Applied Surface Science 284 (2013) 464–471

Contents lists available at ScienceDirect

Applied Surface Science

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

Fabrication of superhydrophobic and superoleophilic textiles for oil–water separation

Chao-Hua Xue [a,b,*], Peng-Ting Ji [a], Ping Zhang [a], Ya-Ru Li [a], Shun-Tian Jia [a]

[a] *College of Resource and Environment, Shaanxi University of Science and Technology, Xi'an 710021, PR China*
[b] *Shaanxi Research Institute of Agricultural Products Processing Technology, Shaanxi University of Science and Technology, Xi'an 710021, PR China*

ARTICLE INFO

Article history:
Received 6 June 2013
Received in revised form 22 July 2013
Accepted 23 July 2013
Available online 31 July 2013

Keywords:
Superhydrophobic
Superoleophilic
Textile
Oil–water separation

ABSTRACT

Superhydrophobic and superoleophilic textiles were fabricated by a simple sol–gel coating using tetraethoxysilane and 1,1,1,3,3,3-hexamethyl disilazane as precursors. After coating, the fibers were decorated with —$Si(CH_3)_3$ functionalized SiO_2 nanoparticles, complimenting the microscale roughness inherent in the textile weave and lowering the surface energy. The textiles indicated superhydrophobic and superoleophilic property simultaneously. Utilizing these properties, a setup was designed using the textile as a screen mesh to filter oil through down to a collector and leave water drops rolling over, realizing continuous oil–water mixture separation.

1. Introduction

Separation of water and oil mixture is becoming an important task with the increase of industrial oily wastewater and polluted oceanic water, as well as the frequent oil spill accidents. The environmental and economic demands urge the necessity for functional materials that can effectively separate oil and water [1–4]. Generally, the wettability of the materials for selective adoption of the oil from oil/water mixtures was demanded to show both superhydrophobic and superoleophilic property simultaneously [5]. It is well known that the wettability of solid surface is controlled by the surface chemistry and the geometrical roughness [6]. According to the Wenzel and the Cassie–Baxter model, the introduction of a proper multi-scale roughness could make a pristine hydrophobic surface to be more hydrophobic or even superhydrophobic owing to the air to be trapped underneath the water droplet as a cushion, whereas an oleophilic surface becomes more oleophilic or even superoleophilic owing to the capillary effect [7,8]. With appropriate design, the surface that simultaneously displayed superhydrophobic and superoleophilic property could be obtained [9].

There have been many reports showing the possibility to prepare superhydrophobic and superoleophilic functional materials by the combination of low surface energy and proper rough topography, as well as the potential for oil–water separation using such materials. These materials include polymer composite film of polyurethane film combined with polystyrene microspheres [10], stainless steel mesh made by the spray and dry process [5], the metal meshes made by the electrochemical deposition method [11], and the wet chemical approach [12], and copper mesh made by solution-immersion process [13], polyurethane sponges [14]. However, there still remain a lot of limitations for large-scale fabrication of such functional materials and for practical applications because of costly materials used, complicated fabrication procedures, and poor scale-up probability.

The textile industry concerned with industrial uses has been receiving benefits from the development of new properties on fibers. There have been many reports about endowing common textiles with superhydrophobicity, focusing mainly on lotus effect for water-repelling or self-cleaning [15–24]. However, only a few literatures report on fabrication of superhydrophobic textiles for water–oil separation [25,26]. Zhang et al. [25] fabricated smart textiles with switchable superoleophilicity and superoleophobicity by grafting a block copolymer comprising pH-responsive poly(2-vinylpyridine) and oleophilic/hydrophobic polydimethylsiloxane blocks on these materials. They showed that the functionalized materials with the switchable superoleophilicity and superoleophobicity can be used in highly controllable oil/water separation. Li et al. [26] fabricated superhydrophobic textiles by coating fibers with nanocrystals and modification of octadecyl thiol. The superhydrophobic and superoleophilic textiles with nanocoatings were effectively used for application in oil/water separation. These studies opened a new avenue to design and prepare functionalized

* Corresponding author at: Shaanxi Research Institute of Agricultural Products Processing Technology, Shaanxi University of Science and Technology, Xi'an 710021, PR China. Tel.: +86 29 86132768; fax: +86 29 86168291.
E-mail addresses: xuech@zju.edu.cn, xuechaohua@126.com (C.-H. Xue).

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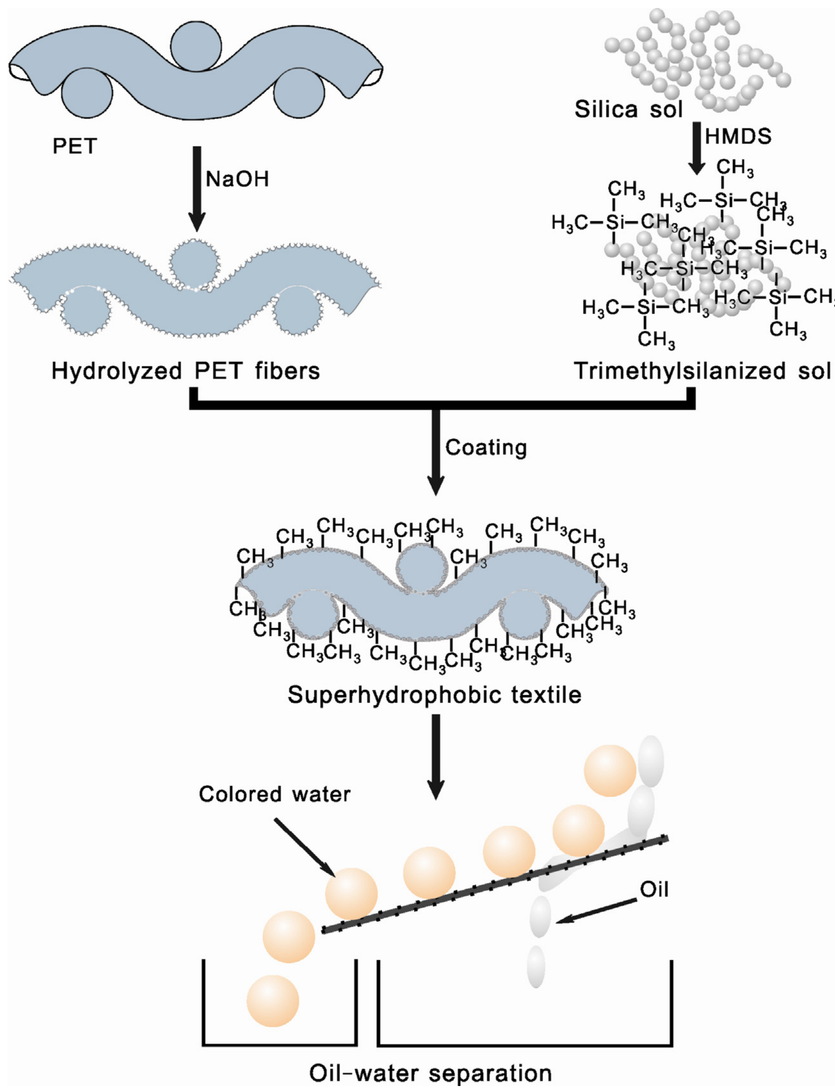
http://dx.doi.org/10.1016/j.apsusc.2013.07.120



Scheme 1. Preparation process of superhydrophobic PET textiles and illustration of oil–water separation.

textiles for separation and filtration applications, although special polymers or complex procedures are needed.

In this work, we propose a simple method for fabrication of superhydrophobic and superoleophilic poly(ethylene terephthalate) (PET) textiles by coating PET fibers with hydrophobic silica sols. The PET textiles were pretreated by NaOH for roughening of the fiber surface and improving the compatibility of the fibers with silica sols. The obtained functional textiles exhibited superhydrophobic and superoleophilic property, which can be used for continuous oil–water separation. The preparation processes of the functional textiles and illustration of oil–water separation using the textile as a filter were shown in Scheme 1.

2. Experimental

2.1. Materials

Tetraethoxysilicate (TEOS), 1,1,1,3,3,3-hexamethyl disilazane (HMDS), n-hexane, ammonia solution (about 25%, AR), hydrochloric acid (HCl), dodecyl dimethyl benzyl ammonium chloride (1227), methanol and n-propanol were purchased from Tianjin Chemical Reagent Co. (China). All chemicals were used directly. PET textiles ($16\,s + 16\,s \times 10\,s$, 84×35, $230\,g/m^2$) were obtained commercially. Deionized water was used throughout all the experiments. Gasoline was obtained from a local gas station. Crude oil was obtained from Yan'an Petroleum Chemical Co., Ltd., China.

2.2. Alkali treatment of PET textiles

Firstly, the PET textiles were washed by deionized water to remove the impurities and immersed in sodium hydroxide solution with 2 g/L dodecyl dimethyl benzyl ammonium chloride (1227). The sodium hydroxide concentration was set at 15 g/L with a liquor ratio of 40:1. Then the solution was heated at 90 °C for 40 min. At last, the textiles were washed by abundant water until the pH of the textile surfaces reached 7, and dried at 80 °C without any tension.

2.3. Preparation of SiO_2 sol

SiO_2 sol was prepared using TEOS as the precursor catalyzed with ammonia in methanol at room temperature. Briefly, 15 g of TEOS was dissolved in 24 g of methanol, followed by dropwise adding a mixture of 8 g ammonia and 24 g methanol under stirring. At this stage, pH of the solution was close to 9. To the above