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Editorial

Super-Hydrophobic/Oleophobic Textiles

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Editorial

The term *hydrophobe* comes from the Ancient Greek word ὑδρόφοβος and is a combination of the words ὕδωρ and φόβος which mean "water" and "fear", respectively. Consequently, the net interaction between a water droplet and a hydrophobic surface is repulsive and this is described by the large contact angle [1] which ranges from 90° to typically 120°. Intrinsic hydrophobic materials that have been used for decades in various applications and the textile industry are polymers of low surface energy such as, for instance, fluoropolymers and polysiloxanes and other smaller, mostly organic, molecules. Super hydrophobicity refers to much higher contact angles (>150°). This extreme non-wetting state is achieved on micro/nano-structured rough surfaces of usually [2] (but not necessarily [3]) intrinsic hydrophobic materials.

Super hydrophobic structured surfaces are often observed in nature. For example, the surfaces of the lotus leaf and rose petal have been extensively used as model surfaces to fabricate biomimetics materials of special and controlled wet abilities. Both biological surfaces exhibit super hydrophobic properties, implying that the contact angle of water droplets resting on these surfaces is >150°. However, it is stressed that the two plant surfaces show different dynamic wetting: water droplets can effortlessly roll off the surface of a lotus leaf (lotus effect) [2] whereas they stay pinned to the surface of a red rose petal (petal effect) [4]. Consequently, we must recognize that super hydrophobicity is not always accompanied by dynamic water repellence which corresponds to low tilt contact angle and low contact angle hysteresis [4, 5].

The textile industry has a special interest on super hydrophobicity and water repellence as these can lead to the production of water-proof, self-cleaning and stain-resistant clothing and other textiles, as highlighted in several review articles e.g. [6, 7]. Researchers in textile engineering, including A.B.D. Cassie who was a Director of Research for the "Wool Industries Research Association", have significantly contributed to our understanding of the origin of super hydrophobicity and water repellence since the 1940s [8-11], that is several decades before W. Barthlott, C. Neinhuis published their famous paper for lotus and other plants in 1997 [2] which is usually considered as a reference point by the recent literature. Interestingly, Cassie and Baxter were clearly aware of the interdependence between surface roughness and water repellence since 1944 when they wrote [8]: "The duck is generally regarded as having attained perfection in water repellence, and it is usually taken for granted that the duck uses an oil or similar coating with larger contact angles than any known to man. In actual fact, the duck obtains its water-repellence from the structure of its feathers." The aforementioned argument of Cassie and Baxter was inarguably confirmed in 2008, when systematic SEM studies revealed a multi scale structure on duck feathers [12]. Finally, to further appreciate the significant early contribution of Cassie and Baxter it should be noted that they provided the fundamental theoretical basis to the field of superhydrophobicity, as they correlated the elevated apparent contact angle observed on a super hydrophobic surface of augmented roughness with the (Young [2]) contact angle measured on a smooth surface [8]. This correlation has become the famous "Cassie and Baxter equation" used extensively in the literature.

The emergence of nanotechnology offered new tools to manipulate the matter on an atomic and molecular scale. Therefore, in the last two decades several methods have been developed to produce super hydrophobic and water repellent textiles including, for instance, sol-gel [13-15], electro spinning coupled to chemical and photo-induced treatment [16,17], plasma treatment [18] and controlled deposition of nanoparticles which are usually embedded into polymer matrices [19-23]. The latter is an easy process of low cost, as it can be implemented using common polymers and nanoparticles, leading to very large contact angles of water droplets (>160°) [22] and very small tilt contact angles (< 5°) [22]. Examples of super hydrophobic cotton and silk surfaces, which were produced by depositing a polysiloxane coating enriched with silica nanoparticles onto the fabrics, are shown in Figure 1 [20-22]. Super hydrophobicity is evidenced by the apparent large contact angles of the resting water droplets. Likewise, large contact angle is observed for the resting oil droplet on the treated silk (Figure 1), thus suggesting that super oleophobicity was induced by the deposition of the polysiloxane-nanoparticle composite coating onto the silk surface.

The development of strategies to produce super oleophobic surfaces can be considered as the natural sequence of the extensive research which has been carried out on super hydrophobicity. The same processing scheme described above to achieve super hydrophobicity on textile surfaces, is followed in the methods which were developed to induce super oleophobicity: both surface geometry and chemical composition of the textile surface are altered to obtain the desired wetting properties. Consequently, the same techniques described above to achieve super hydrophobicity are roughly used to produce super oleophobic textile surfaces and are, for instance, plasma treatment [24, 25], controlled, Vapour-phase and doping polymerization [26-28] and nanoparticle deposition [22-30]. An example of a super oleophobic silk surface which was treated using nanoparticles was shown in Figure 1.

(i) Super omniphobic textiles that can repel not only water but

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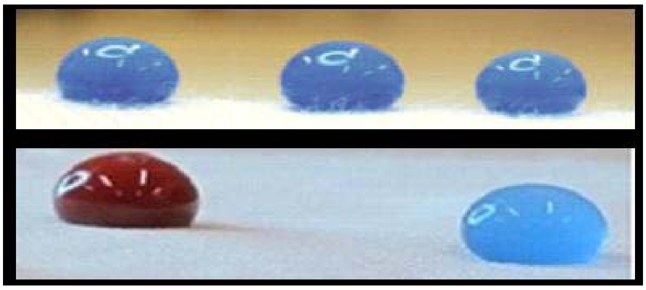

Figure 1: Photographs of droplets of water on treated cotton (above) and droplets of water and olive oil on treated silk (below). For demonstration purposes water and oil were enriched with a blue and a red pigment, respectively.

virtually any liquid thrown on them, offer new perspectives for the textile industry. However, the production of such advanced textiles is a difficult task as liquids of low surface tension (e.g. oil, alkanes etc) tend to easily spread onto surfaces. Hence, the appropriate selection of The materials used to treat textiles and

(ii) The processing conditions, is of enormous importance to extend the range of liquids which dewed from the textile surfaces [22-26].

In principle, the micro/nano-structured surface topography, which is essential for super-hydrophobicity/oleophobitiy, can be easily destroyed by friction. Consequently, the mechanical durability of the materials with special wetting properties is an important issue that several studies attempted to address in the past. A fascinating route that has been recently suggested is the fabrication of materials with self-healing wetting properties induced by externally imposed (mechanical, thermal etc) stimuli [31, 32].

Super-hydrophobic/oleophobic textiles accompanied by water/oil-repellent, self-cleaning and stain-resistant properties have the potential to make an enormous impact on our everyday life. Consequently, the development of strategies to produce these advanced textiles deserves the attention of the scientific community. Some research avenues were briefly presented in this short Editorial Note thus describing, in brief, a major impact of nanotechnology on the textile engineering.

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