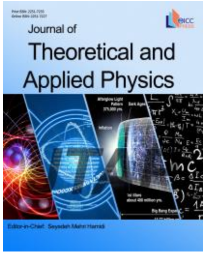

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Making masks with antibacterial properties and the ability to detect paint contamination

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Abstract

In this study, we have studied the fabrication of nanofibers composed of silver nanoparticles. These nanofibers were produced by applying different voltages (from 10 to 20 kV). The structure and properties of these nanofibers were investigated using analytical techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL) spectroscopy. Antibacterial tests have also shown that these nanofibers have antibacterial properties. Also, microscopic images of nanofibers with different voltages indicate significant differences in the structure and properties of nanofibers at different voltages. Finally, photoluminescence spectroscopy of nanofibers containing silver nanoparticles was also evaluated and the effect of pollution and bacteria on the luminescence properties was critically examined. This final research advances the design of smart masks with antibacterial properties and the ability to identify the color of pollution and offers new possibilities for controlling and preventing the spread of diseases.

Keywords: Nanofibers; Antibacterial; Silver; Mask; Photoluminescence

1. Introduction

Nanotechnology has emerged as a vital research field in the past few decades, with a particular emphasis on the synthesis and characterization of nanoparticles.

Among the different nanoparticles, metallic nanoparticles such as silver, gold, platinum and palladium have many applications in various scientific fields such as medicine, medicine, biomedical engineering and health, water purification, sensor technology, and electronic devices and catalysis. Silver has long been used as an antimicrobial agent to treat diseases and preserve food and water. For this reason, it can be said that the most common application of silver nanoparticles is in the medical industry. Silver nanoparticles also have antimicrobial, anticancer, and antioxidant properties [1] ,[2].

The chemical and physical techniques used to synthesize nanoparticles are often very expensive, and the presence of toxic and sometimes carcinogenic reagent residues resulting from these techniques usually leads to the lack of biological utility of the resulting nanoparticles.

Nanoparticles resulting from chemical methods used today have caused great concern due to the use of dangerous and toxic chemicals and the environmental damage they cause. Bionanotechnology is one of the most promising areas of nanoscience and technology in the modern era [3]. Nanoparticles have a major impact on all aspects of human life due to their specific characteristics such as size, shape and morphology.

The use of plants as sustainable and readily available sources for the production of biodegradable nanoparticles has attracted the attention of many researchers in recent years. The advantages of this method include biocompatibility, low cost, non-toxicity, and the production of nanoparticles with high purity. The 2019 coronavirus pandemic has necessitated the widespread use of face coverings as a mandatory measure to reduce the spread of the virus. Face masks act as a barrier to the transmission of airborne particles between the wearer and those around them. This has accelerated the pace of research and development of face masks worldwide. In the scientific literature and company brochures, special attention has been paid to face masks based on electrospun nanofiber membrane materials due to their nano-sized pores, light weight, and high filtration efficiency. Therefore, they are commercially viable and popular among various products available in the market [4]-[7]. The integration of metal organic framework and graphene has opened avenues for more advanced/multifunctional, reusable and high capacity filtration membranes. Rapid prototyping/3D printing techniques have been used to shorten the production time of face masks [8]-[13]. Many research groups around the world have been working on improving face masks, especially in the design and development, selection and use of appropriate materials with the aim of producing masks with multifunctionality, reusability, light weight and ease of use along with large-scale production and cost reduction, etc. [14]-[18]. Nanotechnology is one of the strategies being explored for the safe and economical reuse of masks in the 21st century. These strategies are based on four key elements as follows:

(i) Excellent mechanical properties that give the mask flexibility, durability, and good shelf life. (ii) High thermal properties that give the masks self-sterilizing heat.

(iii) An electric charge controller that provides triboelectric (TE) filtration to the mask. (iv) Antimicrobial response that remains safe in the mask before, during, and after use. These features give new generation masks the ability to overcome the disadvantages of traditional surgical masks such as microbial growth and low filtration efficiency [19]-[22].

In line with the above objectives, this research investigates and fabricates nanofibers used in smart masks containing antibacterial nanoparticles and photoluminescence to detect the color of pollution. Face masks, such as surgical masks, are composed of multiple polymer-based layers. The outer layers are made of nonwoven fabric between 20 and 50 g/m^2 to provide a barrier against moisture. The use of masks has been recommended as a protective measure due to the risks of coronavirus disease. Therefore, the use of "smart masks" to monitor human physiological signals is very beneficial for personal and public health. This work bridges the technological gap between the fabrication of ultra-light but high-frequency responsive sensor materials, signal transmission and processing, and deep learning/machining to demonstrate a wearable device for potential applications in continuous health monitoring in daily life [23]-[27]. The use of nanotechnology in the fabrication of smart masks has brought significant improvements in the performance and efficiency of these products. Using antibacterial nanoparticles, smart masks can effectively disinfect viruses and bacteria. Also, adding photoluminescent nanoparticles to masks allows for the identification of the color of pollution in the environment.

2. Materials and research methods

Nanofibers are made from various materials, including polymers, carbon, silica, metals, and their compounds. Methods such as electrospinning are usually used to make nanofibers. In this method, the desired material is electrically excited in solution or melted form from a needle, resulting in thin fibers. The use of nanofibers in the manufacture of smart masks is also one of their new and important applications. These fibers can be used as the main component of the mask and, by adding antibacterial and photoluminescent nanoparticles, give the mask the ability to remove contaminated particles and identify the color of the contamination. Photoluminescence means the emission of light by a material after absorbing light. If a material can absorb light and then reflect the light as photoluminescent, this property can be used to identify the color of the contamination. When a material is exposed to a contaminated dye, it absorbs sunlight or artificial light and in response to the absorption of the light, emits light of a specific wavelength in the form of photoluminescence. This photoluminescent light may have a specific spectrum that can be analyzed to identify the contaminated dye. Using photoluminescence, it is possible to identify the contaminated dye and protect products from unwanted color contamination.

The method for making nanofibers used in smart masks containing antibacterial nanoparticles and photoluminescence to identify the color of pollution is as follows. Citric acid from lemon was mixed with ethylene diamine in a molar ratio of one to one in 500 ml of deionized water.

Figure 1. Luminescent material.

The mixture was placed in an autoclave reactor and pressurized at 250 °C for 72 hours. The result of the synthesis will be carbon nanoparticles (luminescent carbon dots) that are used as a luminescent material (Fig. 1, luminescent material) in smart masks. Silver nanoparticles were synthesized using ultrasonic method. This method involves mixing silver with a solution and then using ultrasound waves to form nanoparticles. 2 grams of silver nitrate was dissolved in 200 ml of solvent. Lactose was used as a capping agent and co-precipitating agent (Fig. 2.).

5 M ammonia was used in 10 ml as a precipitating agent. Precipitation was performed at 80°C and 200 W ultrasonic waves were applied for one hour. By applying

this optimal power, silver oxide layers were formed on silver.

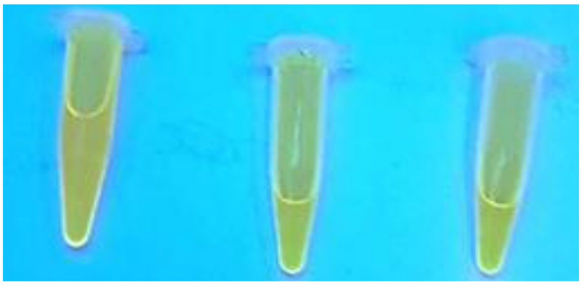

Figure 2. Composite solutions.

The resulting nanoparticles were washed several times with water and ethanol to remove impurities and residual solvents. Then the nanoparticles were dried at 50°C. 200 W power was used for the synthesis of silver nanoparticles. This is because higher ultrasonic power causes impurities and oxidation. However, 1000 W power was used to prepare carbon nanoparticles. Because there is no similar concern about impurities and oxidation. Once the silver nanoparticles are prepared, they are ready to be used in the manufacture of nanofibers. Nanofibers are prepared from carbon and silver nanoparticles using the electrospinning method. In this method, a solution containing carbon nanoparticles and silver nanoparticles is jetted into a mixture using a spinning element.

Applying voltage to polymer salts results in the formation of fibers along which carbon and silver nanoparticles uniformly embedded within the fibers (Fig. 3.).

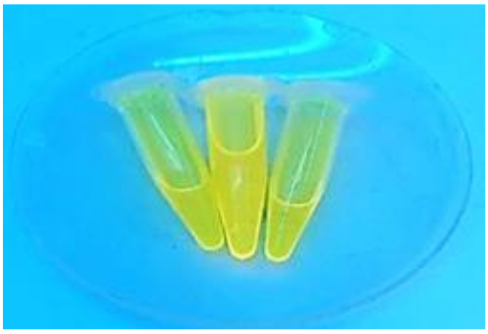

Figure 3. Polyvinyl acetate polymer composite with carbon and silver dots.

Finally, the resulting nanofibers are used in smart masks. These nanofibers have antibacterial properties and can easily identify the color of pollution by photoluminescence (light emission in response to an optical material). This means that when the nanofibers come into contact with the color of pollution and absorb light corresponding to that color, they produce photoluminescence, which can be used to identify and distinguish the color of pollution. After the reactor and washing are finished, ultrasonic waves with a power of 1000 watts were used for 60 minutes to ensure that the carbon plates were nanoquantized. The carbon dots of the carbon plates, which are made of single-layer graphene sheets, are very small and are nano in three directions. These particles have intense quantum dots and, due to quantum confinement, have different and unique properties. Due to the characteristics of quantumization and discreteness of electron levels in carbon dots, these carbon sheets can have unique electronic and optical properties. These properties include luminescent colors and quantum electronic properties that can be used in various research and applications of nanoelectronics, nanophotonics and other fields of nanotechnology. The resulting nanofibers have yellow and gray colors (due to silver) and are collected on aluminum foil (Fig. 4.).

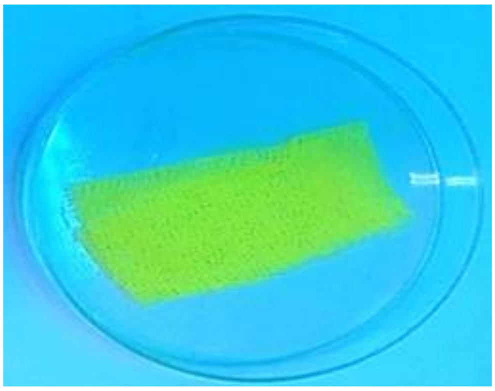

Figure 4. Polyvinyl acetate nanofibers containing yellow and silver-gray nanoparticles.

These nanofibers are separated as a thin layer after collection and removal of excess, like tissue paper. This nanofiber layer is ready to be used in the manufacture of smart masks with antibacterial and photoluminescent properties. Fig. 5. shows the spun polymer of the nanocomposite. The polymer is initially white, but with the addition of nanoparticles, its color appears orange.

Figure 5. Nanocomposite spun polymer.

The results and analyses from the experiments were carefully examined using various techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL) spectroscopy.

3. Results and Discussion

In this section, the crystal structure of nanomaterials has been investigated using the X-ray diffraction pattern technique. This analysis plays a significant role in better understanding the crystal properties and atomic structure of nanoparticles used in masks. In this section, the crystal structure of nanomaterials has been investigated using the XRD technique. According to Fig. 6, the X-ray diffraction (XRD) pattern of silver nanoparticles usually contains peaks that correspond to the face-centered cubic (FCC) crystal structure of silver. These peaks indicate the presence of regular crystal structures in the nanoparticles. The main peaks in the XRD pattern of silver nanoparticles are usually seen at 2θ angles of 1.38°, 3.44°, 4.64°, 4.77° and 5.81°, which correspond to the (111), (200), (220), (311) and (222) planes, respectively (Table 1). These angles correspond to the FCC structure of silver.

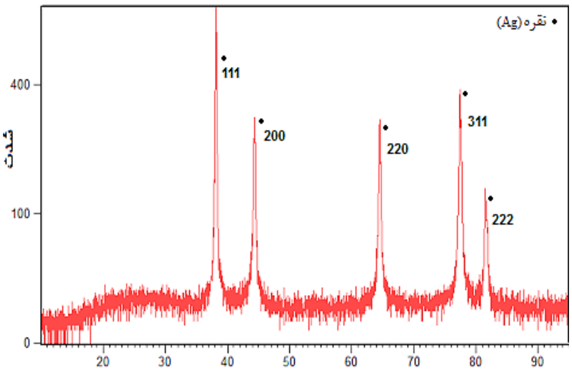

Figure 6. X-ray diffraction pattern of silver nanoparticles.

Fig. 7. shows the EDAX analysis of silver nanoparticles. It can be used to identify different phases in silver nanoparticles, especially if the nanoparticles are synthesized in more complex environments.

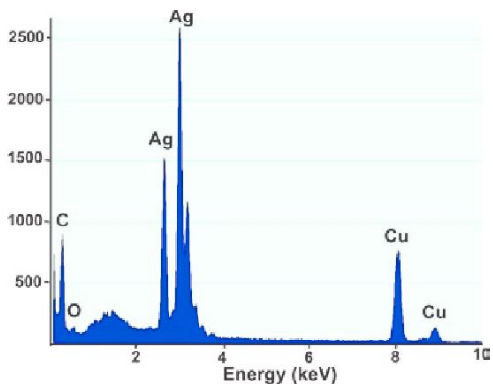

Figure 7. EDAX analysis of silver nanoparticles.

However, it was observed that the general trends of the calculated C4 form factors inadequately mirrored the Experimental data. The behavior of the nuclear form factor in this context may be influenced by the Scanning electron microscope (SEM) images show the surface structure and appearance of nanofibers. With this technique, more information is obtained about the shape, size and surface composition of nanomaterials. In order to investigate the shape and size of the produced silver nanoparticles, SEM images were used, which are shown in Fig. 8. According to the SEM images, the silver nanoparticles are spherical in shape and relatively uniform in size. Fig. 8. shows the scanning electron microscope image of silver nanoparticles. These nanoparticles were prepared on a scale of 500 nm and were arranged in a regular manner. The average crystallite size was measured to be about 50 nm.

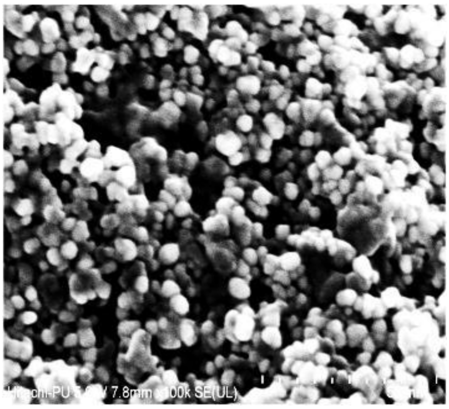

Figure 8. Scanning electron microscope image of silver nanoparticles.

Carbon and silver nanoparticles have been used to make nanofibers using the electrospinning method. This process involves applying voltage to polymer salts to form fibers in which carbon and silver nanoparticles are uniformly and uniformly embedded throughout the fibers. Voltages of 10 and 20 kV have been used to make nanofibers (Fig. 9.).

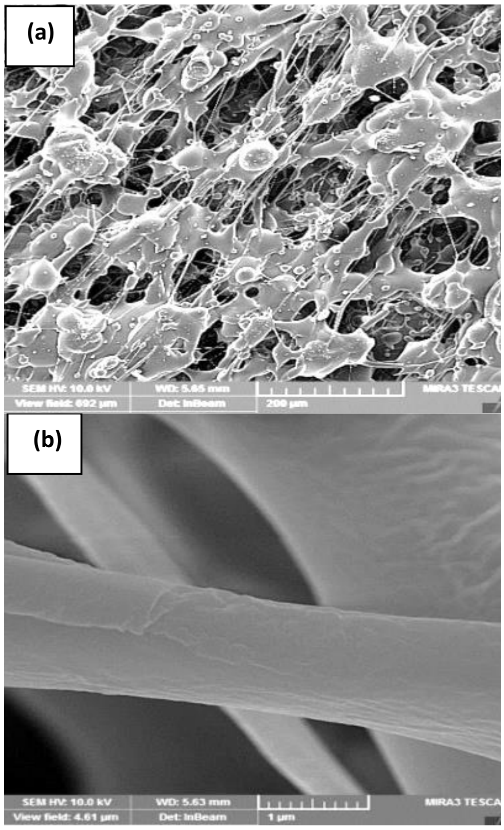

Figure 9. Scanning electron microscope image of nanofibers (a) with applied voltages of 10 kV and (b) 20 kV.

Table 1. Characteristics of silver nanoparticle crystal sheets.

Description	Peak width at half height	Crystal screen specifications	2θ	Peak
Main Peak, FCC Silver Phase Approval	0.1771	FCC-111	38.1	Peak1
The second main courier	0.4723	FCC-200	44.3	Peak2
The third main courier	0.6298	FCC-220	64.4	Peak3
The main fourth courier	0.5760	FCC-311	77.5	Peak4
The main fifth peak	0.6386	FCC-222	84.3	Peak5

These voltages were required to apply waves to the polymer salts and form fibers. For the synthesis of silver nanoparticles, 200 watts of power was used to apply ultrasonic waves. Photoluminescence, or light emission in response to light, is a technique that measures the photoluminescence of nanomaterials. This analysis helps to study the optical and electronic properties of nanoparticles.

Fig. 10. shows the photoluminescence spectroscopy of nanofibers composed of silver nanoparticles, in which the effect of pollution and bacteria on the luminescence of a smart mask as a detector is investigated. When interfering substances such as bacteria or heavy metals and ions enter the luminescent material, they excite electrons and cause light to be absorbed. The main graph (red) is related to the photoluminescence spectroscopy of nanofibers. This graph shows the luminescence properties and the electronic properties of the nanofibers. The two green and blue graphs are lower energy and probably represent different effects of pollution and bacteria on luminescence.

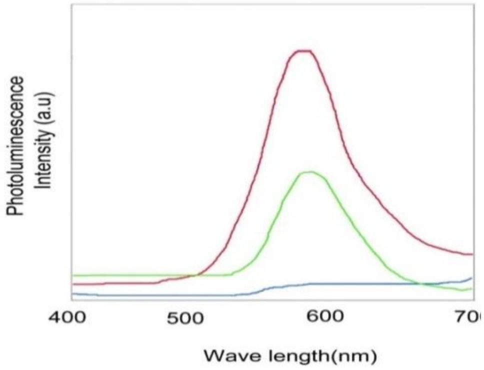

Figure 10. Photoluminescence spectroscopy of nanofibers composed of silver nanoparticles and carbon nanoparticles

Results of antibacterial testing using important bacteria, coliform, have been produced to evaluate the effectiveness of masks containing nanoparticles. These results show the protective importance and safety of the final products.

The testing process is as follows: first, silver nanoparticles and carbon nanoparticles are prepared using the synthesis process explained in the previous steps (Fig. 11.).

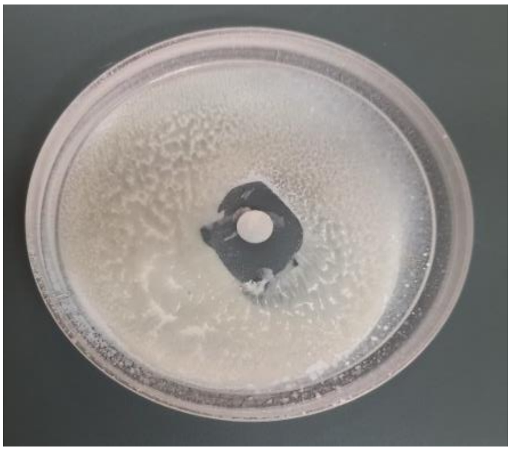

Figure 11. Coliform bacteria.

The resulting nanoparticles are dissolved in a solution and are spread on disks by electrospinning to form nanofibers. We have placed nanofibers containing silver nanoparticles and carbon nanoparticles on culture disks. The disks have been placed in the bacterial culture medium for several hours to examine the antibacterial effect of nanofibers on bacteria. After a certain period of time, halos have been observed around the disks. The observed halos indicate the inhibitory and antibacterial effect of the nanofibers on coliform bacteria. Based on the observations, it can be concluded that the nanofibers used in this experiment have desirable antibacterial properties and can be effective in controlling and preventing bacterial growth.

4. Conclusions

The results of this research in the field of manufacturing nanofibers containing carbon quantum dots for use in smart masks, with emphasis on antibacterial properties and photoluminescence for identifying the color of pollution, have been carefully examined. Initially, the manufacturing of carbon nanoparticles using citric acid and ethylene diamine was described. Then, silver nanoparticles were obtained by ultrasonic method and optimized using solvents and Buchner funnel. These silver nanoparticles were used as antibacterial material in nanofibers. Using analytical techniques such as X-ray diffraction pattern, scanning electron microscopy, and photoluminescence spectroscopy, we analyzed the results accurately and completely. Finally, the results obtained from the research well confirm that nanofibers made from carbon and silver nanoparticles, with antibacterial properties and suitable photoluminescence capability can be used in the manufacturing of smart masks for identifying the color of pollution in the surrounding environment. The synthesis method of carbon and silver nanoparticles was obtained using citric acid and ethylene diamine, and these nanoparticles were used as the main materials in the preparation of nanofibers. Using scanning electron microscopy, the details of the surface structure of the nanofibers were determined and the structural features were determined. The resulting nanofibers with suitable antibacterial and photoluminescence properties are used as the main component in the production of smart masks to identify the color of environmental pollution. The results of the antibacterial test of nanofibers containing silver nanoparticles and carbon nanoparticles show that these nanofibers have the ability to reduce the growth of bacteria. This property can be used in various applications such as the production of antibacterial masks. The results of these tests show that nanofibers containing silver nanoparticles and carbon nanoparticles have antibacterial properties. These observations point to the development of antibacterial and hygienic products, especially in the field of smart masks.

Authors Contribution

All authors conceived of the study, participated in its design and coordination, drafted the manuscript, participated in the sequence alignment, and read and approved the final manuscript.

Availability of data and materials

Not applicable. In fact, all results are obtained without any software and found by manual computations. In other words, the manuscript is in the pure mathematics (mathematical analysis) category.

Conflict of interests

The author states that there is no conflict of interest.

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