ME 517: Micro- and Nanoscale Processes

Lecture 32: Electrokinetics - III

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DC Electrophoresis (EP)

- Particle/ion manipulation using EDL and electrical field
  - Common technique called ‘capillary electrophoresis’ (CE) used to sequence DNA, ala OJ Simpson or Human Genome Project

\[
\begin{align*}
\mu_{ep} &= \frac{u_{ep}}{E_{el}} \\
\frac{u_{ep}}{3} &= \frac{\varepsilon \zeta E_{el}}{\mu} \\
\frac{u_{ep}}{\mu} &= \frac{\varepsilon \zeta E_{el}}{\mu} \\
\lambda_D &= \frac{d_p}{\mu} \\
&= \frac{d_p}{\mu} \\
&= \frac{d_p}{\mu}
\end{align*}
\]
Particle Electrokinetics

- **Polarization of colloids**
- **Electric Double Layer polarization**

Relaxation at high AC frequencies

Interparticle Forces

Dipole-Dipole Interactions

- Dipole-Dipole Interactions

\[ F = 3\pi\varepsilon_m a^6 E_o^2 / r^4 \]

Background: AC Electrokinetics

- Particles themselves will alter electric field

- Distortion leads to a tangential component of the electric field over the electrode surface.
- This generates electrohydrodynamic flow (ACEO)


Background: AC Electrokinetics

- Particle-Particle interactions

Background: AC Electrokinetics

Assembly of 1.5 µm particles in an aqueous solution of NaOH (10⁻⁴ M)

Dielectrophoresis Schematic

- AC phenomenon
- Neutral particles polarized by electric field
- Polarity switches, charge distribution pushes against new electric field
Dielectrophoresis Background

- AC field induced motion in polarizable particles
  - Low Voltage Actuation
  - Suitable for biological systems
- Widely used first order approximation:

\[
F = 2\pi\varepsilon_0\varepsilon_m r^3 \text{Re}\left[ f_{CM} \right] \nabla \left| E_{RMS} \right|^2
\]

\[
f_{CM} = \frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*}
\]

- First order accuracy insufficient to predict dynamics of small particles near electrode edges
Interdigitated Electrodes

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\[ F = 2 \pi r^3 \varepsilon_m \varepsilon_0 \text{Re}[f_{CM}] \nabla |E_{rms}|^2 \]

\[ f_{CM}(\varepsilon_p, \varepsilon_m) = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} \quad \varepsilon_p = \varepsilon(\omega) \]

\[ \varepsilon_1 > \varepsilon_m \quad \varepsilon_2 < \varepsilon_m \]
Manipulation of *L. innocua*

Negative DEP – AC voltage of 1V (V_{pp}) and 1KHz

Positive DEP – AC voltage of 1V (V_{pp}) and 100KHz

Live cells (positive DEP), dead cells (negative DEP)
1V (V_{pp}) and 50KHz,

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