Supplemental material for

Faster multiple emulsification with drop splitting

This document provides information about movies submitted as supplemental material for this paper.

1) Movie “1 Splitting singles.AVI”
Single emulsions being generated and split in a microfluidic device. After being formed, the drops flow into the splitting junction, consisting of one large channels that splits into 16 small channels. This bisects the large initial drops into 16 small drops of nearly identical size. The movie is captures with a video-rate camera with a short electronic shutter. Consequently, droplet motion is strobed. The drops are composed of water dispersed in HFE-7500 fluorocarbon oil containing the ammonium salt of Krytox at 2wt% as surfactant.

2) Movie “2 jetting.AVI”
Singe emulsion drop maker being run at flow rates that are too high. As a result, rather than forming drops, the drop maker is forming a jet of connected dispersed phase. When this jet enters the splitting junction, portions of it break off, forming drops, and other portions remain connected, flowing through the splitting junction and into the outlet without breaking. This movie thus shows how the device fails when flow rates are increased too high.

3) Movie “3 Double splitting.AVI”
Wide-field view of the double emulsion splitting device forming monodisperse double emulsions. The double emulsions are formed in the drop maker (far left) and then flow through a connecting channel into the splitting array, where they are split 3 times into 8 portions. The double emulsions consist of octanol, water with sodium dodecyl sulfate at 2wt% as surfactant, and HFE-7500 fluorocarbon oil containing the ammonium salt of Krytox at 2wt% as surfactant.

4) Movie “4 Mag double form.AVI”
High magnification view of the double emulsion maker forming double emulsions. The double emulsion maker consists of two cross-channel junctions connected in series. Octanol is injected into the central channel of the first junction, and water with surfactant into the second cross junction. The water surrounds the octanol, forming an octanol jet that travels into the second junction. Fluorocarbon oil is injected into the second junction, which surrounds the water and octanol phases. As the water and octanol extend into the nozzle of this junction, the oil squeezes on the water phase interface, causing it to narrow, which in turn squeezes on the octanol jet inside, causing it to also narrow. When the coaxial jet of octanol and water are

sufficiently narrow, they become unstable to the Rayleigh-Plateau instability, snapping, and producing a double emulsion.

5) Movie “5 Mag 1st split.AVI”
High magnification movie of double emulsions bisected in the first splitting stage. As the double emulsion enter the splitting junction, their front interface pushes into both arms of the fork. As it is pushed forward, the double emulsion extends farther into the arms of the fork, such that the back interface approaches the tip of the splitter. Eventually, the two portions of the double emulsion are connected by only a narrow bridge of octanol and water; when this bridge narrows to a sufficiently small diameter, it becomes unstable to the Rayleigh-Plateau instability and snaps, dividing the double emulsions in two.

6) Movie “6 Mag 2nd split.AVI”
High magnification movie of double emulsions being split in the second splitting stage. The process is similar to the splitting of the first stage.

7) Movie “7 Mag 3rd split.AVI”
High magnification movie of double emulsions being splitting the third splitting stage. The process is similar to the splitting in the first two stages.

8) Movie “8 Splitting without plugging.AVI”
High magnification of double emulsions being split in the first stage, in which the double emulsions are smaller in linear dimensions than the channels. Splitting of droplets in devices like these is normally affected by plugging of the arms of the channels as the drops move into the splitting junction. However, splitting is also possible when the drops are too small to plug. In this example, the droplets are pressed against the point of the splitter by the shear of the continuous phase over the back portion of the droplet. Thus, whereas in the previous examples the drops fill the splitting channels and plugging effects are thus important, in this example they are too small to plug, and shearing effects are important.

9) Movie “9 Splitting WOW doubles.AVI”
Movie of water-oil-water double emulsions being split in a splitting device. The double emulsions are formed in a double emulsion maker to the left (not pictured) with spatially patterned wettability. The wettability pattern is such that the first junction in the drop maker is hydrophobic and the second junction, including the splitter, is hydrophilic. Surfactants present in the fluids stabilize the interfaces, enabling the drops to retain their integrity as double emulsions even as they are split into small portions. The phases are water, HFE-7500 fluorocarbon oil with the ammonium salt of Krytox at 2wt% as surfactant, and water with sodium dodecyl sulfate at 0.5wt% as surfactant for the inner, middle, and continuous phases, respectively.