Combination of vertical and planar electrodes for electrorotation and cell positioning in microchambers

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Particle positioning and uniform electrical fields are enabling features for electrorotation experiments. Different approaches have been proposed so far to position particles inside a chamber. Schnelle et al. introduced the use of optical tweezers [1] while Han et al. showed that by modulation of two electrical signals particles can be rotated while they are trapped by dielectrophoresis [2]. In both cases, additional equipment is required, thus increasing both cost and complexity of the setup. For what concerns the homogeneity of the electric field, vertical electrodes would bring clear advantages with respect to planar electrodes[3]. Here we propose a microfabrication process for an electrorotation chamber consisting of vertical electrodes with planar extensions at their base, to achieve particle rotation and cell positioning with only four electrodes.

3D electrodes have the advantage that the electrical potential can be applied over the full channel height. Therefore, the resulting electric field and the rotational torque will be homogenous, with the torque independent from the z-position [3]. In the absence of dielectrophoretic forces in the direction orthogonal to the chip surface, the cell would only be subjected to the torque and to the gravitational force which might cause sedimentation in the time frame of the experiments. For this reason, we propose to include planar electrodes, placed at the base of the vertical electrodes, extending toward the center of the rotation chamber. These features would serve to induce levitation forces on the particles and therefore enable the control of its z-position. We performed finite element simulations of the structures represented in figure 1a, featuring parabolic electrodes of 50 µm height and 60 µm facing-electrode spacing, in order to study the electric field generated. Planar electrodes extend from the 3D structures by 10 µm. We found that the resulting DEP forces in z-direction mainly affect the bottom part of the rotation chamber (Fig. 1b). Furthermore, changes in the rotational torque along the z-axis are minimal as there is less than 1% difference between the top and the bottom of the chamber (Fig. 1c). By making use of negative DEP forces particles will automatically be placed in the center of the microchamber, while the height of the particles can be adjusted with the amplitude of the applied voltage, making use of the DEP levitation principle [4] (Fig. 1d). With such electrodes, it is thus possible to achieve particle trapping in the center of the electrorotation chamber without the need for additional signals and electrodes.

[1] T. Schnelle, T. Muller, C. Reichle, and G. Fuhr, “Combined dielectrophoretic field cages and laser tweezers for electrorotation,” *Appl. Phys. B-Lasers Opt.*, vol. 70, no. 2, pp. 267–274, 2000.

[2] S.-I. Han, Y.-D. Joo, and K.-H. Han, “An electrorotation technique for measuring the dielectric properties of cells with simultaneous use of negative quadrupolar dielectrophoresis and electrorotation.,” *Analyst*, vol. 138, no. 5, pp. 1529–37, Mar. 2013.

[3] S. C. Kilchenmann, F. M. Spiga, and C. Guiducci, “3D electrodes in microfluidic channels for electrorotation experiments,” *Electrophoresis*, vol. submitted.

[4] P. R. C. Gascoyne and F. F. Becker, “Dielectrophoretic manipulation of particles,” *IEEE Trans. Ind. Appl.*, vol. 33, no. 3, pp. 660–669, 1997.

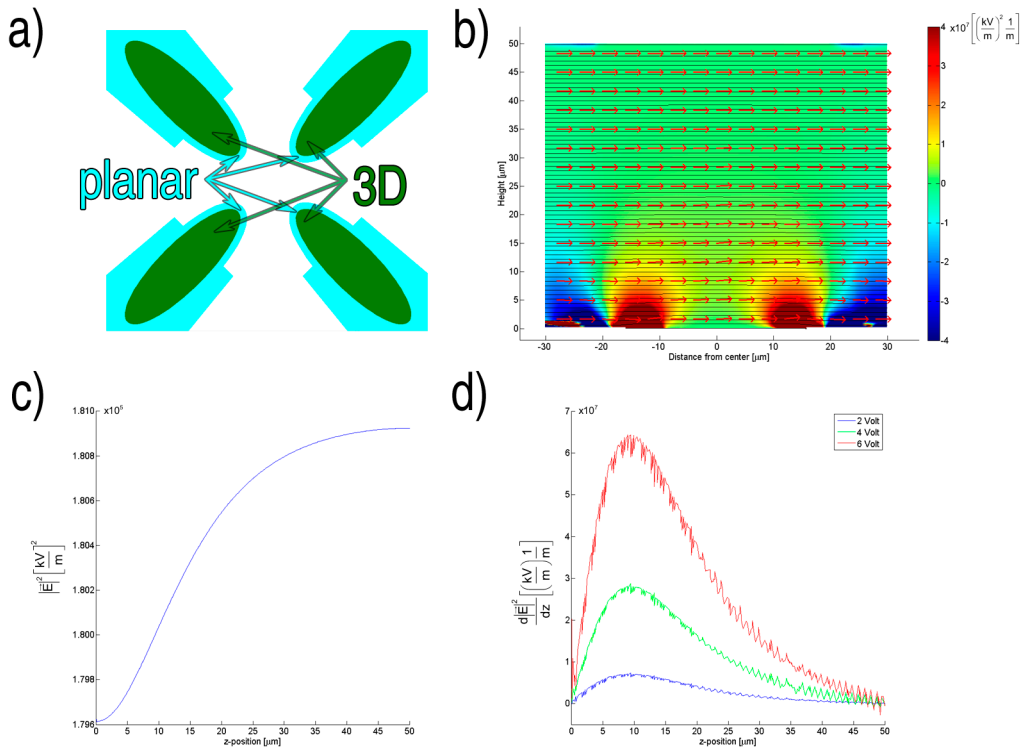


Fig. 1: a) top view of the extruded 3D electrodes (green) and their planar features (blue) b) simulation of DEP forces, the color indicates the z-component of the gradient of the electric field square (legend on the right), while the arrows indicate the direction of the DEP forces c) electric field square along the chamber centerline d) z-component of the gradient of the electric field square along the chamber centerline for different applied voltages.