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CLEMSON INSTITUTE FOR BIOLOGICAL INTERFACES OF ENGINEERING

Elucidating the Mechanism Governing the Cell Rotation Behavior under DEP

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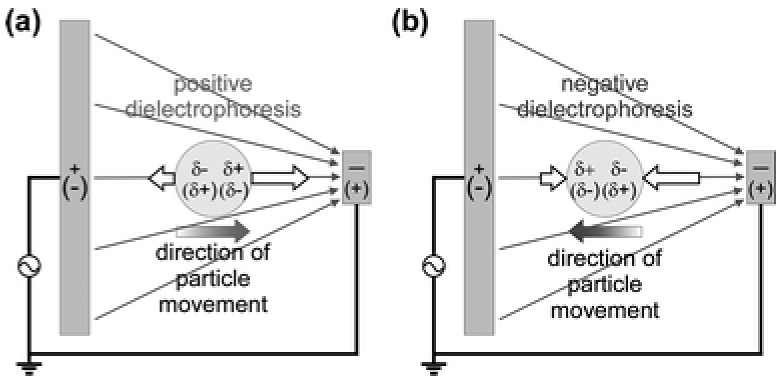
- What is dielectrophoresis (DEP)



http://pubs.rsc.org/en/content/articlelanding/2007/lc/b712784g#!divAbstract

- Application of DEP

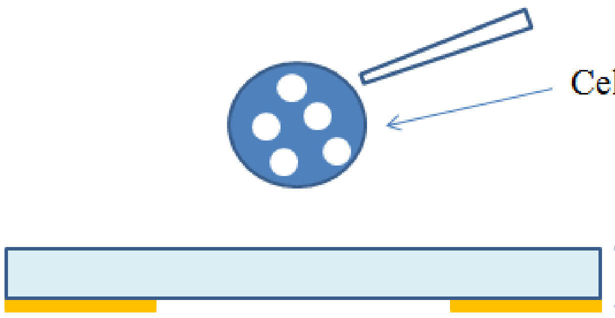
➢ Particle Separation
➢ Cell sorting

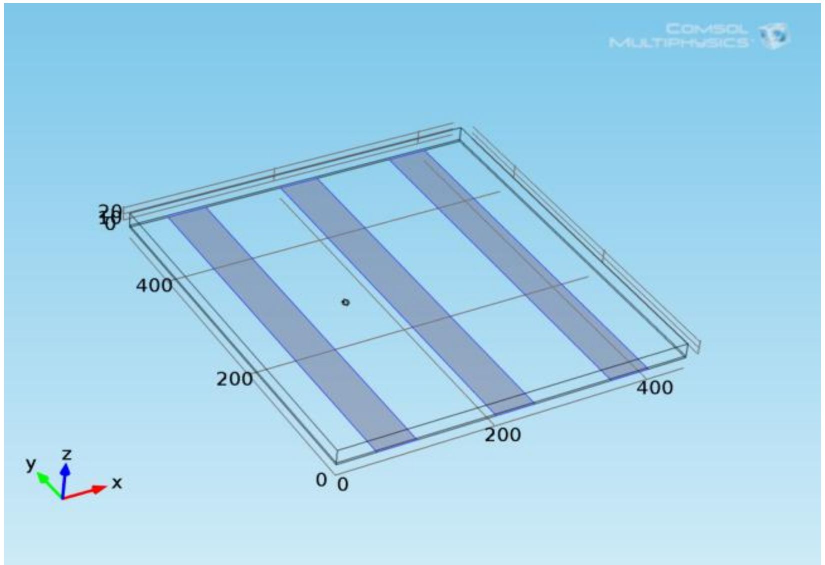
Well explained by current theory

➢ Particle alignment
➢ Cell patterning
➢ Unique single cell behavior

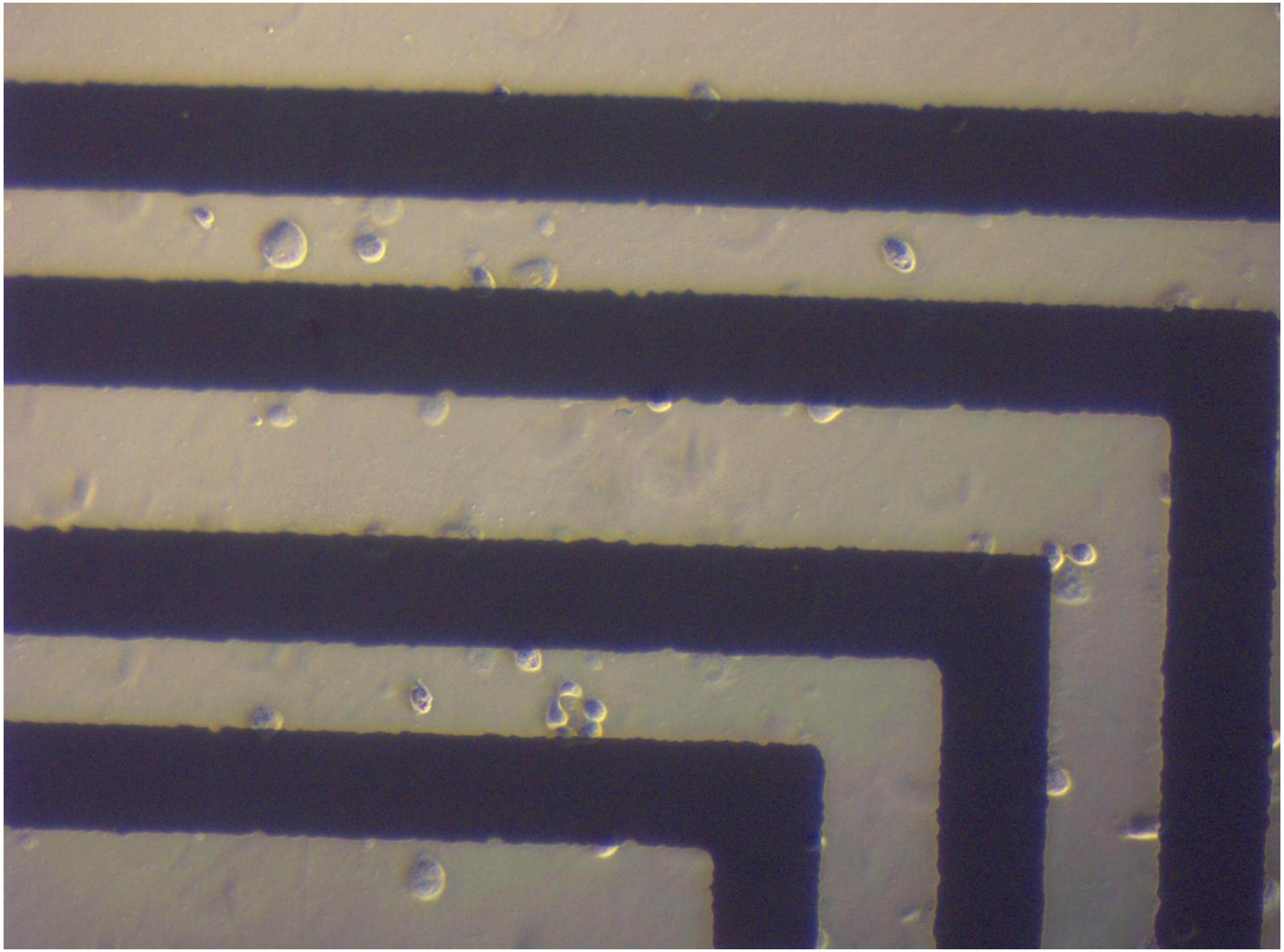
No complete theory

Experimental setup and modeling geometry

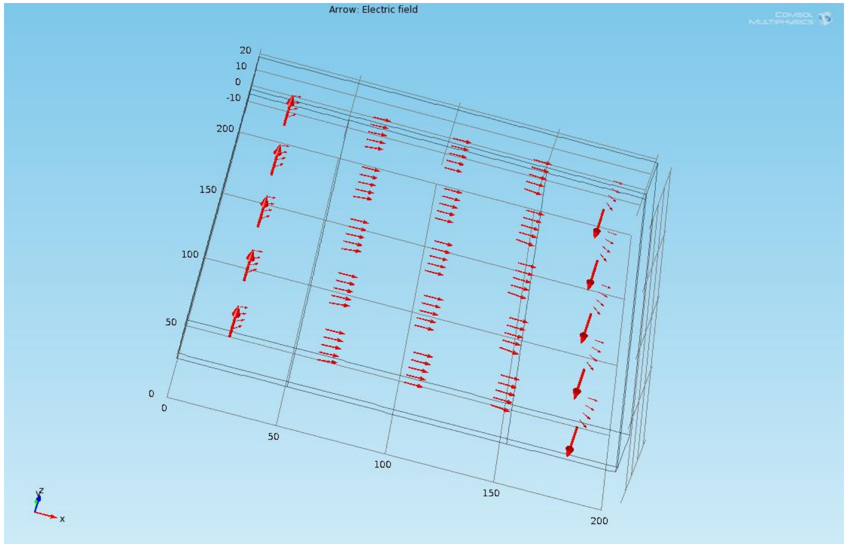




Experimental observation (rat adipose stem cell)



Conventional method



Particle is treated as a point dipole:

$$F = 2\pi a^3 \varepsilon_0 \varepsilon_m Re(f\_cm) \nabla E_{rms}^2$$

$$Re(f\_cm) = \frac{\omega^2(\varepsilon_p - \varepsilon_m)(\varepsilon_p + 2\varepsilon_m) + (\sigma_p - \sigma_m)(\sigma_p + 2\sigma_m)}{\omega^2\left(\varepsilon_p + 2\varepsilon_m\right)^2 + \left(\sigma_p + 2\sigma_m\right)^2}$$

Cannot explain why cell rotates (No phase difference under experimental condition)

New method to overcome limitations

$$F = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} \varepsilon_0 \int (P \cdot \nabla) E dV$$

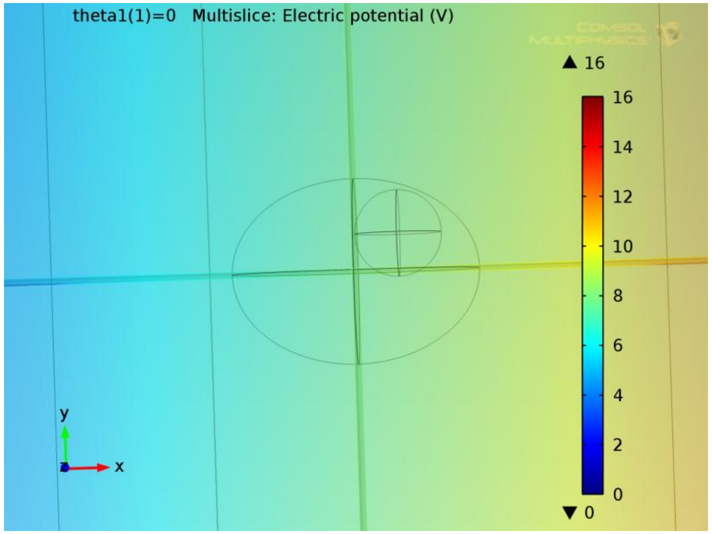
$$T = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} \varepsilon_0 \int r \times [(P \cdot \nabla) E] dV$$

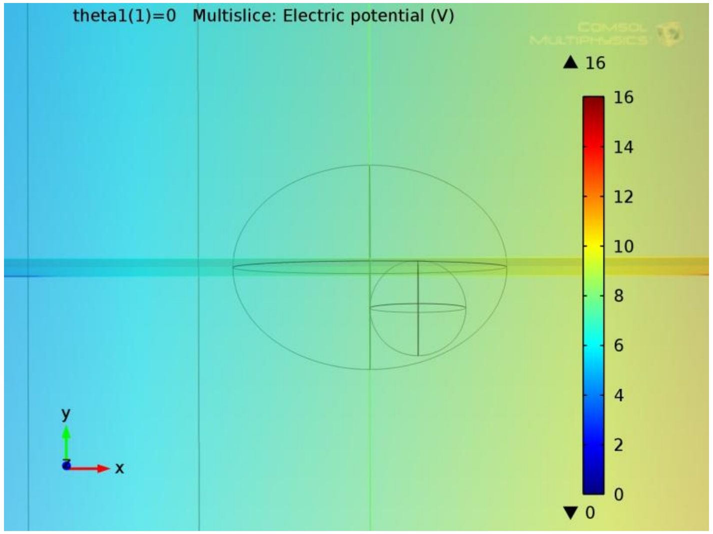
- Size effect is correctly reflected
- The dipole-dipole interaction is included
- Works for particles with non-uniform electric property (e.g. cell)

Cell property

- Non-sphere shape
- Nucleus with high permittivity due to greater hydrated free ion content
- Nucleus usually at fixed position

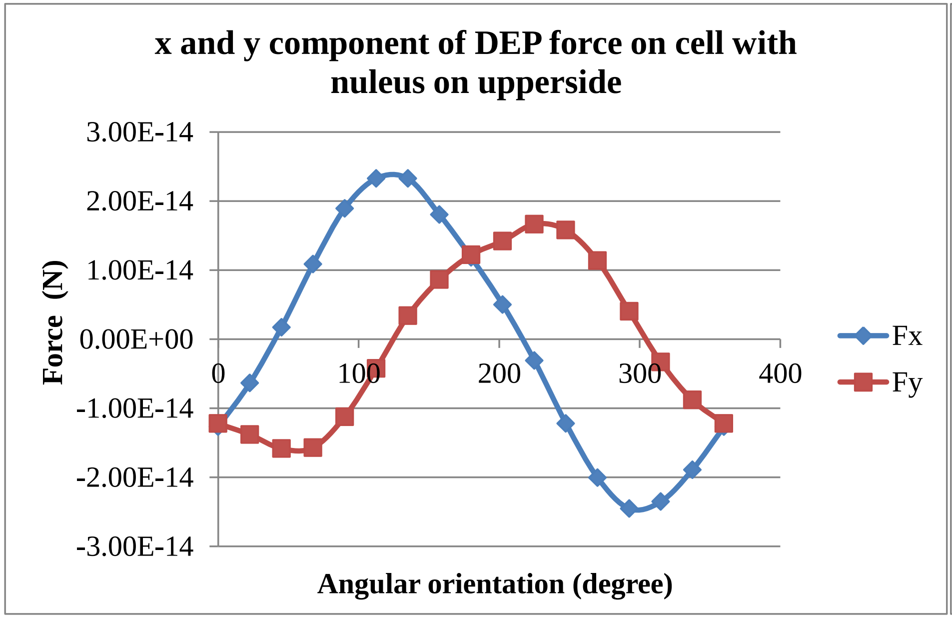
Modeling of cell structure

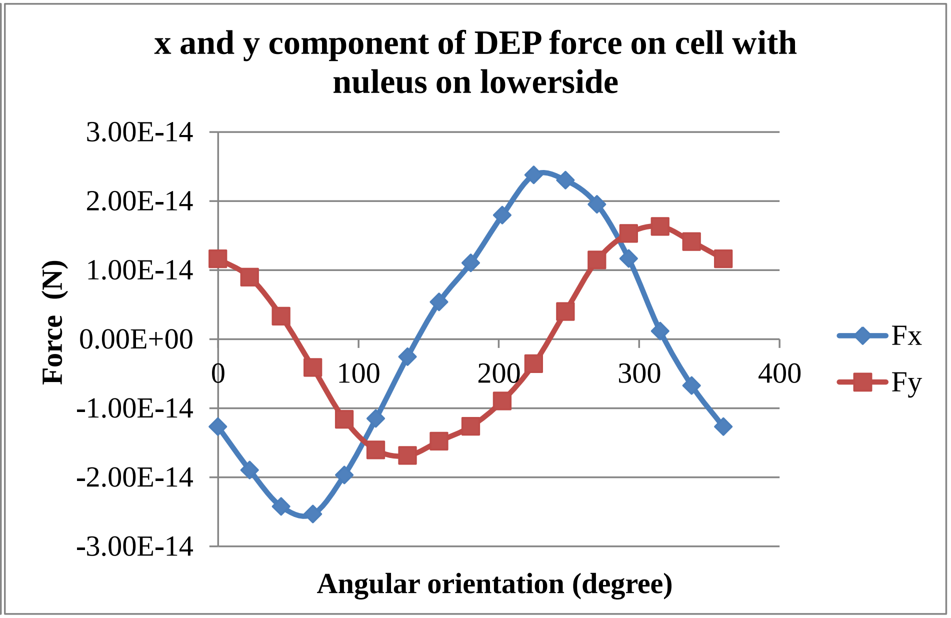




COMSOL model of an ellipsoid shaped cell with an off-centered nucleus; upper(left), lower(right)

Net DEP force on cell at different orientations

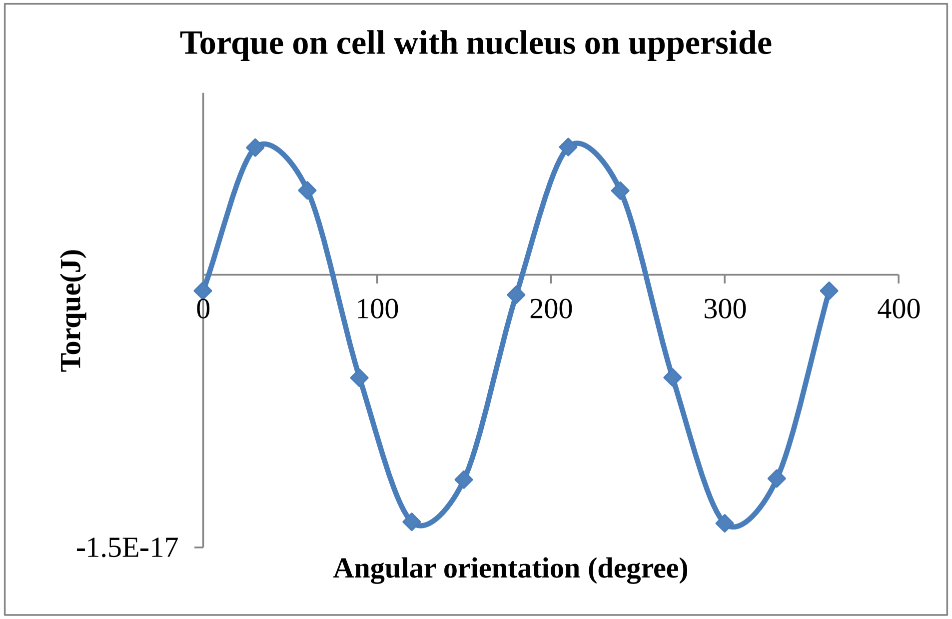


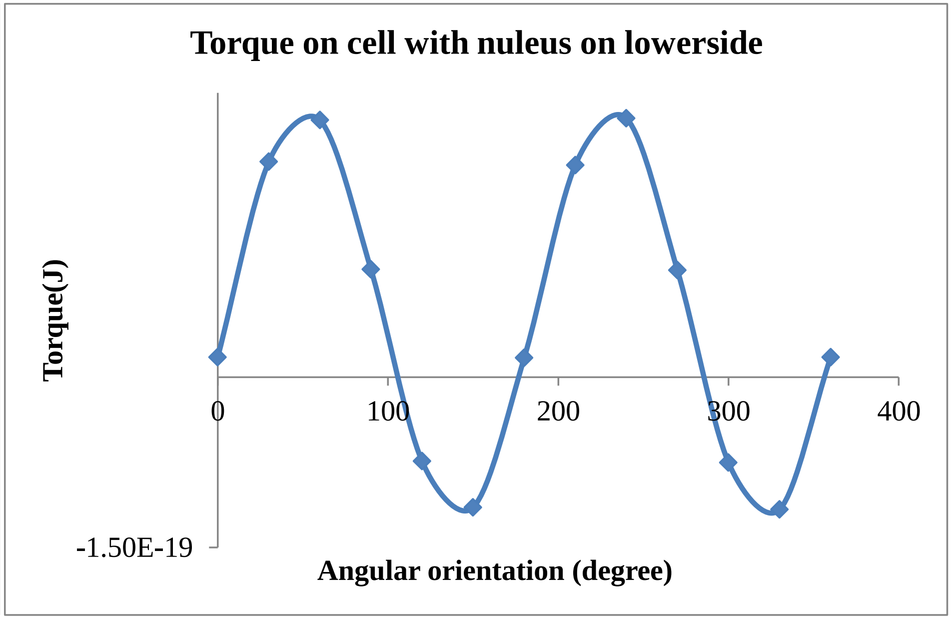


an ellipsoid-shaped cell with upper side off-centered nucleus

an ellipsoid-shaped cell with lower side off-centered nucleus

Net torque on cell at different orientation





an ellipsoid-shaped cell with upper side off-centered nucleus (Average negative torque suggests clockwise rotation)

an ellipsoid-shaped cell with lower side off-centered nucleus (Average positive torque suggests counterclockwise rotation)

Conclusion

- A new numerical method is developed which will overcome the limitations in the calculation of DEP force and torque.

- Our hypotheses that the cell rotation is caused by the non-circular shape of the cell body and the off-centered location of its nucleus and that the rotation direction depends on the relative location of nucleus with respect to the electrical field are confirmed by the simulation results.

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