etch system. In addition, C_4F_8 gas polymerization provides better resilience and repeatability when compared to alternative surface treatment techniques. Significantly, the polymer structures remain unchanged following the plasma treatment, which is thought to be a beneficial fluorocarbon surface treatment. As a consequence, the superamphiphobic surface is extremely repellent to different liquids with a broad range of surface tensions from 22.3 to 72.1 mN m^{-1}. The superamphiphobic surface has a transmittance of up to 90% (Figure 1.4k) and a durability of at least six months (Figure 1.4l).

1.3.2 Special Rough Morphology

The surface topology is another crucial factor. As previously mentioned, air can become trapped on a rough surface when liquids come into contact, significantly decreasing the contact between the surface and the droplet. However, repelling liquids with extremely low surface tension is not always the case for all rough surfaces with low surface energy. It was far from sufficient for industrial applications to repel just liquids with higher surface energy, such as water and glycol. To construct superoleophobicity, only a certain type of rough structure with reentrant geometries is applicable. In recent years, numerous review articles have concentrated on and gathered information about the design of complicated reentrant geometry, overhang structures, inversetrapezoidal structures, and mushroom-like structures, to fabricate superamphiphobic interfaces, as shown in Figure 1.5a–f [46–50]. The rough structure with reentrant curvature balances

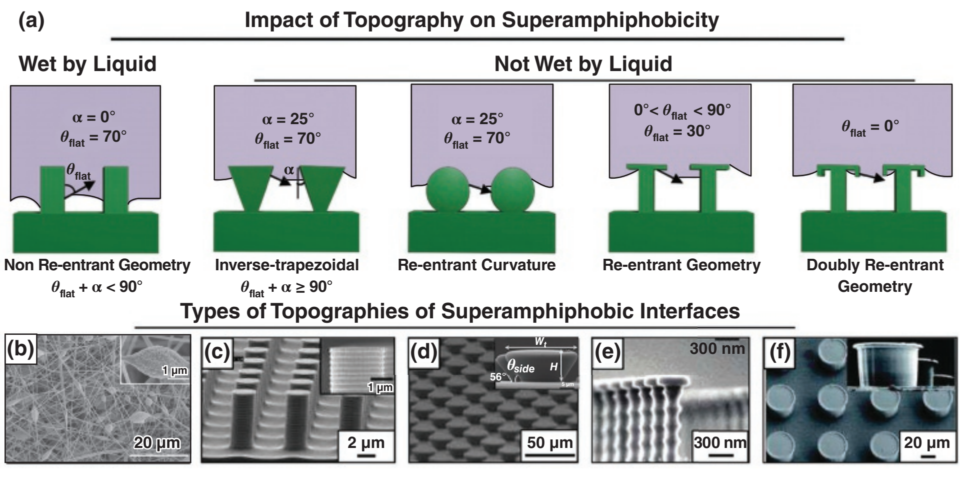

Figure 1.5 (a) Schematic depicting the impact of various reentrant topography for achieving superamphiphobicity. For non-reentrant geometry, the liquid wets the surface for θ_{flat} < 90°. When $\theta_{flat} + \alpha \geqslant 90°$ for reentrant inverse trapezoidal geometry, the liquid does not wet the surface. But curvature geometry in reentrant structure supports the nonwetting of the surface with θ_{flat} = 70°. Also, other reentrant geometries support the nonwetting of the surface for θ_{flat} < 90° and θ_{flat} = 0° [46] / with permission of Elsevier. (b–f) SEM images of various reentrant geometries that aid in exhibiting superamphiphobicity including [51] / American Association for the Advancement of Science – AAAS (b) electrospun morphology, (c) well-defined micropillar type structures, (d) inverse trapezoidal microarrays, (e) wavy stem with wider head. (f) Overhang T-shaped microstructure [50] / The Royal Society of Chemistry.

the downward mixing force generated by Laplace pressure and droplet gravity and generates an upward combined force, therefore repelling liquids with lower surface tension.

1.3.2.1 Reentrant Structure

The notion of the reentrant surface structure was first proposed by Tuteja et al. [51] and used in the construction of superamphiphobic surfaces; it is thought to be an effective technique. Notably, this notion has significantly aided in the advancement of this field. So as to keep low contact angle hysteresis and reasonably high contact angles, superamphiphobic surfaces are predicted to produce composite solid–liquid–air interfaces with air pockets in the valleys between pillars. Reentrant curvature can be produced to some extent via mushroom-shaped structures, micro-hill-like structures, or even randomly stacked nanoparticles [52–55]. As we all know, the concave shape of the top of springtails, as one of the main factors, can contribute to liquid repellency. Kang et al. [52] used silicon microelectromechanical systems and soft lithography techniques to create mushroom-like micropillar (SIMM) arrays that resemble springtails in size and shape, with diminutive heads and broad feet. It was discovered that the meniscus of the SIMM array may be altered to provide selective liquid sliding features by varying the texturing angle and spacing between neighboring microcolumns. This occurs as a result of competition between internal gravity and Laplace pressure near the meniscus. It was shown that the mushroom-like head possesses both superomniphobicity and selective liquid sliding features. Zhang et al. [53] developed superamphiphobic surfaces with micro-hill-like reentrant microstructures by spraying fluorinated multiwalled carbon nanotubes (F-MWCNTs). The F-MWCNTs accumulating randomly and solvent evaporating jointly contributed to this particular reentrant structure. Such surface possesses sliding angles of 1.2° and 4.3° and contact angles of 172.4° and 163.0° for water and cetane, respectively (Figure 1.6a).

1.3.2.2 Overhang Structure

Previous research [56, 57] has indicated that innately hydrophilic materials can be made to exhibit superhydrophobic behavior if they have surfaces with microtextures with overhanging structures. These features contribute to keep water from entering grooves due to capillary forces. Likewise, it has been shown that superoleophobic surfaces can be formed on innately oleophilic substrates with overhang structures preventing oil from penetrating the textures, thus exhibiting superamphiphobicity [58–60]. Wang et al. [59] have developed a multifunctional coating composed of fluorinated alkyl silane, micro-sized ammonium polyphosphate particles, and functionalized silica nanoparticles (Figure 1.6b,c). A unique randomly overhanging hierarchical structure can be constructed on a variety of surfaces using an easy and economical spaying technique and exhibits super-repellency to water and oils with low surface tensions. Reverse imprint lithography and reactive ion etching techniques were used by Wooh et al. [60] to develop superamphiphobic surfaces with overhang patterns. They also incorporated conical, pillar, hole, and linear nanopatterns onto the overhang structure's surface in addition to the single overhang structure. The superoleophobicity of embedded holes and linearity could be enhanced by creating a new overhang angle of approximately 0° beside the original overhang structure, while the embedded conical and pillar nanopatterns just decrease the solid–liquid contact area.

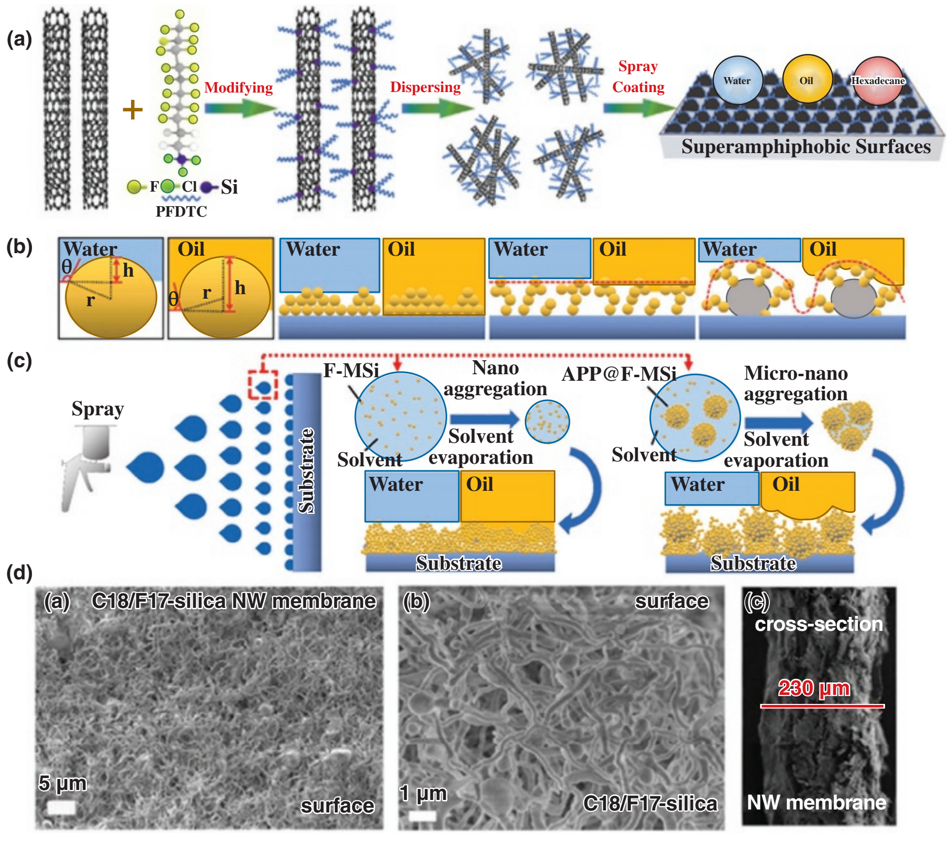

Figure 1.6 (a) Schematic illustration of the process for F-MWCNTs coating preparation [53] / with permission of Elsevier. (b) Schematic illustration of liquid-wetting models of a single particle with the radius r wetted by water and hexadecane. (h: penetration depth of the liquids; θ: the static contact angle of the liquids on a smooth surface possessing identical surface chemistry as the rough surface.) Assumed wetting models for the coating surfaces wetted by water and oil. (c) Schematic illustration of the mechanism of forming the superamphiphobic surface [59] / with permission of Elsevier. (d) General surface SEM, enlarged surface SEM, and cross-section SEM [62] / The Royal Society of Chemistry.

1.3.2.3 Porous Structures

Superamphiphobic coatings with porous structures are rarely constructed because of the unclear correlation between the structural parameters of the pores and the repellency of the coating. Nevertheless, it is worth noting that creating air pockets by trapping gas is crucial for liquid repellency as it creates negative Laplace pressure. Liquid repellency is greatly influenced by the amount of air present in the pores or vacancies of porous structures, another important type of nanostructure for creating superamphiphobic surfaces (Figure 1.6d) [61–63]. An artificial porous superamphiphobic surface has been developed by Li et al. [61] by combining adhesive agent polydopamine with hydrophilic SiO_2 nanoparticles for constructing a porous micro-network. Following a two-step CVD process, the superhydrophilic microstructure porous coating transformed into a superamphiphobic one. It should be highlighted that a porous coating's repellency is significantly influenced by structural factors like pore height and size. Therefore, it is advantageous to optimize the structural characteristics in order to improve the coating's repellency. Besides, Cao et al. [63] have constructed a superamphiphobic, self-cleaning, and robust coatings on a variety of rock substrates depending on the low surface energy of fluorinated compounds and the inherent roughness of stone substrates. The superamphiphobic chemicals are housed in the pores of the stone, which functions as a microstructure to resist abradant removal and maintain the substrate's chemical and physical integrity.

Generally speaking, the two aforementioned factors should be carefully and extensively considered in order to properly accomplish superamphiphobicity.

1.4 Summary and Outlook

This section briefly introduced the several fundamental wetting states, dimensionless parameters, and design criteria that characterize the performance of a well-defined structured surface. Furthermore, commonly used chemical modification materials and a wide diversity of surface topographies of oil-resistant materials were summarized using pertinent classification.

To fully comprehend the superamphiphobic surface, it is important to discuss both current challenges and promising prospects. Firstly, additional investigation is needed to better comprehend the formation concept of a superamphiphobic system. The fundamental theory plays a very important guiding role in the fabrication and applications of superamphiphobic surfaces. Secondly, in order to quantify the performance stability of the superamphiphobic surface and facilitate performance comparison, a set of predetermined standards should be established. Last but not least, long-chain fluoride, which is frequently employed to reduce surface tension during chemical modification, is poisonous and harmful to the environment. Since low surface energy chemistry is not required, double reentrant structures should be further studied to produce superamphiphobic surfaces, as this is thought to be a more environmentally friendly technique. Double reentrant configurations can be optimized and used to build superamphiphobic surfaces by controlling the structural angle of the structured surface.

Generally speaking, there is still a huge potential for the development of superamphiphobic surfaces. With consistent effort, scientists and engineers will propose more theoretical research based on unique results to further grasp superamphiphobicity. A promising future lies ahead for superamphiphobic surfaces because of their high commercialization value and potential, which is driving an increasing number of scientists and engineers to strive for superamphiphobic surfaces.

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