Effect of Electrical Field Distortion on Particle-Particle Interaction Under DEP

G. Zhang[1], Y. Zhao[1], J. Hodge[1], J. Brcka[2], J. Faguet[2], E. Lee[2]

[1]Clemson University, Clemson, SC, USA
[2]TEL U.S. Holdings, Inc., U.S. Technology Development Center, Austin, TX, USA

Abstract

Introduction: In using DEP for particle manipulation, researchers often use a formula to calculate the DEP forces in which the forces are proportional to the particle radius to the third power. This formula assumes that the electrical field, E, will not be affected by the presence of a particle, no matter what the actual size and the dielectric property of the particle are. For using DEP forces for patterning and alignment purposes, as well as for potential sensing applications, a better understanding of the dependence of the DEP force on the physical and material properties of the particle is necessary.

To address this problem, we used COMSOL Multiphysics® to model the DEP phenomenon by considering the influence of the volumetric domains of the particles on the distortion of electrical field. Fig.1 shows a 3D model in which a spherical particle (r =5 um) is placed in an electrical field applicator surrounded by DI water.

Results: Fig.2a shows the x-component of the induced electrical field along a line that goes through the center of the particle (see the line in the figure on the left) and Fig.2b shows the same electrical field when the presence of the particle is ignored. Through comparisons we note that the electrical field surrounding the particle is distorted drastically due to the presence of the particle having a different conductivity and permittivity from the surrounding medium. With this unique way of accounting for electrical field distortion, we further investigated the formation of pearl chains (as we observed in our experiments with particles) as a consequence of the DEP forces and the volumetric effect on electrical field. To simplify matters, we performed a 2D investigation by implementing a moving mesh study. As shown in Fig.3, the left image shows the positions of the two particles at the beginning of the simulation and the right image shows their position after 12 s. These results show that the particle located closer to the electrode is pushed toward the center (the white circle). This result provides a good explanation for the formation of pearl chains of particles near the center of the gap between electrodes in a direction perpendicular to the electrode orientation.

Conclusion: The electrical field distortion is the result of differential conductivity and permittivity between the particle and the surrounding medium. When the conductivity and permittivity of the particle are replaced by those of water, such electrical field distortion will vanish. Moreover, since we integrated over the entire volume of the particle, the effects of the

particle size, shape as well as its location are inherently considered in the resulting electrical field. This is not the case when using the conventional DEP force formula. Thus with this model we can consider the effects of the size, shape and location of the particle upon the induced electrical field and subsequently the DEP forces. Moreover, this study also provides for the first time a quantitative estimate for the level of the driving forces for such pearl-chain formation.

Figures used in the abstract

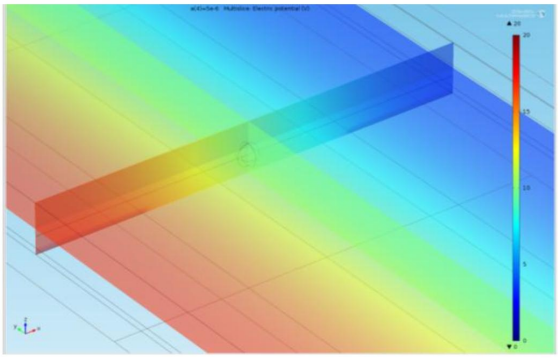
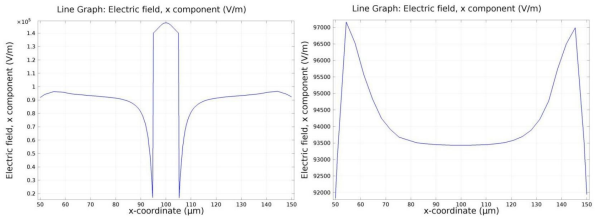


Figure 1: COMSOL model for elucidating the influence of particle volumetric domain on the distortion of electrical field.



(a) (b)

Figure 2: (a) Influence of the particle presence on the electrical field distortion is significant as compared with (b) when the influence is ignored.

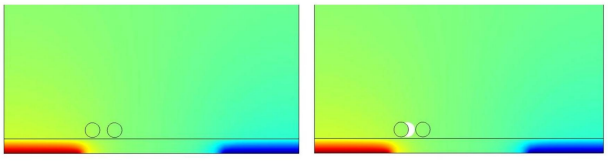


Figure 3: Results showing the movement of 10 micrometer particles in forming a pearl chain.