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Curious Pattern Formation and Ordering Dynamics in Surface Acoustic Wave Driven Microfluidics

We explore a variety of complex and interesting patterns that form within a fluid, on its free surface, or on the substrate on which the fluid is placed, as a consequence of the fluid-structural coupling that arises when a surface acoustic wave (SAW) is induced along a piezoelectric substrate. If the fluid is air, we show that smoke particles with a mean diameter of around 250 nm dispersed in the fluid deposit on the substrate adjacent to regions of large vibration amplitude to form a pattern that corresponds to the surface wave profile, thus offering an inexpensive and quick alternative to laser interferometry for the visualisation of the surface waves. In a liquid-filled microchannel, on the other hand, a peculiar phenomenon is observed wherein a suspension of micro/nano-particles assemble onto nodal lines of the pressure field in the liquid at the bottom of the channel underneath a fast unidirectional throughflow with velocities on the order of 1–10 mm/s, which has implications for rapid microchannel pumping. A more curious side phenomenon is the ability to switch between unidirectional throughflow and oscillatory flow for micromixing in the same microchannel simply by altering the SAW frequency. The third pattern formation we will explore arises when a drop containing a polymeric solution translates and atomizes under the action of the SAW under high intensities. The translation of the drop leaves behind a thin film which is highly unstable and subsequently dewets to form spatially organised periodic polymer patterns on the substrate. Finally, we elucidate the nonlinear dynamics associated with the formation of colloidal patterns that form on the free surface of a liquid drop placed above the vibrating substrate. Strangely, colloidal islands which initially self-assemble due to surface acceleration and capillarity are subsequently erased once fluid streaming becomes significant at higher powers. Due to a curious instability, the system cycles between colloidal island assembly when streaming ceases and erasure when streaming resumes.

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