COMPARATIVE AFFINITY OF GRAPHENE OXIDE ON DIFFERENT TEXTILE FIBRES

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Abstract: *Affinity of graphene oxide towards common textile fibre such as cotton, viscose, silk, wool, nylon, acrylic and polyester fibres is studied by dipping this fibres in 1% w/v graphene oxide aqueous dispersion at 70 ℃. Further the treated graphene oxide dip fibre dried at room temperature and subsequently reduced with sodium hydrosulphite. This fibres are treated in loose fibre form to avoid effect of other structural parameter of yarn and fabric. UV-visible spectrophotometry and FTIR (Fourier transform infrared spectroscopy) confirms successful exfoliation of graphite oxide from graphite powder. The graphene oxide treated fibres are characterize with FTIR and SEM (scanning electron microscopy). FTIR spectra suggest intermolecular hydrogen bonding between graphene oxide and cotton, viscose, silk and nylon fibre. SEM micrographs revealed graphene sheets are homogeneously deposited on the cotton, silk and nylon fibre. Add-on per unit surface area of each graphene oxide treated fibre is measured to find best suitable textile fibre for graphene based electroconductive application. Cotton follow by viscose, silk, nylon, fibre in terms of graphene add-on per unit surface area.*

Keywords: *Graphene oxide (GO), interaction, fibre type, electro-conductive textile.*

1. Introduction

Graphene is a flat monolayer of carbon atoms bound together with double electron bonds (termed as sp^2 bond) which is tightly packed into a two-dimensional honeycomb lattice. Due to its outstanding electronic, optical, thermal and mechanical properties, it has attracted great interest as an outstanding candidate for the production of advanced materials with much potential in various applications (Allen, Tung, & Kaner, 2010; Kuila et al., 2012). (Geim & Novoselov, 2007). Application of graphene onto textile substrates will yield a functional composite which will have synergistic properties of both graphene and textiles. Graphene based electro-conductive textiles can be explored for various potential applications such as flexible sensors or wearable electronic, anti-microbial fabric, hydrophobic fabric, chemical and UV resistance fabric, reinforcement of polymers, EMI shielding, saline or effluent water treatment arena etc. In literature, most of the studies related to graphene coated textile are confined in yarn or fabric form such as woven, nonwoven and knitted structures (Chatterjee, Nivas Kumar, & Maity, 2017; Molina, 2016; Tang et al., 2015). With these form of substrates, it is difficult to understand the inherent affinity of graphene towards the fibre material itself as there are several other structural parameters such as pore size, degree of openness of yarn, fabric surface etc. which may influence graphene add-on. Comparative graphene affinity of different textile materials can be judged more precisely when textile substrates are used in loose fibre form and without any surface modification. Therefore, the aim of the present study is to investigate the influence of fibre type and dipping cycle on graphene add-on, to identify the suitable fibre in terms of higher graphene adsorption.

2. Experimental

2.1 Materials and reagents

Graphite powder (particle size -44 microns) is procured from Alfa Aesar (U.K.). Analytical grade sulfuric acid (H_2SO_4), phosphoric acid (H_3PO_4), sodium hydrosulfite ($Na_2S_2O_4$), potassium permanganate ($KMnO_4$), hydrogen peroxide (H_2O_2), hydrochloric acid (HCl), sodium nitrate ($NaNO_3$) and ethanol are procured from S D Fine Chem Limited (India). Milli-Q grade (resistivity of 13 MΩ.cm.) deionized water is used throughout the experiments. Cotton, viscose, silk, wool, nylon, acrylic and polyester fibres are used as substrate.

2.2 Preparation of graphene coated textile fibres

Graphene oxide (GO), synthesised by improved hummers' method (Marcano et al.,2010). Aqueous GO dispersion of 1% concentration is prepared with deionized water as stock solution. Scoured fibres are soaked in the sonicated GO dispersion (M: L ratio 1:50) for 30 minutes at 70℃ and then dried at 75℃. GO treated fibre are reduced with sodium dithionite solution (Shateri-Khalilabad & Yazdanshenas, 2013a). Same procedure is repeated for consecutive 5 cycles and 10 cycles to obtain graphene coated textiles at different dipping cycles.

2.3 Measurement Methods

UV–visible spectra of graphene oxide and reduced graphene oxide are recorded in the range of 220 nm to 800 nm (UV-2600, SHIMADZU UV-VIS Spectrometer). ATR-FTIR analysis of graphite, graphene oxide, reduced graphene oxide and graphene coated fibre samples are conducted in a spectrometer (Carry 630, Agilent Technologies) within the wave number range of 400 cm^{-1} - 4000 cm^{-1}. Surface micrographs of graphene coated textiles are recorded with JEOL SEM analyzer model no- JSM -6510 LV. Magnifications ranging from 1000X to 10,000X.

Add-on per unit surface area is defined as the increase in weight of the fibre after treatment on the initial weight of the fibre with respective to per unit surface area.

$$\text{Add-on per unit surface area (mg/m}^2) = \frac{W_{gf} - W_f}{\pi d l} \quad \ldots\ldots\ldots\ldots (1)$$

Where, W_{gf} is oven dry weight of graphene coated fibre sample, W_f is oven dry weight of fibre sample, d is diameter of fibre in metre and l is length of fibre in metres.

3. Results and discussion

3.1 UV–visible spectra of GO and RGO

Maximum wavelength absorption in graphene oxide recorded at 229 nm (Figure 1.A) is attributed to $\pi \rightarrow \pi^*$ transitions of aromatic C-C bonds which indicates functionalization of graphite with oxygenated functionalities (Çiplak, Yildiz, & Çalimli, 2015). After the reduction with sodium dithionite 229 nm peak red shifted to 264 nm which indicates restoration of graphene π- π conjugation network (Figure 1.B) (Johra, Lee, & Jung, 2014).

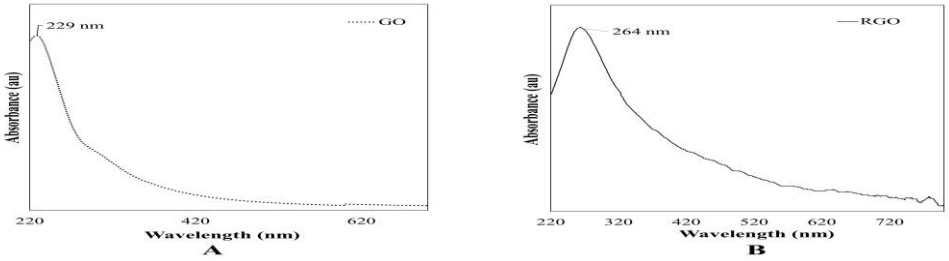
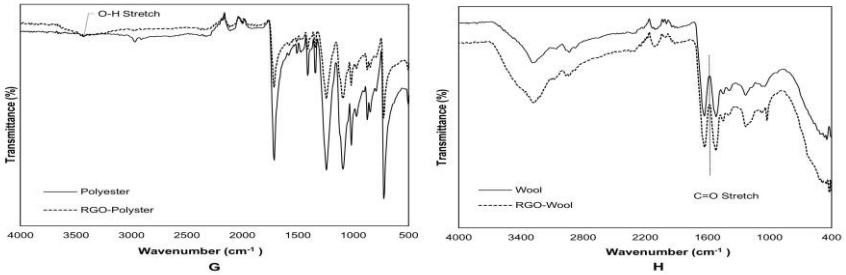


Figure 1: UV- vis absorption spectra of graphene oxide (A) and reduced graphene oxide (B).

3.2 Fourier transform infra-red (FTIR) spectroscopy analysis

FTIR spectra of graphite powder, GO and RGO are shown in Figure 2.A. Vibrational mode spectrum of GO illustrate two characteristics peak at 1635 cm^{-1} and 3308 cm^{-1}, corresponding to stretching vibrations of C=O and O-H respectively, indicating exfoliation of graphite powder to amphiphilic graphene oxide(Pavia, Lampman, & Georg S. Kriz, 2001). In RGO coated cotton spectrum two new bands appears at 1643 cm^{-1} and 1546 cm^{-1} corresponding to C=C unoxidized sp^2 bond and skeletal vibration of graphene nanosheets (Figure 2.B) (Cao & Wang, 2017; Shateri-Khalilabad & Yazdanshenas, 2013b). In FTIR spectra of RGO viscose fibre, the weak band appears at 1565 cm^{-1} may be assigned to C=C skeletal vibration of graphene nanosheets (Figure 2.C). From the FTIR spectra of silk the C-H stretching peak at 2934 cm^{-1} and amide-I band at 1622 cm^{-1} are red shifted to 2886 cm^{-1} and 1618 cm^{-1} after graphene oxide deposition (Figure 2.D)(Fan, 2012; Pavia et al., 2001). In the nylon fibre spectra, peaks arising due to C-H asymmetric stretching vibration are red shifted from 3080 cm^{-1} to 3066 cm^{-1}. Further the C=O stretch and N-H bend are also redshifted from 1634 cm^{-1} to 1629 cm^{-1} and 1538 cm^{-1} to 1533 cm^{-1}(Figure 2.E). From the FTIR spectra of acrylic fibre, peak arising due to C-H stretch is red shifted from 2931 cm^{-1} to 2926 cm^{-1}(Figure 2.F). Compared to FTIR spectra of untreated polyester fibres, the spectrum of RGO coated polyester shows a new broad absorption band at 3428 cm^{-1} which is due to graphene oxide deposition (Figure 2.G). FTIR spectra of Wool fibres show red shifting of C=O stretch from 1629 cm^{-1} to 1625 cm^{-1} (Figure 2.H).



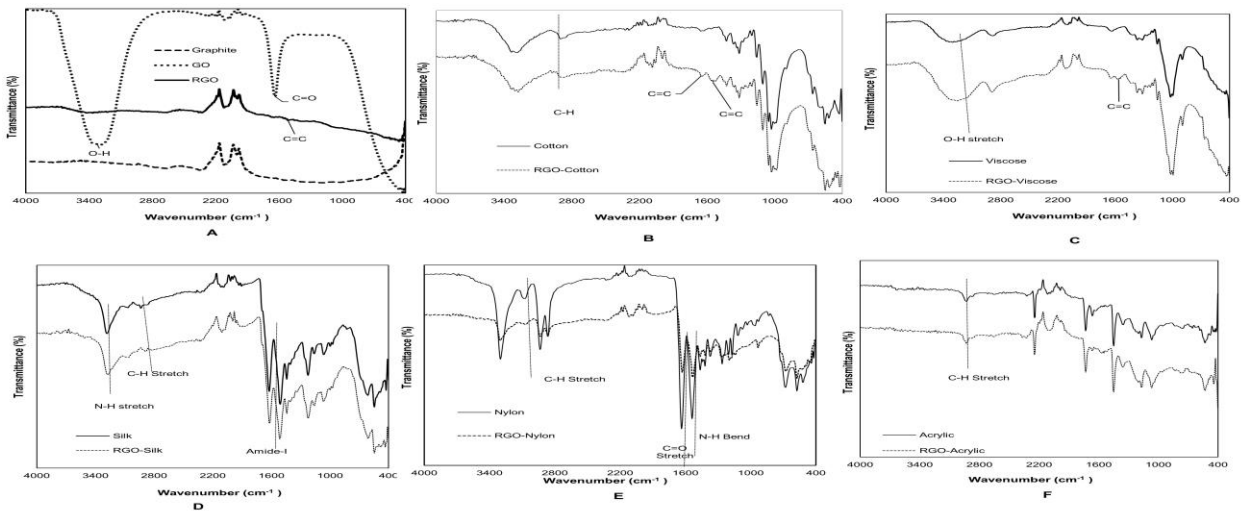


Figure 2: FTIR spectra of (A) graphite powder, GO and RGO (B) cotton (C) viscose (D) silk (E) nylon (F) acrylic (G) polyester (H) wool.

3.3 SEM analysis of GO coated textile fibre

The SEM images of the GO coated fibres are illustrated in Figure 3. Higher GO dipping is observed in cotton compare to other fibres. Relatively uniform distribution of GO sheet is found on cotton, silk and nylon fibre. Localised distribution of graphene is found in case of viscose fibre. It can be observed that the distribution of GO sheets on wool, polyester and acrylic fibre are relatively poor and non-uniform.

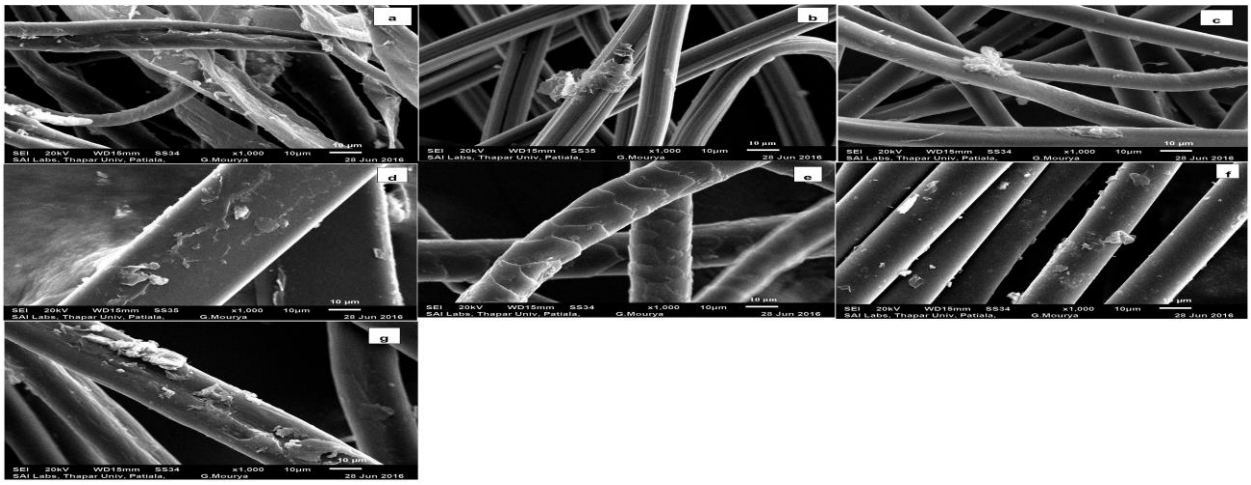


Figure 3: SEM image of RGO coated fibres – (a) cotton (b) viscose (c) silk fibre (d) nylon (e) wool (f) polyester (g) acrylic.

3.4 Comparative assessment of graphene add-on of fibres at different dipping cycle

Dipping cycle vs. add-on curves for different fibres are shown in Figure 4. For first dipping cycle, highest graphene add-on per unit surface area is observed in case of cotton fibre followed by silk, viscose, nylon, wool, acrylic and polyester. For 5 dipping cycles, highest graphene add-on per unit surface area observed in case of cotton followed by silk, viscose, nylon, wool, polyester and acrylic. For 10 dipping cycles, highest graphene add-on per unit surface area observed in case of cotton followed by viscose, silk, nylon, wool, polyester and acrylic. In case of polyester and acrylic fibres no significant improvement in graphene add-on is observed even after 5 dipping cycle.

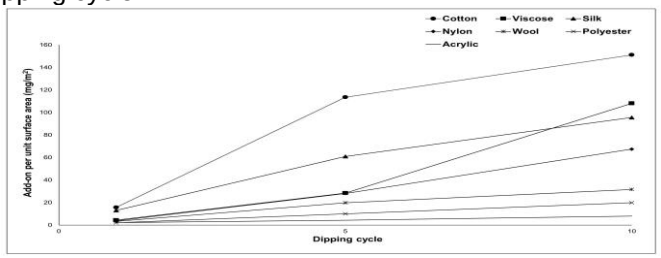


Figure 4: Influence of dipping cycle on graphene add-on for different fibres.

4. Conclusion

Graphene coated cotton, viscose, silk, nylon, wool, polyester and acrylic fibre are successfully prepared by dipping in GO aqueous dispersion. FTIR spectra reveals interaction between graphene oxide and cotton, viscose, silk and nylon fibre. Cotton fibre yield highest add-on per unit surface area in all dipping cycle. Silk yield second highest graphene add-on up to 5 cycle. Further increasing dipping cycle viscose replace silk. Fibre surface texture influence graphene adsorption. SEM micrographs shows GO sheets are relatively uniformly deposited on the cotton, silk and nylon fibre. Poor interaction of graphene with wool, polyester and acrylic is observed.

5. References

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