Introduction: Computational modeling has become more widely used to guide the design of microfluidic devices for manipulating cells using Dielectrophoresis (DEP), and devise novel means for advancing the study of cellular science and engineering. Conventionally, cells are treated as volumeless points in the system, which allows study of the movement of groups of particles under the effect of field. However, this approach often neglects the distortion effect of particle on external field, as well as interactions among particles. Moreover, it ignores the complex inner structures of cell, which are the causes of distinctive cell behavior. To more accurately model the behavior of cells for better understanding of the underlying mechanism, a new numerical method, termed as ‘volumetric polarization and integration method’ has been developed. It has been proved to be more powerful over existing approaches when applied to explain complicated experimental observations.

In the second part, we will showcase how to use integrative modeling to solve complex engineering problems without break the Multiphysics problem into pieces. The coupling of physics in computational modeling provides more realistic guidance to experimental design.

Theoretical development:

Point dipole method:

\[ \Delta \psi = \frac{4 \pi \alpha^2 \varepsilon_0 \varepsilon}{\varepsilon + 2 \varepsilon_0} \]

MST method:

\[ \mathbf{F} = p \mathbf{E} + \mathbf{j} \times \mathbf{B} \]

Volumetric polarization and integration method:

\[ \mathbf{F} = 3 \pi \alpha \mathbf{E} - \mathbf{E}_{\text{particle}} \times \mathbf{E} \]

Method Validation:

Nonhomogeneous particle

<table>
<thead>
<tr>
<th>TABLE I: DEP force on polarized particle</th>
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<tbody>
<tr>
<td>Parameter</td>
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<tr>
<td>DEP force</td>
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<tr>
<td>Electric field</td>
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Results:

1. Cell rotation

Self-rotation was observed for rat adipose stem cells under DEP. Modeling results suggest that the rotational movement is induced by eccentric inclusions with low conductivity inside cell.

2. Tumbling motion of pearl chain in a flow condition

Conclusion:

Computational modeling provides means for examining current theory and developing new theory in order to obtain better understanding of experimental observation. It also lays the foundation for solving complex engineering problems in an integrative way.

Reference: