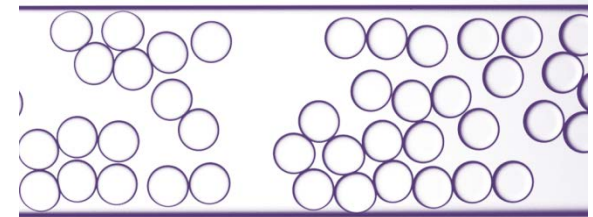
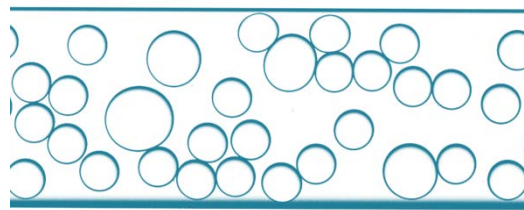
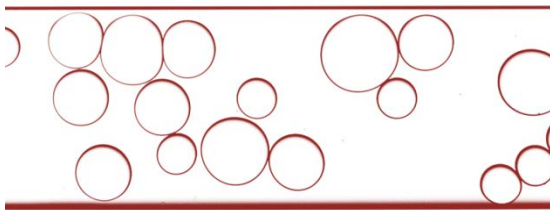


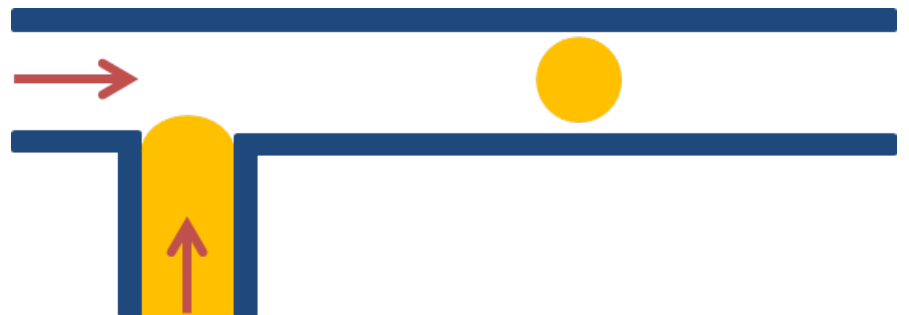
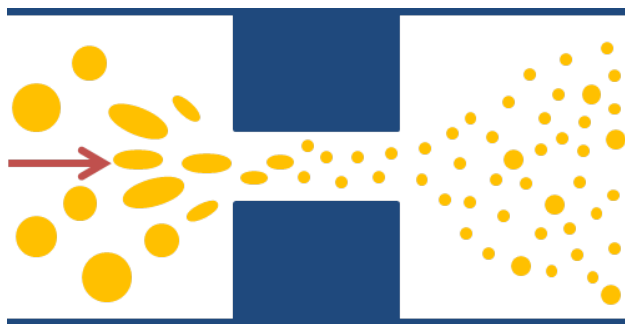
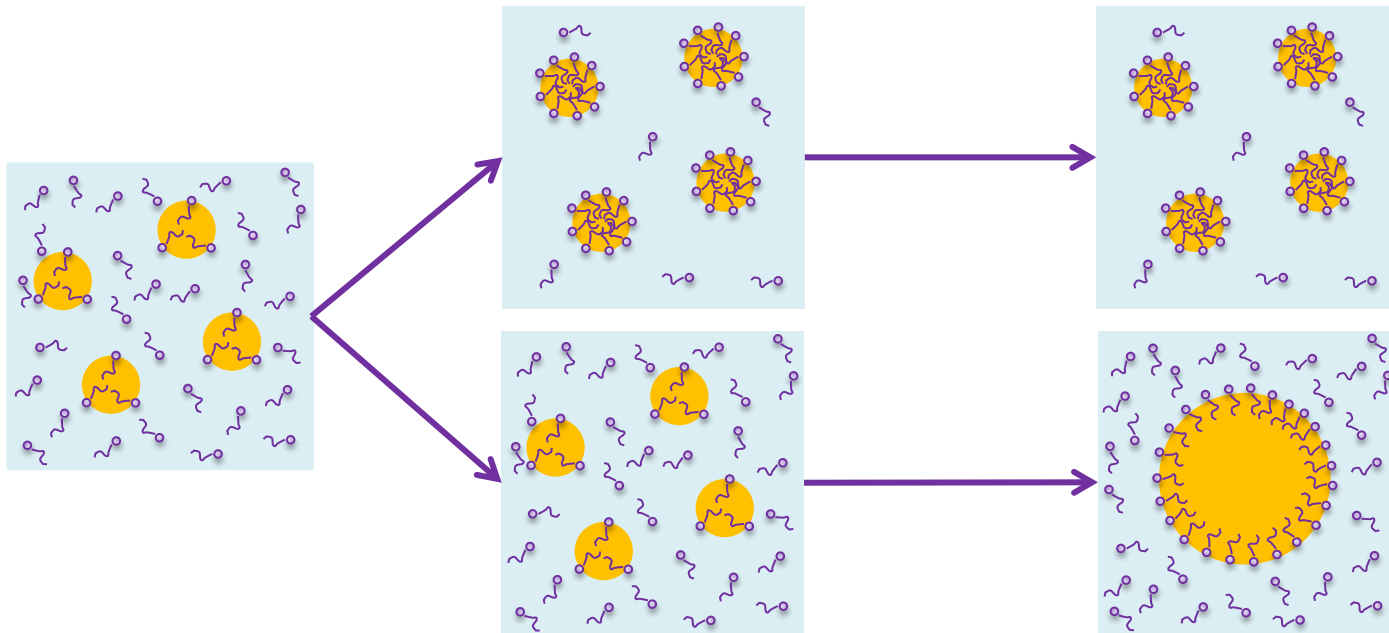


Microfluidic methods to study emulsion formation

Kelly Muijlwijk

Claire Berton-Carabin and Karin Schroën

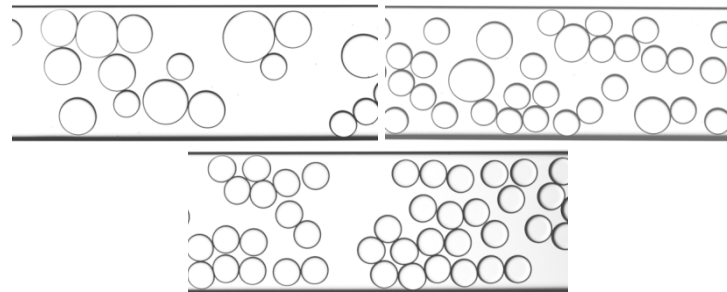


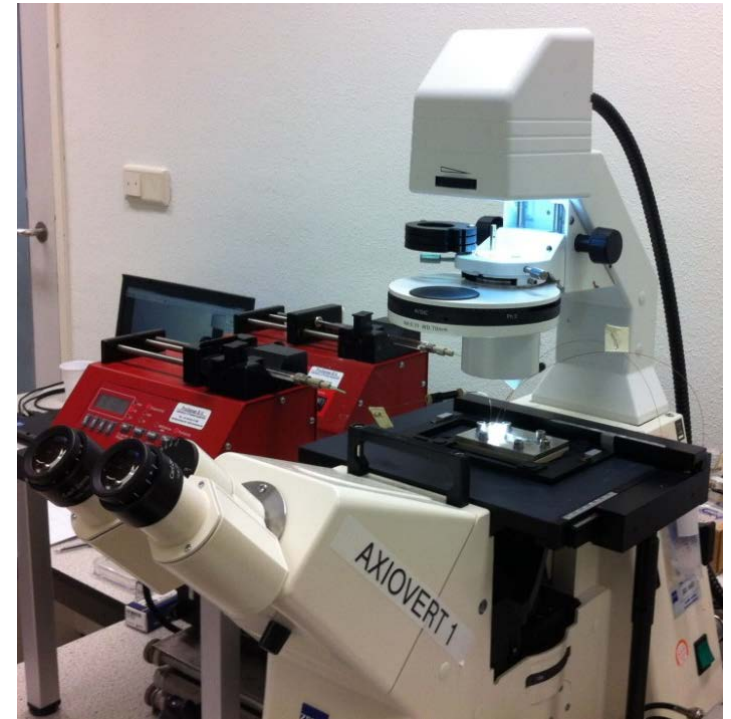
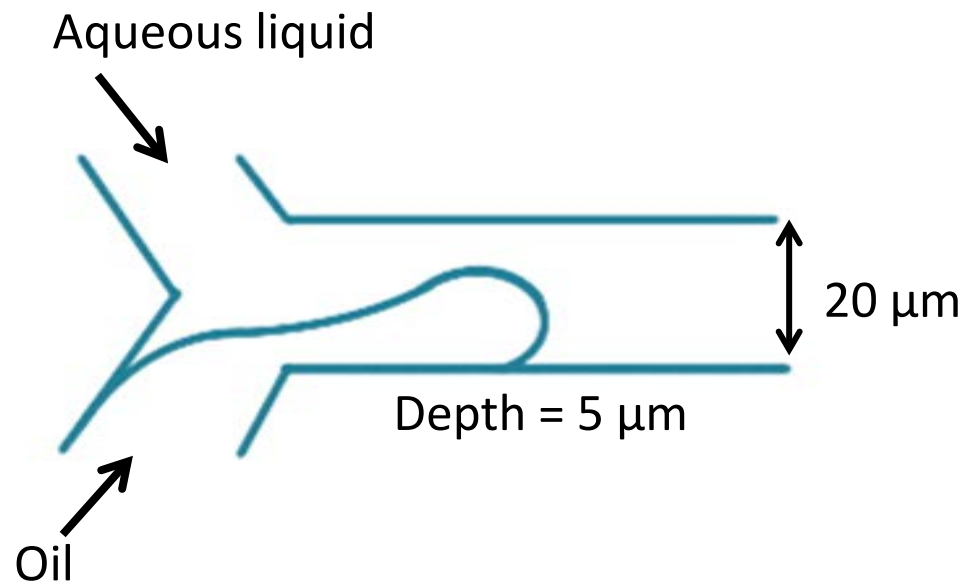


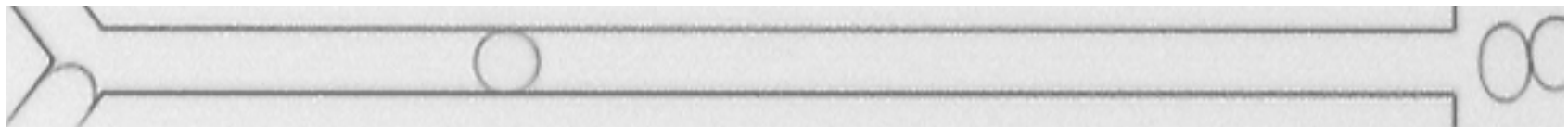
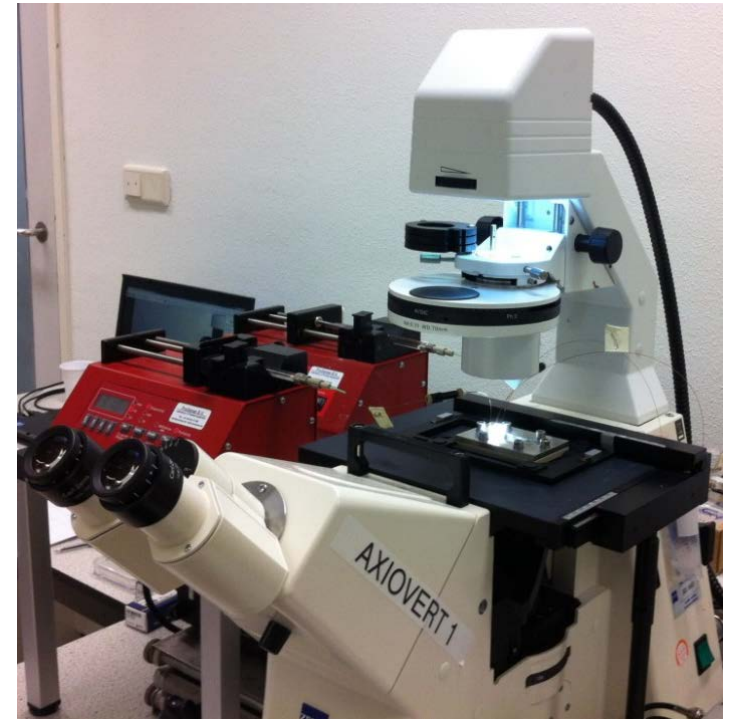
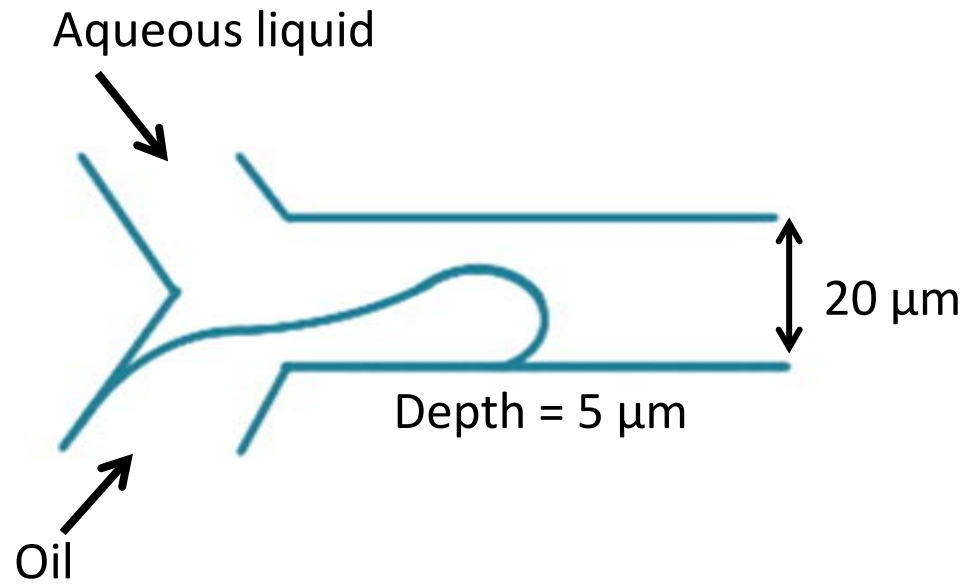
Emulsifier adsorption



Coalescence



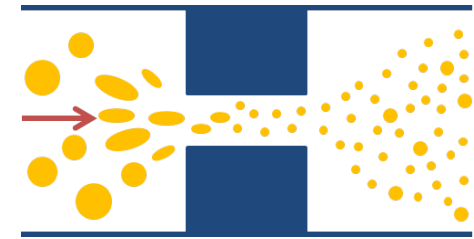




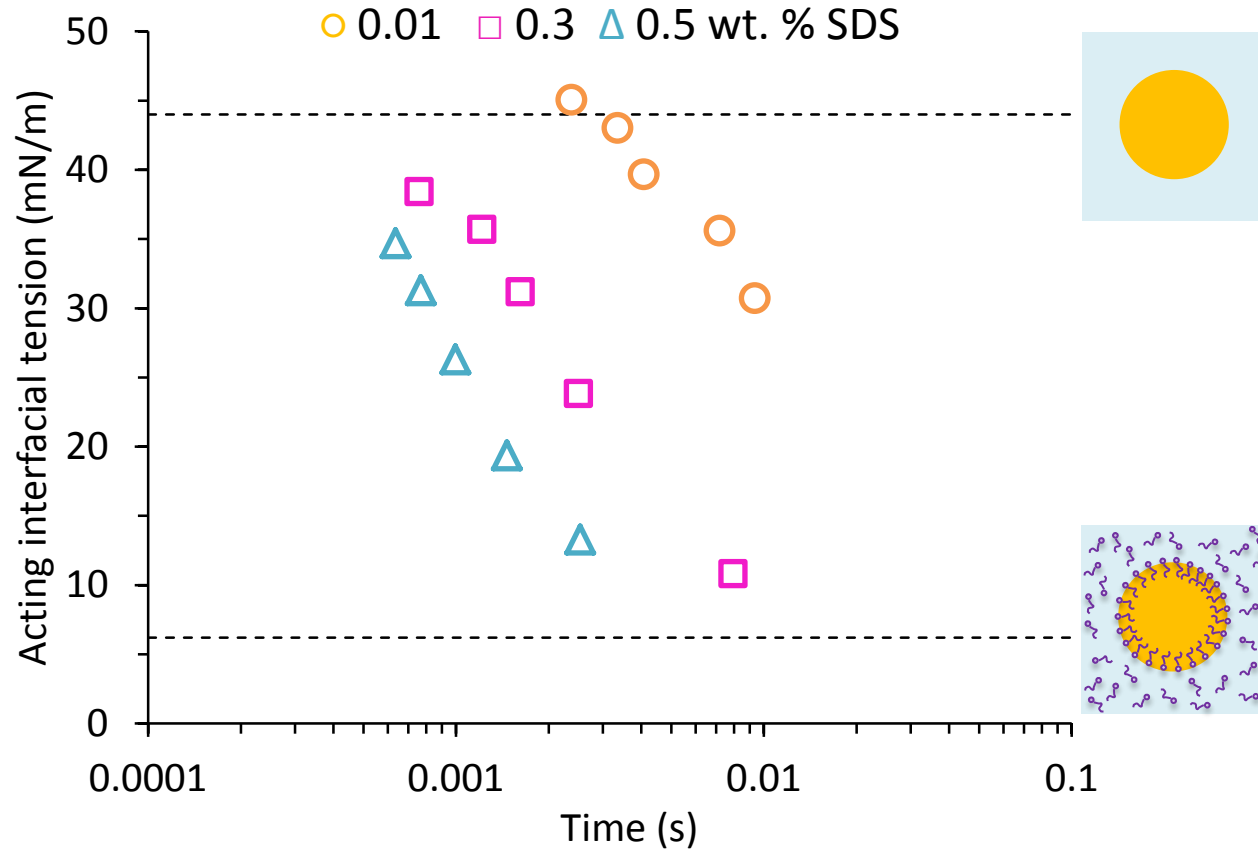
Recorded at 18000 frames/second
Movie at 7 frames/second

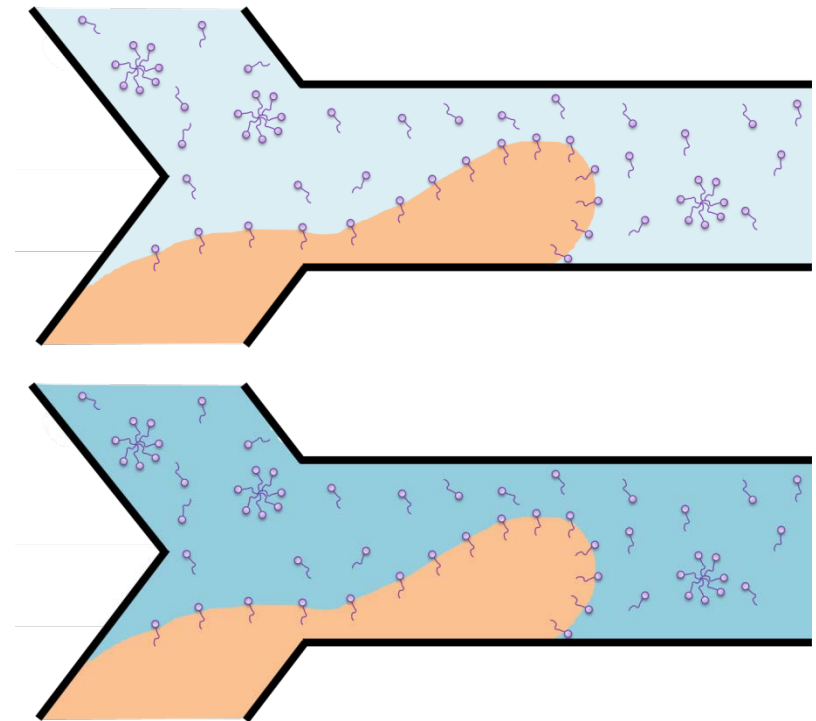
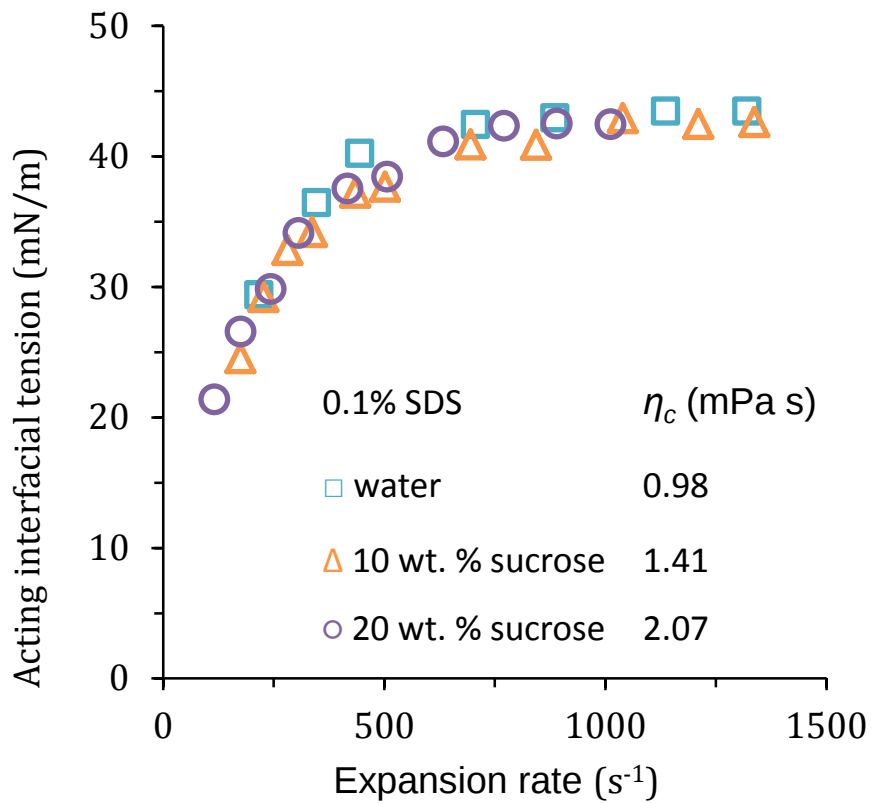
Measure interfacial tension

- Based on droplet size
- At droplet detachment (0.4-9.4 ms)

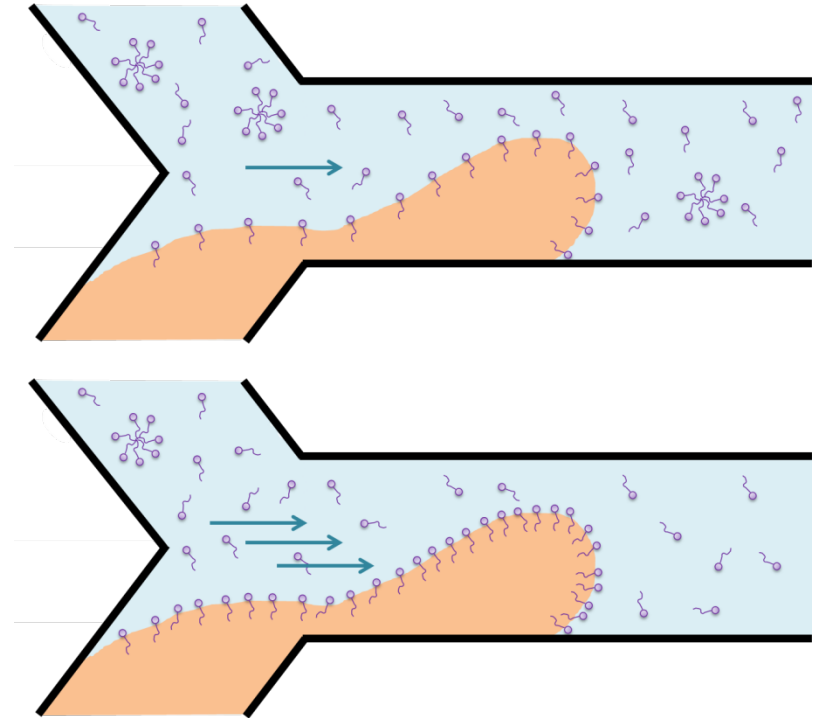
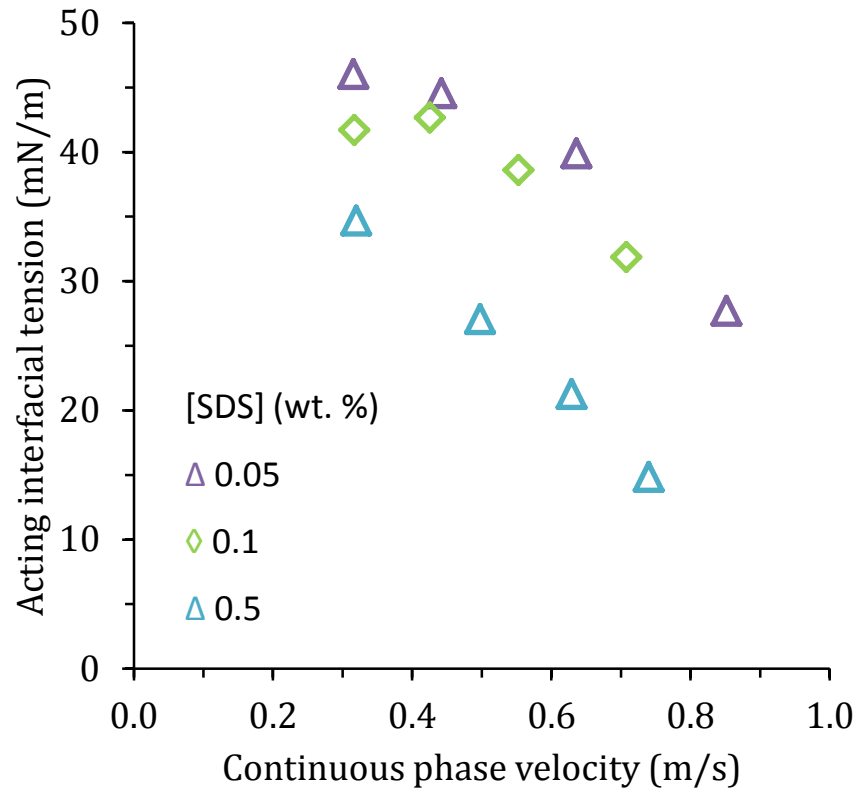


$$t_{\text{ads}} = 0.1-30 \text{ ms}$$



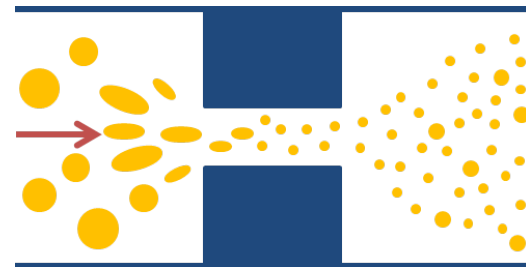


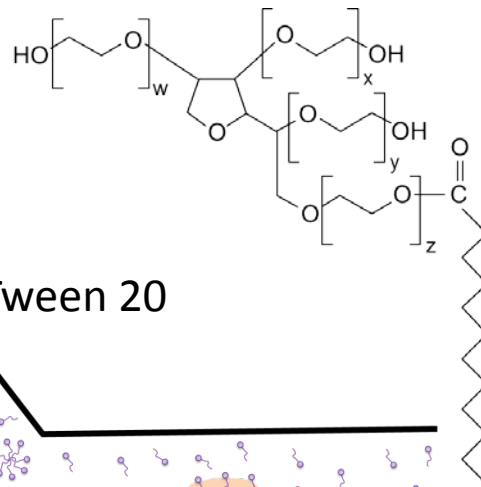
Continuous phase viscosity: no influence on adsorption



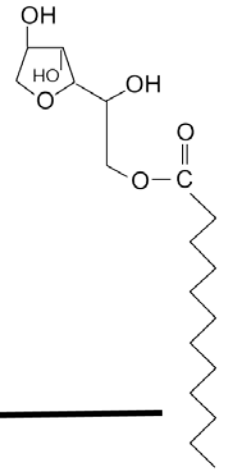
Continuous phase velocity: adsorption increases with velocity

→ Convective mass transport



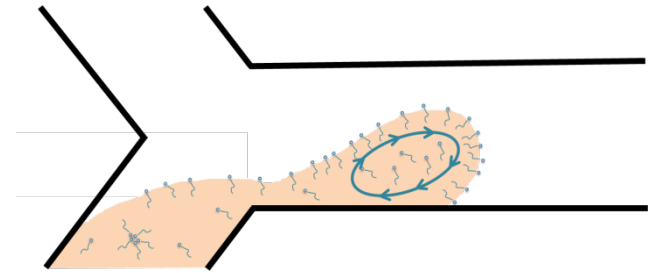
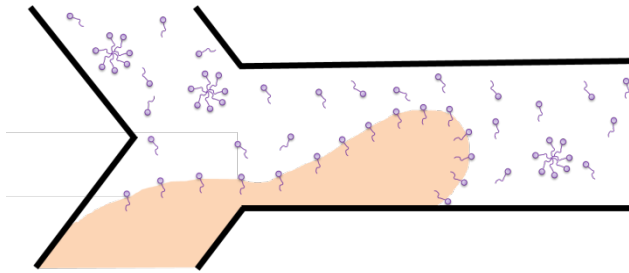


Tween 20

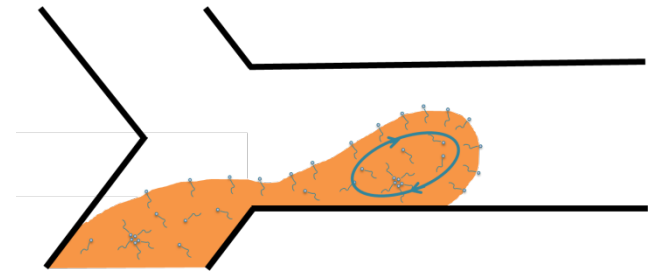
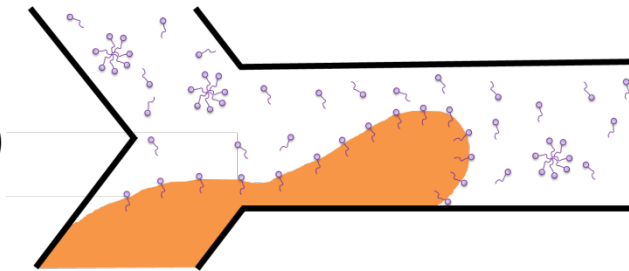


Span 20

Decane ($C_{10}H_{22}$)
 $\eta_c = 0.9 \text{ mPa s}$



Hexadecane ($C_{16}H_{34}$)
 $\eta_c = 3.5 \text{ mPa s}$



Small effect due to intercalation

Large effect due to convection

Microfluidic method to measure emulsifier adsorption

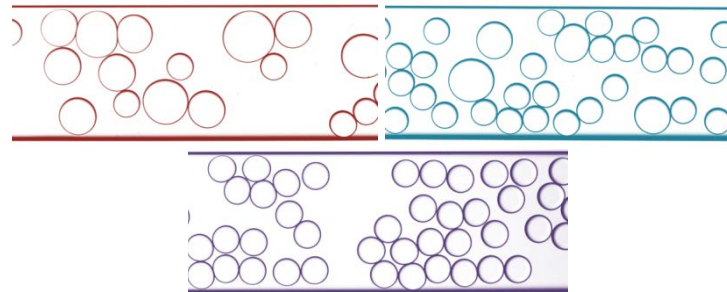
- At high expansion rates ($100\text{-}2000\text{ s}^{-1}$)
- Within milliseconds ($0.4\text{-}9.4\text{ ms}$)
- Convective mass transport (continuous phase and dispersed phase)
- Different oils can be used (hexadecane, dodecane, and decane)
- Food-grade emulsifiers (Span 20 and Tween 20)

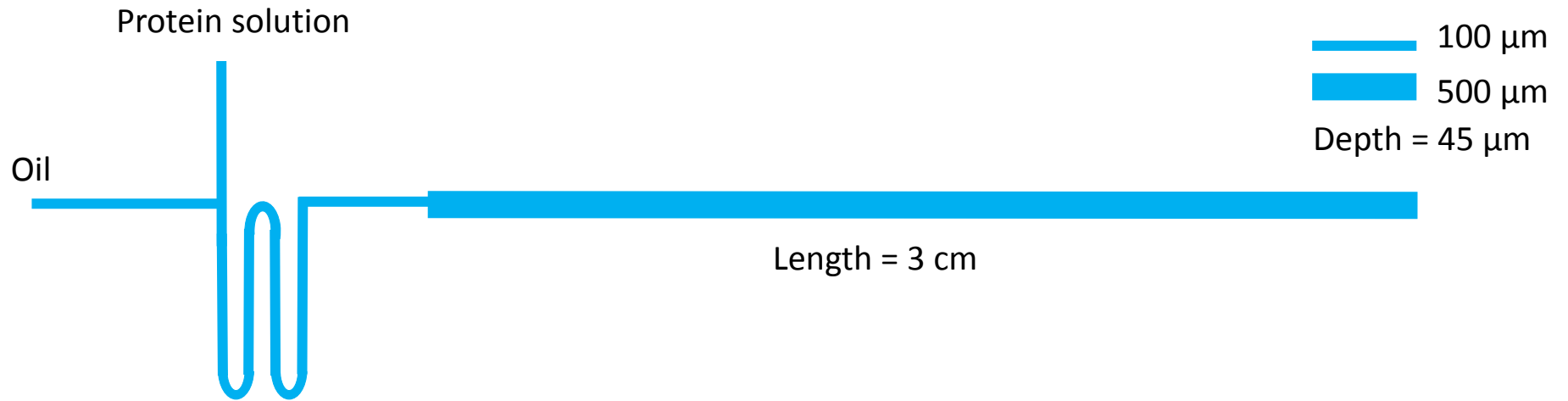


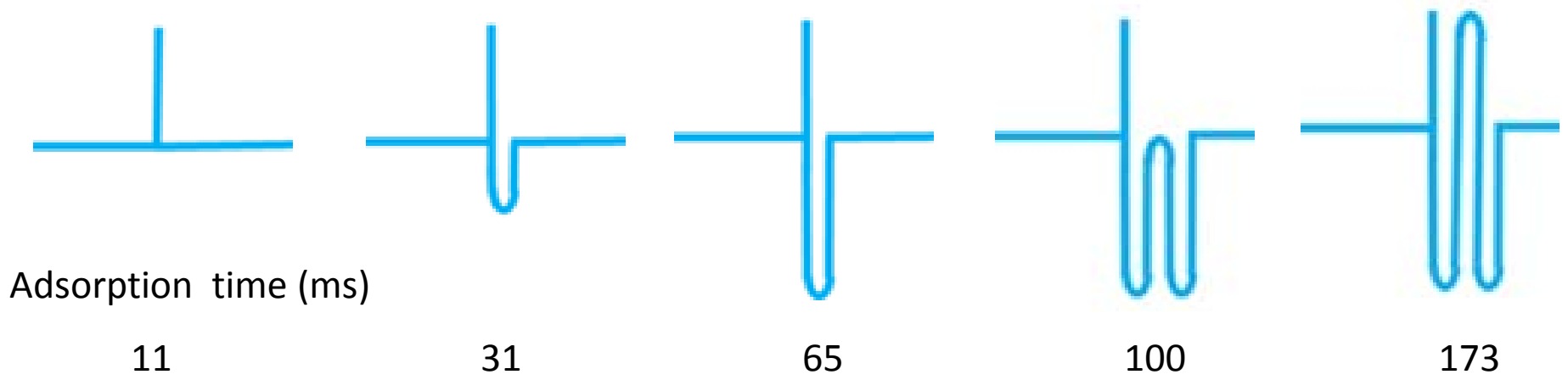
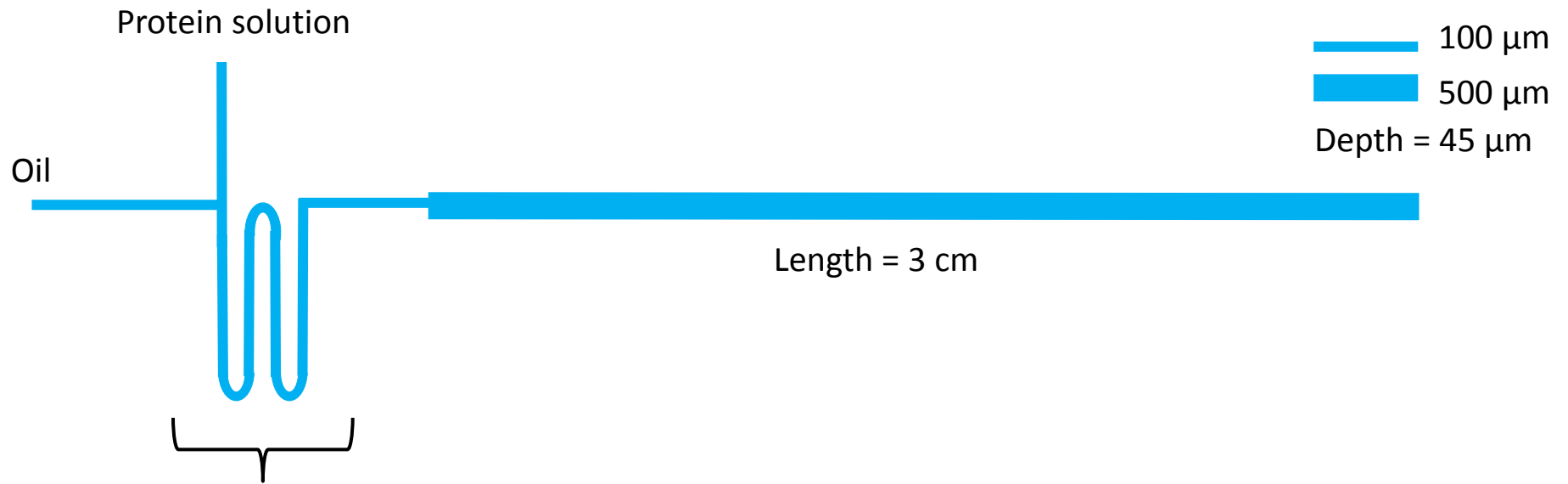
Emulsifier adsorption

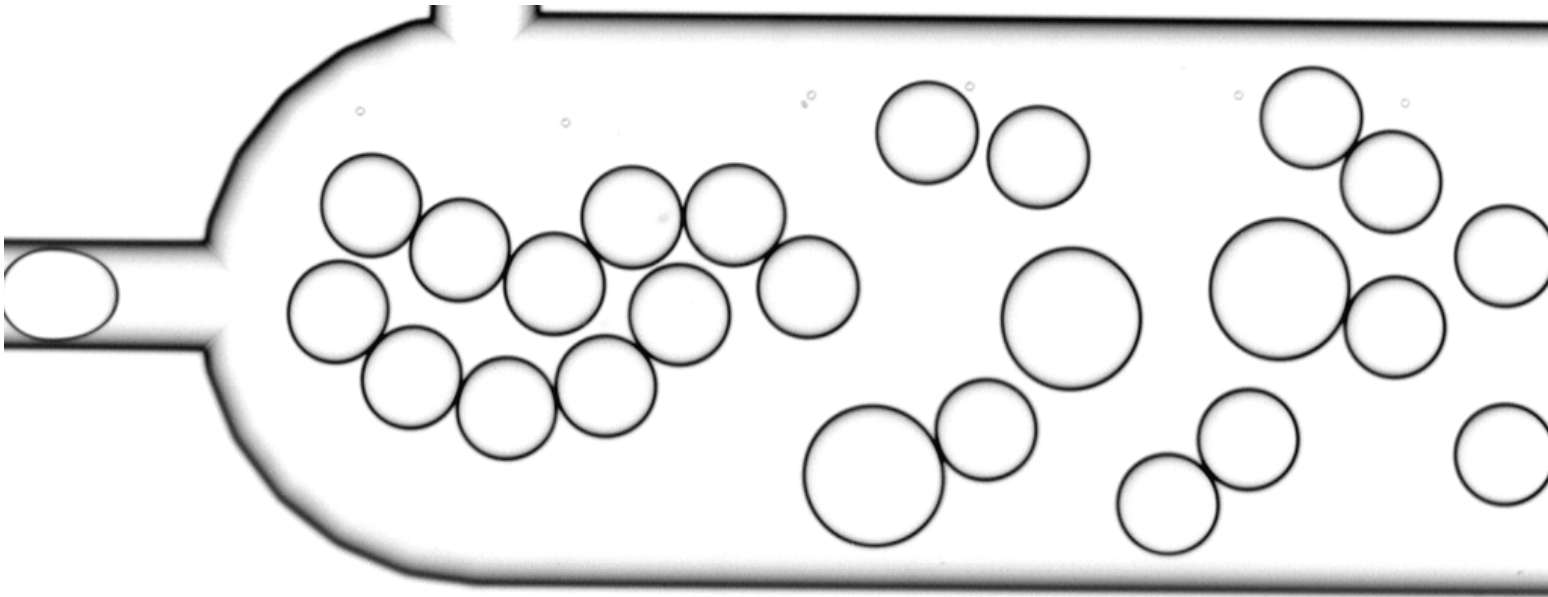
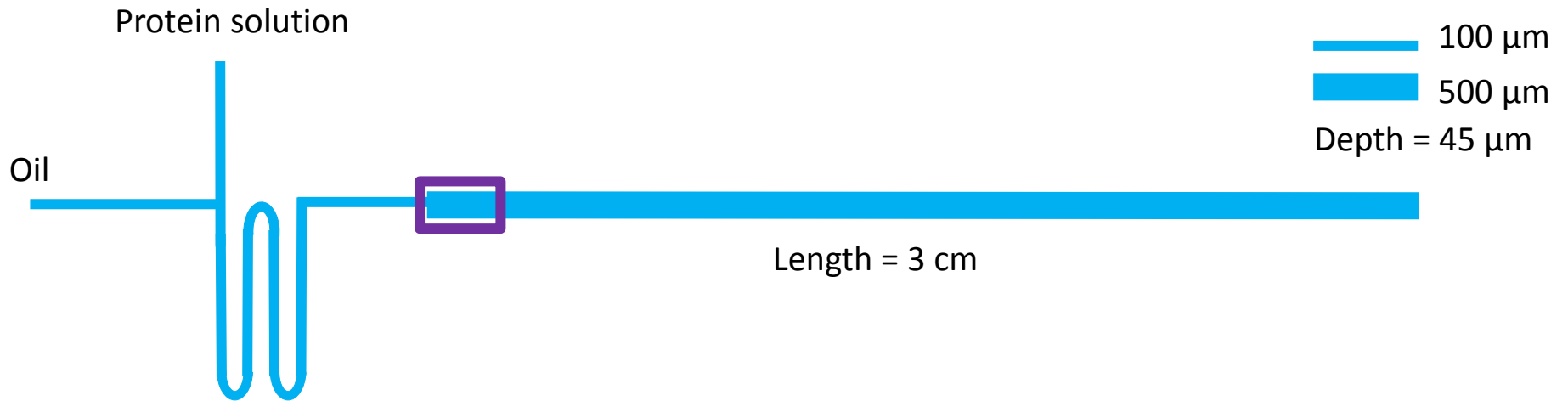


Coalescence

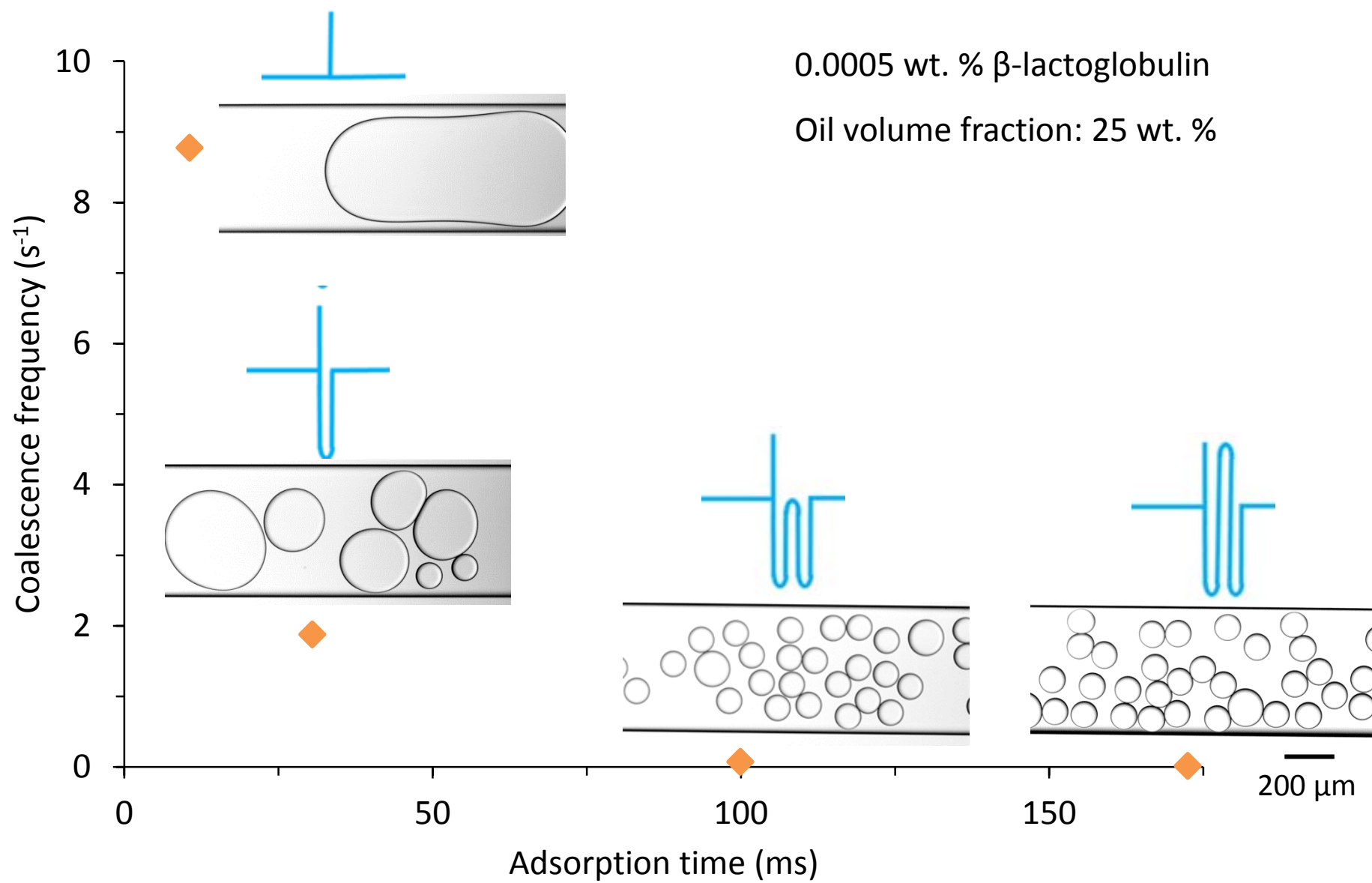


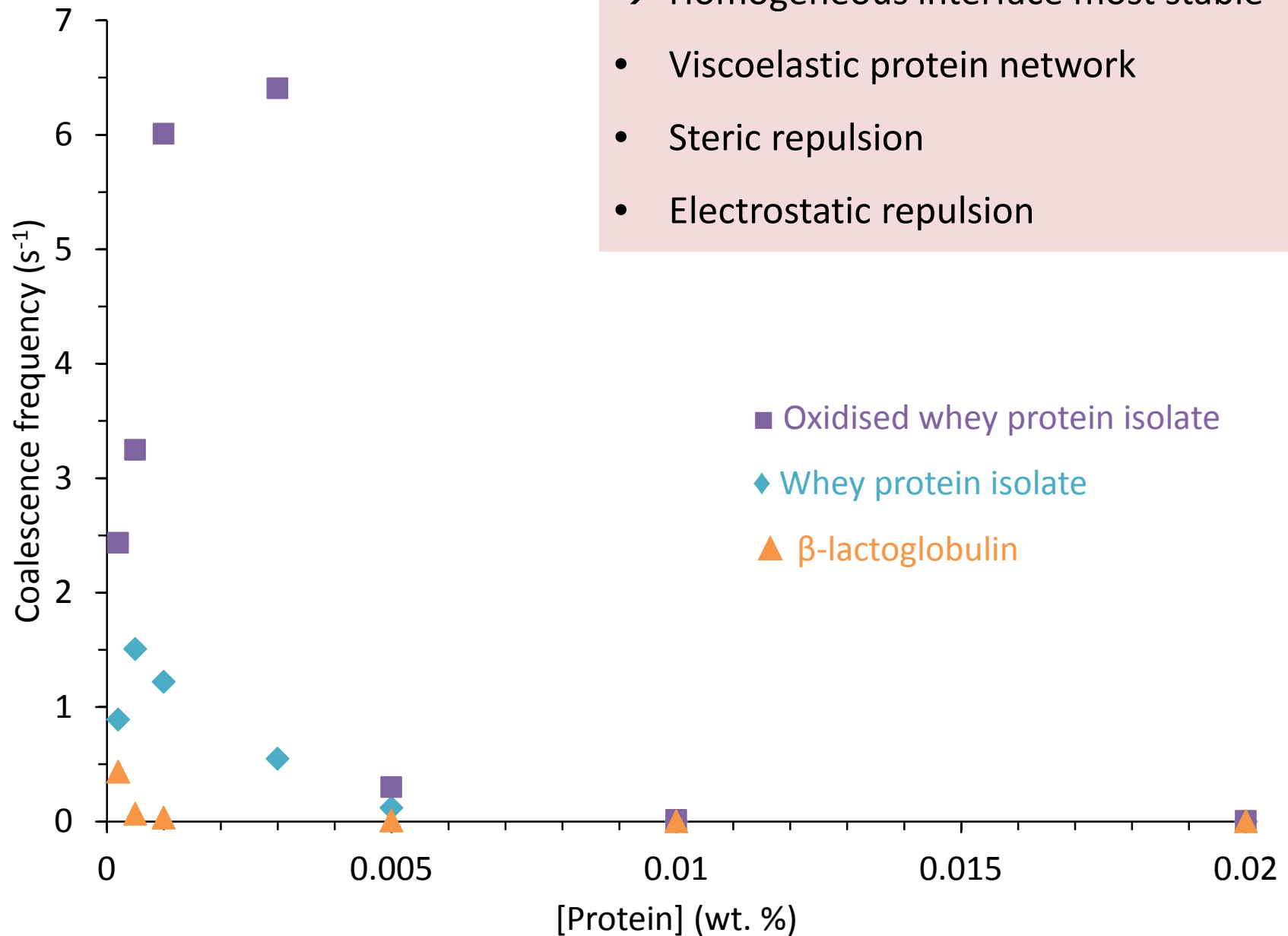






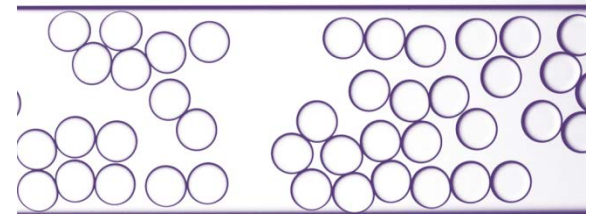
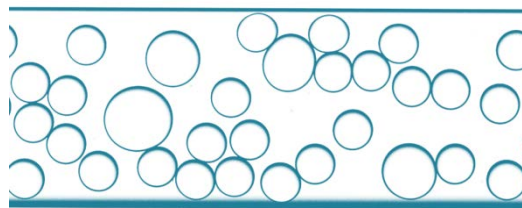
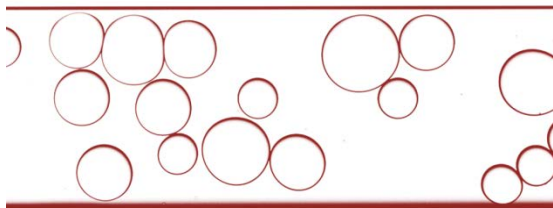
Recorded at 1000 frames/second
Movie at 7 frames/second



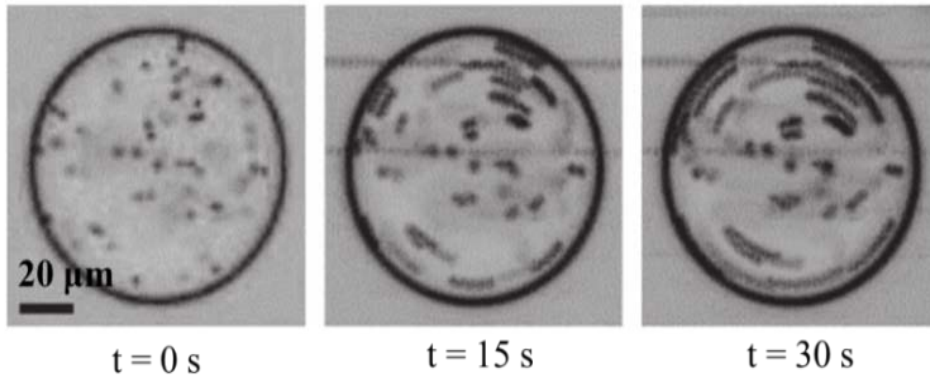


Microfluidic method to measure coalescence

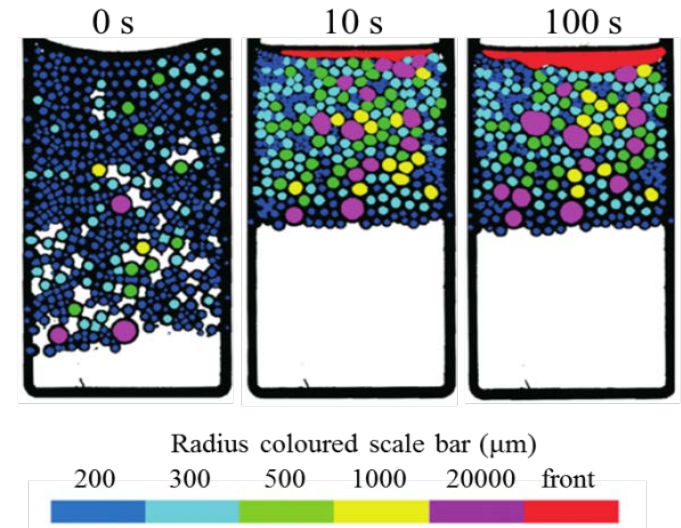
- During flow (2-6 mm/s)
- Dense system (25-60 % oil)
- Adsorption time can be varied (11-173 ms)
- Food-grade emulsifiers (whey proteins)
- Also foams can be measured



Other microfluidic methods



Interfacial mobility and rheology



Storage stability

Martin et al., Advanced materials, 2011, 23, 426-432

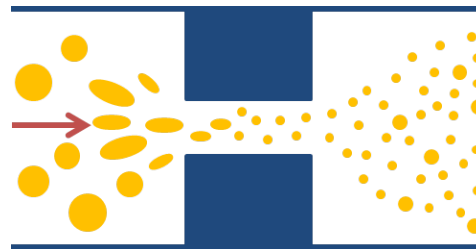
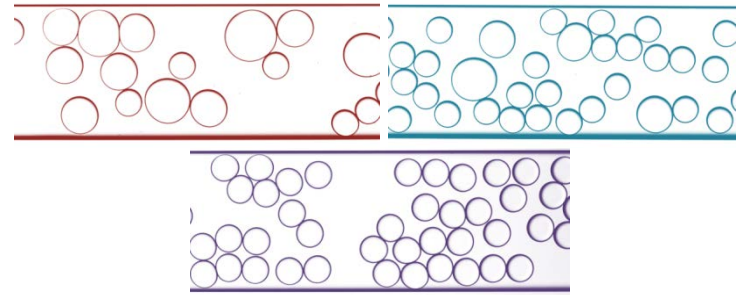
Martin and Hudson, New Journal of Physics, 2009, 11, p115005

Feng et al., Loac, 2014, 15, 188-194

Emulsifier adsorption



Coalescence



- Ingredient and formulation screening
- More efficient emulsification



Microfluidic methods to study emulsion formation

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