

Lab on a Chip and Microfluidics

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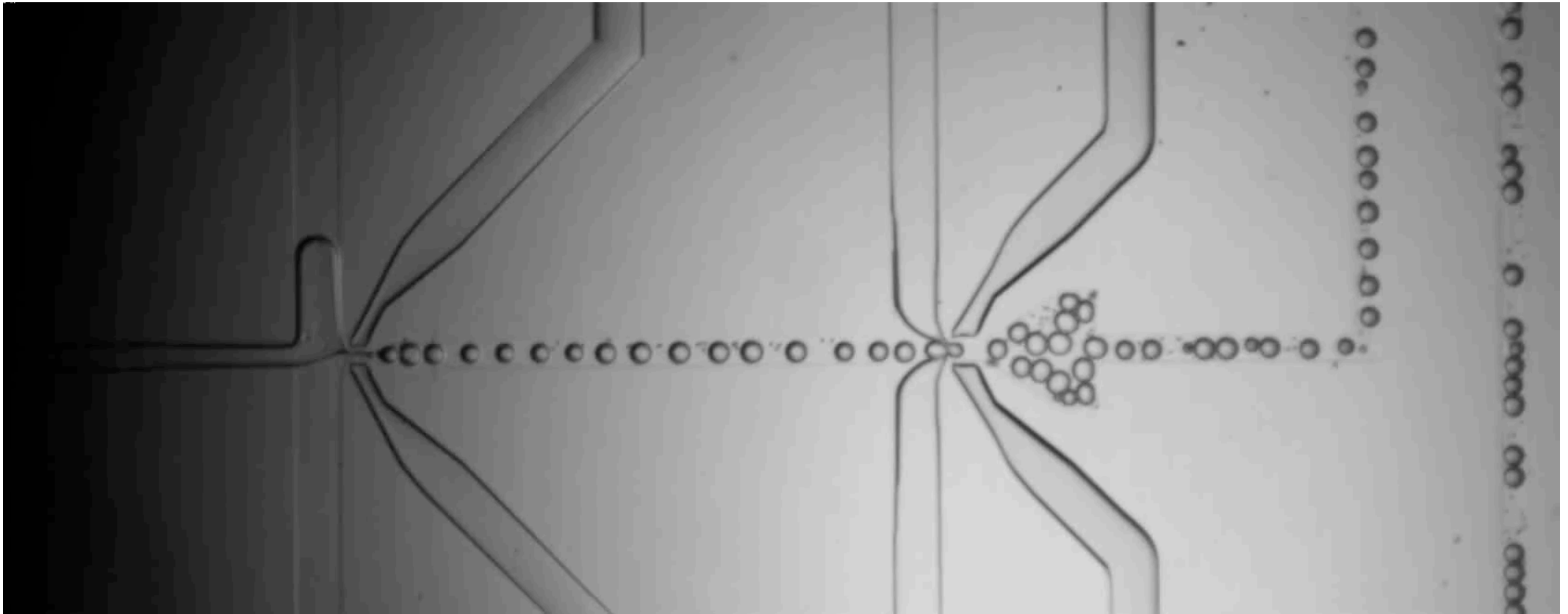
l'institut
d'électronique



Part VI. Diphasic microfluidics

Diphasic Microfluidic

Droplet Microfluidics, Segmented Flows

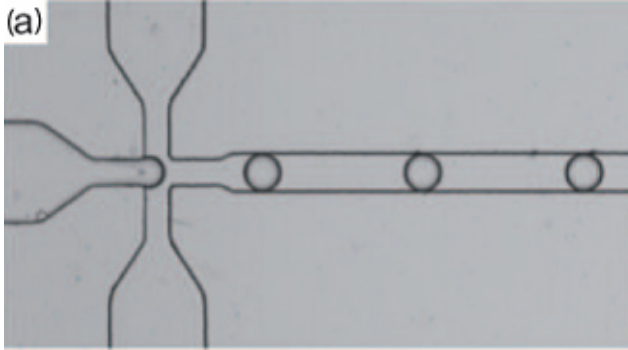


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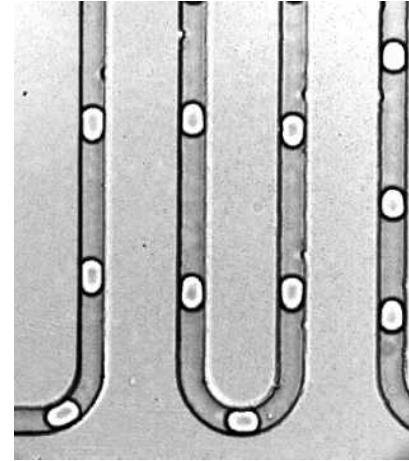
Droplet = microreactor

Make, fill, Mix, Split, Combine, Drive, Sort

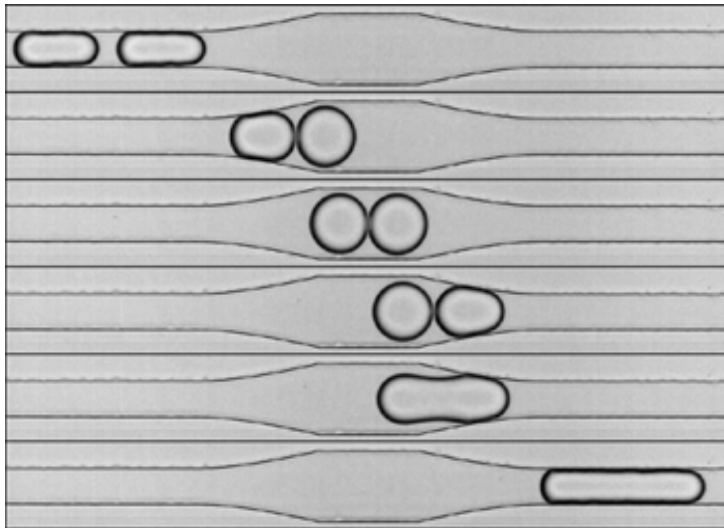
Diphasic Microfluidic



Generation



Transport



Coalescence

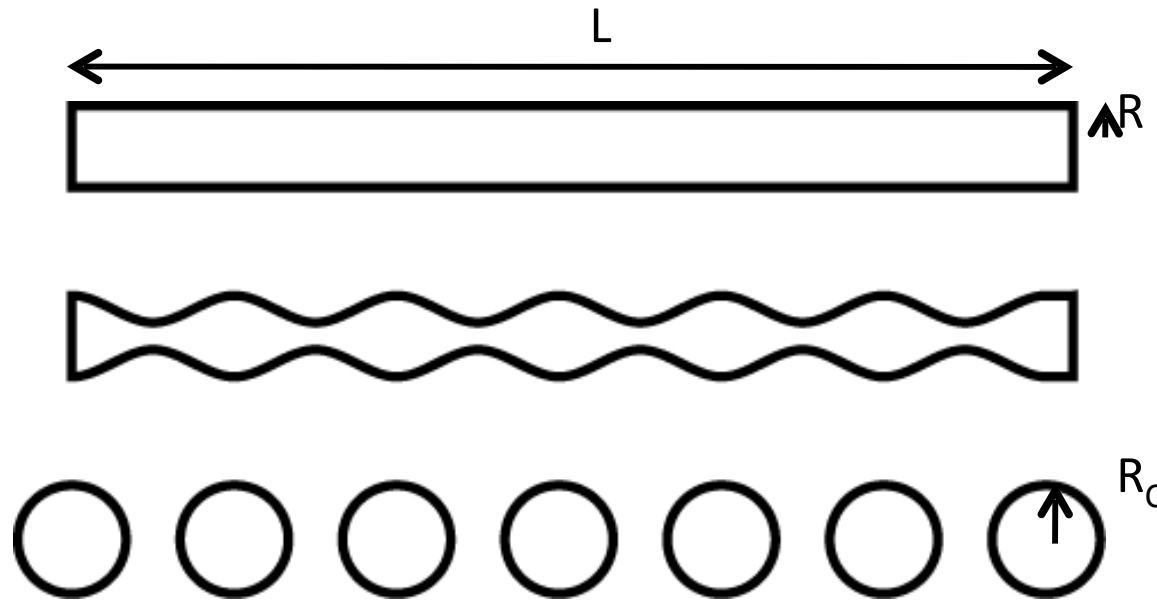
Droplets Generation

Air/water is a
diphasic problem too



Droplets Generation

Rayleigh Plateau instability



Liquid Volume V

Surface tension γ

Surface energy :

$$E_s = 2\pi RL\gamma$$

Destabilisation

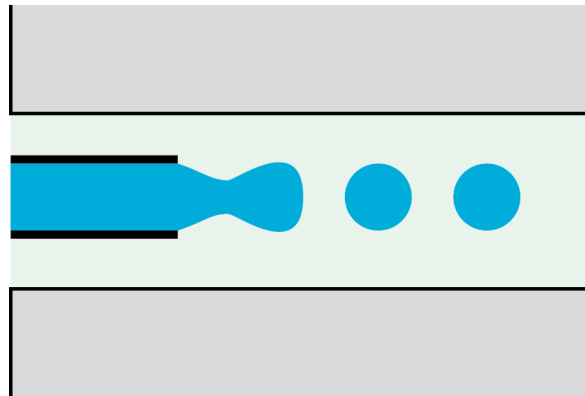
Surface energy of a sphere :

$$E_s = 4\pi R_c^2\gamma$$

When $R_c > \frac{3}{2}R$ The droplets are energetically favorable

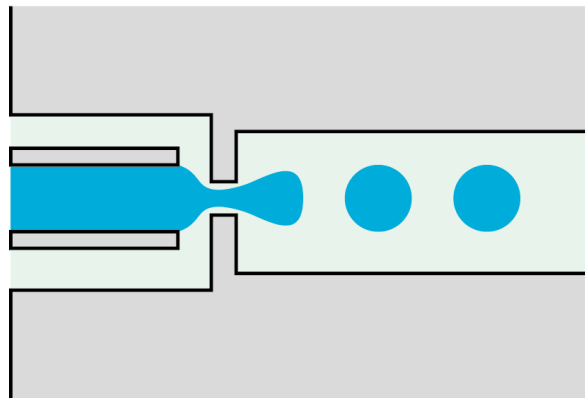
Droplets Generation

Rayleigh Plateau
instability

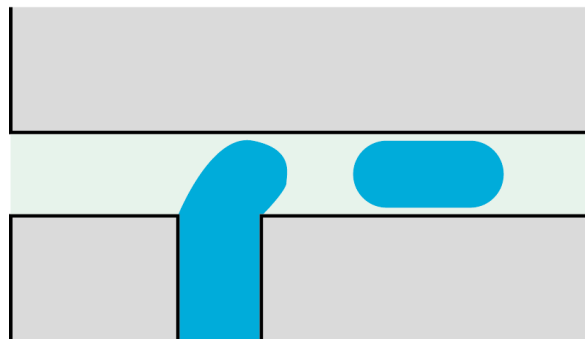


Co Flow

Surface tension
drives the
mechanism

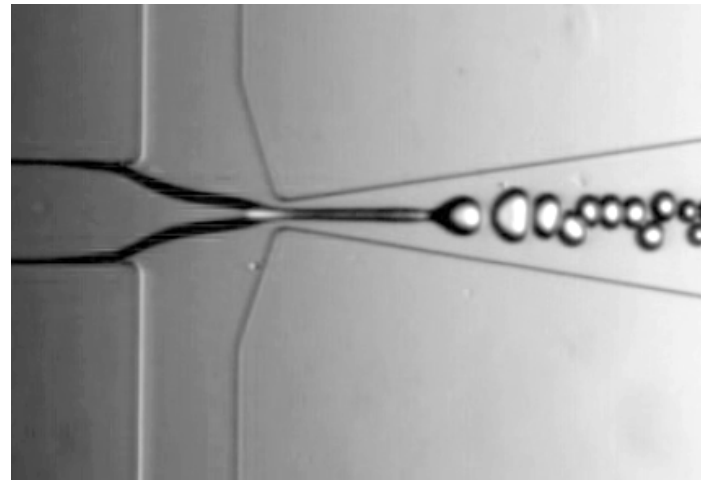
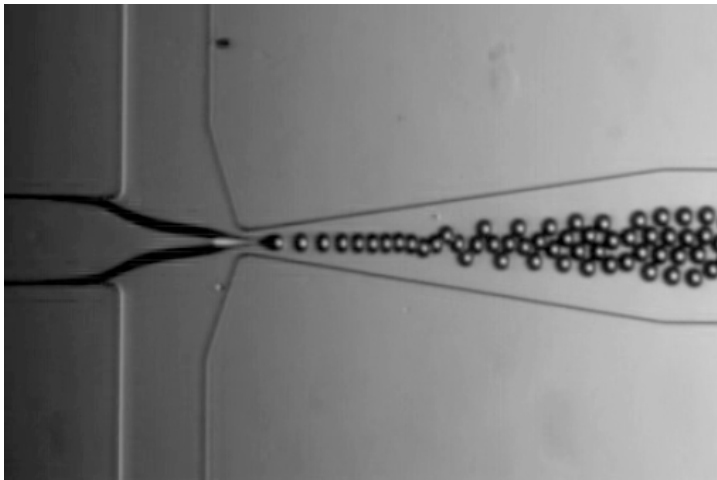
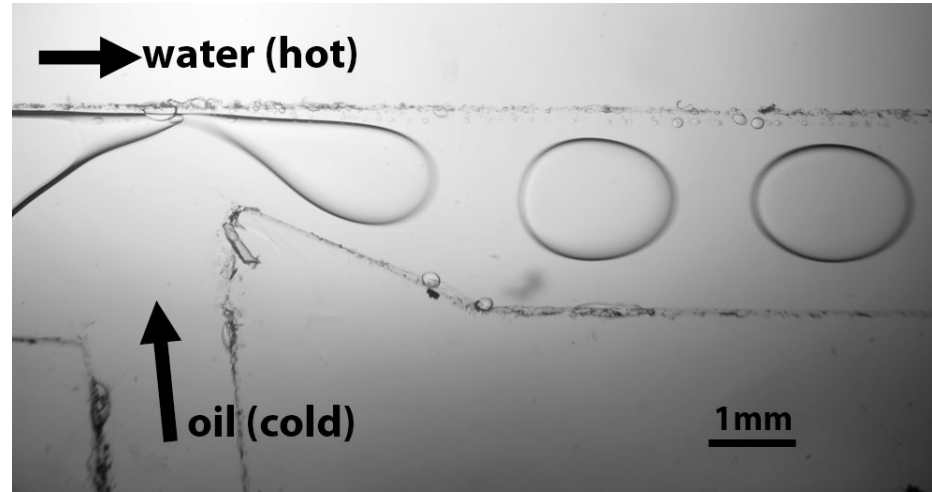


Flow Focusing

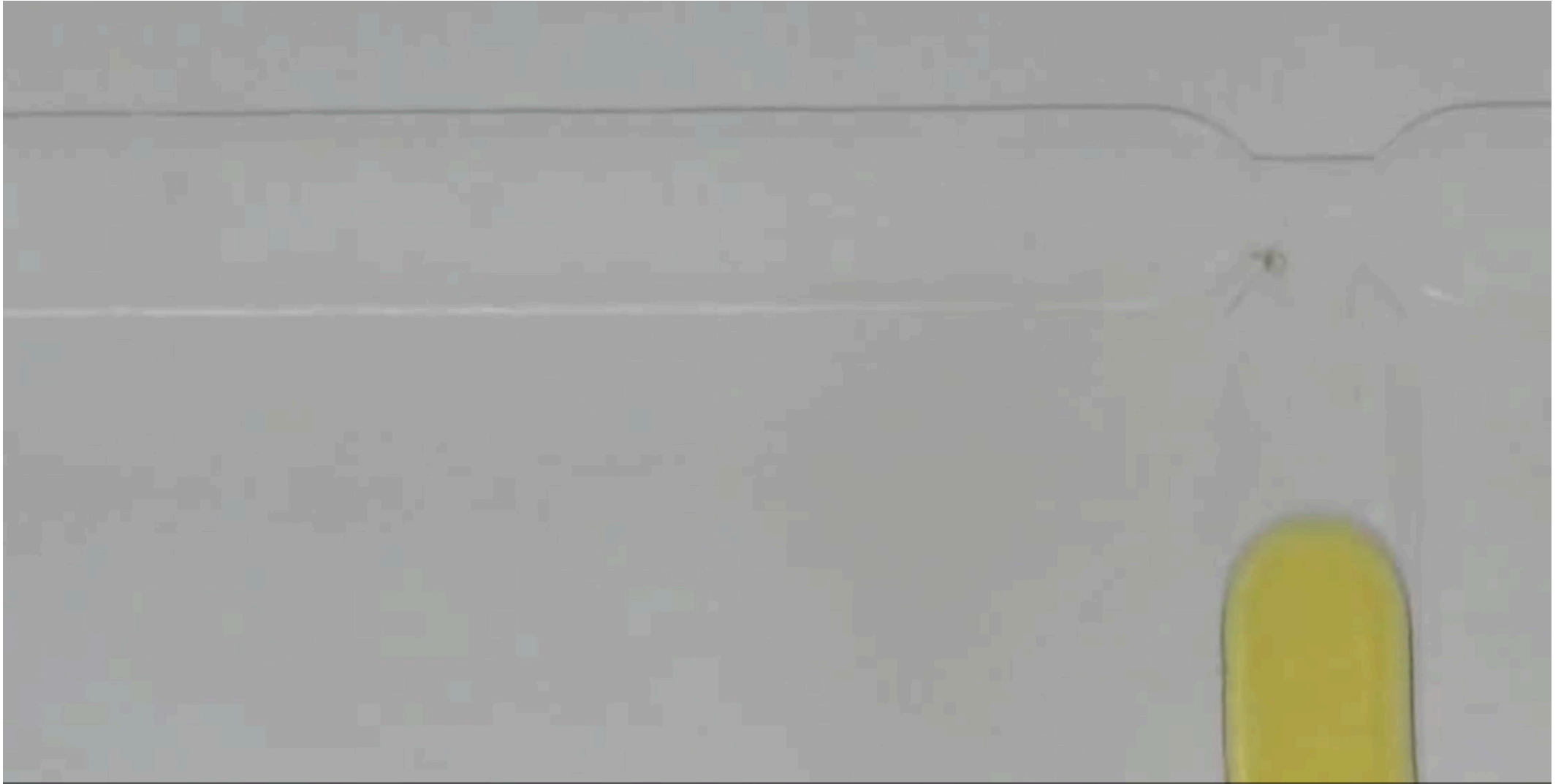


T Junction

Droplets Generation



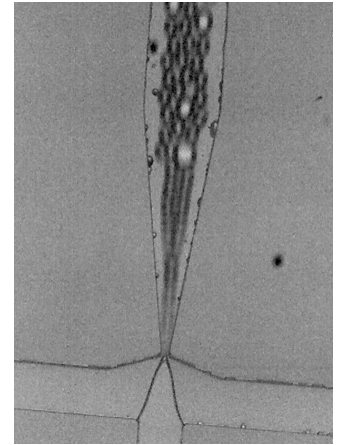
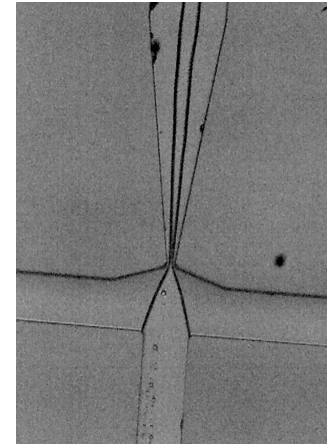
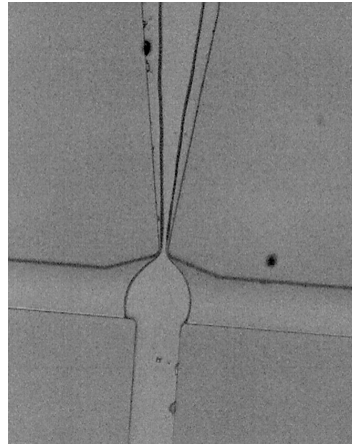
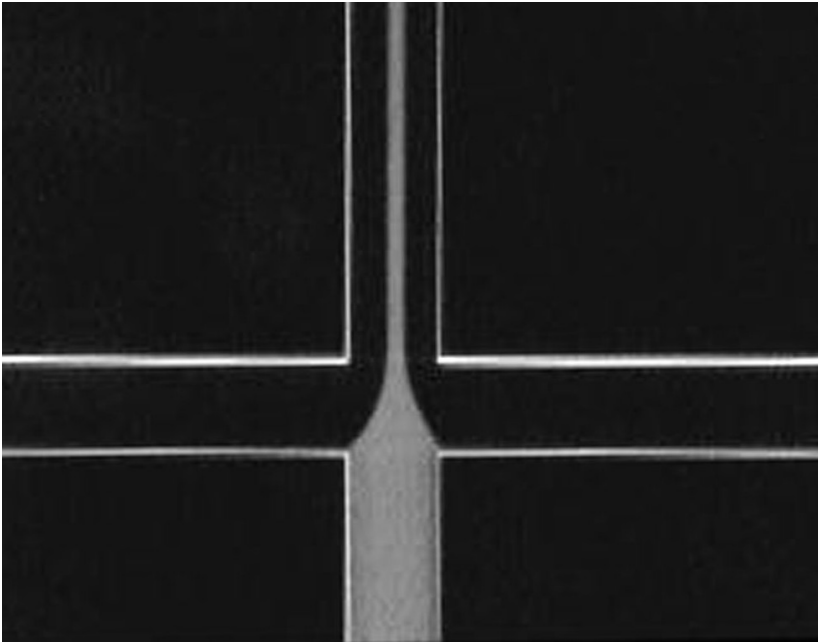
Droplets Generation : T Junction



Elveflow

Droplets Generation

It doesn't work if the flow is too contained



Double Emulsion Generation

Génération de liposomes (vesicules artificielles) et / ou de polymersome

Structures fermées composées d'une ou plusieurs bicouches lipidiques

Encapsulation de formulations
Vectorisation

Bangham method

Detergent depletion

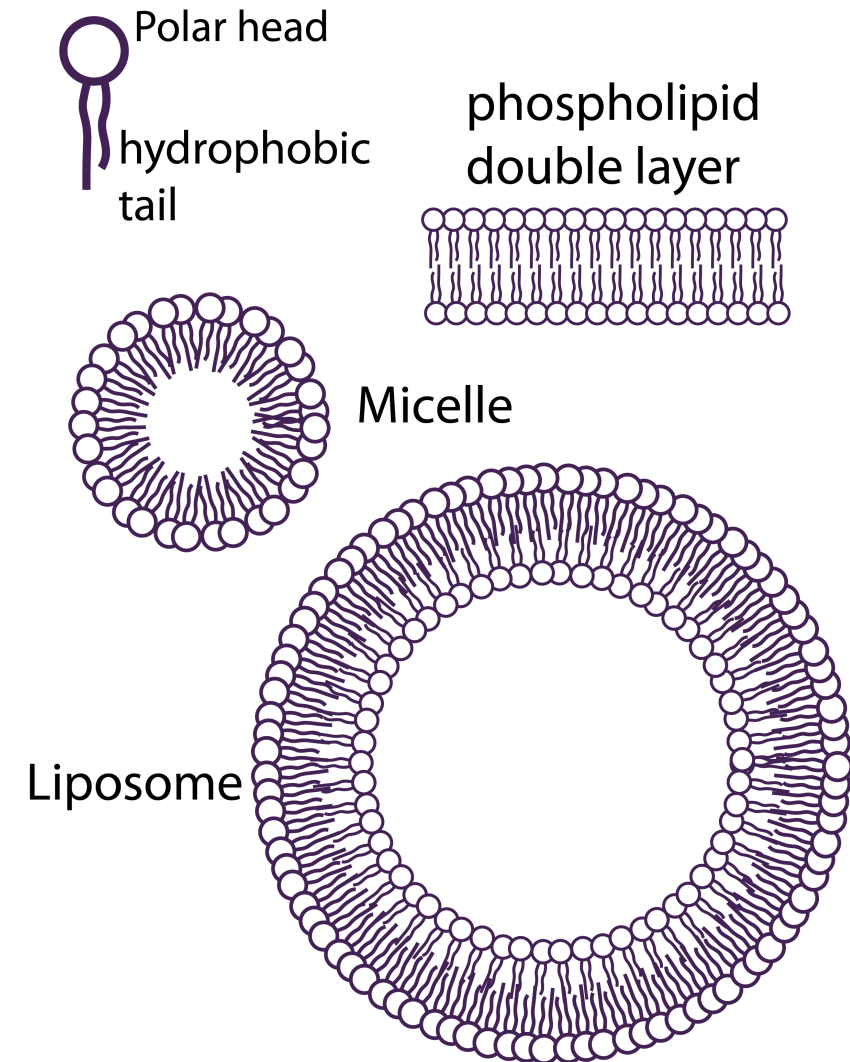
Reverse phase evaporation

Emulsion

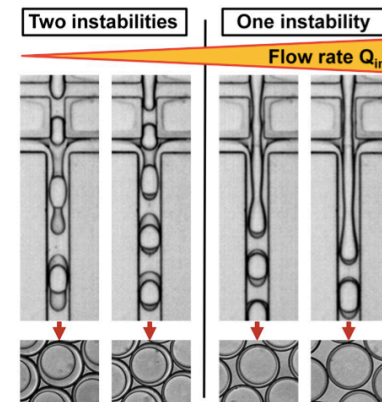
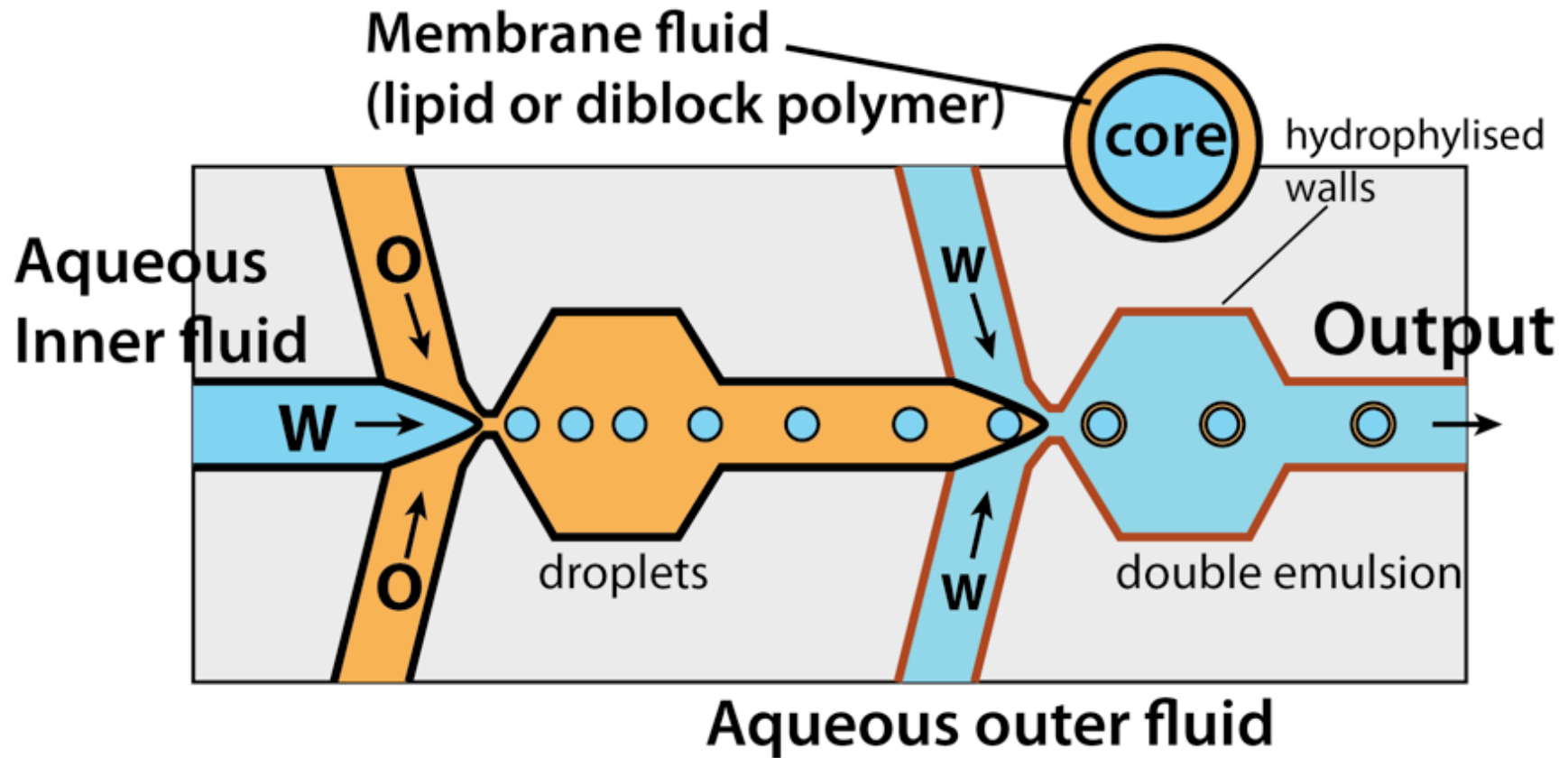
Freeze drying of monophasic solution

Supercritical fluid

Microfluidic



Consecutive Flow focusing



J.Thiele
U. Hambourg

Experiment with lipids

Input 1: DI water
+5% pluronic

Input 2: oleic acid

Input 3: DI water +
10% ethanol + 20%
glycerol

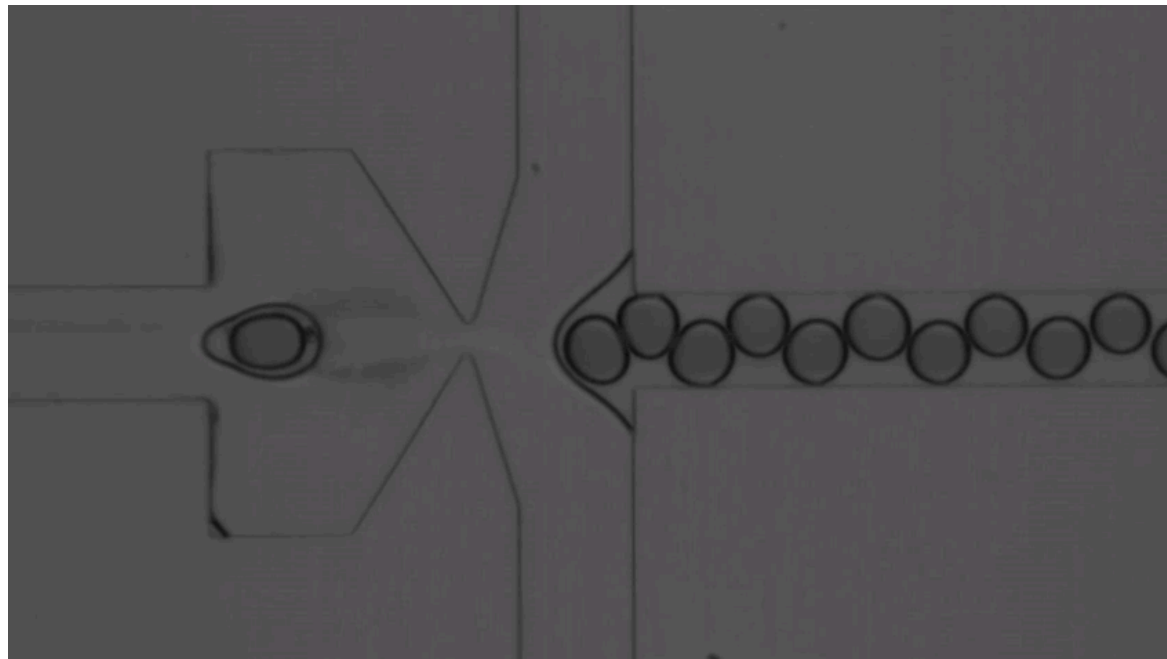
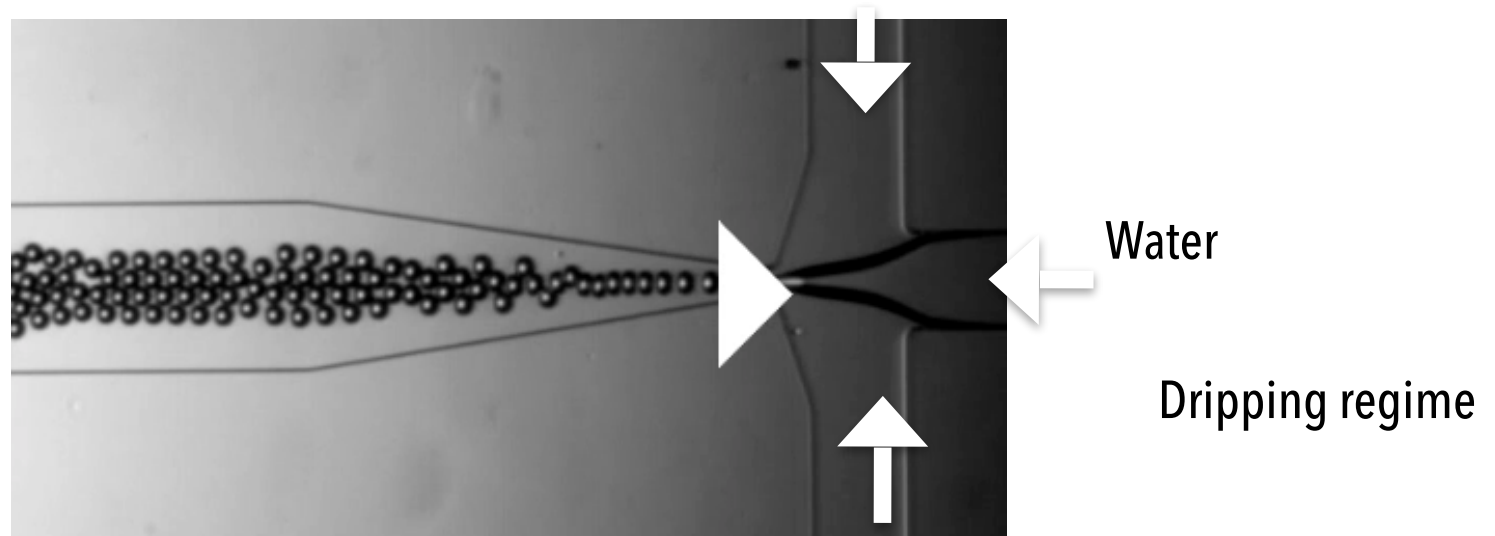
Elveflow OB1

Pressure controller

Pressure ratio :

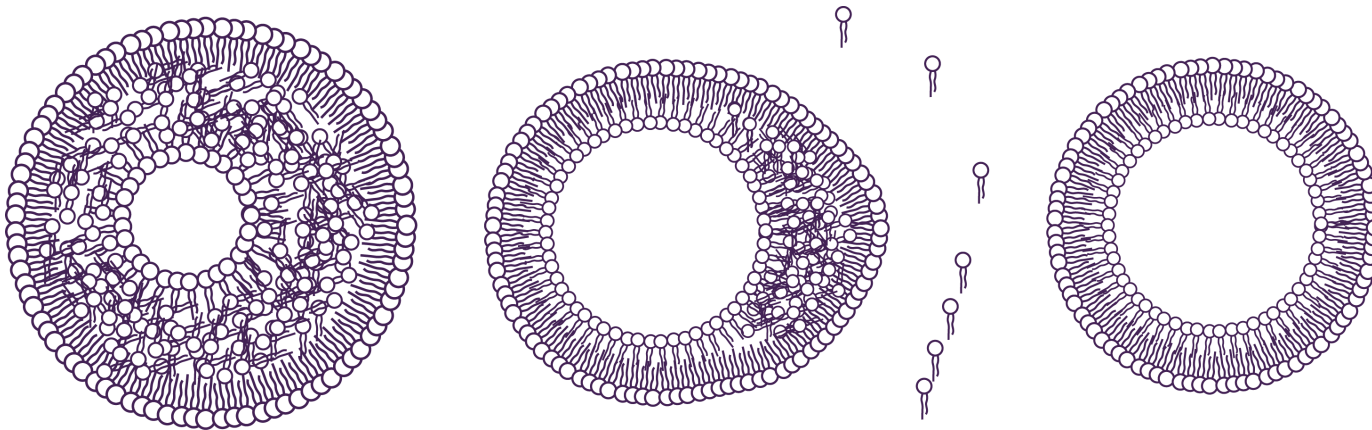
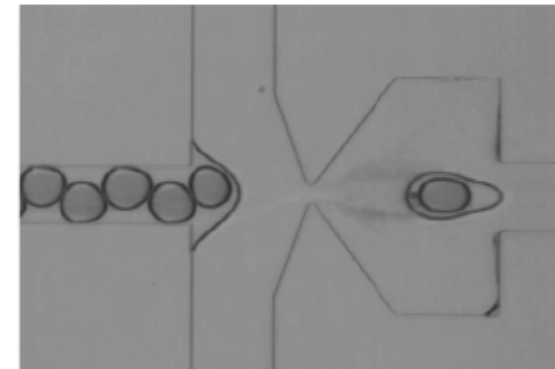
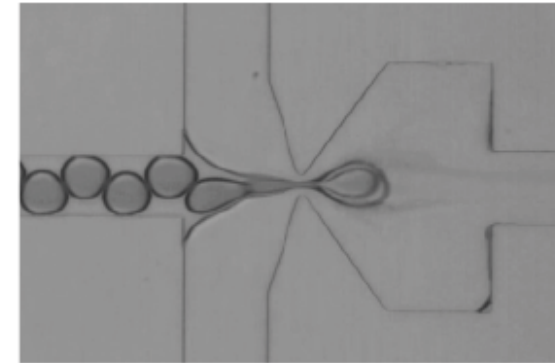
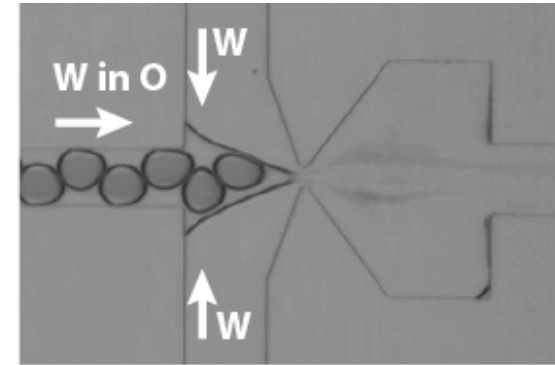
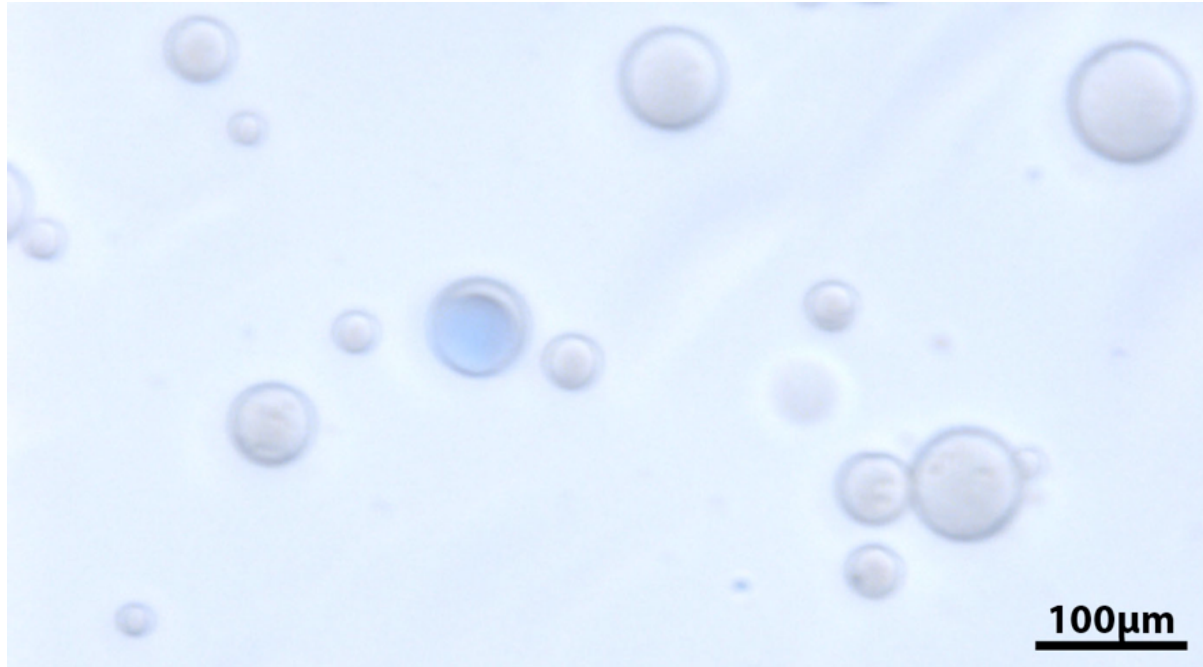
1-3-10

Mikrotron High fps
camera, 40x



Dynamic equilibrium : Very dependant to pressure conditions

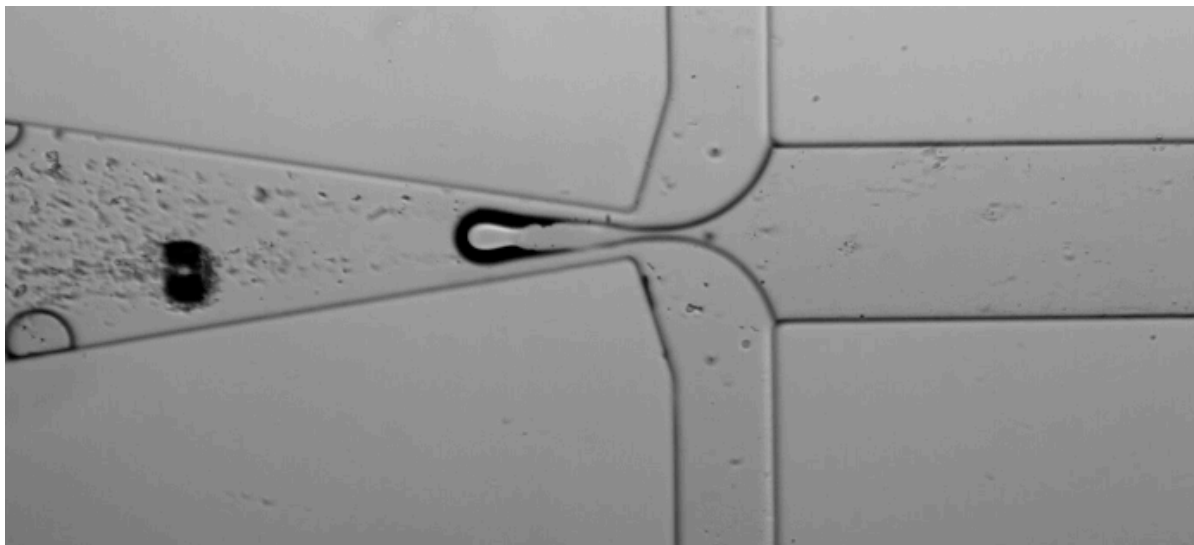
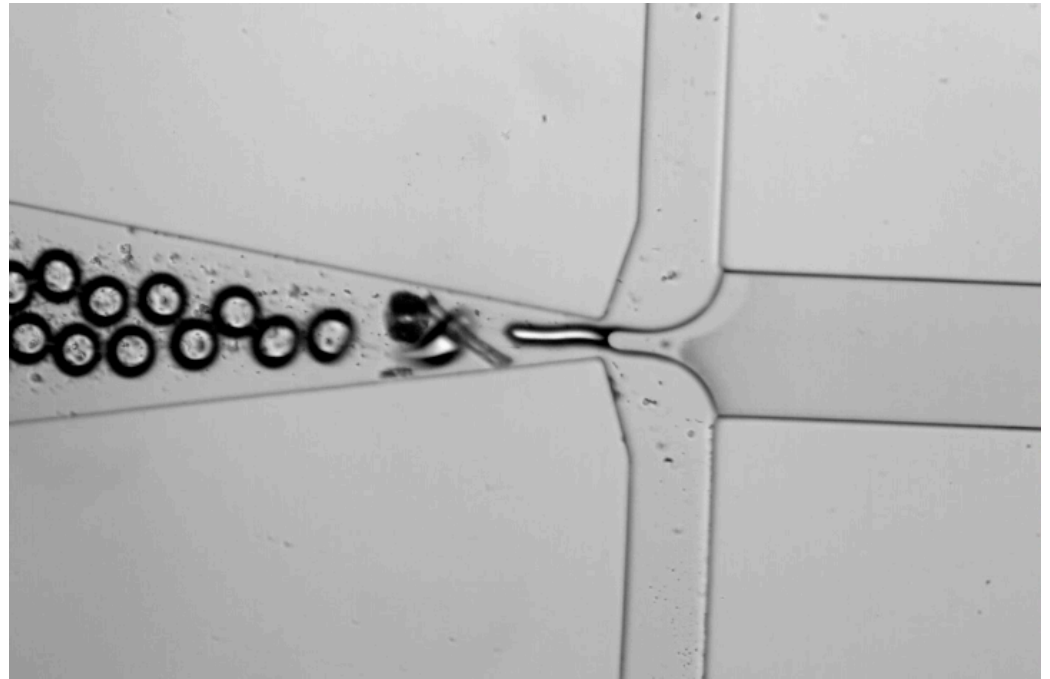
Droplets Generation



Solvation of the excess lipid

Polymersomes

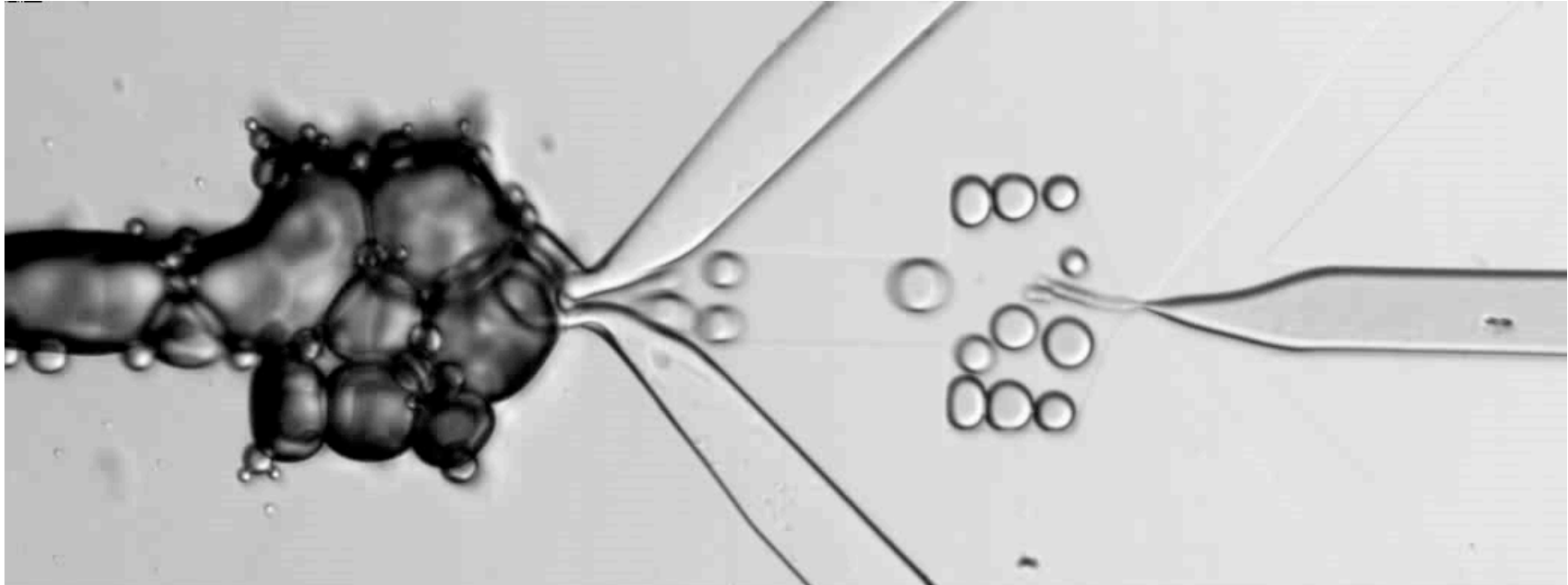
285fps
24 μ s shutter



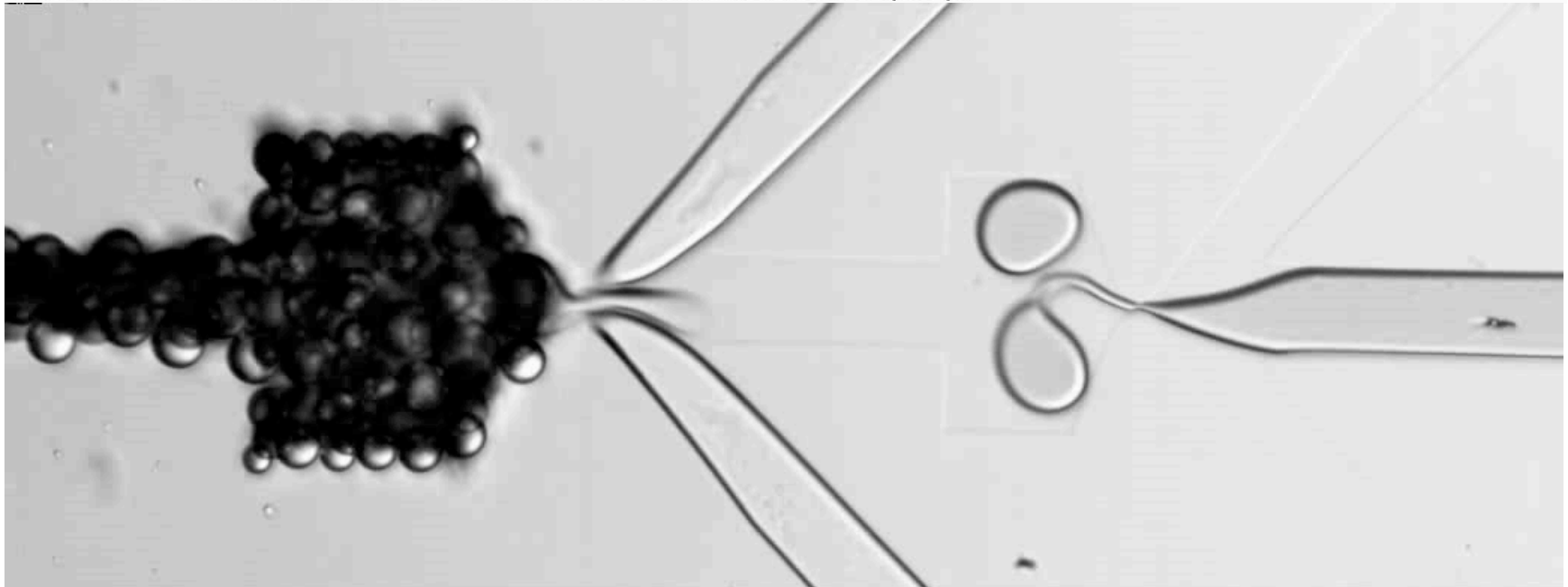
Jetting regime

Different droplet formation dynamic - non newtonian fluids -
Solvent solubility in water is a key parameter

Droplets Generation



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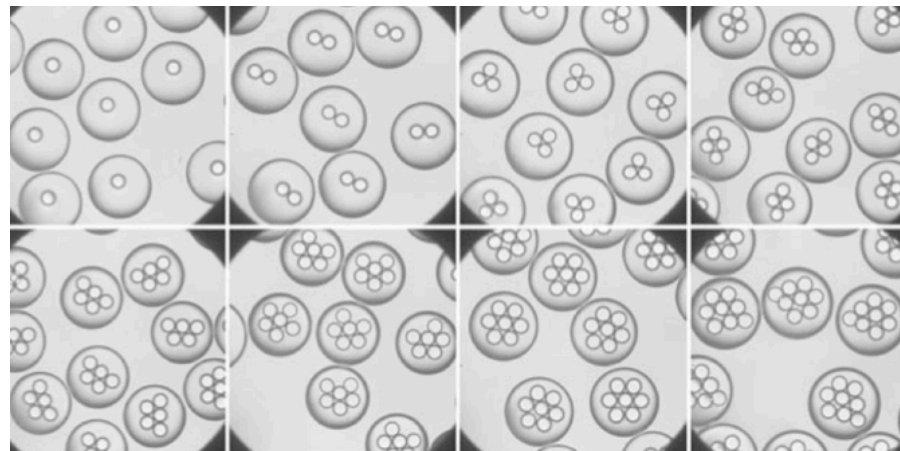
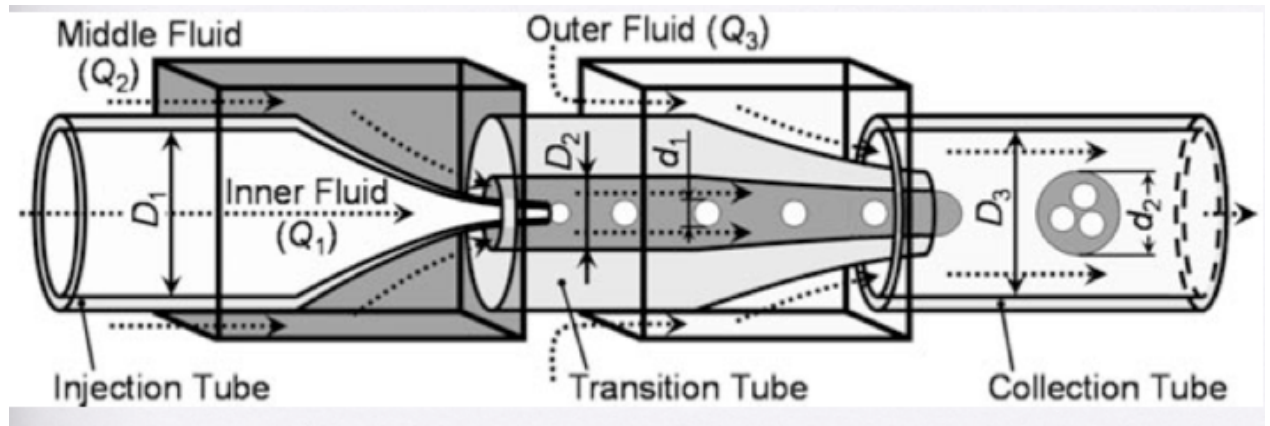
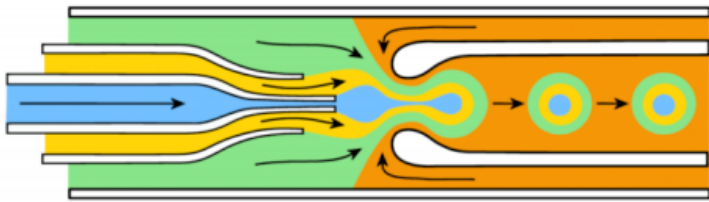
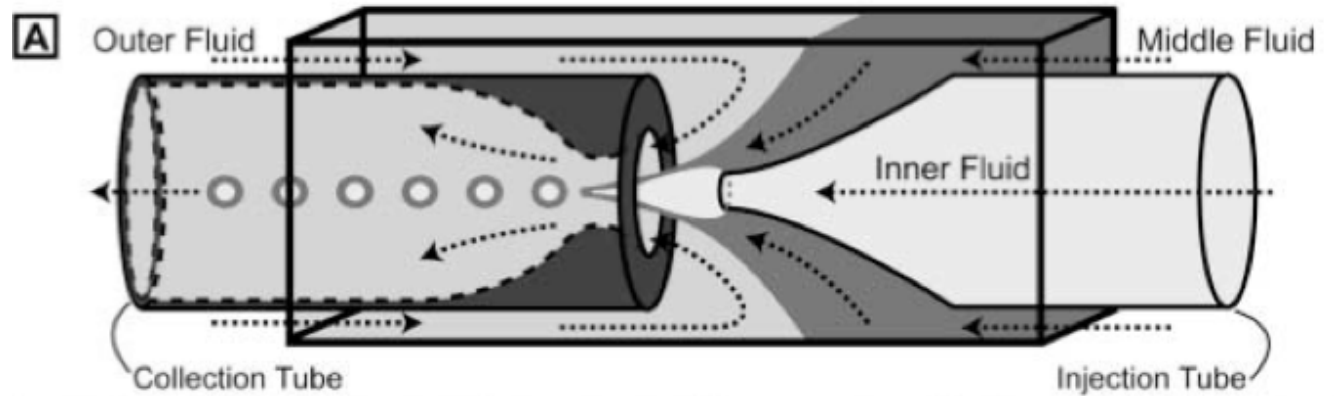


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Droplets Generation

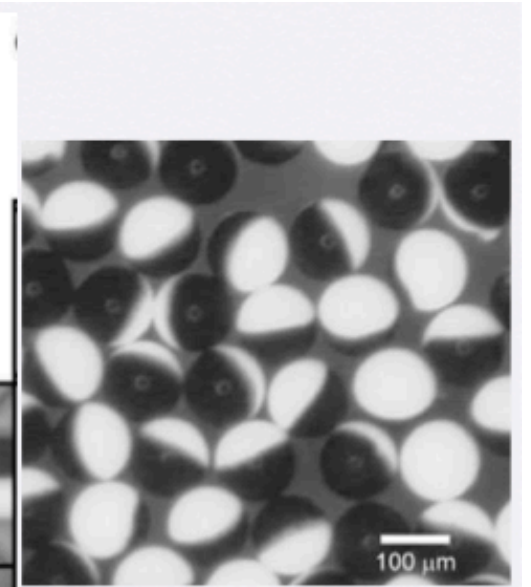
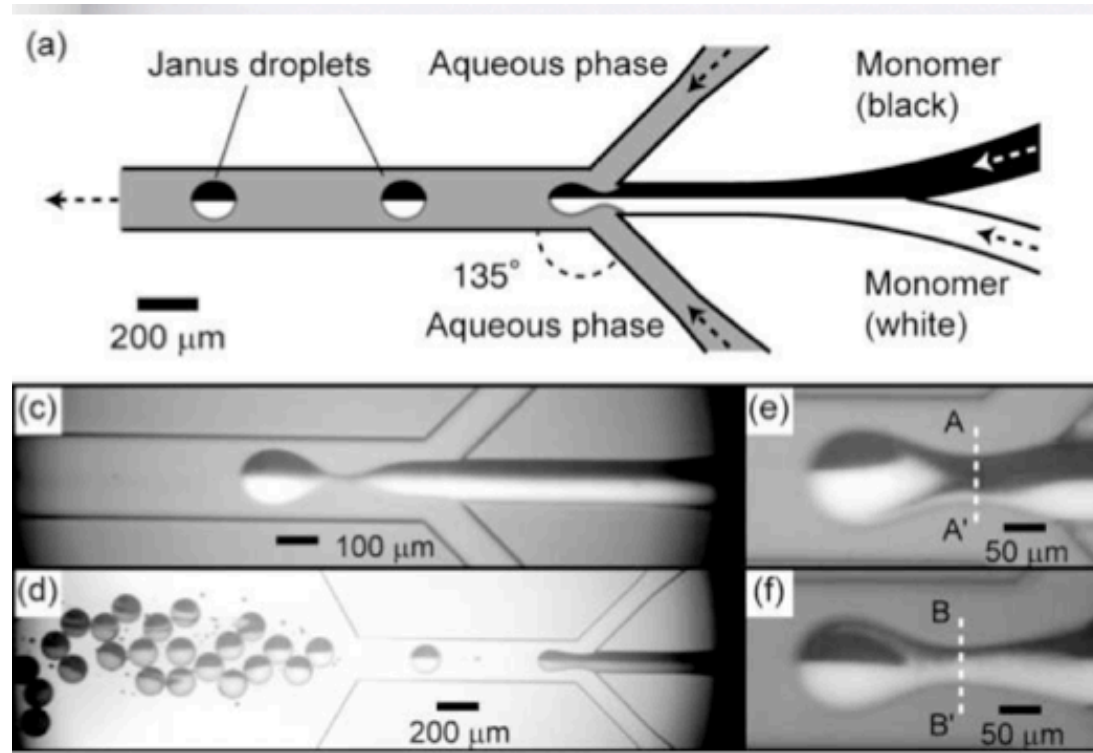
Coaxial pipettes

D.A.Weitz
Harvard

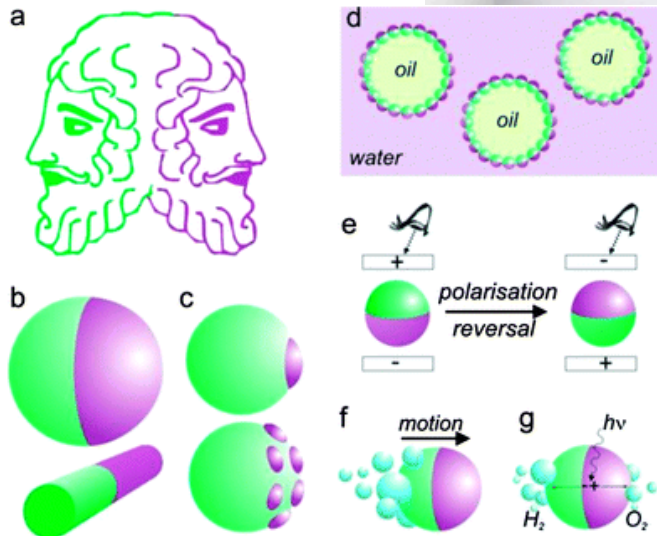


Droplets Generation

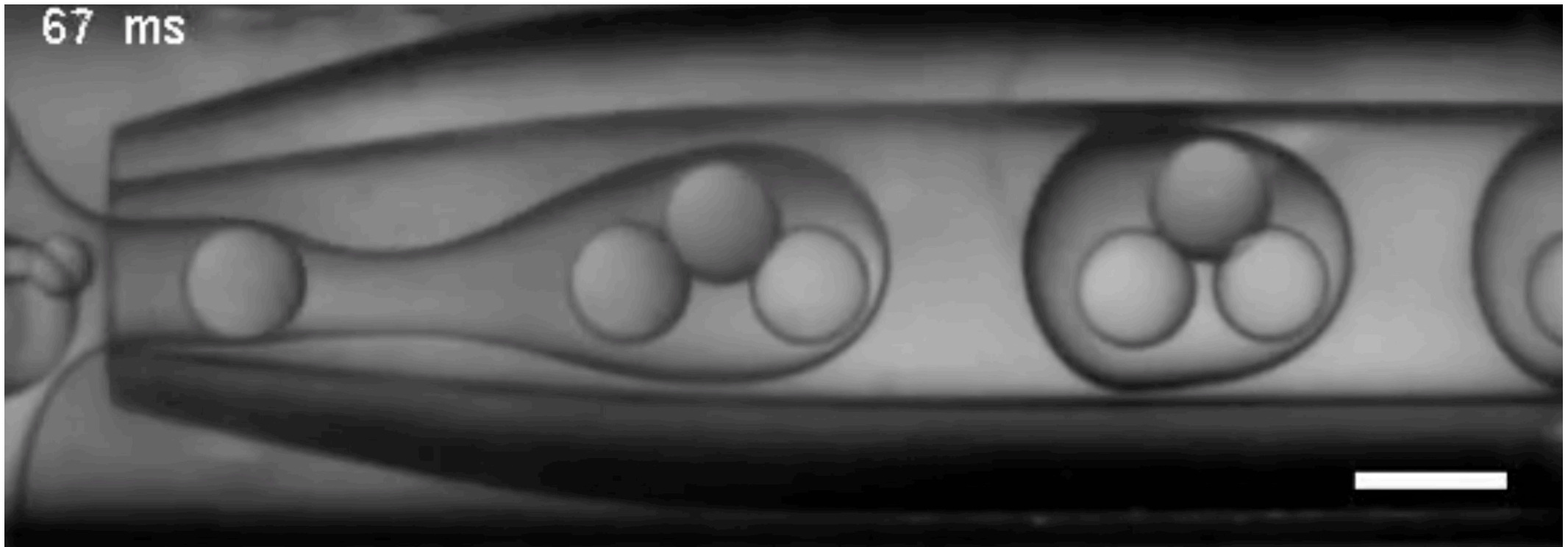
« Janus » particles



Nisisako et al. Adv. Mat. 2006



Encapsulation in droplets

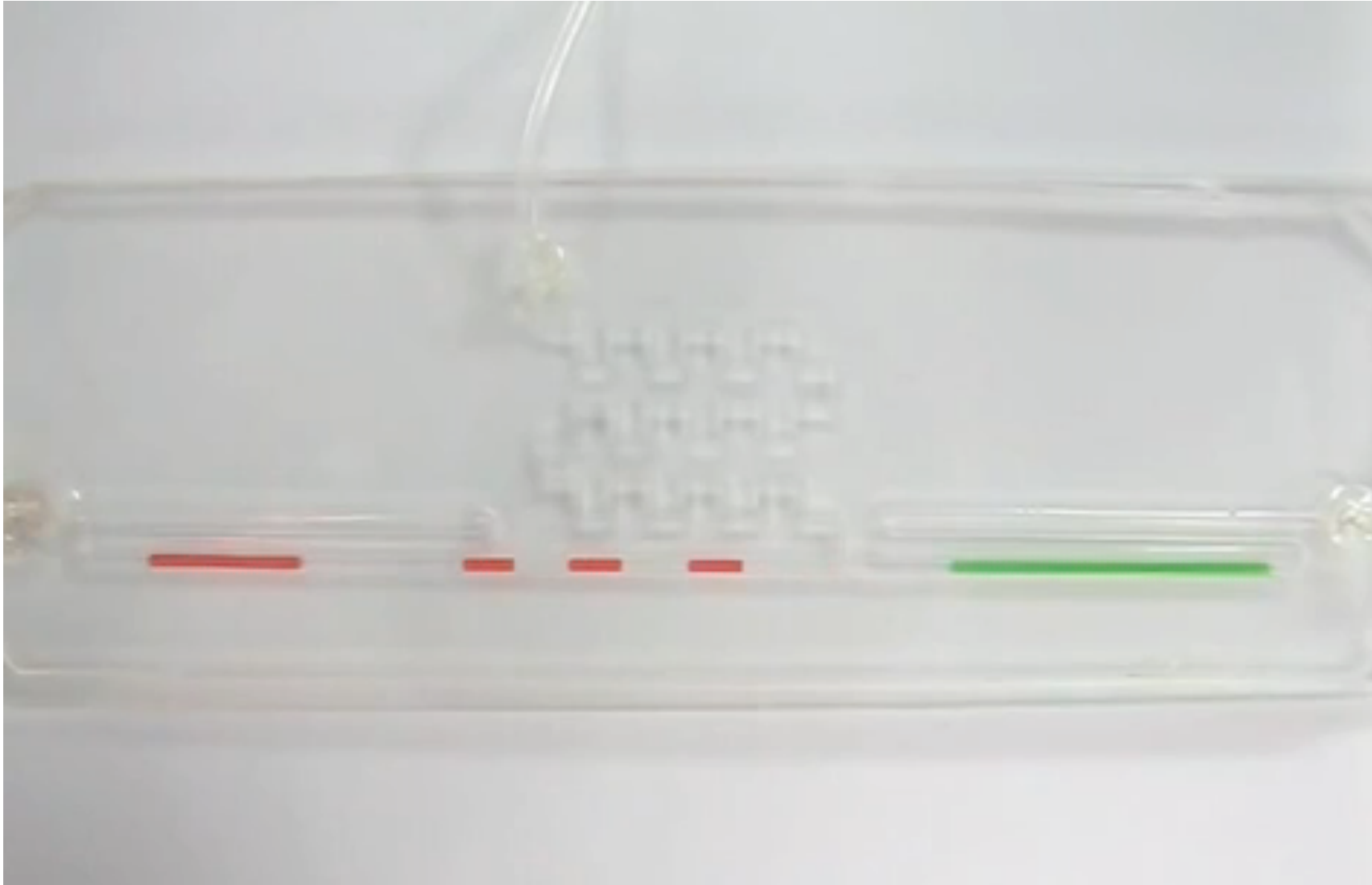


Formation of double emulsion drops with exactly three inner drops at the inner fluid flow rate of 2 mL/h, the middle fluid flow rate of 0.8 mL/h, and the outer fluid flow rate of 6 mL/h. Drops are formed by co-flow coupled with counter-current flow focusing.

S.A Nabavia G. Vladislavljevića V. Manović « Mechanisms and control of single-step microfluidic generation of multi-core double emulsion droplets », Chemical Engineering Journal
Volume 322, 15 August 2017, Pages 140-148

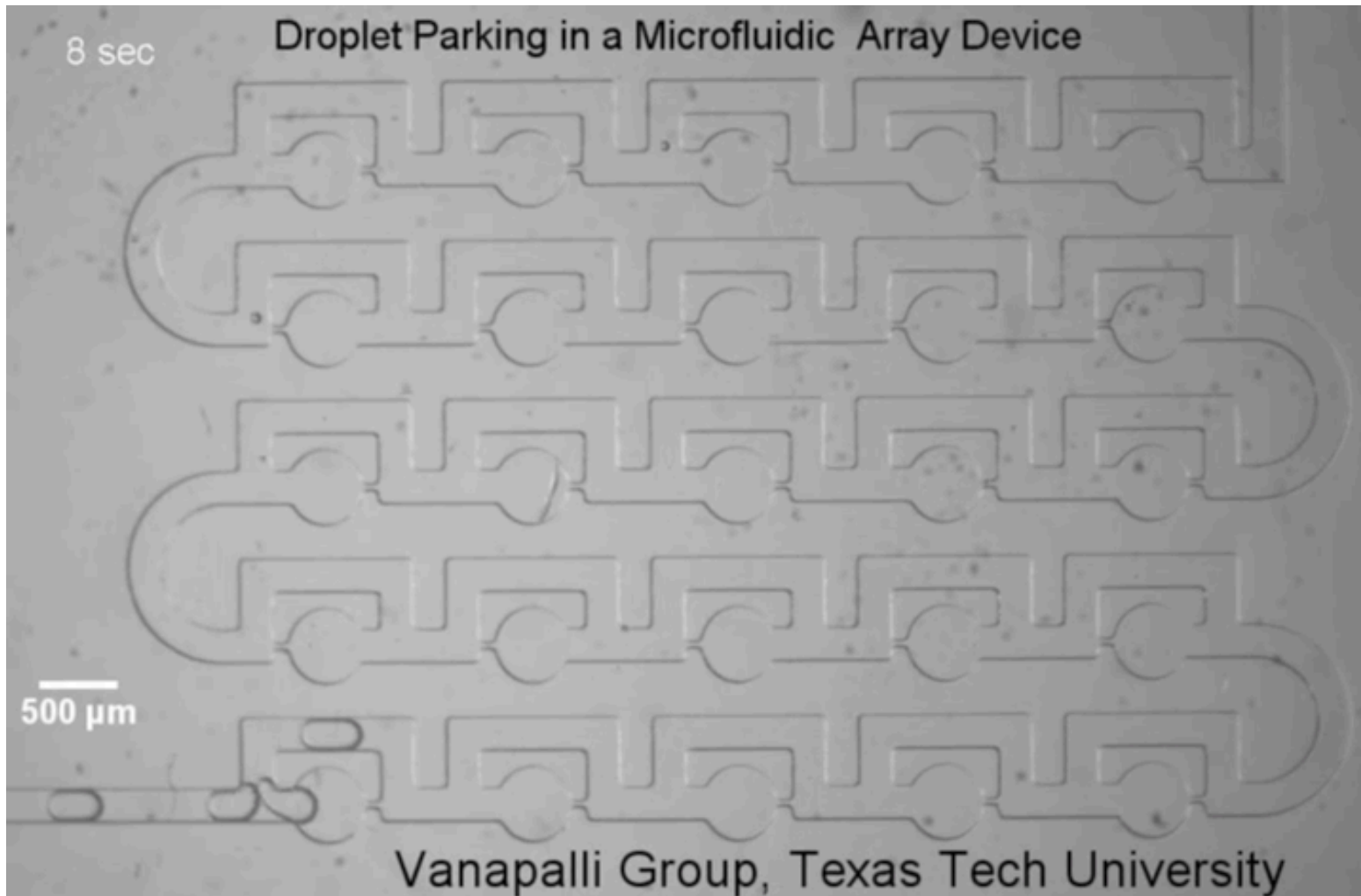
Droplets manipulation

Diphasic flow : generation,
separation and mixing



Droplets sorting

Diphasic flow : generation,
separation and mixing



Droplets

L.Mazutis et al. Multi-step microfluidic droplet processing: kinetic analysis of an in vitro translated enzyme, Lab Chip, 2009, 9, 2902-2908

