Contact angle hysteresis and depinning behaviour of sliding droplets on chemically patterned surfaces

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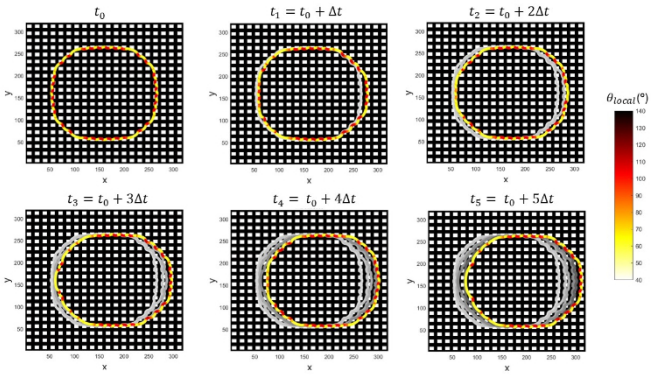
We numerically studied three-dimensional droplets sliding on tilted and chemically heterogeneous surfaces composed of a hydrophilic base surface patterned with a square array of hydrophobic square-shaped defects. The simulations were performed with our in-house multiphase code implementing the phase-field lattice-Boltzmann method of Liang et al [1]. For each droplet simulated, and at every time step, the triple contact line shape was obtained from several thousands of discrete points interpolated thanks to a spline interpolation. The local contact angles all along the triple contact line were likewise determined from the spline interpolation. Using the method of Wang et al [2], the apparent advancing and receding contact angles of the droplet were also estimated at every time step from different 2D profiles along the symmetry planes of the surface pattern, either parallel to a row of defects or diagonal relative to the defects .

The pattern period, and the equilibrium contact angles of the base surface (equal to 60°) and of the defects (equal to 110°) remained constant for all the simulations. We investigated the dynamic of the triple contact line and the effect of the defect size within the pattern, with values of the defect size to pattern period ratio ranging between 0.25 and 0.75, with a 0.125-increment.

The results show that the droplets exhibit a stick-slip motion with a periodic variation of the apparent and local contact angles. The droplets display different pinning-depinning characteristics depending on the considered axe of symmetry of the surface pattern. The study of the advancing and receding contact angles, both apparent and local, as a function of the defect size to pattern period ratio, gives further insight into the depinning regimes that can be involved in the droplet anisotropic behaviour.

Keywords:

Contact line dynamics, dynamic contact angles, pinning-depinning regimes, three-dimensional droplet, numerical simulation.



Two-dimensional views (in lattice units) of the triple contact line coloured as a function of the value of the local contact angle at different times, with gray-coloured lines corresponding to the previous positions of the contact line.

References:

[1] Liang, H. et al., "Phase-field-based multiple-relaxation-time lattice Boltzmann model for incompressible multiphase flows", Physical Review E, 89, 2014.

[2] Wang, Y. et al, "Droplet sliding: The numerical observation of multiple contact angle hysteresis", Langmuir, 35, 2019.

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