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Tuning elastic membrane instabilities for adaptive single and multi-phase fluid transport

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The flexibility and adaptability of microfluidic networks have become more important as the field is rapidly increasing and more sophisticated fluidic systems are going to be introduced in soft autonomous robotics. A new generation of smart fluidic devices requires autonomous feedback-driven structures which can manipulate droplets, bubbles and fluid flows as well as react to different internal and external stimuli. We are using the coupling of fluid dynamics with newly developed delicate elastic structure designs to manipulate, accelerate and shape single and multiphase flows. The device structures consist of microfluidic networks separated by thin elastic membranes. Local variations of the flow fields, which are controlled by the pressure distribution and the spatial geometric design of the fluidic network, result in spatial-dependent elastic response of the separating membranes, which, in turn, lead to direct feedback on the flow fields. Moreover, using fluid mixtures of solvents with and without membrane swelling capacities, we are not only able to induce membrane instabilities but also to tune the amplitude and wavelength of these instabilities. Surpassing a critical fluid pressure results in an oscillation of the membrane with propagating waveforms. Depending on the fluid pressure as well as on the properties of the membranes, a frequency range of the oscillations from sub Hz to kHz can be covered. This novel microfluidic process design enables us to specifically shape single and multi-phase flows as we introduce a pacemaker or clock into fluidic networks for autonomous smart soft devices.

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