Controlling pattern formation in a single hole lifted Hele-Shaw cell

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A Hele-Shaw cell consists of a liquid sandwiched between two parallel plates at a fixed separation distance. When one plate is lifted from the other, a pressure differential is created which forces ambient air into the liquid. As the liquid recedes, a Saffman-Taylor instability develops at the liquid-air interface, which evolves into long fingers, leaving a branched liquid pattern behind [1]. Control over the branching pattern can be achieved by strategically introducing asymmetry in one of the plates and controlling air entry points, for example, through the addition of holes [2]. By controlling the path of air in this Hele-Shaw cell, the pattern formed by the liquid can be controlled.

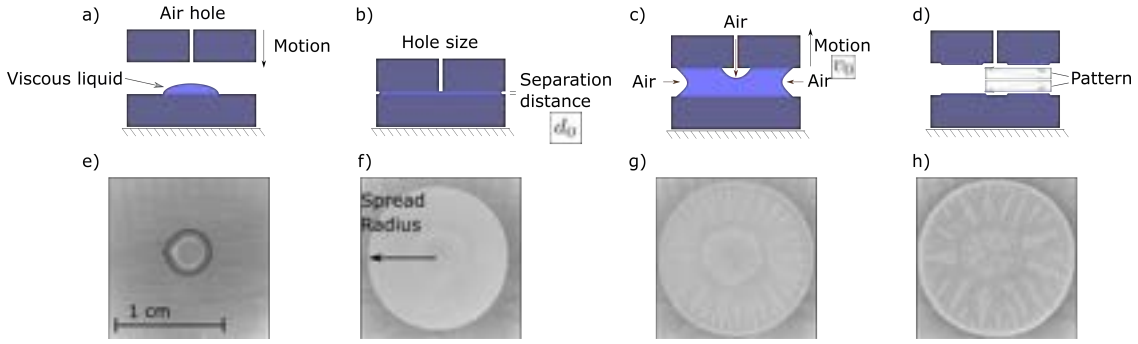

Figure 1: Depiction of a lifted Hele-Shaw cell process. a) Liquid is deposited on to the bottom plate. b) The deposited liquid is pressed between the top and bottom plates ensuring a separation distance d_0 between the plates. c) The top plate lifts away from the bottom plate at a constant velocity. A capillary bridge is formed, air displaces the liquid radially inwards, deforming the liquid-air interface. d) The liquid bridge collapses resulting in a fractal-like multiscale pattern. e-h) Shows the lifted Hele-Shaw cell process through a top down experimental view.

This work investigates methods of control over pattern formation in single hole lifted Hele-Shaw cells, the mechanism of which is outlined in Figure [1]. Addition of an air hole introduces another liquid-air interface which initiates air fingers from the centre to the outer liquid-air interface. The two air fingers create a ring of liquid at a radial distance between the outer liquid-air interface and the central hole. The height, width, inner and outer radii of the ring is characterised for different hole sizes, separation distances, lift speeds and spread radii.
By understanding the conditions under which these patterns form, a catalogue of formation environments can be built, providing a strategy for precise control over pattern formation in lifted Hele-Shaw cells using asymmetry. These strategies hold significant potential for bio-mimicry of multiscale structures, providing the fundamental requirements for more efficient transport networks.

References

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