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Numerical Optimization of two Multi-microelectrode systems for Single-cell Manipulation by Dielectrophoresis

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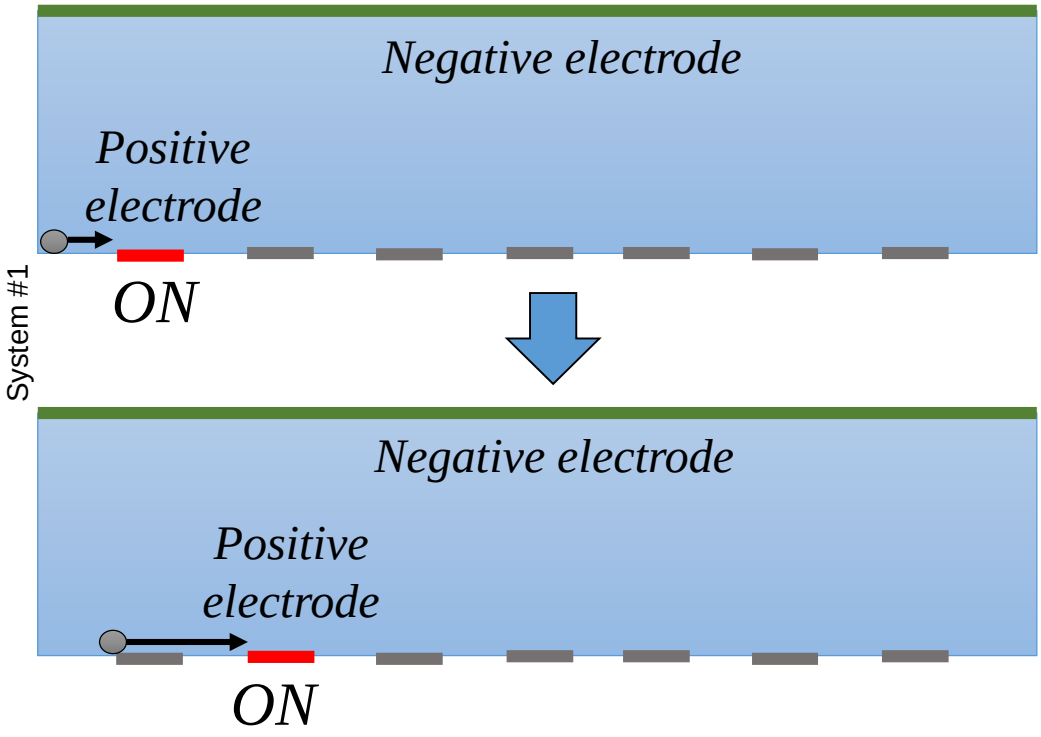
Introduction

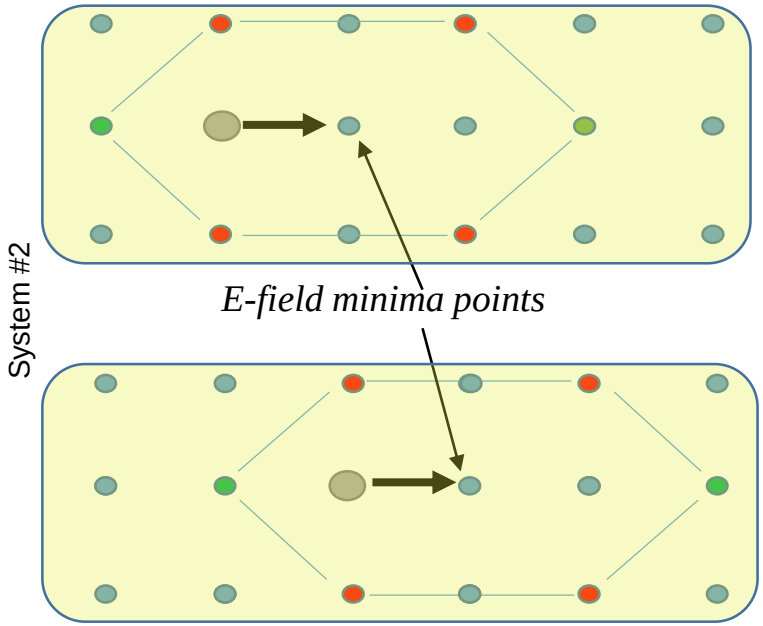
- The ability to control cells' location on a substrate is highly desirable in biomedical applications like tissue engineering, cell-based sensors, or to study single cell interactions.
- Traditional methods such as magnetic or optical tweezers have drawbacks (lengthy pre-treatment[1] and local heating[2], respectively).
- DEP controls cell's location based on electric field intensity distribution and permittivity index (Clausius-Mossotti factor, CM).
- Manufacturing microelectronics for testing is costly → COMSOL numerical simulation.

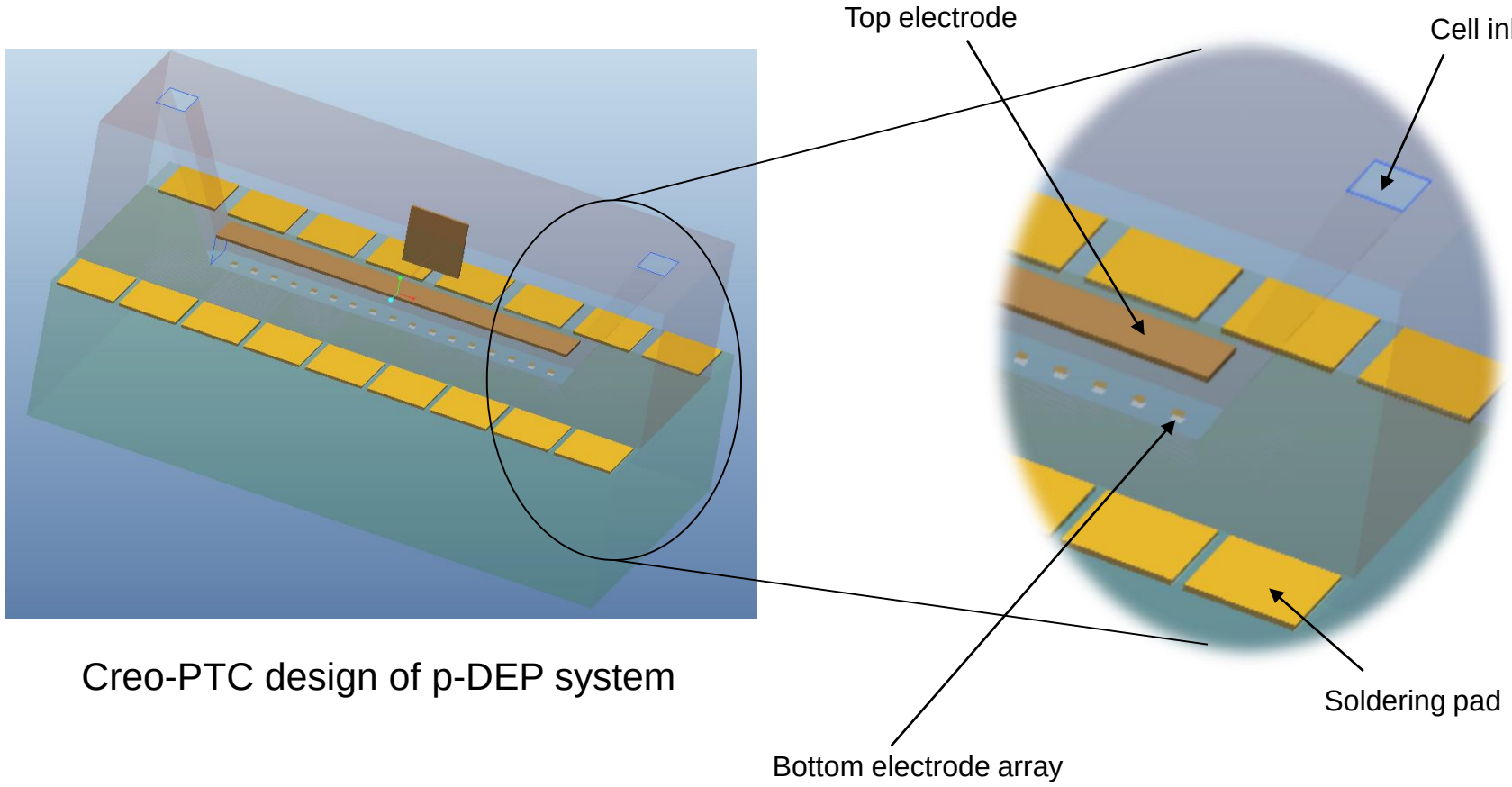
Electrode Configuration Design

p-DEP with DC and AC-DEP



n-DEP with DC

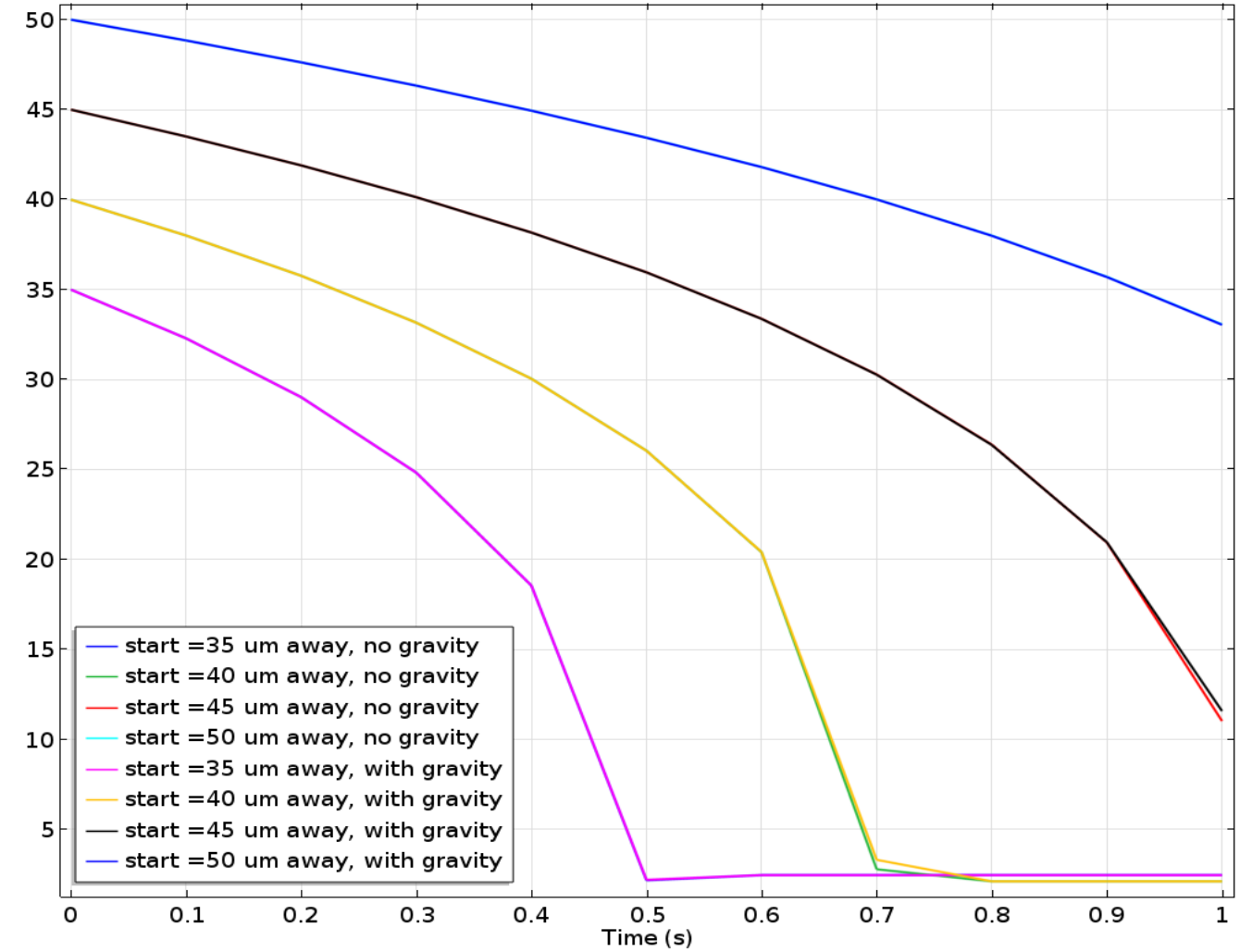




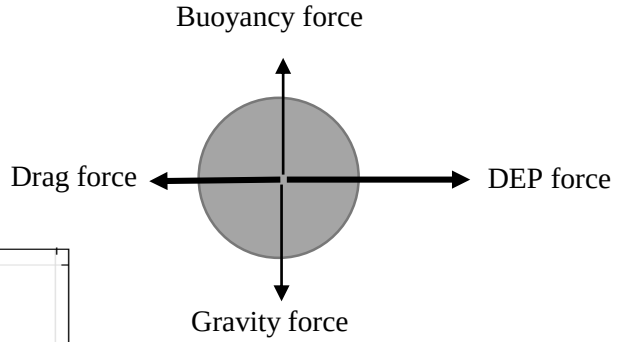
Creo-PTC design of p-DEP system

Results

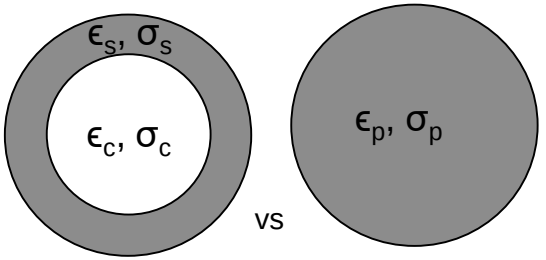
•DC, p-DEP (ϵ_p=125 > ϵ_m=80)



Optimize inter-electrode gap size



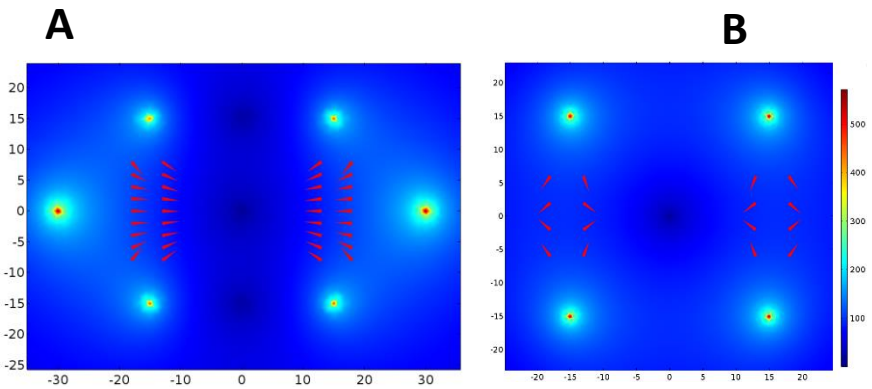
Physical forces on the cell



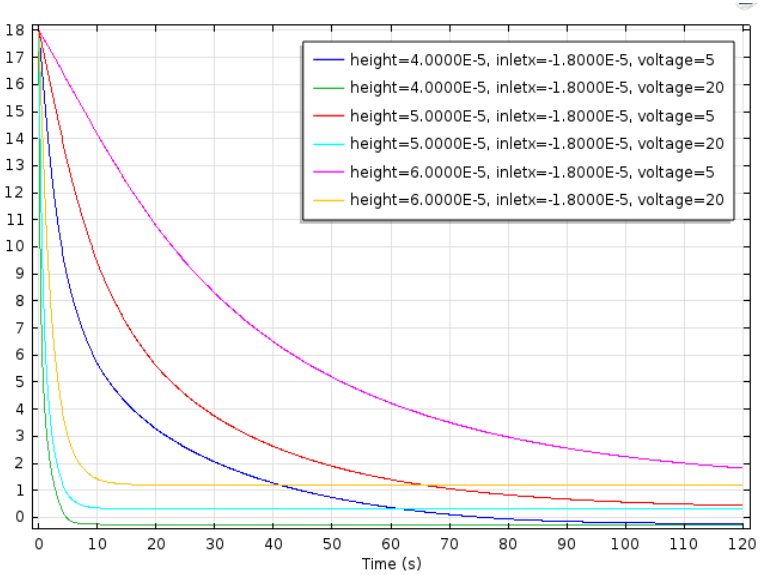
Single-shell model used for improved accuracy

Results (continued)

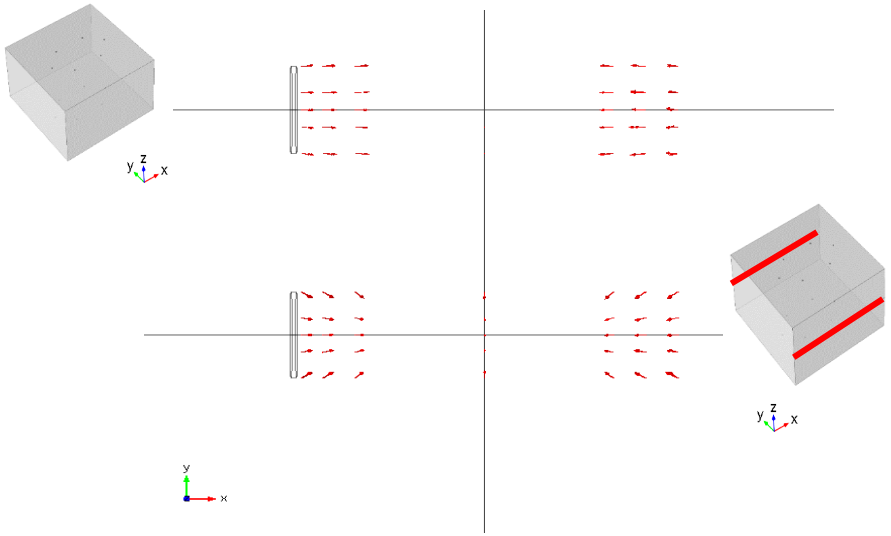
•DC, n-DEP (ϵ_p=59 < ϵ_m=80)



Hexagonal electrodes give more robust control in step-wise cell movement than quadruple electrode

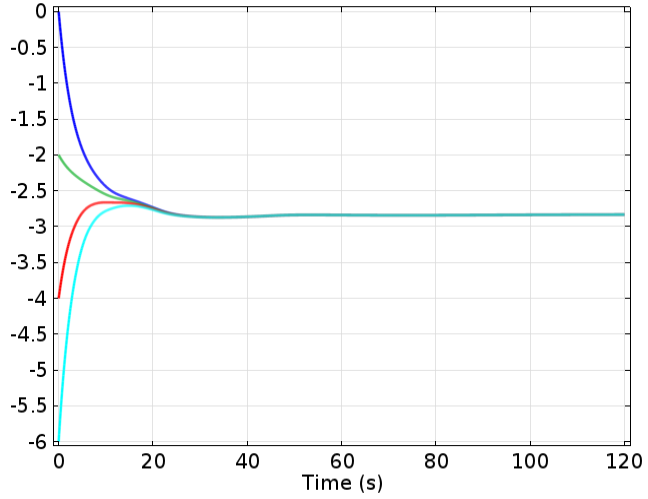


Optimize channel height



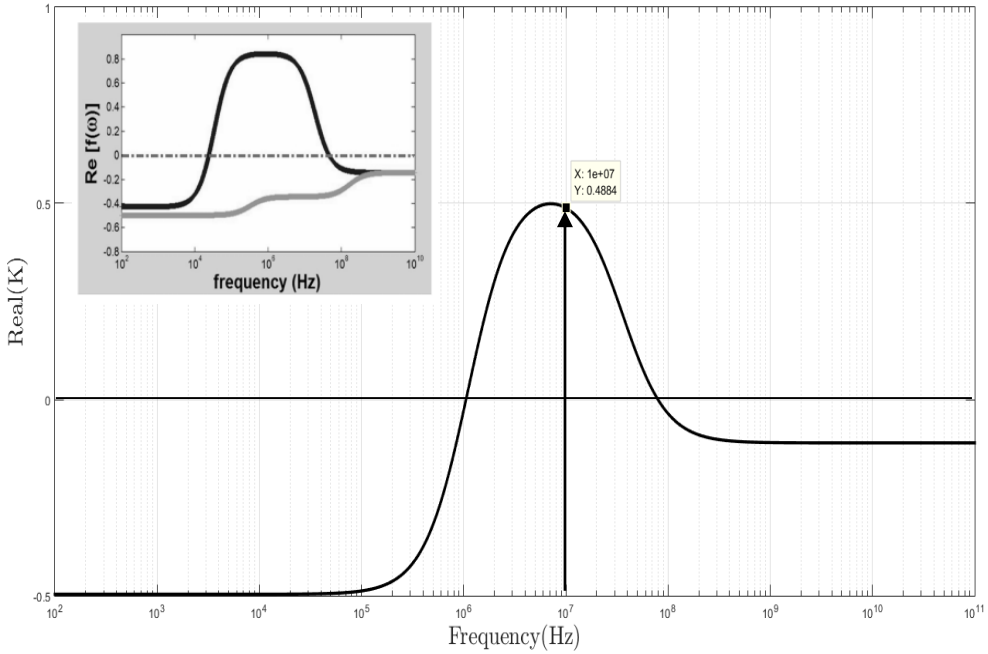
Side electrodes added to direct cell to the center in 3D extension of n-DEP

B

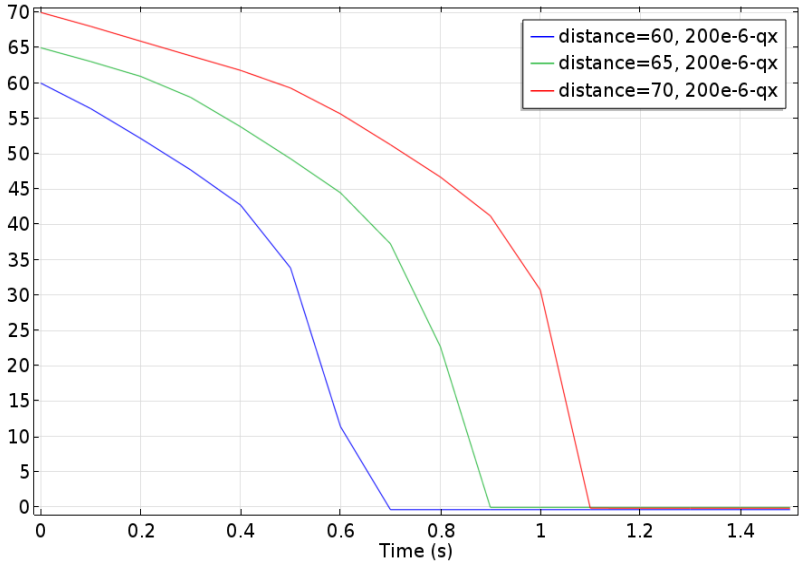


Confirm cell's levitation height

- AC converts n-DEP to p-DEP (ϵ_p=59 < ϵ_m=80).



CM factor spectrum of a cell plotted with MATLAB. The inset figure[3] shows the CM factors with different media. For normal media (grey line), p-DEP is not possible



Optimize inter-electrode gap size

Conclusion

•AC is more efficient at moving cell due to the tunability of the CM factor. It also enhances cell viability compared to DC.
•n-DEP trap is weaker than p-DEP, but still needed for applications with delicate cell lines kept in normal media instead of DEP buffer.
•Future direction: separate electrodes from cells using an encapsulation layer for reusability.
•We provided 2 customizable models that work for a wide range of scenarios for DEP cell manipulation: different cell permittivity, different media conductivity, using either DC or AC signals.

1. Chen L, Offenhäusser A, Krause H-J. *Review of Scientific Instruments*. **2015**;86(4):044701.
2. Seol Y, Carpenter AE, Perkins TT. *Optics letters*. **2006**;31(16):2429-31.
3. Lin RZ, Ho CT, Liu CH, Chang HY. *Biotechnology journal*. **2006**;1(9):949-57.