NANOPARTICLE MANIPULATION BY DIELECTROPHORESIS

Universitatea de Vest din Timişoara

A. NECULAE, R. GIUGIULAN and M. LUNGU

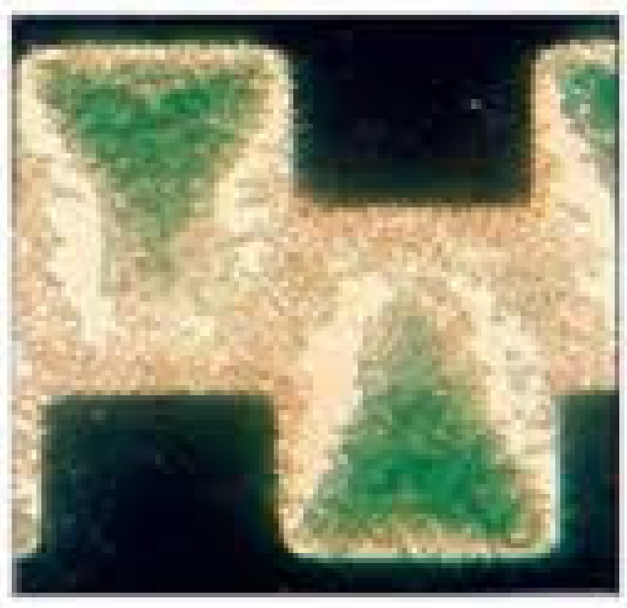
Faculty of Physics, West University of Timisoara, ROMANIA

PHYSICS UVT

Abstract

In the last decades, non-uniform electric field proved to be the most promising technique for nanoparticles manipulation with applications in fields such as medicine, biology, physics or nanotechnology.

The paper presents a set of numerical results concerning the influence of the dielectrophoretic (DEP) forces on a nanoparticle suspension. The DEP force depends on the electric properties of the nanoparticles, as well as their shape, size and mass, and the properties of the surrounding medium. The numerical study was performed in the frame of a mathematical model describing the electric field distribution and the suspended nanoparticle movement in a dense and viscous fluid. The equations are solved, together with the appropriate boundary conditions using a code based on the finite element method. The dielectrophoretic force distribution, the particle trajectories and the nanoparticle concentration profile are computed. This type of analysis leads to the optimization of the control parameters and is crucial in the designing process of an experimental microfluidic device with application in the separation of submicronic particles.



Cell separation by dielectrophoresis [2].

Problem formulation

- Equations for the computation of the electric potential:

$$V(\mathbf{x},t) = \mathrm{Re}\{\tilde{V}(\mathbf{x})e^{j\omega t}\}$$

$$\tilde{V} = V_R + jV_I$$

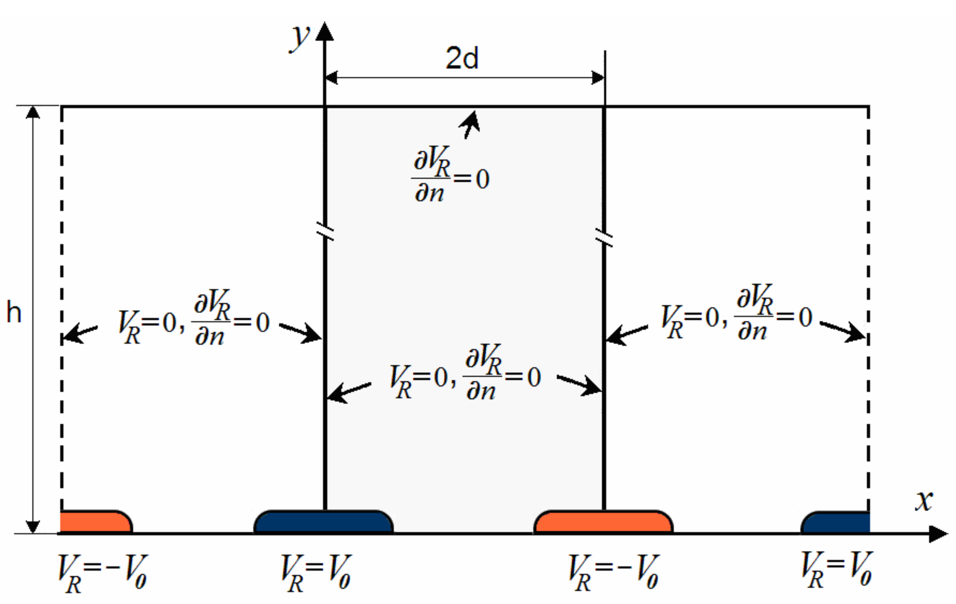
$$\nabla^2 V_R = 0 \quad \text{and} \quad \nabla^2 V_I = 0$$

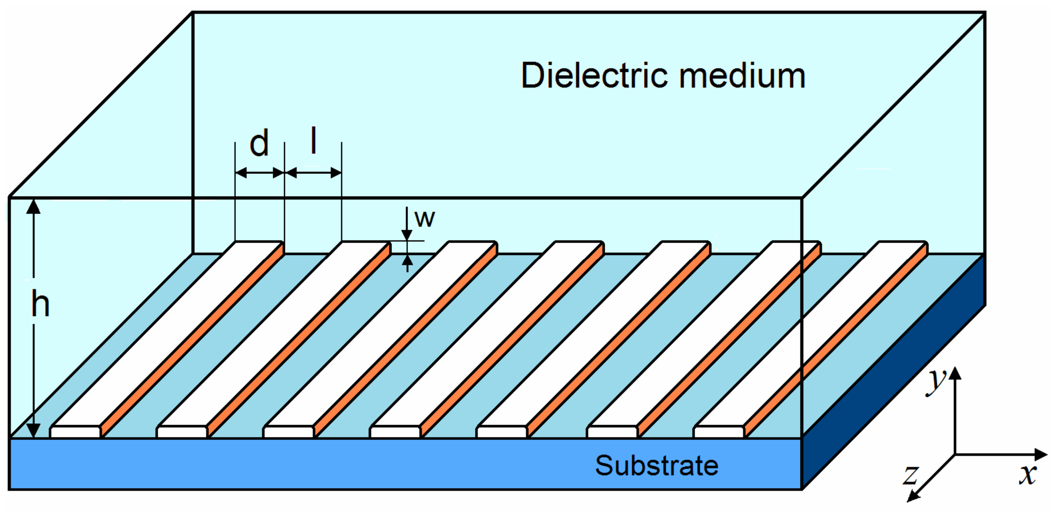
Dimensionless form of the equations (parameters):

$$V'_R = V_R/V_0,\ V'_I = V_I/V_0 \text{ and } \mathbf{x}' = \mathbf{x}/d$$

$$\tilde{k}(\omega) = \frac{\tilde{\varepsilon}_p - \tilde{\varepsilon}_m}{\tilde{\varepsilon}_p + 2\tilde{\varepsilon}_m}$$ **- the Clausius-Mossotti factor**

Boundary conditions:





Schematic representation of the computational domain for the DEP force calculation

- Dielectrophoretic (DEP) force:

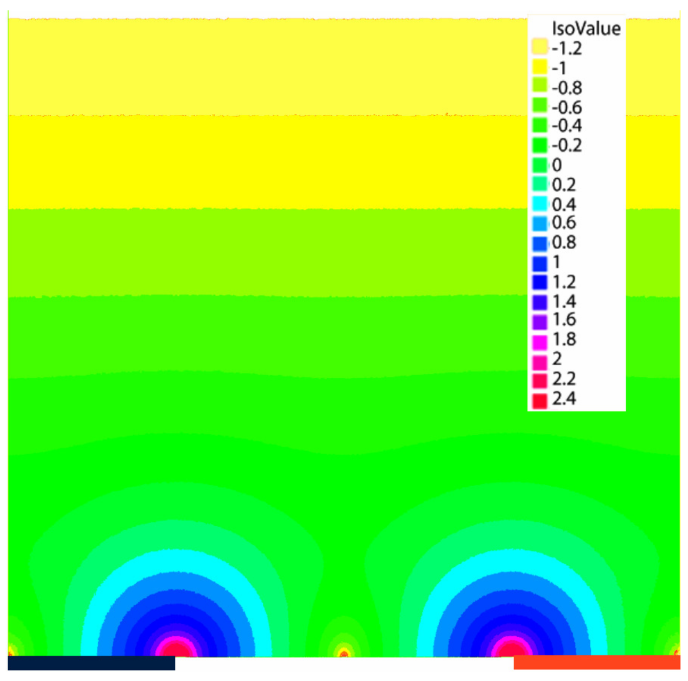
$$\langle \mathbf{F}_{DEP} \rangle = F_{0DEP} \nabla' \left(|\nabla' V'_R|^2 + |\nabla' V'_I|^2 \right), \quad \text{where} \quad F_{0DEP} = \frac{3}{4} \varepsilon_m \tilde{k}_r \frac{V_0^2}{d^3}.$$

- Equations describing the particle concentration field:

$$\mathbf{v}' = \mathbf{u}' + Q_s \mathbf{F}' \quad \text{where} \quad \nabla \mathbf{u}' = 0 \quad Q_s = 2a^2 F_0 d / 9\eta D$$

$$\frac{\partial C'}{\partial t'} + \nabla \cdot \mathbf{j}' = 0 \quad \text{where} \quad \mathbf{j}' = C'\mathbf{v}' - D\nabla C'$$

Numerical results



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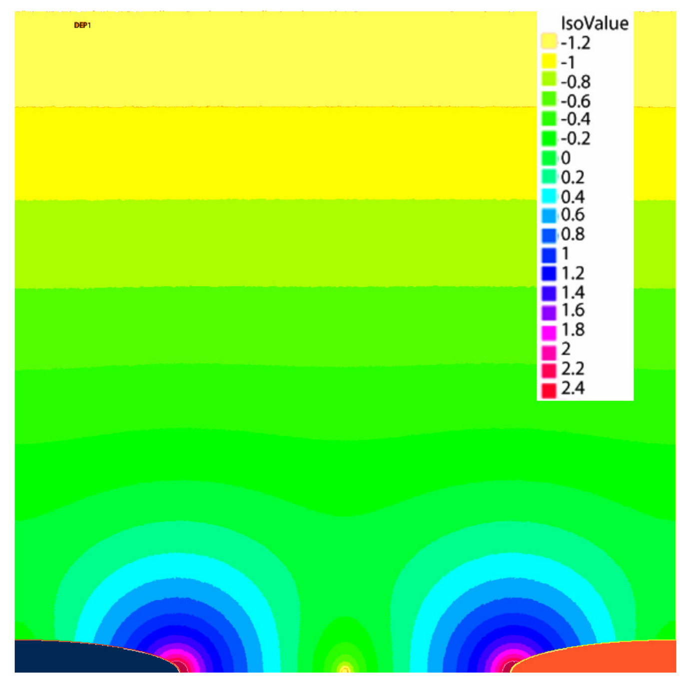
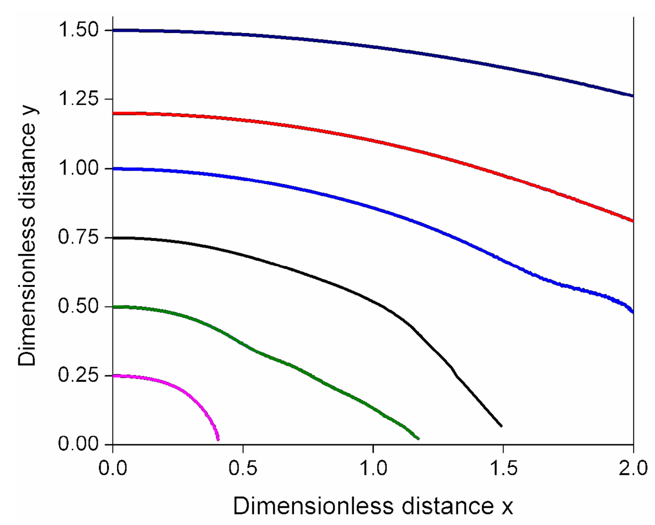


b)

Calculated values for the magnitudes of the dimensionless DEP force, plotted on logarithmic scale; (a) plane electrodes, (b) elliptic electrodes.



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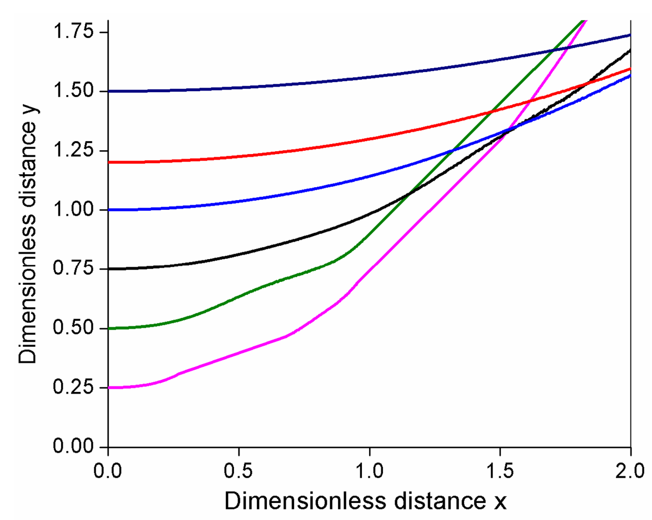
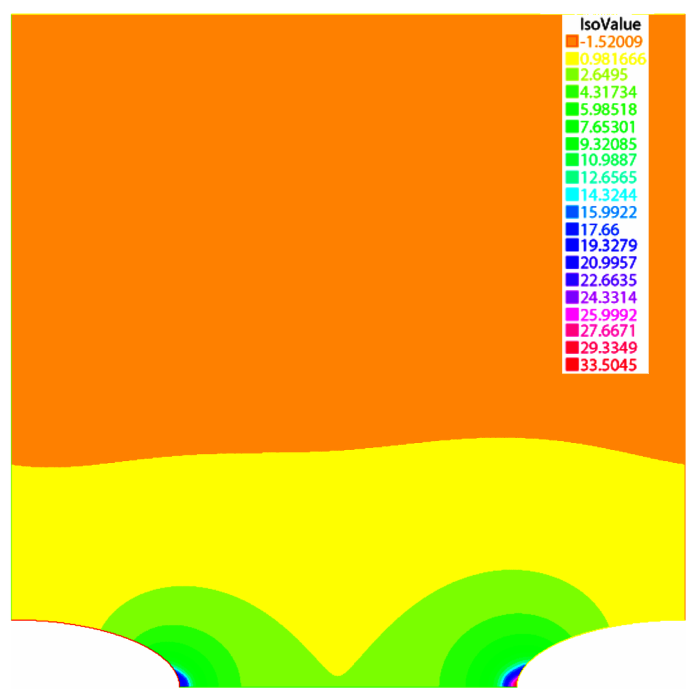
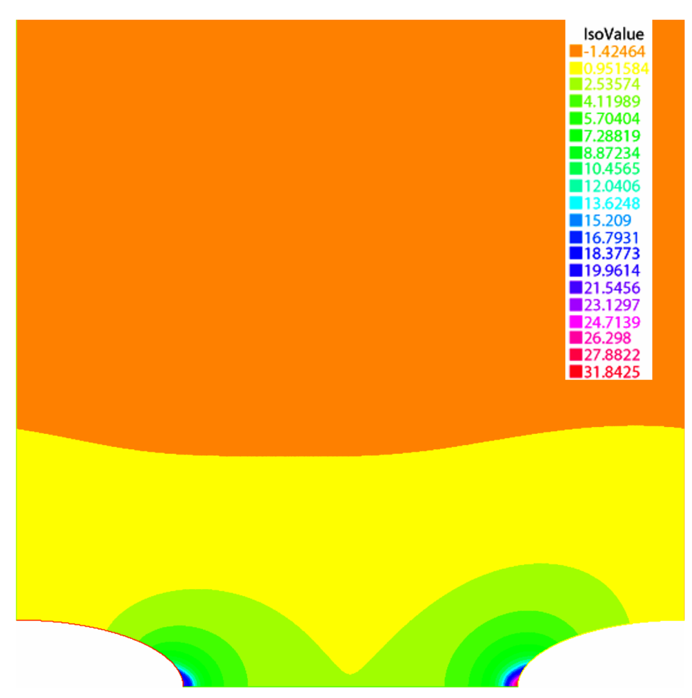


b)

Calculated particle trajectories in case of positive DEP (a), and negative DEP (b) respectively.



a)



b)

Positive DEP for Q_s=0.2 and v=1 (a), and v=10

Conclusions

- The paper presents a set of numerical results concerning the description of the nanoparticles behavior in a suspension under the action of DEP force.
- As the Clausius-Mossotti factor is a complex function of particle and fluid properties (permittivity, conductivity) and frequency of the applied field, a particle can experience both positive and negative DEP forces at different combinations of the above variables.
- The results reveal the influence of the main experimental parameters on the dielectrophoretic effect on the suspension's concentration field and provide an important tool in the particle manipulation within microfluidic systems.

References

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