

Control of evaporation by geometry in capillary structures.

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Evaporation is a key phenomenon in the natural environment and in many technological systems involving capillary structures. Understanding the evaporation front dynamics enables fine control of the evaporation rate from microfluidic devices and porous media. Of particular interest is the ability to control the position of the front using well-thought designs. In this study, the capillary structures consist of arrays of cylinders, with a 50 μm height and diameter, sandwiched between two horizontal, flat plates. Control of the evaporation kinetics is achieved by playing with the spatial organization of the cylinders.

Two types of control are demonstrated. The first one relies on the control of the sequence of primary invasions through the pore space, while the evaporation front remains pinned at a fixed location (see Figure, left). The second relies on the control of the secondary liquid structures (elongated liquid films, liquid bridges between cylinders, etc...), that form in the region of pore space invaded by the gas phase (see Figure, right). In both cases, quantitative predictions of the phase distribution and evaporation rate can be achieved, notably in the much more involved second case, where the modelling involves numerical simulations of the liquid film capillary shape and of the evaporation-induced flow within the films. The present study thus opens a route to control the evaporation kinetics from tailored capillary structures.

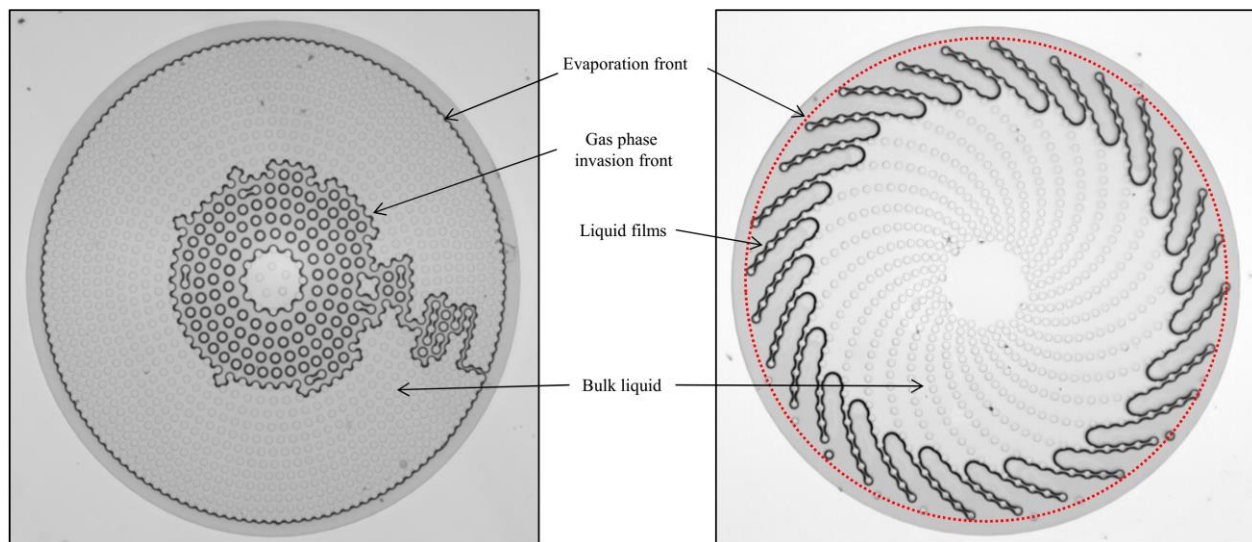


Figure: Top view of two microsystems with different spatial arrangement of the confined cylinders. Gas-fluid interfaces appear in black. Fluid is ethanol (fully wetting the epoxy-based microdevice). Left: Pattern with a decreasing radial gap between the cylinders, from the center to the periphery. The evaporation front remains pinned to the external rim of the pattern while air bursts progressively invade the microsystem center. The evaporation rate is constant. Right: Phyllotaxy-inspired pattern (Fibonacci spiral). As long as the fluid is transported within the elongated liquid films up to an effective evaporation front (red dotted line), the evaporation rate is constant.