Numerical Optimization of Microelectrode Systems for Single Cell Manipulation By Dielectrophoresis

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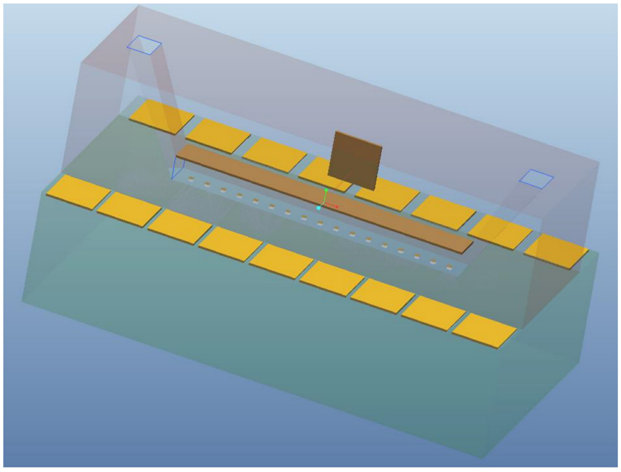
Abstract

Precise single cell manipulation is useful for many biomedical applications such as tissue engineering, cell-based bio-sensing, image-based cell selection and cell-cell interaction. Among the various techniques to control the location of cells, dielectrophoresis (DEP) proves to be a very promising approach to manipulate large quantity of cells with easy operation and less damage than traditional methods like magnetic or optical tweezers. DEP force causes dielectric particles, such as cells, to move under an externally applied non-uniform electric field. Depending on the permittivity difference between the particle and the medium, two types of DEP forces may be generated: positive DEP (p-DEP) and negative DEP (n-DEP). In this numerical study, we provided two multi-microelectrode systems using either n-DEP or p-DEP to control a wide range of cells with different internal permittivity. The systems also allow for step-wise single cell translocation. The AC/DC module was used in conjunction with the Particle Tracing for Fluid Flow Module. For the p-DEP case, a single large electrode was placed on top of an array of micron-sized electrodes. This configuration was used for both DC and AC electric fields. For the DC, n-DEP case, a novel configuration with microelectrodes at hexagonal placement was designed and tested in 2D and 3D geometries, and was shown to be more robust than the traditional quadruple configuration. For both systems, working parameters such as inter-electrode gap and channel height were optimized to achieve the most efficient cell translocation. Cell's levitation height was also confirmed in the n-DEP case. The n-DEP trap was found to be less efficient than p-DEP due to the inherently weaker DEP force.

Figures used in the abstract



3D illustration of p-DEP model to displace single cells in a step wise fashion

Figure 1: 3D illustration of p-DEP model to displace single cells in a step wise fashion