Anisotropic interactions between charged colloidal particles under external electric fields

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1. INTRODUCTION

We have developed a unique method for direct numerical simulations (DNS) of dense colloidal dispersions [1]. This method enables us to compute the time evolutions of colloidal particles, ions, and host fluids simultaneously by solving Newton, advection-diffusion, and Navier-Stokes equations so that the electro-hydrodynamic couplings can be fully taken into account. The electrophoretic mobilities of charged spherical particles are calculated in several situations. The comparisons with approximation theories show quantitative agreements for dilute dispersions without any empirical parameters; however, our simulation predicts notable deviations in the case of dense dispersions [2].

Recently, there observed experimentally the formation of string-like objects made of charged colloidal particles, similar to a "pearl chain" if external AC electric fields are applied. We have used our numerical method to investigate the mechanisms of this phenomena.

2. METHOD AND RESULTS

We calculated the force acting between a pair of particles fixed at a constant distance r with and without external AC fields. Distributions of ions become anisotropic under electric fields as schematically in Figure 1. This leads to an occurrence of anisotropic dipole-dipole type interactions which can be a possible mechanism for the pearl chain formation. The following equations [2] are solved simultaneously to examine this scenario.

i) The Navier–Stokes equation for fluid motions:

$$\rho(\partial_t + \vec{v}\cdot\nabla)\vec{v} = -\nabla p + \eta\nabla^2\vec{v} - \rho_e\nabla(\Psi + \Psi_{ex}) + \phi\vec{f_p}, \tag{1}$$

with incompressible condition $\nabla\cdot\vec{v} = 0$.

ii) The Newton's and Euler's equations of motions for colloid motions:

$$\dot{\vec{R}}_i = \vec{V}_i, \quad M_p\dot{\vec{V}}_i = \vec{F}_i^H + \vec{F}_i^c, \quad \boldsymbol{I}_p\cdot\dot{\vec{\Omega}}_i = \vec{N}_i^H, \tag{2}$$

iii) Advection-diffusion equation for ionic densities:

$$\partial_t C_\alpha^* = -\nabla\cdot C_\alpha^*\vec{v} + f_\alpha^{-1}\nabla\cdot((\boldsymbol{I} - \vec{n}\vec{n})\cdot C_\alpha^*\nabla\mu_\alpha), \tag{3}$$

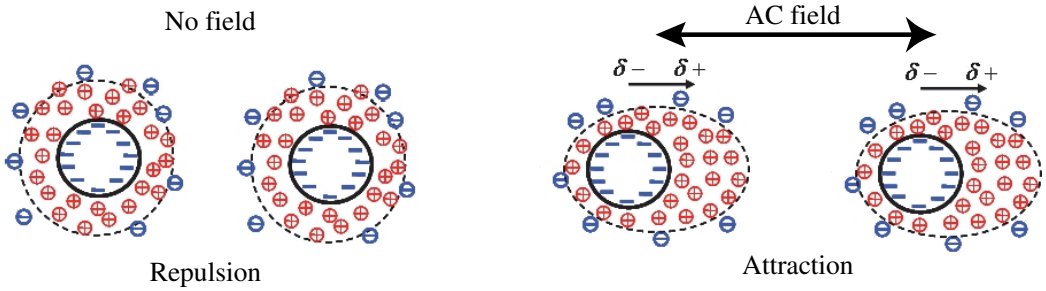

Figure 1: test

Surprisingly good agreements were obtained between our numerical results and experiments. We conclude that the present scenario is correct.

REFERENCES

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