

Effect of Electric Field Distortion on Particle-Particle Interaction under DEP

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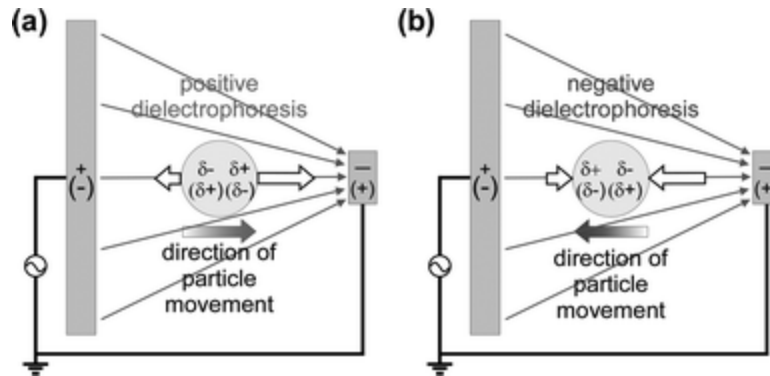
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- What is dielectrophoresis (DEP)



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

- Application of DEP

- Particle Separation

- Cell sorting

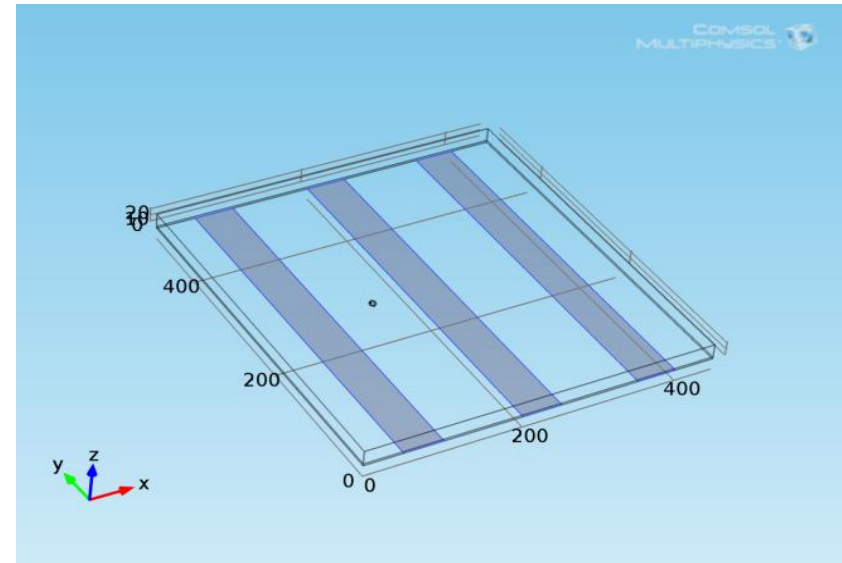
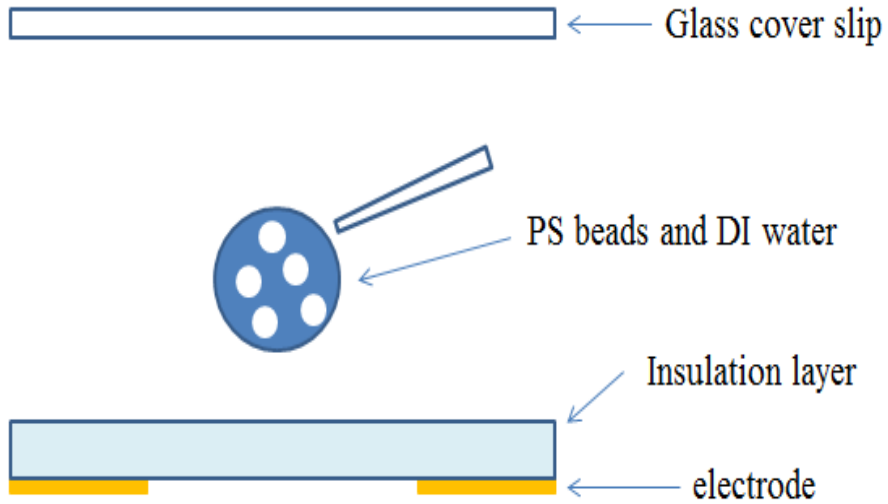
- Particle alignment

- Cell patterning

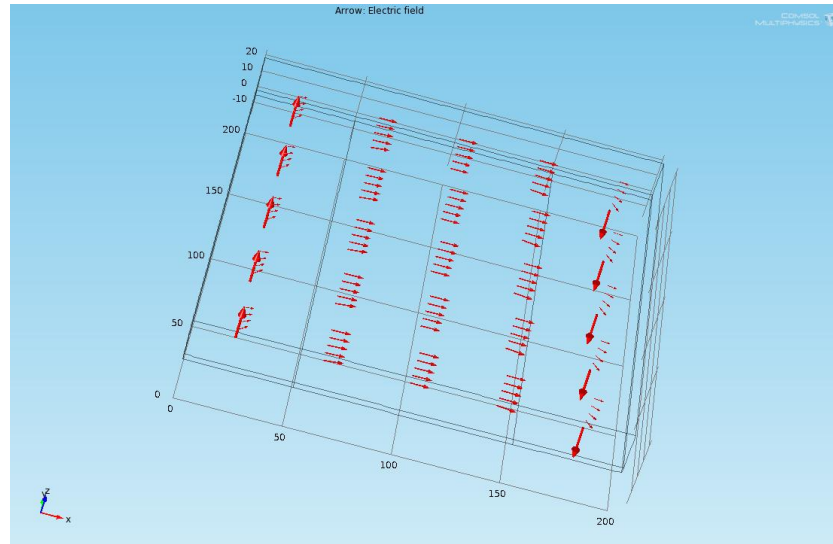
} Well explained by current theory

} Particle interaction involved, no complete theory

Experimental setup and modeling geometry



Conventional method

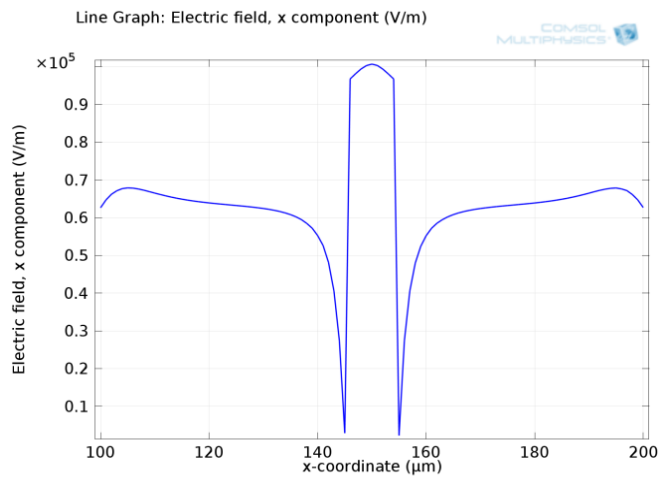
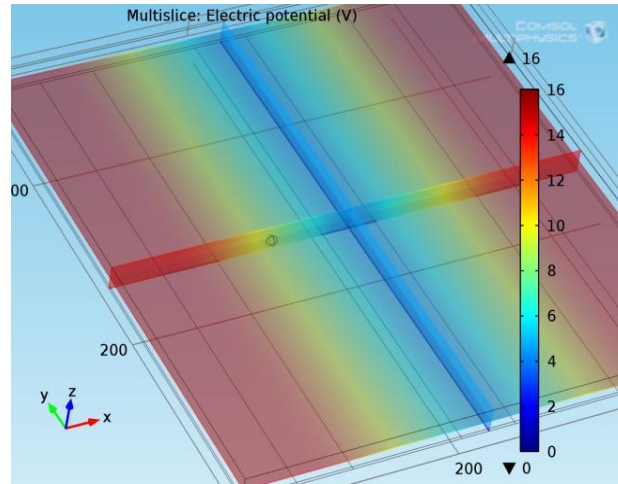


Particle is treated as a point dipole:

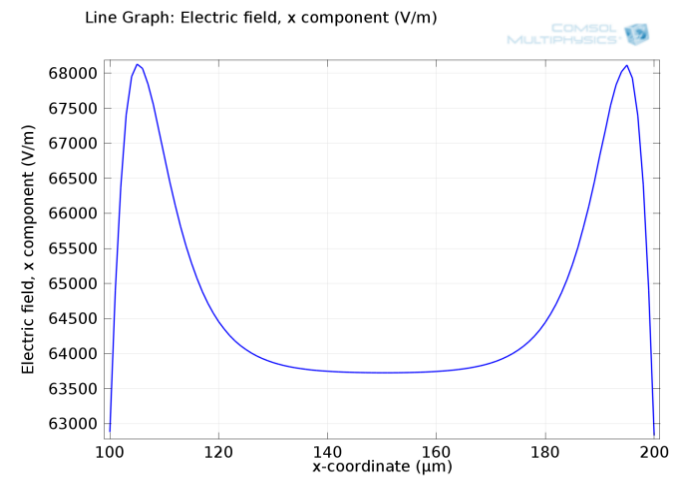
$$F = 2\pi a^3 \epsilon_0 \epsilon_m \text{Re}(f_{cm}) \nabla E_{rms}^2$$
$$\text{Re}(f_{cm}) = \frac{\omega^2 (\epsilon_p - \epsilon_m) (\epsilon_p + 2\epsilon_m) + (\sigma_p - \sigma_m) (\sigma_p + 2\sigma_m)}{\omega^2 (\epsilon_p + 2\epsilon_m)^2 + (\sigma_p + 2\sigma_m)^2}$$

Only applies for the case where particle size is extremely small

Electric field distortion Effect of particle

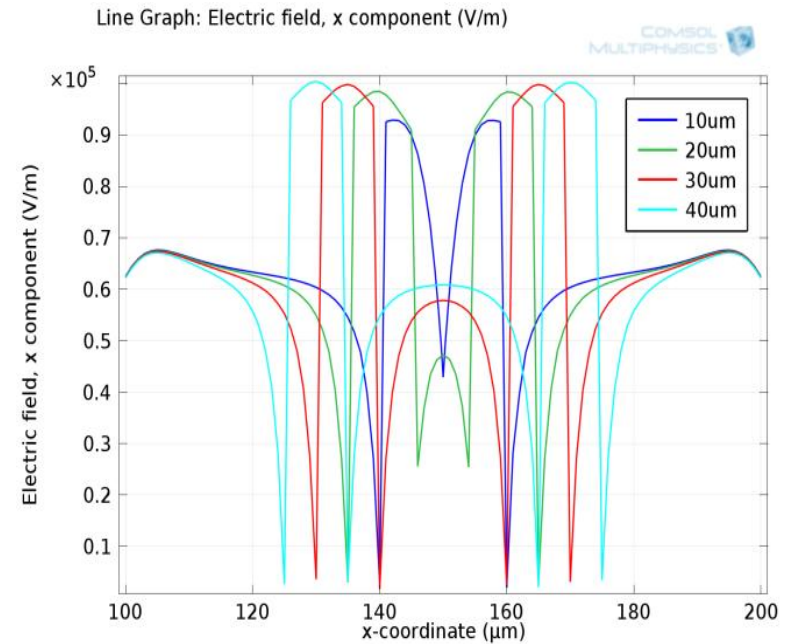
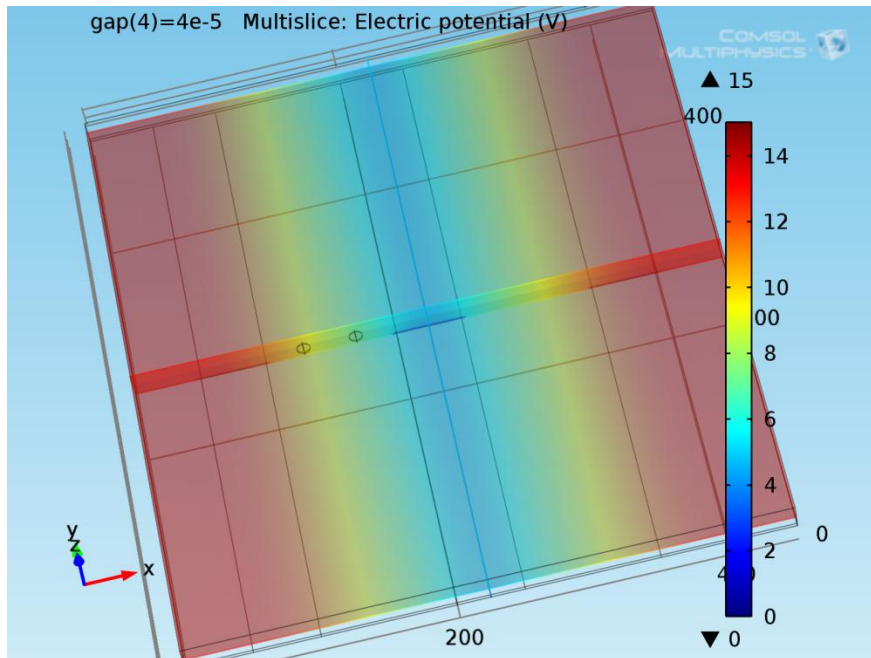


Influence of the presence of the particle



the presence of the particle is ignored

Particle-particle interaction



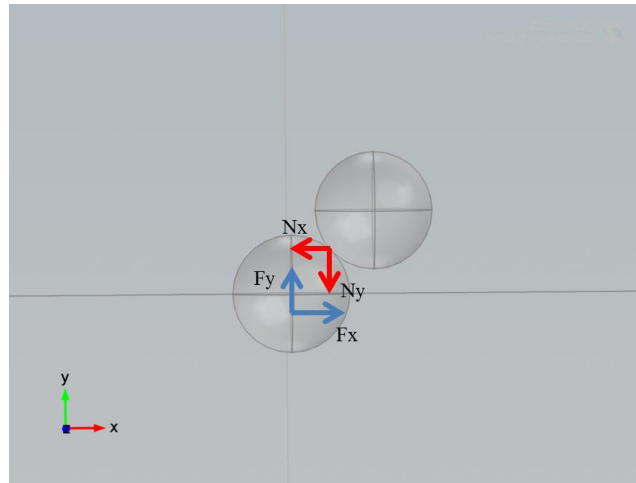
Influence of distance between particles on distortion of electric field

New method to overcome limitations

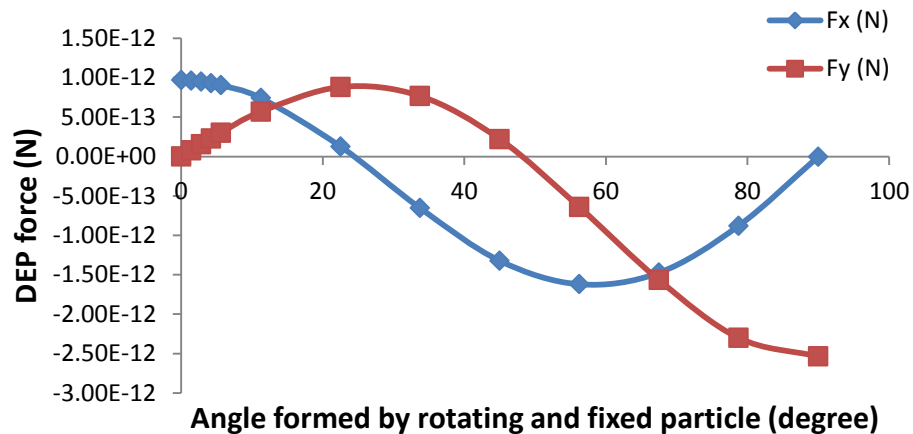
$$F = \frac{\epsilon_p - \epsilon_m}{\epsilon_p + 2\epsilon_m} \epsilon_0 \int (P \cdot \nabla) E dV$$

- Size effect is correctly reflected
- The dipole-dipole interaction is included

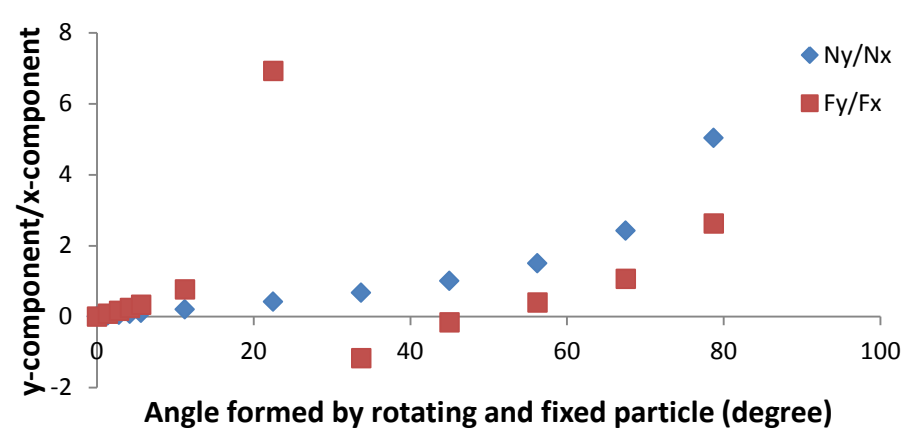
Optimal Orientation



x and y components of DEP force at different orientations



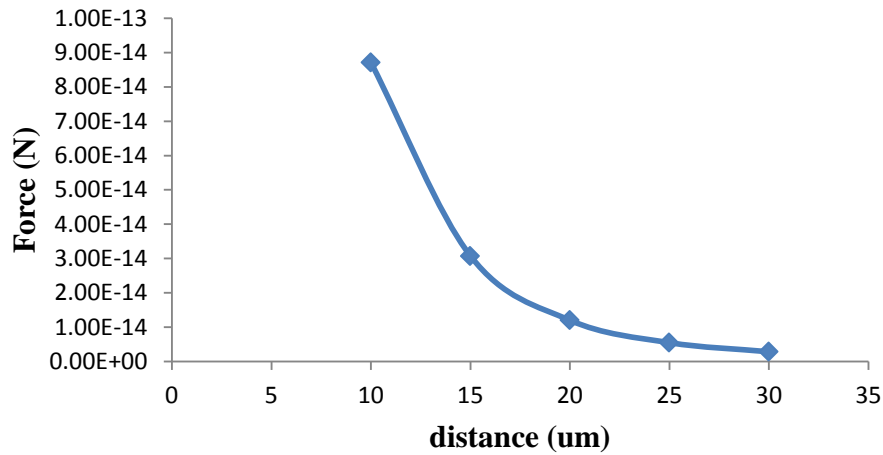
y-component/x-component ratio of contact force and DEP force at different orientations



The stable orientation converges to zero degree where F_y/F_x equals N_y/N_x

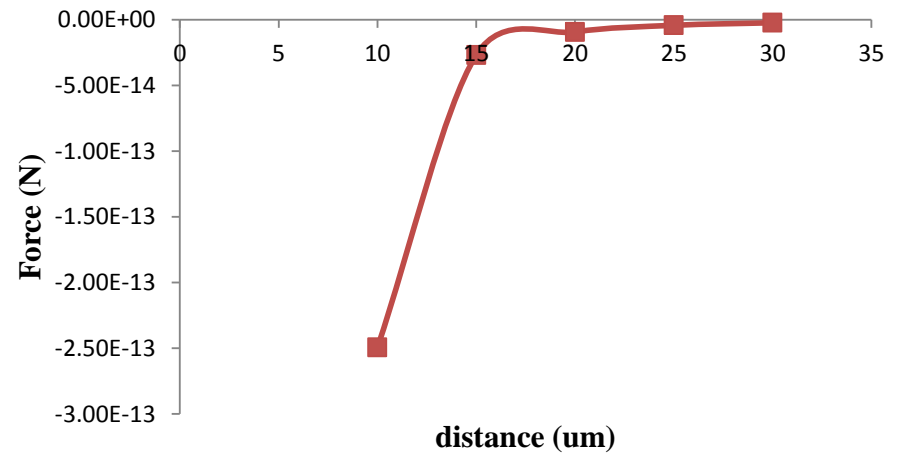
Trend of dipole-dipole interaction in orthogonal direction

Force magnitude vs distance between particles



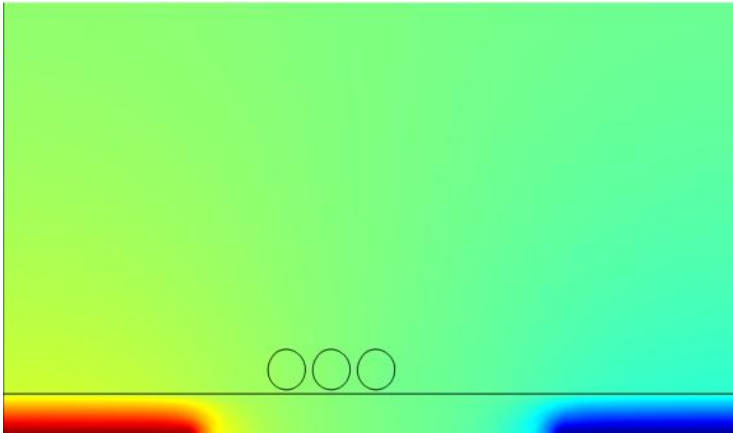
Beads get attracted in perpendicular direction

Force magnitude vs distance between chains

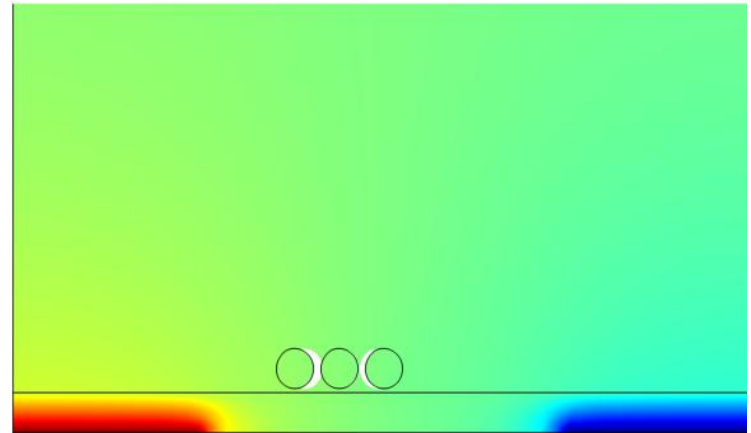


Chains repel each other along electrode orientation

2D model shows chain formation



Movement of 10um particles on one side of center particle in forming a pearl-chain

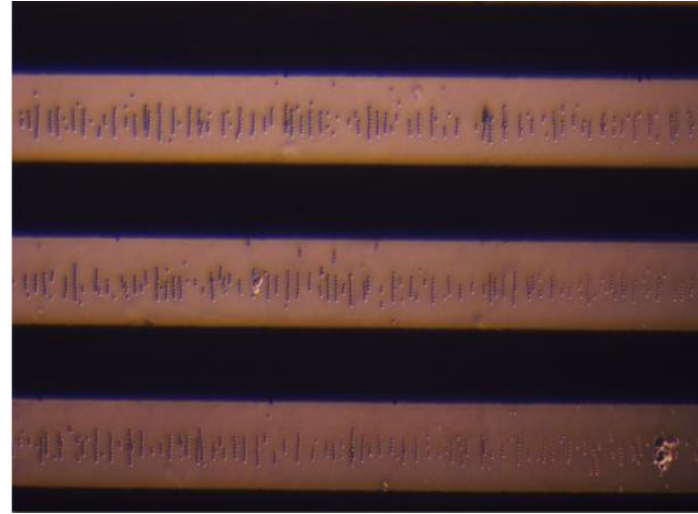


Movement of 10um particles on both sides of center particle in forming a pearl-chain

Experimental observations (pearl chain)



No potential, beads scattering



15V, 200kHz beads in chain

Conclusion:

- A new numerical method is developed which will overcome the limitations in the calculation of DEP force
- Particle size, shape and the presence of neighboring particle will all affect DEP interaction
- Our experimental observations validate modeling results

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