REDUCTION OF NANOPARTICLE EMISSION BY ELECTROHYDRODYNAMIC FILTERING OF RESIDUAL COMBUSTION GASES

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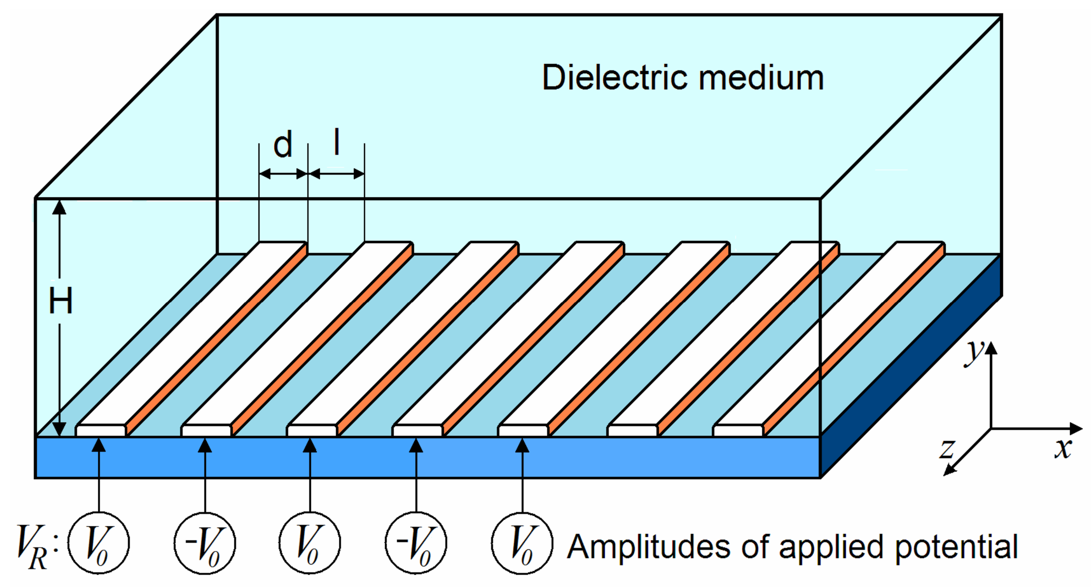
Abstract

The nano-sized particles are massively generated in combustion processes (waste incineration, internal combustion engines) and are highly toxic to human health. Therefore, the reduction of nanoparticles emissions in the air by filtering of the residual gases is a very important issue. The most promising nanoparticles manipulation and controlled spatial separation methods are those based on electrohydrodynamics, a combination of dielectrophoretic and hydrodynamic forces. Dielectrophoretic (DEP) force is exerted when a neutral particle is polarized in a non-uniform electric field, and depends on the dielectric properties of the particle and those of the suspending medium. The integration of DEP in microfluidic systems permits numerous applications in different areas as micro/nano particles manipulation and separation. The paper presents a 2-D model for the DEP-based separation micro system consisting of a micro channel controlled with an interdigitated electrode array and analyses the behavior of a nanoparticle suspension in a fluid under dielectrophoretic and hydrodynamic forces. A device for nanoparticle separation from combustion gases is proposed. The dielectrophoretic forces and the submicron particle concentration profile inside the proposed device are computed using a finite element code.



Schematic representation of the computational domain for the DEP force calculation

Mathematical model

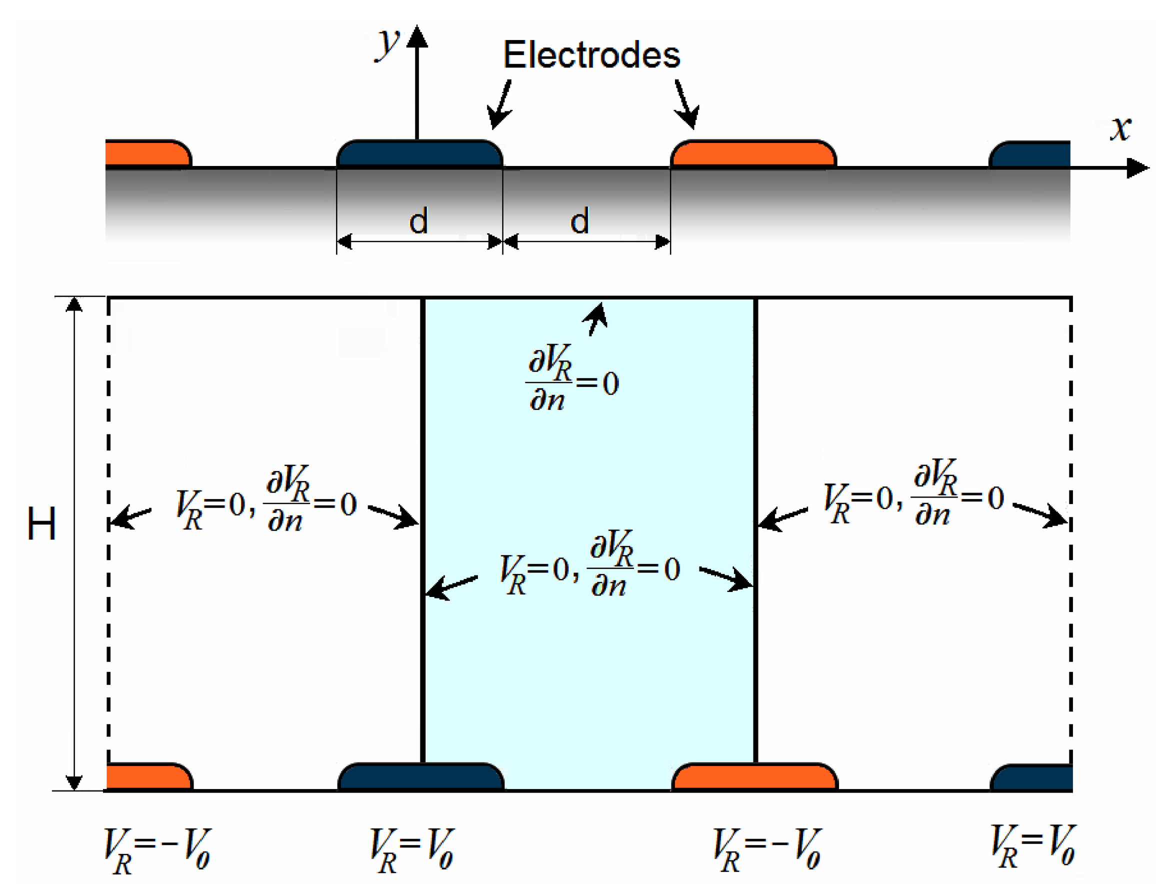
Computation of the electric potential:

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

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

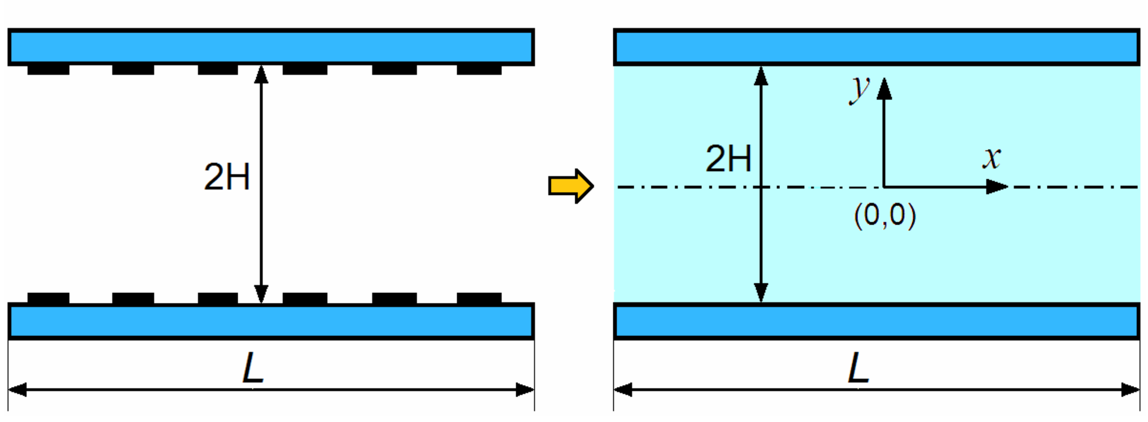
$$\nabla^2 V_R = 0 \quad \text{and} \quad \nabla^2 V_I = 0$$

Boundary conditions:



Dielectrophoretic force:

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



Simplified computational domain used for the concentration field calculation.

Computation of the particle concentration field:

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

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

Acknowledgements

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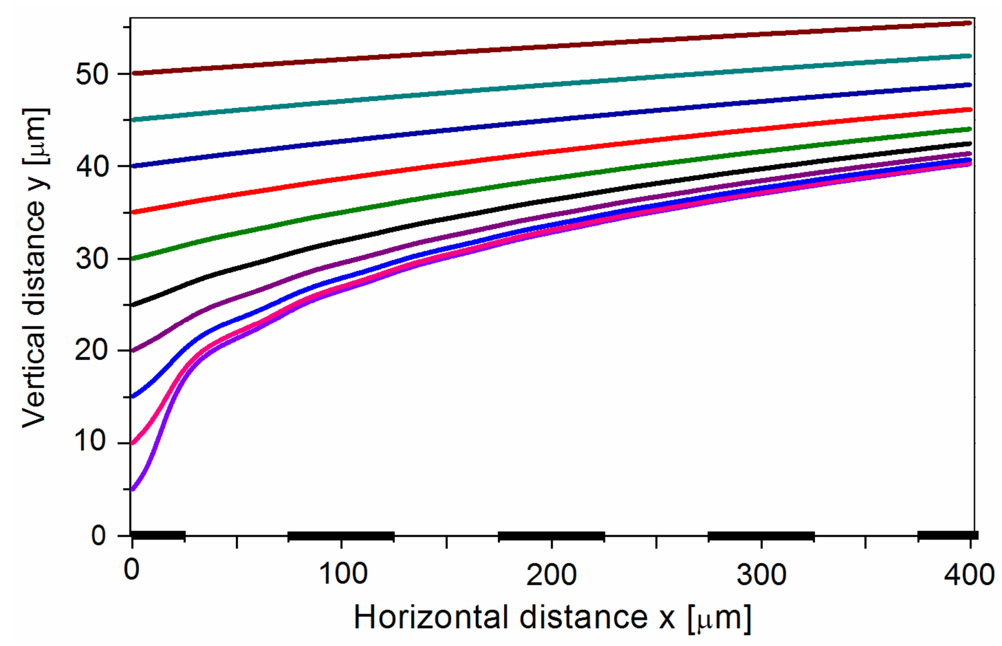
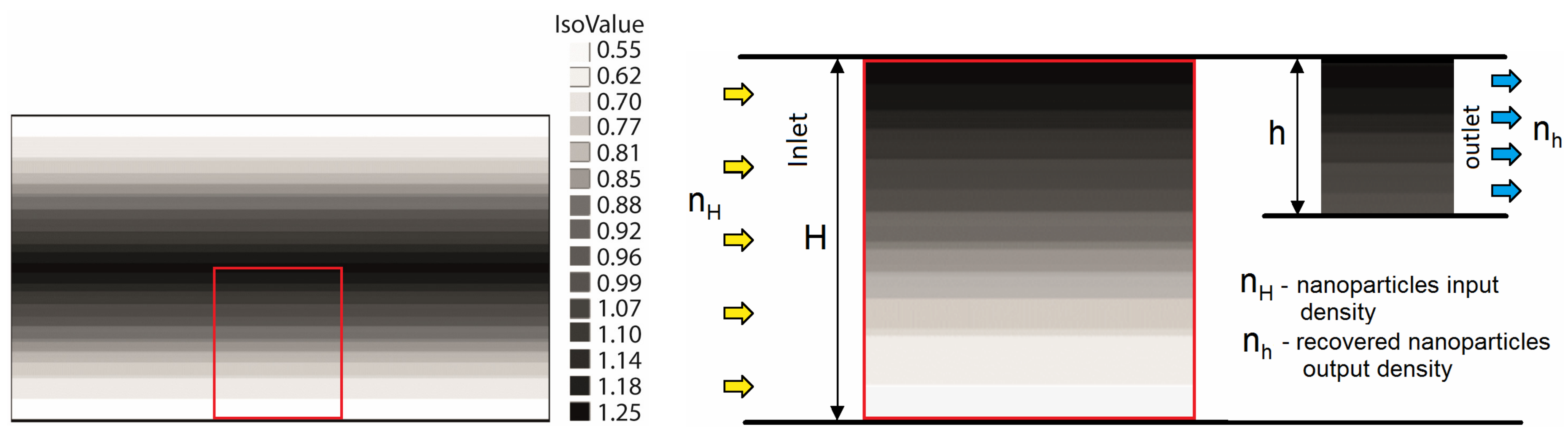
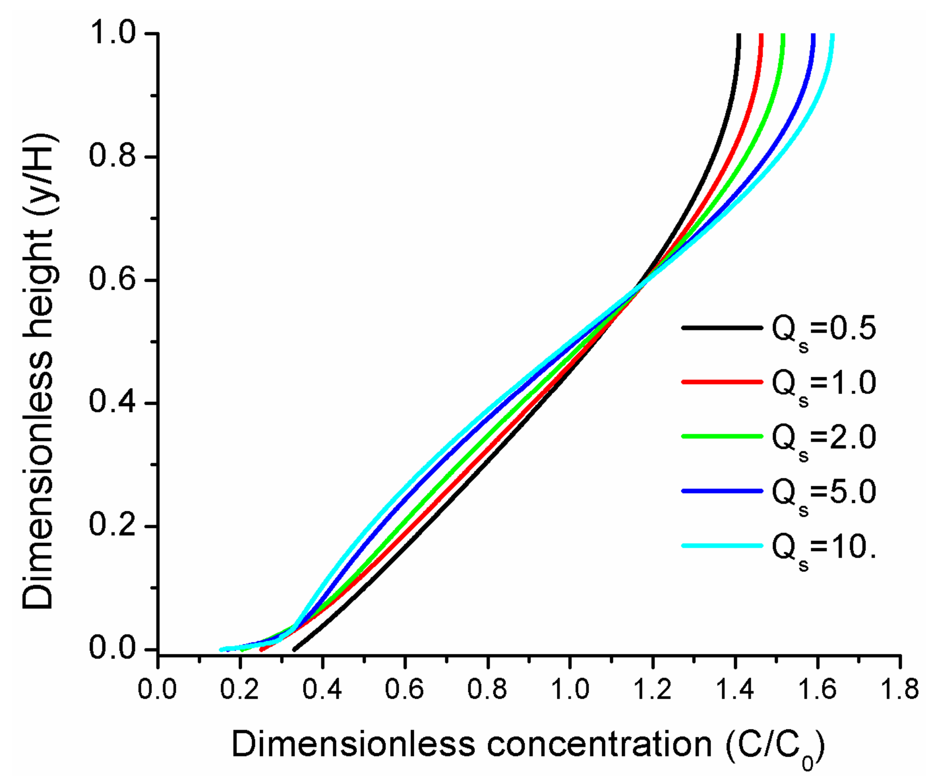
Numerical results



Particle trajectories computed in the vicinity of the electrodes:

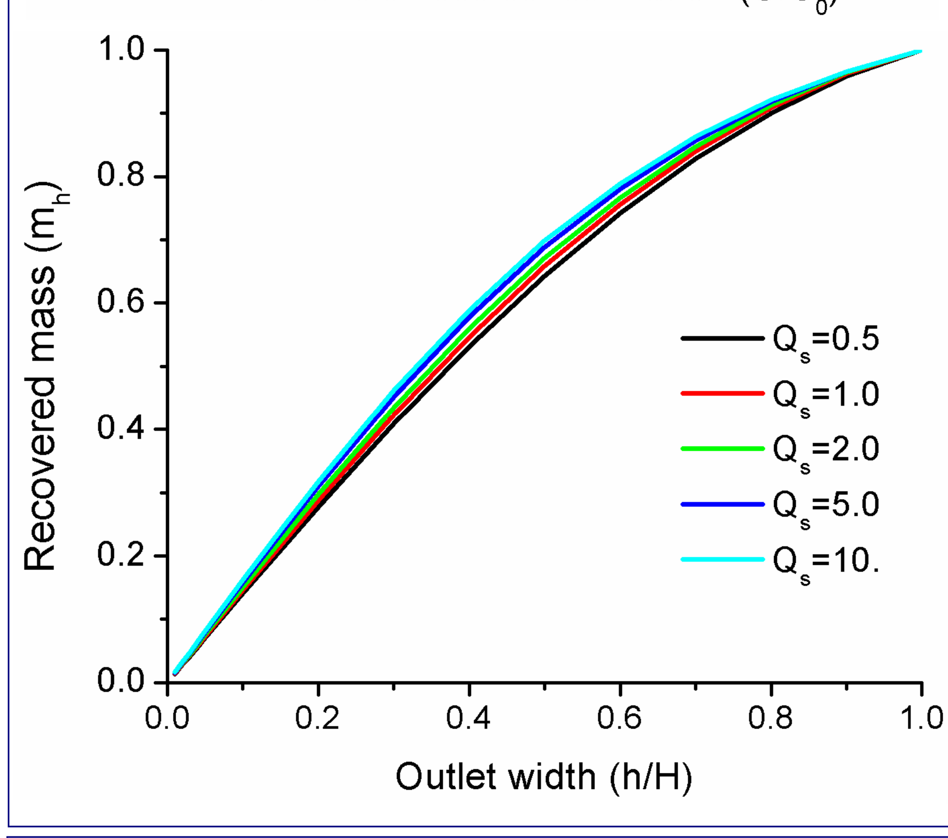
Concentration field computed in the simplified domain and detail with the recovery zone:

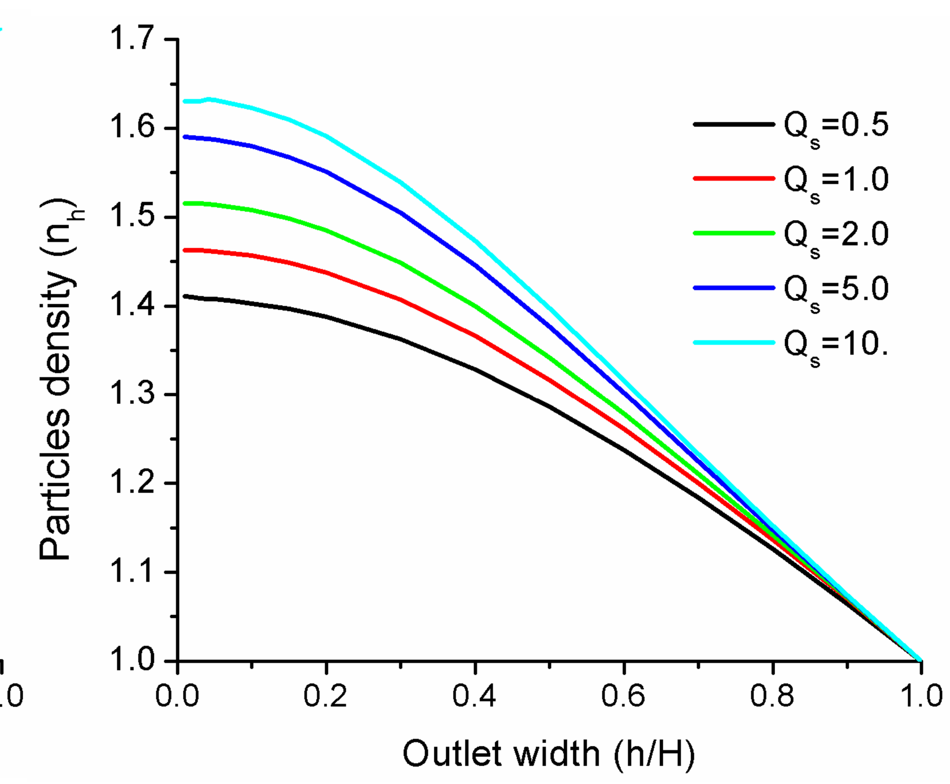




The distributions of concentration, recovered mass and particles density for different outlet width and DEP force intensities:

$$m_h = \int_0^h C' dy \;, \quad n_h = \frac{m_h}{h}$$





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