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Hydrophobic and superhydrophobic material surfaces and properties

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Abstract

Hydrophobic and superhydrophobic properties are found in the structure of many living plant or animal species in nature. With the discovery of this mysterious world of nature, researchers have fabricated different surfaces or surface coatings to be used in different application areas. Hydrophobic and superhydrophobic materials have a wide range of utilizations because of their hygienic surface properties for example antibacterial, antiviral, antimicrobial, easy cleaning, and self-cleaning which they provide to products used in different areas. The fact that hydrophobic surfaces are easy to clean and the self-cleaning feature of superhydrophobic surfaces have led to the emergence of new products in many different fields such as the health sector, textile sector, ceramic and glass sector, and construction sector. Superhydrophobic surfaces are an area needed especially in today's applications, and they are preferred because they add increased value to the products they are used in, such as being hygienic, saving energy and labor, and increasing the service life of the products. In this study, the basic principles and concepts in the production of these surfaces, examples inspired by nature, industrial application areas, properties, production techniques and analysis methods used in the examination of these surfaces are systematically explained and discussed.

Introduction

Hydrophobic materials are sometimes described as water-repellent, but hydrophobic materials actually attract water, but this attraction between water and surface molecules is weaker than between water molecules [1]. The contact angle is the result of a method used to measure the hydrophobicity of a surface and is a measure of the wetting characteristics of the surface. According to the contact angle value, surfaces are classified as wet (CA<90^o), non-wetting (CA>90^o) and (CA>150^o). If the test liquid used is water, these surfaces are called hydrophilic, hydrophobic and superhydrophobic according to the contact angle [2-6]. The contact angle of hydrophobic and superhydrophobic surfaces with water is the main factor in the easy cleaning of material surfaces and the self-cleaning properties.

When a drop of liquid is dropped on a hydrophobic surface, the shape of the liquid drop formed on the surface is determined by the equilibrium contact angle between the surface and the liquid and the liquid volume. If the volume of the droplet is a multiple of μl or fewer, the gravitational effects are less effective and the shape of the droplet is very similar to that of a sphere. The equilibrium contact angle changes depending on the condition of the surface. If the surface is in ideal condition, the equilibrium contact angle is equal to Young's angle. Young's equation is determined by the force balance between the interface tensions in the liquid, solid and vapor three-phase contact line. This force balance is expressed by the well-known Young's equation [2-6]. According to Young's equation, the lower the surface tension, the larger the contact angle. The lowest free energy among all surfaces was obtained with hexagonal tightly packed CF3 groups. The water contact angle for such a surface was measured as 119°. This is the highest contact angle for all materials known so far [7]. On real surfaces, the equilibrium contact angle does not exactly match the Young's value. However, it changes in a range close to that value. The angle at the liquid edge in the direction of rotation of the water is called the 'advancing contact angle', the angle at the edge where the liquid leaves the surface is called the 'receding contact angle'. The difference between them creates the contact angle hysteresis [3]. Rough and microstructured surfaces naturally increase the hydrophobicity of hydrophobic surfaces through two very different mechanisms. Wenzel assumes that the liquid fills the voids of the rough surface. The wetted surface area is greater on a rough surface compared to a flat surface. Therefore, the net energy decreases in wetting, and the water-repellent surface property is more for a rough surface than for a flat surface. Therefore, the water repellency of the rough surface increases. In the Cassie-Baxter approach, the liquid drop creates a composite surface on the rough surface on the substrate. The liquid does not fill the voids of the rough surface, and the liquid-surface interface is actually a two-phase interface. That is, it is the liquid-solid and solid-gas (air) interface [3, 4, 6, 8, 9].

Many living things in nature show superhydrophobic properties. Lotus leaf, rose petal, rice leave, butterfly wing, water strider's foot are examples of these creatures (Figure 1) [C10-14]. These surfaces appear as materials needed in many sectors due to their superhydrophobic properties in self-cleaning, anti-corrosion, antibacterial properties, anti-fogging properties, oil-water separation applications, and similar areas [15-20].

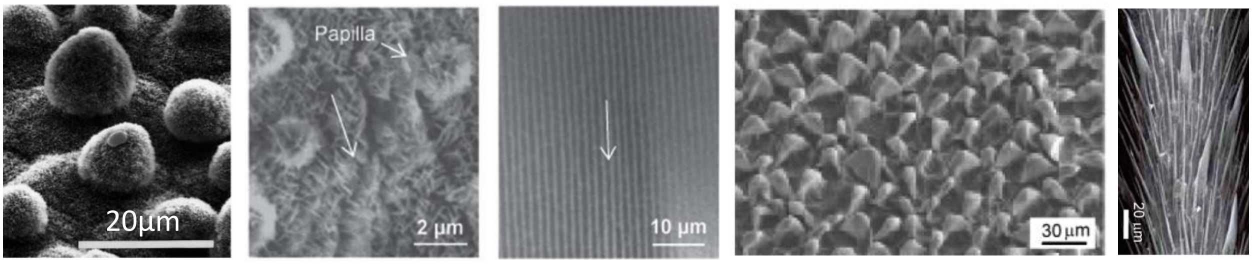

Figure 1. SEM microstructure images of lotus leaf, rice leaf, butterfly wing, rose petal, water strider leg, respectively.

Therefore, it is important to produce superhydrophobic surfaces and determine their surface properties. In this study, the production methods of superhydrobic surfaces and the contact angles of the produced surfaces were examined.

Material and Method

The production methods used to obtain superhydrophobic surfaces are given in Table 1. In order to obtain a superhydrophobic surface, appropriate surface morphology and surface chemistry must be provided together and appropriate contact angle hysteresis must be obtained within these two criteria. The superhydrophobic surface production process by lithography technique is shown in Figure 2.

Table 1. Production method and contact angle SHP

Artificial Superhydrophobic (SHP) Surfaces Production Method	Contact Angle	References
Litography	150.3, 167	21, 22
Sol-gel	165, 157	23, 24
electrospinning	150-166.7	25
etching	153	26
electrochemical deposition	≤174.6	27, 30
chemical vapor deposition	>160	28
Spreying	>160, 155	29, 20
Template	157	31

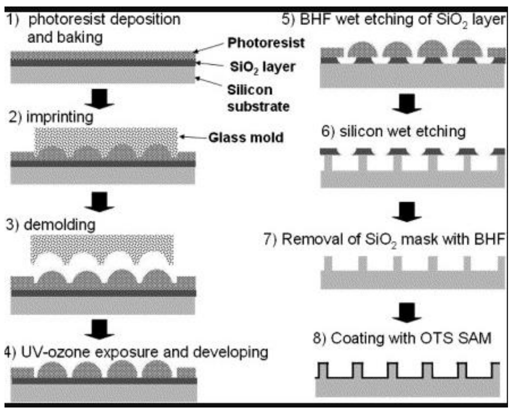

Figure 2. Schematic of fabrication process(lithography), [22]

Superhydrophobicity is achieved by using organic materials, inorganic materials, and both in combination on product surfaces.

Conclusion

The contact angles of the surfaces obtained by the techniques used to obtain a superhydrophobic surface are shown in Table 1 and schematic representation is given in Figure 3.

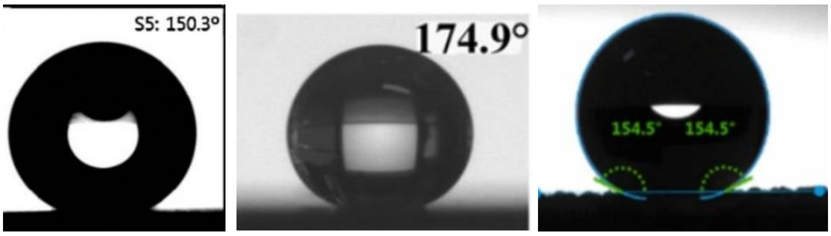

Figure 3. Contact angle images and results [20,21,30]

Considering the contact angles in the studies examined, the criterion of >150 contact angle, which is one of the basic criteria for superhydrophobicity, is met. Successful results were obtained when the surfaces were tilted at 3 degrees, and the difference between the angles of advancing and leaving the droplet remained below 5 degrees. Another important case is how long these surfaces can maintain these properties under usage conditions. Scientists continue to work on material surfaces to be used in different areas according to the conditions of use.

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