Reduced Graphene Oxide Coated Conductive Hemp Yarn for Wearable Electronic Textiles Applications

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Literature Review. Electronic textiles, also known as e-textiles, have drawn a growing interest to the researchers in recent years. It has a wide variety of applications including textiles, protective clothing, military, medicals, sports, touch screen displays, energy storage and sensors for a number of areas (Bashir, 2013). Typically, conductive yarns are the prerequisite to functioning smart textiles (Grancarić et. al., 2018). The existing trend of wearable e-textiles is full integration of devices through coating or printing that provides more flexibility, stretchability, and comfort to users (Zeng, 2014). The metal-based wearable technologies are costly, sometimes toxic and nonbiodegradable (Irimia-Vladu et. al., 2012). So, it initiates the development of an alternative to metal-based technologies for wearable e-textiles applications (Afroj et. al., 2020). Natural fiber-based e-textiles are sustainable due to their biodegradability, recyclability, and environmental benefits. Previous studies have already shown that rGO coated natural fibers (cotton, jute, silk) possess a good electrical conductivity and they have diversified applications in e-textiles (Jang et.al., 2021; Karim et. al., 2021).

Over the last few decades, many researchers are paying more attention on graphene coated wearable textiles after the discovery of graphene as a two-dimensional (2D) material with a layer of carbon (Nozariasbmarz et. al., 2021). Due to grahene's some outstanding properties, including extensive surface area, high tensile strength, high Young's modulus, high thermal conductivity, high electrical conductivity, the demand of graphene based wearable e-textiles has increased significantly (da Luz et. al., 2020). This article is mainly focused on rGO coating on hemp yarn (natural fiber) to make it electrically conductive, electrical resistance measurement of rGO treated and untreated hemp yarn and prospects of electrically conductive hemp yarn for wearable electronic textiles applications.

Experimental Methodology.

Materials. Hemp yarn was sourced from Dynamic Wool Solutions, USA. Graphite powder, sulphuric acid, potassium permanganate, hydrogen peroxide, ethanol, 20% hydrochloric acid and L-ascorbic acid were purchased from the Thermo Fisher Scientific, USA.

Synthesis of GO. Graphite powder was used as primary material for the conversion of graphite into graphene oxide. GO was synthesized using the modified hummers method (Hummers Jr. & Offeman, 1958; Park et. al., 2008). In brief, 2g of graphite powder was added to 50ml of sulphuric acid keeping the beaker in an ice bath followed by continuous stirring using a magnetic stirrer. Then 6g potassium permanganate was added slowly keeping the temperature less than 20˚C and the ice bath was removed after 20mins. The solution was stirred for 3hrs. Then 100ml of distilled water was added dropwise keeping the temperature less than 50˚C and thereafter 200ml of distilled water was added instantly. Finally, 10ml of hydrogen peroxide was added to

the solution to stop the reaction. The mixture was centrifuged at 7500rpm for 2hrs, and the bottom fraction was collected. Thereafter, the obtained solid material was successively washed with 200ml of DI water, 200ml of 20% HCl and 200ml of ethanol (2×) with centrifugation at 7500rpm for 2hrs. To adjust the P^H to a neutral level, the supernatant solution was washed multiple times with DI water followed by centrifugation at 7500rpm for 1hr. Finally, the solid material was vacuum dried at 35˚C for 72hrs and obtained GO powder (figure 1.a).
Preparation of rGO coated hemp yarn. A stable suspension of GO with a concentration of 3mg/ml was formed by ultrasonicating at room temperature for 45mins. Then 2 yds hemp yarn (bought scoured and bleached) was dipped into the GO suspension at room temperature for 30 mins, washed with DI water, and dried at 60˚C for 30 mins. The process was repeated 3 times to increase the GO uptake. In the figure 1(b), the GO-coated hemp yarn is shown. The reduction of GO coated yarn was performed by immersing into 50ml of 0.1M L-ascorbic solution, a green reducing agent, at 90˚C for 45mins with constant stirring. Then the sample was washed with DI water and dried at 35 ˚C overnight. The resultant yarn was denoted as rGO coated hemp yarn (figure 1.c).
Results.

(a) (b) (c) (d)

Figure 1: (a) GO Powder, (b) GO coated hemp yarn, (c) rGO Coated hemp yarn, (d) rGO coated hemp yarn conductivity vis connecting LED.

To demonstrate the conductivity of the rGO coated hemp yarn, it was used as electrical connections to light a red LED under 3.5 V that is shown in the figure 1(d). The LED was lit up which indicated that the treated hemp yarn was electrically conductive. In addition, the electrical resistance of rGO coated hemp yarn was also tested as electrical resistance measures the ease with which an electrical current pass and its' reciprocal quantity is electrical conductance. It was found that the linear resistances of rGO coated hemp yarn were 0.06 MΩ/20cm, 0.11 MΩ/40cm, 0.23 MΩ/60cm, 0.29 MΩ/80cm, 0.37 MΩ/m whereas the untreated hemp yarn acts like an insulator (resistance of insulators is infinitely high). The electrical resistance value of rGO coated hemp yarn indicates that the rGO treated yarn possess a good electrical conductivity.
Application of rGO coated hemp yarn. Electrically conductive yarns are being widely used as sensors in medical textiles for health monitoring to measure the temperature, pressure, humidity, light intensity, heart rate depending on the electrical conductivity values (Xue & Tao, 2005; Pötschke et. al., 2010). rGO coated hemp yarn can also be used in this regard. By further conductive polymer coating (such as PEDOT: PSS, Polypyrrole etc) over the rGO coated yarn, it can be used as electrodes used for electrocardiogram (ECG) performance without any exterior masking (Shathi et. al., 2020). Furthermore, conductive yarns can also be used to the production

of fibrous solar cell panels, pressure sensors, and actuators as conductive yarns act as an active substrate for the deposition of multiple layers of different materials (Bashir, 2013). In a sum, this highly conductive rGO coated hemp yarn has multifunctional electronic applications.

Conclusion. In this experiment, attempts were made to produce conductive hemp yarn from commercially available hemp yarn. The hemp yarn was successfully transformed into conductive yarn by rGO coating. For future research, woven and knitted structures can be made using this conductive yarn and tried as sensors in the medical sector. For sustainable energy sourcing, the use of conductive hemp yarn in the field of thermal electricity can also be investigated.

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