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

Objectives:

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

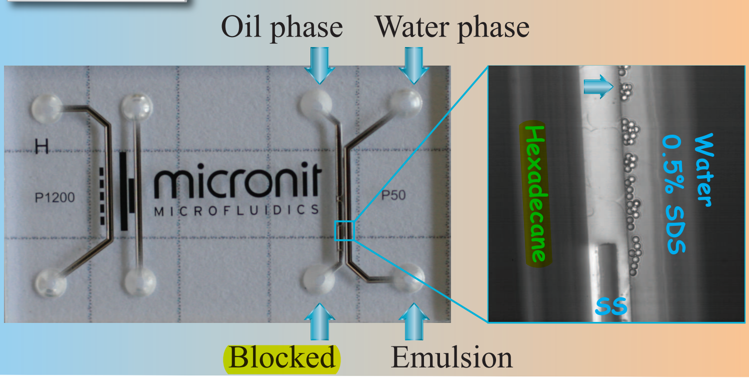
However, the presence of a shallow plateau introduces aspects that have to be investigated before the actual large scale usage of EDGE systems can be envisaged.

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.

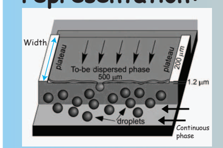
[1] K. C. van Dijke, G. Veldhuis, K. Schroën, R. M. Boom, AIChE Journal, 2010, 56, 833-836.
[2] A. A. Maan, R. Boom, K. Schroën, Microfluid Nanofluidics, 2013, 14, 775-784.

EDGE chip



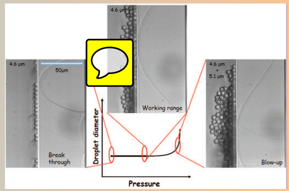
Working principle

Artistic representation:



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

Working principle sketch:



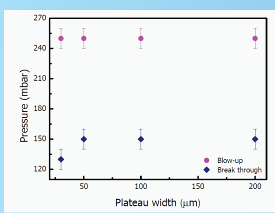
Plateau wettability prerequisites:

- ✓ Larger affinity for continuous phase
- ✓ Adsorption of emulsion components does not modify wettability in undersired way

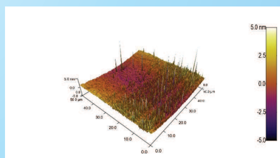
Results:

- ✓ Stable working range was obtained for system consisting of: hexadecane/water/SDS (sodium dodecyl sulphate)
- ✓ Match working ranges found for glass/silicon chip
- ✓ Stable reproducible over time working range confirms no wettability modifications by emulsion components
- ✓ Working range and droplet size are independent of plateau width
- ✓ Pronounced fingering likely due to roughness of sputtered SS thin film
- ✓ Food grade emulsion formation: ongoing...

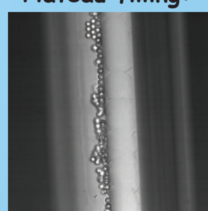
Experimental working ranges:



AFM of SS sputtered film:



Plateau filling:



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