Ibn Al-Haitham Journal for Pure and Applied Sciences

Journal homepage: http://jih.uobaghdad.edu.iq/index.php/j/index

Enhancement of Antibacterial Activity of Face Mask with Gold Nanoparticles

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Article history: Received 26 April 2022, Accepted 14 June 2022, Published in July 2022.

Doi: 10.30526/35.3.2844

Abstract

The emergence of new dangerous diseases worldwide has led to the need to think about the possibility of enhancing prevention by using new technologies. One of the most important requirements emphasized in the recent studies is the effectiveness of the masks against pathogenic bacteria. In this study, the efficiency of anti-infection protective face masks against bacteria was enhanced by using gold nanoparticles prepared by the chemical precipitation method. The absorption spectrum of the prepared gold suspension shows a clear plasmonic peak at 522 nm. The measurements showed that the sample was made of polypropylene fibers, where X-ray diffraction tests showed peaks matching its crystalline structure. Immersion with gold suspension led to the emergence of peaks belonging to the composition of gold. The immersion treatment increased Young's modulus from 36.5 to 61.7 Mpa. The antibacterial assay showed the efficacy of the samples against *E-Coli* bacteria with an inhibition zone of 3 cm.

Keywords: Au NPs, antibacterial, precipitation method.

1. Introduction

Due to the increasing demand for the use of protective face masks due to the emergence of new dangerous diseases, it is, therefore, necessary to study the efficiency of commercial face masks and study the possibility of improving them. One of the most important criteria that has been focused on in recent studies is the effectiveness of masks as an antibacterial agent [1].

One of the most important and most widely used materials in the manufacture of face masks is Polypropylene. Polypropylene (PP), is a synthetic resin built up by the polymerization of propylene. The PP is molded or extruded into many plastic products. It is also spun into fibers for employment in industrial and household textiles[2].

In recent years, nanotechnology has played an essential role in the development of smart fabrics. Nanomaterials have been used to provide antibacterial, ultraviolet resistant, hydrophobic, and fire resistant qualities into textiles in a sustainable manner [3].
The nanomaterials have been used in the development of the new generation masks with the greatest effect in terms of filtration effectiveness, antibacterial efficiency and comfort [4].

Various methods for the fabrication of nanomaterials were revealed in the literature review, including vaporization under vacuum, chemical vapor deposition (CVD), chemical deposition, sol-gel, solid-state reaction, and laser ablation [5, 6, 7].

Silver is a popular nanomaterial because of its antibacterial effect against a wide variety of microorganisms such as bacteria and fungi [8]. Furthermore, gold nanoparticles (AuNPs) with chemical, optical, and surface engineering properties have been the focus of much research and applications in biology and medicine for diagnostic and therapeutic purposes. These include cancer cell imaging, drug delivery, and phototherapy [9].

In previous study textile for a face mask was created with antibacterial capabilities using the renewable resources material oil of Folium [10]. The fractional concentration of nitric oxide from exhaled breath was assessed before and after mask wear. The results revealed that the mask was more comfortable, breathed better, has antimicrobial properties, and reduced allergy symptoms. The antimicrobial efficacy of Au NPs by contrasting the multiple techniques of synthesizing. By using the origins of antimicrobial properties [11], they found that the antibacterial effects are directly related to particle size, dispersibility, and surface modification by different reactions improved the nonwoven surgical mask by using spray nozzles to add nano-coating hybrid copper nanoparticles (CuNPs) to increase its hydrophobicity for repelling water droplets [12]. The resultant surface exhibited photocatalytic and photo-thermal capabilities for antimicrobial action during solar irradiation, creating a high amount of free reactive species, so the masks self-cleaning.

This work aimed to optimize the antibacterial activity and mechanical properties of commercial face masks by using gold nanoparticles prepared by a simple one-step chemical precipitation method.

2. Experimental

Gold(III) chloride tri-hydrate ($HAuCl_4 .3H_2O$) was used as the gold precursor. 0.0049 gm of gold chloride salt dissolved in 50 ml water. 0.5 gm of sodium triacetate dissolved in 50 ml distilled water, which acts as both stabilizing and reducing agents. The gold salt solution was heated to boiling point then the reducing solution was added gradually to the solution till the solution convert to red color.

The optical properties of Au NPs suspension sample were examined by UV-visible absorbance (type SP-8001). The crystalline structure and crystallite size of the free PP textile sample and that immersed in Au-NPs suspension were examined using X–ray diffraction system (Shimadzu XRD 6000). The source of radiation was Cu (K_α) with a wavelength λ= 1.5405 Å, the current was 30.0 mA and the voltage was 40 kV with a speed of 5.00 (degree /min). Finally, the antimicrobial activity of the soaked mask samples against Escherichia coli microorganisms was evaluated inhibition zone around the sample attached to the agar surface.

3. Results and discussions

The prepared nanoparticle suspensions in water were examined by UV-Visible absorption. The solutions were put in sonication for 10 minutes before the optical studies. **Figure 1** displays the UV-visible absorbance spectra of the Au NPs suspension in distilled water. The pattern shows a surface Plasmon resonance band at 522 nm, which is in the range of the specific peak of Au NPs [13]. This band was exposed due to the interaction of quantum size confined electrons. The free electrons within part of the wavelength dimension have resonance frequency due to interaction with electromagnetic wave frequency. These peaks confirm the formation of NPs in the solution [14].

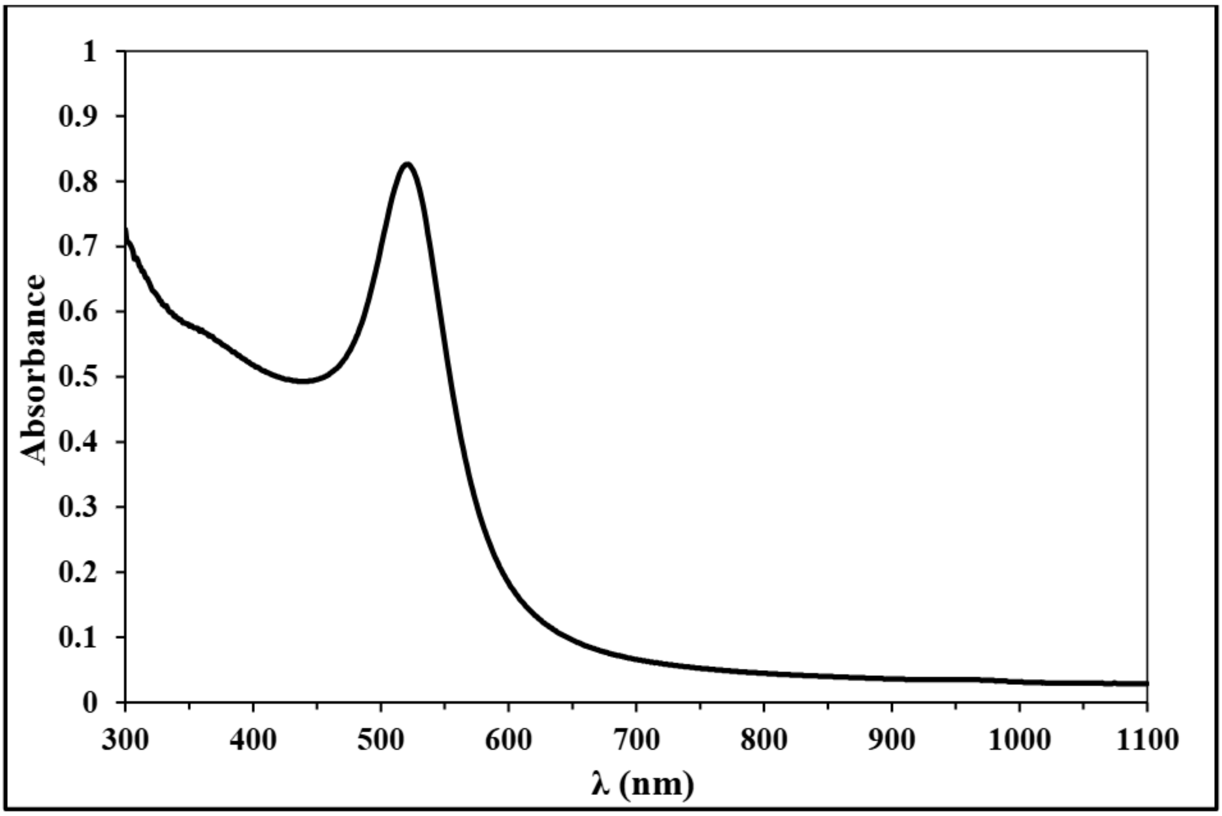

Figure 1. UV-visible absorbance spectra for the Au NPs suspended in water

The polypropylene (PP) polymer fibers are the basic material in the manufacture of most commercial face masks. **Figure 2** shows the X-ray diffraction of samples taken from a mask before treatment compared to samples treated with the prepared Au NPs suspensions. The characteristic peaks of PP which appeared at the diffraction angles 2θ= 13.8985, 16.7384, 18.3161, 21.3454 and 25.2582° correspond to the diffractions from crystalline planes for PP with Miller's indices of (110), (040), (130), (111), and (060) respectively. The preferred direction of growth was along (110) and this agrees well with previous studies [15]. The samples treated with Au NPs show small peaks of gold particles appearing at a diffraction angle of 38.3219 ° and 44.8537 °, which corresponds to the crystal planes of (111) and (200), respectively, for the crystalline structure of Au NPs matched with standard card No.96-901-2954.

The interlayer distances of the crystal planes were calculated using the Bragg equation [16].

$$n \lambda = 2 d_{hkl} \sin \theta \qquad (1)$$

where λ, n are the monochromatic X-ray wavelength corresponding to K_{α} transition of Cu target and the diffraction order respectively.

The crystal size was calculated according to the full width of diffraction lines (FWHM) using Scherrer's formula as follows [17]. As shown in **Table 1.**

$$C.S = \frac{0.9\,\lambda}{FWHM\,.cos(\theta)} \quad (2)$$

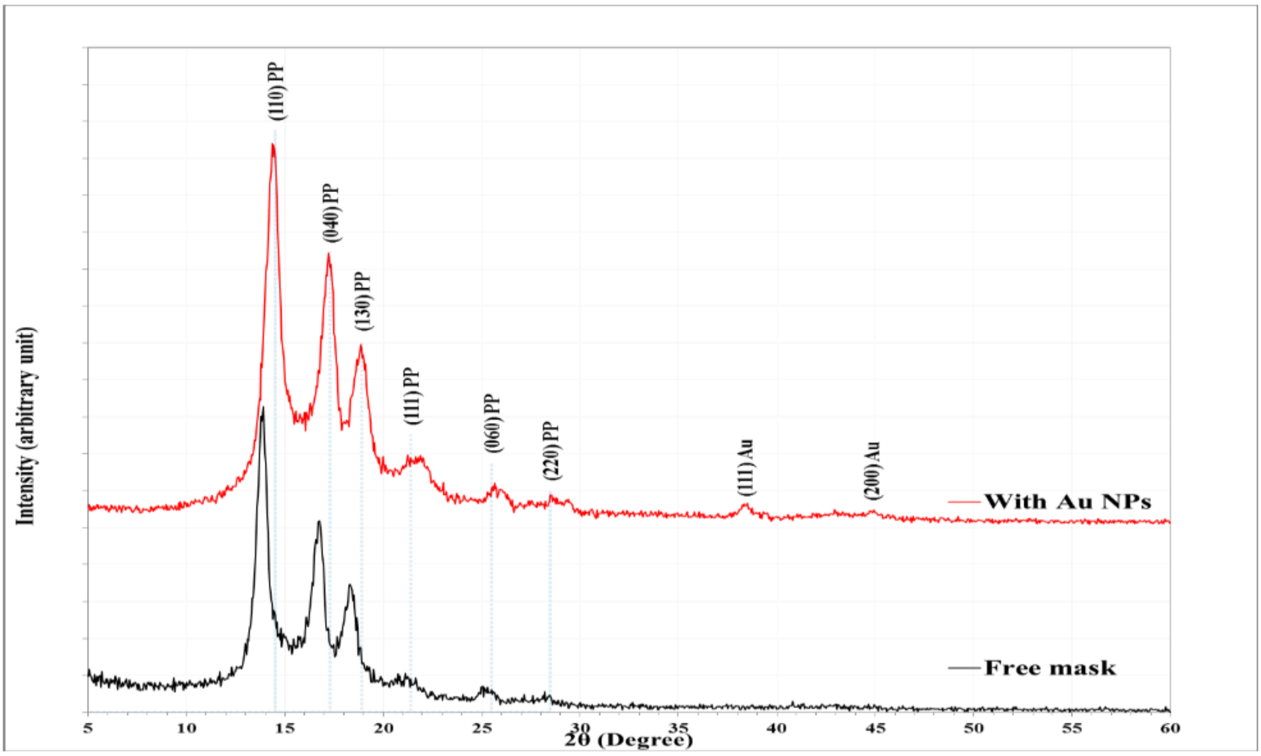

Figure 2. XRD patterns for pure mask and decorated samples with Au NPs.

Table 1. XRD peaks for pure mask and decorated samples with Au NPs.

Sample	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	Phase	hkl
Free mask	13.8985	0.5996	6.3666	13.3	PP	(110)
	16.7384	0.6626	5.2923	12.1	PP	(040)
	18.3161	0.6942	4.8398	11.6	PP	(130)
	21.3454	1.0097	4.1593	8.0	PP	(111)
	25.2582	0.8204	3.5232	9.9	PP	(060)
With Au NPs	14.4033	0.8204	6.1446	9.8	PP	(110)
	17.2117	0.6942	5.1478	11.6	PP	(040)
	18.8526	0.7574	4.7033	10.6	PP	(130)
	21.8503	1.0097	4.0643	8.0	PP	(111)
	25.7631	0.8204	3.4552	9.9	PP	(060)
	28.5714	0.7257	3.1217	11.3	PP	(220)
	38.3219	0.5680	2.3469	14.8	Au	(111)
	44.8537	0.5048	2.0191	17.0	Au	(200)

Figure 3 displays the tensile test curves for the free mask sample and that immersed in Au-NPs suspension and treated at 60 ºC. The two patterns show typical stress–strain behavior[18], starting with the elastic linear region which end at the elastic limit at about 0.15% strain. Then followed by the plastic region and ends at the fracture point. It seems that the Young Modulus slightly increased after immersing in the Au NPs and heat treated. On the

other hand, reducing the sample elasticity. **Table2** illustrates the Young modulus and maximum elongation for a sample before and after treatment with Au NPs.

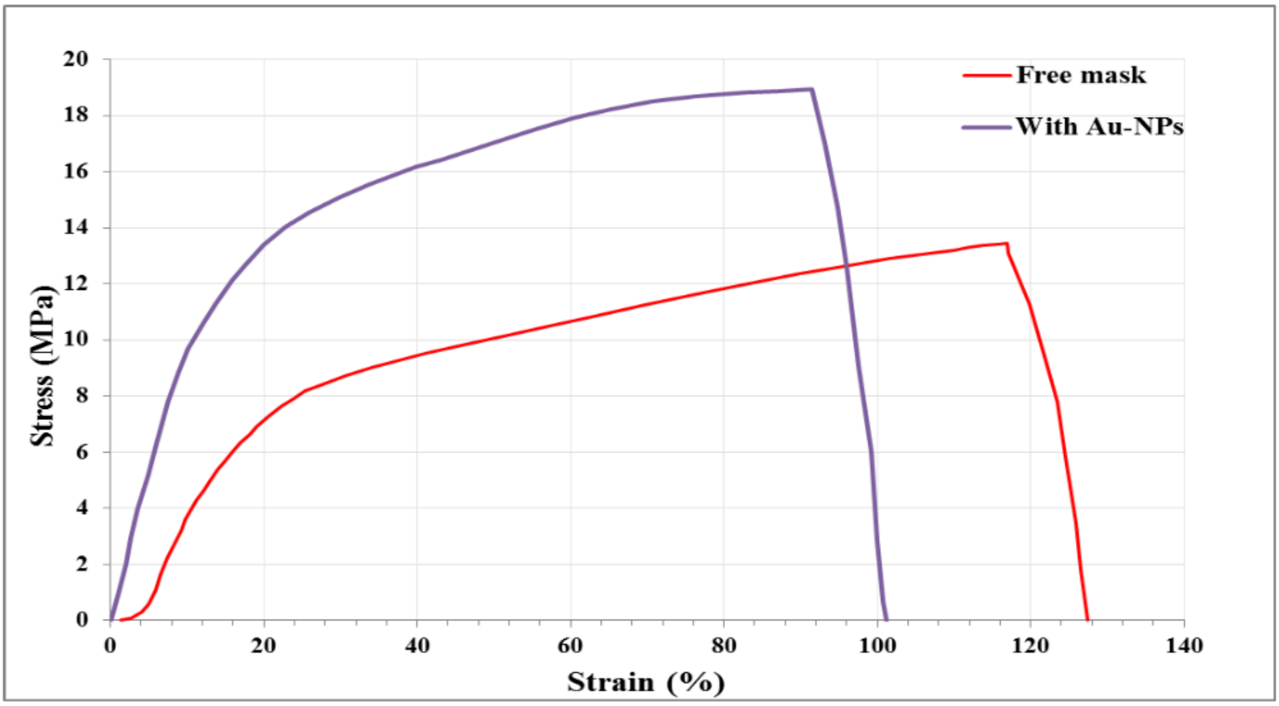

Figure 3. Stress- strain test for pure mask and decorated samples with Au NPs.

Table 2. Stress- strain parameters for pure mask and decorated samples with Au NPs.

Sample	Max Stress	Max elongation (%)	Young Modulus (Mpa)
Free mask	13.455	116.80	36.5
With Au-NPs	18.949	91.50	61.7

Figure 4 shows the antibacterial test against *E-Coli* bacteria. It seems highly affected of the mask samples soaked with the Au NPs with inhibition zone 3 cm compared with the untreated samples. The antibacterial activity of Au-NPs is mainly by two mechanisms: the first is to alter cell membrane permeability, which causes a decline in its metabolic activities; the second is to inhibit the ribosome subunit for RNA binding causing a collapse of the biological process[19]. Furthermore, bactericidal gold NPs do not produce any ROS-related processes, even though the formation of ROS is the cause of cellular death for the majority of bactericidal medicines and antibacterial nanomaterials. The low toxicity of gold NPs to mammalian cells is explained by their ROS-independent mechanism of action [20].

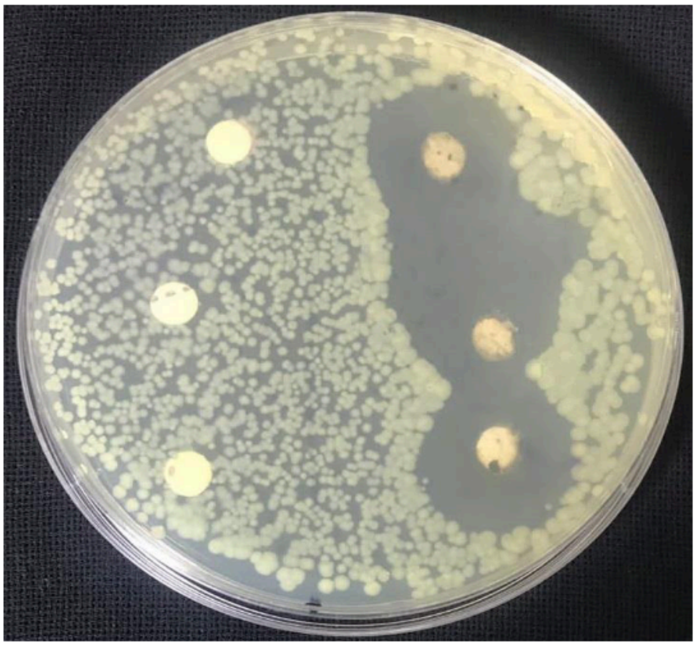

Figure 4. Antibacterial test against E-Coli (the three samples to the left for pure mask as control samples and three ones to the right for the decorated samples with Au NPs).

4. Conclusions

Au-NPs were successfully synthesized by simple precipitation. The plasmonic peak appeared at522 nm. The study showed the efficiency of the method of dipping face masks in the gold suspension that was prepared to be anti-bacterial, which supports the possibility of wearing the masks for a longer period. The mechanical properties showed an increase in Young's modulus of the samples after treatment.

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