Transparent Electrodes Fabricated via Graphene and Silver Nanowire Hybrid Films

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Abstract. The transparent electrodes were fabricated via graphene and silver nanowire hybrid films using vacuum filtration method. The influence of raw material concentration on the structure, morphology and the properties of the thin films were studied. With the content of silver nanowires and graphene increase, the conductivity of the electrodes promote rapidly. However continue to increase graphene and silver nanowires, the electric conductance cannot change but light transmittance decrease.

1 Introduction

Transparent electrodes are critical components of optoelectronic devices such as touch screens, displays and solar cells. Indium tin oxide (ITO) has been the most dominant transparent conductor material. However, further development and application of ITO has been receded due to two issues of its scarcity of supply and fragile ceramic nature.[1-2] These two key issues in the use of ITO are being addressed by the emergence of the next generation flexible transparent materials such as conducting polymers, carbon nanotubes (CNTs), graphene, as well as metal nanostructures.[3-8]

Graphene, a two-dimensional (2D) monolayer sheet of hexagonal sp^2-hybridized carbon atoms arranged in a honeycomb lattice, has attracted a lot of attention since its experimental discovery in 2004.[9] Owing to its remarkable properties, such as large specific surface area, excellent electrical and thermal conductivity, good light transmission and high mechanical strength, graphene-based materials have been developed for active materials of energy storage and conversion, transparent conductors, nanoelectronics, and chemical sensors, etc.[10-19]

Silver nanowires (AgNWs), a one-dimensional (1D) nanometer material, have demonstrated great character on electrical, optical and mechanical properties. The synthesis of transparent conductive thin films with silver nanowires show the advantages of high transparency, low surface resistance, smooth surface and so on.[20-23]

The graphene-AgNWs hybrid films using vacuum filtration method have high conductivity, good mechanical properties, excellent light transmittance, etc. And the films have great prospect in the transparent electrode, microelectronics and other aspects.

2 Experiment

Different volumes of AgNWs dispersion were added into the same volume of graphene oxide (GO) dispersion. Then the mixed dispersion was ultrasonic dispersed. The Transparent Electrodes was fabricated by depositing the dispersion onto the mixed fiber filter paper by vacuum filtration method, then the film is transferred to the PET using isopropanol, and repeatedly washed by acetone and alcohol till the films were washed up.

The films were dipped in 10 mg/mL sodium borohydride solution at room temperature for 30 min and then washed with DI water to remove any residual reductant.

The morphology of the prepared graphene-Ag NWs films were observed with a field-emission scanning electron microscope (FESEM) at an accelerating voltage of 10.0 kV. X-ray diffraction (XRD) spectra were recorded using a Bruker AXS D8 Advance diffractometer with CuKα radiation (λ = 1.54 Å) at a generator voltage of 40 kV and a generator current of 40 mA with a scanning speed of 4°/min. Fourier-transform infrared spectroscopy (FT-IR) was carried out on a Nicolet Nexus 670 spectrometer. UV/visible spectrophotometer test the light transmittance. Sheet resistance were recorded using a RTS-4 4-point probes resistivity measurement system from Guangzhou four-probe Technology Co., Ltd..

3 Results and discussion

XRD pattern of GO is shown in Fig. 1, which reveal information of its structural evolution. GO exhibits an interlayer distance of 0.69 nm corresponding to 2θ of ~14。, indicating an ordered structure. XRD pattern of Ag NWs in Fig. 2, three diffraction peaks correspond to three planes which are (111), (200) and (220), which proved that the material is sliver. In Fig. 3, XRD pattern of graphene /AgNWs composite films shows that the raw materials contain graphene and AgNWs.

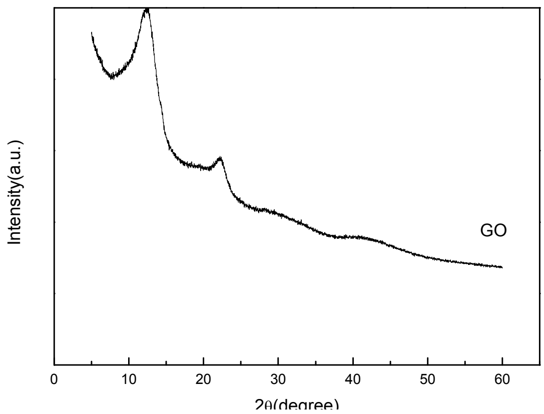

Fig 1. XRD pattern of graphene oxide

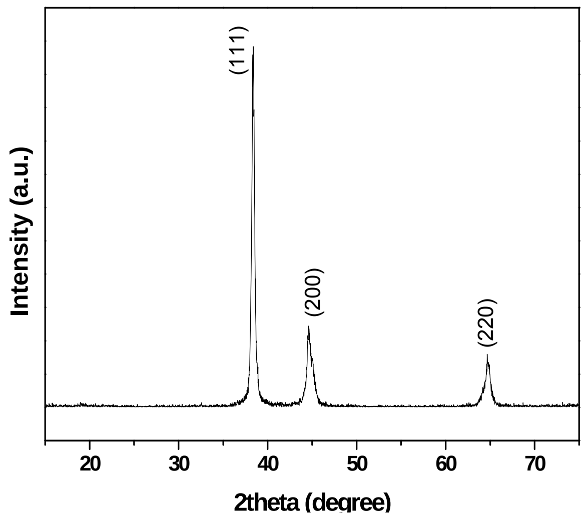

Fig 2. XRD pattern of AgNWs

Fig. 4 a and b are FESEM images of composite films prepared with 0.2 mL of GO and 0.025 mL of AgNWs under different magnifications. From Fig. 4 we can see that Ag NWs have uniform size with length of about 80-100 μ m, diameter of about 100 nm, and graphene intertwined.

Fig. 5 shows the light transmission of the as-prepared electrodes with different concentration of silver nanowires. It can be seen that with certain concentration of GO and different Ag NWs, the optical transparency of the film gradually becomes poor with the Ag NWs content increased. The light transmission of the as-prepared electrodes with different concentration of GO is shown in Fig. 6, demonstrating that with concentration of certain AgNWs, the content of GO higher, the lower the light transmission.

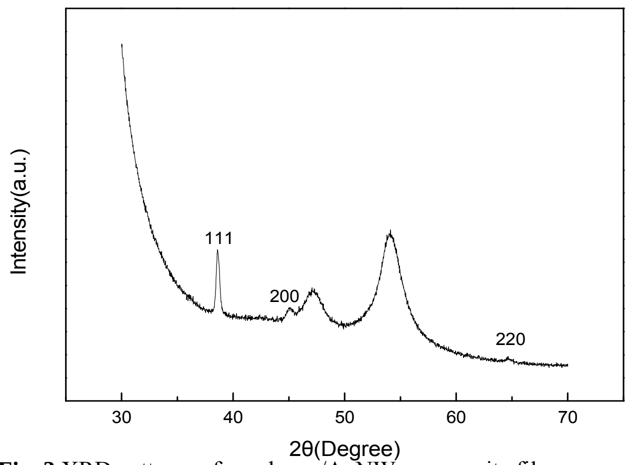

Fig. 3 XRD patterns of graphene /AgNWs composite films

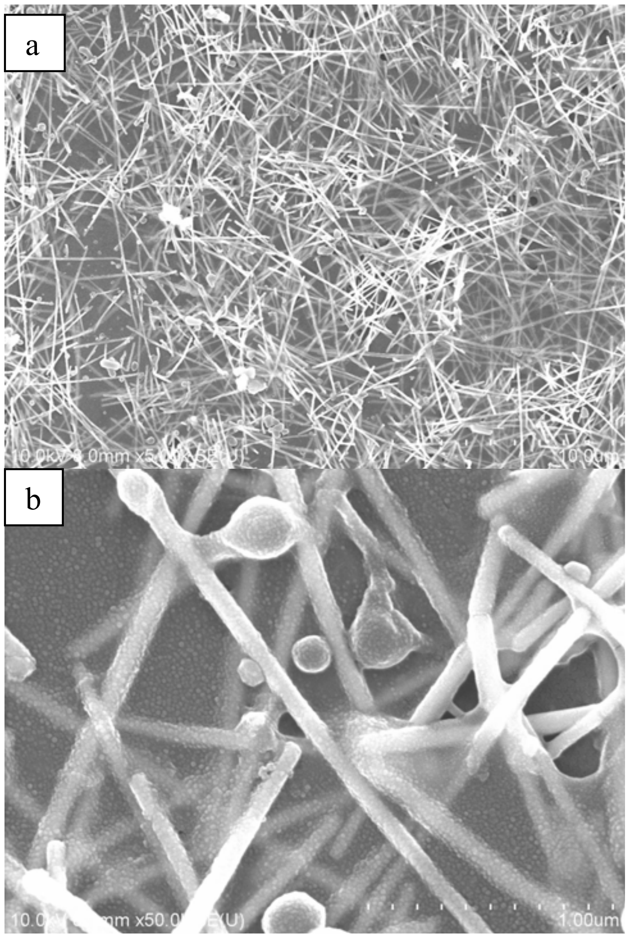

Fig. 4 FESEM images of graphene /AgNWs composite films with different magnifications: a, low magnification and b high magnification

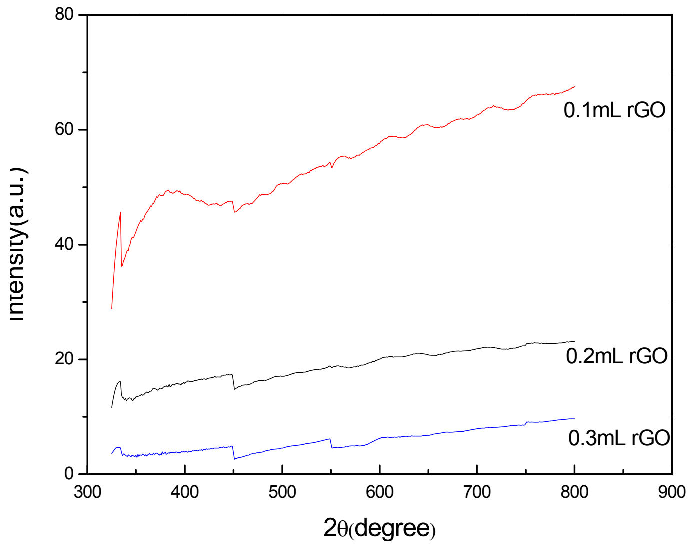

Fig. 5 Light transmission of the as-prepared electrodes with different concentration of AgNWs

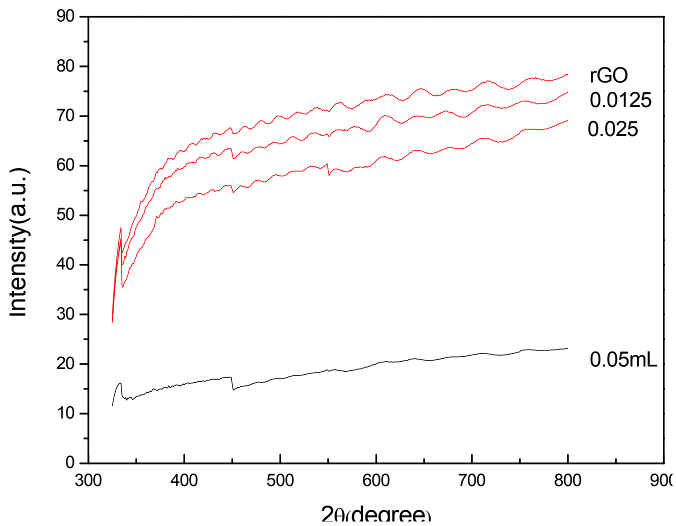

Fig. 6 Light transmission of the as-prepared electrodes with different concentration of GO

In Table 1, Such as samples 1 and 3, it can be seen that the higher concentration of graphene lead to the higher electrically conductive with fixed amount of AgNWs. at the same amount of graphene conditions, such as samples 1 and 2, it can be seen that the less concentration of AgNWs lead to the lower electrically conductive with fixed amount of graphene.

And we can see the resistance of composite films before and after reduction in Table 1. It can be seen that sodium borohydride reducing the composite films will improved its conductive capacity significantly.

Table 1. Resistance of composite films before and after reduction.

Samples	1	2	3	4	5
The volume of AgNWs (mL)	0.05	0.025	0.05	0.025	0.0125
The volume of GO (mL)	0.3	0.3	0.2	0.2	0.2
Resistance before reduction (Ω)	7	1000	4000	900	5000
Resistance after reduction (Ω)	3	76	80	7	860

4 Conclusions

The graphene/Ag NWs composite films were prepared by vacuum filtration method successfully. The silver nanowires content, graphene concentration, and reduction have huge influence on the graphene/AgNWs composite film ' s structure, morphology and conductivity. With the certain concentration of GO and different Ag NWs, the transmittance became lower with Ag NWs content increased. Meanwhile, with the certain concentration of Ag NWs and different GO, the transmittance became lower with GO content increased. Furthermore, the sodium borohydride reducing the composite films will improved its conductive capacity significantly.

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