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Development of Superhydrophobic Surfaces on Polyester and Cotton Fabric using "Silica Nano SOL-GEL with PDMS"

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Abstract—*The super hydrophobic textile materials have a wide range of applications in the field of protective textiles. The defense sector has a tremendous need of such materials for the development of next generation protective clothing such as CBRN protective Suit, Glacier Clothing; Jacket Wind Cheaters, Trousers Wind Cheater, Gloves, Cap, Poncho and various allied items like Rucksack, Bag Carrying Rescue, Gaiters, Tents and shelters. Looking at the urgent need of such materials, this research initiative is taken to fulfill the demands.*

This paper work reports on the development of superhydrophobic textile materials. The inherently flame retardant polyester and cotton fabric is considered here as the substrate material for development of superhydrophobic surface.

The substrate material is initially treated with silica nanosol for enhancement of surface roughness and subsequently, treated with hydrophobic chemicals like poly (dimethylsiloxane) (PDMS), for development of Superhydrophobicity. The Superhydrophobicity of the material is evaluated in terms of static water contact angle and water repellency test. The higher contact angle represents better hydrophobicity and a contact angle approaching to 150^0 or above achieved with any material designates it as superhydrophobic material. Higher rating of water repellency indicates better hydrophobicity. The concentration of PDMS is varied from 2% to 8%, on textiles substrate pretreated with nanosols for assessing the influence of the chemical on contact angle and water repellency. The SEM images of the treated samples are captured and scrutinized for evenness of the coating process.

The coating of any material on textile substrate affects its various physical and functional properties like tear strength, bending rigidity, air permeability and flame retardency. As in this research work, the coating of titania, Silica and their hybrid nano sol and followed by chemical treatment with PDMS are carried out in order to achieve the superhydrophobic surface, hence evaluation of the above mentioned properties is carried out and compared with Static WCA of the developed substrate to assess the variations due to coating. The optimum Superhydrophobicity is decided by the maximum value of water contact angle and highest water repellency rating with insignificant influence on the physical and functional properties of the substrate material.

Keywords: *Superhydrophobic surfaces, lotus effect, superhydrophobicity, silica sol, cotton and polyester fabrics, Trevira CS.*

1. INTRODUCTION

The superhydrophobicity (hydrophobicity) of solid surfaces has been investigated with considerable attention over the past few years and remarkable progress has been achieved. [1–2]. In nature, many surfaces like the wings of butterflies and the leaves of plants such as cabbage are highly hydrophobic and self-cleaning. The most popular example of a super hydrophobic self-cleaning surface is the leaves of the lotus plant, which is botanically recognized as *Nelumbo Nucifera* (Gulrajani, 2006; Taurino *et al*., 2008).[3,4] The leaves of this plant always remain clean because water droplets easily roll off of the ultra hydrophobic leaf surface, collecting and removing the dirt and contaminations. Therefore, the effect of self-cleaning by flowing water droplets is called "Lotus effect". The main reason for the superhydrophobicity of the leaves is its surface roughness and low surface energy (contain 20-40μm protruding nubs covered with a smaller scale rough surface of epicuticullar wax crystalloids). Generally most surfaces, has the hydrophilic surface, with water contact angle of below 90°. A slightly hydrophobic solid surface can be achieved with a water contact angle (CA) of above 90°. It becomes super hydrophobic after roughening, and CA reaches above 150° (Nosonovsky *et al*., 2009). The effect of roughness-induced superhydrophobicity was theoretically predicted and experimentally observed in the 1930s.[5] but superhydrophobic surfaces were found long later. It has been discovered that water droplets on hydrophobic surfaces can exhibit a contact angle higher than 90°, and some can even be approaching approximately up to 180° [6–8]. In particular, the contact angles related to superhydrophobic (or ultrahydrophobic) surfaces are greater than 150°. And those superhydrophobic surfaces are very likely to have phenomenal roughness with micro- or nanosized (or even smaller) protrusions coming out of the surface [9,10]. Self-cleaning can be achieved in many superhydrophobic surfaces by removing dust, dirt and contaminates particles with water drops moving over the surfaces. An increasing number of publications on superhydrophobicity have appeared since last two decades, when micropatterning technology matured, and it became possible to build superhydrophobic surfaces with desired properties (Nosonovsky *et al*., 2009).[5] Therefore, the liquid might contact only a few bits of the superhydrophobic surface without fully wetting it. Indeed, fluid interacting with superhydrophobic surfaces is one important discipline of research in the 21st century, and can essentially influence a lot of cutting-edge topics in engineering and biotech research which involve surface structures, fluid motivation, and their physical and chemical properties. Basically, the contact angle related wetting phenomena are of great interest and importance to current research progress. A considerable amount of work has been carried out to study the involved mechanisms and principles [11–34].

2. RESEARCH METHODOLOGY

A literature review is firstly used to find the comments from the past articles, journals and textbooks which mentioned about the water repellent and nanotechnology applied for repellent finished. So background of knowledge and recent development can be studied.

Sol gel method and pad-dry-cure are used to apply the repellent composite on inherently flame retardant polyester fabric and cotton fabrics. Combinations of various types of nanoparticle solutions, curing temperature and concentration will be varied and then performance of treated fabrics will be evaluated, in order to find out the optimum condition and materials for application of the water repellent finish.

Also, national and international standards such as IS and BS testing methods have to be applied, to evaluate the performance of specimens. Moreover, analytical instruments and characterization techniques like contact angle measurement and scanning electron microscope can be used in evaluation of the surface morphology and surface tension of the repellent treated specimens.

3. EXPERIMENTAL PROCEDURE

3.1. Materials

Trevira CS inherently flame retardant polyester fabric developed by Hoechst AG, Germany was used for the study. This inherently flame retardant polyester fabric is promoted and marketed by Reliance Industries in India. Finished Cotton fabric was purchased from Shri Ganesh mills in Panipat (Haryana). Tetraethylorthosilicate (TEOS), stearic acid, toluene, acetone, ammonia, polydimethylsiloxane(PDMS) were purchased from Aldrich.

Table 3.1: Specification of raw material

Fabric Specification		Polyester (Inherent FR)	Cotton
GSM		106.55	123
Density	EPI	92	103
	PPI	95	74
Weave		Plain Weave	Plain Weave

3.2 Synthesis of Silica nanosol for treatment of finished cotton/polyester fabric:

A 100 ml solution of ethanol was stirred for 2-3 minutes, then 5ml ammonia solution was added drop wise and stirring of solution was continued for 30 minutes. Heat and speed of the stirrer is gradually increased and temperature of the stirrer is maintained at 60 °C. After 30 minutes of stirring 6 ml, 11.18 ml, 16.8 ml, 25ml, 30ml, 35ml TEOS was added drop wise into the solution in 3 different flasks and stirring was continued for 90 minutes at 60 °C temp. The silica nano sol solution is then left for 12 hrs (overnight).

3.3 Application onto the fabric:

Sol of the silica nano-particles was applied on to the finished cotton/polyestereqqw2w22q fabric through padding mangle (pressure applied 2.75 kg). The fabrics were then dried at room temperature for 5 min and cured at 80° C for 3 min in an oven.

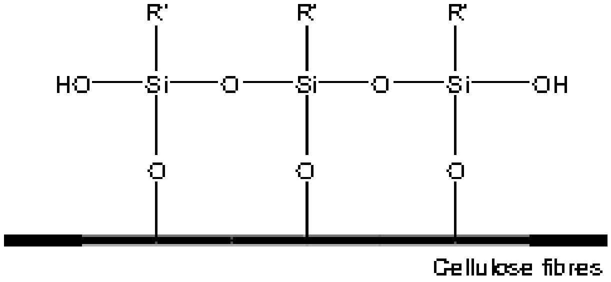


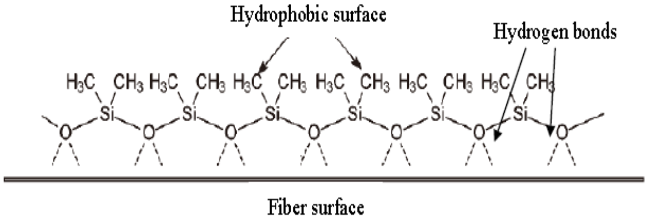
Figure 3.3: Covalent binding of the precursor silanol group to the hydroxyl group of the textile fibre in the reaction of condensation.

3.4 Preparation of Super hydrophobic surface on to SiO_2 nano sol on Trevira CS PET and finished cotton fabric:

A solution of toluene was stirred for 2-3 minutes. There after PDMS chemical solution was added to the solution, there after acetic acid was added to the solution to adjust PH at 5 (acidic medium) and stirring of solution was continued for 10 minutes. This whole process was done at room temperature.

3.5 Application of PDMS solution onto silica nanosol treated sample:

The sample were dipped in solution for 10minute at room temperature and passed through the automatic padding magnate machine. At the same nip pressure of 2.75 kg per cm^2. After that Samples were dried at 110^o C for 3 min and cured at 135^o C for 30 min. in a preheated oven.



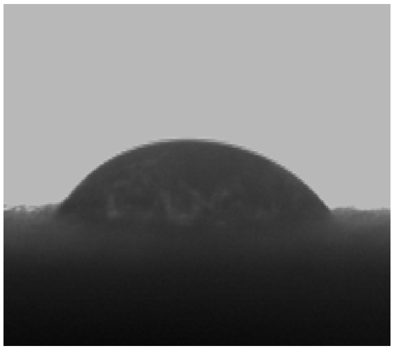
3.5 Structure of polydimethylsiloxane molecule on fiber surface

3.6 Characterization:

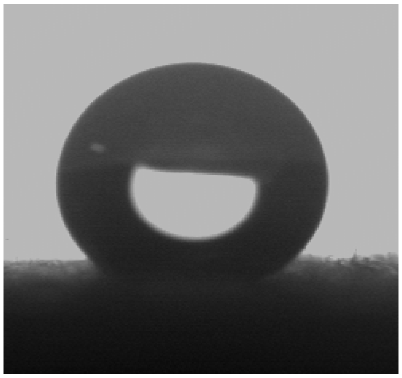
Contact angles (CA) were measured with a 5μl deionized water droplet on a Dataphysics OCA 20 (Kruss Dataphysics, Germany) instrument at room temperature. All the contact angles were determined by averaging values measured at 5–6 different points on each sample surface. Scanning electron microscopy (SEM) images were obtained on (M/s Carl Zeiss LVSEM).

4. RESULTS AND DISCUSSION

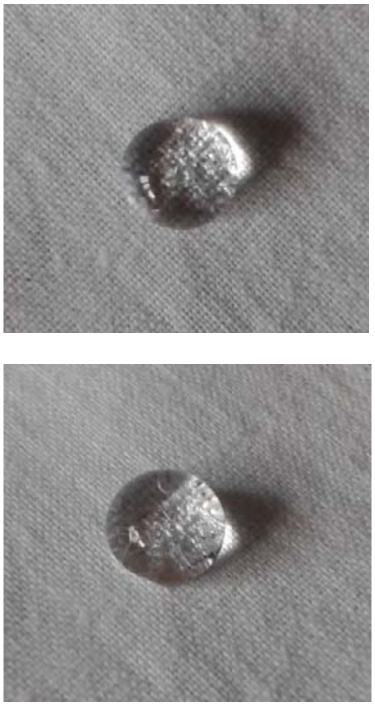
Performance evaluation of super hydrophobic surfaces on inherent FR polyester/cotton fabric by using poly(dimethylsiloxane)



(a.) Contact Angle of scoured sample



(b.) Contact Angle of treated sample



(c.) Image of the water droplate of treated sample

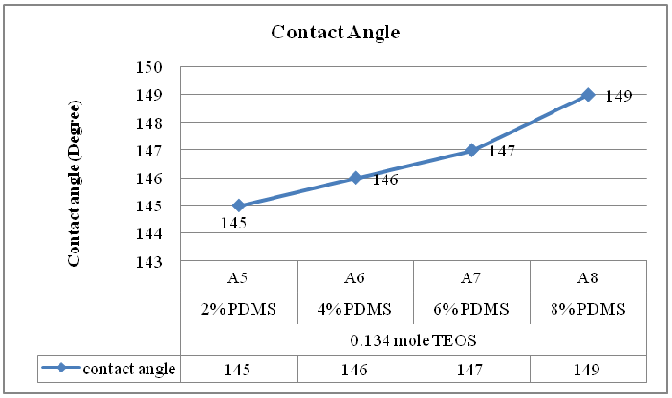


Fig. 4.1 Contact Angle Measurement of 0.134 mole and PDMS treated Cotton fabric at various concentrations.

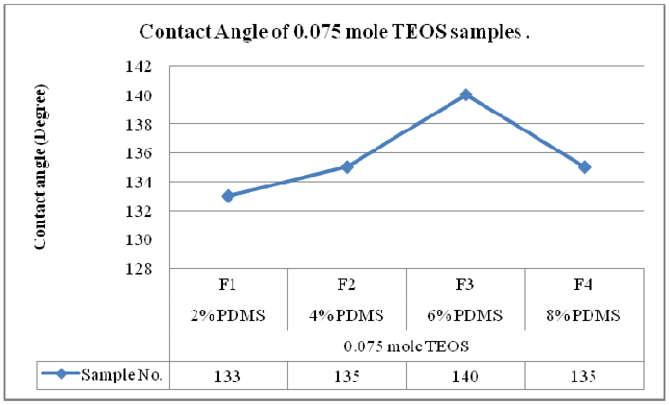
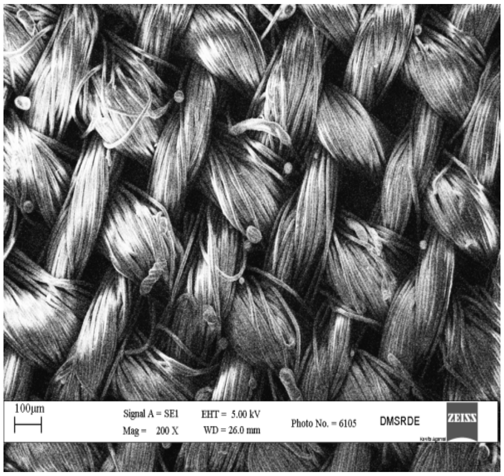
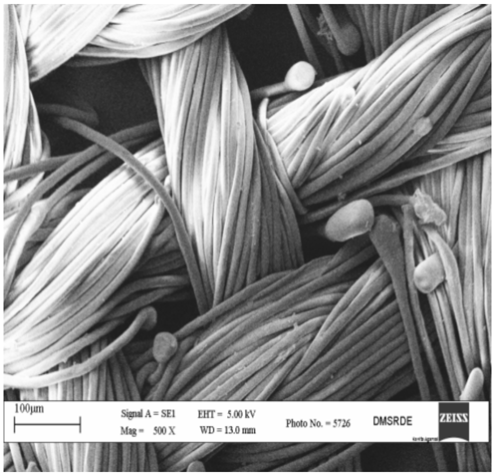


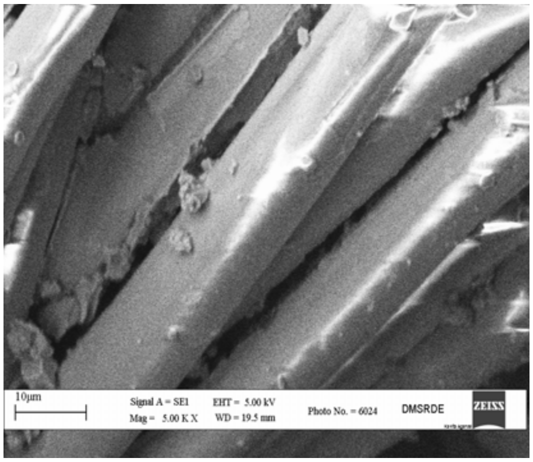
Fig. 4.2 Contact Angle Measurement of 0.075 mole and PDMS treated inherent FR polyester fabric at various concentrations.



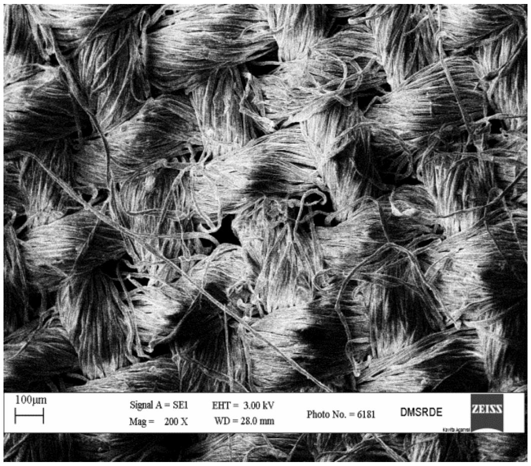
(a) SEM images of polyester scoured fabric surface



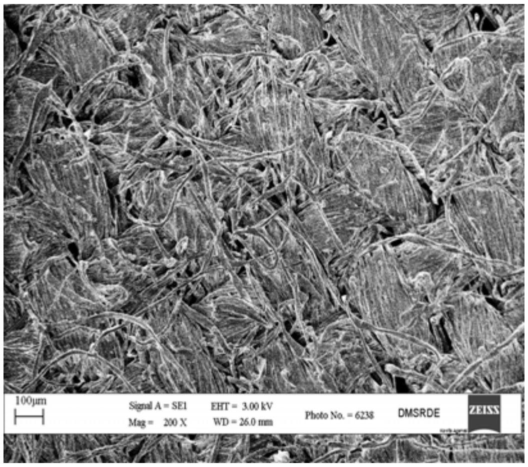
(b.) polyester silica nanosol treated fabric surface



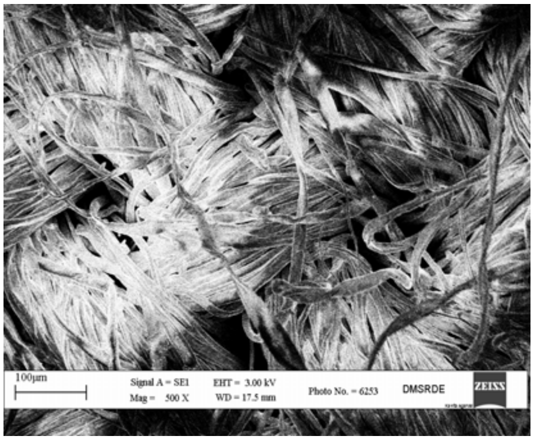
(c) SEM images of silica nanosol and PDMS treated Polyester fabric.



(a.) SEM images of Cotton scoured fabric surface



(b.) cotton sio$_2$, nanosol treated fabric surface



(c) SEM images of sio$_2$and PDMS treated Cotton fabric

5. CONCLUSIONS

In activity titled "Development of Superhydrophobic Polyester and Cotton fabrics using sol-gel technique" following conclusion are made

The aim of this work was to develop superhydrophobic coatings. To realize this aim, the water repellent behaviors on solid surfaces have been studied and several methods to develop superhydrophobic surfaces have been investigated.

I also demonstrated that common polyester/cotton textiles can be successfully transferred into superhydrophobic textiles by introducing silica nano particles on the surface of polyester/cotton fiber. By in-situ introducing silica particles to polyester/cotton fibers to generate a dual-size surface roughness, followed by hydrophobization with polydimethylsiloxane (PDMS) on substrates silica. Normally hydrophilic cotton has been easily turned superhydrophobic, which exhibits a water advancing contact angle of 155º for a 10-µL droplet.

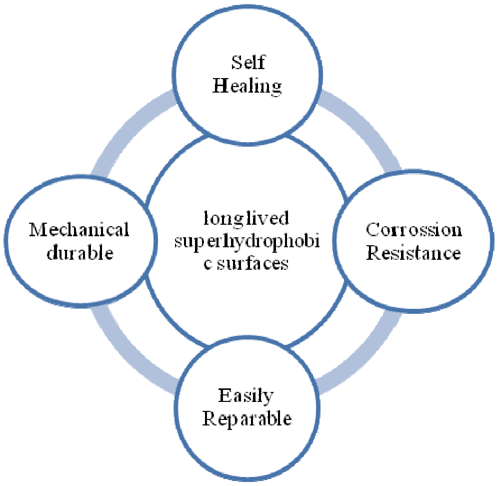
Throughout the experiment, certain factors were found to have impact on the water repellent performance of the treated fabrics. These factors were the type of silica nanoparticles used, the charge of ions contained in the silica solution, the concentration of nanoparticles solution used and also the curing temperature.

The important area of application of superhydrophobic surfaces is reversible superhydrophobicity, that is, the ability of a surface to switch between the hydrophobic and hydrophilic states with the influence of some external stimuli like electric potential, ultraviolet or light irradiation, or temperature. This property can be used in new emerging technologies.

- The static water contact angle of 150^0 and water repellency rating of 100 achieved with silica nanosol and PDMS treated cotton fabric led to development of superhydrophobic surface.
- The highest water contact angle is achieved with 30 ml of TEOS in silica treatment with 8% of PDMS.
- The highest water contact angle of 150^0 achieved with cotton fabric changed its original status of hydrophilic and highly hygroscopic (water contact angle 35^0) material to superhydrophobic.
- The air permeability and tear strength is found to reduce with the silica and PDMS coating on cotton fabric.
- The bending rigidity is found to increase with the application of silica and PDMS coating on cotton fabric.
- The PDMS coated cotton fabric showed better hydrophobicity compared to polyester fabric.

6. FUTURE SCOPE OF THE STUDY

- Most of the artificial superhydrophobic surfaces that have been fabricated to date are not formed on biodegradable, renewable, nor mechanically flexible substrates and the substrate material is often expensive, which limits potential applications. In contrast, cellulose is a biodegradable, renewable, flexible, inexpensive, biopolymer that is abundantly present in nature. Although it satisfies the requirements listed above, cellulose surfaces are not inherently superhydrophobic.
- Prolonging the lifetime of superhydrophobic surfaces is required so that the materials can be used practically. Thus, great efforts have been made in designing surfaces that maintain micro- and nanoscaled hierarchical structures and low surface-energy property, which are necessary for superhydrophobicity, during use. It was demonstrated that improving surface mechanical strength to increase wear resistance helps maintain hierarchical roughness, retarding the loss of superhydrophobicity. Additionally, designing self-healing materials that can recover their structure and/or properties when damaged has been suggested and demonstrated to sustain the superhydrophobicity of surfaces. This paper focuses on recent advances in developing mechanically durable, corrosion-resistant, self-healing, and easily repairable superhydrophobic surfaces, which will enable prolonged lifetime of superhydrophobicity for practical applications in the future.



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