RESEARCH ARTICLE

Synthesis of gold nanoparticles for being used in the production of conductive inks

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ABSTRACT

Conductive inks resemble standard conventional printing inks, but they must also conduct electrical current efficiently. In this study, gold nanoparticles were initially synthesized using glucose and characterized. The physical methods performed indicate the formation of gold nanoparticles. X-ray diffraction spectroscopy employed to confirm the formation of gold nanoparticles and ascertain their crystal structure. The resulting nanoparticles used to create conductive inks based on previously published methods. The electrical resistance of the glucose– gold nanocomposite film measured after drying at 60°C using a digital ohmmeter. The electrical resistance of the film found to be 0.00045 Ω, significantly lower than that of glucose without gold nanoparticles (210 Ω). This reduction in electrical resistance compared with the film without gold nanoparticles, indicates the enhancement of electrical conductivity due to the addition of gold nanoparticles. A microwave method proposed for the quick and direct preparation of nano ink. Conductive inks have many uses in the industry.

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INTRODUCTION

Conductive inks enable the fabrication of printed electronic devices that offer significant advantages over conventional silicon-based electronic devices [1]. Their versatility is one of their most attractive features, as they can be used to create a variety of devices, including printed circuits, wearable sensors for remote health monitoring, flexible electrodes, photovoltaic cells, flexible displays, and light-emitting diodes. Additionally, organic light-emitting diodes, thin-film transistors, smart fabrics, and other products have been developed using these inks [2]. Typically, these devices are manufactured by applying conductive ink to a substrate through various printing techniques, such as flexography, inkjet printing, screen printing, and pattern printing [3,4]. Conductive inks, including conductive materials in solvents or solvent compositions, contain coupling agents, surfactants, or polymers as stabilizers [5]. One-step printing of electrically conductive inks on textiles is one of the simplest and most promising methods for producing wearable electronic devices.

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EXPERIMENTAL

The necessary ingredients included auric acid tetrachloride; Merck Germany), Acetone (Majlili, Iran), Methanol (Merck Germany), Glucose (+) (German Merck) and Nitrocelloulose (.Merck Germany),

For the manufacturing and characterization of gold nanoparticles and conductive ink, spectroscopic and imaging equipment and devices as well as laboratory equipment are required, which are Ultraviolet-visible spectrometer, X-ray diffraction spectrometer, Fourier transform infrared spectrometer, transmission electron microscope, scanning electron microscope, and digital ohmmeter.

Synthesis of gold nanoparticles

A reducing agent and a stabilizing agent are generally required for the synthesis of metal nanoparticles. In this study, glucose, a reducing monosaccharide [6], is simultaneously employed as both a reducing and stabilizing agent.

To synthesize gold nanoparticles, a 0.001 M solution of salt was prepared. This solution was created by dissolving 0.04 g of Au- salt in 100 ml of distilled water. Next, a 1 mM glucose solution was prepared by dissolving 0.7 g of glucose in 250 ml of water. Glucose was added drop by drop to the gold salt solution, which had been alkalized using a 0.1 M sodium hydroxide solution. Throughout this process, the solution was stirred at room temperature with a stirring rate of 1500 rpm. Once the gold nanoparticles had formed, a centrifuge at 13,000 rpm was utilized to precipitate the particles, separating the upper solution.

To remove any unreacted reagents, the obtained sediments were cleansed with deionized water and gold nano particles were redistributed using an ultrasonic bath. Washing process was done three times, and in the third repetition, the sediments were dried using a freeze dryer.

Characterization of synthesized nanoparticles

To achieve this, the absorption spectrum of the solution was acquired within the 300 to 700 nm range to ascertain the surface plasmon resonance (SPR). This task was executed employing a UV-VIS spectrometer from Varian Company, with measurements undertaken at specific time intervals .To ascertain the crystal structure of the nanoparticles, gold nanoparticles were dispersed in acetone via ultrasonic bath treatment. Subsequently, a nanoparticle layer was deposited onto a microscope slide. The acquisition of X-ray diffraction (XRD) spectra from these deposited layers was carried out using a Seifert XRD apparatus from Germany, encompassing measurements within the 2θ angle range of 10 to 80 degrees. Identification of both the nanoparticles and their respective crystal structures hinged upon the analysis of peaks discerned at specific 2θ angles, correlating with their Prag values.To assess particle morphology and size, transmission electron microscopy (TEM) imaging techniques were employed. In this procedure, the nanoparticles were redispersed in deionized water, and a droplet was deposited onto the carbon grid of a TEM device.

Conductive ink

Conductive ink was formulated by incorporating gold nanoparticles, following the procedure outlined by Camargo et al. [6]. In alignment with this methodology, 0.5 grams of gold nanoparticles, synthesized through the involving glucose, was blended with an equivalent amount of nitrocellulose, serving as the polymer component, within a centrifuge tube. Acetone was employed as both a dispersing agent and a lubricant, facilitating the uniform dispersion of the gold nanoparticles within the mixture. Subsequently, this amalgam was subjected to ultrasonic agitation in a bath for a duration of 20 minutes, maintaining a temperature of 25 degrees Celsius to ensure the even distribution of the gold nanoparticles throughout the medium.To evaluate the electrical conductivity of the formulation, 1 milliliter of the nitrocellulose composite containing gold nanoparticles was applied onto a microscope glass slide, and its electrical resistance was quantified using a digital ohmmeter, yielding measurements within the micro-ohms range.

RESULTS AND DISCUSSIONS

To monitor the progress of the reaction, the absorption rate of the solution in the Surface Plasmon Resonance (SPR) region of the resulting gold nanoparticles was measured. Spectroscopic studies were conducted using UV-Vis spectroscopy in the range of 300 to 700 nm, starting from the moment the reaction commenced and continuing every half hour for 2 hours thereafter (Figures 1).

Based on the SPR absorption of gold nanoparticles within the range of 530-545 nm and the presence of a peak at approximately 532 nm, this can be attributed to the formation of gold nanoparticles and the emergence of the SPR absorption peak within the mentioned range. X-ray diffraction spectroscopy was employed to confirm the formation of gold nanoparticles and ascertain their crystal structure. As mentioned earlier, for this purpose, the colloidal mixture of gold nanoparticles, produced using glucose, was subjected to a refrigeration drying method after precipitation through centrifugation at 13000 rpm and subsequent washing with deionized water. To obtain the XRD spectrum, the obtained gold nanoparticles was redisposed in acetone and a thin layer of nanoparticles was deposited onto a microscope slide. Subsequently, the XRD spectrum (as shown in Figure 2) was recorded over the 2θ angle range of 10 to 80 degrees, utilizing a copper lamp.

The resulting image from the transmission electron microscope (Figure 3) shows the resulting gold particles, which are spherical in shape and have an average size of 19.42 nm.

The ink based on gold nanoparticles, which contained 50% by weight of gold nanoparticles coated with glucose and 50% by weight of nitrocellulose, was fixed as a layer on a glass microscope slide (Figure 4) at a temperature of 60 degrees Celsius.

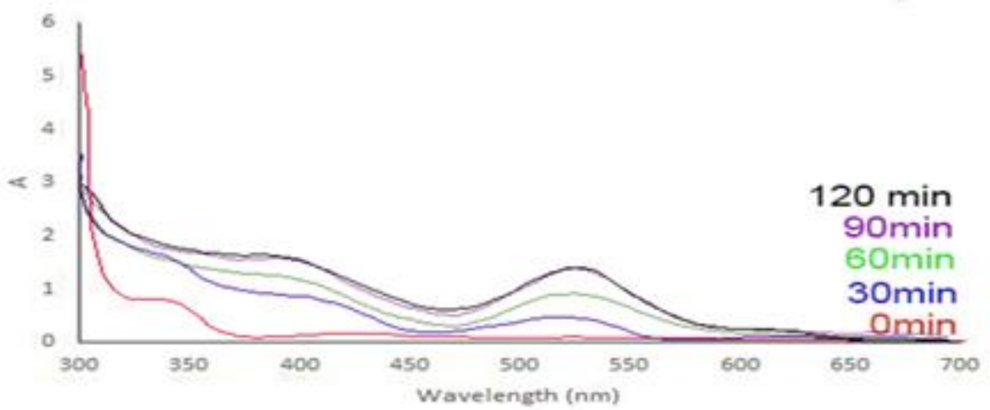

Figure1- UV-VIS absorption spectrum at different times (0-120 min)

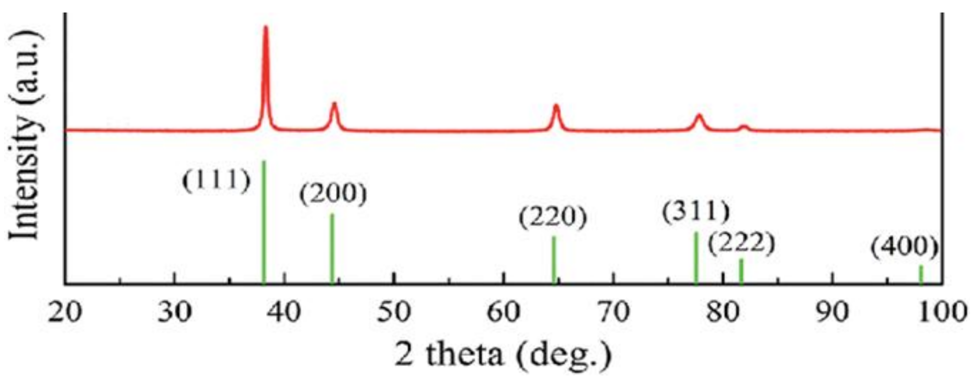

Figure2 - XRD spectrum of gold nanoparticles

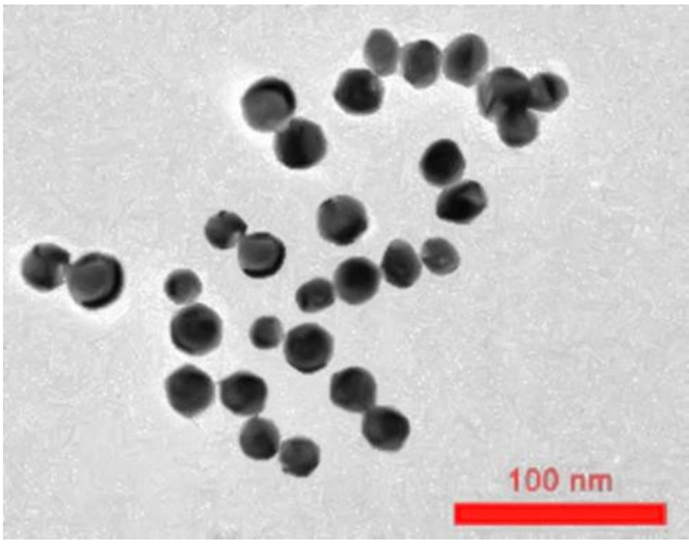

Figure 3- Electron microscope (TEM) image of the synthesized gold nanoparticles

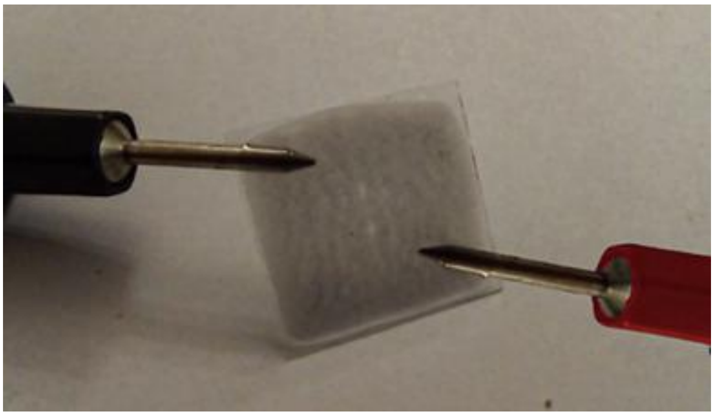

Figure 4: Nitrocellulose nanocomposite film - gold nanoparticles

The measured electrical conductivity of the nanogold-nitrocellulose composite film was found to be 0.00045 ohms. In comparison, the nitrocellulose film without gold nanoparticles had a much higher resistance, measuring 210 ohms. This significant difference in resistance indicates that the incorporation of gold nanoparticles into the nitrocellulose film has greatly improved its electrical conductivity. Therefore, the synthesized composite film is electrically conductive, which is a desirable property for various applications in electronics and materials science.

CONCLUSION

The decrease in electrical resistance compared to the nitrocellulose film without gold nanoparticles indicates the emergence of electrical conductivity due to the addition of gold nanoparticles to the nitrocellulose film. Here are some results of other investigations that are done on conductive inks. A microwave method was proposed for the quick and direct preparation of nano ink. The conductive ink consists of gold nanoparticles and gold nanorods as conductive components. Nano-Gold with different sizes can provide high conductivity. The prepared conductive ink can be stored for 20 days without affecting its usability. The resulting ink exhibited significant conductivity at low gold concentration (0.025 M) [7].

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