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Review

Super-non-wettable surfaces: A review

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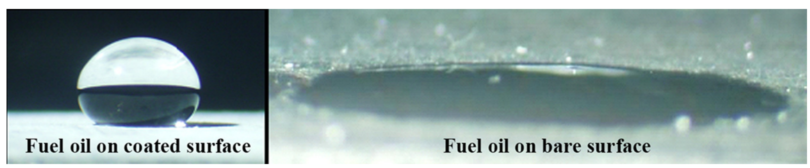
HIGHLIGHTS

- The fabrication methods and applications of super-liquid-repellent surfaces were reviewd.
- The fundamental theories and characterization methods of non-wettable surfaces were described.
- The underwater superoleophobic surfaces were also presented.
- The surfaces with switchable wettability were also summerized.

GRAPHICAL ABSTRACT



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ABSTRACT

The liquid repellency is one of the crucial surface properties which plays important roles in many practical applications but the researches related to this field are in their infancy. This article reviews the fundamental theories and recent achievements in the design, fabrication and applications of super-non-wettable surfaces.

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1. Introduction

During the past few years, the features of bio-inspired non-wetable surfaces have aroused worldwide interest. These surfaces have many practical applications, including separation of oil/water dispersions, self-cleaning, drag reduction, anti-fogging, anti-bacteria, anti-fouling, anti-icing, corrosion resistance, stain-resistant surfaces [1–12]. The wettability of a solid surface by a liquid is evaluated using the contact angle (CA). It is the angle formed between the tangent plane to the surface of the liquid droplet and the tangent plane to the surface of the solid at the point of intersection [13,14]. The superhydrophobic and superoleophobic surfaces exhibit a CA greater than 150° for water (WCA) and oil (OCA), respectively [3,15–19]. These surfaces can be found in the nature on the lotus leaves, rice leaves, red rose petals, ramee leaf surface, Chinese watermelon surface, butterfly's wing, water strider's legs, skins of fish and shark, desert beetle's backs, peacock feather, mosquito compound eyes, Cicada wing, gecko feet, taro leaf and so on [3,17,20–36].

Inspired by the amazing wettability of these natural species, many artificial superhydrophobic surfaces have been fabricated but there are very few reports about the artificial surfaces with superoleophobic property [16,37]. Also, there are many reviews about the superhydrophobic surfaces [38–56]. Because of the low surface tension of most oils, creating superoleophobic surfaces with high static contact angles of oil droplets is much more difficult than creating superhydrophobic surfaces [4,16,20,21,25,37,38,57]. Oleophobic surfaces have more wide applications than the hydrophobic surfaces. The oil-repellent coatings, anti-crawling materials, marine anti-fouling, fluid power systems, anti-oil treatment of oil pipelines, resistance against wax deposition in fuel oil tanks, and anti-bioadhesion is some important applications of superoleophobic surfaces [11,20,24,58]. Because of this variety of application areas, the super-anti-wetting coatings have been fabricated on the wide variety of substrate materials such as silicon [6,10,16,17,19,25,59–61], textile [62–71], wood [72–75], glass [9,18,26,76], concrete [77], aluminum [78–80], steel [81–84], other metal surfaces [80,85] and so on.

The surface free energy and surface geometrical structure are the most important parameters which affect the wettability of the surface. In this regard, the low surface energy and enhanced surface roughness is essential to prepare super-liquid-repellent surfaces [2–6,9–12,16,19,21,25,26,86,87].

In this review, we will cover the fabrication, characterization, applications and recent achievements of super-liquid-repellent surfaces, which are composed of the following sections. In the next section, we focus on the fundamental theories of liquid repellency. Section 3 summarizes the natural non-wettable surfaces. Section 4 describes the artificial super-liquid-repellent surfaces, particularly on the design of surface structure and chemical modification for lowering the surface energy and coating methods. We summarize the characteristics of liquid repellency in Section 5. In Section 6, we will present the applications of super-liquid-repellent surfaces in more details than other sections. Sections 7 and 8 review the underwater superoleophobic surfaces and switchable wettability, respectively. Finally, the conclusions and outlook on the future of this research will be discussed.

2. Theories

2.1. Spreading coefficient

A liquid droplet spreads out on the super-wetting surfaces to increase the contact surface. Contrariwise, the liquid drop remains spherical on the anti-wetting surfaces. The factor determining the spreading or anti-wetting for a liquid droplet is called spreading coefficient which is defined as:

$$S = \gamma_{SA} - \gamma_{SL} - \gamma_{LA} \quad (1)$$

where γ_{SA}, γ_{SL} and γ_{LA} are the surface tension at solid–air (gas), solid–liquid, and liquid–air (gas) interfaces, respectively. For partial wetting or anti-wetting, $S < 0$, and for complete wetting $S = 0$.

2.2. Smooth surfaces

If a droplet of liquid is placed on a smooth solid surface, the wettability of the surface can be described using a relationship between the surface free energy of liquid/air (γ_{LA}), solid/air (γ_{SA}) and solid/liquid (γ_{SL}) as follow:

$$\cos\theta = \frac{(\gamma_{SA} - \gamma_{SL})}{\gamma_{LA}} \quad (2)$$