Dynamics of Ions in Nematic Liquid Crystals

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Abstract

ネマチック液晶中の荷電粒子が与える静的、および動的な効果について、Ginzburg-Landau 理論の枠組を用いて議論する。(i) ネマチック相にある液晶に荷電粒子を配した場合の、配向秩序の変形、およびその結果としての欠陥生成について調べた。特に荷電粒子の及ぼす寄与が強い場合、粒子近傍で電荷誘起のアンカリング現象が期待される。(ii) 定常電場、および振動電場を与えた場合の、ネマチック液晶中の荷電粒子の運動について調べた。我々の数値計算の結果は、電荷の効果が顕著になるに従い、移動度が小さくなることを予測する。これは、電荷の効果が強くなるにつれ、配向秩序が変形する空間領域が拡大するため、有効的な流体半径が増大すると理解できよう。また、多数の荷電粒子が液晶に浸されている場合の複雑な現象に付いても、併せて報告したい。

1 Introduction

Over the years, the physical properties of charged particles in solutions have been central reserch subjects in physical chemistry, and they still provide many unsolved fundamental problems. In this presentation, we report both static and dynamic nonlinear effects of charged particles in nematic liquid crystals.

2 Model

Recently, one of the authors presented a general Ginzburg-Landau theory for the electric field effects in nematic liquid crystals[1, 2].

$$F = \int d\mathbf{r}\left(f_{LdG}(\overleftrightarrow{\mathbf{Q}}) + \frac{1}{2}L|\nabla \overleftrightarrow{\mathbf{Q}}|^2 + \frac{1}{8\pi}\mathbf{E}\cdot \overleftrightarrow{\epsilon} \cdot\mathbf{E}\right), \tag{1}$$

where f_{LdG} is the Landau-de Gennes free energy density, the second term is the Frank energy density, and the last term is the electric contribution. The dielectric tensor $\overleftrightarrow{\epsilon}$ depends on $\overleftrightarrow{\mathbf{Q}}$ as $\overleftrightarrow{\epsilon} = \epsilon_0 \overleftrightarrow{\delta} + \epsilon_1 \overleftrightarrow{\mathbf{Q}}$. Thus, the electric potential Φ is given by solving the equation $\nabla\cdot \overleftrightarrow{\epsilon} \cdot\nabla\Phi = -4\pi\rho$. Based on the above free energy and the elecric potential, we numerically investigate charge effects in nematic liquid crystals, by solving liquid crystal hydrodynamic equations in 3D.

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3 Numerical Results

First, we show contour surfaces of the Frank elastic energy density around a chraged particle in nematic states in Fig.1. We can see the charge-induced anchoring, which becomes more remarkable with increasing ϵ_1/ϵ_0.

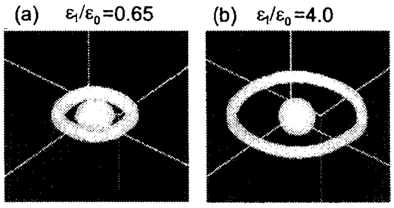

Figure 1: Contour surfaces of the Frank energy density $L|\nabla \overleftrightarrow{\mathbf{Q}}|^2/2 = L/400\ell_B^2$.

Next, we examine the dynamics of a charged particle under constant electric fields for various values of ϵ_1/ϵ_0. In Fig.2(a), the effective mobility of the charged particle for relatively weak applied fields in steady states is plotted. Our numerical results predict that the effective mobility decreases as $(\epsilon_1/\epsilon_0)^{-1/3}$. This should be because the spacial region where the director orientations are strongly deformed expands, so that the Stokes radius of a particle increases. In Fig.2(b), we show non-stationary defect structures and velocity fields for relatively strong applied field and $\epsilon_1/\epsilon_0 = 1.5$. In this case, the Saturn-ring shrinks, because the director field cannot follow particle motions.

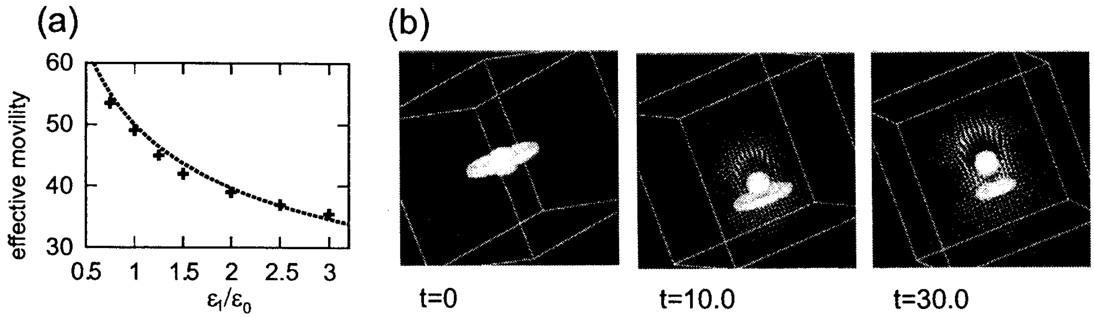

Figure 2: (a)Effective mobility observed in steady states. (b)Non-stationary defect structures and velocity fields for relatively strong electric field.

In this presentation, we also report frequency dependencies of the effcetive movility, and nonlinear and nonequilibrium effects of many charged particles which are immersed in nematic liquid crystals.

References

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