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Emulsion preparation using stainless steel EDGE microfluidic devices

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Introduction

Food and cosmetic products that we use on a daily base are emulsions: mixtures of two immiscible liquids stabilized by various surfactants. Large scale batch preparation methods have following drawbacks:

- ✓ Large energy input in preparation
- ✓ More than 90% of input energy may be lost in form of heat
- ✓ The resulting emulsions are very polydisperse
- ✓ Polydispersity results in poorer emulsions stability over time

Objective

Developing new ways of emulsion creation based on microfluidic technologies that present following advantages:

- ✓ Low energy input in preparation
- ✓ Mild emulsification conditions
- ✓ Intrinsically monodisperse emulsions
- ✓ Improved emulsion stability over time

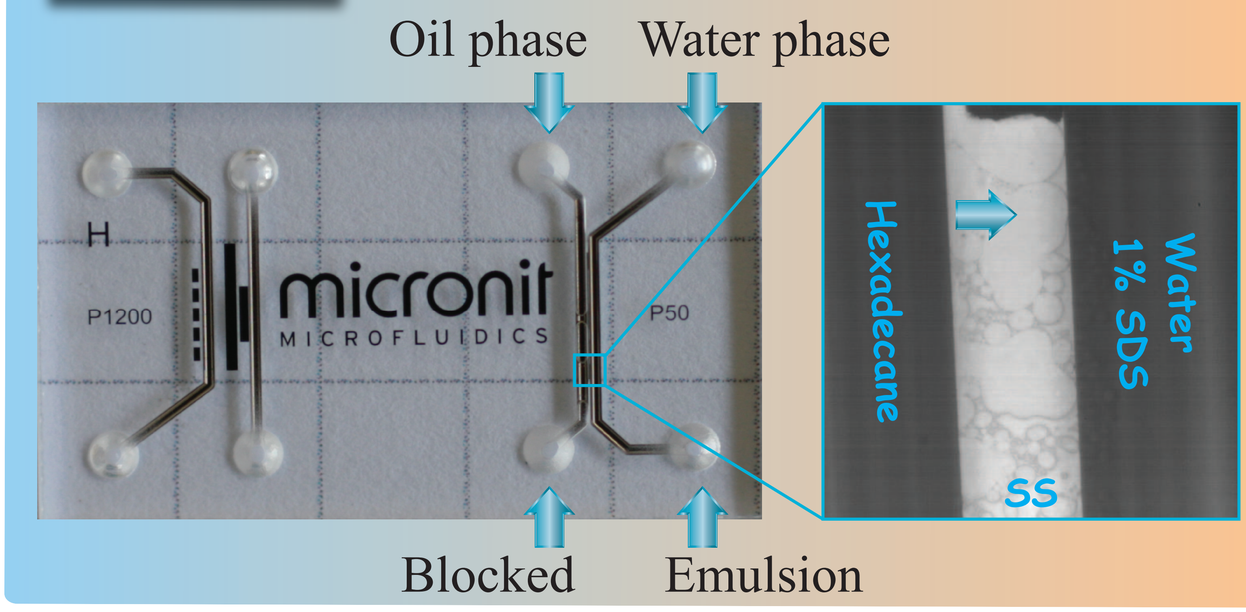
However, the presence of a shallow plateau introduces aspects that have to be investigated before the actual large scale usage of EDGE systems can be envisaged.

Emulsification with EDGE microfluidic devices

We have recently introduced a new spontaneous droplet formation technique called EDGE (Edge-based Droplet GEneration) capable of producing multiple droplets from a single droplet formation unit [1]. Promising results obtained with silicon and glass EDGE devices made it a prospective candidate for industrial usage. However, metal surfaces are a prerequisite for industry so Cu and CuNi plateau EDGE were successfully tested [2]. The next step towards industrial applications is the use of stainless steel (SS) surfaces, that are however intrinsically more complex from a structural point of view.

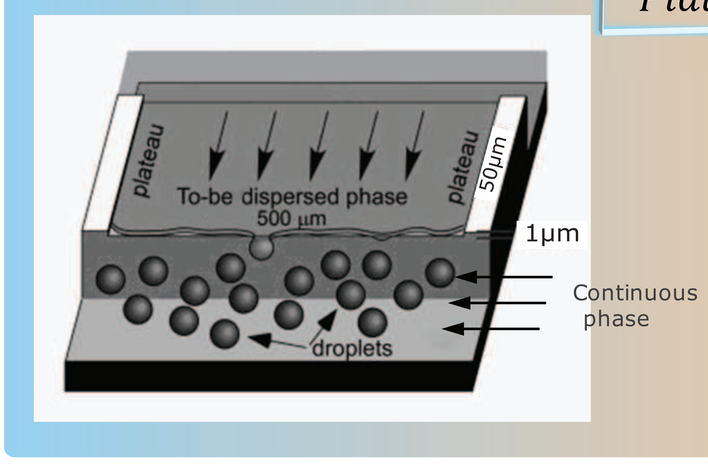
[1] K. C. van Dijke, G. Veldhuis, K. Schroën, R. M. Boom, AIChE Journal, 2010, 56, 833-836.
[2] A. A. Maan, R. Boom, K. Schroën, Microfluid Nanofluidics, 2013, 14, 775-784.

EDGE chip



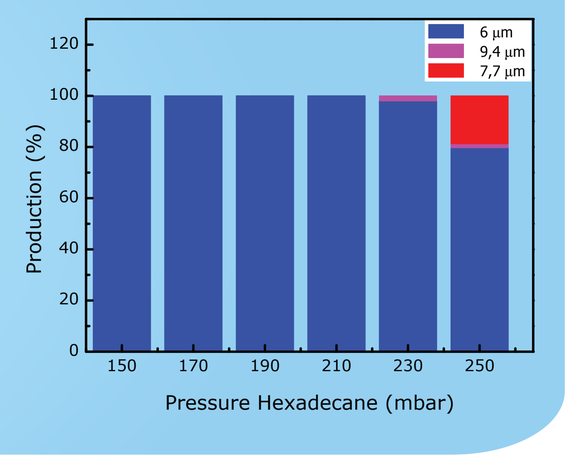
Working principle

Scaling:
$$\frac{Droplet\ diameter}{Plateau\ height} = 6$$



Results:

- ✓ Highly monodispersed emulsion in SS chips
- ✓ Droplet size agrees with scaling parameter
- ✓ Appreciable stable working pressure range
- ✓ Pronounced fingering of hexadecane on plateau due to intrinsic roughness and chemical heterogeneity
- ✓ Droplet formation positions do not shift with pressure
- ✓ Droplet formation frequency increases with pressure



Conclusions:

For the first time a monodispered emulsion is prepared using stainless steel coated EDGE microfluidic chip. Due to inhomogeneous chemical and topographical surface structure of stainless steel plateau incomplete plateau filling and pronounced fingering of the dispersed phase (hexadecane) was observed. A promising way to overcome the surface related issue is plateau surface modification with self-assembled monolayers (SAMs). By covalently coupling hydrophilic SAMs to SS plateau we expect not only to tune surface wettability but to improve EDGE functioning with regard to plateau filling, pressure stability range and resistance to fouling.

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