Trapping of Single-Cells within 3D Electrokinetic Cages

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INTRODUCTION: Recently our group developed a fabrication process to integrate 3D electrodes in microfluidic channels. These electrodes provide a homogeneous electric field over the complete channel height, which is advantageous for dielectrophoretic applications, since constant force is achieved over the channel height. We are modelling these electrodes in COMSOL® in order to find the best experimental conditions and geometries.

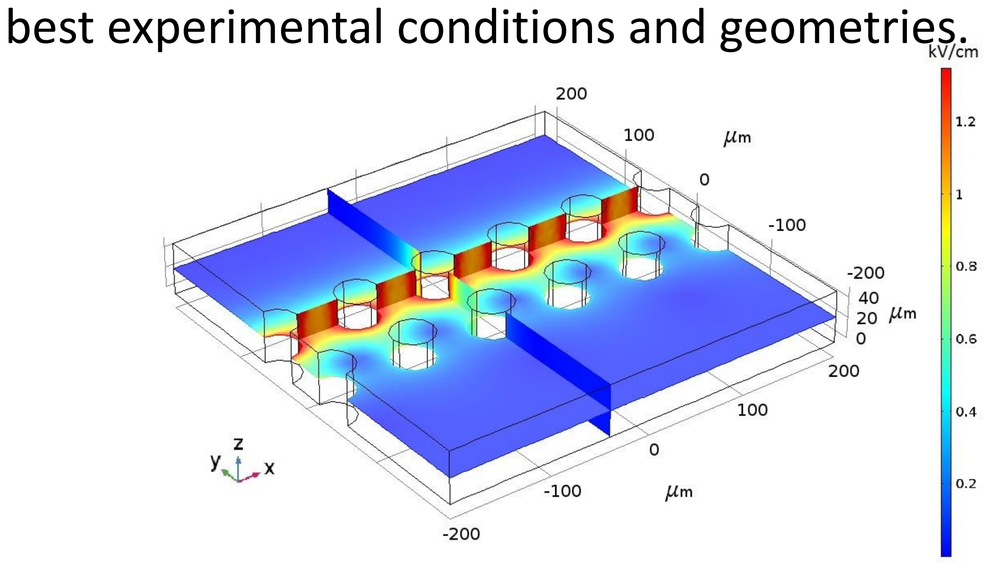

Figure 1. Using 3D electrodes the electric field is homogeneous over the height of a microfluidic channel.

COMPUTATIONAL METHODS: The electric and the laminar flow are modeled for 3D section of a microfluidic channel.

$$\langle \boldsymbol{F}_{DEP} \rangle = \pi \varepsilon_0 \varepsilon_m R^3 Re(CM) \nabla E_{pk}^2 \quad (1)$$

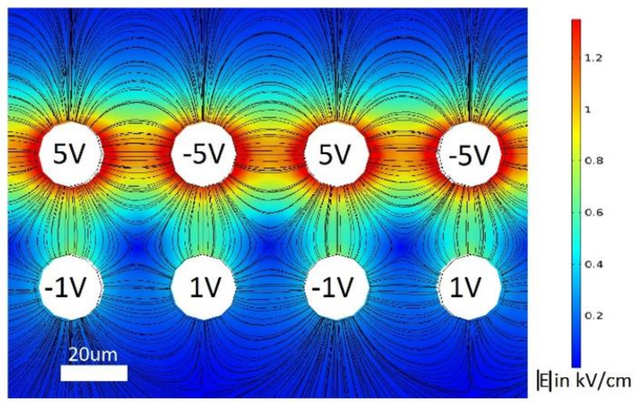

Figure 2. Electric field in the microfluidic channel.

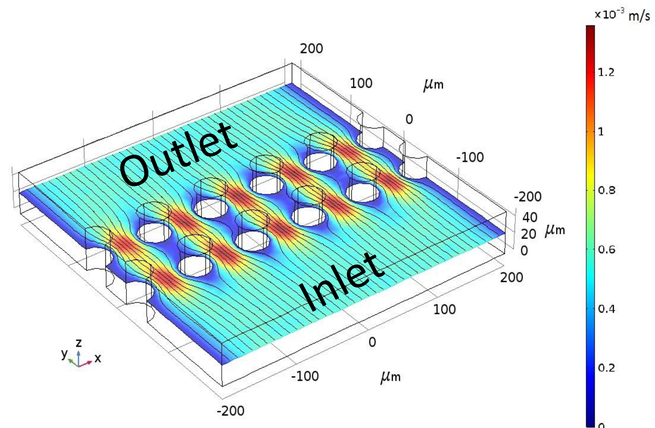

Figure 3. Velocity profile and streamlines of the microfluidic flow.

Based on these results, the dielectrophoretic force (given in Eq. 1) and the fluid drag force, the trajectory of cells in the microfluidic channel is predicted using the Particle Tracing for Fluid Flow interface.

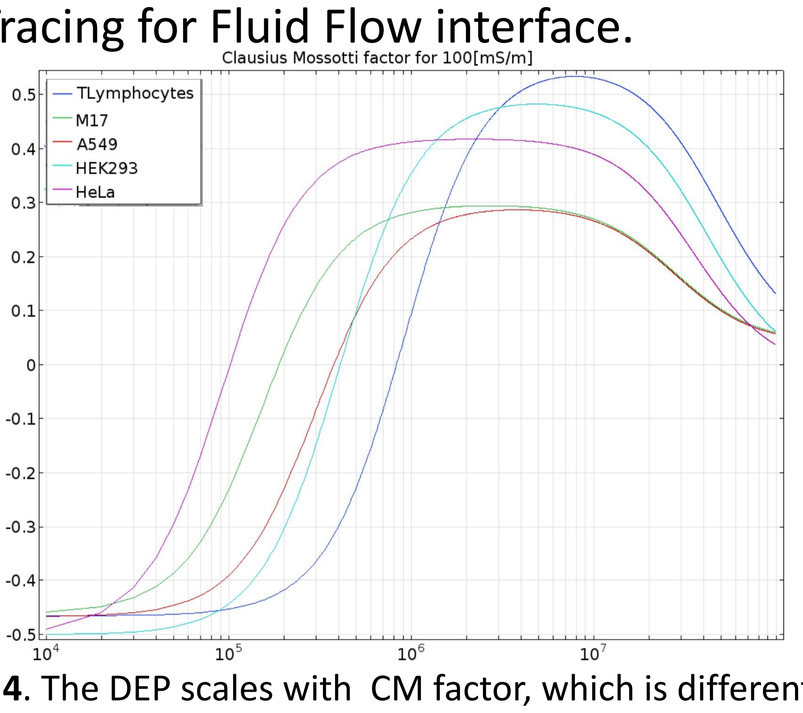

Figure 4. The DEP scales with CM factor, which is different for different cells and medium conductivities.

RESULTS: Depending on the parameters as the frequency of the electric field, the medium conductivity, the pressure, the cell type and the trap size, cells get trapped in an trapping array or not.

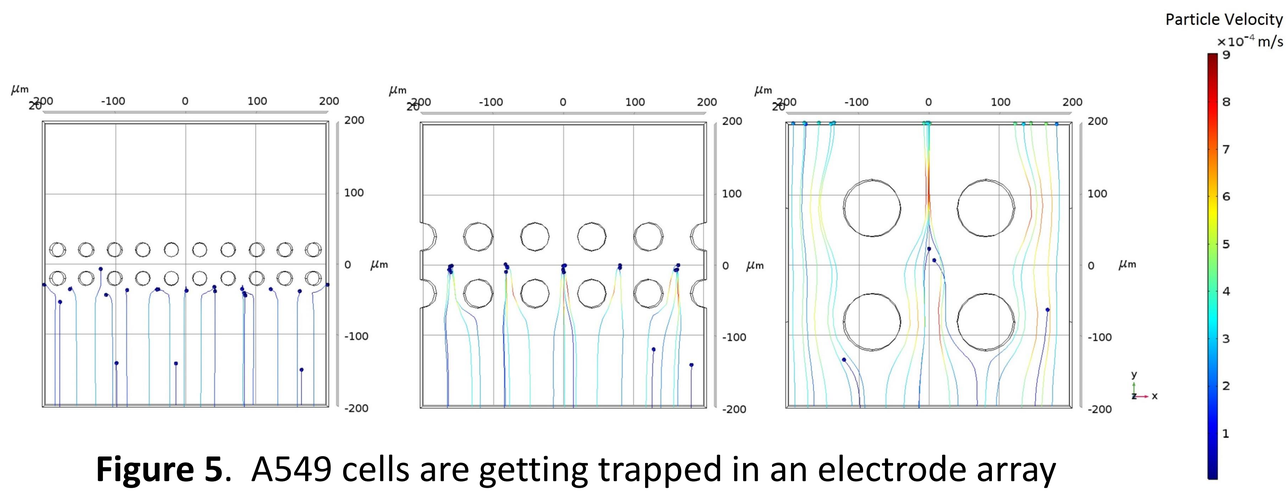

Figure 5. A549 cells are getting trapped in an electrode array depending on the trap size.

At the same trap size and experimental conditions specific cell types show a different trapping behavior.

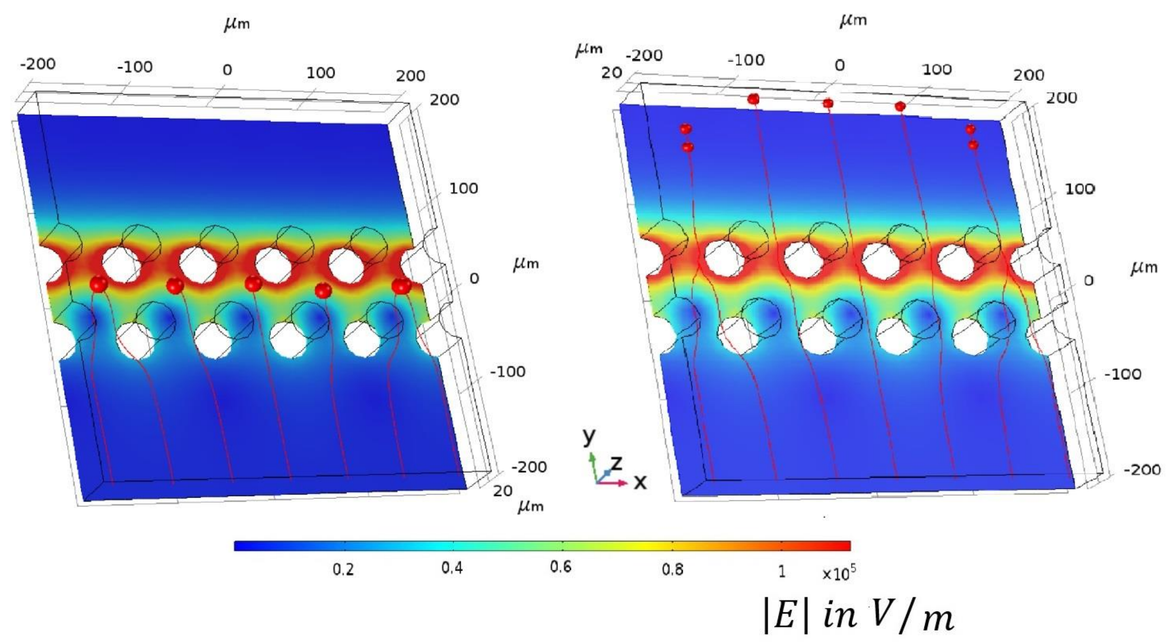

Figure 6. M17 cells (left) getting trapped and T lymphocytes (right) are not getting trapped at the exact same conditions.

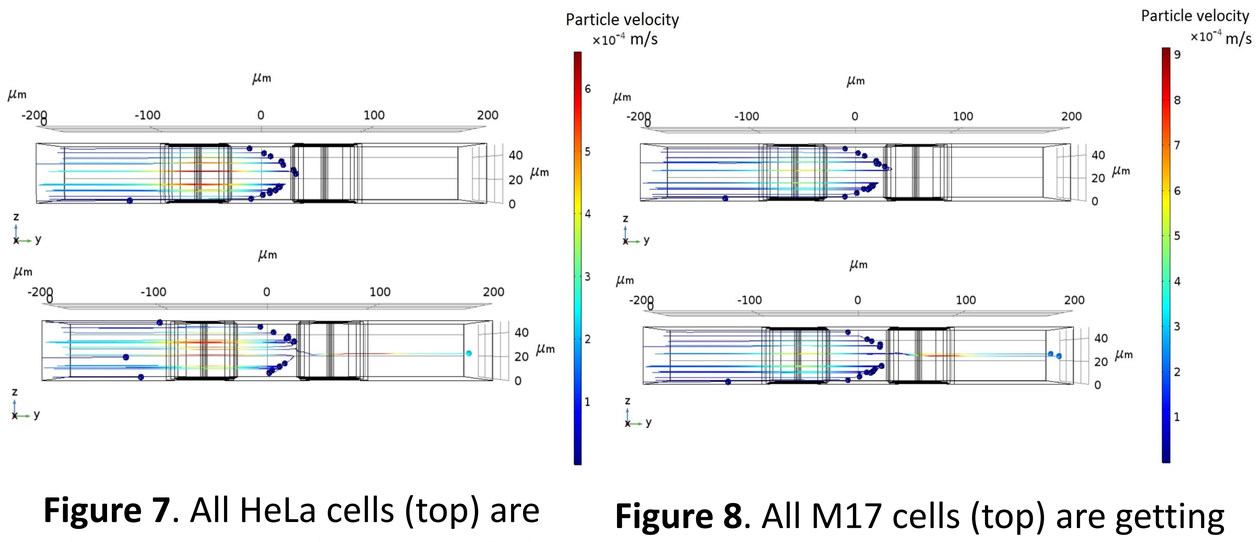

Figure 7. All HeLa cells (top) are getting trapped, while some HEK203 cells (bottom) are getting through the array.

Figure 8. All M17 cells (top) are getting trapped, while some T lymphocytes (bottom) are getting through the array.

CONCLUSIONS: The trajectory of cells in DEP traps can be predicted using COMSOL® simulations. Small changes in the experimental conditions can determine trapping, therefore simulations shall be run before each experiment.

REFERENCES:

1. K. Keim, P. Éry, A. Dellatre, and C. Guiducci, "3D electrode arrays for trapping, analysis and selective release of single cells using," microTAS 2018, Taiwan.
2. This work was finance by the Swiss National Science Foundation (205321_179086).