

Elucidating the Mechanism Governing the Cell Rotation Behavior Under DEP

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Abstract

Introduction: In our experiments with manipulating cells (rat adipose stem cells) with DEP, we noted an interesting phenomenon: some cells are constantly rotating in the gap regions. Fig.1 shows two images captured at two different times. Although these are still images, one can see the different orientations of the two cells circled in red and green. The red-circled cell is rotation counter clockwise and the green-circled cell clockwise. This work is to elucidate the underlying mechanism for the observed phenomena.

Use of COMSOL Multiphysics®: We hypothesized that the cell rotation is caused by the non-circular shape of the cell body and the off-centered location of its nucleus and that the rotation direction depends on the relative location of nucleus with respect to the electrical field.

To prove this hypothesis, we performed modeling in COMSOL Multiphysics® by considering ellipsoid-shaped cells with off-centered nucleus. We considered two cases: in the first one the nucleus is located above the center line (see Fig.2a) and in the second one it is located below the center line (Fig.2b).

Results: Fig.3 shows the x- and y-components of the obtained DEP force as a function of the cell's initial orientation angle for both the upper and lower off-centered cases. Clearly, as the initial orientation angle changes from 0 to 360 degree, the x- and y- components of the DEP force follow a wave pattern having 90 degree phase delay. This means that the x- and y- components actually follow the sine and cosine wave patterns, respectively, an indication that the net total force will cause the cell to rotate. To examine this further, we calculated the force vectors (magnitude and direction angle) as a function of the initial cell orientation angle. Figure 4 shows the obtained vector plots for both cases: when the nucleus is located above the center line (upper side off centered case) the cell will experience a clockwise rotational force (Fig.4a) and when the nucleus is located below the center line (lower side off centered case) the cell will rotate counter clockwise (Fig.4b). These results support our hypotheses.

Conclusion: The observed cell rotation was investigated via modeling in COMSOL. Our hypotheses that the cell rotation is caused by the non-circular shape of the cell body and the off-centered location of its nucleus and that the rotation direction depends on the relative location of nucleus with respect to the electrical field are confirmed and validated by COMSOL models.

Figures used in the abstract

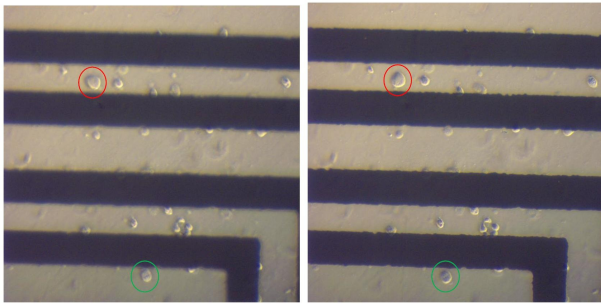


Figure 1: Images showing cell rotation under DEP forces at 200 Vpp and 300 KHz.

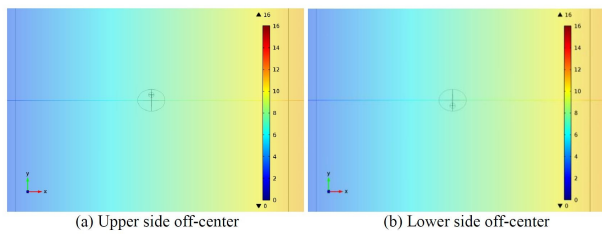


Figure 2: Models of an ellipsoid shaped cell with off-centered nucleus.

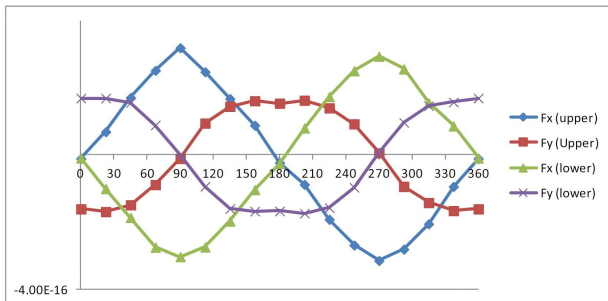


Figure 3: The x- and y-components of the DEP force obtained from an ellipsoid-shaped cell with either upper side off-centered or lower side off-centered nucleus.

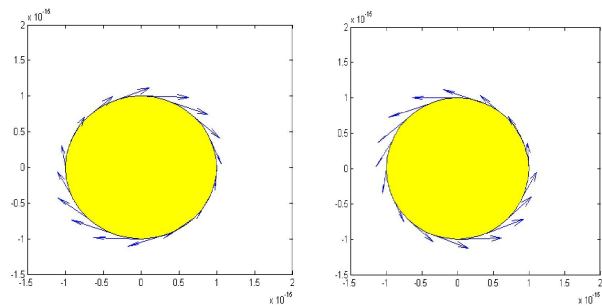


Figure 4: Vector plots of the DEP force experienced by an ellipsoid-shaped cell with off-centered nucleus.