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Superhydrophobic cotton by fluorosilane modification

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Cotton with a superhydrophobic surface and self-cleaning ability has been prepared by the treatment with 1H, 1H, 2H, 2H-fluorooctyl triethoxysilane. An increased level of treatment increases the water contact angle, thereby exhibiting a self-cleaning ability.

Keywords: Cotton, Fluorosilane, Superhydrophobic surface

Superhydrophobic materials are those having surfaces that are extremely difficult to wet, with water contact angle of > 150°. Since the hydrophobicity of a surface is determined by its chemical composition and topography (surface roughness), the superhydrophobicity can be obtained by lowering the surface free energy (by the treatment with fluorinated or silicon compounds)[1-4] and by enhancing the surface roughness with a fractal structure[5-8].

Cotton, a cellulose-based material, that is greatly hydrophilic, is more benefited when made hydrophobic. Modification of cotton to make it superhydrophobic extends the use of cotton even further to various other end-uses, like water-repellent, self-cleaning fabric or it could even be used in oil-spill clean-up where it would repel the water and absorb the oil.

Different approaches have been used to obtain superhydrophobicity on cotton, including coating with different modified silica sols[9], co-hydrolysis and polycondensation of hexadecyltrimethoxysilane, tetraethoxyorthosilicate, and 3-glycidyloxypropyltrimethoxysilane[10], or treatment with densely packed aligned carbon nanotubes[11], and polyacrylonitrile (PAN) nanofibres[12].

This paper reports a very simple and easy method of creating superhydrophobicity on a cotton fabric by lowering its surface energy by coating with a fluorosilane.

Commercially available bleached cotton fabric (107 g/m^2) was used in all the experiments. A sample size of about 10 × 10 cm was used for the different treatments. 1H, 1H, 2H, 2H-fluorooctyl triethoxysilane (FOS) was purchased from Aldrich.

1H, 1H, 2H, 2H-fluorooctyl triethoxysilane (1, 5, 10, 20% per weight of cotton) was added to a mixture of 3:1 EtOH and H_2O and a catalytic amount of HCl. The solution was heated to 40°C for 2 h to activate the silane. Cotton fabric was then dipped into the silane solution, which was heated to ± 80°C (in an oil bath) and kept at this temperature for 3 h. The cotton was removed and dried between two layers of Teflon in an oven at 110°C for 30 min.

Perkin-Elmer 100 Spectrum (FTIR) was used for the structural analysis and an Olympys SZ61 microscope was used to measure the contact angle for studying the hydrophobicity caused due to the FOS treatment. The images were captured by a CC_12 soft image system.

Due to the use of commercially available bleached cotton, no further scouring or pre-treatment with hexane or acetone to remove unwanted oils and waxes from the surface of the fabric was done.

Prior to reaction with cotton (cellulose), the FOS needs to be activated. Activation involves the hydrolysis of ethoxy groups. This reaction is catalysed by acid and the labile silanol groups [R-Si$(OH)_3$], which promotes the silane adsorption onto the OH-rich cellulose structure through hydrogen bonding, are formed. The formation of siloxane bond between the silane and the cellulose occurs after thermal activation (Fig. 1). The silanol groups can also condense with other silanol groups to form siloxane dimers and further condensation forms a polysiloxane network.

From the FTIR analysis, it can be concluded that the fluorosilane is present on the cotton, as indicated by the peaks at 1150-1250 cm^{-1} in the region where CF stretching occurs (Fig. 2).

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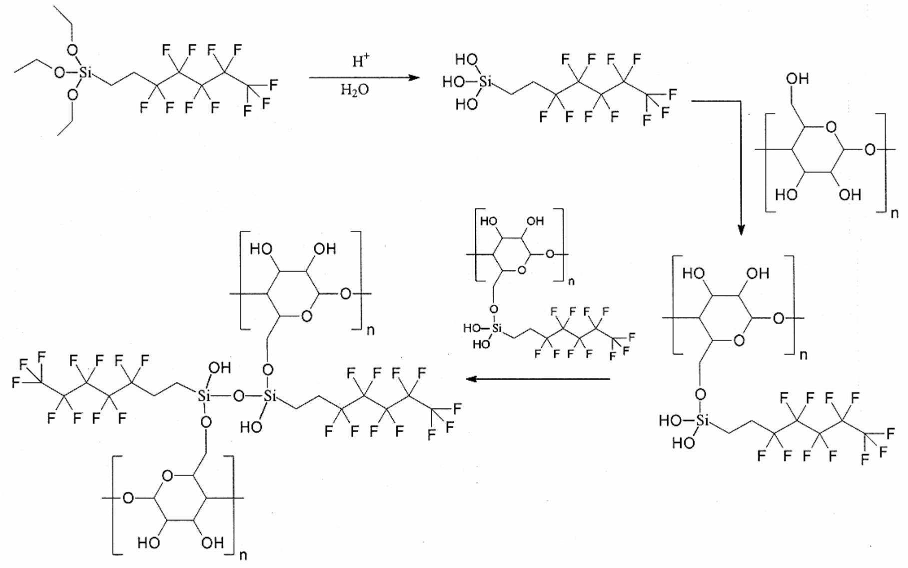

Fig. 1—Activation and condensation of FOS onto cotton

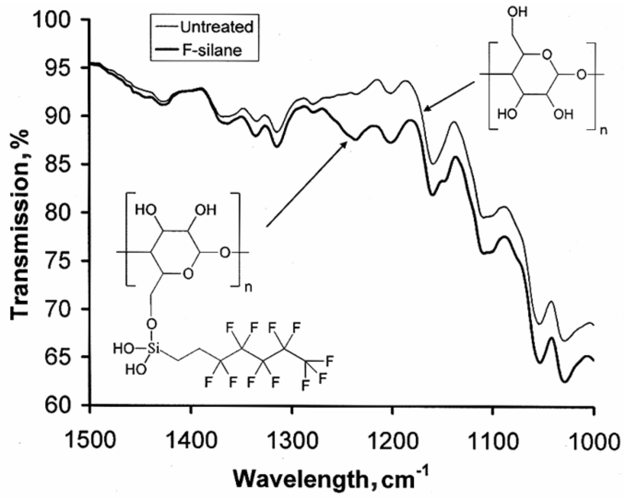

Fig. 2—FTIR spectra of unmodified cotton and the cotton modified with FOS

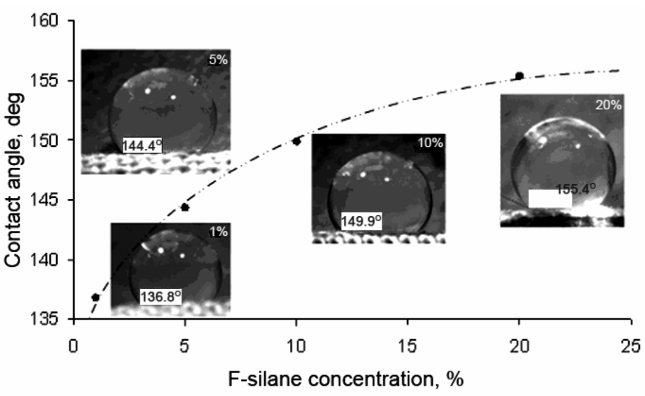

Fig. 3—Increased contact angle with increased FOS concentration

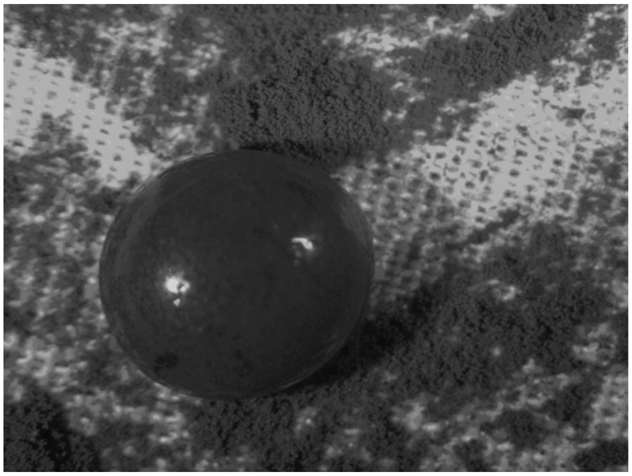

Fig. 4—Self-cleaning ability of the FOS-modified cotton fabric

Water contact angle measurements reveal a hydrophobic surface after FOS modification of the cotton. However, the exact contact angle was difficult to determine due to the inherent roughness of the cotton fabric surface. To investigate the increase in number of fluoro groups which causes superhydrophobicity (free surface energy), the concentration of the fluorosilane was varied from 1% to 20% of the weight of the cotton fabric. It is found that with the increase in FOS concentration, the contact angle of the water also increases (Fig. 3). This could be explained by more effective surface coverage with FOS.

The self-cleaning ability of the FOS-modified cotton fabric was also investigated. The surface of the treated cotton fabric was contaminated with carbon black powder; a drop of water was applied onto the surface to collect the powder. The drop of water containing the carbon black powder rolled off the surface when the cotton fabric was tilted, leaving a clean surface (Fig. 4).

A superhydrophobic surface can be obtained on cotton fabric by the application of FOS. The higher the level of treatment of the FOS, the bigger is the water contact angle, thus demonstrating the improvement in superhydrophobicity of the cotton fabric surface.

Industrial Importance: Imposing superhydrophobicity in cotton is of great industrial importance due to the demanding consumer market for high performance textiles. It is not only a high value-added characteristic but it also has high commercial use and wide spectra of applications. Superhydrophobicity implies self-cleaning, but the chemicals used to create this superhydrophobicity can also impart UV-protection or UV-shielding. Patterned superhydrophobic surfaces have the potential for the lab-on-a-chip, microfluidic devices and it can drastically improve the surface based bioanalysis.

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