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Superhydrophobic / Superoleophilic Cotton Fabric for Oil /Water Separation

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Abstract

Super-hydrophobic and super-oleophilic Textile oil-water separator was successfully prepared by a coating of modified silane solution on the textile cloth surface by a spray coating method. To prepare superhydrophobic cotton oil water separator, raw cotton cloth was treated with detergent, cleaned with water, and dried in air. The formation of an oil-water separator by modified silane solution for superhydrophobicity was confirmed by dropping on the surface of modified cotton with a colour solution and investigated the wetting behavior and absorption capacity of probing liquids on the superhydrophobic cotton by the water contact angle. The silane coated cotton showed higher water repellent activity and higher absorption capacity of oil than raw cotton with 146.2˚C of water contact angle and absorption capacity of two kinds of probing liquids were greater than raw cotton fabric.

Keywords - *Textile cloth, superhydrophobic, a spray method, FTIR, probing liquid*

I. INTRODUCTION

Along with increasing offshore oil extraction and transportation, oil contamination problems are becoming serious, posing a threat to the living environment and human health [1, 2]. Therefore, cleaning oil from water is an urgent and challenging task [3]. A wide variety of strategies [4] have been developed to eliminate oil pollution, such as burning [5], mechanical extraction [6], coagulation [7], and absorption[8]. Among these technologies, the application of absorbents is considered the most attractive for oil removal because of the high efficiency and ease of operation[9].

Separation of oil/water mixtures can appear during oil extraction, crude oil production and refinery, petrochemical and metal finishing, textile and leather processing, food processing, and lubricant, representing severe harms for the environment [10, 11, 12]. Every crude oil type is classified into different compounds. About 50 to 98 % of oil is composed of hydrocarbons, primarily alkanes (paraffin) such as n-hexane [13]. The refineries are one of the places in which hexane and its derivatives are produced. The common application of hexanes is the extraction of oil and grease pollutants from water. Due to the application of hexane in the aquatic environment, the separation of oil pollution from water resources is an essential issue [14].In recent years, the development of hydrophobic and oleophilic materials for the fabrication of membranes to separate oil from water has attracted much consideration because of their extraordinary separation efficiency and great applicability [10, 13, 15]. The hydrophobic property makes materials reject water entirely, but the oleophilic feature allows oil to permeate easily. Thus, hydrophobic and oleophilic materials can separate oil-water effectively [13]. Various methods have been developed to fabricate superhydrophobic and superoleophobic materials for oil/water separation consisting of sol-gel process [10,16,17], electrospinning techniques [10, 18,19], electrochemical deposition [20]. In recent years, a new generation of membrane processes is developing. It means that a filtration medium (support) is selected; afterward, it is modified or functionalized with appropriate materials, and then it is used for separation. Some of these supports are cotton, wools, linens, fibers, porous carbon, sand, diatomite, coal, quartz, and metals, including mesh film, filter paper, resin, sawdust. Among them, fiber has attracted much attention. The improvement of fiber properties has made significant benefits [4,21, 22,23].

In this work, we prepared with the spray method to fabricate superhydrophobic and superoleophobic cotton fabric by coating modified silane solution. We prepared various modified silane solutions by using two solvents (ethanol and isopropyl alcohol). After that, we compared superhydrophobic cotton fabrics prepared by these two solvents by the water contact angle. The prepared modified cotton fabric was suitable to clean up in the laboratory for spilling the oils.

II. EXPERIMENTAL SET UP

A. Materials

Textile cloth(white colour), Tetraethoxysilicate (TEOS), dimethyl dimethoxy silane (DMDMS), methyl trimethoxy silane (MTMS), isopropyl alcohol, ethanol, detergent, concentrated hydrochloric acid, n-hexanel, o-dichlorobenzene, crude oil, chloroform were used directly. Ultrapure water was used throughout all the experiments.

B. Synthesis of Superhydrophobic Cotton Fabrics

Superhydrophobic cotton fabrics were prepared by the following.

a) Preparation of Silane Solution by using EtOH as Solvent

1ml of TEOS, 1ml of DMDMS, and 10ml of EtOH were mixed in a beaker and stirred in a magnetic stirrer for 5 minutes. After that, 0.4ml of H_2O and some drops of concentrated HCl were added and stirred for 2-3hours. The prepared solutions were kept in the bottle for 12hours.

b) Variation Parameters for Solution

0.5ml of TEOS prepared silane solutions, 1ml of TEOS and MTMS was used as a modifying agent.

c) Preparation of Silane Solution by Using Isopropyl Alcohol as Solvent

1g of DMDMS, 0.7g of TEOS, and 16ml of IPA were mixed in a beaker and stirred in a magnetic stirrer for 5 minutes. After that, 0.4ml of H_2O and some drops of concentrated HCl were added to the solution and stirred for 2-3hours. The prepared solutions were kept in the bottle for 12hours.

d) Variation Parameter for Solution

MTMS was used as a modifying agent instead of DMDMS.

e) Synthesis of Silane Coated Cotton Fabrics

For the coating process, the pristine cotton gauze (Pristine cotton) was attached tightly to a tray frame with an open space of 27 cm in length and 20 cm in width. The fabrics were sprayed with a coating solution by using a sprinkling bottle. To achieve uniform coating on both sides, one side was sprayed evenly with a coating solution (1:2 ratio of silane solution and IPA). Then the sample was dried at 100 ˚C for 40 min to evaporate solvent /water. Similarly, the same amount of coating solution was applied on the other side.

III. RESULTS AND DISCUSSION

A. Evaluation of the Hydrophobic Behavior Influenced on the Effect of TEOS Concentration and pH of Silane Solution on Coated Cotton Fabric

The cotton fabric (12cm x 12cm) was immersed in the original solution and solutions diluted with ethanol 1:2 v/v and 1:5 v/v for 30 minutes and dried in an oven at 120 C for 1 hour. The hydrophobicity of as prepared silane coated cotton fabrics was investigated by measuring the contact angle (CA) of the sample against water on a Goniometer (XGCAMA, Shanghai Xuanyichuangxi Company) at ambient temperature. At least five measurements were made within 10 s of water droplet formation on the sample average values were calculated. The results are shown in Table (1) and (2).

Table1.Contact Angle Measurement of Uncoated and Coated Cotton for DMDMS Modifying agent

Sample	Concentra -tion of TEOS	v/v ratio of (silane and EtOH)	Contact Angle (˚C)	pH of Silane solution
Pristine cotton			0	
Silane solution (1)	0.5ml	Original solution	109.5±3	<4
Silane Solution (2)	0.5ml	1:2	115.3±2	3-4
Silane Solution (3)	0.5ml	1:5	119.5±3	4-5
Silane Solution (4)	1ml	Original solution	114.4±1.8	˜<4
Silane Solution (5)	1ml	1:2	125±3	3-4
Silane Solution (6)	1ml	1:5	120.4±2	4-5

Table 2.Contant Angle Measurement of Uncoated and Coated Cotton for MTMS Modifying Agent

Sample	Concentr a-tion of TEOS	v/v ratio of (silane and EtOH)	Contac t Angle (˚C)	image	pH of silane solution
Pristine cotton			0		
Silane solution (1)	0.5ml	Original solution	104±1. 8		3
Silane Solution (2)	0.5ml	1:2	119±3		4-5
Silane Solution (3)	0.5ml	1:5	106.3± 1		>5
Silane Solution (4)	1ml	Original solution	108.4± 1		3
Silane Solution (5)	1ml	1:2	129.2± 2		4-5
Silane Solution (6)	1ml	1:5	119.8± 2.1		>5

B. Evaluation of the Hydrophobic Behavior Influenced on the Effect of Modifying Agent and Effect of pH on Coated Cotton Fabric

The cotton fabric (12cm x 12cm) was immersed in the original solution and solutions diluted with isopropyl alcohol 1:2 v/v and 1:5 v/v for 30 minutes and dried in an oven at 120 ˚ C for 1 hour.

Pristine cotton showed hydrophilic and oleophilic properties. In other words, the material can adsorb water and oil compounds. In contrast, the silane coated cotton showed hydrophobic properties with remained oleophilic (Fig. 1.A and B).

Fig.1A Hydrophilic and Oleophilic Behavior of pristine cotton

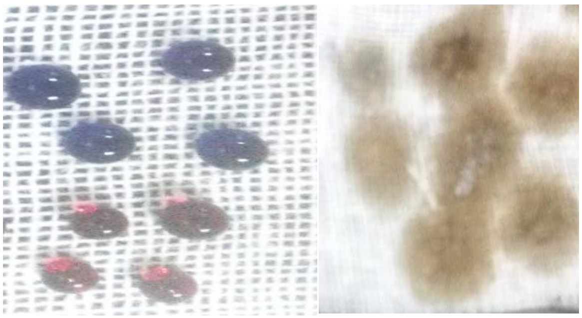

Fig.1B Hydrophobic and Oleophilic Behavior of silane coated cotton

The hydrophobicity of as prepared silane coated cotton fabrics were investigated by measuring the contact angle (CA) of samples described in above section 3.1. Results are shown in Table (3).

Table.3 Contact Angle Measurement of Uncoated and Coated Cotton for DMDMS and MTMS as Modifying Agents

Sample	Modifying Agent	v/v ratio of(silane and EtOH)	Contact Angle (˚C)	image	pH of silane solution
Pristine cotton			0		
Silane solution (1)	DMDMS	Original solution	141±1.8		<4
Silane Solution (2)	DMDMS	1:2	143±3		4-5
Silane Solution (3)	DMDMS	1:5	136.3±1		>5
Silane Solution (4)	MTMS	Original solution	121.4±1		4
Silane Solution (5)	MTMS	1:2	146.2±2		>5
Silane Solution (6)	MTMS	1:5	119.8±2.		>5

Note:
DMDMS - dimethyl dimethoxy silane
MTMS - methyl trimethoxy silane

The adsorption capability of different samples (defined by the weight change of sample before and after immersing into a specific liquid for 10 min) was measured using water and two representative oily compounds, crude oil and chloroform probing liquids. Quantitative data showed that Pristine cotton could soak up water by 6.4 times its weight (Fig. 2) due to its inherent hygroscopicity and porous structure. Interestingly, the water adsorption capacity of the sample dropped to about 48%of weight after silane coating, whereas the adsorption capabilities for oily compounds changed a few times no matter which coating was applied to the cotton.

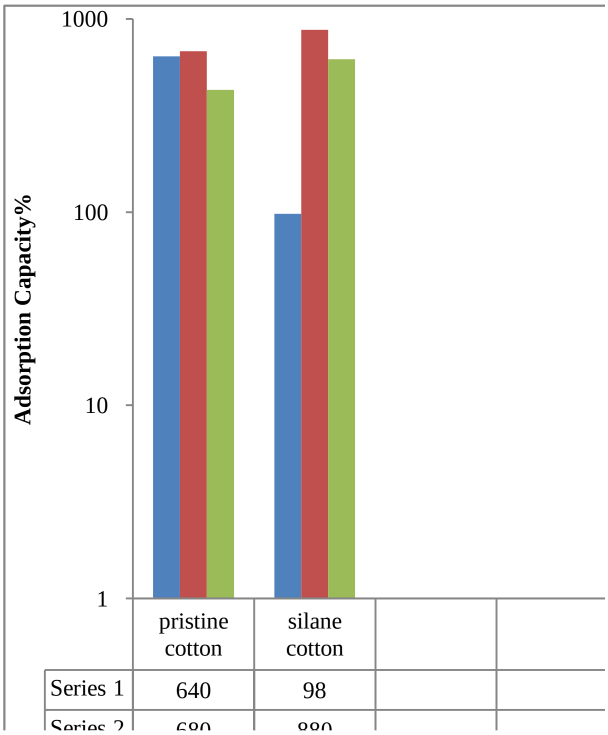

Fig .2 shows that the absorption capacities of silane coated cotton for various oily liquids range from 3.5 to 5.6 times its weight.

C. Hydrophobic and Oleophilic Behavior of silane uncoated and coated cotton

Measurement of CA is a useful technique to evaluate the textile surface's hydrophobicity, and a higher CA generally indicates a lower amount of hydrophilic groups formed on the sample surface. The average CA values and static images of samples against water are summarized in Table 1. Table (4) show the condition of pH, amount of modifying agent, and the wetting behavior of the sample. Figure 3 showed the absorption capacity of superhydrophobic cotton fabric for organic ois. Crude oil can be absorbing the highest, and o-dichlorobenzene can absorb the lowest.

Table 4 Contact angle measurement of Uncoated and Coated Cotton

Sample	Dimension of Cotton Fabric	(Silane Solution: IPA)	pH value	coating silane cotton (wt%)	contact angle (˚C)
Pristine cotton					0˚C
Silane coated cotton	27cm x 20cm	12ml (4:8)	4-5	3.9%	143±2.2 ˚C
Silane coated cotton	27cm X 20cm	18ml (6:12)	4-5	7.8%	149±1.8 ˚C

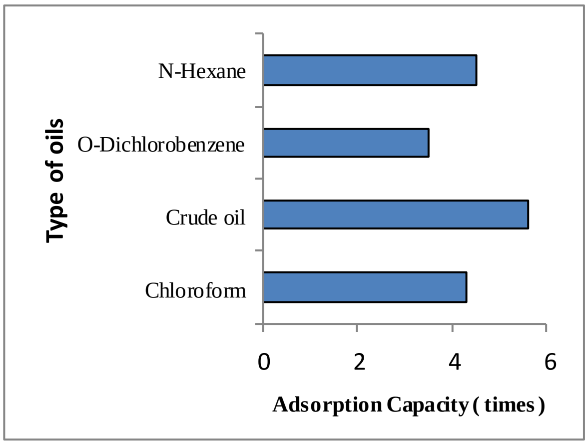

Fig.3 Adsorption Capacity of Silane Coated Cotton for Various Oily Compounds

IV. CONCLUSION

In conclusion, we have prepared a simple and easy spray type method for textile oil/water separator. It was made using a silane solution modified with isopropyl alcohol as a solvent with various ratios to get superhydrophobic / superoleophilic textile cloth as a filter to separate oil and water from oil/water mixture. It is a versatile filter for cleaning in lab and household.

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