Two-phase microfluidic systems for bioanalitical applications

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Motivation

Cheap, easy to use microfluidic device available to anyone e.g.

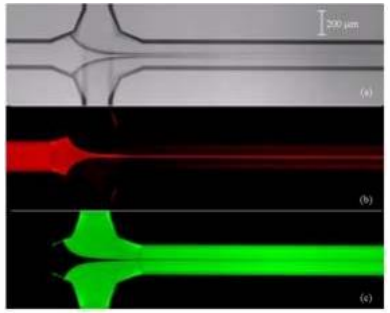
- to investigate the physiological response of cell populations / individual cells exposed to a chemical agent
- for cell analysis and sorting
- to control biochemical reactions

Objective of the semester

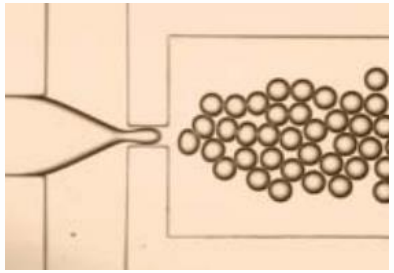
- Literature search for recent studies and applications
- Manufacturing microfluidic systems using micromechanical technologies
- Modify a previous system design to enhance droplet formation stability and trapping efficiency

Introduction

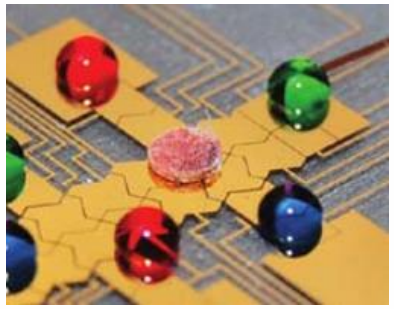
The specific types of microfluidics



Continuous



Two (or more) phase



Digital

Source: https://biomems.hu/sites/www.biomems.hu/files/BME_ETT_BIOMEMS_mikrofluidika_2017.pdf

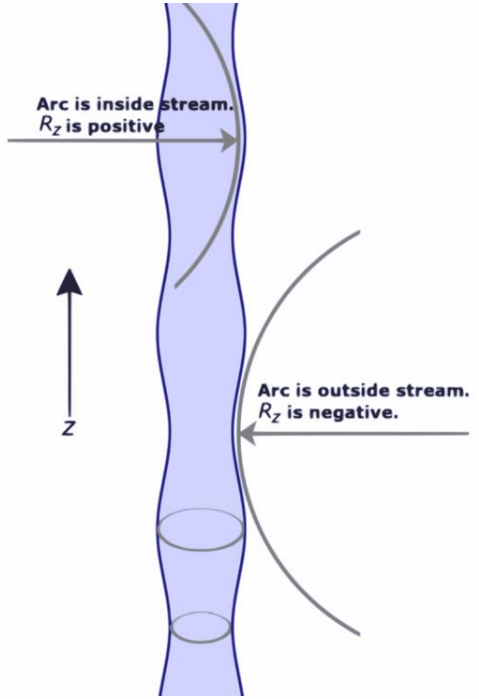
Laplace pressure

$$\Delta P = P_b - P_k = \gamma\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Reynolds number

$$Re = \frac{\rho v a}{\mu}$$

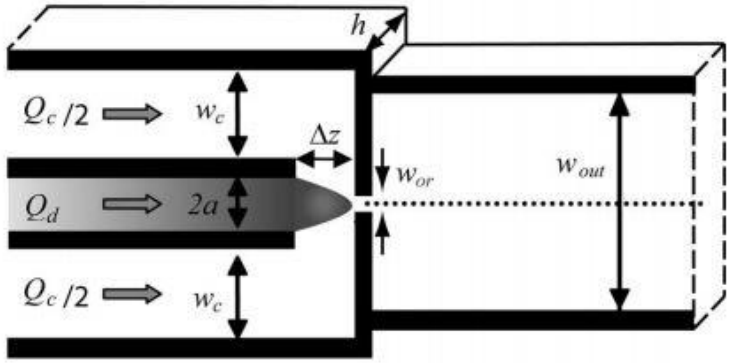
Plateau-Rayleigh instability



Source: S. L. Anna, H. C. Mayer, Physics of Fluids, 2006

Introduction

Capillary number and its effect on droplet size



Source: W. Lee, L. M. Walker, Physics of Fluids, 2009

$$Ca = \frac{\mu_c a \Delta U}{\gamma \Delta z} = \frac{\mu_c Q_c a}{\sigma h \Delta z}\left(\frac{1}{w_{or}} - \frac{1}{2w_c}\right)$$

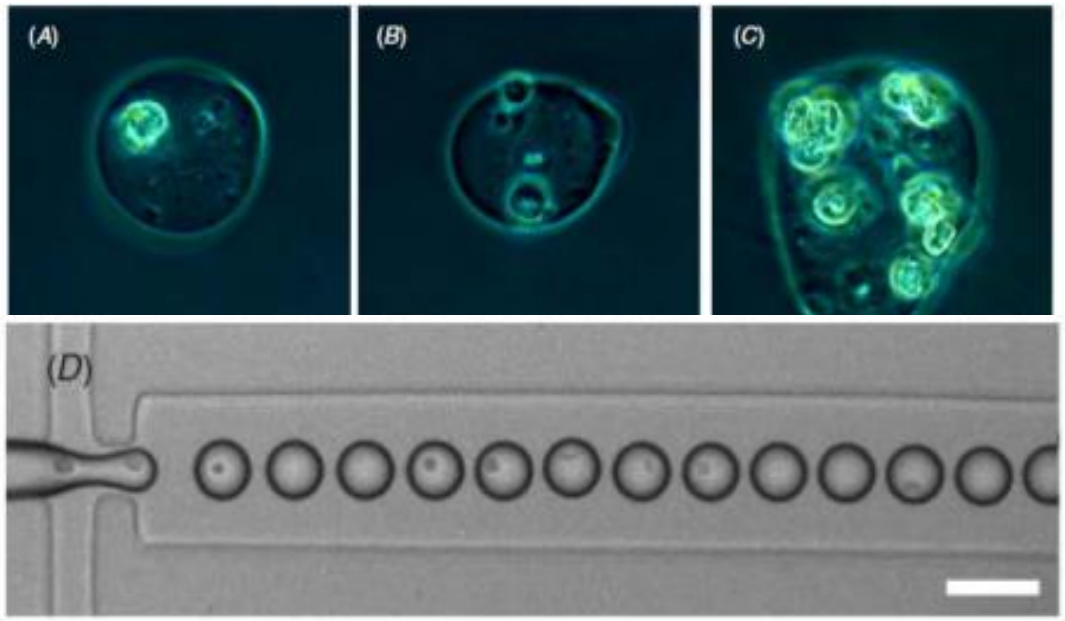
Changing the Capillary number

Dedicated droplet size

Source: https://biomems.hu/sites/www.biomems.hu/files/BME_ETT_BIOMEMS_mikrofluidika_2017.pdf

Application of droplet based microfluidics

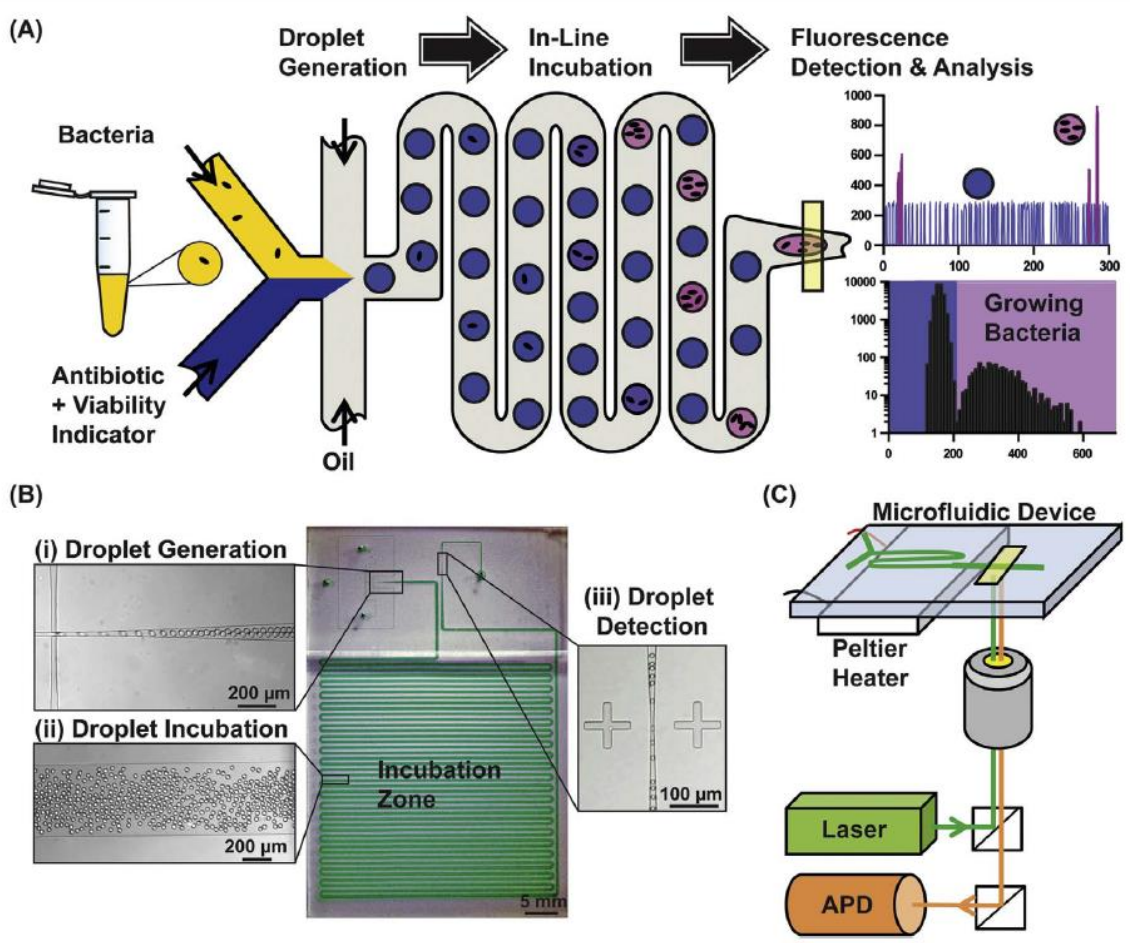
- Bioelectric scattering (BES)
- Individual study of cancer cells
- Examination of a unique chemical environment
- **Fluorescence-based cell separation**



Source: J. Hong, A. J. deMello, IOP Science, 2010

Recent studies

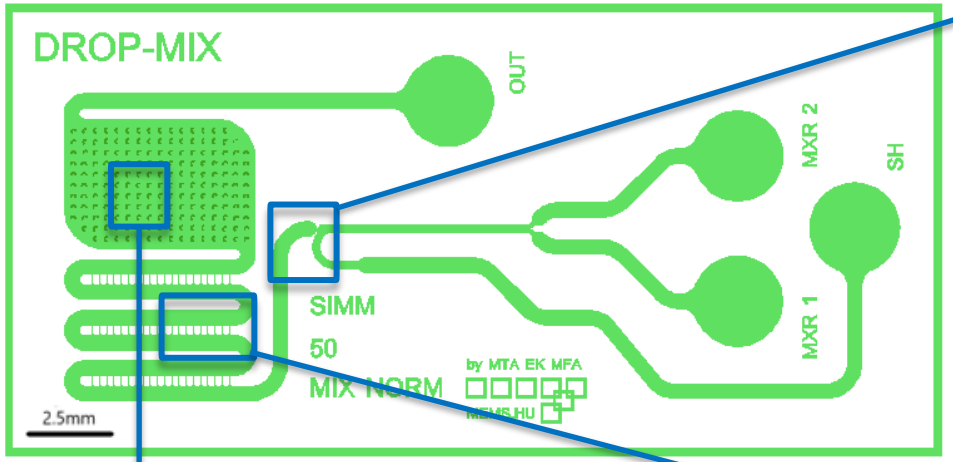
Accelerating bacterial growth detection and antimicrobial susceptibility assessment in integrated picoliter droplet platform

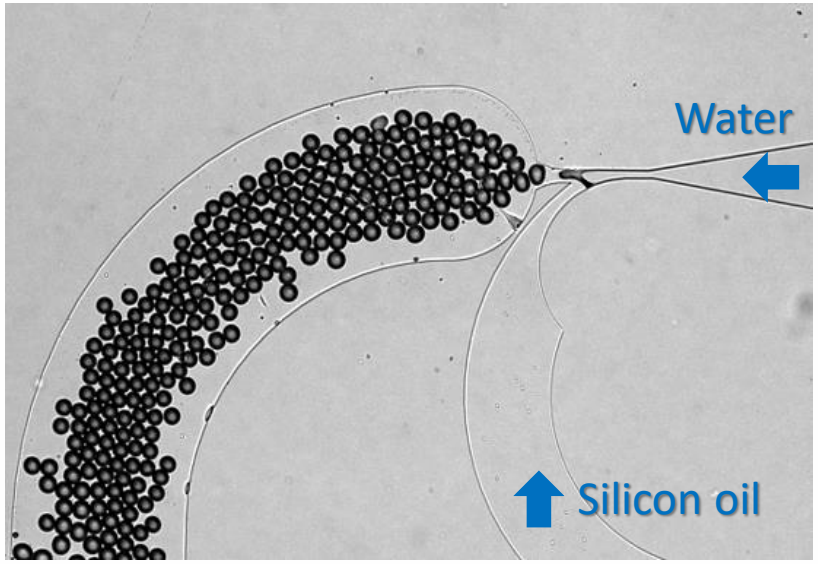


Source: A. M. Kaushik, K. Hsieh, Biosensors and Bioelectronics, 2017

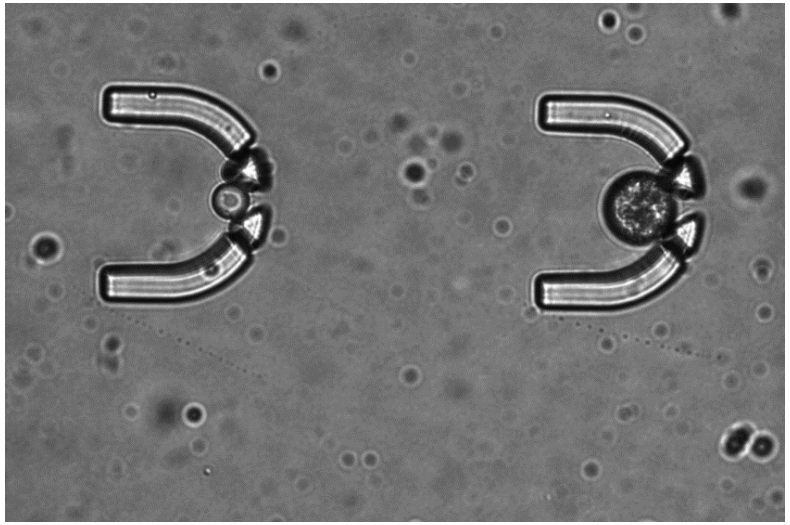
Two-phase microfluidic chip - Overwiev

The fabricated structure in CleWin

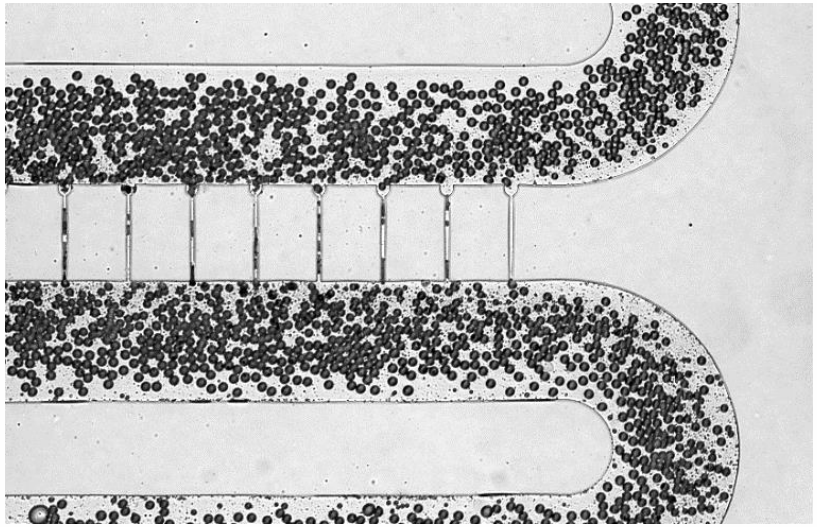




Droplet formation region



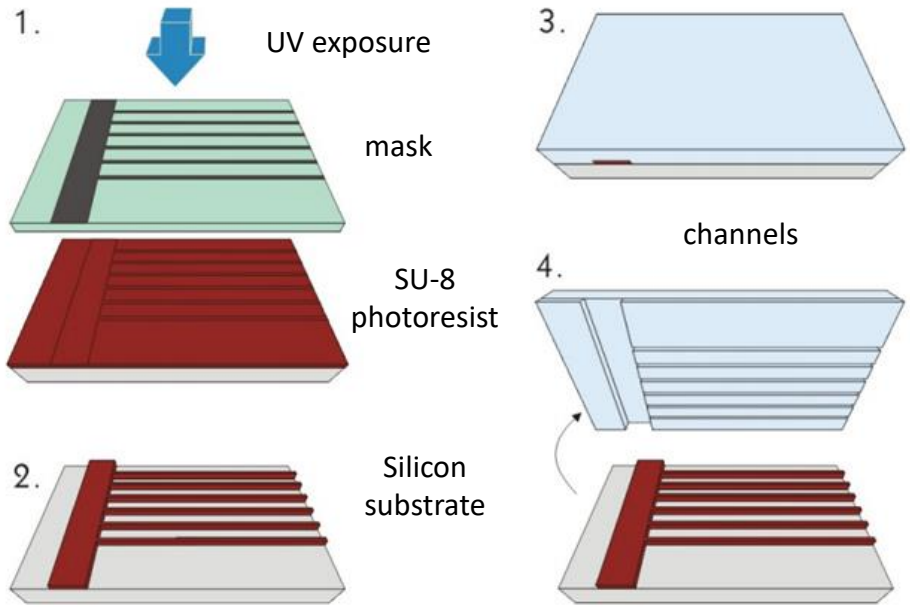
Trapping region



Winding channel region

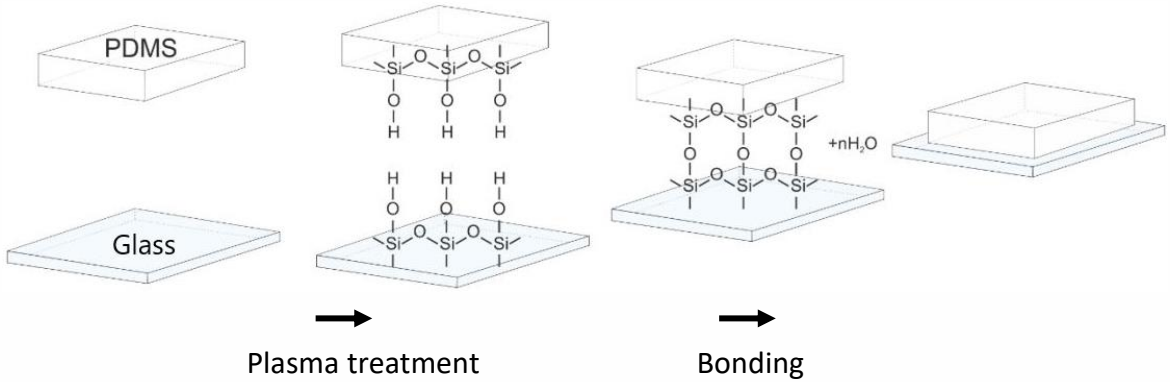
Creation of the microfluidic device - Methodology

Technological steps of soft lithography

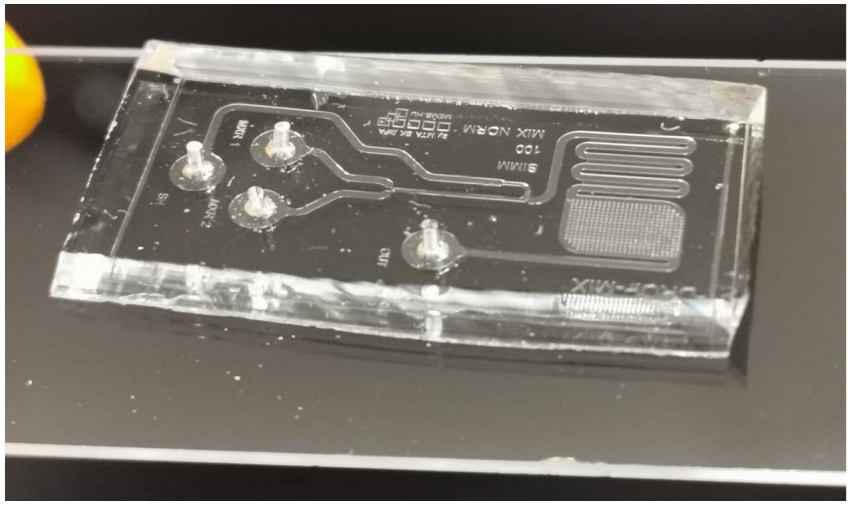


Source: http://www.biomems.hu/files/BME_ETT_BIOMEMS_mikrofluidika_2017.pdf

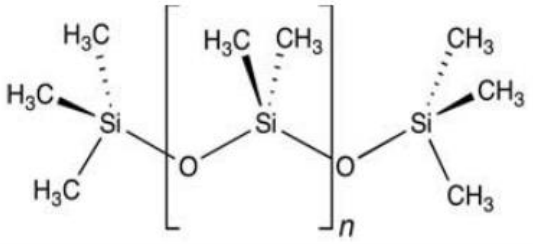
Polydimethylsiloxane bonding with glass



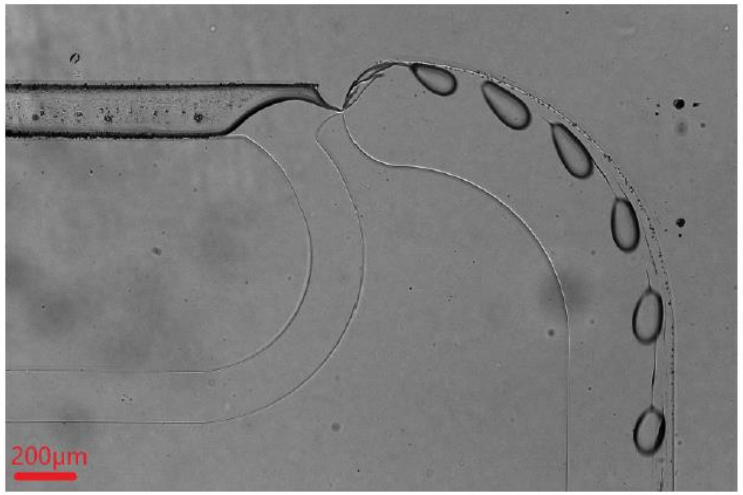
A fabricated microfluidic chip



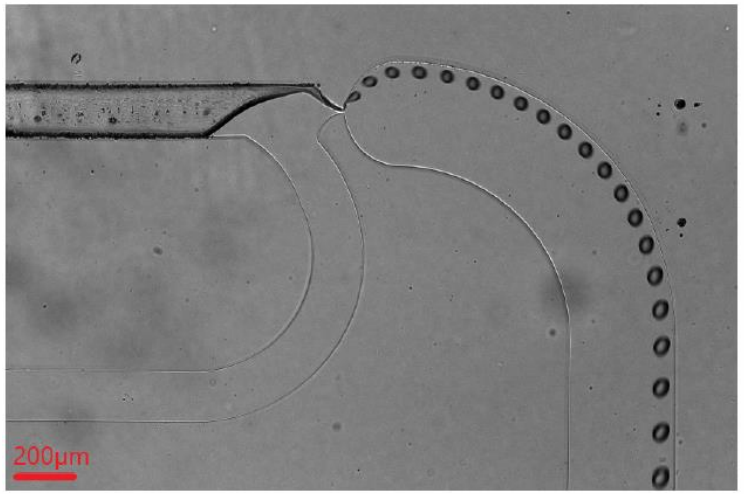
Structure of PDMS



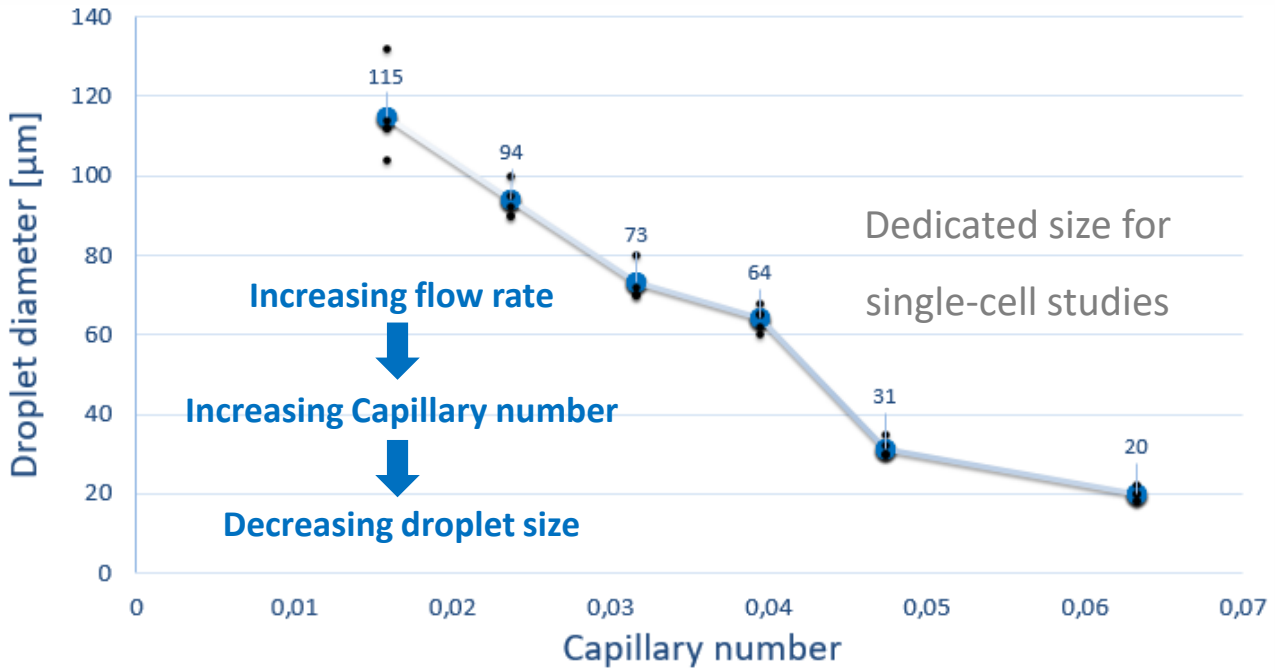
Droplet generation in the microfluidic device - Results



Oil 0.7 [µl/s], Water 0.5 [µl/s]



Oil 0.7 [µl/s], Water 0.3 [µl/s]



Future plans

- Creating a compact, intergrated optical platform (IR) for in-situ measurement of droplet size and generation frequency (and content analysis - fluorescent)
- Investigate droplet generation, mixing and trapping phenomena using Finite Element Method (COMSOL Multiphysics)
- **Publication:** Modelling and analyzing of fluid dynamic phenomena in two-phase microfluidic system

Publications in the past

- P. Hermann, Zs. Szomor, O. Hakkel, Z. Hajnal, P. Fürjes, ***Effects of hydrodynamic parameters of droplet formation in two-phase microfluidic structures***, Lab on-a-Chip Europe Conference, Rotterdam, The Netherlands, 2019 – Poster
- Zs. Szomor, E. L. Tóth, P. Fürjes, ***Comprehensive analysis of mixing processes within microdroplets***, International Meeting in Chemical Sensors Conference, Mátrafüred, Hungary, 2022 – Poster
- Zs. Szomor, J. M. Bozorádi, B. Beiler, Z. Szabó, P. Fürjes, ***In-situ optical characterization of droplet generation in two-phase microfluidic system***, International Conference on Micro and Nano Engineering - Eurosensors, Leuven, Belgium, 2022 – Poster

Upcoming conferences

- Zs. Szomor, L. Bató, S. Stágl, O. Hakkel, A. Sulyok, Cs. Dücső, Zs. Baji, P. Fürjes, ***Non-Stoichiometric Titanium-Oxide Gate Electrodes for EGFET Based pH Sensors***, Micro and Nano Engineering Conference – MNE Eurosensors, Lecce, Italy, 2023 – Poster
- Zs. Szomor, E. L. Tóth, P. Fürjes, ***3D Finite Element Modelling of heat transfer in continuous flow two-phase droplet microfluidic systems using on-chip thermal control***, Therminic 29th international workshop, Budapest, Hungary, 2023 – Poster
- Zs. Szomor, E. L. Tóth, P. Fürjes, ***Finite element modelling and analysis of fluid dynamic phenomena in two-phase droplet based microfluidic systems***, Hungarian Biophysical Society 29th National Meeting, Budapest, Hungary, 2023 – Poster

Courses completed

- BioMEMS: Miniature Biosensors (Zoltán Fekete)
- Selected chapters of material testing methods I.: FTIR, HPLC/MS (Erzsébet Takács), SEM, STM, AFM (Judit Telegdi)
- Nanotechnology – chemical materials science (Éva Kiss)

Thank you for your attention!