Integrated microfluidics / lab-on-chip systems for point-of-care medical diagnostic applications

Anita Bányai
Supervisor: Dr. Péter Fürjes

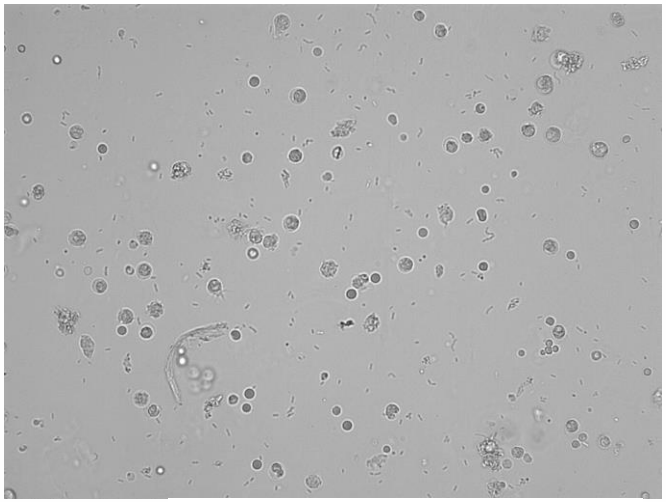
ELKH Centre for Energy Research
Institute of Technical Physics and Materials Science
Microsystems Laboratory

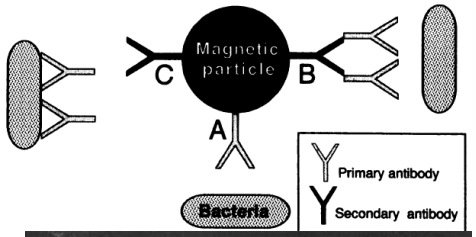
E-mail: banyai.anita@ek-cer.hu

www.ek-cer.hu | www.mems.hu | www.biomems.hu

The aim of my research

- design and development of integrated microfluidic systems for sample transporters to be used in fast and reliable diagnostic tools
- screening bacteria on a targeted microfluidic platform in urine
- study and determine the geometry and material structure of the microfluidic system;
- promoting compatibility with industrial technologies



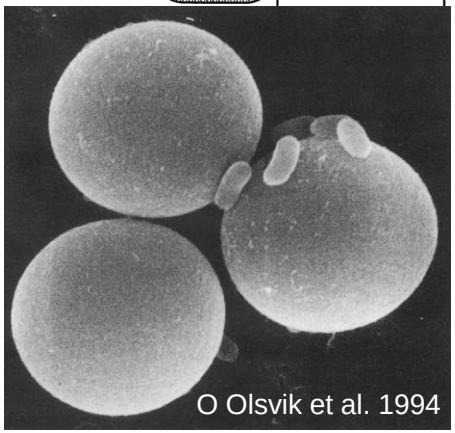


Main tasks of this semester

Until now passive and active separation methods were tested: **Deterministic lateral displacement (DLD)**, **Crossflow filtration (CF)** ,**Lateral focusing (LF)** and **Magnetophoretic separation**.

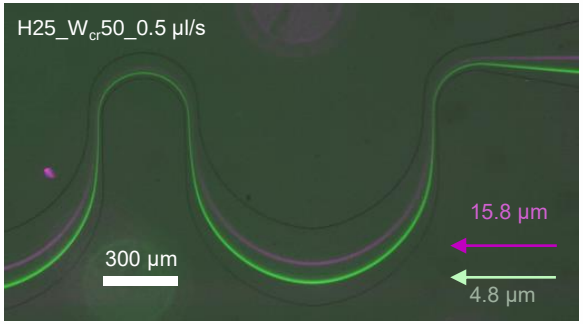
In this semester:

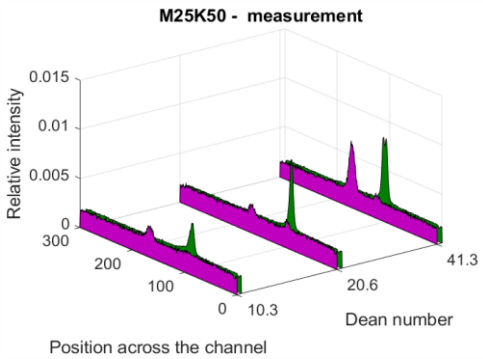
- **Magnetoforetic separation** – in autonomous fluidics
- **Lateral focusing (LF)** – with living cells

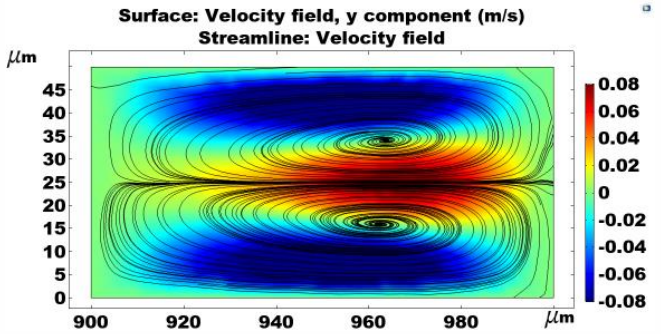


Previous semester – passive separation

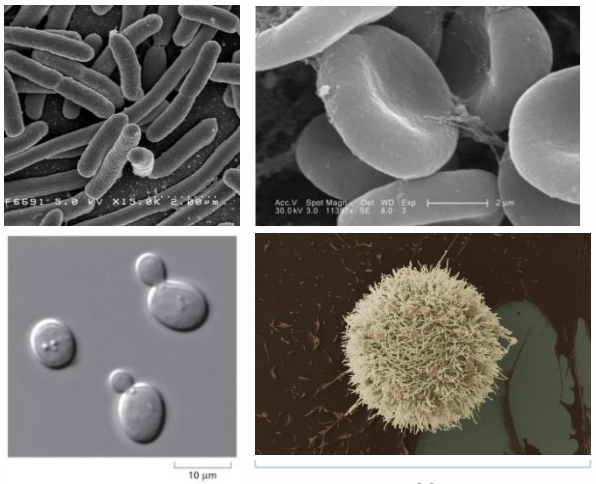
Lateral focusing – Model vs. living cell







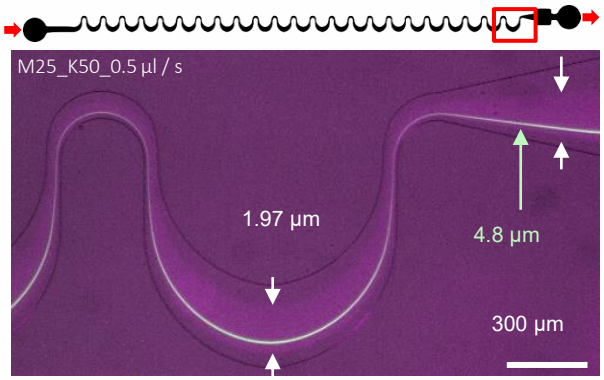
	Used cell	Figure	Size		Size of the Modell beads(Ø)
			Height	Width	
Bacteria	E.coli	rod	0.5 µm	2 µm	0.5 - 1.1 - 1.97 - 2.9 µm
Hematopoietic	Red Blood Cell	donut	2.2 µm	7.2 µm	2.9 - 4.8 - 5.4 - 6.08 µm
Yeast	Saccharomyces cerevisiae	round or oval	5-10 µm		5.4 - 6.08 - 10.2 µm
Cancer cell line	HeLa cell	diverse, inhomogeneous, spherical in suspension	20-40 µm (according to some sources: 17.1 µm)		15.8 - 16.8 µm



https://www.microbiologyinpictures.com/bacteria-photos/escherichia-coli-photos/e.coli-bacteria-sem.html
https://www.nisenet.org/catalog/scientific-image-human-red-blood-cells-sem
B. Alberts, *Essential cell biology*, Fourth edition. New York, NY: Garland Science, 2013
https://wellcomecollection.org/works/a3q9b4tb

Lateral focusing – Challenges

A.



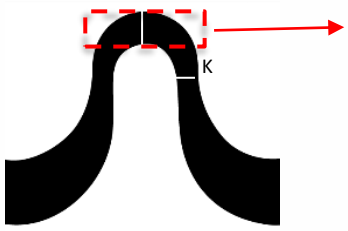
B.

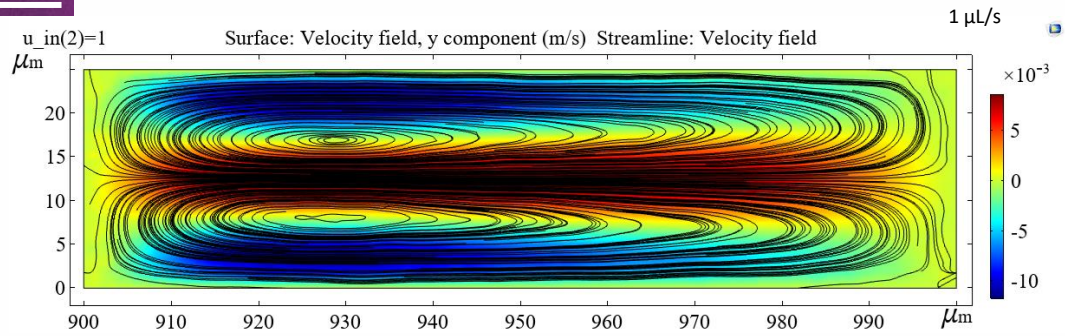
a/Dh > 0.07

Dino Di Carlo et.al.

Height (H) µm	Critical width (W_{cr}) µm	Dh	a/Dh 4.8/Dh	1.97/Dh	1/Dh	0.5/Dh
25	50	33,3	0,14	0,06	0,03	0,02
20	50	28,6	0,17	0,07	0,04	0,02
15	50	23,1	0,21	0,09	0,04	0,02

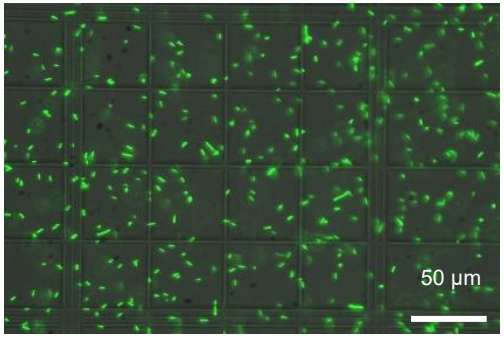
C.



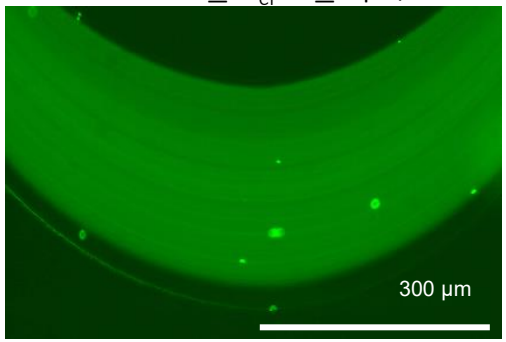


D.

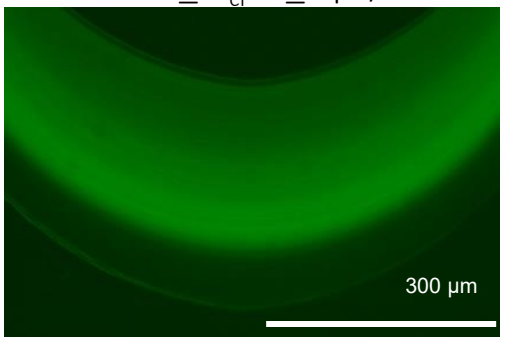
GFP-E.coli



H25_W_{cr}50_1 µl / s



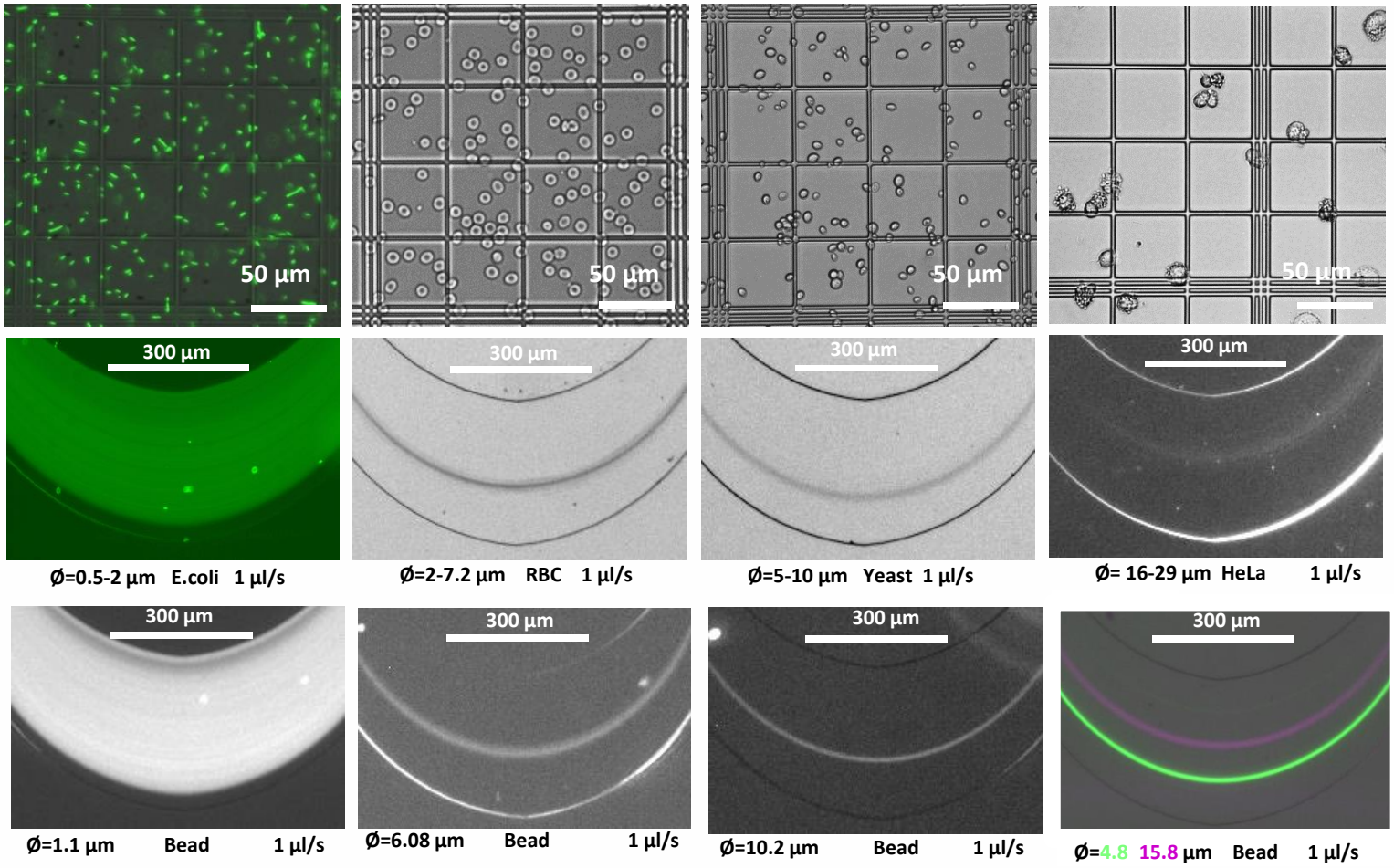
H15_W_{cr}50_1 µl / s



Lateral focusing – Model vs. living cells

Living cell

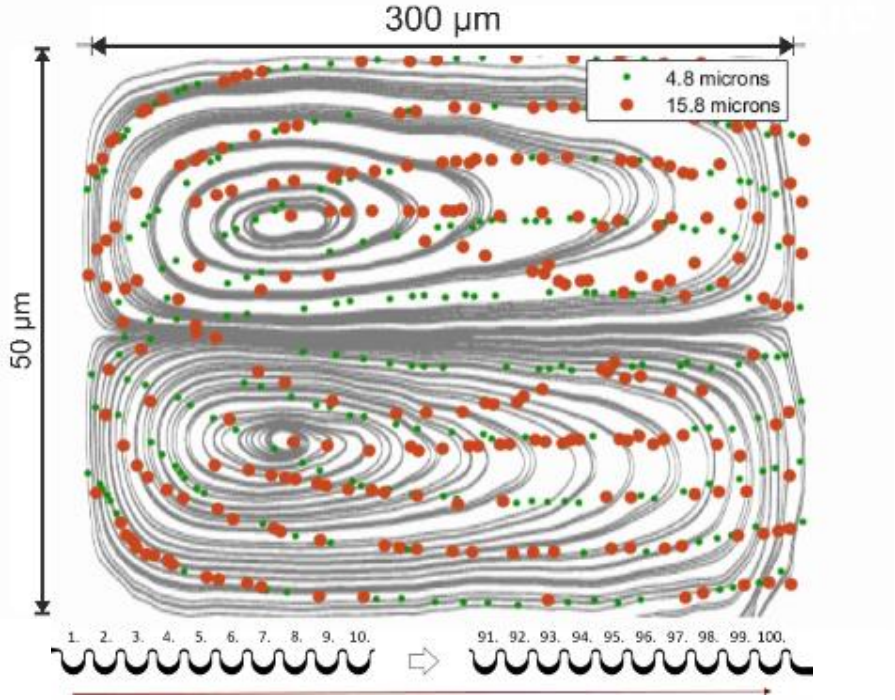
GFP - E.coli | RBC | Yeast | HeLa cell

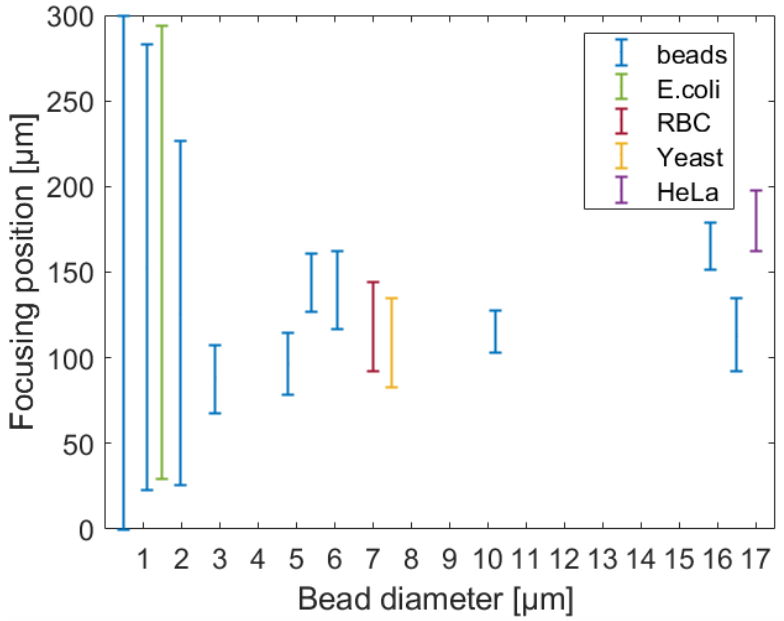


Bead models equivalent to the lateral position of the selected living cells

Lateral focusing – Model vs. living cells

3μL/s





1. Bányai, Anita ; Farkas, Enikő ; Jankovics, Hajnalka ; Székács, Inna ; Tóth, Eszter L. ; Vonderviszt, Ferenc ; Horváth, Róbert ; Varga, Máté ; Fürjes, Péter
Dean-Flow Affected Lateral Focusing and Separation of Particles and Cells in Periodically Inhomogeneous Microfluidic Channels ; SENSORS 23 : 2 Paper: 800 , 19 p. (2023)

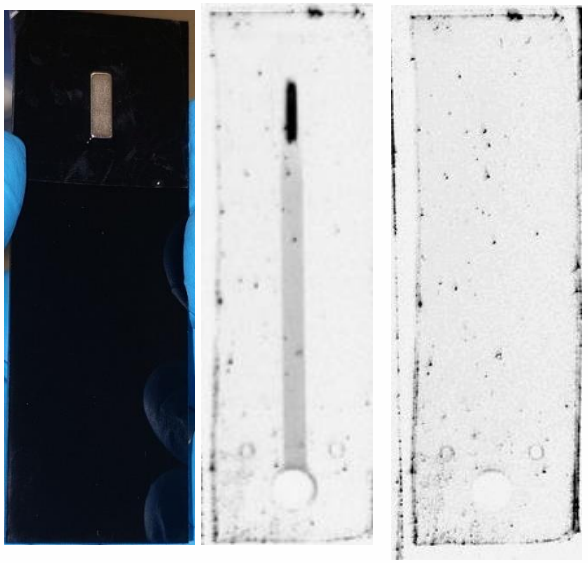
2. Bányai, Anita ✉ ; Tóth, Eszter Leelőssyné ; Varga, Máté ; Fürjes, Péter
Geometry-Dependent Efficiency of Dean-Flow Affected Lateral Particle Focusing and Separation in Periodically Inhomogeneous Microfluidic Channels ;SENSORS 22 : 9 Paper: 3474 , 13 p. (2022)

Active separation, IVD

- Continuing **work at 77 Elektronika Kft.** in the frame of Cooperative doctoral program: Lab-on-a Chip device development for in-vitro diagnostics (IVD) device.

- Studies in autonomous fluidics
  - magnetophoretic separation
  - aiming uniform distribution of magnetic beads between the 3 sensor spots
  - investigating biological bond between the selected bacterial strains and surface-treated magnetic beads
  - investigating the adhesion of selected bacteria strain (10^7 - 10^4 cells/ml) on the sensor spots without the use of magnetic beads,

100x_0.9um
Full charge of fluifics: 7 min

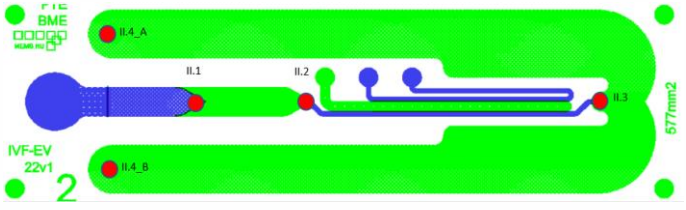


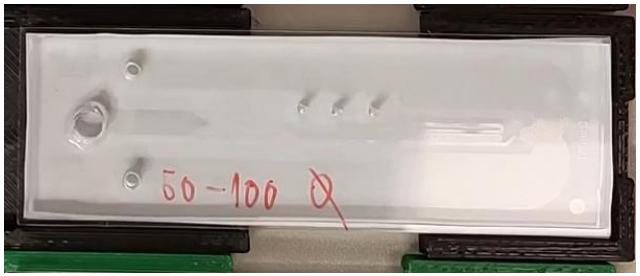
Bottom side | Sample | Sample + Washing step

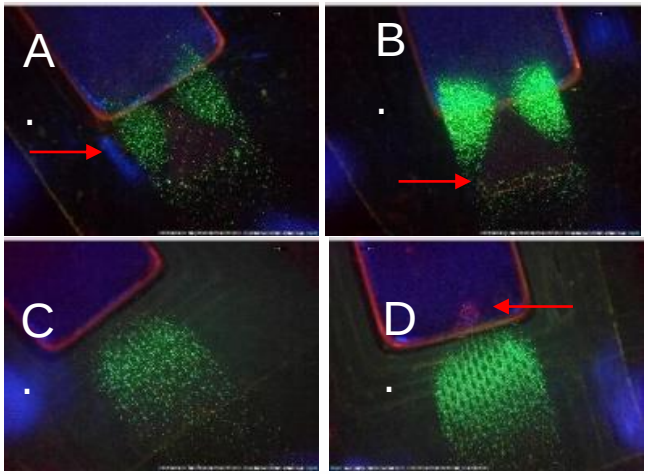
Cooperation with University of Pécs

Magnetic trapping efficiency (flow rate dependence)

ChemiDoc







Idő *perc*	MµP csapdázása	Idő *perc*	Mosás
0	Áramlás	11	
1		12	
2		13	
3		14	
4		15	
5		16	
6		17	
7		18	
8		19	
9		20	
10		21	

Summary

- Lateral focusing of biological samples (RBC, E.Coli, yeast, HeLa cells) were characterised and compared to behaviour of rigid beads
- Magnetic separation was investigated by using autonomous microfluidics design to ensure segregated trapping of magnetic beads at the sensor zone

(1) Executing measurements with functionalised magnetic beads

(2) Testing different designs for proper filling of specific volume, and magnetic trapping

(3) Surface treatment, and trapping different bacteria strains on the microfluidic surface

Plans

- Continue cooperation with 77 Elektronika Ltd. and University of Pécs in microfluidics development
- Give in the manuscript for Deterministic Lateral Dispalcement (DLD)
- Finalising dissertation

Publications submitted this semester

Conferences & Posters

- Mátrafüred – International Meeting on Chemical Sensors 2022, Visegrád
  Filtration efficiencies of crossflow type microfilters for E.Coli separationr
  Anita Bányai[1,2,3] , Máté Varga[3], Péter Fürjes[1]
- SelectBio, Lab-on-a-Chip and Microfluidics Europe 2022, Rotterdam 2022
  Effect of channel morphology on magnetic separtation in microfluidic particle trapping
  Anita Bányai[1,2,3], Eszter Leelőssyné Tóth[1], Péter Fürjes[1]
- AMETIS 2022, Taglio, Corse, France (study course in materials science)
  Shape design dependent performance of DLD (deterministic lateral displacement) based particle separation systems - FEM modelling and validation
  Anita Bányai[1,2], Petra Hermann[1], Orsolya Hakkel[1], Eszter Leelőssyné Tóth [1], Péter Fürjes[1]

Published

[1]Dean-Flow Affected Lateral Focusing and Separation of Particles and Cells in Periodically Inhomogeneous Microfluidic Channels
Bányai, Anita[1,2,3,*] ; Farkas, Enikő [1]; Jankovics, Hajnalka [4]; Székács, Inna [1]; Tóth, Eszter L. [1]; Vondervisztt, Ferenc [4] ; Horváth, Róbert [1]; Varga, Máté [2]; Fürjes, Péter[1]

Sensors 2023, 23(2), 800; https://doi.org/10.3390/s23020800

Under evaluation – Hungarian Article

[2]Áramlástani jelenségek mikroszkopikus mérettartományban – mikrofluidikai rendszerek és alkalmazásaik
Bányai Anita [1,2,3]; Bató Lilia[1,2]; Leelőssyné Tóth Eszter[1]; Varga Máté[3], Fürjes Péter[1],*

Fizikai Szemle – Magyar Fizikai Folyóirat