence of a core-shell structure in the earlier formation stages of Au-Ag nanoparticles by pulsed laser ablation in water," *Chem. Phys. Lett.*, vol. 457, no. 4–6, pp. 386–390, 2008, doi: 10.1016/j.cplett.2008.04.051.
- [14] A. Gopanna, R. N. Mandapati, S. P. Thomas, K. Rajan, and M. Chavali, "Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy and wide-angle X-ray scattering (WAXS) of polypropylene (PP)/cyclic olefin copolymer (COC) blends for qualitative and quantitative analysis," *Polymer Bulletin*, vol. 76, no. 8, pp. 4259–4274, 2019, doi: 10.1007/s00289-018-2599-0.
- [15] N. Rasana and K. Jayanarayanan, "Nano, micro and multiscale filler-reinforced functionalized polypropylene composites: FTIR characterization and mechanical study," *Polyolefins J.*, vol. 9, no. 1, pp. 33–43, 2022, doi: 10.22063/POJ.2021.3002.1198.
- [16] D. A. Raja, F. Munir, M. R. Shah, M. I. Bhangar, and M. I. Malik, "Colorimetric sensing of cephadrine through polypropylene glycol functionalized gold nanoparticles," *R. Soc. Open Sci.*, vol. 8, no. 5, p. 210185, May 2021, doi: 10.1098/rsos.210185.
- [17] H. S. Mahmood and M. K. Jawad, "Investigation of Chitosan/PEO Reinforced with AgNPs for Antibacterial Activity Prepared by Solution Casting Method," *Ann. Trop. Med. Public Heal.*, vol. 22, no. 09, pp. 70–

82, 2019, doi: 10.36295/ASRO.2019.220910.

- [18] Y. Cui, Y. Zhao, Y. Tian, W. Zhang, X. Lü, and X. Jiang, "The molecular mechanism of action of bactericidal gold nanoparticles on *Escherichia coli*," *Biomaterials*, vol. 33, no. 7, pp. 2327–2333, Mar. 2012, doi: 10.1016/j.biomaterials.2011.11.057.
- [19] H. S. Mahmood and M. K. Jawad, "Antibacterial activity of chitosan/PAN blend prepared at different ratios," in *AIP Conference Proceedings*, 2019, vol. 2190, no. December, p. 020078, doi: 10.1063/1.5138564.