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Mixing Diagnostics in Confined, High-Speed Droplet Collisions

BRIAN CARROLL, CARLOS HIDROVO, University of Texas at Austin — Fast mixing remains a major challenge in droplet-based microfluidics. The low Reynolds number operating regime of most mixing devices signifies orderly flows that are devoid of any inertial characteristics. To increase droplet mixing rates, a novel technique is under development that uses a high Reynolds number gaseous phase for droplet generation and transport and promotes mixing through binary droplet collisions at velocities near 1m/s. Limitations in existing mixing diagnostic methodologies has persuaded cultivation of a new technique for measuring droplet collision mixing in confined microchannels. The technique employs single fluorophore laser-induced fluorescence, custom image processing, and meaningful statistical analysis for monitoring and quantifying mixing in high-speed droplet collisions. Mixing progress is revealed through two statistics that separate the roles of convective rearrangement and molecular diffusion during the mixing process. The end result is a viewing window into the rich dynamics of droplet collisions with spatial and temporal resolutions of 1μm and 25μs, respectively. Experimental results obtained across a decade of Reynolds and Peclet numbers reveal a direct link between droplet mixing time and the collision convective timescale. This work provides valuable insight into the emerging field of two-phase gas-liquid microfluidics and opens the door to fundamental research possibilities not offered by traditional oil-based architectures.

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