Preparation and characterization of graphene nanosheet doped with silver nanoparticles

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Abstract. Simple process (exploding wire technique) was used to Prepared silver nanoparticles (AgNPs). The graphene sheet was added to AgNPs with different concentrations (0.002g/ml and 0.01g/ml). well dispersion of AgNPs are achieved by simple chemistry process. The samples were characterized by ultraviolet-visible spectroscopy (UV-Vis),x-ray diffraction (XRD), atomic force microscopy (AFM) and Field emission scanning electron microscope (FESEM). The results showed a wide band absorption of AgNPs-graphene (AgNPs-GN) extended from UV to IR region, surface plasmon resonance (SPR) absorption peak position for the AgNPs at (350-600) nm, XRD confirmed the clear distribution of the peaks attributed to polycrystalline for AgNPs appeared at $2\theta=38.14^\circ$, $44.27^\circ$, $64.33^\circ$, and $77.37^\circ$ respectively and AgNPs-GN at $2\theta=26.51^\circ$ and $54.65^\circ$. The AFM showed that AgNPs have uniformly distribution on the surface of graphene sheet. The average size of AgNPs was confirmed by around (50-80) nm by FESEM and the AgNPs-GN have average particle size (20-40) nm. The AgNPs-GN could become prominent candidate for optoelectronic applications.

1. Introduction

Because of the large specific surface area, optical transparency, high carrier mobility at room temperature, and electrical, mechanical, and thermal properties of graphene, graphene-based technologies have attracted a lot of attention. [1]. Graphene is a planar sheet of carbon content that is one atom thick (mono layer) and tightly packed in a honeycomb crystal lattice structure. Large surface to volume ratio and highly conductive nature allows it to show amusing characteristics [2]. The single or few-layer graphene sheet shows exceptional optical, thermal, mechanical properties and high electrical conductivity [3–6]. Single or few-layer graphene sheets incorporated nanocomposites were extensively studied and analysed for diverse applications such as field-effect transistors (FETs), fuel cells, photovoltaics supercapacitors, resonators and various energy applications [7–9]. High-quality graphene can be prepared by various methods including micro mechanical exfoliation of graphite, epitaxial growth and chemical vapor deposition (CVD) [10,11]. Because of their unique electrical, optical, physical, chemical, and magnetic properties, nanoparticles have piqued people's interest. Catalysis, optoelectronic materials, magnetic fluids, composite materials, fuel cells, pigments, and sensors are only a few of the applications they have. [12,13].

Silver nanoparticles (AgNPs) can be utilized in a great application; such as, antimicrobial medical materials, surface Plasmon resonance (SPR), sensors, energy storage systems and conducting dough [12,14]. As compared to their bulk principle materials, silver nanoparticles, which are usually smaller than 100 nm and contain 20–15,000 silver atoms, have different physical, chemical, and biological properties. The size and shape of silver nanoparticles have a significant effect on their optical, thermal, and catalytic properties. Silver nanoparticles have also become the most commonly
utilized sterilizing nanomaterials in consumption and medical items, such as textiles, food storage bags, fridge surfaces, and personal attention products, due to their broad-spectrum antimicrobial capacity. A laser beam [15], an electron beam, mechanical milling, electrical exploding wire [16,17], chemical vapor deposition, and plasma enhanced chemical vapor deposition [18,19] have all been used to create metal nanoparticles.

The nanoparticles in this study were created using the predominant spark explosion mechanism, which is a modification of the phenomenon known as electro-explosion of wires (EEW), in which both electrodes export particles when surrounded by a liquid medium. When a high current density passes through the electrodes during their physical contact, the two electrodes melt, vaporize, and transform into plasma. The metal plasma bursts at supersonic speeds, causing a shock wave to propagate through the surrounding medium. Finally, the contact with the liquid resulted in the formation of nanoparticles. In comparison to ambient air, the evaporated particles dissolve more quickly in a liquid. In comparison to EEW in gas, this method has only recently been developed to synthesize metallic nanoparticles in a solution; EEW in liquid has received low attention. Because of its simplicity, efficiency, and low cost, it has become one of the most promising methods for synthesis metallic nanoparticles. The synthesis of nanoparticles in liquid does not necessitate the use of a vacuum system. Furthermore, nanoparticles can be made without impurities in water or any other solution [20]. The properties of nanoparticles synthesized by EEW are influenced by a number of factors, including wire dimensions (diameter and length) and content, electrical circuit characteristics, and ambient medium [21,22]. Graphene and nanometals, such as Ag, Au, and Cu, are now commonly used in chemical, biological sensors, nanomedicine, and solar energy generation [23–26]. Because of its high surface free energy, graphene easily forms agglomeration clusters, which limits its use in bulk materials. As metal nanoparticles are incorporated into GNs, they can prevent agglomeration through increased hydrophilicity, they also have novel physical and chemical properties, making them ideal for making high-performance bulk composite materials. [27–30].

At present works the effect of adding different percentage of graphene to silver NPs was studied. the optical, structural and morphology properties were carried out.

2. Materials Methods

2.1 Preparation of AgNPs
As mentioned earlier, this technique involves passing very high currents through thin metal wires in a very short period of time. Here are the most important factors in controlling EEW:
(1) For the explosion phase, the current I must be very large, which means that very high current densities are required, which leads to some nonlinearity in the volt-ampere properties.
(2) The first stage of EEW a sudden reduction in the diameter of the wire at the explosion point, which effectively reducing the cross-sectional area of contact to 1/100th of the rest of the conductor, causing the explosion, which greatly increases the required current density as the contact is made and broken.
(3) The medium in which the explosion would occur.
The wire is guided through a wire guide and blown onto a board of similar material. To conduct a current, a low DC voltage was used before a marked explosion. The explosion occurred in a medium dense like water. A silver wire of 0.3 mm in diameter and 1 meter in length was used.

2.2 Preparation of Graphene-silver nanocomposites
Graphene was prepared by adding GN powder (0.05 and 0.01) g to 5 mL of distilled water. After 1h of sonication, the mixed solution was stirred for 3-5 days to form a homogeneous GN suspension. Then, 2 mL of AgNPs were quickly added to the above solution while stirring. The same steps for preparing graphene were repeated after addition of the AgNPs solution.
3. Results and discussion

3.1 X-ray diffraction (XRD) studies

Figure 1 illustrates the XRD patterns of (a) AgNPs, (b) GN and GN–AgNPs composites. For AgNPs, the crystalline peaks appear at $2\theta = 38.14^\circ$, $44.27^\circ$, $64.33^\circ$, and $77.37^\circ$ with d-spacing values of $(2.36, 2.04, 1.44, 1.23)$ Å correspond to the (111), (200), (220) and (311) planes, respectively. As seen in Figure 1b, the diffraction peaks of graphene appear at $2\theta = 26.76^\circ$ and $54.86^\circ$ with d-spacing values of $3.327$ and $1.671$ Å correspond to the (002) and (110) planes, respectively. The diffraction peaks of GN–AgNPs appear at $2\theta = 26.51^\circ$ and $54.65^\circ$ with d-spacing values of $3.36$ and $1.67$ Å correspond to the (002) and (110) planes, respectively. However, after the addition process, the peak of diffraction shifted to $26.51^\circ$ with $3.36$ Å d-spacing. This is seen in the increasingly wide d-spacing of $2.36$ to $3.36$ Å.

The AgNPs peak has a very low intensity, decreasing compared to GN and GN-AgNPs indicating that the grains tend to have an amorphous crystal structure.

![Figure 1. XRD patterns of (a) AgNPs (b) GN and GN-AgNPs with different concentrations of graphene.](image)

3.2 Field emission scanning electron microscope (FESEM)

Surface morphology and size of AgNPs were analysis by the Field emission Scanning electron microscopy (FESEM), before and after adding GN. The suspension consisted of nearly spherical particles for the silver with average particle size (50-80) nm. Figure 2 (a, b and c) shows FESEM image for silver nanoparticles before and after adding GN. The distribution of AgNPs on the GN sheets depended on the mixing of AgNPs and GN. Figure 2(a) shows FESEM image for silver nanoparticles before adding GN. Figure 2 (b and c) show FESEM images for silver nanoparticles after adding GN for different concentrations of GN (0.002g/ml and 0.01g/ml) and the AgNPs-GN have average particle size (20-40) nm.

The graphene is very thin and wrapped around silver particles, as shown in Figure 2(b and c). Silver particles, on the other hand, prevented graphene agglomeration, suggesting that the graphene was well dispersed during the ultrasonic crushing process.
Figure 2. FESEM images of AgNPs (a) before adding GN and (b, c) after adding GN.

3.3 Atomic force microscopy (AFM)

Figure 3 (a, b and c) shows AFM image for silver nanoparticles before and after adding GN. Figure (3a) shows AFM image for AgNPs before adding GN. Figure 3 (b and c) show AFM images for after AgNPs adding GN for different concentrations of GN (0.002g/ml and 0.01g/ml). The existence of uniformly distributed AgNPs on the GN nanosheets was revealed by AFM analysis. The rippled like structure of the GN is further confirmed by the AFM study.

Figure 3. Three-dimensional AFM image of Ag NPs (a) before adding GN and (b, c) after adding GN.

3.4 UV-vis Spectroscopy

Figure 4 shows UV–visible spectra of (a) AgNPs, (b) GN and (c) Ag/GN with different concentrations of graphene. We have observed characteristic surface plasmon band at range (350-600) nm, which indicates the Ag nanoparticles formed as shown in fig.4(a). Figure 4(b) shows UV-visible spectra of GN.

The UV-visible spectra of GN contains two distinct absorption bands. At 193 nm, the absorption band was based. Figure 4 (c) shows the UV-vis spectra of Ag/GN composites made with various graphene concentrations. At 386 nm, an SPR band of silver nanoparticles appears in Ag/GN nanocomposite samples prepared at 0.002gm/ml graphene. The SPR band maxima is 377 nm when
graphene concentration is increased from 0.002 gm/ml to 0.01 gm/ml, which can be due to a decrease in silver nanoparticle scale. The lack of AgNPs and graphene absorption peaks in this case indicates that the percentage of silver nanoparticles is very low, which is not picked up in optical absorption measurements.

Figure 4. UV-Vis spectra of (a) AgNPs (b) GN and (c) GN-AgNPs with different concentrations of graphene.

4. Conclusions
In this study, well dispersion of AgNPs is achieved by a simple chemistry process. The XRD confirmed the crystalline structure for Ag NPs and graphene nanosheet. The absorption spectrum (especially the SPR region) indicates the formation of Ag NPs. Morphology test indicated the uniform distribution for graphene and Ag NPs.

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