Elucidating the Mechanism Governing Particle Alignment and Movement By DEP

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Abstract

Dielectrophoresis (DEP) has played an important role in manipulating small particles and biological cells for bioengineering application. We routinely experiment with manipulating particles and cells with DEP using designed electrodes and fluidic channels to achieve various aims. In order to fully understand and control the behavior of particles and cells, a better elucidation of the DEP phenomena, especially when multiple particles are present, becomes crucial. In the case of multiple particles, the interactions between particles are believed to govern not only the alignment but also the movement of the particles. However, in most existing EDP works particle-particle interaction and its effect on alignment/movement of particles are often ignored. The closets some previous studies ever get is to either investigate the movement of several particles or restrict the movement of particles in two-dimensional plane. In this work, we use COMSOL Multiphysics® software to reexamine the DEP theory by considering these important aspects in three-dimensional space.
Our modeling results demonstrate that by including volumetric effect of particles and boundary condition along the wall, we can successfully predict the formation of pearl chains of particles in both 2D and 3D situations. When particles of similar sizes are considered, our modeling results capture mot only the formation of pearl chains of multiple particles but also the flipping motion of the pearl chains. When particles of different sizes are present, they form antenna-like structures and the orientation of these structures depends on the frequency of the input AC signal. In terms of cells, using concentric circular electrodes our model predicts the retention of cells by the electrodes. What makes our modeling results even more exciting is the fact that all the predicted alignment and movement of particles and cells closely resemble our experimental observations. This confirms the validity of our method of reexamining and redeveloping the DEP theory using COMSOL. This work for the first time successfully explains many of our experimentally observed phenomena including the common particle alignment in the form of pearl chains, the less common alignment in the form of antenna structures, a new phenomenon of the flipping motion of pearl chains, and the movement and retention of a large number of cells in a flow condition.