Formation of 3-Dimensional Networks of Colloidal Particles in a Nematic Host

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Abstract

We reported pushing of colloidal particles by a moving isotropic-nematic phase boundary.[1] *Here, we report tailoring the structure of 3-dimensional networks formed by these particles by adjusting the rate of phase transition and by application of an electric field. The resulting networks affect the electro-optic performance of liquid crystal devices.*

1. Objectives and Background

Colloidal dispersions of particles in a liquid crystal differ from ordinary colloids because of the orientational ordering of the liquid crystal, which can induce structure in the resulting colloid. For example liquid crystal ordering induces topological defects[2,3] and additional long-range forces [4] among colloidal particles. These forces can result in the formation of supermolecular structures,[5,6] cellular structures[7,8] and even soft solids.[9]

We recently reported on the formation of these 3-dimensional dispersions during an isotropic to nematic phase transition.[1] We experimentally observed the pushing of colloidal particles by a moving isotropic to nematic phase boundary. This occurs during cooling of a mixture of particles randomly dispersed in the isotropic liquid crystal (Figure 1).

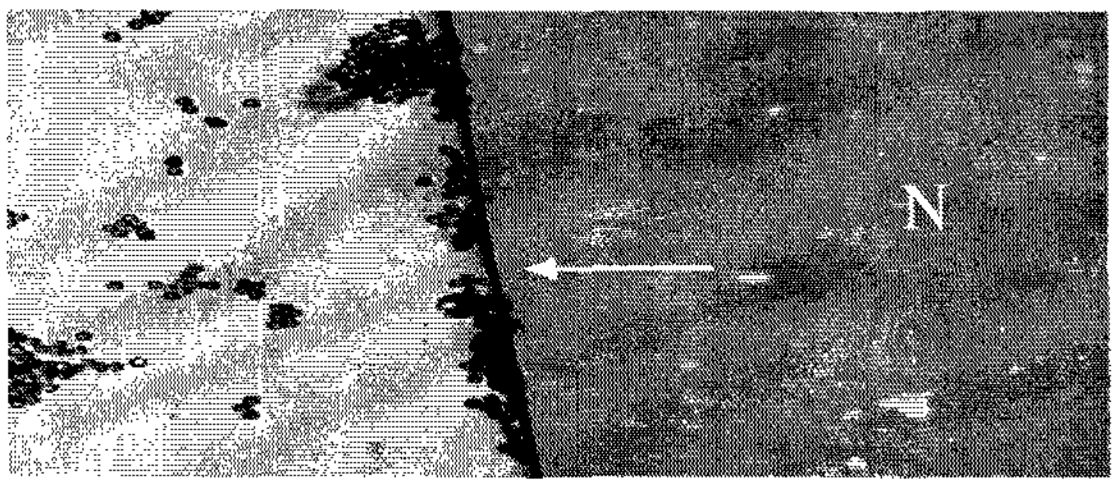

Figure 1: Microphotograph of moving isotropic-nematic boundary pushing polystyrene spheres.

The particles are pushed by several forces resulting from the surface tension of the boundary, from the energy produced by the defects induced in the nematic phase by the particles and from the drag produced by pushing the particles through the isotropic liquid. These forces depend on a number of factors including the size of the particles, the elastic energy and viscosity of the liquid crystal, the speed of the moving front and the anchoring energy of the liquid crystal on the particle surface.

The resulting particle networks are surprisingly stable even upon heating back into the isotropic phase. As added polymers, these particle networks can be used to adjust the stability and electro-optic performance of the liquid crystal host. In this paper we report new techniques to precisely control the structure of these networks.

2. Results

In order to easily observe the movement of particles we utilized 16 µm polystyrene spacers dispersed at 0.2 wt % in the liquid crystal, 5CB. The spacers were mechanically dispersed in 5CB and the resulting mixture placed on an ITO coated glass slide treated to produce homeotropic alignment and heated to 60°- 70° C. A cell was formed using a second glass slide and 120 µm thick polyester films to maintain separation. One edge of the resulting cell was placed on a hot stage with the remainder of the cell in contact with air at room temperature. This produced a temperature gradient across the cell that could be continuously adjusted by changing the temperature of the hot stage.

Cooling the hot stage produces an advancing nematic boundary. The advancing nematic boundary pushes particles forming a line of particles. Stopping the cooling and heating the hot stage reverses the direction of movement of the nematic boundary. This change in direction drops the particles at the point of furthest advance of the boundary. Using this technique we were able to precisely place lines of particles in the sample. Interestingly, a fast moving nematic boundary will pass over a line of particles without moving them.

Application and removal of an electric field also leads to the particles being dropped by an advancing nematic front. We placed an electric field across the sample. With the field applied, particles were pushed by an advancing nematic front, just as observed with no field applied. However, if the field is suddenly removed the moving nematic boundary drops the collected line of particles while continuing to advance. It is possible to precisely control where particles are dropped by removing an applied electric field. The field is then restored and particles are again pushed by the advancing front.

We used these techniques to precisely control the placement of the polystyrene spacers in the 5CB nematic host (Figure 2).

3. Impact

Particle networks can be used to stabilize and adjust the electro-optic performance and related properties of liquid crystal materials and devices. In this paper we demonstrate techniques to precisely control the structure of these particle networks. This ability to precisely control the structure of these networks may allow more precise control of the electro-optic performance of liquid crystal displays and opens the potential to produce advanced photonic devices.

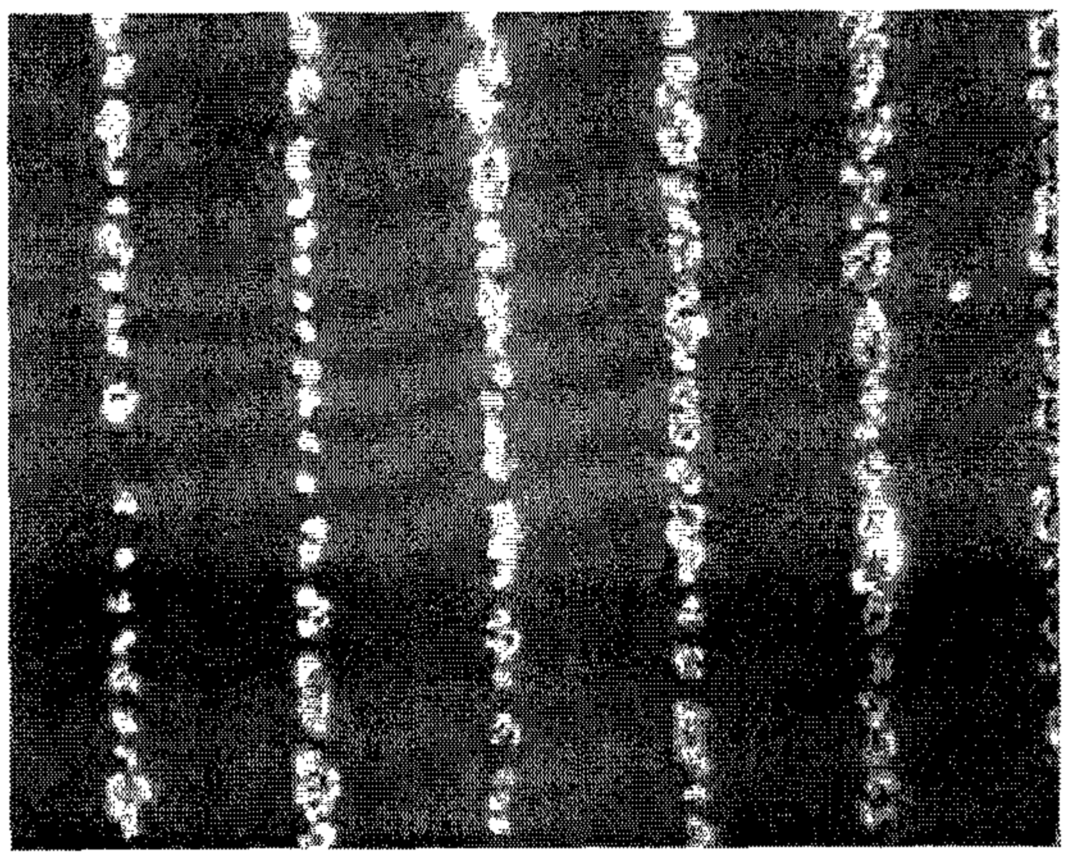

Figure 2: Stripes of polystrene spacers formed by a moving isotropic nematic boundary in a 5CB host.

4. Acknowledgements

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5. References

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