Progress In Electromagnetics Research Letters, Vol. 2, 89–94, 2008

A CONCEPT OF MOVING DIELECTROPHORESIS ELECTRODES BASED ON MICROELECTROMECHANICAL SYSTEMS (MEMS) ACTUATORS

L. Li and D. Uttamchandani

Department of Electronic and Electrical Engineering
University of Strathclyde
Royal College Building, G1 1XW, UK

Abstract—A concept of moving dielectrophoresis electrodes (MDEP) based on Microelectromechanical Systems (MEMS) actuators is introduced in this letter. An example design of tuneable dielectrophoresis filter is presented. Finite Element Analysis of the electrostatic field of the tuneable filter has been conducted. Results show that the trapping force can be adjusted by actuating the MEMS actuators.

The principle of the dielectrophresis (DEP) is based on polarization of the dielectric particles under electrostatic field. Polarized dielectric particles can be moved toward the direction of the electric field gradient. Examples of polarized objects include dielectric materials, metallic particles, and many biological objects, such as nucleic acids, proteins, cells, and virus. DEP has been proven to be a powerful technique to perform sample sorting, trapping, manipulation, and concentration [1]. The classical DEP has been expanded to travelling wave DEP in order to get high throughput cell manipulation without external liquid pumping [2], CMOS DEP in order to achieve parallel manipulation of large number of cells [3], and laser induced DEP by optically programmable electrodes [4]. Microfabricated interdigitated electrode array was introduced previously [5] for application of separating two populations of particles pumped across the electrode array, one population of particles having positive dielectrophoresis and another having negative dielectrophoresis.

The above approaches are all based on fixed electrodes arrangement. A concept of moving dielectrophoresis electrode (MDEP) is introduced based on microelectromechanical systems

(MEMS) electrostatic or electrode thermal actuators in this letter. The electrostatic or electrothermal actuators were previously operated under the water [6], which proves the idea of MDEP very feasible. Previous research on interdigitated electrodes [7] shows that the DEP force changes with electrode dimensions (electrode width and gap) at a given voltage. If for example, the gap of the electrodes changes, the trapping force will also changes accordingly. A tuneable DEP filter as an example of MDEP is therefore generated, which is schematically shown in Figure 1.

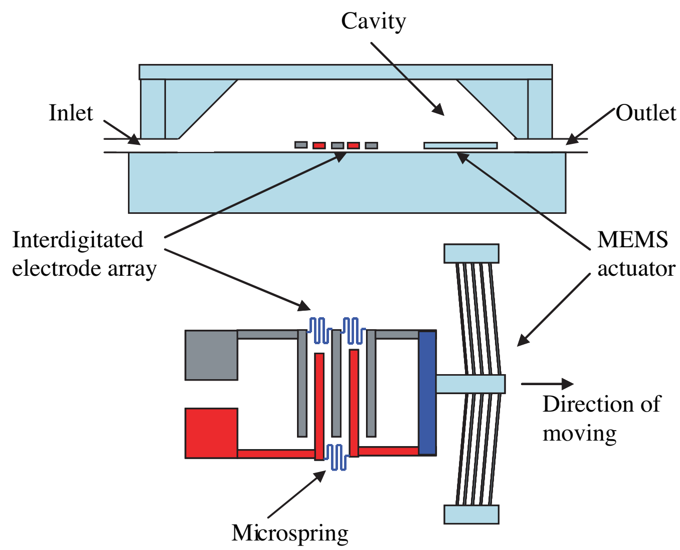

Figure 1. Schematic picture of a moving dielectrophresis electrode (MDEP) filter.

The interdigitated comb fingers act as two opposite electrodes of DEP, which can be stretched by either electrothermal or electrostatic actuators. There are microsprings connecting two adjacent comb fingers to allow uniform gap changing. Microelectrodes are electrically separated and mechanically connected with the microactuators, so that the driving signal for the microactuators does not affect the DEP electrodes. The microactuated electrodes can be fabricated easily using relevant MEMS foundries. The cavity contains micro particles such as cells can be manufactured using transparent dielectric materials, such as glass or sapphire. The two chips will be then flip-chip bonded to form a tuneable DEP filter.

Theoretical analysis of the DEP force of the tuneable filter is conducted in this letter to show the scale of the tenability. The expression of the DEP force F for spherical particles is well known and given as [8]:

$$F = 2\pi r^3 \varepsilon_m R_e[K] \nabla E^2 \tag{1}$$

whre r is the particle radius, E is electrical field, ε_m is the absolute permittivity of the suspending medium. $R_e[K]$ is the real part of the polarization factor, defined as:

$$K = \frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*} \tag{2}$$

where ε_m and ε_p are the complex permittivity of the particle and medium respectively. The complex permittivity for a dielectric material ε^* can be described by its permittivity ε and conductivity σ, $\varepsilon^* = \varepsilon - j\frac{\sigma}{\omega}$, here ω is the angular frequency of the applied electrical field E. From the Equation (1), the dimensions of the electrode (width and gap) determine the electrical field E at a given AC voltage. In the tuneable DEP filter design, the interdigitated electrode finger width is designed to be $20\,\mu$m, and the gap can be varied from $5\,\mu$m to $20\,\mu$m using MEMS actuators. The electrical field E of $5\,\mu$m, $6\,\mu$m, $7\,\mu$m, $10\,\mu$m, $15\,\mu$m, $20\,\mu$m gap electrodes array have been analyzed using Finite Element Method (FEM) with the CoventorWare NetFlow package [9]. The conductivity and permittivity of surrounding medium is taken to be xxx and xxx respectively. The thickness of the cavity is designed to be $20\,\mu$m. AC RMS voltage of 30 V has been applied to the electrodes. Figures 2–4 show the simulation results of the electrical field E generated by $5\,\mu$m, $10\,\mu$m, and $15\,\mu$m gap electrodes arrays. From the results, we can see that the electrical fields are symmetrical about the vertical line of electrode edge. As the gap become wider, the electrical field between the electrodes becomes weaker. The maximum electrical field is located in the corner of the electrodes. The maximum electrical field E_m of $5\,\mu$m is around $5.5\,\mathrm{V}/\mu$m, the E_m of 10 μm is around $3.2\,\mathrm{V}/\mu$m, the E_m of $15\,\mu$m gap is about $2.6\,\mathrm{V}/\mu$m.

The ∇E^2 along the vertical line of the electrode edge has been extracted from the FEM results, which is shown in Figure 3. It is clear shown that as the spacing of the electrodes increases, the ∇E^2 reduces, therefore the trapping force reduces. By adjusting the gap between the electrodes using MEMS actuators, the tuneable DEP filter can be realized.

In conclusion, a design concept of the tuneable DEP filter using MEMS actuators have been presented. FEM modelling of the electrical

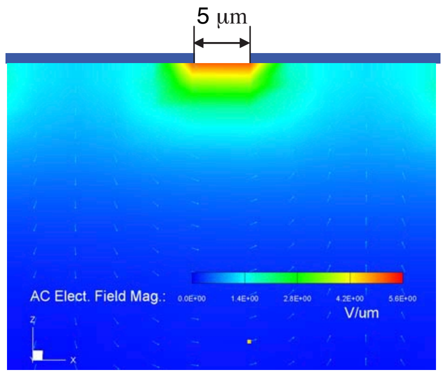

Figure 2. Electrical filed E of $5\,\mu$m gap.

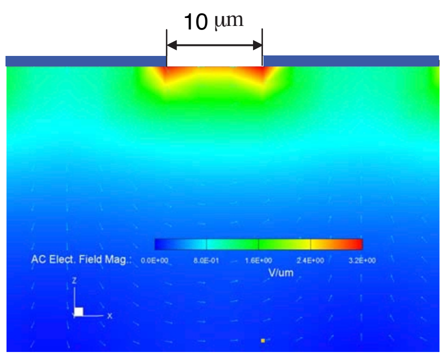

Figure 3. Electrical filed E of $10\,\mu$m gap.

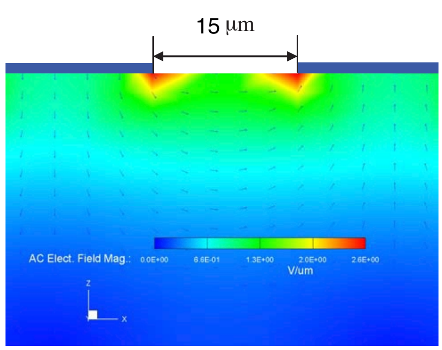

Figure 4. Electrical filed E of $15\,\mu$m gap.

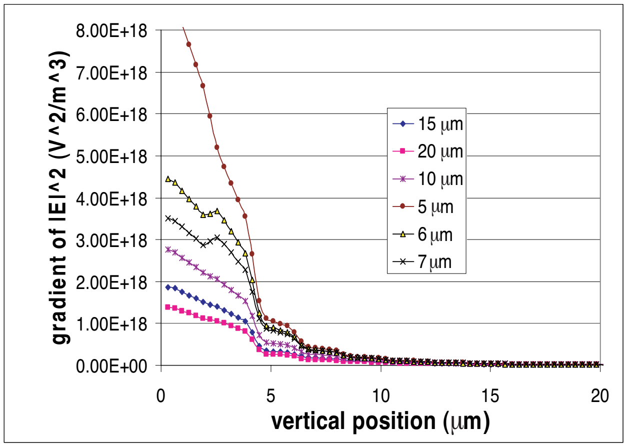

Figure 5. Electrical filed E of $15\,\mu$m gap.

fields of different electrode gaps have conducted in order to validate the concept. The simulation results show that with adjustable gap electrode array, tuneable trapping force can be achieved. The MEMS actuators operated in the water [] proves this idea is feasible from the MEMS point of view. Device manufacture is being pursued and will be reported in the future.

ACKNOWLEDGMENT

The project was supported by the Scottish Funding Council under the Scottish Consortium in Integrated Micro-Photonics Systems.

REFERENCES

1. Hughes, M. P., *Nanoelectromechanics in Engineering and Biology*, CRC Press, Boca Raton, FL, 2003.
2. Masuda, S., et al., "Separation of small particles suspended in liquid by non-uniform travelling field," *IEEE Trans. Ind. Appl.*, Vol. 23, 474–480, 1987.
3. Manaresi, N., et al., "A CMOS chip for individual cell manipulation and detection," *IEEE J. Solid-state Circuits*, Vol. 38, 2297–2305, 2003.
4. Chiou, P., A. Ohta, and M. C. Wu, "Massively parallel

manipulation of single cells and microparticles using optical images," *Nature*, Vol. 436, 370–372, 2005.

5. Li, H., Y. Zheng, D. Akin, and R. Bashir, "Characterization and modelling of a microfluidic dielectrophoresis filter for biological species," *Journal of Microelectromechanical Systems*, Vol. 14, No. 1, 103–112, Feb. 2005.
6. Sameoto, D., T. Hubbard, and M. Kujath, "Operation of electrothermal and electrostatic MUMPs microactuators underwater," *Journal of Micromechanics and Microengineering*, Vol. 14, 1359–1366, 2004.
7. Gadish, N. and J. Voldman, "High-throughput positive-dielectrophoretic bioparticle microconcentrator," *Analytical Chemistry*, Vol. 78, No. 22, 7870–7876, 2006.
8. Jones, T. B., *Electromechanics of Particles*, Cambridge University Press, Cambridge, U.K., 1995.
9. CoventorWare, Coventor Inc., http://www.coventor.com/.