Liquid interface on a structured surface and apparent contact angle

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Abstract

Two well-known wetting states of a liquid drop on a structured surface can be distinguished: The Wenzel case corresponding to the fully wetted surface and the Cassie-Baxter case associated with partially wetted surface. The Cassie-Baxter state is frequently related to the phenomena of super-hydrophobicity which has numerous industrial applications.

In order to predict the apparent contact angle in the Cassie-Baxter regime, the exact shape of the liquid/surface and liquid/gas interface at the substrate has to be determined. This is not an easy task if the surface structure is three dimensional.

In this experimental and numerical study, a new model for the description of the shape of the liquid interface in the Cassie- Baxter state and for the prediction of the apparent contact angle of a droplet resting on a structured surface is developed.

The liquid interface between the structures is considered in detail. The local shape of the liquid surface is predicted numerically using Surface Evolver. These numerical simulations allow us to estimate the local pressure and curvature at the interface and the average projected surface energy. The numerical simulations for the interface shape are validated by comparison with the experimental data. The experiments were performed under microgravity conditions during the 46th ESA parabolic flight campaign. The microgravity conditions allow us to upscale the surface structure in order to observe the liquid interface better.

Simulations for different droplet volumes and material wettabilities were performed in order to determine the relations between the local pressure at the interface and the apparent contact angle. These numerical predictions can be used to calculate the final shape of liquid droplets resting on the structured surface.

Finally, we have demonstrated that the Wenzel, Cassie-Baxter expressions lead to the non-physical results. We propose also a simple explanation why these models, developed on the base of surface energy considerations, are not able to reliably predict the value of the apparent contact angle. We have also demonstrated that Surface Evolver can be a useful tool for the investigation and prediction of the wettability phenomena.

Key words: Structured surface, Wenzel, Cassie-Baxter, surface evolver, contact angle, wettability, μ-g, microgravity

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