FILLING DYNAMICS AT THE ONSET OF THE SPONTANEOUS CASSIE BAXTER-WENZEL TRANSITION

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Several natural materials, one of the most famous being the lotus leaf, show that initial hydrophobicity can be drastically enhanced by textures. Possible applications range from microfluidics and coating to medical uses [1]. When a droplet of water is softly deposited on a micro-patterned hydrophobic surface, a suitable coupling of surface energy and surface topography can lead to the so-called superhydrophobic *Cassie-Baxter* state [2]. The liquid then bridges across the surface features, providing effective contact angles of 160° and beyond. When such a state is metastable, a small perturbation can make it spontaneously break down: the liquid enters the underlying structure in some point and propagates into the surface features. This complete wetting characterizes the so-called *Wenzel* state [3].

The conditions for spontaneous transition as well as its dynamical properties are discussed, both experimentally and through theoretical modeling, by considering a surface made of micrometer-sized square pillars set on a regular square lattice with height $h = 10\mu m$, width $w = 5\mu m$ and, as control parameter, a gap $a = 2$ to $17\mu m$.

For the experimental part, we use a polymeric translucent thin film (thickness $\sim 40\mu m$) fabricated by Phase Separation Micromolding method [4], allowing for optical imaging from the bottom, i.e. through it. The contact angle is $\theta \sim 100°$ on a smooth surface of the same material. A droplet of ultra-pure water is gently deposited onto the film, initially in the metastable Cassie-Baxter state. The rapid filling process is recorded with a high-speed imaging system (Photron Ultima APX-RS) through a microscope. For the numerical modeling, we use a 3d Lattice Boltzmann algorithm for single component multiphase flow, with the same geometry as in the experiment [5].

By balancing free and liquid-gas interface energies for the advancing front between two pillars, we obtain $\cos\theta_c = -1 + 2h/(2h + a)$, with θ_c the critical contact angle. The transition is energetically favored if $\cos\theta_c < \cos\theta < 0$, which corresponds to $a \gtrsim 4\mu m$ in the experiment. Moreover, by taking into account that viscous dissipation dominates inertia at such a scale, and so by balancing the energy gain due to the filling and the energy lose due to viscous dissipation, we deduce the time scale $\tau \sim (1 - \cos\theta/\cos\theta_c)^{-1}$, which explains the critical slowing down of the front close to the critical contact angle θ_c.

The structured surface properties as well as the problem geometry are found to strongly influence the dynamical behaviour of this filling process, leading to the appearance of a well-defined capillary dynamics. For large a values, the filling occurs with a fast (beyond $1m/s$) and round shape front. For small a values,

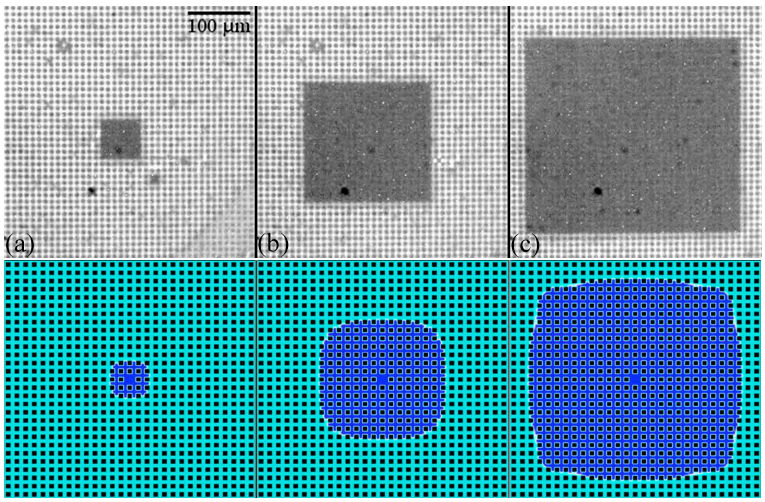

FIGURE 1. Bottom view. Large scale time evolution for filling process in the experiment (top) with $a = 5\mu m$, and in a 3d Lattice Boltzmann simulation (bottom).

for which lower front velocities are observed, large and small scale evolutions are studied as well. In particular, it is observed that the pattern geometry determines the shape of the propagating front at large scale (see Fig. 1), whereas details of a more complex dynamics are evidenced at smaller scale: a slow front dynamics in between the pillars followed by a brief "jump" to the next row of pillars, in the form of a *zipping* mechanism [6]. Finally, for $a = 2\mu m$, no filling is observed, as expected.

The critical contact angle θ_c as well as the critical slowing down are consistent with our experimental and numerical results. We aim to extend our analysis to other geometries and materials.

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