Optical and Electrical characterization of Silver nanowire-reduced graphene oxide hybrid thin film on PET for transparent electronics

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Abstract. Abstract: Graphene is an excellent nanoscale allotrope of carbon in which carbon atoms are bonded through sp² hybridization. Graphene itself or its thin film exhibits excellent transparency to visible light. Silver nanowires are also being used for making transparent electrodes. Herein, we prepared a thin film of reduced graphene oxide and silver nanowires on flexible PET (polyethylene terephthalate) substrate. Characterization of graphene oxide/reduced graphene oxide has been carried out through X-ray diffraclometry, FTIR (Fourier transformed infrared spectroscopy). Ultraviolet-visible spectroscopy and I-V measurements demonstrated high conductivity and transmittance of the above prepared film.

Keywords: Graphene, Ag, PET, transparent electronics.

1. Introduction

Transparent conducting films (TCFs) have found applications in various electronic devices such as flat panel displays, solar cells, wearable electronics etc. [1]. Indium tin oxide (ITO) has been used at large scale for making TCFs but it suffers from some serious drawbacks like limited availability, high cost and brittle nature [2,3]. Graphene has the potential to replace ITO in electronic industry due to its superior properties like excellent transparency, great mechanical flexibility and low processing cost. Silver nanowires have also been considered as potential candidate for making TCFs [4, 5]. However, nanowire-nanowire junction resistance, high material cost and instability are some of the issues with silver nanowires to be used alone for fabricating thin TCFs [6-8]. In contrast graphene is stable, excellent electronic conductor. A combination of carbon nanotubes and silver nanowires has been utilized to prepare highly conductive TCFs [9-11]. Herein, we have demonstrated the use of a combination of graphene and silver nanowires to prepare high quality TCFs. The properties of graphene and silver nano wires are utilized through a single nanohybrid film. The hybrid will have large number of conductive channels, therefore the percolation threshold will be reduced [12]. Graphene can be easily prepared using Hummer’s method, chemical vapor deposition (CVD), molecular beam epitaxy (MBE) and simple mechanical exfoliation [13-15]. Mechanical exfoliation technique is not suitable for industrial applications, whereas, CVD and MBE techniques cost very high. We have used improved Hummer’s method for producing graphene oxide. In-turn graphene oxide was reduced using ascorbic acid [16].

2. Materials and Methods
2.1 Materials

Graphite flakes were obtained from Sigma Aldrich, India. Chemical reagents, H$_2$SO$_4$, H$_3$PO$_4$ and H$_2$O$_2$ were from Sigma Aldrich, India, silver nitrate (AgNO$_3$), Polyvinylpyrrolidone and ethylene Glycol were procured from Fisher Scientific, India. Ferric chloride (FeCl$_3$) was procured from Sigma Aldrich, India.

2.2 Experimental

Graphene oxide was prepared by following modified Hummers method and reduced using ascorbic acid [15-18]. Silver nanowires were prepared previously reported literature [19]. 1 mg rGO and mixed it in 5 mL of DMF, dispersed through sonication for 30 min and a thin film on PET sheet was prepared by simple drop casting and allowed to dry in an oven for 4 hrs at 40 °C. Afterwards, rGO/PET film was dipped in silver nanowire solution four times and again dried. The schematic of experimental procedure is shown in figure 1.

![Schematic diagram of rGO/PET and PET/rGO/Ag nanohybrid film.](image)

Figure 1: Schematic diagram of rGO/PET and PET/rGO/Ag nanohybrid film.

3. Results and Discussion

XRD pattern of the film is displayed in figure 2. The XRD pattern of reduced graphene oxide gives a characteristic peak around $2\theta=26^\circ$ confirming the effective reduction of GO. The XRD pattern of rGO/Ag thin film showed a peak $2\theta=38.26^\circ$, which is attributed to (111) plane reflection of FCC lattice of silver nanowires [20].
Figure 2: XRD spectra of rGO/Ag nanowire hybrid and rGO.

The wavelength dependence of optical transmittance spectra of rGO and rGO/Ag transparent films are given in figures 3(a) and 3(b) respectively. The observation reflects the good crystallinity of the prepared films. The optical transmittance of the films is about 70% at wavelength 550 nm for rGO which is further enhanced after introducing Ag nanowires in rGO to 82% at wavelength 550 nm [21]. The optical constants of rGO and rGO/Ag were determined from transmittance spectrum of rGO and rGO/Ag nanowire composite.
Figure 3: (a) UV-Vis Spectra of rGO film (b) UV-Vis Spectra of rGO/Ag film.

Figure 4 (a) shows FTIR spectrum of rGO film. The absorption peaks at 1648, 1006 cm\(^{-1}\) attributes to C=C and C-O bond stretching vibrations respectively [23]. Figure 4 (b) shows FTIR spectrum of rGO/Ag nanowire composite film. The absorption band at 3222 cm\(^{-1}\) is due to stretching vibrations of –OH groups on graphene surface. Absorption peak at 1705 cm\(^{-1}\) may be attributed to C=O stretches in PVP or some unreduced part of rGO. 1356 cm\(^{-1}\) is related to –CH\(_2\) bending of PVP, 1250 cm\(^{-1}\) related to CH\(_2\) wagging in PVP, 1098 cm\(^{-1}\) C-O stretching in rGO (unreduced), 860 cm\(^{-1}\) CH\(_2\) bending of PVP, 725 cm\(^{-1}\) due to CH\(_2\) rocking of PVP [24].

Figure 4: FTIR Spectra of (a) rGO and (b) rGO/Ag nanocomposite.
Electrical properties of rGO and rGO/Ag nanocomposite are studied by Current-Voltage (I-V) characteristics. I-V is done by using Keithley source meter 2400. I-V response for rGO and rGO/Ag nanocomposite is shown in figure 5. The value of resistance for rGO and rGO/Ag nanocomposite was found to be $2.6 \times 10^5 \ \Omega$ and $0.5 \times 10^5 \ \Omega$ respectively. The results show that the resistance of the rGO has decreased after introducing silver nanowires.

![I-V graph of rGO and rGO/Ag nanowire hybrid](image)

**Figure 5:** (a) I-V graph of rGO, (b) I-V graph of rGO/Ag

4. Conclusion

In this work we successfully synthesized rGO and rGO/Ag nanocomposite film. The optical and electronic properties of rGO and rGO-Ag Nanowire hybrid are studied. XRD and FTIR verified the synthesis of rGO and rGO/Ag nanowire hybrid.

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