Carbohydrate Polymers 137 (2016) 264–270

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Preparation and characterization of cotton fabric with potential use in UV resistance and oil reclaim

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ARTICLE INFO

Article history:
Received 24 July 2015
Received in revised form 24 October 2015
Accepted 27 October 2015
Available online 30 October 2015

Keywords:
Superhydrophobic
Cotton textile
UV-resistance
Nanocomposite coating
Oil reclaim

ABSTRACT

Here we report a simple, facile and low-cost approach to the cotton textile with significant properties. After treatment, the cotton textiles exhibit not only an excellent superhydrophobicity with the water contact angle (WCA) of 151.5°, but also an efficient shielding property against UV with the transmittance under 2.0%. More importantly, this cotton displays an outstanding potency in oil reclaim, which can recycle oil from the waste water with oil stain efficiently. Apparently, our results suggest an innovative material that should find practical and diversified applications, particularly in the field of oil spill cleanup.
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1. Introduction

The lotus leaf and many other biological organisms exhibit the unique wetting characteristic of superhydrophobicity after millions of years of evolution (Gao et al., 2007; Gao & Jiang, 2004; Shi et al., 2007; Wang, Li, & Xu, 2012; Zheng, Gao, & Jiang, 2007). So far, superhydrophobic surfaces with the water contact angle greater than 150° have attracted enormous attention in both of scientific areas and industrial areas including energy conversion, self-cleaning paints and windows, water/oil separation, corrosion resistance, functional textiles, fluid resistance for aquaculture and microfluidic devices, anti-freezing, anti-fogging (Zhi et al., 2015). In recent forty years, the oil spill and the explosion of oil rig happened frequently on a global scale, which cause the water pollution with thousands of square kilometers and the death of tens of thousands seafowls. Without question, they are the huge tragedies for mankind and other lives. The good news is that an increasing number of scientists and researchers have focused on the solution of this serious problem with the development of science and technology.

Nowadays, numerous solid materials have been investigated and explored such as calcium carbonate powder (Arbatana, Fang, & Shen, 2011), carbon nanotube sponge (Gui et al., 2010), metal mesh (Lee, Johnson, Drelich, & Yap, 2011; Yang et al., 2011), porous ceramic (Sua, Xu, Zhang, Liu, & Li, 2012), nanoporous polymers (Zhang et al., 2009; Zhang, Huang, & Han, 2006), freestanding manganese oxide nanowire (Yuan et al., 2008). Although these efforts won many encouraging achievements, the limitations still exist such as difficulties of biodegradation and recovery, low repeatability, potential toxicity, poor mechanical stability, low flexibility and high cost. As a type of environment-friendly, biodegradable, flexible and penetrable bio-material with low cost and density, cotton textiles defeating polyester textile have received intensive attention for practical application. However, the fabrics can be easily wetted and polluted by water and dyestuff, which greatly restrict the further application and development of cotton textiles. The existing toolbox for the fabrication of superhydrophobic cotton includes chemical vapor deposition (Zimmermann, Reifler, Fortunato, Gerhardt, & Seeger, 2008), radiation-induced graft polymerization (Deng et al., 2010), wet chemical coating technique (Zhou et al., 2012; Wang et al., 2011), self-assembly of block copolymers (Gao, He, & Qing, 2011), and layer-by-layer self-assembly (LbL) (Zhang, Wang, Wang, & Li, 2012).

Although these methods are widely implemented in research, the super-hydrophobicity of their productions is not permanent,

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http://dx.doi.org/10.1016/j.carbpol.2015.10.087
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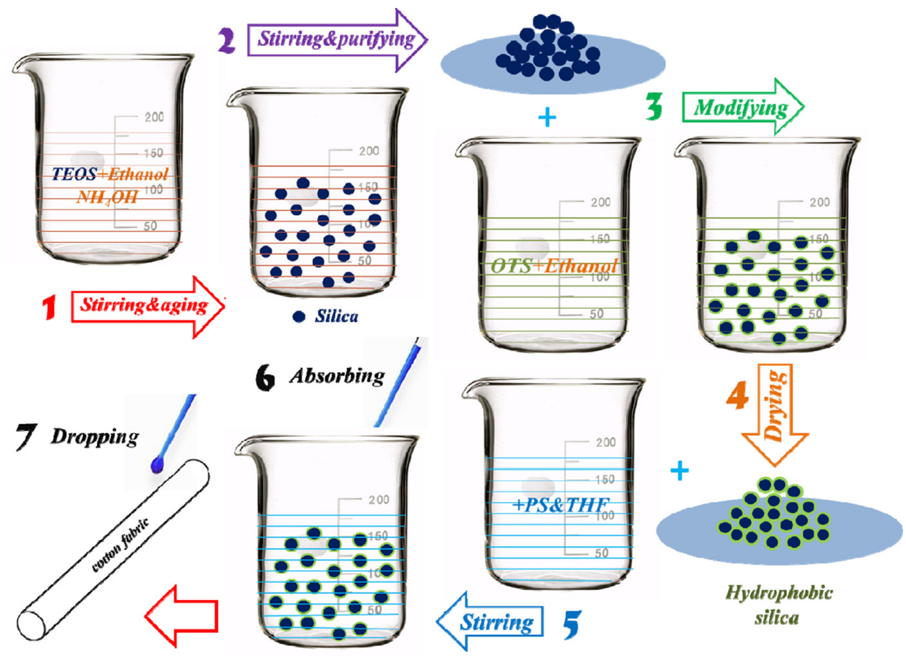

Fig. 1. Experimental strategy for the fabrication of superhydrophobic cotton fabric.

and these cotton samples are rarely applied to water/oil separation (Zhang & Seeger, 2011). Compared with the nanoparticles/polymer composite textiles, they still have many limitations for practical use in harsh conditions, such as strong acid/alkali/oxidant and mechanical washing. Moreover, the above-mentioned procedures could not be successfully adopted to large-scaled manufacture because of the severe requirements, complicated operations and introduction of perfluorocarbon silane. In contrast, drop coating procedure with silica derivatives and PS is easier and more economically feasible to acquire superhydrophobic cotton fabrics, which even can create surface roughness, achieve superhydrophobicity and improve mechanical stability at the same time.

More importantly, there are many advantages of this treatment in comparison with other textile finishing treatments using metallic nanoparticles. First of all, it is the outstanding properties of silica, such as large specific surface area, abilities of surface adsorption and light absorption, high chemical purity, good dispersion performance, superior stability and so on. These performances make SiO_2 be widely used in the materials of magnetism, catalytic, UV resistant, thermal resistance, et al. Secondly, the grain size and morphology of silica can be control well since Werner Stöber and his coworkers reported their achievement. However, the synthetic process of other metallic nanoparticles is more expensive and harder to command. Therefore, we are so excited to present this cotton for water–oil separation with the significant functions of superhydrophobicity and UV-resistance by drop coating method, which was roughly presented in Fig. 1. The performance of superhydrophobic cotton has been investigated to identify whether this superhydrophobic cotton could be applied in practical purposes such as UV-resistance and oil reclaim.

2. Materials and methods

2.1. Materials

Cotton textile (3 cm × 3 cm) was obtained from Harbin, which was further purified by ultrasonic washing with distilled water, acetone and ethanol for 5 min, respectively, and then completely dried in the oven at 80 °C. Tetraethyl orthosilicate (TEOS, 98.0%), ethanol (99.7%) and ammonia (28.0%) were obtained from Tianjin Kaitong Chemical Reagent Co., Ltd. Polystyrene (PS) (Mw = 100,000) and tetrahydrofuran (THF) (>99.0%) were provided by Daqing petroleum chemical industry plant and Xilong Chemical Industry Co., Ltd, respectively. Octadecyltrichlorosilane (OTS) used for surface hydrophobic modification was purchased from New Jersey. All of the chemicals were used as received without further purification.

2.2. Synthesis of superhydrophobic cotton

As shown in Fig. 1, the specific strategy has been presented as follows:

(I) Under the condition of magnetic stirring, TEOS (5 ml) and NH_4OH (5 ml) were added into the absolute ethanol (50 ml) at ambient temperature.
(II) One hour later, the mixture solution was stalled and aged at room temperature for 12 h. Then the silica particles were purified and collected.
(III) The as-prepared silica and OTS reagent (0.3 ml) were introduced to the absolute ethanol (50 ml) via 12 h of magnetic stirring at ambient temperature.
(IV) The hydrophobic silica particles were collected and purified by repeated centrifugation for three times in absolute ethanol, and then dried in a vacuum oven at 60 °C for 12 h.
(V) In the typical process, PS (0.10 g) was completely dissolved in THF (5 ml), and then as-obtained hydrophobic silica (0.10 g) was ultrasonically dispersed in THF solution at ambient temperature.
(VI) Followed we absorbed couples of droplets from the dispersed mixture.
(VII) Then the mixture was drop-coating onto the textile surface, dried at 75 °C for about 20 min, and finally the modified cotton textile was obtained.

2.3. Characterization

The size distribution of silica particles was measured by a Zeta Potential and Particle Size Analyzer (Brookhaven, ZetaPALS) in

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