Research Article

Preparation of Graphene Nanosilver Composites for 3D Printing Technology

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1. Introduction

With the development of industry, the continuous progress of science and human technology, the energy crisis, and environmental pollution have become the problems that people pay more and more attention to. With the emergence of problems such as energy crisis and environmental pollution, people have higher and higher requirements for improving production efficiency and protecting the environment. Most chemical production processes take place in various reactors. The development of structured reactors, catalysts, and adsorbents can effectively improve the reaction activity, increase the heat and mass transfer capacity, and reduce pressure loss. 3D printing is an intelligent production technology based on the Internet of Things, which has developed rapidly in various industries in recent years. Compared with the traditional process, the 3D printing process has the advantages of digitization of the forming process, short product cycle, and many types of materials available. It is especially suitable for the design, development, and management of new products, which is a hot topic in the field of rapid prototyping in recent years. 3D printing technology has developed rapidly, and its applications include rapid prototyping, prototyping, micro-electromechanical manufacturing, and biomedicine. One or more layers of graphene were prepared by separating graphite flakes by the liquid phase method [1]. Nanosilver has important application prospects in the fields of catalysis, optics, surface enhancement, and bacteriostasis. Graphene is widely used in energy storage materials due to its unique electronic properties.
energy band structure endowed with excellent electrical properties. Ag nanoparticles are loaded on its surface, which can improve the electrochemical performance and expand the range of composite materials.

At present, the development of graphene nanosilver composites has become an important topic in the field of graphene-inorganic nanocomposites. Zhi used hydrazine hydrate as a reducing agent, PVP as a dispersant, graphene oxide and silver nitrate as precursors, and prepared nanosilver/graphene composite powder by chemical reduction method under the conditions of reaction temperature of 60 °C and pH value of 6. The effect of silver nitrate concentration in solution on the morphology and structure of nanosilver/graphene composite powder was studied by SEM, XRD, IR, and RAMAN. The results showed that the silver nanoparticles were uniformly distributed in the graphene sheets. Using 0.75 g/L silver nitrate and 0.25 g/L graphene oxide, spherical silver particles with better dispersibility and uniform particle size can be obtained. The size of silver nanoparticles on graphene sheets is centered around 100 nm, but not very practical [2]. Shi investigated oxygen reduction (ORR) and oxygen evolution (OER) in alkaline electrolytes. The LMO-NR/RGO composite was synthesized using cetyltrimethylammonium bromide (CTAB) as a template by a simple hydrothermal reaction and heat treatment. Electron microscopy showed that LMO-NR was uniformly coated on silver nanoparticles in RGO flakes. The special composite form of Ag/LMO-NR/RGO promotes the diffusion of electrolyte and oxygen in addition to increasing the electrical conductivity. Electrochemical experiments demonstrated that Ag/LMO-NR/RGO has a good synergistic effect with Ag nanoparticles, LMO-NR, and RGO. Using this catalyst, a reversible charge-discharge Zn-air battery was fabricated and exhibited good cycle characteristics [3]. Mutuk used a mixture of mixed HaP, chitosan, GNS for GNS, and Si3N4 (SN), binary powder to strengthen the composite of mixed Ti, thereby improving its biosurface function. The industrial applicability of the coating was studied by artificial body fluid experiments. Through the determination of its biological activity and the analysis of its microstructure, it was found that HaP had the greatest effect on pH (pH was 11.80). When pure titanium is 10 d, its mass change is the smallest (0.0005 g). The largest mass change (0.0210 g) was obtained by the HaP-coated titanium composite. Through antibacterial experiments, it was found that the nanofibers doped with silver had good antibacterial properties against Escherichia coli. The fabricated electrospin-coated hybrid composites can serve as potential candidates for dental, orthopedic implants, and tissue engineering [4]. Sandeep reported the selection of levodopa using crude polyphenol oxidase (PPO) immobilized on electrochemically reduced graphene oxide-silver nanoparticles (RGO-Ag) nanocomposite-modified graphite (Gr) electrodes. The graphite electrode was first modified by electrochemical reduction of graphene oxide-silver (GO-Ag) nanocomposite to RGO-Ag nanocomposite on the graphite electrode. Crude PPO extracted from Manilkara Zapota fruit was subsequently immobilized on Gr/RGO-Ag modified electrodes. The surface features of the modified electrodes were analyzed by scanning electron microscopy (SEM). The developed sensor exhibited good electrocatalytic activity for the detection of levodopa in the concentration range of 1–150 μM with a low detection limit and high sensitivity [5]. Since the beginning of the 21st century, composite materials have developed rapidly in the global market, especially in the Chinese market in Asia, and the improvement in the production of space three-dimensional models has been slow. However, the research combined with 3D printing technology will be a promising solution to fabricate terahertz devices with good controllable characteristics and low cost [7]. Yang introduced the preparation methods, development status, and application prospects of ceramic 3D printing and reviewed the recent progress of oxide (Al2O3, ZrO2) and non-oxide (Si3N4, SiC) ceramic suspensions for direct 3D printing and stereolithography. The influence of the molding method on the properties of ceramics is shown, and the development of 3D printing is prospected [8]. These studies provided a detailed analysis of the preparation of graphene nanosilver composites. It is undeniable that these studies have greatly promoted the development of the corresponding fields. We can learn a lot from methodology and data analysis. However, the research combined with 3D printing technology is relatively few and not thorough enough, and it is necessary to fully apply these technologies to the research in this field.

In this article, the nanocomposites were characterized by XRD, infrared spectroscopy, Raman spectroscopy, and other methods. Through XRD, it was found that Ag/rGO appeared silver (111), (200), (221), (310) diffraction peaks. Using sodium hydroxide as a reducing agent, comparing the infrared spectra of GNS and GNS-Ag-2 with GO, it was found that the absorption peak of C=O at 1730 cm⁻¹, the absorption peak of C–OH at 1401 cm⁻¹, and the absorption peak of epoxy all have strong attenuation, indicated that the reducing agent has a certain reducing effect on graphite oxide. The Raman spectral analysis results of GNSs and GNSs-Ag-2 showed that the intensity of the two peaks of GNSs-Ag-2 was seven times that of GNSs peak, indicating that silver
nanoparticles had a significant effect on the Raman signal enhancement of GNs. Through the test of the antibacterial effect of Ag/rGO composites on Escherichia coli and Staphylococcus aureus, it was found that in the fifth hole (drug concentration of 20 μg/ml), Escherichia coli showed an increasing trend, and in the eighth hole (drug concentration of 250 μg/ml), Staphylococcus aureus showed an increasing trend.

2. Methods for the Preparation of Graphene Nanosilver Composites for 3D Printing Technology

2.1. Graphene Nanosilver Composites. Compared with traditional silver, nanosilver has a larger specific surface area and an increased contact surface with bacteria, so its antibacterial effect is increased. However, due to their small size, the dispersion of silver nanoparticles in solution is poor and extremely unstable, and the agglomeration phenomenon is serious. Graphene and its derivatives have received extensive attention due to their excellent properties [9]. The large specific surface area of graphene is suitable as a carrier for nanoparticles, and the excellent performance of nanoparticles can be better played because it improves the agglomeration problem on graphene sheets. The surface and edges of graphene oxide are rich in oxygen-containing functional groups, and its preparation method is simple and can be mass-produced, so it can be used as a precursor of graphene-based composite materials. The functional groups on the surface of GO can not only provide reaction sites for some metal cations, but also improve the water solubility of the composites in water or organic solvents, making them better used in the field of biological antibacterials [10]. The graphene/silver-based composite material not only maintains the excellent characteristics of silver nanoparticles, but also can use graphene as a carrier to reduce the bonding between silver particles, so that it can be evenly loaded on the graphene sheet. This composite material has broad application prospects in transparent conductive films, super-capacitors, sensors, surface-enhanced Raman light scattering, etc. [11].

Graphene is a two-dimensional crystal with a single atomic layer connected by sp² hybridized carbon atoms with a thickness of only 0.335 nm. The graphene structure can not only be used as the basis of other carbon materials, but also has good stability. The connection between carbon atoms is very flexible. Under the action of mechanical force, the surface of graphene will bend to a certain extent. The carbon-carbon bond is difficult to break, so its crystal structure is also stable [12]. The unique single atomic layer structure of graphene determines that graphene has many excellent physical properties.

During the reaction of graphene oxide, the nanosilver particles were successfully loaded on the graphene sheet, which played a role in preventing the re-agglomeration of the graphene sheet that had been exfoliated by intercalation, that is, the generated nanosilver had an effect on the structural defects of graphene. There is a certain modification effect. A schematic diagram of the common preparation method of this composite material is shown in Figure 1 [13].

In microwave synthesis, the reaction system is placed in a microwave field, and the microwave energy is converted into heat energy. When the reaction system as a whole reaches a certain temperature and meets the conditions of the synthesis reaction, the target substance is obtained [14]. Microwave heating is that after the material absorbs microwaves, it will generate energy by itself, so that the entire material can be heated quickly and evenly at the same time.

According to the microwave transmission theory, for example, in a single-layer planar material, the normalized incident impedance $Z$ of a beam of electromagnetic waves incident on the surface of the material from free space is [15]

$$Z = \left(\frac{\mu}{\varepsilon}\right)^{1/2} \tan \left(\frac{2\pi f \lambda}{\lambda} (\mu \varepsilon)^{1/2}\right).$$

In Formula (1),

$$\varepsilon = \varepsilon^' - \varepsilon^\prime,$$

is expressed as the complex permittivity.

$$\mu = \mu^' - \mu^\prime,$$

is the complex magnetic permeability.

When the electromagnetic wave is vertically incident to the material from space, the reflectivity $W$ is

$$W = \frac{Z - 1}{Z + 1}.$$ (4)

The propagation coefficient $\rho$ of electromagnetic waves in a material can be expressed as

$$\rho = \alpha + j\beta = j\left(\frac{2\pi f}{c}\right) (\mu \varepsilon)^{1/2}.$$ (5)

In Formula (5), $\alpha$ is the attenuation coefficient; $\beta$ is the phase coefficient; $c$ is the speed of light; and $f$ is the frequency.

The attenuation coefficient $\alpha$ of electromagnetic waves in materials can be expressed as

$$\alpha = \frac{\pi f}{c} (\varepsilon \mu)^{1/2} \left\{ 2 \left[ \tan \gamma_c \tan \gamma_m - 1 + \left( 1 + \tan^2 \gamma_c + \tan^2 \gamma_m + \tan^2 \gamma_c \gamma_m \right)^{1/2} \right] \right\}^{1/2}. \quad (6)$$
In Formula (6), \( \tan \gamma = \varepsilon' / \varepsilon'' \) is the dielectric loss tangent of the material, and \( \tan \gamma_m = \mu' / \mu'' \) is the magnetic loss tangent of the material.

2.2. 3D Printing Technology. 3D printing (three-dimensional printing) is essentially a rapid process production technology that forms materials at one time. This technology often requires the use of 3D modeling software to digitize documents and slice 3D digital model files: the model is described in the form of thin slices, and the thickness of the thin slices is generally 10–100 microns; no matter how complex the shape of the model is, it is just a simple plane vector scan. In this scan, the contour lines of each layer represent a thin slice boundary [16]. In computer-aided design, digital control, laser technology, and material science and engineering technology, a variety of forming materials are used, layer-by-layer printing, and the materials are layered in various shapes to form three-dimensional objects of any shape. As an emerging rapid additive technology, 3D printing technology has great development space and application prospects. It is a perfect combination of reverse engineering and rapid additive technology, which breaks the traditional mechanical manufacturing method and meets the needs of modern industry for short cycle and rich products [17].

3D printing technology mainly includes photosensitive curing molding, fused deposition modeling, selective laser sintering, layered entity manufacturing, and other processes. Figure 2 is a classification diagram of 3D printing technology by principle [18].

Fused deposition (FDM) 3D printing technology is a kind of rapid prototyping technology. Based on the 3D model, the thermoplastic resin material is used to heat and melt the wire by layer-by-layer accumulation and increase the material to accumulate, cool and solidify on the printing platform, and gradually obtain the solid material. The main printing process is shown in Figure 3, first use 3D software to draw a 3D model, export it in STL format, then import the STL file into the slicing software, set various parameters for printing, and slice the STL file to obtain the layered path G-code code of each slice layer. Move the PLA wire control to the nozzle, and the nozzle is gradually extruded and formed according to the path code [19].

Ideally, the shape of the filament extruded from the printing consumables from the nozzle of the printer is cylindrical, and the shape formed on the platform is usually understood as a regular rectangle. But in fact, it is not a regular rectangle, but a trapezoid-like shape, mainly because the material will spread to the surroundings in a fluid state. At the same time, the material is also affected by the printing speed and extrusion speed. The speed ratio can change the thickness of the material [20]. The following will reset the proportional relationship between the printing speed and the extrusion speed of the printer for composite materials, and select the appropriate printing accuracy [21].

In the case of material extrusion under ideal conditions, the filament is in a natural sagging state when extruded in the nozzle, which can be regarded as a cylinder. When the filament touches the printing platform, it will print a cuboid shape with a certain thickness [22]. However, because the material is affected by its own gravity, fluidity, etc., a final shape of the wire cannot be determined, but it can be simply regarded as a trapezoid-like cross section optimization analysis. Figure 4 is the irregular figure ABCD showing the actual wire output effect on the platform.

Assuming that the printing speed is \( v_1 \), the extrusion speed is \( v_2 \), the diameter of the wire is \( d \), the thickness of the material is \( h \), the volume of the extruded material per unit time is \( V \), the printing material per unit time is \( V_1 \), and the printing time is \( t \). According to the conservation of 3D printing volume, it can be obtained that

\[
V_1 = V_2. \quad (7)
\]

Due to a diffusion phenomenon of the material, the actual effect printed by the material is a closed area composed of arcs AD, BC, and straight lines DC, AB, instead of the rectangular section \( h \times w \) as shown in Figure 4. The arc can be approximated as a sector with OD as the radius and O as the center. The total cross-sectional area is

\[
S_{Total} = 2S_{sector} + 2S_{sector}, \quad (8)
\]

\[
S_{Total} * v_1 * t = \left( \frac{d}{2} \right)^2 * t * v_2. \quad (9)
\]

The diameter of the nozzle of the printer used in the experiment is 0.4 mm, that is, the diameter of the molten wire is \( D = 0.04 \) mm, and the printing accuracy is 0.1mm-0.3 mm. \( L \approx R \).
Since the material is in a fluid state during the printing process, \( \theta \) is greater than \( \pi/4 \), and the viscosity of the material itself is relatively high. When \( \theta \) is less than \( \pi/3 \), the value is \( 1<\tan^2 \theta<3 \), that is, the printing speed is about 6 to 18 times the extrusion speed.

The appearance of printing can be roughly analyzed by two representative appearances, one is a regular pyramid-like structure, and the other is a circular arc top structure.

After analyzing these two structures, the characteristics of other structures can be calculated. Figure 5 is a schematic diagram of the pyramid type and the arc top type, which is used to indicate the existing area error. A layer of printing is arbitrarily selected, and the relationship between the overall surface accuracy and layer height is deduced by calculating the layer formula. When the cross-section is the triangular slope in the left figure, the obtained error \( \Delta S \) is

\[
\Delta S = \frac{h_2}{\tan \beta}
\]

In formula (12), \( \beta \) is the tilt angle of the print. Since the angle does not change, each missing area is the same size. Therefore, under this condition, the printing surface
accuracy is only related to the size of the bottom angle. In the range of 90°, the smaller the angle, the worse the surface accuracy. When the surface of the workpiece is the arc surface in the figure on the right, the missing area $\Delta S$ of each layer of the section is different:

$$\sin \theta = \frac{G_2}{R} = \frac{G_1 + h}{R},$$  \hspace{0.5cm} (13)$$

$$\cos \theta = \sqrt{1 - \left(\frac{R \sin h + h}{R}\right)^2},$$  \hspace{0.5cm} (14)$$

$$L = R (\cos \alpha - \cos \theta),$$  \hspace{0.5cm} (15)$$

$$\Delta S = \frac{1}{2} L \cdot h.$$  \hspace{0.5cm} (16)$$

Then, there are

$$\Delta S = \frac{1}{2} h \cdot R \left( \cos \alpha - \sqrt{1 - \left(\frac{R \sin h + h}{R}\right)^2} \right).$$  \hspace{0.5cm} (17)$$

Since $\alpha$ cannot really reach 90° and can only be approached, and $\alpha$ represents the highest layer $N-1$, the length, width, and height of the 3D printer used in this article are within the range of 350 mm $\times$ 350 mm $\times$ 350 mm, and the printing accuracy is 0.1 mm.

Infill density has a significant impact on print performance. The filling density and filling pattern are the filling part of 3D printing. When printing each layer of the solid, first print the outer outline of the model, and then fill in the outline. The higher the filling density, the more wires are needed, and the higher the density of the printed part. There are three main types of filling patterns: line, grid, and concentric line, as shown in Figure 6.

The main advantage of 3D printing technology is that it does not require molds, let alone mechanical processing. It can directly convert the electronic model data designed in the computer into any real object. And 3D printing technology can print parts that cannot be made by traditional methods. The traditional manufacturing method needs to first make a blank product by pouring metal or plastic into a mold, and then process the blank product, such as cutting and grinding, and the process is complicated.

3D printing technology has a short process cycle and high manufacturing precision. It does not need to spend a long time to manufacture molds, nor does it require auxiliary processing work in the later stage. It avoids the leakage of processing data in various production processes, so it is more significant for the military industry. The one-time molding process also avoids subsequent processes such as welding, and the stability and connection strength between product structures are very good. The products produced can be used in aviation, aerospace, nuclear power, and other industrial applications that require extremely high parts [23]. Since the time for production preparation and different process flows is greatly reduced, the cost for producing small quantities of products is greatly reduced, so it is especially suitable for new product development, single-piece small batch production, and individual production.

The main disadvantage of 3D printing technology is the high cost of equipment, so it is more suitable for the production of customized, small batch or personalized products. If 3D printers are used for mass production, it is not suitable from the perspective of time and cost. The price of consumables for 3D printers is relatively high, and in order to meet different application needs, the development of different printing consumables is still the focus of research. In the long run, improving production efficiency remains a top priority for the development of 3D printing technology.

### 3. Preparation of Graphene Nanosilver Composites for Experimental Preparation

The experimental reagents are graphite powder (particle size $\leq 43 \mu m$); polyethyleneimine (PE I, $M_N = 70000$, viscous liquid); the experimental reagents are all analytically pure. The experimental water was ultrapure water ($pH = 6.1$, °C).
Graphene oxide was prepared by a modified Hummers method, after the oxidation reaction of potassium permanganate in concentrated sulfuric acid and graphite powder, brown graphite flakes with derived carboxylic acid groups at the edges and mainly phenolic hydroxyl groups on the plane can be obtained. The graphite flake layer can be exfoliated into graphene oxide by ultrasonic or high shear vigorous stirring, and a stable, light brown-yellow monolayer graphene oxide suspension is formed in water. Graphene-silver composites were prepared by a microwave-assisted method. Specific steps are as follows:

1. Take 30 ml of graphene oxide solution with a concentration of 0.25 mg/ml and 5 ml of silver nitrate solution with a concentration of 5 mmol/L and ultrasonically disperse for 20 mins to fully mix the two.
2. Prepare sodium hydroxide with a concentration of 0.1 mol/L.
3. Under the action of strong magnetic stirring, take 10 ml of the pro-reactant solution and add it to the mixture of GO and AgNO₃, set the experimental parameters of the microwave heating body, and react for 2 min under the power of 500 W; the whole process is carried out under the condition of mechanical stirring.
4. After the samples were cooled, they were centrifuged and washed to pH = 7, frozen, and then vacuum-dried at 60°C for 12 h, and the prepared Ag/rGO composites were refrigerated for later use.

The printing parameters of FDM 3D printing technology have an important impact on the performance of 3D printed parts. There are many parameters of 3D printing. Among them, the main factors that have a greater impact on the performance of printed parts are slice layer height, filling density, filling pattern, printing temperature, printing speed, printing direction or angle, etc. In order to keep the size of the printed component from changing greatly and to ensure the dimensional accuracy of the component in practical applications, it is necessary to adjust the temperature of the printing head and the hot bed.

Tables 1 and 2 show the setting parameters during the 3D printing process.

4. Experimental Data of Graphene Nanosilver Composites

4.1. Performance Characteristics of Nanocomposites. As can be seen from Figure 7, the graphene oxide nanosilver composite material has silver (111), (200), (221), and (310) diffraction peaks at 38°, 44°, 64°, and 77°. The other XRD patterns of the graphene nanosilver composites did not find this situation, which indicated that the layered structure of the graphite oxide layer or ordered graphene stack is broken. For example, when thin graphite layers are exfoliated and silver nanoparticles are added between the thin graphite layers, the size and distribution of silver nanoparticles can cause irregular changes in the spacing of the thin graphite layers. Graphene oxide was modified into aminated graphene oxide using TETA under alkaline conditions. After ultrasonic dispersion of aminated graphene oxide and AgNO₃ in deionized water, in a high-temperature reactor, the amino groups grafted on the surface of graphene oxide were, not only can reduce graphene oxide to graphene, but also can reduce Ag + to nanosilver particles, which is a one-step hydrothermal reduction method. The research results showed that: under the action of sodium hydroxide, the graphene nanosilver matrix composite can be obtained after adding silver nitrate to graphite oxide [24].

Figure 8 showed the infrared spectra of GO, GNs, and GNs-Ag-2. Compared the infrared spectra of GN and GNs-Ag-2 with sodium hydroxide as a reducing agent with that of GO, the C=O absorption peak at 1730 cm⁻¹, the C–OH absorption peak at 1401 cm⁻¹, and C–OH almost disappeared, and all absorption peaks between 1230 and 1730 cm⁻¹ disappeared. Compared with GNs, the absorption peaks of GNs-Ag-2 were further weakened, and the absorption peaks of C=O and C–OH almost disappeared.

Figure 9 showed the Raman spectra of GNs and GNs-Ag-2. Raman spectroscopy is one of the effective methods to quickly and easily detect the characteristics of carbon materials. The GNs in Figure 9 also have only two peaks, but the intensity ratio of the peaks varies greatly. Table 3 showed the ratio of the two peaks of GNs, GNs and GNs-Ag-2, the ratio of the two peaks of GNs is larger than that of GO, because, after the reduction of graphite oxide by NaOH, the area of sp² hybridized carbon atoms is smaller, which leads to the increase of the peak ratio. In Figure 9, the peak intensity of the GNs-Ag-2 Raman spectral curve is seven times that of the GNs peak, indicating the enhancement effect of silver nanoparticles on the Raman spectral signal of GNs; in GNs-Ag-2, the ratio of the two peak positions is slightly increased compared with GNs, which indicated that the presence of silver nanoparticles is beneficial to the oxidation of graphite and can accelerate the sp³ hybridization of carbon atoms.
4.2. Antibacterial Effect of Samples against Escherichia Coli and Staphylococcus. The microplate reader is a commonly used enzyme-linked immunosorbent assay equipment. Its detection principle is based on the absorption spectrum of substances and visible light colorimetric technology. The microplate reader has the characteristics of rapid detection and micro-application, and is suitable for rapid detection of large samples and research on inhibiting bacterial activity. The effect of Ag/rGO composites on the light absorption values of Escherichia coli and Staphylococcus aureus is shown in Figure 10.

Table 1: Printer parameters.

| Parameters          | Settings       | Parameters          | Settings       |
|---------------------|----------------|---------------------|----------------|
| Nozzle temperature  | 200 °C         | Outer edge speed    | 46 mm/s        |
| Hot bed temperature | 50 °C          | Filling speed       | 85 mm/s        |
| Print speed         | 50 mm/s        |                     |                |

Table 2: Graphene nanosilver printing parameters.

| Parameters                             | Settings   | Parameters                             | Settings   |
|----------------------------------------|------------|----------------------------------------|------------|
| Print layer thickness (mm)             | 0.13       | Filling density (%)                    | 100        |
| Shell thickness (mm)                   | 0.80       | Vertical resolution (mm)               | 0.002      |
| Bottom/top layer thickness (mm)        | 0.42       | Printing temperature (°C)              | 234        |
| Bottom plate temperature (°C)          | 23         | Wire diameter (mm)                     | 1.81       |

Figure 7: XRD patterns of GO, rGO, and Ag/rGO synthesized with different Ag concentrations.

Figure 8: Infrared spectrum of the sample.
As shown in Figure 10, (a) higher value of OD490 indicates that a large number of active bacteria are still present. Overall, the light absorption values of the two bacteria increased with decreasing Ag/rGO composite concentration at different time points. The absorbance curve was almost flat at the beginning and showed an upward trend in the fifth well (drug concentration of $20 \mu g/ml$). At 1 h, the sample and bacteria began to react. Due to the reaction between bacterial mitochondrial dehydrogenase and CCK-8, an orange-yellow water-soluble substance formazan will be formed, the concentration in Figure 10b is $250 \mu g/ml$, but the OD value is higher than the light absorption value of bacteria in other samples with lower concentrations. The reason may be that the high concentration of Ag/rGO composite can directly inhibit the growth of bacteria, and the lower value of OD490 during the measurement process easily affects the precision of the antibacterial test. However, at low concentrations of antibacterial drugs, the growth of bacteria is faster and the OD value is higher.
5. Conclusion

Graphene is a new two-dimensional carbon nanomaterial with excellent properties. It has high optical absorption, high strength, large specific surface area, and low production cost (compared with carbon nanotubes). It is composed of sp² carbon atoms and is the basis of various crystallization theories for carbon materials, and it is an ideal material for the development of high-performance composite materials, which have attracted extensive attention, and these materials can be inexpensively mass-produced. Nanosilver has unique optical, electrical, catalytic, and bactericidal properties. Based on the synergistic effect of the two nanomaterials, graphene-nanosilver composites have shown good application prospects in many aspects. With the continuous in-depth research of graphene nanosilver composites, its application has gradually expanded to various fields such as analysis and detection, industrial catalysis, biological antibacterial, and environmental governance. In this article, graphene oxide and silver nanocomposites were taken as the research objects, graphite oxide (GO) was prepared by the modified Hummers method, and the antibacterial effect of Ag/rGO composites was studied. The results showed that the sample had an obvious bacteriostatic effect on Escherichia coli and Staphylococcus. This opened up a new approach and approach for the development of novel high-efficiency antibacterial composites, which have broad application prospects.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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