



LAB MODULE 4: Dielectrophoresis

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Purpose and Expected Outcome:

The purpose of this laboratory module is to provide an introduction and a hands-on demonstration of dielectrophoresis on a chip. Microfluidic biochips with patterned silicon device with electrodes, and PDMS channels will be used to demonstrate trapping and concentration of micro-particles and cells in fluids. The students will be able to vary flow rates, voltage bias condition, and related experimental parameters to examine the interactions between the particles and the electric fields generated by the inter-digitated electrodes patterned on the chip. The expected outcome is for the students to gain a basic understanding of dielectrophoresis (DEP) and its potential applications for biology and medicine.

Overview of Dielectrophoresis:

Dielectrophoresis (DEP) is the electrokinetic motion of dielectrically polarized particles in non-uniform electric fields. The phenomenon arises from the difference in the magnitude of the force experienced by the charges at each end of the induced dipole when a spatially non-uniform electric field is applied, as shown in Fig. 1. The following is the DEP force equation, with given complex permittivity of the medium and the particle.

$$F = 2\pi\epsilon_s R^3 \operatorname{Re} \left(\frac{\epsilon_p - \epsilon_s}{\epsilon_p + 2\epsilon_s} \right) \nabla E^2$$

Many biologically important particles behave as dielectric particles in external electric field. They can be described by multi-shell model, in which the particle is assumed to be composed of thin membrane and internal material, with specific conductivity and permittivity. With this model, the strength of dielectrophoresis force on various biologically important can be estimated.

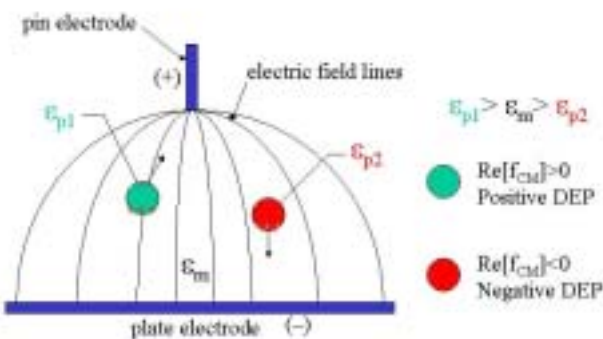


Fig. 1 Schematic illustration of dielectrophoresis

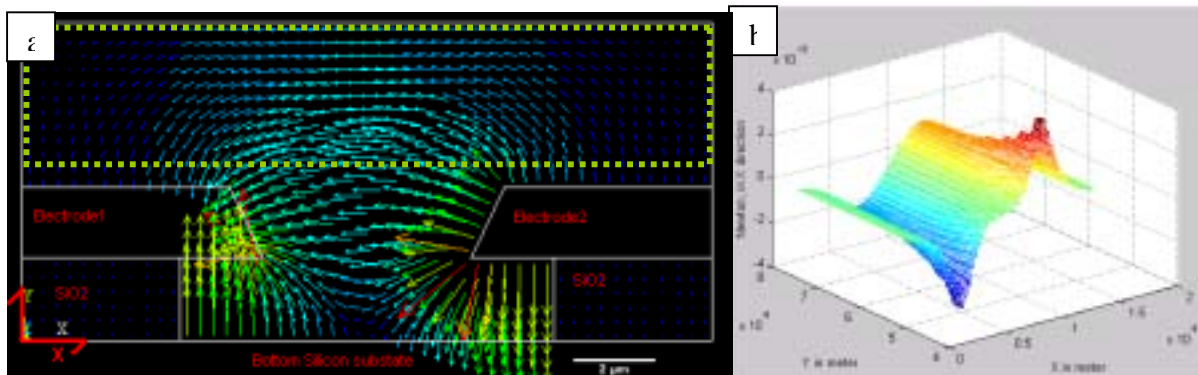


Fig. 2. An example of the DEP force simulation. (a) shows the electric field distribution inside the microfluidic channel. Electrode 1 and electrode 2 is assumed to be at +10V and -10V, and the Bottom silicon substrate is assumed to be grounded. As expected, a strong electric field is produced between each electrode and between electrodes and the bottom silicon substrate. (b) shows the calculated DEP force inside the yellow box in Fig. 1(a), in x-axis direction, with Clausius Mossotti factor of -0.2 and the particle size of 125nm.

Equipment, Materials, and Supplies:

- Microfluidic Biochips
- Syringe Pump
- Syringes, connectors, tubing
- AC Function Generator
- Upright Optical Microscope with at-least a 20X objective, preferably with dark-filed imaging and CCD camera. (10X in eye pieces – total magnification 200X)
- Poly-styrene 2um diameter particles in DI Water

Module Outline and Workflow:

The students are expected to experience the over all process to learn the DEP phenomena, from the sample preparation, device assembly and micro-fluidic connection, as well as DEP phenomena itself.

The student will prepare the poly-styrene beads in DI water, by diluting the original mixture. Also, they will assemble the PDMS cover and silicon device. Then, the tubing from the PDMS cover will be connected to the syringe pump and the sample solution with the poly-styrene particles will be injected. After confirming right flow rate of the sample solution, the electrical equipment will be connected and the setup will be mounted on the microscope as shown in figure 3. Then the students will apply the DEP signal and find the minimum DEP voltage and maximum flow rate which results in particle diversion and blocking.

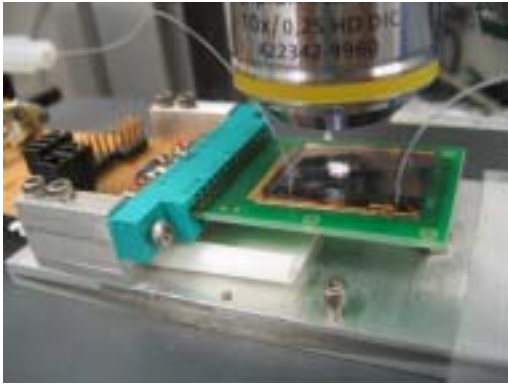


Fig. 3 The probe array is attached to the PCB for convenient electrical connection to DEP signals. The tubes are connected to input and output of the fluidic channel.

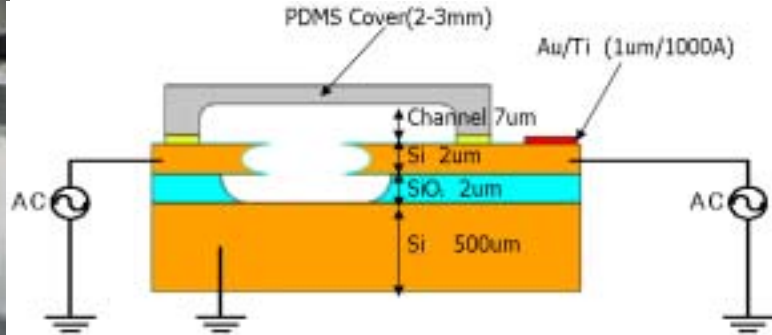


Fig. 4 The device is made from SOI (silicon-on-insulator) wafer. The silicon layer is doped to be very conductive etched to form electrodes. The buried silicon dioxide layer serves as an insulator.

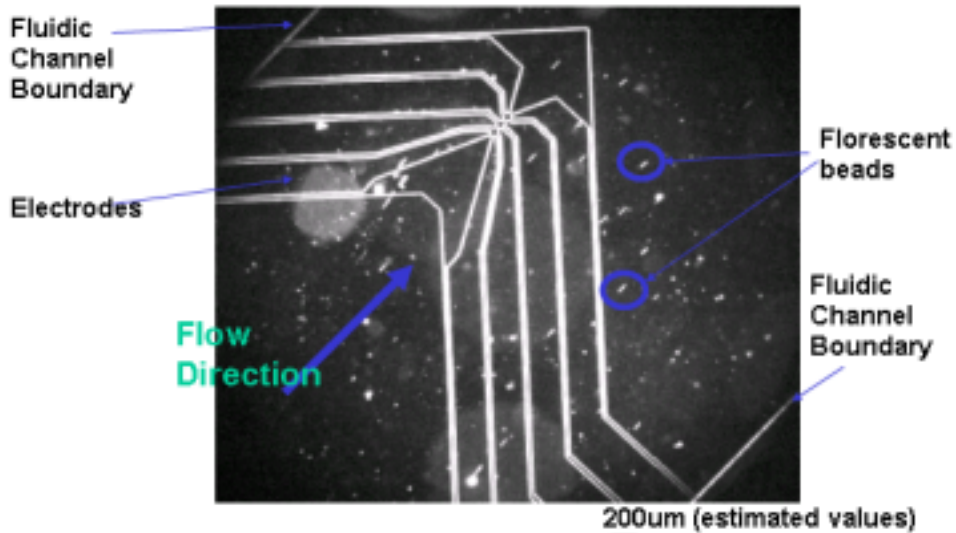


Fig. 5 Dark field images of the device, with fluorescently labeled 3um poly-styrene beads. The trajectories of the poly-styrene beads are visible as short lines, indicating the traveled distance within camera exposure time.

Related References:

1. P. R. C. Gascoyne, J. Vykoukal, "Particle separation by dielectrophoresis", *Electrophoresis* 2002, 23, 1973-1983.
2. Michael Pycraft Hughes, "Nanoelectromechanics in Engineering and Biology", CRC Press, 2002.
3. B. M. Taff & J. A. Voldman, J. A Scalable Addressable Positive-Dielectrophoretic Cell-Sorting Array. *Analytical Chemistry* 77, 7976-7983 (2005).
4. H. Li, Y. Zheng, D. Akin, R. Bashir, "Characterization and Modeling of a Micro-Fluidic Dielectrophoresis Filter for Biological Species", *IEEE/ASME Journal of Microelectromechanical Systems*. Vol. 14, No. 1, February 2005, pp. 105 - 111