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RESEARCH PAPER

Conductive and photoactive properties of polyethylene terephthalate fabrics treated with nano TiO_2/nano carbon blacks

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Abstract: A polyethylene terephthalate (PET) fabric was pretreated by alkaline-hydrolyzation. Both the pristine and pretreated PETs were loaded with nano carbon blacks (CB1515 and CB156), mixtures of nano TiO_2 (NTO) and NCBs (CB1515 or CB156) using an impregnation method with sodium dodecyl sulfate as a dispersing agent. Citric acid (CA) and sodium hypophosphite (SHP) were also used as a cross-linking agent and a catalyst respectively in addition to the dispersant to load NTO+CB1515 and NTO+CB156 onto the PETs with and without pretreatment as comparisons. It is found that CB156 is more effective than CB1515 to decrease the electrical resistivity for all samples. The samples from the pristine PET have lower resistivities than those from the pretreated PET when NTO is added. However, this is reversed when NTO is not added. Use of CA and SHP can significantly lower the resistivity of samples in all cases by increasing the loading level and dispersion uniformity of NCBs and NTO in the fabrics. A synergistic effect of NCBs and NTO is found to increase UV absorption of the treated fabrics. The samples from the pristine PET loaded with NCBs and NTO were more active than those from the pretreated PET for the degradation of methylene blue. The activity can be increased by loading with NTO or by adding both CA and SHP and the former is more effective than the latter.

Key Words: PET fabric; Nano carbon black; Nano TiO_2; Electrical resistance; Photo activity

1 Introduction

Loading of nanoparticles with various properties on fabric produced high performance functional textiles[1, 2]. Coating nanostructured carbons on fabric generated electronic textiles allowed for many applications such as high performance sport wear, wearable displays, embedded health monitoring device that were impossible with traditional electronic technology, owing to lightweight and flexibility of fabric [3, 4]. Nanostructured carbons and nano TiO_2 (NTO) endow the fabric with the photo catalytic activity for water purification [5].

The carbon black (CB) is a form of nanostructured amorphous carbon with a high surface area to volume ratio, which was applied as radar absorbent [6] materials and UV absorber. CBs are electrical conductors with a conductivity of 0.1 to 10 S/cm. CBs are widely used as fillers in polymers for conductive packaging for electronic components and electromagnetic shield materials for cables. The electrical conductivity of CBs is also important in other applications such as in fuel cell electrodes [7]. The natural and synthetic fabrics have been directly dyed by surface modified CB to open new applications of nanotechnology in textile production [8]. On the other hand, NTO coating have received much attention as photo catalyst in practical applications such as environmental protection[9], deodorization, sterilization, antifouling and self-cleaning[10], owing to their high oxidation ability, non toxicity, long term stability and low cost [11]. Carbon nanotubes (CNTs) as conductive nanostructured materials have been known for increasing electrical conductivity of textiles [12] and their composite with NTO have been applied to the treatment of contaminated water and air, owing to a high photo catalytic activity of the CNT/TiO_2 composite [5,13]. TiO_2 composited with a residue carbon and iron enhanced photo activity of TiO_2 [14].

In this paper, the multifunctional textiles were prepared by compositing polyethylene terephthalate (PET) fabric raw and alkaline hydrolyzed with CBs and NTO by a sonication assisted impregnation method using citric acid (CA) as a cross linking agent and sodium hypophosphite (SHP) as a catalyst. Electrical resistance, decoloration of aqueous methylene blue (MB) solution and UV protection of the treated fabrics were investigated. The electrical resistivity of the PET fabrics composited with NCB/NTO/CA/SHP decreased and a light emitting diode (LED) device can be easily powered by a 30 V power supply. To the best of our knowledge, there is no report on the electrical conductive PET modified by NCB. However, conductive textiles modified by

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CNTs have been already reported, which are much expensive and toxic [15-18]. These facile and low-cost conductive textiles (e-textile) can provide new design opportunities for various applications such as wearable electronics, energy storage and high-performance sport wear [3,12,19].

2 Experimental

2.1 Materials

The raw PET fabric, plain-woven with a 85 g/m^2 fabric mass, and the alkaline-hydrolyzed PET fabric (Hejab Shahrekord Co, Iran) was used. The flexible and stable PET fabric was selected, owing to its wide range of applications in textile industry, especially for medical and sport[20]. The other materials were carbon black, Printon black 156 (NCB) (pH=7), Printon black 1515 (NCBF) (pH=8-9) with an average particle size of 25 nm (Micronized Powder Co, Iran Islamic Republic). The TEM image of NCB is presented in Fig. 1, which indicates that its diameter is around 25 nm. Nano TiO_2 P25 (NTO) was supplied by Evonik Degussa, Germany. Citric acid (CA) was used as a cross linking agent, sodium dodecyl sulfate $CH_3(CH_2)_{11}OSO_3Na$ (SDS) as a dispersing agent and sodium hypophosphite (SHP) as a catalyst (Riedle-dehean, Germany). MB ($C_{16}H_{18}ClN_3S{\cdot}XH_2O$, X=2-3) was supplied by Merck, Germany.

2.2 Instruments

Scanning electron microscopy (SEM) was carried out on a SEM (VEGA/TESCAN (Czech Republic) by using an accelerating voltage of 15 KV for a magnification of 30000 and a SEM LEO 440i (England) equipped with energy dispersive X-ray spectroscopy EDX on a SAMX (France). The samples were coated with gold for the SEM observation and EDX analysis. Transmission electron microscopy (TEM) images of NCB were obtained on a Phillips EM208 (Czech Republic) electron microscope using an accelerating voltage of 100 KV. The sample for the TEM observation was prepared by ultrasonically dispersing the NCB in ethanol. X-ray diffraction (XRD) patterns were obtained by a XRD diffractometer (PW 1800 Philips, Holland). Thermal gravimetric analysis (TGA) was carried out on a Dupont 951 Thermogravimetric Analyzer (U.S.A). The sample was placed in a platinum pan and heated from 50 to 740 °C at a rate of 20 °C /min under N_2 flow. The UV reflection spectra of PET fabrics were obtained by a Varian Cary 500 UV-Vis spectrophotometer (U.S.A). A 6500 B Impedance Analyzer (Wayne Kerr Electronics, England) was employed to measure the electrical resistance of fabrics. Also, an electrical furnace (Carbolite, England) was used to obtain ash content.

2.3 Scouring

The PET samples (20×10 cm^2) were scoured in a solution with 1g/L nonionic detergent at 60 °C for 20 min using a liquor to PET mass ratio of 40:1[21], then rinsed thoroughly with distilled water and dried at room temperature.

2.4 Carbon black /nano TiO_2 treatment

The impregnating solutions were prepared according to the formulations in Table 1, sonicated for 20 min in ultrasonic bath and stirred with a homogenizer at 15 000 rpm for 5 min to obtain a disperse solution of nanoparticles. The PET fabrics were treated at 80 °C for 30 min in the disperse solution. The treated samples were then dried at 120 °C for 10 min and cured at 200 °C for 3 min. The CA treated fabrics were cured at 150 °C [21] and then rinsed with cold and hot distilled water for several times to remove the unbound nanoparticles on the fabric.

2.5 Electrical resistance measurement

The electrical resistance of the treated fabrics was measured according to AATCC-76-2005 with a fabric dimension of 8×2 cm^2 [22]. The fabrics were fixed using two gold electrodes of a Precision Impedance Analyzer 6500 B (Wayne Kerr Electronics, England). The electrical resistance was measured at least five times for each sample and the average results were listed in Table 1. The electrical resistivity of the NCB/NTO/CA/SHP treated PET fabrics has been decreased and a LED device can be easily powered with a 30 V power supply.

2.6 Photo catalytic MB degradation

The exact mechanism of MB photo degradation is still not established. Tatsuma et al proposed two possible mechanisms for MB decolorization, a reversible reduction of MB to the leuco form and an irreversible oxygenation or decomposition of MB[23]. The decomposition activities of colorant stains were assessed by analyzing the decrease in concentration of the colorants during exposure to UV irradiation. The treated samples 2×7 cm^2 were cut into six pieces placed in a 50 mL erlenmeyer, containing 50 mL MB aqueous solution with a concentration of 10.5 mg/L. Then the

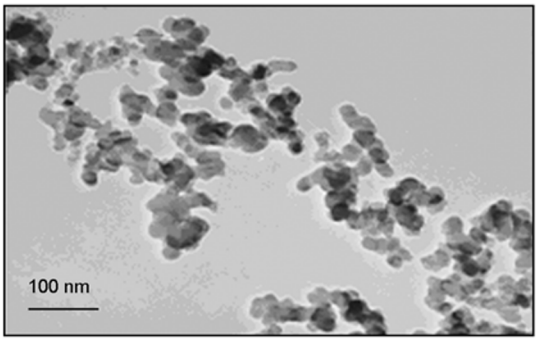

Fig. 1 TEM image of carbon black (NCB).