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Cellulose/graphene nanocomposite as multifunctional electronic and solvent sensor material

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ABSTRACT

At present continuous advance of modern electronics, the demand for eco-friendly multifunctional and flexible material importance rapidly grows. Graphene/cellulose nanocomposite with good mechanical, dielectric and electrical performances was reported in this study by combining with modified graphene oxide sheets cellulose in a well-controlled manner. The synthesized nanocomposite was characterized by Fourier transforms infrared, X-ray diffraction and scanning electron microscopy. The performance as solvent sensor was also evaluated on the basis of relative capacitance change with the interaction with various solvents. The sensing ability and selectivity explained based on solubility parameters and diffusion processes.

1. Introduction

Cellulose is the most abundant organic resource on earth and it is renewable, colorless, and nontoxic material [1]. Besides it shows some great properties such as flexibility, high mechanical strength, biocompatibility, biodegradability, transparency which makes it a good candidate for many applications such as pharmaceuticals, food, textiles and so on [2]. Recently cellulose has been discovered as smart material which makes it suitable for sensor and actuators, flexible electronics etc. [1]. Graphene is a flat monolayer tightly packed carbon atoms in a two dimensional honey comb lattice. This material has shown many unique properties, such as the quantum hall effect (QHE), high carrier mobility at room temperature, large specific surface area, optical transparency, high mechanical strength and excellent thermal conductivity [3]. Graphene sheets have extraordinary electronic transport properties and high electro catalytic activities, and they have been investigated as electrode materials in optoelectronic devices, electrochemical supercapacitors, fabricated field effect transistors, and constructed mechanical sensors [4], such as gas sensor, proximate sensors [5], gas sensors and biosensors [6]. Nowadays, polymer based on graphene materials are being developed and studied for applications as sensors in the chemical, actuator and biomedical fields because of low cost and flexibility [6–8].

In this paper we report cellulose graphene oxide (GO) covalently bonded nanocomposite as semiconductor, dielectric and liquid solvent sensor based on the change of surface capacitance when come with the interactions of solvents. The work principal is based on the change in their electrical properties, which are modulated upon interaction with a variety of solvents. Eco-friendly sensors have some potential application such as energy storage, memory storage, solvent leak detection etc.

2. Experimental details

2.1. Materials

Cotton pulp of 98% purity and degree of polymerization 4500 was obtained from Junsei Chemicals, South Korea. Natural flake graphite, hexamethylene-1,6-diisocyanate (HMDI), sulfuric acid (H_2SO_4), nitric acid (HNO_3), hydrochloric acid (HCl), potassium permanganate ($KMnO_4$), 30% hydrogen peroxide (H_2O_2) solution, dimethyl acetamide (DMAc), n-hexane, chloroform, toluene, acetone, ethanol, isopropyl alcohol (IPA) and lithium chloride (LiCl) were procured from Sigma-Aldrich.

2.2. Preparation of composite

Cellulose solution was obtained by dissolving cellulose pulp in common DMAc/LiCl mixer [1]. First of all, cotton pulp, LiCl and anhydrous DMAc in a ratio of (2:8:90) were heated at 155 °C following by stirring. Then, the solution was centrifuged at

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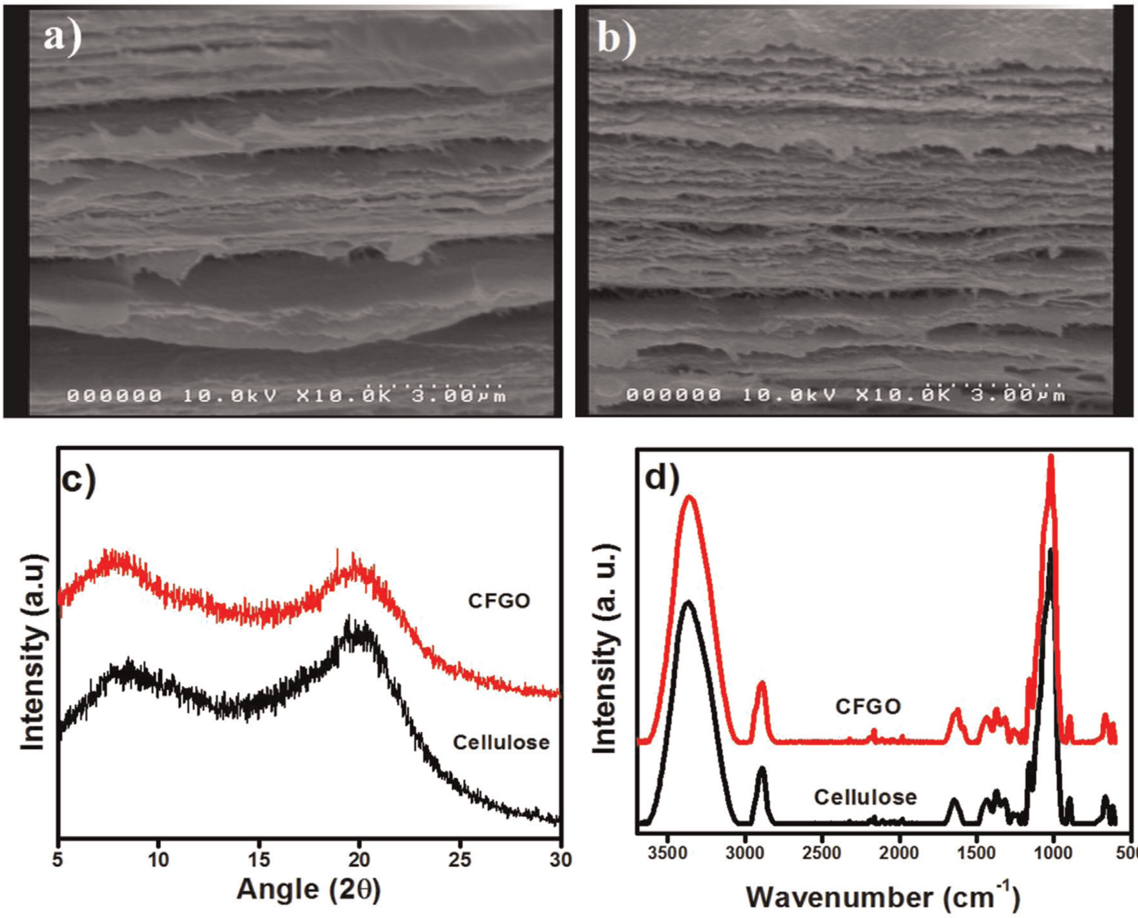

Fig. 1. SEM cross section image of (a) Cellulose (b) CFGO (c) XRD (d) FTIR analysis of the pristine cellulose and CFGO.

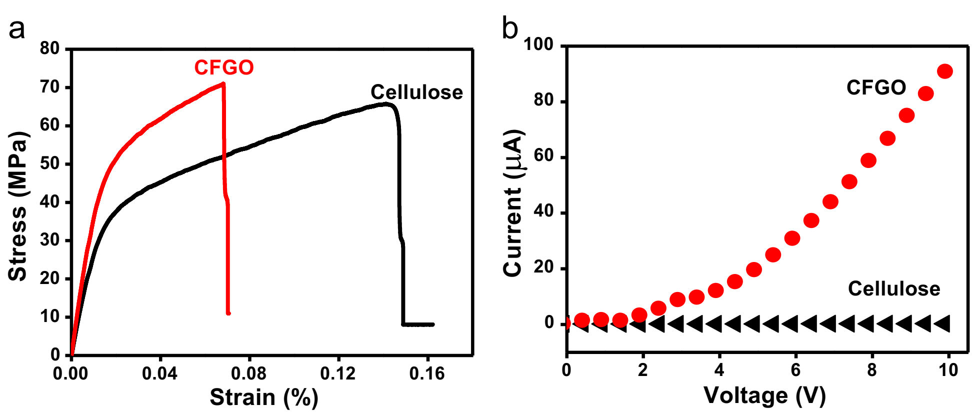

Fig. 2. (a) Stress–Strain curve of cellulose and CFGO, (b) *I–V* curve for cellulose and cellulose-FGO nanocomposite.

11,000 rpm to eliminate the undissolved cellulose fibers. The improved graphene oxide synthesis method was used for preparing GO [9,10]. GO (6 mg) was functionalized by treating with HMDI at 110 °C in anhydrous DMAc solution. To this functionalized GO (FGO) mixture, 1.5 wt% cellulose dissolved in DMAc solution (40 mg) was added following by mechanical stirring. Finally the composite solution was cast on a glass plate using a doctor blade and cured using deionized water and IPA mixer. Finally the cured nanocomposite with 1 w% of FGO in cellulose was obtained by drying in a vacuum oven at 60 °C, which is termed as cellulose-FGO (CFGO) [11]. For comparison, a cellulose film was made by casting the same cellulose solution followed by the same curing and drying processes. Characterization techniques of the nanocomposite are added in Supplementary information.

3. Results and discussion

3.1. Morphology and structure

Fig. 1a, b shows the cross-sectional FE-SEM images of the pristine cellulose and CFGO, respectively. The images indicate morphological change because of good reinforcement between FGO with cellulose. FGO was dispersed very smoothly as no agglomeration of particles was observed in CFGO. The roughness of the cellulose reduced upon the addition of GOs. Fig. 1c represents