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Adkhamjon Gafurov
Namangan Institute of Engineering and Technology
Namangan, Uzbekistan

Dilshodbek Olim Ugli Isakov
Namangan Institute of Engineering and Technology
Namangan, Uzbekistan

DURABLE SUPER HYDROPHOBIC COTTON FABRIC TO SEPARATE OIL FROM WATER

***Abstract**: Oily wastewater not only pollutes the environment seriously but also is difficult to separate. Herein, by spraying the polytetrafluoroethylene aqueous dispersion onto the cotton fabric, a superhydrophobic/superoleophilic cotton fabric (coded as SSCF) was prepared. The so-prepared SSCF could separate the stratified and emulsified oil with high separation efficiency (above 95.0%). These experimental results showed that the SSCF provided an effective method in oil/water separation.*

***Key words**: oily water, filter fabric, superhydrophobic, oil/water separation, durability.*
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Introduction

Leakage of oil and water mixed with oil can lead to serious water pollution and even endanger the safety of people and wildlife [1]. Thus, the separation of oil and water is a big problem. Traditional approaches to solving this problem include physical adsorption, chemical decomposition, membrane separation, gravity separation, gravity separation methods, hydrades, and others [2]. These methods are practical, but have various disadvantages, including high cost, negative environmental impact, secondary pollution, low oil separation efficiency, and poor selectivity and processing performance, etc. Consequently, there is a great need for inexpensive, environmentally friendly safe technologies for separating oil from water and in new materials that can be reused very well. Recently superhydrophobic (water wetting angle more than 150 ° and sliding angle less than 10 °) / super oleophilic surfaces (oil wetting angle less than 5 °) for oil / water separation with high selectivity and high separating power, and also recyclable with perfect sample ... Various superhydrophobic / superoleophilic materials have been produced for oil and water separation, including two-dimensional metal mesh, three-dimensional sponges, and cotton fibers [3]. For example, Jiang et al. Have developed a superhydrophobic and superoleophilic mesh film coating for separating diesel and water. Shi et al. Developed an oil and water separator separating self-forming monolayers by sequential formation of chemical metallic sludge for highly efficient oil spill treatment. Lu and others developed a two-layer stainless steel mesh modified with a demulsifying poly (N, N-dimethylaminoethyl methacrylate) and poly (divinylbenzene) agent, which demonstrated high fluidity and excellent separation efficiency when separating an aqueous emulsion in oil [4]. Pan et al. Prepared superhydrophobic and superoleophilic sponges to collect and remove oil and organic solutions from water surfaces. Wang et al. Developed a simple single layer superhydrophobic and super oleophilic polyurethane sponge by the soak method, which has demonstrated excellent sorption properties for separating various types of water-oil mixtures and oil emulsions in water. Lee et al. Developed a highly efficient and environmentally friendly superhydrophobic polyurethane sponge with an attapulgite surface for separating oil / water and oil-in-water emulsions. Superhydrophobic and super oleophilic cotton fibers developed by Wang et al. Have shown high selectivity and efficiency in separating oil from oil / water and oil emulsions in water [5]. However, the preparation of the aforementioned superhydrophobic and superoleophilic surfaces is relatively complex, and their long-term effectiveness or effectiveness in separating oil from oil / water and oil emulsions in water is not well understood [6]. In this paper, we present a method for obtaining a mature superhydrophobic and superoleophilic surface by spraying an aqueous dispersion of polytetrafluoroethylene (PTFE) onto cotton fabric, the product obtained by this method is inexpensive, flexible, environmentally friendly, and superhydrophilic in nature. The resulting superhydrophobic and super oleophilic cotton fabric, coded as SSCF, and an immiscible oil and water mixture, can also be used to separate oil from oil emulsions in water.

2. Production of superhydrophobic and superoleophilic cotton fabric.

The surface of the cotton cloth was cleaned with ultrasound in acetone, etalon, and dionized water to remove debris. The condensed dispersion of PTFE was mixed with deionized water in a ratio of 1:10. The superhydrophobic and superoleophilic cotton fabric was then prepared by spraying the prepared PTFE dispersion onto the cotton fabric. A sprayer with a nose diameter of 1 mm was used, with spray pressure and flow rate of 0.3 MPa and 2 ml / s, respectively. The distance between the sprayer and the cotton cloth was maintained at around 20 cm and the spraying was repeated 3 times. After that, the cotton cloth was dried in an oven at 150 ° C for 2 h. For convenience, the superhydrophobic / superoleophilic cotton fabric is coded as SSCF.

2.1. Descriptions.

Water contact angle (WCA), slip angle (WSA) and oil contact angle (OCA) were measured using an optical contact angle meter (DSA 20, Kruss, Germany). One drop of water or oil (5 μl) was dripped onto the SSCF, and five different conditions were identified to obtain an average value. Surface (surface) morphology was observed using an electron microscope (FESEM, FEI-Nova NanoSEM 450, USA). The chemical composition was checked using X-ray photoelectron spectroscopy (XPS, Physical Electronics, PHI-5702, USA). Obtained under a microscope (Olympus-CX31, Japan) using optical micro-images of water-oil emulsion before and after separation. Physical friction characteristics were measured with a friction resistance tester (BF-FS9, China, Fig. S1) at a friction velocity of 104 ± 1.5 mm / s at a friction (head) with a vertical friction pressure of 9 N. The friction head reversed the cycle once and the total distance was 208 ± 1.5 mm.

2.2. Experiments on the separation of oil and water.

Picture of equipment for separation of oil and water. Shown in 3e. By mixing 50 ml of water and 50 ml of oil, immiscible fat water mixtures were obtained. The efficiency of oil separation in SSCF was calculated using the following equation:

$$\eta\% = B_1 / B \times 100$$

where, B and B_1 represents the starting oil (50 ml) and the volume of oil collected, respectively.

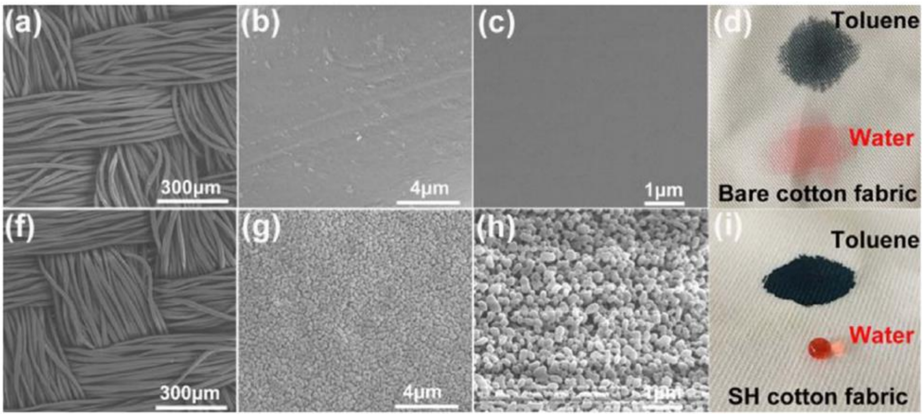
3. Results and discussion

3.1. Morphology, chemistry and surface moisture.

A clean cotton cloth is easily moistened with water and oil (Fig. 1d). This was due to the special surface microstructure and surface chemistry. In particular, as shown in Figure 1a-c, the pure cotton fabric consisted of smooth microfibers baked into a simple woven structure. As shown in Figure 2a, i.e. for pure cotton fabric, there were only two strong signals coming from XPS, carbon, and oxygen.

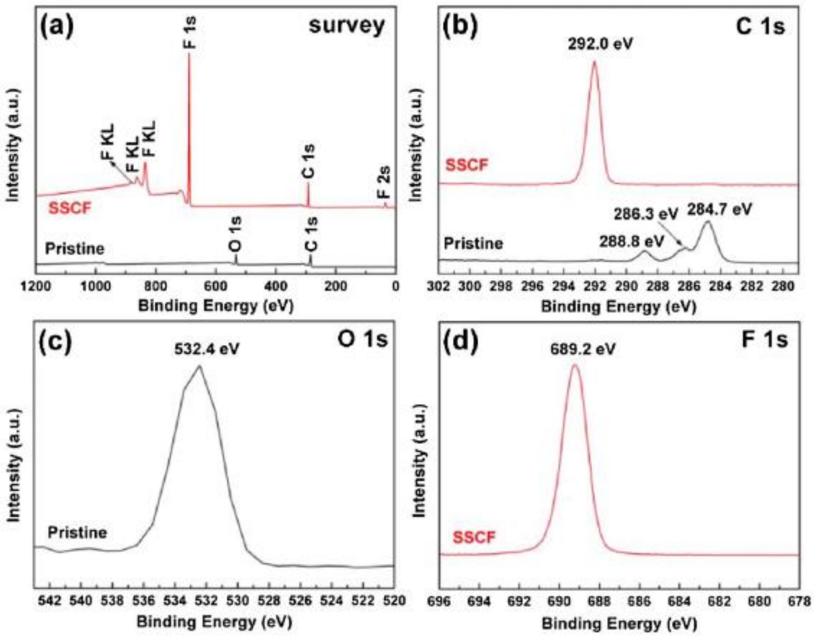
The spectrum C 1 s (Fig. 2b) showed three peaks located at 284.7 eV, 286.3 eV, and 288.8 eV, respectively, belonging to C-H / C-C, C-OH, and O-C-O, respectively. The spectrum O 1s showed a basic peak at 532.4 eV relative to C-O (Fig. 2c). In other words, the cotton fabric was originally superhydrophilic due to the large number of hydroxyl groups in the cotton cellulose and the rough microstructure. Pure cotton fabric WCA and OCA rated 0 °, which showed excellent superhydrophilicity and superoleophilicity.

After spraying the PTFE, the surface of the microfiber was densely and uniformly coated with nanoparticles measuring 200 nm (Fig. 1g), which significantly increased the surface roughness of the cotton fiber (Fig. 1h). PTFE is an image for SSCF obtained in this way to test XPS sinking. 2a and b. shown in. Signals from oxygen were lost, and signals from fluorine were generated (F 1 at 689.2 eV). In addition, C1 s switched to 292.0 eV, which is the typical binding energy for C-F bonds. All of these signals indicated that the cotton fabric was completely covered with PTFE nanoparticles.



Picture. 1. FESEM images for pure (a - c) and superhydrophobic / superoleophilic (f - h) cotton fabrics; pure (d) and superhydrophobic / superoleophilic (i) water (red) and toluene (black) photographs on the cotton surface.

After drying for 2 h at 150 ° C, the PTFE coating showed good adhesion to the underside of the cotton fabric. Two main measures were taken to achieve good adhesion of PTFE to the fabric. First, the PTFE used is not dry PTFE nanoparticles, but PTFE nanoparticles are a concentrated dispersion containing water and dispersants. PTFE is simply sprayed onto the fabric. Second, and most importantly, the sample was heated to improve the adhesion between the PTFE and the fabric sprayed in this way. At high temperatures (e.g., 150 ° C), PTFE nanoparticles are assumed to come together and adhere tightly to the tissue. Presumably, the high-temperature treatment increased the movement of the PTFE molecular chain and enhanced the adhesion of the PTFE to the cotton surface. The PTFE-prepared coating reduces the surface energy of the fabric and creates hierarchical micro / nanometer-like structures that trap more air under a drop of water. This means that the water droplet was mainly in contact with the trapping air and the cotton fabric could no longer get wet and exhibited a superhydrophobic property with high WCA 160.2 ± 1.4 ° and low WSA 2.8 ± 0.3°.

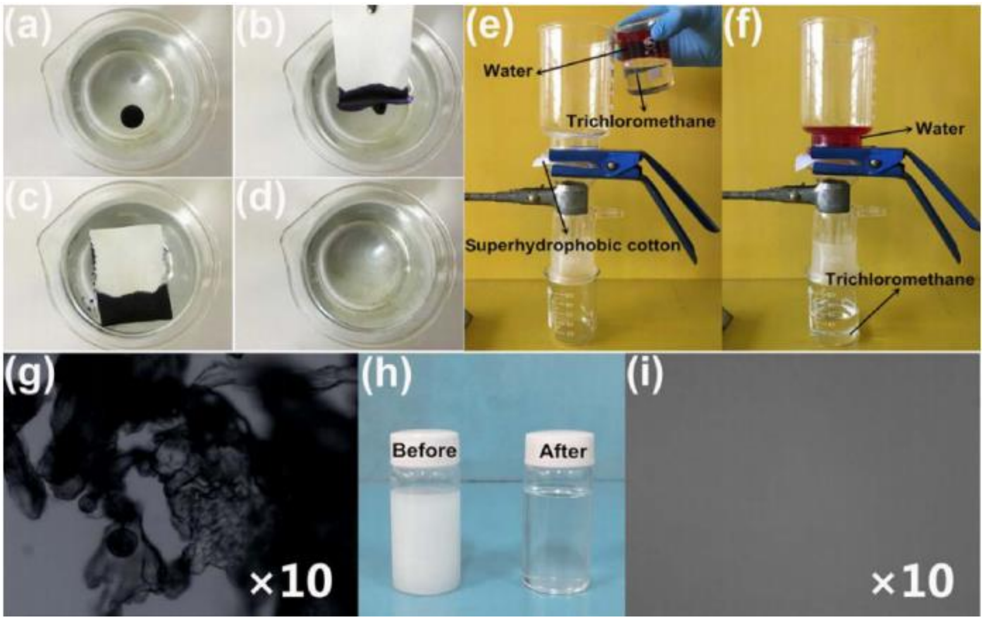


Picture. 2. XPS spectra of pure and superhydrophobic / superoleophilic cotton fabric surface: general appearance (a), C 1s (b), O 1s (c) and F 1s (d).

However, the superhydrophobic cotton fabric still retained its superoleophilicity, and the toluene that fell on it was quickly dispersed by OCA at 0 ° (Fig. 1i). When immersed, the SSCF floated in the water and the clean cotton cloth was quickly submerged. However, when placed in toluene, both the primary and the SSCF were submerged.

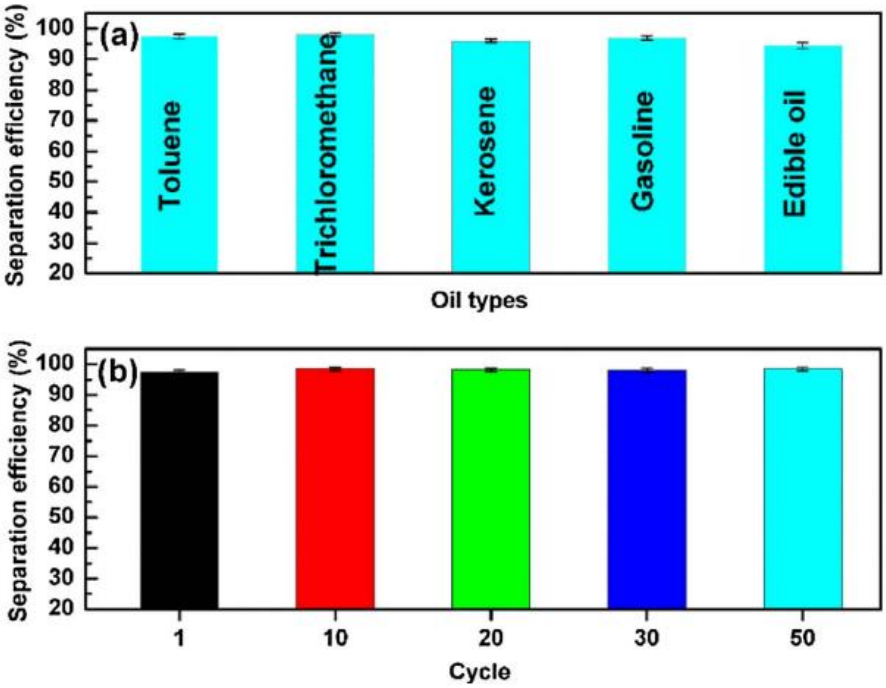
3.2. Separation of oil and water.

SSCF demonstrated excellent selective sorption of oil from water. As soon as the SSCF comes in contact with a colored drop of unmixed toluene floating on the surface of the water, the toluene is rapidly adsorbed and dispersed upwards (Fig. 3b). SSCF, which adsorbs toluene, can float on the water surface due to its lightness and water repellent properties (Figure 3c). Toluene was completely adsorbed (absorbed) from the water surface and no clear residues of toluene were observed after SSCF removal (Fig. 3d). In addition, the SSCF did not drink water. Figure 3e and f show the process of separating a mixture of unmixed oil (trichloromethane) and water using a small oil and water separation device and SSCF. When a mixture of oil and water consisting of 50 ml of trichlormethane and 50 ml of water was poured into a high glass vessel (Fig. 3e), the oil rapidly passed through the SSCF and passed under the glass in 3 minutes due to superoleophilicity and gravity.



Picture. 3. Photographs of the oil sorption process for 1 ml of toluene (stained with Sudanese black) floating in water over (a) 0s, (b) 2s, (c) 8s, (d) 10s; the process of separating oil from immiscible (painted with Biebrich Scarlet) water and a mixture of trichloromethane (e, f); optical microscopy and photograph of oil and water emulsion before and after separation (g - i).

When water could not enter the SSCF and stood above it (Fig. 3f), the amount of oil after separation was 48.5 ml and the separation efficiency of SSCF oil reached 97.0%. The efficacy of separating SSCF with various oils such as toluene, trichloromethane, gasoline, kerosene, and edible oils has been studied. The oil separation efficiency of these oils in the first cycle exceeded 95.0% (Figure 4a). To evaluate the reuse of SSCF, the oil separation efficiency (as a toluene representative) is structured as a function of the separation cycle Figure 4b. The separation efficiency of toluene was 98.5% even after a 50-fold separation period. After use, SSCF regained its original properties when washed with acetone. Even after use for 50 cycles, the WCA was still above 150 °. This result showed that SSCF not only has the efficiency of separating oil from water, but also makes it reusable. SSCF can also be used in emulsified oil separation.



Picture. 4. Efficiency of oil separation from superhydrophobic / superoleophilic cotton fabric: for different types of oils (a); for toluene after different separation cycles (b).

The emulsified oil was prepared by mixing water and toluene in a 1:25 volume ratio and stabilized with Span 80. The emulsion in oil and water was mixed at 2000 rpm for 1 h before separation and turned a milky white color (Fig. 3h). Immediately after pouring 50 ml of emulsion into the oil separator, it passed through SSCF. Meanwhile, the water and emulsifier were returned and left in the top glass container. Optical micrographs of the original emulsified oil showed a large black area due to the inability of light to enter the solution (Fig. 3g). However, the optical micro-images of the collected oil were not black and were very transparent (Fig. 3i). The amount of water in the collected oil was also measured with an oil moisture meter (GY106, Wuhan Guoyi Company, China). The water content of toluene (20 ml) collected after separation of the oil and water emulsion was 0.16 μg / ml. This showed that the emulsified oil was separated and that only a small amount of water was present in the oil after separation.

4. Conclusions.

Thus, a superhydrophobic / superoleophilic cotton fabric was successfully produced with a simple approach. The oil can be quickly adsorbed (absorbed) and separated from the oil / water mixture (boiling water, ice water, 1ml HCl, 1ml NaOH and 1ml NaCl) and can even form emulsified oil using SSCF samples. In addition, the oil separation efficiency for different oils consistently exceeded 95.0% even after a 50-fold separation period. In addition, SSCF showed excellent chemical (in boiling water, ice water, strongly corrosive solutions and organic solvents) and mechanical (friction and ultrasonic treatment) resistance. SSCF samples can be widely used in the treatment of oily wastewater due to their high oil separation efficiency and durability.

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