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Author(s)	Lee, S. B.; Matsui, T.; Nakayama, K. et al.
Citation	電気材料技術雑誌. 2000, 9(2), p. 27-28
Version Type	VoR
URL	https://hdl.handle.net/11094/81593
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Preparation of Photonic Crystal with Dispersion of SiO_2 spheres in Liquid Crystal

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The field of liquid crystals has a long history. In the last decade the new exciting research area has emerged - photonic crystals. Recently both fields have been linked into liquid-crystal photonic-band-gap materials showing tunable light localization effects.[1-3] These new materials are made by infiltration of various liquid crystals into the air pores of regular 2D and 3D ordered opal and its inverse replica. In this paper, we propose the application of liquid crystals for formation of regular silica spheres structure. We present the results of study of dynamical behavior of silica particles dispersed in liquid crystals under a low frequency ac applied voltage. Silica particles exhibit a novel behavior such as a unique migrating behavior and alignment. These characteristics are found to depend on the size of particles, the surface state of nanoparticles, liquid crystal phases, the amplitude and the frequency of applied voltage. Such system could be very attractive for study of the influence of tunable interface potential on 2D and 3D colloidal crystals.

Suspensions of small dielectric particles in isotropic dielectric liquids have been studied for a long time. If dielectric constants of particles and a liquid are mismatched, the high electric field applied to such dispersions induces the long-range dipole interaction between the induced dipole moments of the particles. If the field exceeds a critical value it leads to one-dimensional chaining of particles along field lines[4] and, finally, to columns of particles of a body-centered tetragonal lattice, in which the particles are closed-packed along the electric field direction.[5,6]

Recently, dispersions of small dielectric particles in anisotropic dielectric liquids have attracted much attention from fundamental interest as well as because of technological potential.[5] One example of such dispersion is so called filled nematic liquid crystal (FNLC) which consists of silica particles in nematic liquid crystal (LC). Fundamental interest includes new type of colloidal anisotropic interactions because of strong elastic distortions of the liquid crystal host which can be useful in the design of new composite materials with potentially useful applications and the formation of a desired structures with controlled ordering at different length scales.

In anisotropic dielectric liquids at least three additional interparticle interactions come into play: 1. Because of incompatibility between the boundary conditions on particle surface and at infinity the silica particles give rise to topological defects such as disclinations in the director field (***n***)which results in an effective interparticle interaction. This interaction is highly anisotropic and depends on the elastic constants of LC and on the interaction energy between liquid crystal molecules and the particle surfaces (the anchoring strength of ***n*** on particles surfaces). Using electrostatic analogy, it has been shown that the long-range attractive force between particles has a dipolar character for normal or homeotropic anchoring and leads to the formation of chainlike structures. The repulsion arises from the presence of a topological defect between neighboring particles. For tangential or homogeneous anchoring, the long-range interaction is theoretically expected to have a quadrupolar character. The interaction potential is highly anisotropic and depends not only on inter-particles distance and the orientation of the line connecting the particles centers relative to director field but also on the anchoring energy and the particle size.

Interplay of the van der Waals attractive forces and the repulsive hard-core interaction makes the dielectric colloids intrinsically unstable and leads to flocculation. Screened electrostatic interactions govern the structure of stabilized charged colloidal particles in an isotropic dielectric liquid and are quantitatively described with the well established Derjaguin-Landau-Verwey-Overbeek theory.

On the other hand, in the case of anisotropic dielectric liquids such as liquid crystals the behavior of silica particles in LC can be viewed in the purely dielectric interaction picture. In liquid crystals of very high purity the ionic current through the sample is negligibly small ($< 10^{-8}$ A/cm^2) and no electrohydrodynamic flow was observed in polarizing optical microscope.

In anisotropic dielectric liquid a new anisotropic interactions arise between dielectric silica particles without applied electric field resulting in 3D bead-like structures of particles connected by weak hydrogen bonds. The ac electric field changes the long range anisotropic interaction potential to short range one and leads to agglomeration of particles.

New type of colloidal anisotropic interactions can be useful in the design of new topologically controlled colloidal structures with potentially useful applications and formation of desired structures with controlled ordering at different length scales by delicate balancing between the attractive and repulsive colloidal interaction. More complex patterns of desired structure can be made by using special electrode configurations and fixed by photopolymer.[7] This principle could be used in future nanoarchitecture with nanoparticles as building blocks and orientational elasticity of liquid crystal as building force.

The dispersions of particles in layered smectic liquid crystals is very interesting. This study has shown the possibility of formation of regular structures with positional order during phase separation. The helical pitch size of smectic liquid crystal are not fixed and can be tuned by temperature or external potential. Hence, the study of effects of commensurate/incommensurate surface potential seems to be possible. This also opens the possibility of formation of micron-size photonic crystal structures from sub-micron size particles and seems to be very promising in the light of the predicted anisotropic and tunable liquid crystal photonic band gap materials. The possibility for control of the shape of ordered aggregates and formation of tunable photonic crystal utilizing silica particles dispersed in liquid crystal are now under study.

Acknowledgement

This work was financially supported by NEDO International Joint Research Grant.

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