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Viscous fingering in a microfluidic network

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We study experimentally and numerically two-phase flow in a rectangular network of microfluidic channels. If the pressure gradient is oriented along the lattice, growth of long and thin dendrites ('thin fingers') is promoted. The dynamics of thin finger growth is of interest due to their appearance in a variety of other pattern forming systems, such as the growth of dendrites in electrochemical deposition experiments, channeling in dissolving rocks or side-branches growth in crystallization. Due to their simplicity, thin finger models are also attractive for theoretical analysis.

A characteristic feature of these systems is a strong competition between the fingers which is a reflection of Saffman-Taylor instability acting in a nonlinear regime. Surprisingly, the case of miscible fluids turns out to be different, with the competition between the fingers hindered due to the strong lateral currents of the displaced fluid, which eventually cut off the heads of the advancing fingers, thus preventing their further growth. The heads continue to move through the system, preserving their shapes, thus forming the 'miscible droplets'. In immiscible case this process is hindered by the presence of the surface tension. A detailed analysis of this phenomenon is given with a particular emphasis on the scaling properties of the system.