Flow rate influence on the nanoparticle distribution in microfluidic devices under dielectrophoresis

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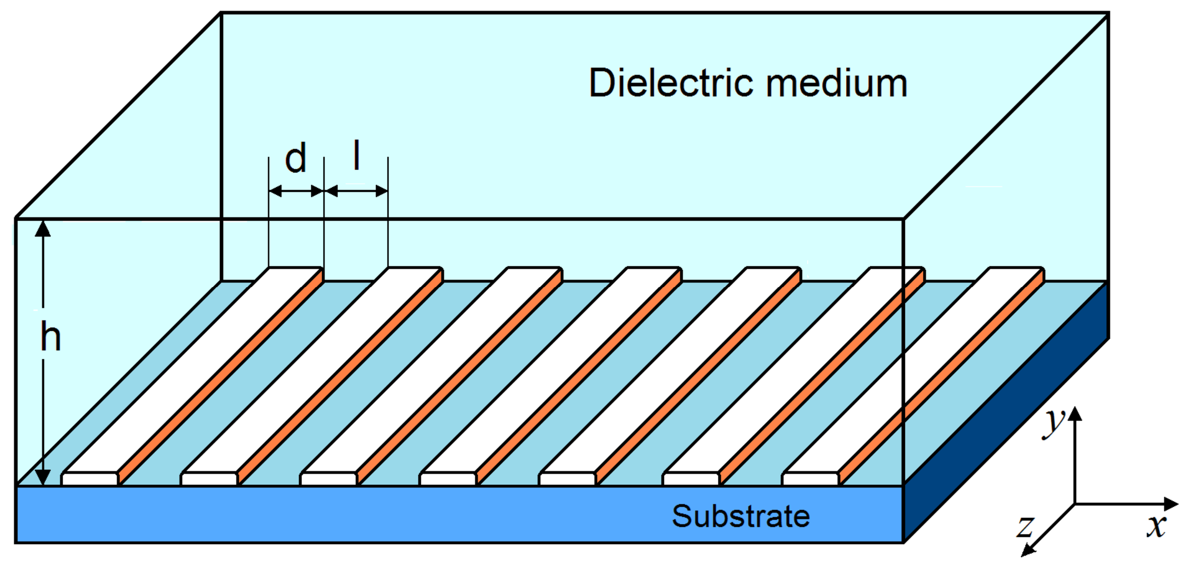
Abstract

Dielectrophoresis (DEP) in microchannels with interdigitated electrodes is one of the most promising tools used in the control of the nanoparticles manipulation in fluid media. Dielectrophoresis is a phenomenon that induces spatial movement of polarizable particle placed in a nonuniform electric field, depending on the electric properties of the particles and the surrounding medium. This paper presents a set of numerical results concerning the influence of flow rate on concentration distribution profile of nanoparticles suspended in a dense and viscous fluid in a microfluidic channel under DEP. The numerical study is performed in the frame of a two-dimensional mathematical model, the governing equations being solved, together with the appropriate boundary conditions, using a code based on the finite element method. 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.



Schematic of the dielectrophoretic patterning chamber with interdigitated bar electrodes at bottom surface used for DEP separation.

Mathematical model

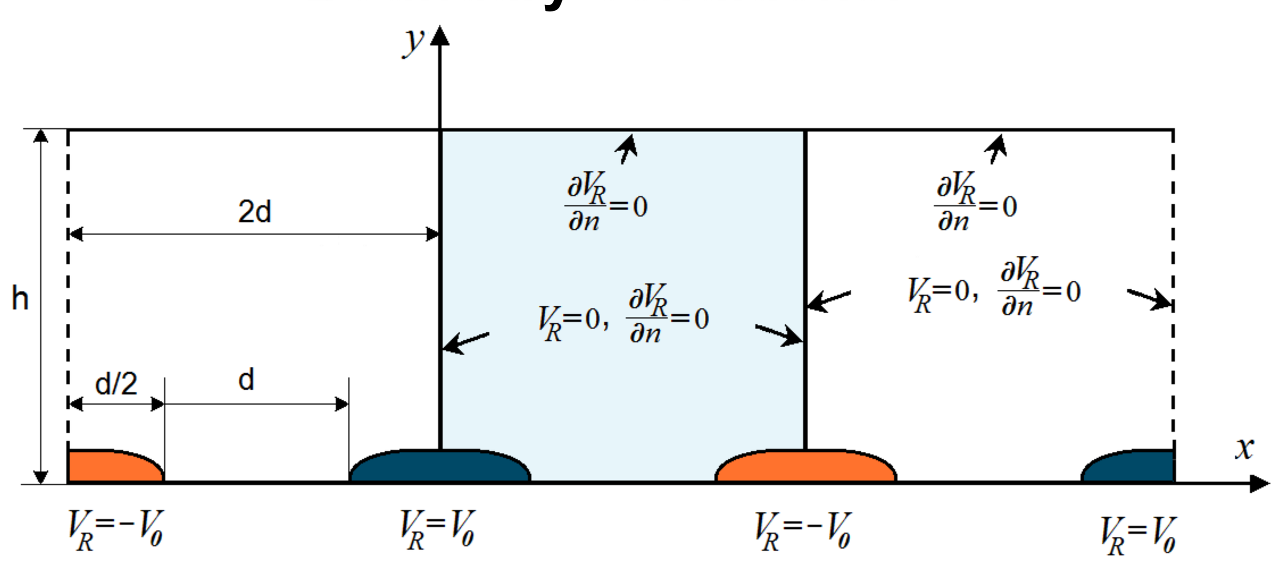
Computation of the electric potential:

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

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

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

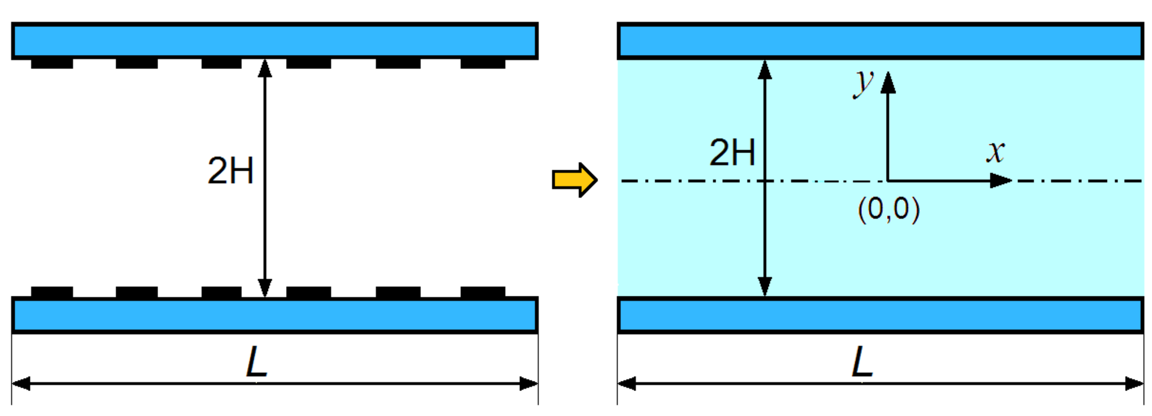
Boundary conditions:



A schematic representation of computational domain with geometrical proportions and boundary conditions for the real part V_R of the electric potential. The solid lines indicate the basic unit cell.

Dielectrophoretic force:

$$\langle \mathbf{F}_{DEP} \rangle = \frac{3}{4}\varepsilon_m \tilde{k}_r \nabla\left(|\nabla V_R|^2 + |\nabla V_I|^2\right)$$



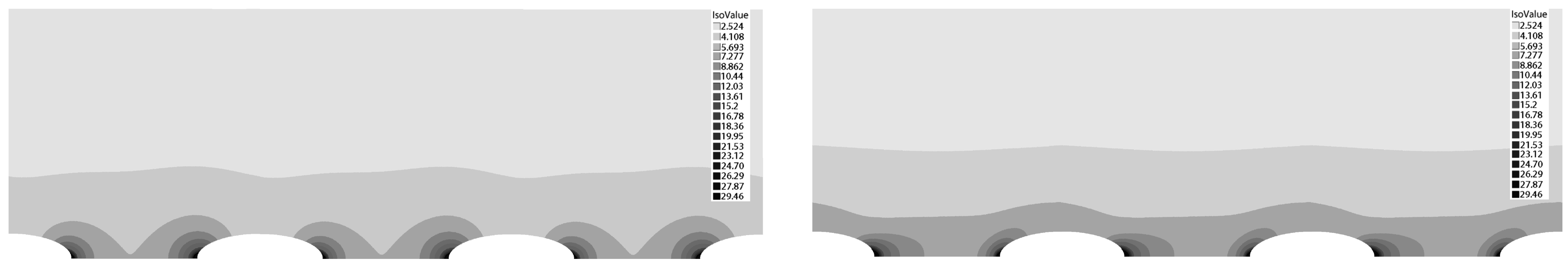
Simplified computational domain used for the concentration field calculation.

Computation of the particle concentration field:

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

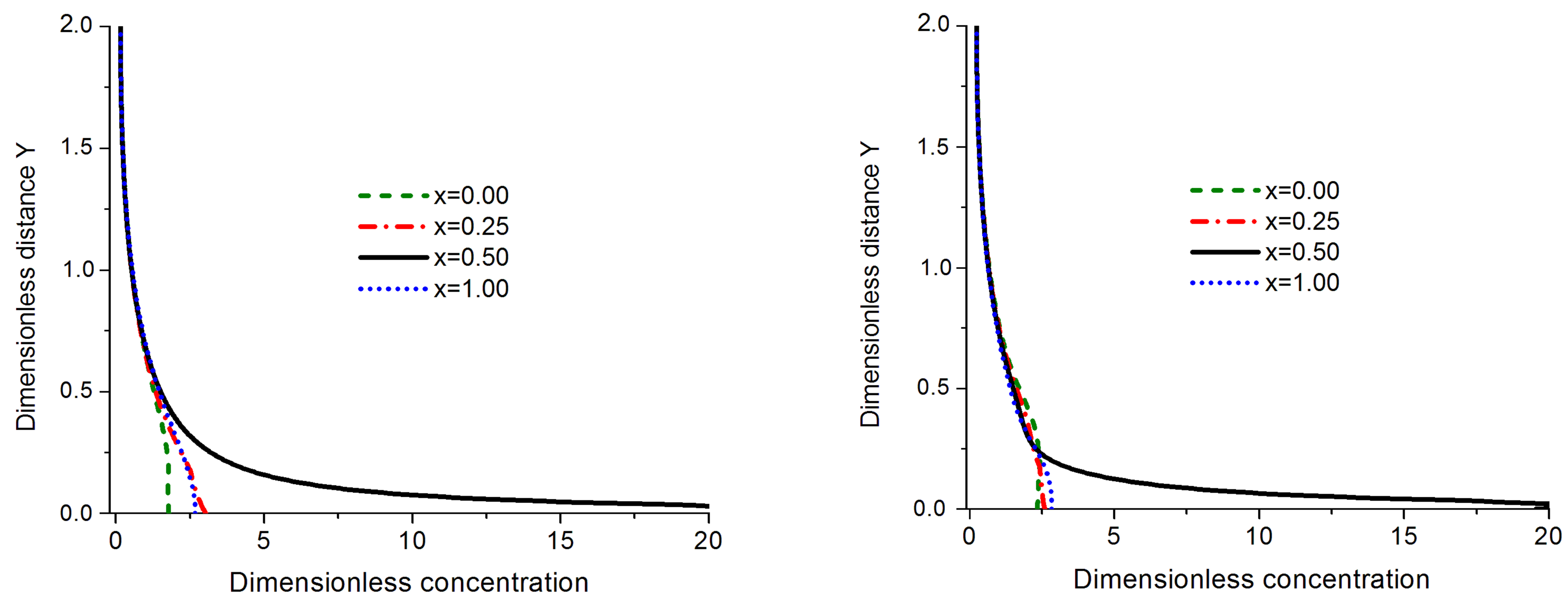
$$\frac{\partial C'}{\partial t'} + \nabla\cdot\mathbf{j}' = 0 \qquad \text{where} \qquad \mathbf{j}' = C'\mathbf{v}' - D\nabla C'$$

Numerical results



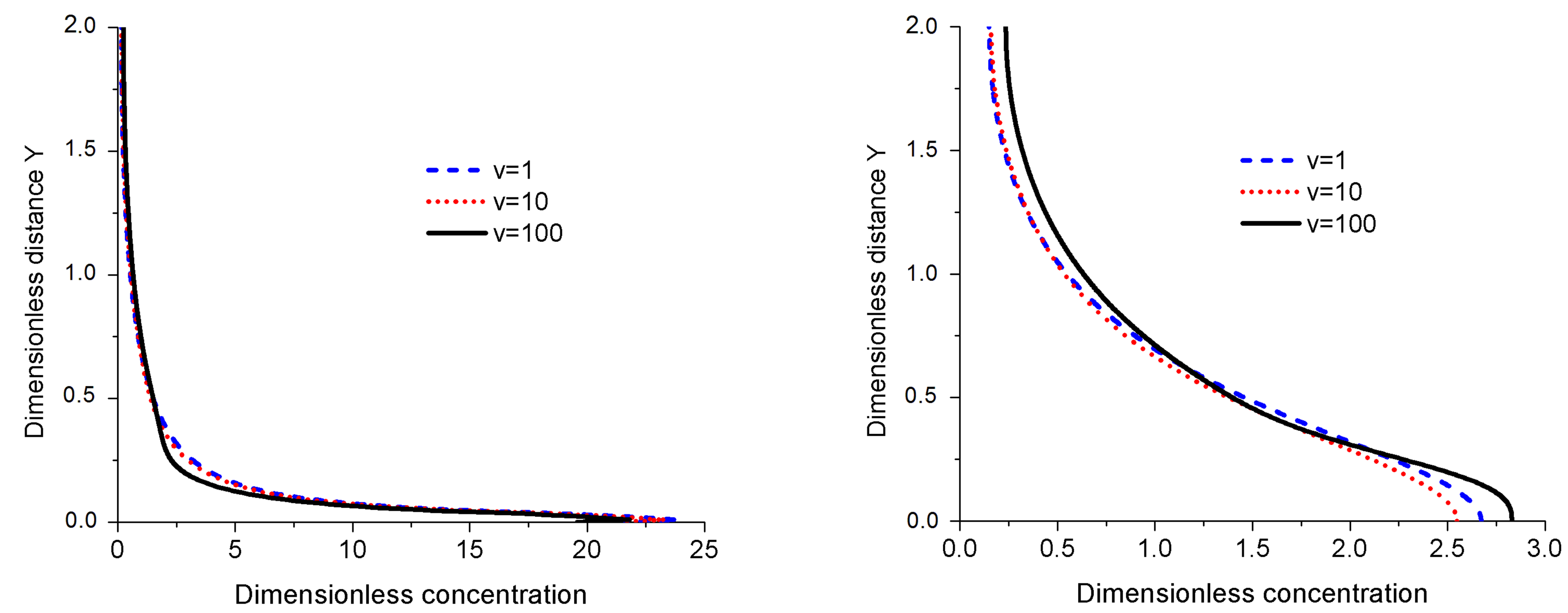
(a) (b)

Concentrations field for positive DEP at Fo=0.2 and v=1 (a), and v=100 (b).



(a) (b)

Concentration variations for positive DEP at v=1 (a) and v=100 (b).



(a) (b)

Concentration variations for positive DEP at x=0.5 (a) and x=1.0 (b).

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.
- The main goal is to investigate the role of the flow rate and of the geometrical parameters of the device on the concentration field.
- The numerical 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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