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A new approach to fabricate graphene electro-conductive networks on natural fibers by ultraviolet curing method

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ABSTRACT

A new approach has been reported to reduce the graphene oxide (GO) onto the wool and cotton fibers to create electro-conductive networks by UV light. GO was fabricated on the surfaces of cotton and wool fabrics through the brushing and drying technique. The pH of the solution was adjusted to 4.50 before treating wool by GO. After GO coating both the fabrics were passed under UV curing chamber. After treatment GO converted to reduce graphene under the UV light and creates a conductive graphitic colored thin layer on the fabrics. Electrical conductivity is increased as the number of passes increased under UV curing. The surface resistivity of graphene coated cotton decreases from 331.0 to 100.80 kΩ/□ and graphene coated wool shows a decrease from 139.50 to 45.0 kΩ/□ .This is an easy, energy-saving and environmental friendly technique to produce the electrically conductive fabrics by graphene.

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1. Introduction

Recently conductive textile is representing a new class of textiles known as E-textiles or smart textiles. Such conductive textiles are based on conductive coating materials such as nano materials, conductive polymers, metals and alloys. Conductive textiles demonstrating many functional applications like conductive threads, flexible energy storage, electromagnetic shielding, computing, digital component electronics, antibacterial fabrics and wearable sensing in biomechanical monitoring [1–8]. These days E-textiles by using materials such as conjugated polymers, carbon nanotubes and metal-based powders are still popular but these materials are expensive and their applications on textile fabrics requires complicated methods and have some disadvantages such as low outdoor stability, flexibility and non-uniformity of coatings.

Carbon nanotubes were already evaluated by UV blocking on cotton fabrics [9] but no study has investigated the ultraviolet properties of cotton fabrics by graphene and this is the first time we studied the anti UV property of graphene coated cotton fabrics. Exposures of sensitive skins to ultraviolet radiation (UVR) causes problems such as carcinogenesis, cataracts, sunburn, and photoaging. The ultraviolet radiation (UVR) band consists of three regions: UV-A (320–400 nm), UV-B (290–320 nm), and UV-C (200–290 nm). UV-C does not reach to the earth because it is absorbed by the atmosphere. UV-A has reaction on the skin and shown to decrease the immunological response of skin cells but UV-B is most responsible for the cancer [10]. GO and reduced graphene can block UV rays and can provide excellent UV protection to the substrates [11,12].

Now a day's graphene gained high rate of interest for researchers because it has unique properties with good flexibility, mechanically strong, optical and electro-conductive that makes graphene superior to many other conductive materials like metals powder, carbon nanotubes and conductive polymers. Graphene is a light weight paper-like flat two dimensional nanosheet material looks like a honeycomb lattice that tightly stacked on each other like building blocks. A small amount of graphene can give excellent conductivity when it mixed with other material or applied directly to the substrates [13–16]. Graphene structure contains hydroxyl and carboxyl groups on the edges so it can easily disperse into water and other organic solvents [17–20].

In last few years the popularity of graphene in textile applications is increased because of its interesting multifunctional properties like conductivity, supercapacitor, photocatalytic activity, hydrophobicity and antibacterial on different textile materials like cotton, acrylic and polyester [21–25]. Methods for reducing GO onto the textiles substrates included chemical reduction by using different reducing agents and thermal reduction by high-temperature annealing under chemical reducing gases and/or inert

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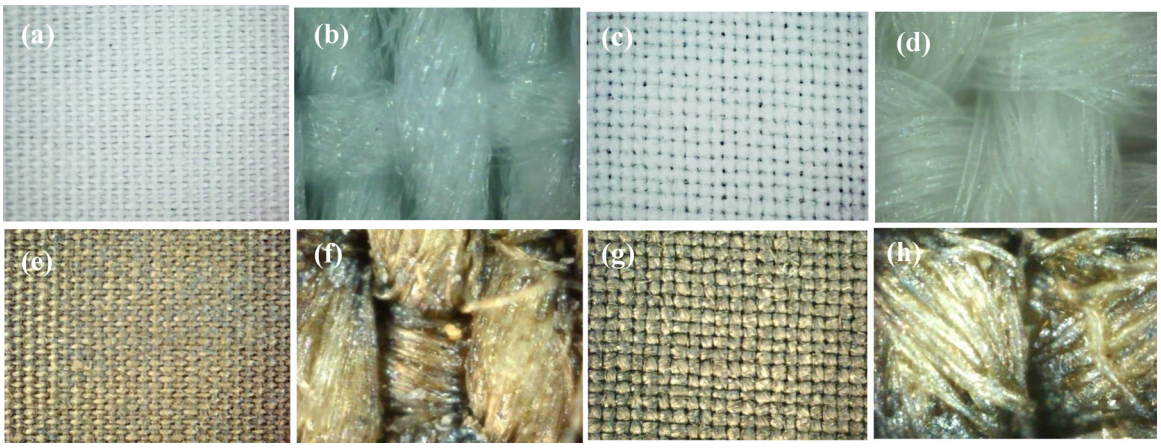

Fig. 1. Macro and micro images of PC and PW (a, b and c, d) and GOC and GOW (e, f and g, h).

atmospheres were investigated [21,23,26,27]. Although several of these methods demonstrated relatively high-quality reduction of GO, but many of them are limited because of expensive equipment, chemicals and complex methods. Reduction by high annealing temperatures can decompose the fiber structure and original strength also nitrogen impurities in the final product. Therefore, a UV reduction method of GO is an inexpensive process that does not need reducing agents and expensive equipment and high annealing temperatures. This is a simple and direct fabrication of UV light reduced graphene (UVG) on flexible substrates that simplifies lightweight conductive fabrics with good conductivity.

2. Experimental

2.1. Materials

All reagents used were of analytical grade. GO kindly provided by Institute of Coal Chemistry, Chinese Academy of Sciences China. Ammonia solution and acetic acid were supplied by Sinopharm Chemical Reagent Co., Ltd. (China). Pure wool (PW) plain woven fabric (worsted yarn 300 g/m^2) supplied by Wuxi Xiexin Worsted Spinning Weaving and Dyeing Co., Ltd. (China). Pure 100% cotton fabric (PC) plain weave (141 g/m^2) was used, which was produced by Jiangsu Hongdou Industrial Co., Ltd. (China).

2.2. Preparation of GO coated wool and cotton fabrics

GO dispersion was made by a bath sonicator (SK2510HP KUDOS, Shanghai, China). In detail GO was dispersed in ultrapure water with the concentration of 2 mg/mL and sonicated at 300 W for 60 min. Initial pH value of GO dispersion was neutral (7.00) which was measured by a digital pH-meter at 25 °C then adjusted to 4.50 to the isoelectric point of wool scales [28] by using ammonia solution and acetic acid before coating GO onto wool. A stable homogeneous GO dispersion was painted with a brush onto the cotton and wool fabrics using a brush-coating method [26]. After coating both GO coated cotton (GOC) and GO coated wool (GOW) were subjected to a drying process for the removal of water by putting into an oven at 90 °C for 10 min.

During the drying process, the water evaporates and the GO sheets form an entangled random networks on the fabrics. Repeating this simple brush-coating and drying process 5 times so that a large-area of GO coated on both fabrics was readily fabricated and finally four samples of cotton and wool were prepared by this manner (GOC1, GOC2, GOC3, GOC4) and (GOW1, GOW2, GOW3, GOW4).

Macro and micro images of the samples were taken by USB digital microscope (AM801, Zhongshan Maisi Electronic Technology Co., Ltd., Guangdong, China). PC and PW were shown in Fig. 1(a, b and c, d) while GOC and GOW shown in Fig. 1(e, f and g, h). It is clear from the images that and PC and PW changed the color from white to the yellowish which represents that GO was successfully painted on wool and cotton fabrics.

2.3. Preparation of UV reduced GO on wool and cotton fabrics

GO fabricated fabrics were subjected in a UV-curing line (Rongda Electronic Equipment Co., Ltd., Baoding, China) equipped with a 2000 W medium pressure mercury lamp (light intensity was 100 W/cm), wavelength 365 nm and speed was adjusted at level 1. At this level the transmission speed was 1.2 m/min. The GO coated fabrics were passed from 5 to 8 times under UV curing chamber and four samples were prepared by passing initially GOC1 and GOW1 for 5 times, GOC2 and GOW2 for 6 times, GOC3 and GOW3 7 times and GOC4 and GOW4 for 8 times.

After UV light irradiation the brown color of GOC and GOW changed to a graphitic color [21]. This change of color indicates that GO was reduced and converted to graphene and most of the oxygenated species in GO were remove from the structure. Four samples of UV reduced graphene cotton (UVGC1, UVGC2, UVGC3, UVGC4) and UV reduced graphene wool (UVGW1, UVGW2, UVGW3, UVGW4) were obtained after that samples were placed at 60 °C overnight for further measurements. Macro and micro images after UV reduction of cotton and wool samples were shown in Fig. 2 UVGC (a, b) and UVGW (c, d). From the images it is obvious that the color of the samples were changed from yellowish to graphitic which indicates that the GO was converted to reduced graphene.

2.4. Characterizations

Surface resistivity was measure by four probe multimeter (SZT-2A Genesis Electronics Co., Ltd., China). Scanning electron microscopy (SEM) observations of the surfaces of the fabrics were examined using Hitachi VP-SEM SU1510. Investigations of functional groups of GO-coated wool were confirmed through the Fourier transform infra-red (FTIR) spectroscopy by Nicolet iS10 FT-IR spectrometer. Raman spectra were acquired with a Jobin Yvon Raman spectrometer (LabRAM HR Evolution UV/Vis/NIR) using 532 nm laser excitation. Ultraviolet protection factor (UPF) was measured by using Cary 50 UV/Vis/NIR spectrophotometer (Varian made in Australia).

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