

ELECTROHYDRODYNAMIC FILTRATION AND SEPARATION OF NANOPARTICLES USING DIELECTROPHORESIS

Part II: Experimental review

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Abstract

The separation of the nano-sized particles into distinct bands, spatially separated from each other has also brought considerable attention in many scientific areas recently. The filtration and controlled spatial separation of nanometric particles by a combination of dielectrophoretic and electrohydrodynamic forces is presented. Using planar microelectrode arrays, a mixture of two differently sized particles can be separated into constituent components. This paper aims to analyzing some of the most promising techniques that combine the use of dielectrophoretic and electrohydrodynamic forces for controlling the movement of nano-particles, in view of their selective sorting or filtration from a fluid.

1. Experimental

Nanometer sized particles can be both stably trapped in nanofabricated electrode arrays and, more importantly, that a heterogeneous mixture can be separated into two populations using dielectrophoresis.. A parallel, planar, interdigitated electrode array is depicted in figure 1 [1], [2]. When a potential is applied across alternating electrodes, this array establishes a nonuniform electric field dependent on dimensional and material properties. Particles suspended in a fluid experience a spatially varying DEP force that governs particle kinetics.

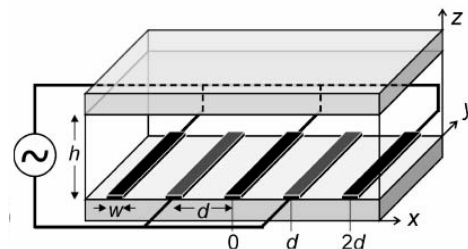


Figure 1: Schematic of the DEP patterning chamber with interdigitating bar electrodes (shaded) at bottom surface.

Experiments described in [2], [3] and [4] were conducted on charged latex spheres of 93 and 216 nm diameter, using planar electrodes manufactured by electron-beam lithography.

A scanning electron microscope image of the nanofabricated planar electrode arrays is shown in figure 2. This array had a feature periodicity of 6 μm and an electrode gap of 4 μm . In this way, the high electric field gradient regions are produced between adjacent tips together with well defined low field gradient regions in the bays.

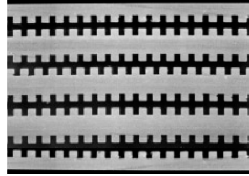


Figure 2: Scanning electron micrograph of a castellated microelectrodes array (grey) used for separation experiments.

At frequencies greater than 500 kHz, the particles behaved in a manner consistent with conventional dielectrophoretic theory. Particles experienced either positive or negative forces depending on whether the particles were more or less polarisable than the medium [2], [3].

For frequencies below 500 kHz the direction of the flow was constant, parallel to the substrate surface and perpendicular to the edge of the electrodes. The movement of the fluid exerted a viscous drag on the particles and at a certain threshold fluid velocity the particles move with the fluid flow in a direction that drove them onto the electrode surface and away from the electrode edge. This flow pattern is shown schematically in figure 3. As a result the 216 nm diameter particles were pushed into a plane of symmetry running along the top of the electrodes and perpendicular to the surface, a region which corresponds to a minimum in the electric field.

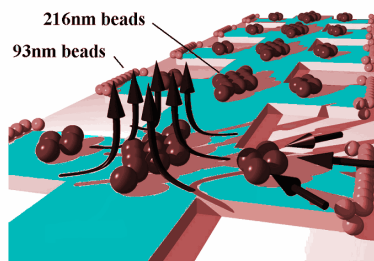


Figure 3: Schematic illustration of the fluid flow patterns observed on the microelectrodes at frequencies below 500 kHz. Fluid flow lines run parallel to the substrate. At the centre of the electrode the converging flows move upwards, perpendicular to the substrate.

The collection point in the centre of the electrodes was stable and it was observed that the 216 nm diameter spheres remained here for as long as the field was applied. At the same time the 93 nm spheres remained trapped at the electrode tips, under positive DEP forces, so that the two particle types were physically separated.

Based on phenomenological scaling data presented above, one can predict that nanoparticles and maybe even single molecules can be trapped to the center of the electrodes with a 10 nm gap under the bias of about 1 volt [5], [7]. As a future work, carbon nanotubes present a natural candidate as nanoelectrodes, as indicated in figure 5. This concept could provide a route to single molecule electronic devices which are actively fabricated.

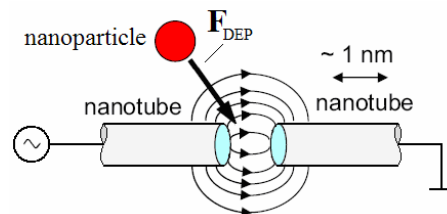


Figure 5: Schematic indication of the strongly divergent electric fields expected at the tip of a nanotube. These field gradients should exert strong influence which can overcome Brownian motion even at the molecular scale.

2. Lab-on-a-chip

In the lab-on-a-chip concept [2], [6], [7] all of the components are built in a single device. Often the manufacturing techniques have come from microelectronics, and have thus utilized silicon wafers etc, but also glass or plastics are used. Also, as nano-technology progresses, there is a rapidly growing need to manipulate small objects, such as carbon nanotubes, nanoparticles, etc. An increasingly important application of DEP is in selective separation of nanoparticles in lab-on-a-chip systems, and the feasibility of this has already been demonstrated for different types [2], [5]. Lab-on-a-chip microsystems are capable of performing high-throughput analyses, reducing the required processing time from hours to a matter of seconds. These devices allow for experimentation to be done with superior resolution, allowing for isolation and manipulation of single biological particles such as cells and viruses. Furthermore, lab-on-a-chip microsystems are cost-efficient because electronics can be integrated onto them and they are fabricated using processes in which they can be mass-produced. All of these factors make the future of lab-on-a-chip microsystems bright. Dielectrophoresis is the method used by the lab-on-a-chip concept. The scheme of a dielectrophoresis-based lab-on-a-chip designed to manipulate and detect nanometer scale particles is presented in figure 6:

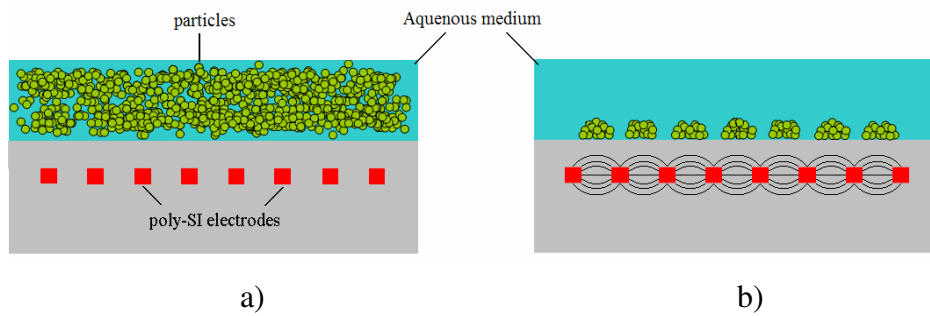


Figure 6: (a) Random distribution of particles contained within the fluidic trench of lab-on-a-chip, (b) Particles arranged by dielectrophoresis into a periodic grating pattern in the presence of electric field

The central components of the lab-on-a-chip design are the microfluidic trench and dielectrophoresis electrode array. The design of these components begins by designating a large area as an electrical contact pad and then chemically etching away the top-level metal layer.

References

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