Tip-streaming Generation of Sub-micrometer-sized Emulsions in 3D Flow Focusing Microfluidic Devices

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Droplet-based microfluidics have attracted extensive interest because of their potential uses in high-throughput screening for drug discovery or toxicology, and materials synthesis. Previously, monodisperse emulsions were successfully produced in T-junction or flow-focusing geometry. However, their minimum achievable size and volume were generally limited to a few micrometer and femtoliter, respectively. In the present study, we have introduced a three-dimensional (3-D) flow-focusing design optimized for stable tip-streaming mode production of sub-micrometer-sized emulsion droplets. Our 3-D flow-focusing channel consists of square waveform geometry with its side view and zigzag path for more drag force in dispersed phase channel. Therefore, the hydraulic resistance toward the direction of water flow inlet became much higher than the direction of downstream flow. As a result, the fluctuation-induced retraction of Taylor-cone for tip-streaming mode was suppressed significantly. We investigated the experimental condition for establishing a stable tip-steaming mode and producing submicron-sized water-in-oil emulsion with a narrow distribution.