Drops on noisy surfaces (phase field modelling)

by

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Abstract: Dynamics of water drops has been intensively studied during the last century on different materials: from natural and artificial porous clothing surfaces (to avoid the falling rain drops to penetrate the structure) to heterogeneous/chemically patterned substrates, and, more recently, on gradient and soft surfaces. The main aim is to create at the liquid-air, liquid-solid interfaces the physico-chemical conditions in such a way that, tending to minimize its surface energy, the droplet experiences an already anticipated motion. This droplet manipulation has large applications in micro-fluidic and eventually nano-fluidic devices without power supply, laboratory-on-a-chip, ink-jet printing, or surface cleaning technologies.

Altering the surface wettability by external stimulation has received a great attention in the last years. Smart materials were created which are adaptive, reconfigurable, and switchable under different external parameters, such as temperature, pH or light. These substrates change adaptively the wettability properties of the liquid droplet and are valuable for control and manipulation of droplet motion. Dependence of the wetting characteristics of a solid on surface roughness and surface morphology is inherent in the everyday life. In particular, they can strongly influence the characteristic time scales of fluid flow in thin films during spinoidal dewetting and of spreading drops. Thus, the control of surface roughness and morphology would allow regulated motion of small portions of liquids (or drops) on structured substrates.

In this contribution, we present a systematic investigation of liquid droplets on noisy surfaces. The statistical properties of the surface roughness will be studied by the correlation length. We investigate numerically the role of the correlation length in drop behavior on noisy surfaces. To this aim, we adopt a continuum thermodynamic description using a phase field tool earlier developed for describing static and dynamic contact angles [1,2]. Theoretical results are confirmed by experiments of distilled water drops sitting on stainless steel and silicon surfaces textured by laser-induced periodic self-organized structures: an increase of the noise amplitude results in an amplification of the original behavior (i.e., hydrophobic is getting more hydrophobic, hydrophilic is getting more hydrophilic). Furthermore, computer simulations in two and three spatial dimensions allow for predictions of drop behavior on noisy sloped substrates under a gravitational force, a problem of large interest in controlled motion in micro- and nanofluidics.

References

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