Some Commonly Neglected Issues Which Affect DEP Applications

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Abstract

Introduction: Dielectrophoresis (or DEP) is an important phenomenon induced when a dielectric particle is placed in a non-uniform electric field. The force generated by DEP has been exploited for various micro and nano fluidics applications like patterning, sorting and separation. In the case of alternating current DEP, electrical fields of a particular magnitude and frequency are used to manipulate particles with greater selectivity.

Although DEP has been widely used, there are several commonly neglected issues in quantifying DEP forces. Such negligence could potentially lead to wrong DEP force predictions and estimates, posing difficulties in correlating experimental observations with theories. Among the commonly neglect issues, the effect of the radius of a particle on its conductivity is often ignored, which, as a result, will lead to a wrong estimate of the DEP magnitude and its crossover frequency. Moreover, biological particles, such as cells, are nonhomogenous. Treating them as uniform dielectric particles will surely lead to wrong results.

Use of COMSOL Multiphysics®: In this work, we use COMSOL Multiphysics® to investigate the effect of radius induced conductivity change and the effect of using a shell model for cells on the resulting DEP forces. Fig.1 shows a 3D model of the electrode setup consisting of parallel electrodes separated by insulating gaps between them. These parallel electrodes are biased in an alternating positive and ground pattern. The top side of the electrodes is protected by a cover layer made of an oxide film. Above the cover layer is a liquid chamber filled with de-ionized water for particle suspension and manipulation.

Results: Fig.2 shows the DEP force plotted against the particle radius. Two different cases are shown. In the first case the effect of radius on conductivity is considered and in the second the effect is ignored. It is clear that when particles are large (> 30 um), neglecting the effect of particle size on its conductivity may not have much effect. However, when particles are small (< 30 um), neglecting the size effect will lower the predicted DEP force significantly.
Fig.3 shows the DEP forces plotted against frequency when considering a cell (E.coli cell) as a homogeneous particle (zero shell) and as a shell structure (single shell). Clearly, not only a shift in the cross-over frequency is observed, but also the trend of decreasing DEP force with increasing frequency when a zero-shell model is used changes to that of increasing force with increasing frequency when a single-shell model is used.

Conclusion: This work demonstrates that neglecting these issues discussed above may lead to wrong predictions and estimates in DEP force calculation. For many practical applications using DEP forces, it is necessary to reevaluate the actual situations.

Figures used in the abstract

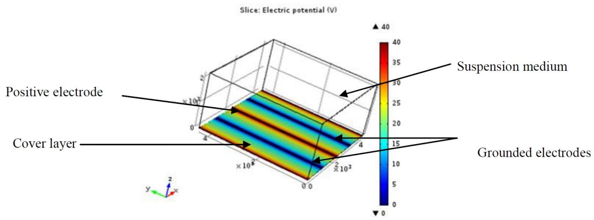

Figure 1: 3D model of the electrode setup used in determing the DEP force.

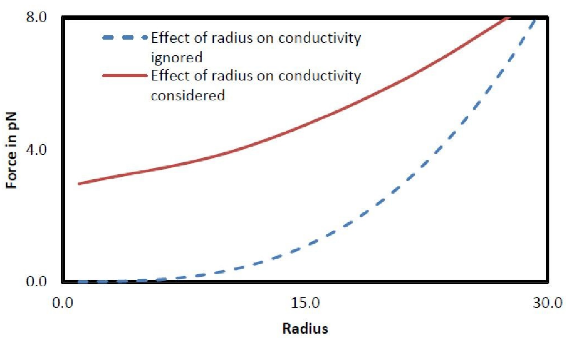

Figure 2: Difference in the DEP force when the effect of radius on conductivity is considered and when it is neglected.

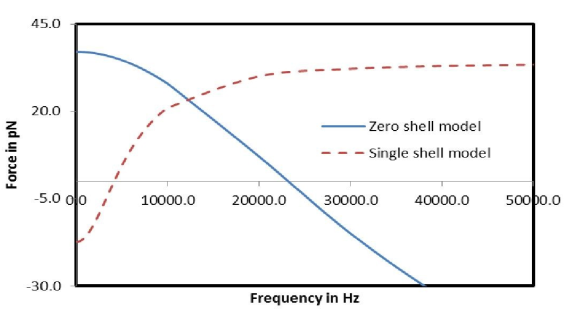

Figure 3: Differences in the variation of DEP force with frequency when a cell is treated using a single-shell and zero-shell models.