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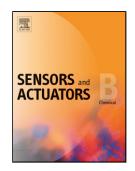
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Electric-Field Triggered, On-Demand Formation of Sub-Femtoliter Droplets

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ABSTRACT

This paper presents an electrohydrodynamic emulsification scheme that is capable of producing

sub-femtoliter aqueous droplets on demand. A pressure-controlled flow focusing scheme is enhanced

by integrating a time-varying electric field, which induces electric forces locally on the water-oil

interface. More specifically, electric forces act against interfacial tension and trigger the breakup of

droplets via tip streaming. PDMS microfluidic chips with embedded solid electrodes and diaphragm

valves are utilized to realize the proposed on-demand droplet formation scheme. In the prototype

demonstration, a low melting-point alloy mixed with magnetic nanoparticles was inductively heated

and injected into microchannels to form solid electrodes. It is demonstrated that the emulsification

process is controlled by the applied fluid pressures and electric field, but not limited by the minimum

width of flow channel. Extremely small droplets with volumes less than 1 femtoliter can be readily

produced. By applying a voltage ramp of 8 kV/s (0 to 400 volts in 50 ms) across a distance of 6 mm,

droplets with diameters less than 1 µm were successfully produced. The higher the voltage ramp rate,

the smaller the resulting droplet volume. By adjusting the voltage ramp rate accordingly, on-demand

formation of a droplet stream with preset diameter order was demonstrated. As such, the demonstrated

emulsification scheme could potentially realize the controllability of electric field on the on-demand

formation of extremely-small droplets, which is desired for a variety of applications.

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