Electro-hydrodynamic Chopping of Water-in-water Jet in Coflowing Microfluidic Channels

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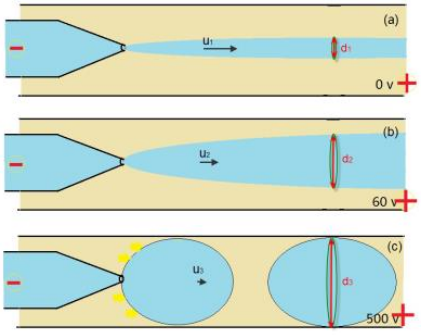
In the co-flowing capillary microfluidic channels, two immiscible aqueous phases typically forms water-in-water (w/w) jet. Due to the ultra-low interfacial tension (<1mN/m) between the two phases, breakup of the w/w jet can hardly be induced by capillary instability alone [1]. Electrostatic force, applied by separately charging two aqueous phases with different electro-conductivity, can be an auxiliary force to break up the w/w jet. Successful breakup of the w/w jet may provide a new approach for generation of w/w emulsion in an all-aqueous environment free of organic solvents, which are potentially useful in biochemical and biomedical applications.

Water-in-water emulsion has been successfully fabricated by hydrodynamic perturbation [1] and electro-hydrodynamic approaches [2]. However, breakup of the w/w jet has not been demonstrated in viscous aqueous phases, which are frequently used in practical solutions. We inject a single phase of sodium dextran sulfate (SDS)/dextran into its immiscible continuous phase of PEG solution to form a w/w jet. Upon applying a DC electric field at 30-80 volts, the viscous jet expands in diameters with the applied voltage [3]. By tracing the velocity of small particles inside the jet, we found the jet velocity is also reduced because of the restriction of mass conservation. When further increasing the applied voltages to 200-1000 volts, we observed an interesting transition from jetting to dripping: along with the deceleration and expansion of the inner fluid, the jet nearly stops in the channel and almost blocks the entire channel before it is chopped and pushed downstream by the continues phase (schematic 1). The jet chopping is induced by force balancing among the electrostatics, hydrodynamics and interfacial tension.



Schematics 1 A w/w jet breaks up in an electro-hydrodynamic chopping approach. A viscous w/w jet (a,b) expands after electrical charging at 60 volts and (c) breaks up into droplets at 500 volts. The jet diameter increases ($d_1 < d_2 < d_3$) with the applied voltage, while the jet velocity decreases ($u_1 > u_2 > u_3$) accordingly.

References

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[3] Y. Song, Z. Liu, T. T. Kong, and H. C. Shum, Chem. Commun. **49**, 1726-1728 (2013).