Wetting of hydrophobic, superhydrophobic and lubricant impregnated surfaces

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Introduction

Drops and liquids are omnipresent and therefore they are of enormous industrial and environmental relevance. The wetting properties of drops determine the outcome of all printing or spray coating processes, including spreading dynamics of pesticides and fungicides. Wetting is a key factor in many heat transfer processes and determines the stickiness of liquids to surfaces.

The wetting properties of a drop depend on the involved interfacial tensions, i.e. the interfacial tension liquid-air, solid-air and solid-liquid. However, only the interfacial tension between liquid-air can easily be quantified. In the first part of my lecture, I'm going to discuss what determines the interfacial tension of a liquid, and how can it be measured and altered. In the presence of surface, a liquid drop takes a certain shape. The angle the drop forms with the surface is given by the Young's equation[1]. The Young's angle is also termed the contact angle of the material. It's provides a good thermodynamics description of wetting. However, its value depends on details of the surface, including how a drop is deposited.

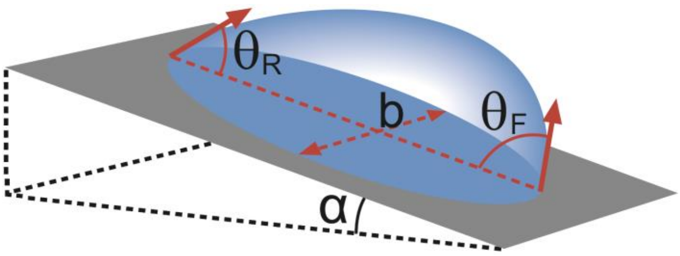

Figure 1: A drop deposited on a tilted surface. It starts rolling off, as soon as the gravitational force exceeds the lateral adhesion force. This is the case if the surface is tilted by an angle α.

Even on a smooth surface, two characteristic angles exist, the advancing contact angle, θ_F, and the receding contact angle, θ_R.[2] The reason is that even the tiniest chemical or topographical or inhomogeneity provides pinning sites for the droplet. The strength of pinning is reflected in the difference between both contact angles. The correlated lateral adhesion force is given by the angle a drop takes when it rolls off the surface, assuming that adhesion does not prevent rolling off.[3]

For several applications easy roll-off is highly desired. These so termed super-liquid-repellent surfaces show particularly low lateral adhesion and friction, i.e., a deposited drop rolls off as soon as the surface is tilted by less than 10°.[4] Three distinct approaches exist for achieving super-liquid repellency: Superhydrophobicity,[5, 6] lubricant impregnated surfaces[7-9] and liquid-like surfaces.[10]

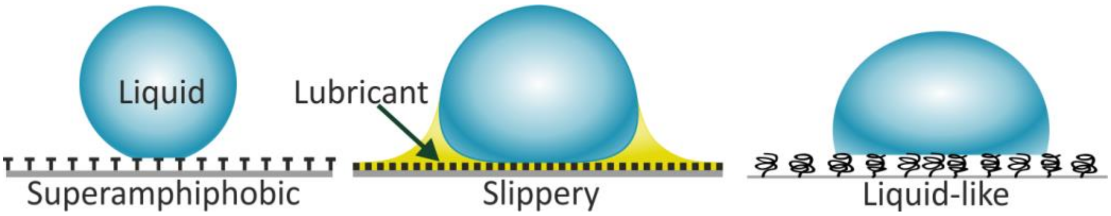

Figure 2: Recent strategies to make super-liquid repellent surfaces.

Superhydrophobicity (hydro- meaning water, -phobicity meaning fear), prevents drops of water from sticking on nano-/micro-roughened surfaces. This is demonstrated by low water-to-surface adhesion and facile droplet roll-off. **Superamphiphobicity** (amphi- meaning both) expands on this effect, enabling repellency towards both water and low surface tension oils. Both superhydrophobicity and superamphiphobicity rely on the presence of air gaps within the nano-/micro-structured surface asperities, thus reducing the solid-liquid contact area. Superamphiphobicity also requires so termed overhangs and fluorination.

In case of slippery surfaces hydrophobic lubricants are first infused within a porous material. Capillary forces help to keep the lubricants in place. Depending on the interfacial tensions the drop is cloaked by a thin layer of lubricant. However, the depletion of lubricant still presents a significant challenge for long-term applications. This depletion takes place *via* 3 primary routes: Liquid cloaking and wetting ridge formation leads to the sacrificial loss of lubricants during droplet repellency. I'm going to discuss the formation of a lubricated layer using an emulsion. For the so termed liquid-like surfaces,[10] a nanometric layer of PDMS is attached to the target surface. It point towards the essential of the chemical modification of the coating.

A problem to understand the wetting properties of drops on super-liquid repellent surfaces forms the high contact angle. This makes is difficult to image the shape of the drop. This problem is particularly severe for drops on superhydrophobic or slippery surfaces. In the former case the shape of the water-air meniscus under the drop cannot be monitored using video microscopy. In the latter case the problem is caused by the poor optical contract between different liquids. I will discuss the possibilities and limitations of confocal microscopy to image the dynamics of drops on super-liquid repellent surfaces.[11-13]

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