Universität Bremen*
*EXCELLENT.

MIMENIMA
Graduiertenkolleg

Investigation of Dielectrophoretic Effects in Porous Structures

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Research student: Simon Kunze, Tristan Oltmanns

Aim and Approach - 1. Generation

Development of a dielectrophoretic filtration setup

- Filter between two electrodes and polarized due to electric field
- High field regions (sharp tips in structure) electrokinetically attract particles

How to design filter for maximized electrical effect?

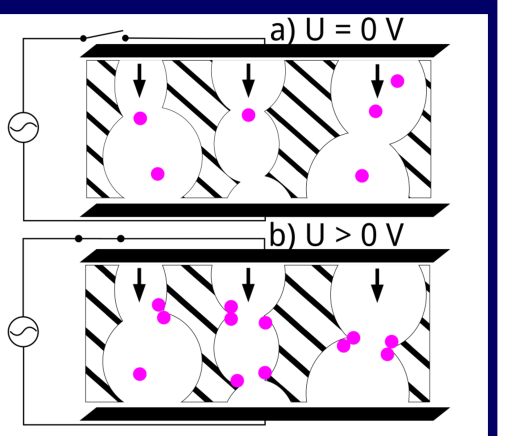
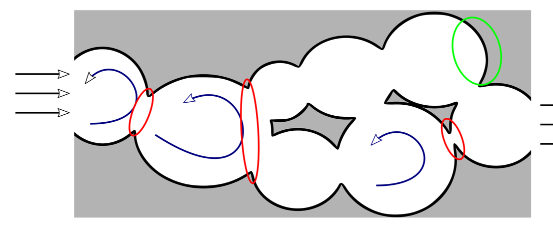


Fig. 1: DEP trapping effect in a porous filter between electrodes.

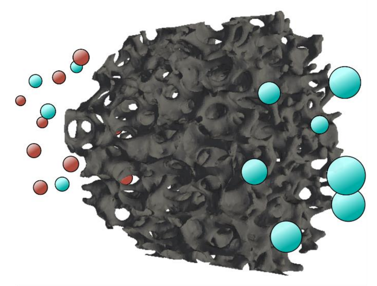
Aim and Approach - 2. Generation

Investigation of DEP particle separation in ceramic foams and µ-channels of representative 2D porous structures.



Influence of
- pore window sizes
- pockets (dead zones)
- vortices

on particle trapping



Investigation of the possibilities of size- and material-selective particle trapping in ceramic filters.

Fig. 2: Exemplary effects occurring in porous media.

Materials and Methods

1. Abstract filter model

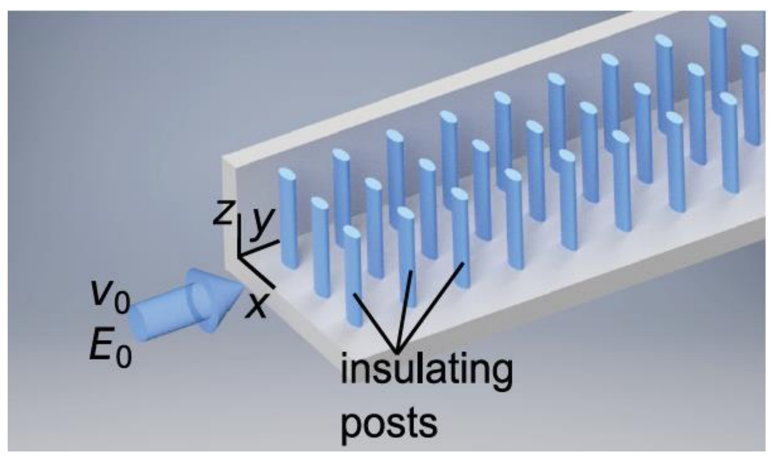
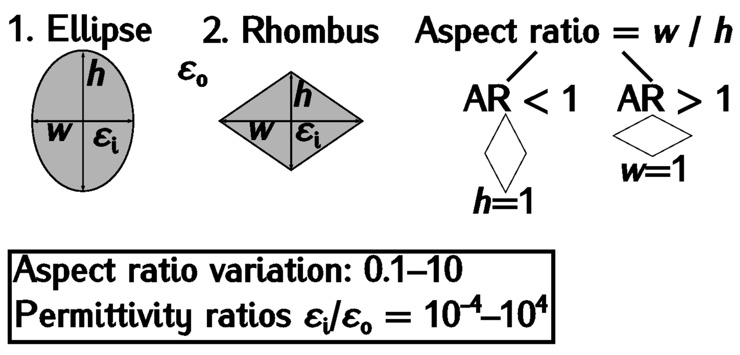


Fig. 3: DEP filter channel with ellipsoid posts.

Simulation: Different post geometries and materials. Finite Element Method (FEniCS)



2. Particle trapping

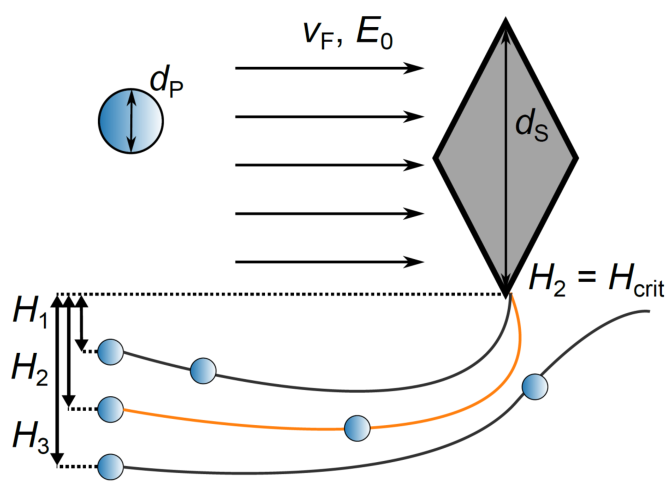


Fig. 4: Particle trajectories around a single post.

Simulation of particle trajectories around single posts.

3. Microfluidic flow channel

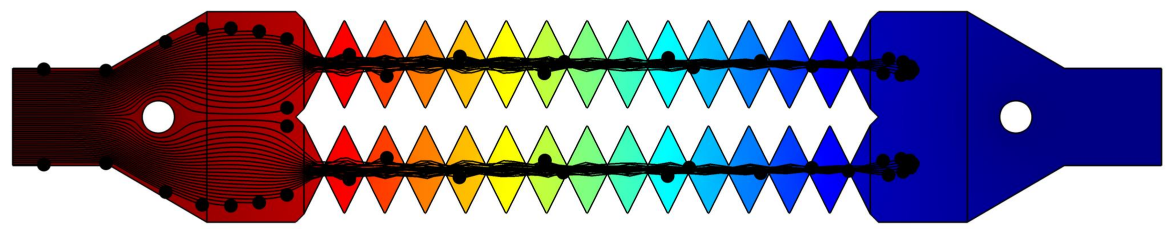


Fig 5: DEP µ-channel design.

Simulation and experiment of particle separation in microfluidic flow channels.

- Simulation: COMSOL Multiphysics
- Experiments: PS Particles in PDMS micro channels

How is the electric field and the post polarization influenced by the post geometry?

How do operational and design parameters (system size, volume flow, particle size) influence the particle retention at single posts (2) and in real flow channels (3)?

Results and Discussion

1. Abstract filter model

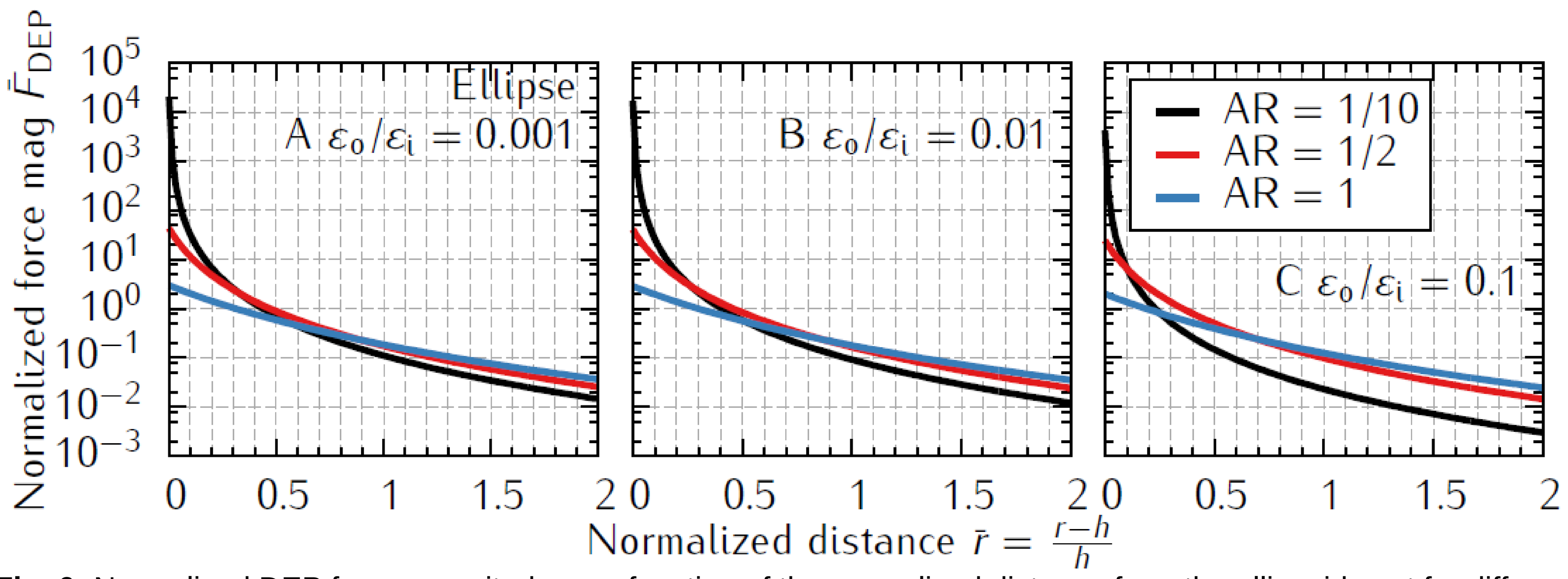


Fig. 6: Normalized DEP force magnitude as a function of the normalized distance from the ellipsoid post for different aspect ratios (AR) and varying polarization differences between medium and post $\varepsilon_o/\varepsilon_i$.

- Increasing sharpness of tip (AR↓): Increasing force close to tip, lower force far away from tip.
- Force increases with increasing polarization difference between medium and post ($\varepsilon_o/\varepsilon_i$↓).

2. Particle trapping

- Rules for designing a separation process using electric field obstacles:
- Designing a separation process (particle size d_P and trapping efficiency H_{crit}/d_S) by balancing throughput (fluid velocity v_F), system size (post diameter d_S) and applied field strength (E_0).

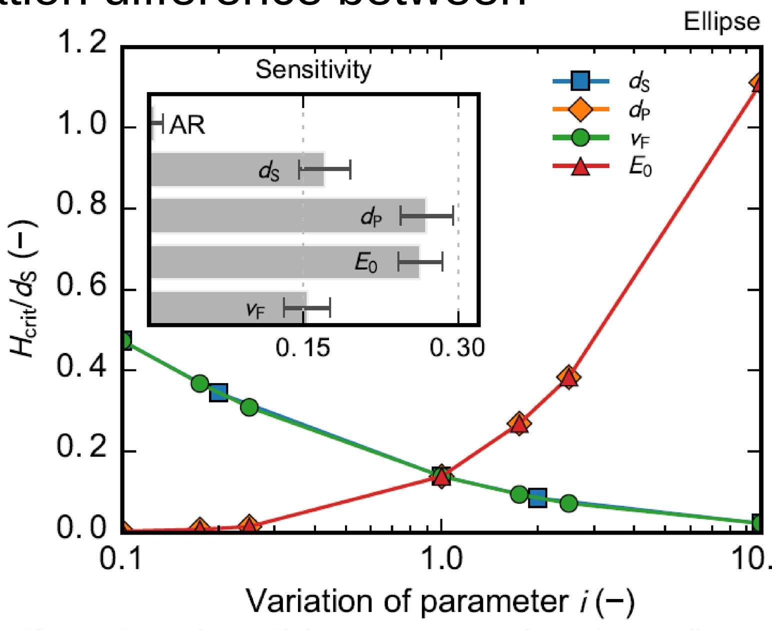
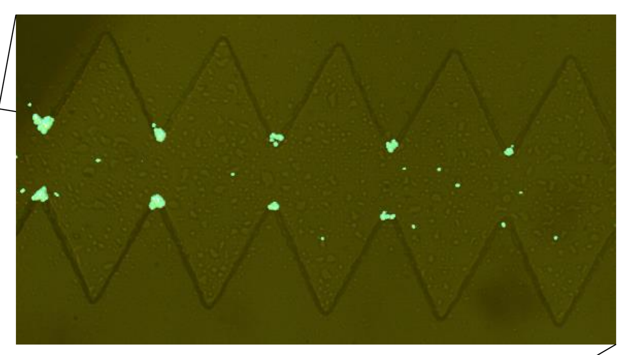


Fig. 6: Trapping efficiency as a function of post diameter, particle diameter, fluid velocity and applied el. field strength.

3. Microfluidic flow channels

„Trapped" fluorescent 5µm PS particles
200 V_{eff} mm^{-1}, 30 kHz



Comparison between simulaton and experiment

Experiment: Counting particles at the inlet and outlet of the separator.

Fig. 7: Fluorescence microscopy image of a sawtooth µ-channel.

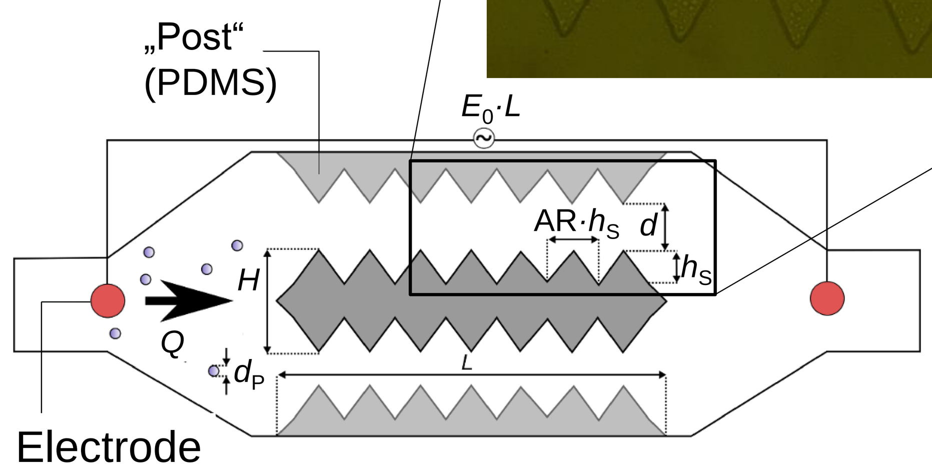


Fig. 8: Sketch of a sawtooth µ-channel.

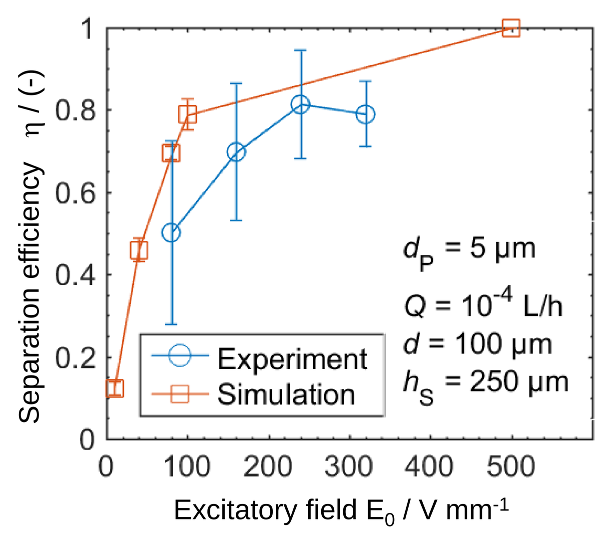


Fig. 9: Separation efficiency as a function of the excitatory field strength.

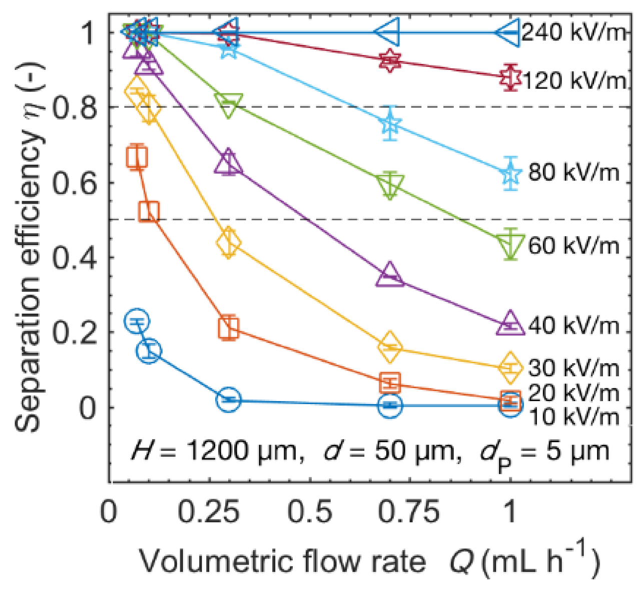


Fig. 10: Separation efficiency as a function of the volumetric flow rate.

Design rules for real separation channels.

Derived by simulations and verified by experimental results.

Conclusion and Outlook

- **Understanding the polarization of electric field obstacles (posts) and designing separation process step by step:**
  From the polarization field of a single post via the particle dynamics around it through to the separation of several particles in a real-life flow channel.
- **Experimental investigation of DEP particle trapping in porous structures to transfer the designing criteria for idealized filter structures onto real filters.**

Collaboration

Pouyan E. Boukany, Product and Process Engineering, TU Delft: Microchannel fabrication and experimentation.
Jorg Thöming and Lars Kiewidt, FP12/01: Simulation methods.
Stefan Odenbach and Thomas Ilzig, FP06/02: µCT-analysis of porous media.
Udo Fritsching and Alexander Schulz, FP10/02: Simulation of multiphase fluid flow through filter using Lattice Boltzmann methods.