Dynamics of colloidal particles in soft matters

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1. INTRODUCTION

Recently, colloids or nanoparticles suspended in complex fluids, such as liquid crystals and polymer solutions, have attracted considerable attention from its fundamental and practical importance. Although numerical simulation is a useful tool for studying their dynamic properties, there remain some difficulties originating from the long-ranged nature of hydrodynamic interactions. In order to study the role of such hydrodynamic interactions in colloidal systems, we have developed a new numerical method, which is named fluid particle dynamics (FPD) [1]. To get rid of the difficulty associated with the solid-fluid boundary condition on colloid surfaces, we regard a colloidal particle as an undeformable fluid one, which has much larger viscosity than the solvent. This method also allows us to straightforwardly introduce order parameters, such as charge density field and nematic orientational order, into the solvent.

2. Method

In our method, a colloid particle is described as a concentration field with a smooth interface profile in lattice space: $\phi(\mathbf{r})=[\tanh\{(a-|\mathbf{r}-\mathbf{R}_i|)/\xi\}+1]/2$ [1]. Here a and ξ are, respectively, the radius and interface width of the particle located at $\mathbf{R}_i$. We set the viscosity to be proportional to $\phi(\mathbf{r})$ and solve Navier-Stokes equation with the space-dependent viscosity. The position of a particle is updated in off-lattice space, using the particle velocity, which is calculated by spatially averaging the velocity field inside the particle. Here we study three types of colloidal systems immersed in soft matters, by introducing the following order parameters; ionic distribution $\rho(\mathbf{r})$ for charged colloidal suspensions [2], orientational order parameter $Q_{ij}(\mathbf{r})$ for colloids suspended in nematic liquid crystal [3], and concentration field $\Psi(\mathbf{r})$ for colloids suspended in a phase-separating binary fluid [4].

3. RESULTS AND DISCUSSIONS

Here we show results on colloids suspended in nematic liquid crystal [3,5]. We study colloids accompanying Saturn-ring defects. It is known that for this case the interparticle interaction has the quadrupolar symmetry [Fig. 1(a)]. In addition to this, we found a new type of interaction, which is induced by a disclination line with the figure of eight shape [Fig. 1(b)]. The dislination line tends to shrink to reduce the elastic energy and bind the particles, but cannot cross itself due to the large energy barrier associated with the topological change of the defect [3]. Application of our method to the other systems will also be presented in the presentation.

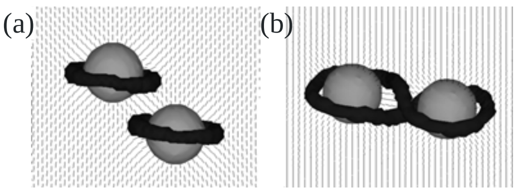

FIG. 1 Stable configurations of a particle pair in a nematic liquid crystal, due to a quadrupole symmertry (a) and a single stroke disclination (b).

REFERENCES

1. H. Tanaka and T. Araki, Phys. Rev. Lett. **85**, 1338 (2000); Chem. Eng. Sci. **61**, 2108 (2006).
2. H. Kodama, K. Takeshita, T. Araki and H. Tanaka, J. Phys.: Condens. Matter **16**, L115 (2004)
3. T. Araki and H. Tanaka, J. Phys.: Condens. Matter **18**, L193 (2006); Phys. Rev. Lett. **97**, 127801 (2006).
4. T. Araki and H. Tanaka, Phys. Rev. E **73**, 061506 (2006); to appear in J. Phys.: Condens. Matter.
5. See a review, H. Stark, Phys. Rep. **351**, 387 (2001); M. Ravnik *et al*., Phys. Rev. Lett. **99**, 247801 (2007).