Using microfluidics to study dynamic interfacial tension during emulsification

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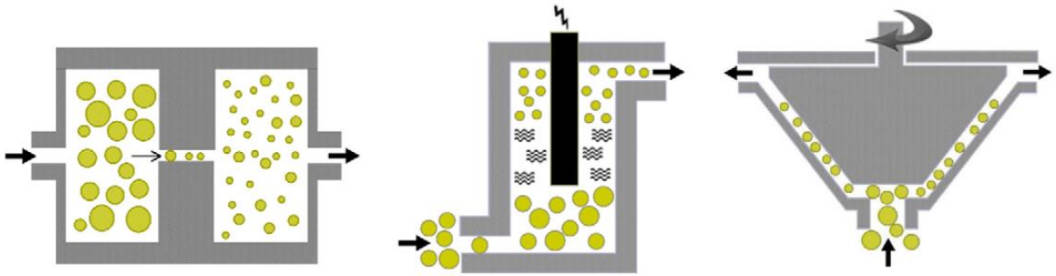
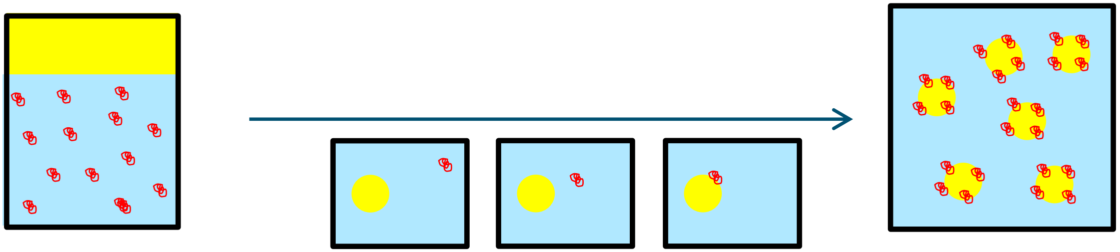
Emulsification



Droplets are formed within milliseconds

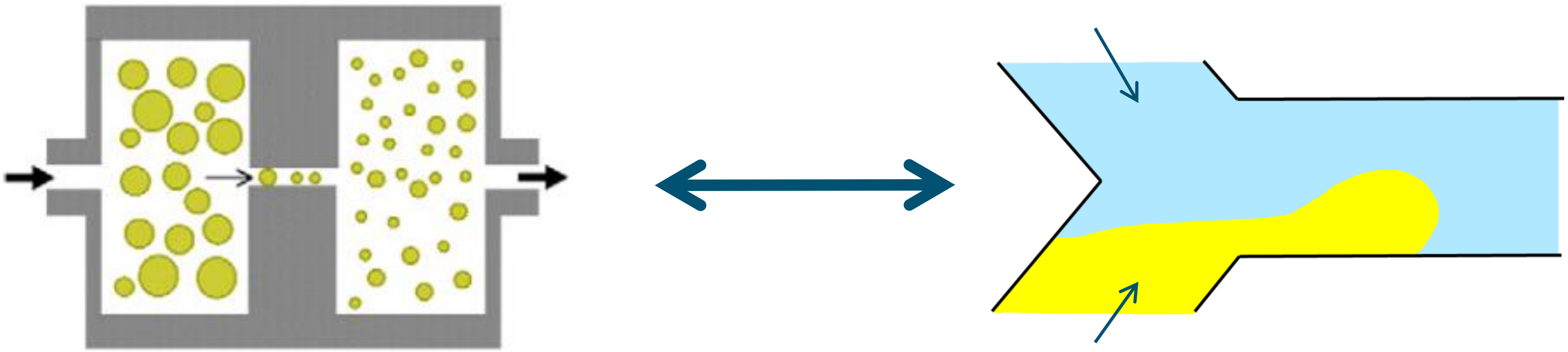


Protein adsorption

Do proteins adsorb during homogenisation?

Interfacial tension measurement > 1 second

Microfluidics and industry

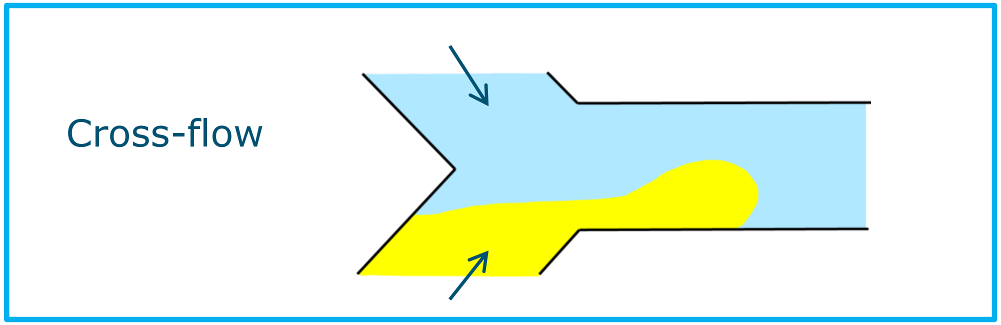


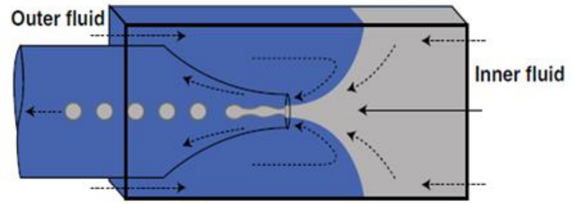
Microfluidics can be used to understand formation of emulsions in industrial processes

Optimise product formulation and processing conditions

Microfluidic devices

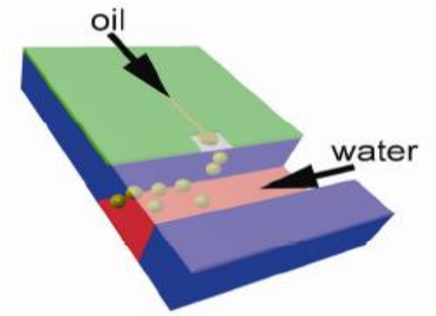
- Shear based systems



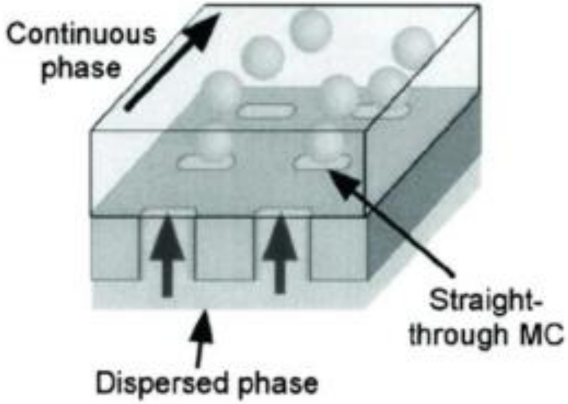


Flow-focusing

- Spontaneous emulsification systems

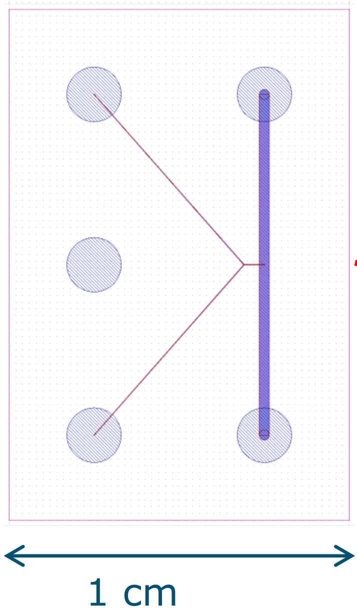


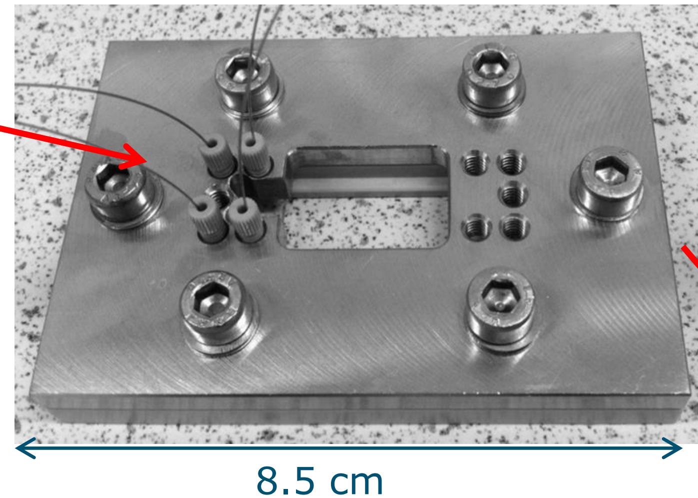
Grooved microchannel

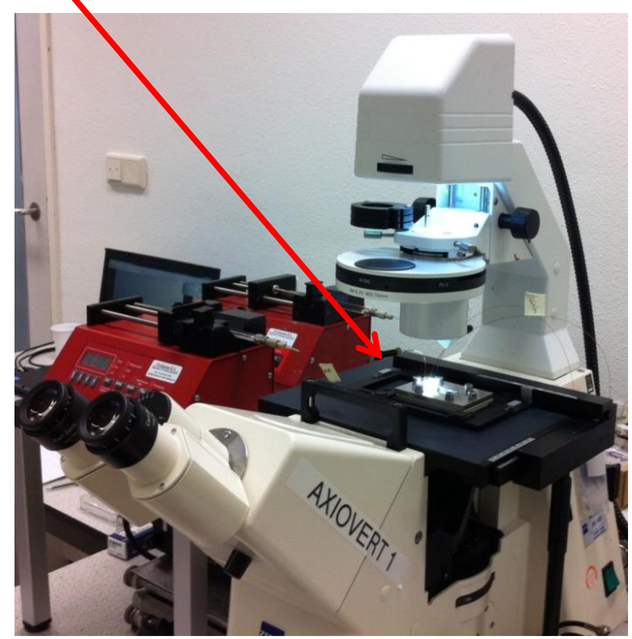


Straight-through microchannel

Microfluidic set-up

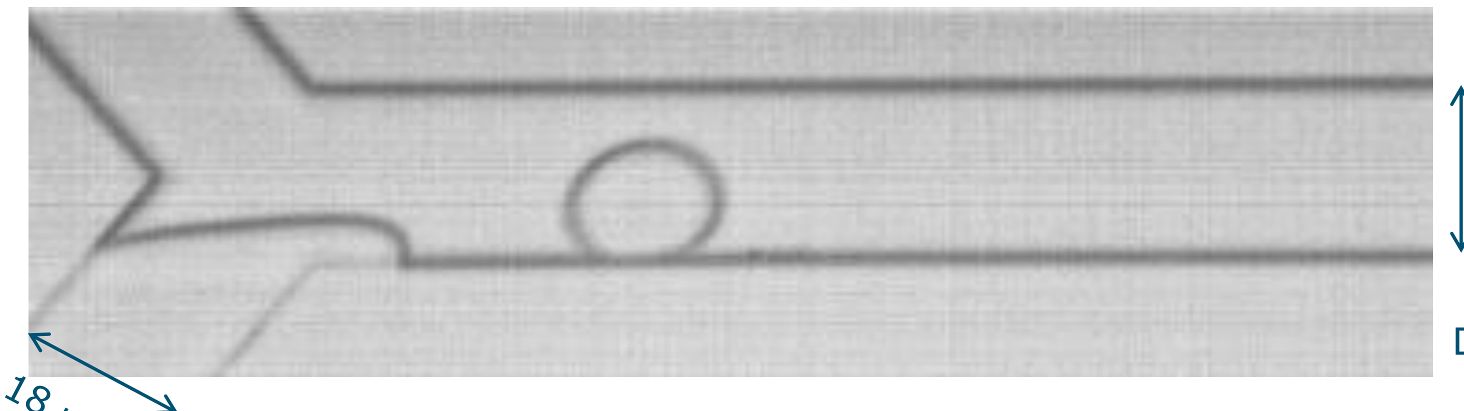






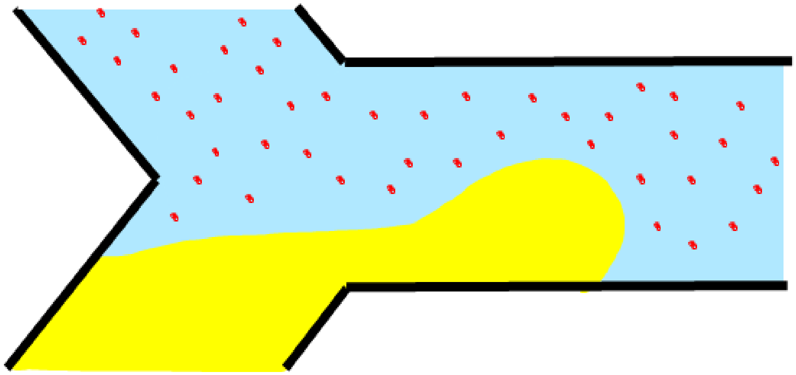
Y-junction

Droplet formation is a balance between shear force and interfacial tension



Recording up to 100.000 frames/sec
Droplet formation in 0.2 - 10 millisecond

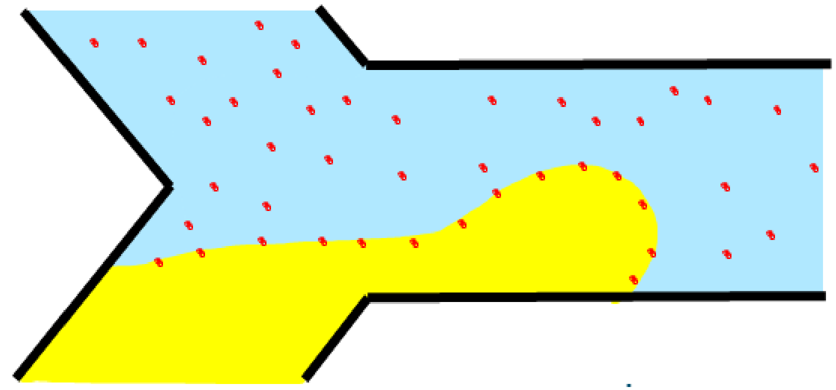
Dynamic interfacial tension



No adsorption

$\gamma_{dynamic}$ = high

→ Large droplets



Adsorption

$\gamma_{dynamic}$ = low

→ Smaller droplets

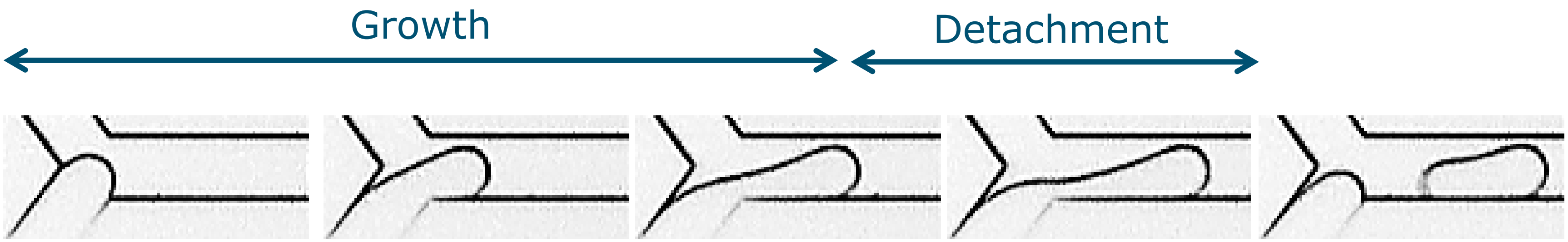
Approach

Optimise model

Measure dynamic interfacial tension

Sodium dodecyl sulphate	Whey protein isolate

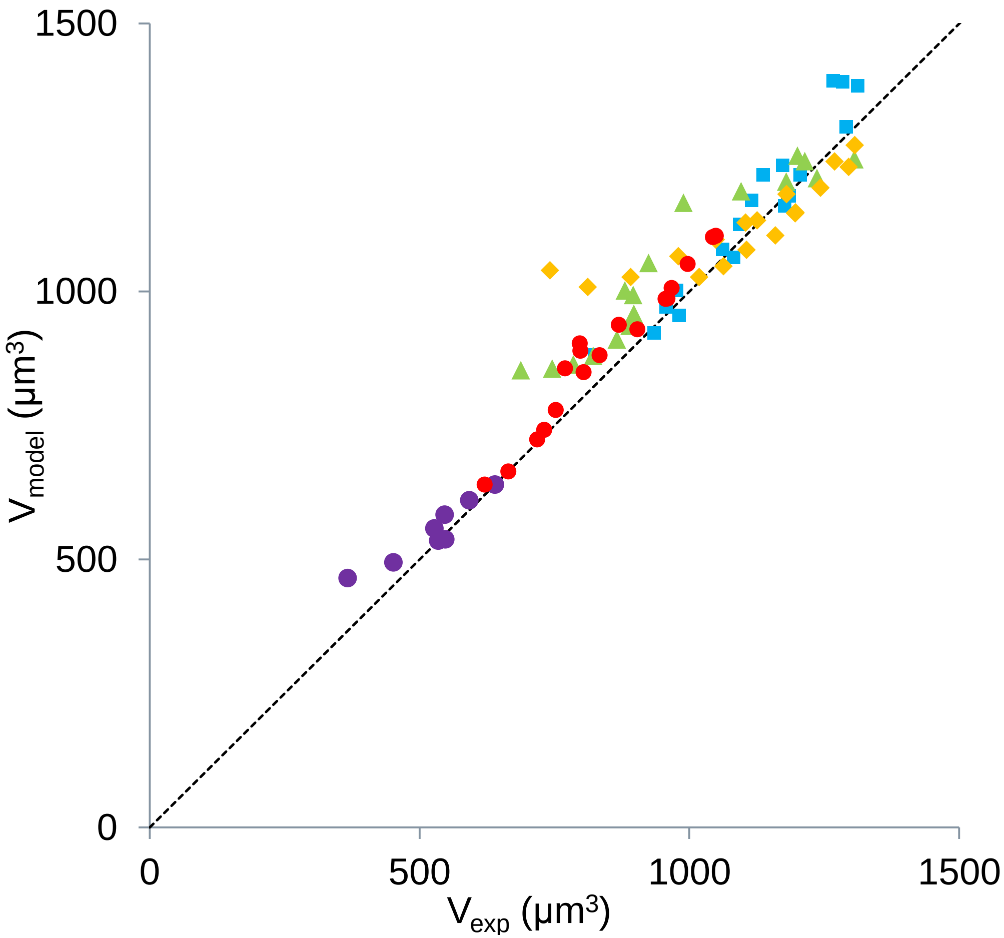
Two-step model



$$V = \underbrace{A\left(\frac{\gamma}{\eta_d v_c}\right)^c}_{V_{growth}} + \underbrace{\varphi_d B\left(\frac{\gamma}{\gamma_0}\right)^c}_{V_{detachment}}$$

V_{growth} $V_{detachment}$

Two-step model



$$V = A\left(\frac{\gamma}{\eta_d v_c}\right)^C + \varphi_d B\left(\frac{\gamma}{\gamma_{MQ}}\right)^C$$

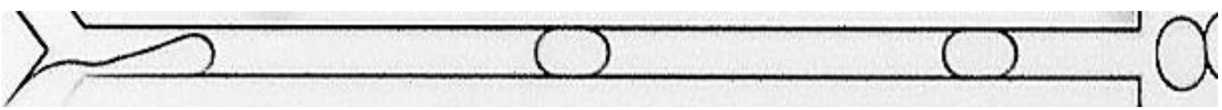
	γ (mN/m)
■ water	46
▲ 9 wt. % Ethanol	27
● 28 wt. % Ethanol	15
♦ 20 wt. % Glycerol	37
● 30 wt. % Glycerol	35

Volume and flow rates are determined with image analysis

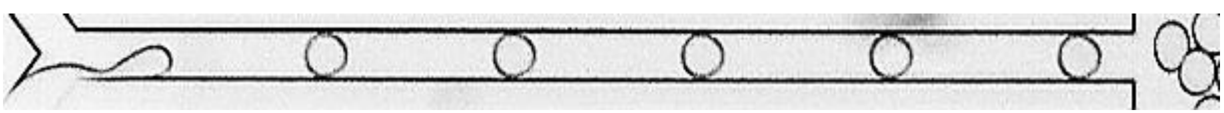
Fitting parameters:
A B C

Dynamic interfacial tension

$$\gamma_d = \left(\frac{V}{\frac{A}{(\eta_d v_c)^C} + \frac{\varphi_d B}{\gamma_{MQ}{}^C}} \right)^{\frac{1}{C}}$$



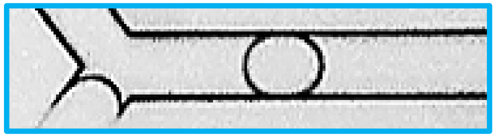
Water
γ = 46 mN/m
V = 2200 µm³



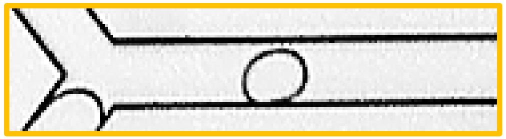
28 wt. % Ethanol
γ = 16 mN/m
V = 1000 µm³

Sodium dodecyl sulphate

0.01 wt. % SDS

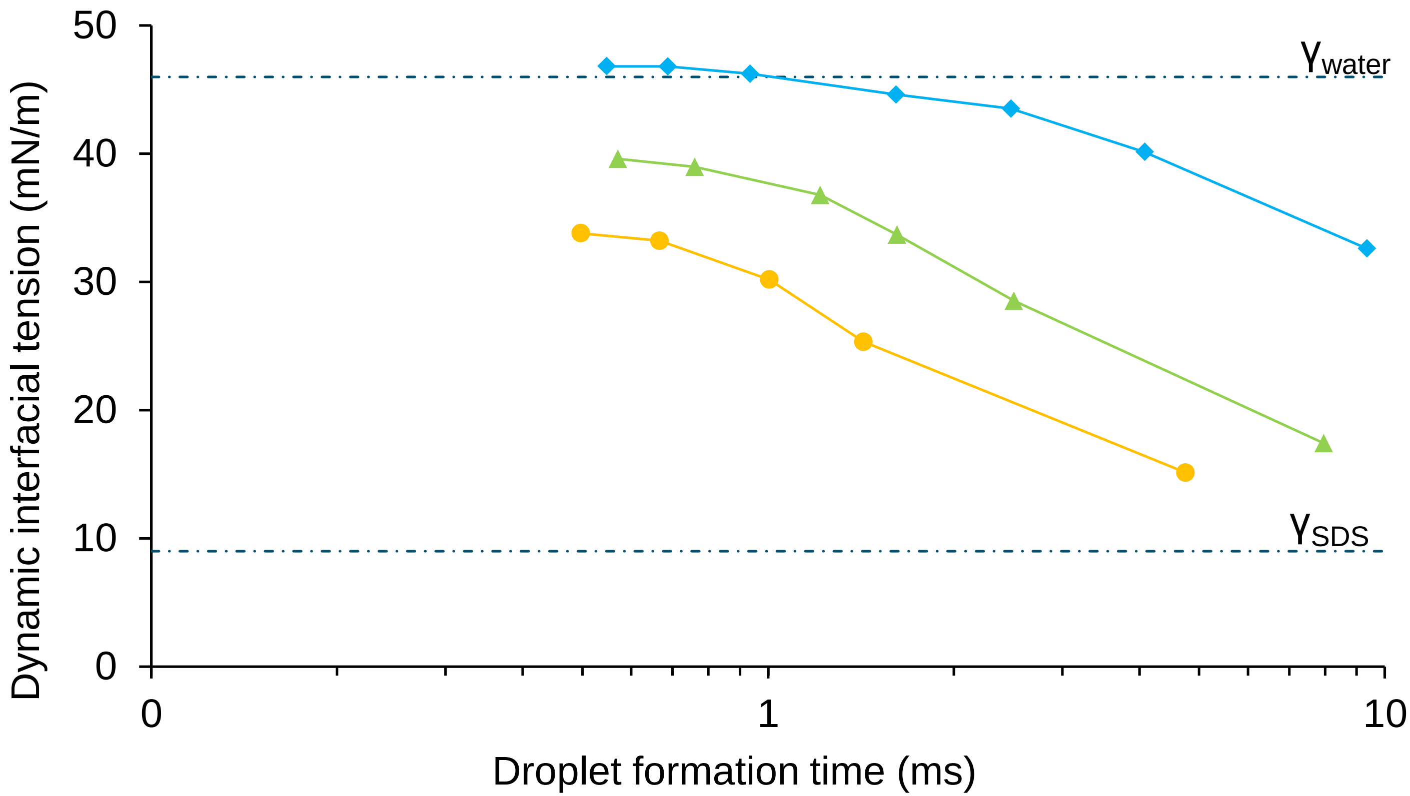


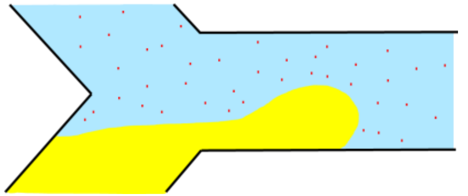
1 wt. % SDS

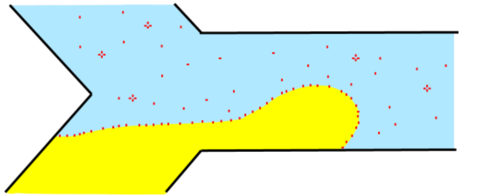


♦ 0.01 wt. % SDS
▲ 0.3 wt. % SDS
● 1 wt. % SDS

CMC = 0.23 wt. % SDS



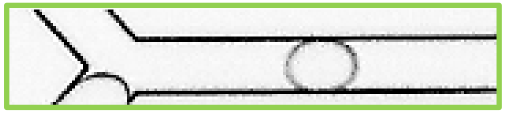


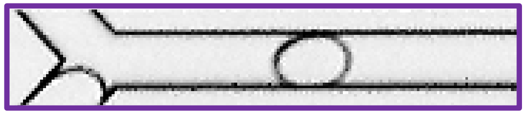


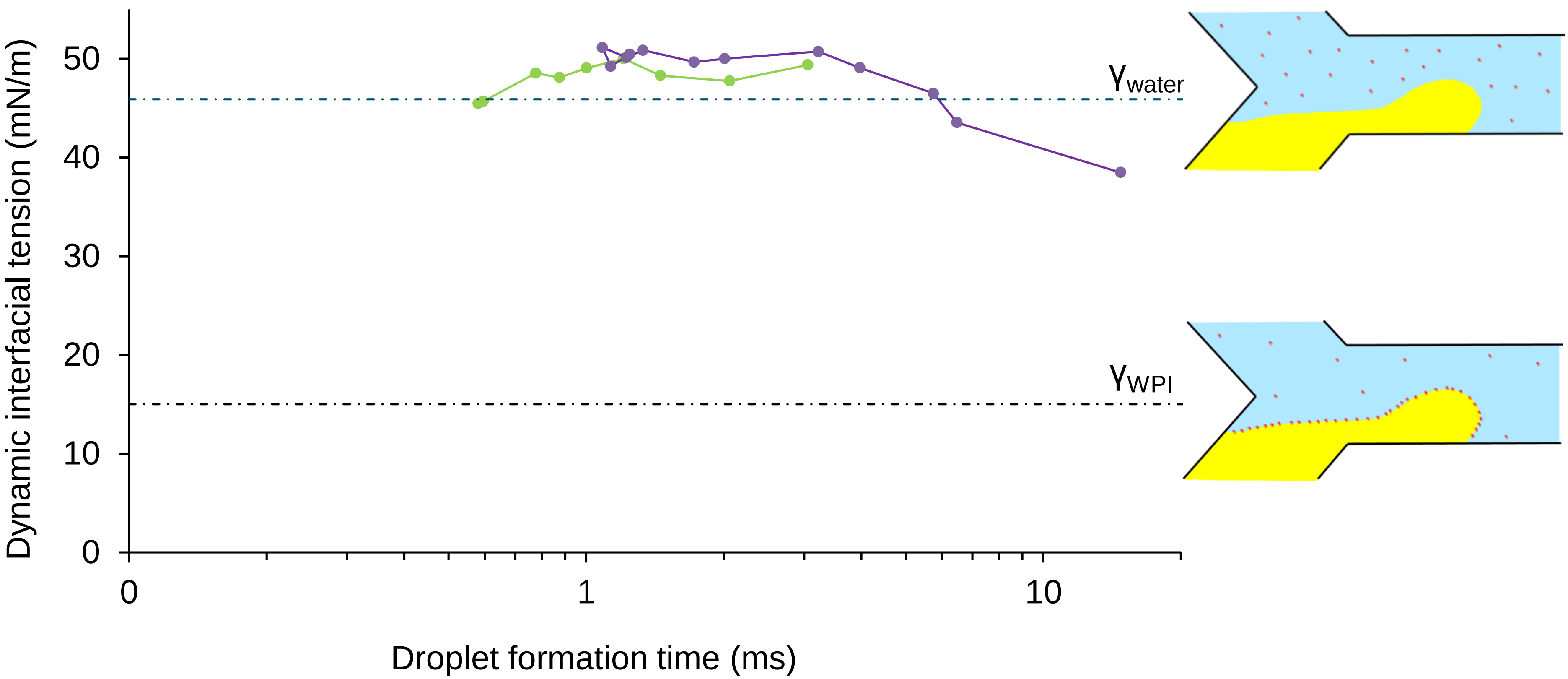
Whey protein isolate

0.1 wt. % WPI

1.3 wt. % WPI

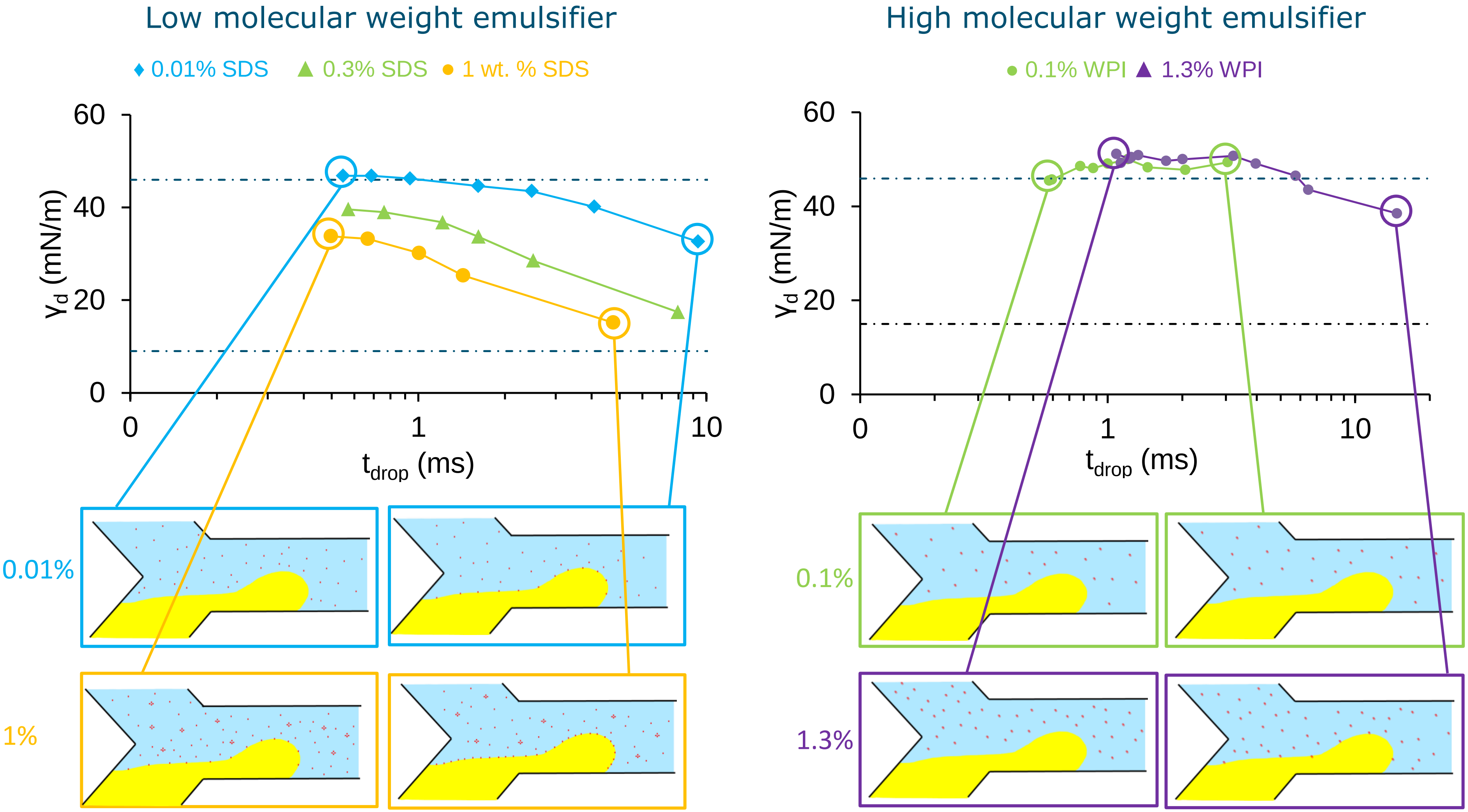




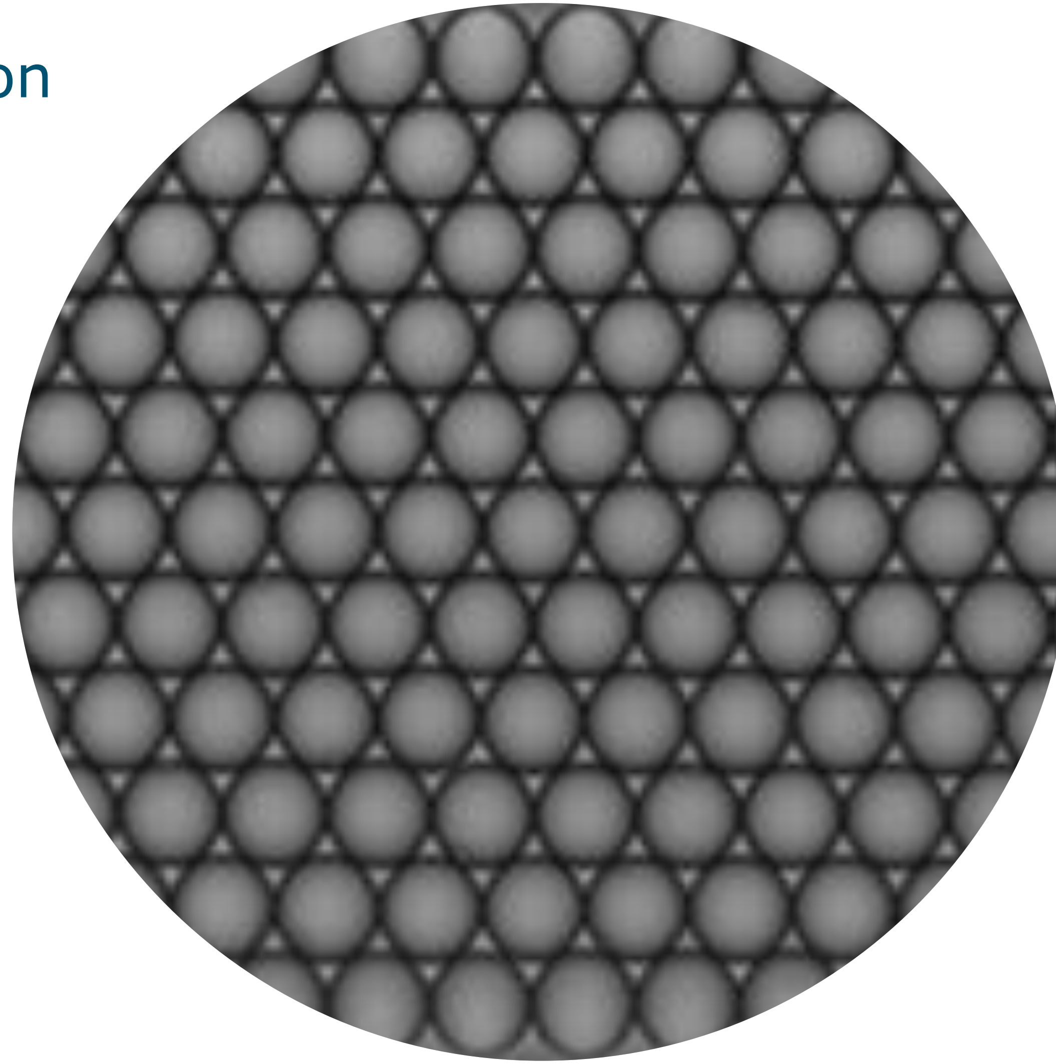


Overview

$$\gamma_d = \left(\frac{V}{\frac{A}{(\eta_d v_c)^C} + \frac{\varphi_d B}{\gamma_{MQ}{}^C}} \right)^{\frac{1}{C}}$$



Thanks for your attention



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innovating with micro and nanotechnology

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