Optimal Design of 3-D Carbon Micro-electrode Array for Dielectrophoretic Manipulation of Nanoparticles in Fluids

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***Abstract*—The 3-D carbon micro-electrode array, have been designed and simulated for dielectrophoretic manipulation of nanoparticles in fluids. The effects of electrode shape, applied voltage, electrode spacing and geometric size of the electrodes on the gradient in the electric field intensity is considered. Results show that the magnitude in the gradient in the electric field intensity produced by square column electrodes is relatively larger compared to other two electrode shapes, which is favorable to realize dielectrophoretic manipulation of particles; the dependence on the applied voltage is found to be on the order of the applied voltage squared, and as the spacing and the width is reduced, the magnitude of the gradient increases exponentially. With the increment of the height of electrode, the electric field is extended into wider space, which is beneficial to the improvement of manipulation efficiency and throughput.**

BACKGROUND

The manipulation of nanoparticles using electric fields has gained increasing importance with the development of miniaturized devices [1]. Dielectrophoresis (DEP) is one such method, exerting forces on particles via dipoles that are induced by electric field gradients [2].Through the years development of dielectrophoresis technique, the key lies in constructing the suitable configuration of the electrodes so as to obtain proper nonuniform electric field for each specific sample and achieved success in nanoparticles addressing, trapping, separation, transportation and etc. [3]. However, most studies were based on inertial metal electrodes with 2-D planar structure, which is costly, not biocompatible and not flexible. In the meanwhile, most of designs are plagued by a common problem (low throughput and efficiency), since the DEP force rapidly decays as the distance from the bottom of the planar microelectrode arrays increases [4]. In this study, we carried out the design and optimization of 3-D carbon microstructures for dielectrophoretic manipulation of nanoparticles, which can be fabricated from C-MEMS process [5].

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CURRENT RESULTS

Three types of common electrode shape are investigated, which is circular column, square column and triangular column electrode, as shown in Fig. 1. The effects of carbon micro-electrode array shape, width, spacing, height and applied voltage on the gradient in the electric field are presented one by one in the following. Fig.2 is a surface plot of the gradient in the electric field intensity produced by square column quadrupole electrodes. The gradient in the electric field intensity is sampled at vertical planes, the distance of which from the channel floor is 10μm. The magnitude of the gradient is taken logarithm, which is $\log_2 \left|\nabla\left(E\cdot E\right)\right|$.The height of electrodes are all 20μm. It is found that the gradient maxima in the electric field occur near the electrode edges, while the gradient maxima may vary from point to point for the same height since the gradient is proportional to the curvature of the point at the edge of electrode. The curvature of the point in the four edges and corners of square column is larger than other points, so the largest gradient is obtained in the corner. It is founded that square column electrode produce the largest gradient of the electric field which is favourable to improve DEP force and the property of the dielectrophoretic systems by comparative analysis as shown in the Fig.3. Therefore, square column electrode is the most suitable for dielectrophoretic manipulation. In Fig.4, the gradient in the electric field intensity, which is proportional to the DEP force, is plotted as a function of the applied voltages for different electrode geometric parameters. H is the height of electrode, L is electrode width, D is electrode spacing and S is the distance of sampled points from the channel floor. In Fig.5, the gradient is plotted as a function of the distance from the bottom of the channel for different electrode height. From the diagram we can obtain that the effective DEP force is extended into much wider space as the height of electrode increases. Therefore, a 3-D design used for the dielectrophoretic manipulation can significantly improve the efficiency and the throughput of the manipulation.

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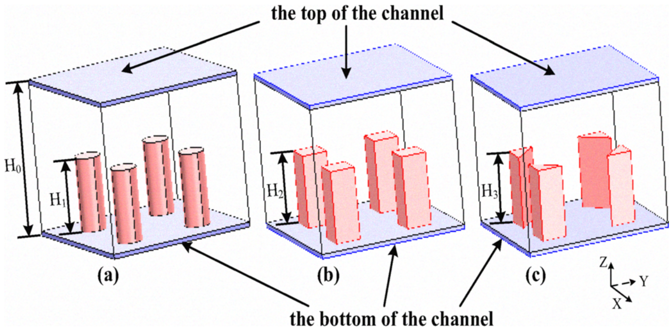

Fig.1 The schematic diagram of three-dimensional electrode; (a) circular column electrodes (extruded quadrupole configuration); (b) square column electrodes (extruded quadrupole configuration); (c) isosceles right triangular column electrodes (extruded quadrupole configuration).

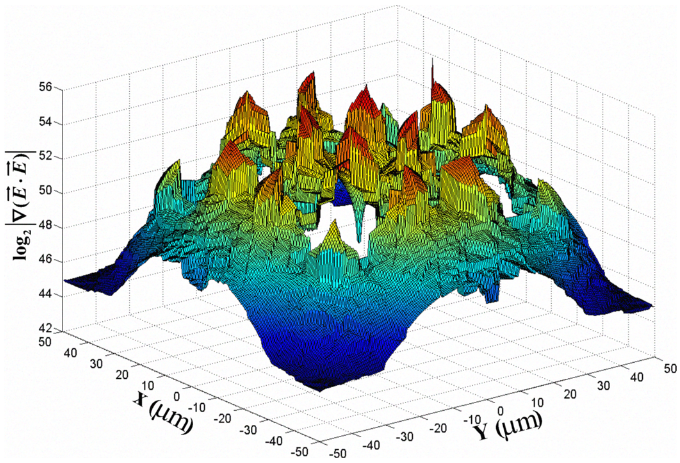

Fig.2 3-D surface plots depicting the magnitude $\log_2|\nabla(E\cdot E)|$ in various horizontal cross section at the height of 10μm above the channel floor for a 20μm high square column quadrupole electrodes

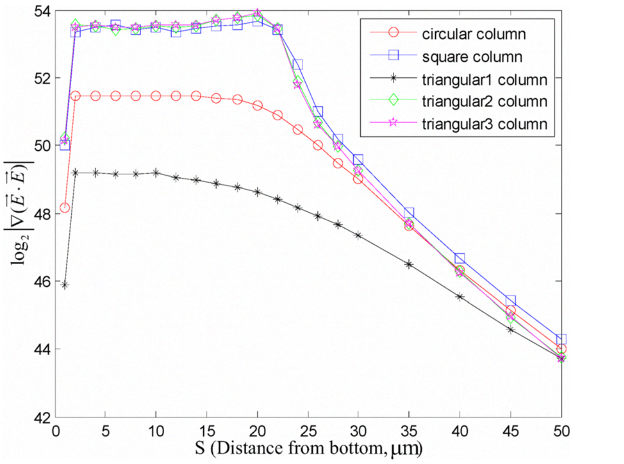

Fig.3 The magnitude of the gradient in the electric filed intensity as a function of the distance from the channel floor for different electrode shapes.

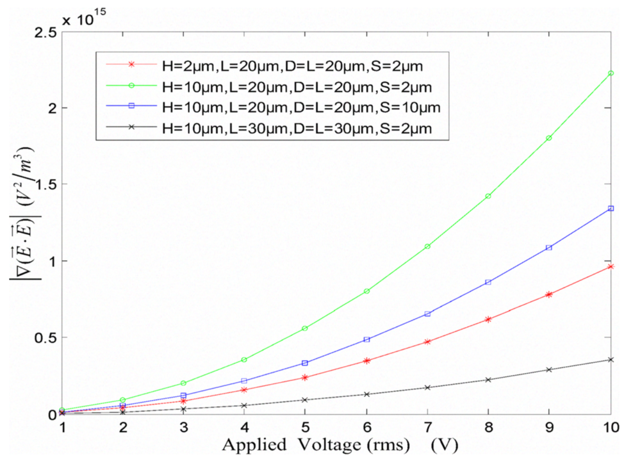

Fig. 4 The magnitude of the gradient in the electric filed intensity as a function of applied voltage V.

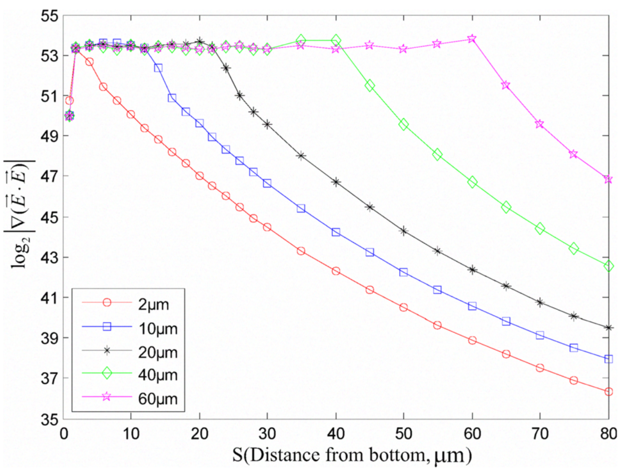

Fig.5 The magnitude of the gradient in the electric filed intensity as a function of the distance from the channel floor