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Electrical conductivity of different carbon nanotubes on wool fabric: An investigation on the effects of different dispersing agents and pretreatments

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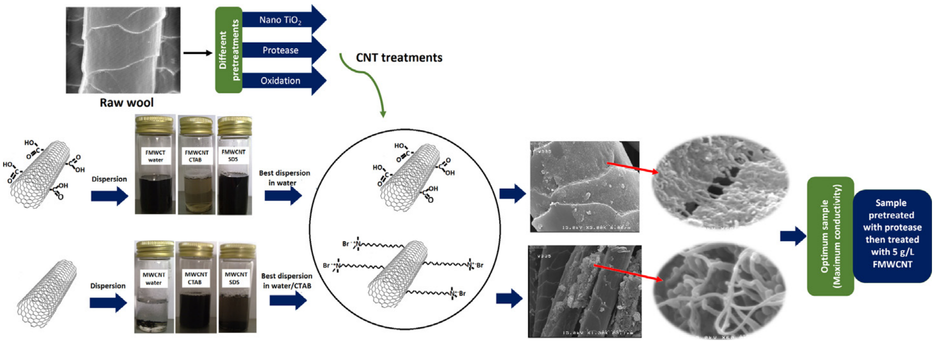
HIGHLIGHTS

- Producing conductive wool fabric using MWCNT and FMWCNT.
- Better dispersion of MWCNT with CTAB against SDS contrary with FMWCNT.
- Higher adsorption of CNT by TiO_2, oxidation and protease pretreatments.
- Maximum conductivity for pretreated with protease then treated with 5 g/L FMWCNT.
- Improved tensile strength of the CNT treated wool fabrics.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, conductive wool fabrics were prepared using different concentrations of multiwall carbon nanotube (MWCNT) and carboxylated multiwall carbon nanotube (FMWCNT) in presence of citric acid as a cross-linking agent and sodium hypophosphite as a catalyst. Effects of different pretreatments including oxidation by potassium permanganate, enzyme treatment with protease and nano TiO_2 finishing were also studied. An anionic and a cationic surfactants namely sodium dodecyl sulphate (SDS) and cetyltrimethylammonium bromide (CTAB) were also used to provide the best conditions for dispersing the nanotubes. While CTAB was more effective for dispersing MWCNT in water, the best dispersion bath for FMWCNT needed no surfactant. The samples treated with FMWCNT indicated conductivity 10 times higher than MWCNT due to interactions between the functional groups of wool and carboxyl groups of FMWCNT. Wool fabric pretreated with protease then treated with 5 g/L FMWCNT regarded as the optimum sample with the highest electrical conductivity of 2×10^{-3} S/cm along with improved mechanical properties.

1. Introduction

Carbon nanotubes have attracted researchers for their vast applications including electronics, composite materials, fuel cells, sensors, optical devices, and biomedicine due to their mechanical,

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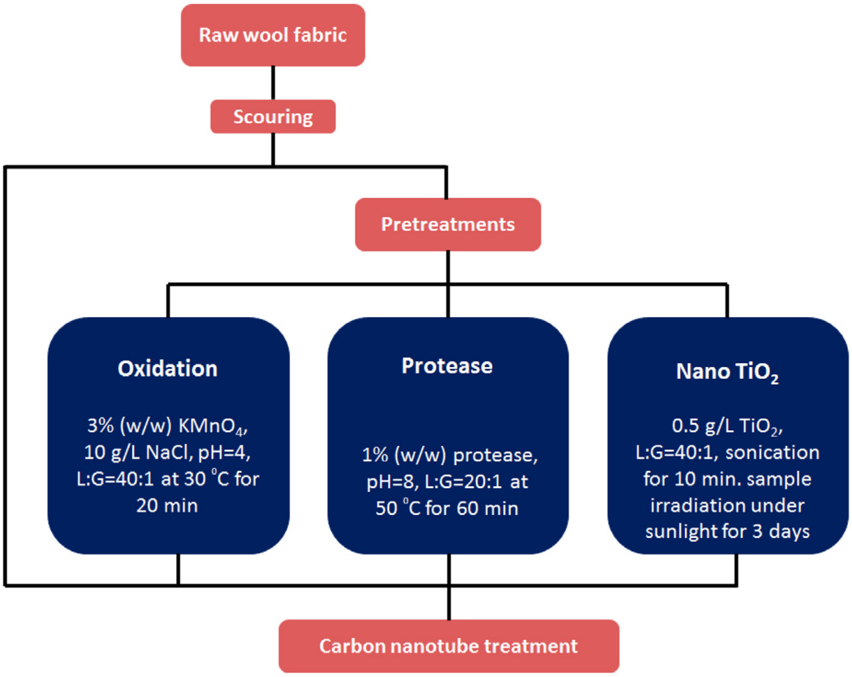

Fig. 1. Different steps of treating fabrics with carbon nanotubes.

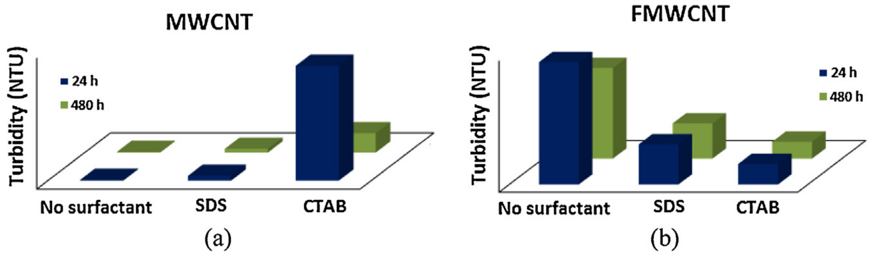

Fig. 2. Effect of various surfactants on turbidity of (a) MWCNT and (b) FMWCNT dispersions after 24 h and 480 h.

thermal, and electronic properties [1,2]. As carbon nanotubes are susceptible to agglomeration, there is always a need to provide their homogeneous dispersions in organic and aqueous solvents for further applications. However, this is difficult due to the deficiency of side groups or other functionalities on carbon nanotubes interacting with the surrounding solvent to overcome the large inter tube Van der Waals interactions.

DC electric field along with other treatments such as ultrasonic and surfactants were applied to improve the dispersion of carbon nanotubes in liquid. The applied method was effective depending on the use of high voltage, low frequency and proper exposure time [3,4]. Many attempts have been made toward the dispersion of carbon nanotubes in suitable solvents. For instance, various surfactants, polymers, enzyme and natural macromolecules have been used as dispersing agents [5–10]. Combining carbon nanotubes with organic moieties and biomolecules has led to the various applications of carbon nanotubes [11–15]. Covalent functionalization of carbon nanotubes with proteins has been demonstrated by reaction between the free amine groups on the surface of a protein and carboxylic acid groups generated by sidewall oxidation of carbon nanotubes and subsequently activated using carbodiimide [16,17]. However, the noncovalent solubilized carbon nanotubes are superior to covalent functionalization which disrupts and changes the properties of carbon nanotubes [18,19]. It has been reported that covalent functionalization necessarily disrupts the one-dimensional electronic structure and desired optical properties of carbon nanotubes. In contrary, noncovalent modification using electro-active species preserves the carbon nanotube electronic structure [19].

Although electronic textiles (e-textiles) can be supplied through weaving and knitting of metal electrodes, the produced textiles suffer from stiffness and low flexibility [2,20,21]. The incorporation of carbon nanotubes into textiles through immersion into carbon nanotubes dispersion provides a simple way to fabricate conductive textiles [22]. In this contribution, we aimed at producing conductive wool fabric using multiwall carbon nanotube (MWCNT) and carboxylated carbon nanotubes (FMWCNT). For this purpose, first the best condition for dispersing both carbon nanotubes in water was assessed using anionic and cationic surfactants (SDS and CTAB). Second, the wool surface was activated using different methods prior to MWCNT and FMWCNT treatment. According to our previous studies focusing on wool activation for enhanced nanomaterials adsorption [22–24], oxidation of wool with potassium permanganate, wool bio-finishing with protease, and wool nano-finishing with TiO_2 nanoparticles were applied. The positive effect of potassium permanganate activating wool surface improving carbon nanotube adsorption has been confirmed [22]. Bio-finishing of wool fibers regarding as an eco-friendly process allows for the enrichment of carboxylic groups [23]. Photo-induced hydrophilicity of wool samples treated with TiO_2 nanoparticles has been also proved [24]. In addition to the improved wettability, nano TiO_2 treatment imparts multifunctional properties to textiles [25].