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Recording of Virtual Disclination Lines by Means of Surface Polymerization in a Nematic Liquid Crystal

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On performing an in-situ UV-polymerization of tri-acrylate in 5CB nematic samples, we observe the formation of a film onto the cell plates that is able to record virtual disclination lines. This memory effect evidences that the director orientation is imprinted onto the substrates during the polymerization process. Interestingly here, the nematic phase works twice, at the writing and at the reading stages.

Keywords: imprinting; memory effect; photo-polymer; virtual disclination line

Disclination lines are currently observed on cooling a nematic liquid crystal sample from the isotropic phase. A good manner to observe them is to prepare cells with planar orientations on both plates with the easy axes perpendicular to each other. Two symmetric distortions, respectively left-handed and right-handed, corresponding to $\pm\pi/2$ twists over the cell thickness, may then arise. Their elastic energies are equal for symmetry reasons, if the cell is carefully built. They both correspond to the ground state of the cell, so that things should keep at equilibrium in principle, with steady distortion walls, separating the two types of domains. However, because the walls contain some free energy, that mainly arises from their elastic distortion, one generally observes that they actually retract and eventually vanish after a while following a process usually known as the coarsening process. Nevertheless, due to particular anchoring conditions onto the plates,

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some walls eventually get trapped and the relaxation process stops [1]. We show here that it is possible to record the pattern that the walls draw at equilibrium, on a thin polymer film that is directly synthesized at the surface of the cell plates. To this aim, we use the liquid crystal twice, at the writing and at the reading stages.

The structure of the walls roughly corresponds to the one sketched in Figure 1a. Because they essentially involve twist distortions, they are generally called twist walls. As one can see on the figure, a disclination line should arise in the middle of the wall. In fact, this type of wall is stable if the cell thickness D is larger than about 50 μm. In our samples, where the spacing distance $D \sim 25$ μm, the elastic torques are stronger and exceed the anchoring torques. This allows the disclination lines to be expelled out of the cell. In compensation, an anchoring energy is involved since the director is deviated from the rubbing direction on the plates (Fig. 1b). The disclination lines therefore become *virtual* lines [1]. They nevertheless have a real action onto

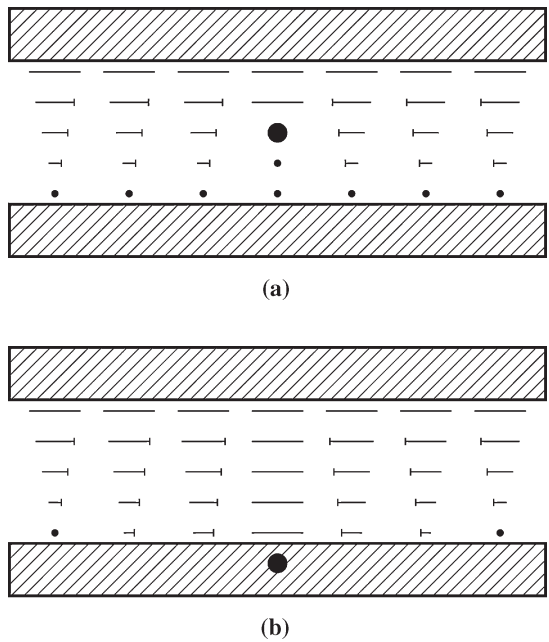
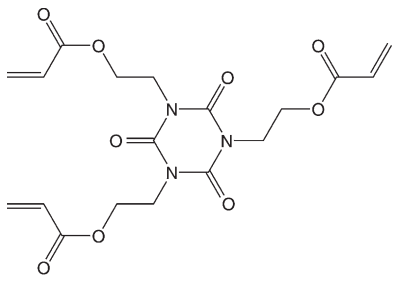


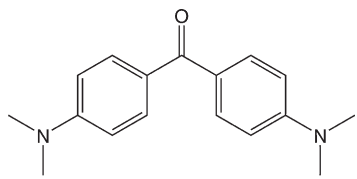
FIGURE 1 a) Sketch of a disclination line (full dot) that is perpendicular to the figure in the middle of a cell, in the case of strong planar anchoring. The molecules are shown as nails. b) In the case of weak anchoring, the defect line may become virtual, and located out of the sample.

the orientation of the nematic director around them, and they are indeed observed by means of the distortion that they generate into the whole sample. In particular, they determine the orientation of the director onto the substrates.

The experiments are performed using the well-known 4-cyano-4′-*n*-pentylbiphenyl compound (5CB). Under proper conditions of pressure and temperature, the rubbing of the cell plates with poly (tetrafluoroethylene) (PTFE) allows one to deposit a unidirectional, thin and homogeneous film with excellent planar anchoring properties [2]. However, the alignment layers are then too sleepy to stabilize the walls, so that they shrink and eventually disappear. We therefore come back to the unidirectional polishing of the glass plates with a powder of $\sim 1\,\mu m$ diameter alumina grains to realize the required planar orientation. The plates are then glued after their parallelism is interferometrically controlled, with a spacing distance $D \sim 25\,\mu m$ in-between. Small amounts of tri-acrylate 0.1 w% (Fig. 2a), and of a photoinitiator 0.003 w% (Fig. 2b), are dissolved in the 5CB liquid crystal before it is introduced into the cells. The polymerization is triggered by means of UV irradiations while the sample is in the nematic phase. With such a small quantity of monomers, the cross-linking reaction is only marginal in the bulk, and we do not observe the formation of any polymer flakes, nor the formation of a gel, the nematic



(a)



(b)

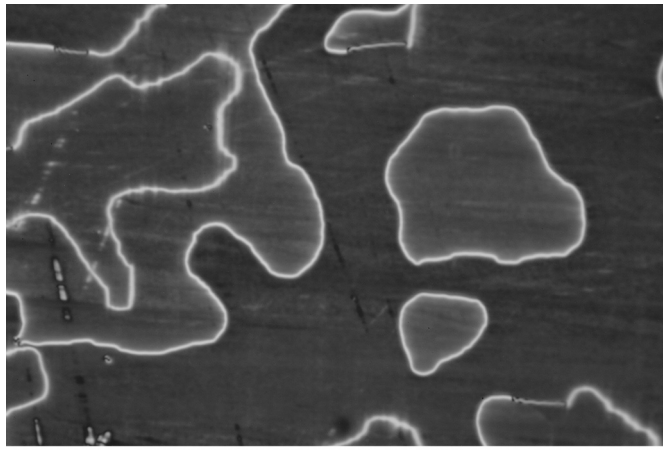
FIGURE 2 a) Tri-acrylate monomer. b) Photoinitiator.

keeping fluid as before the irradiation. Close to the surfaces, however, the concentration of the monomer increases, since it tends to be rejected from the bulk as any impurity does. This effect explains that the polymerization threshold is overwhelmed in contact to the plates, and consequently that a polymer film may be synthesized there only.

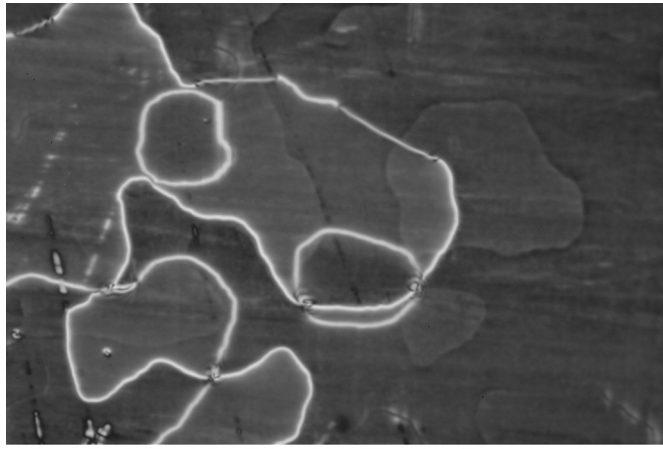
By means of AFM analyses, we observe that the UV flash is actually able to produce a thin, but strong, polymer film onto the sample substrates. Though in principle each monomer may produce 6 chemical bounds, probably only a part of them are effectively synthesized. Nevertheless, the cross-linking of the polymer layer seems to be sufficiently dens to give a good mechanical quality to the film. In particular, we observe that the film is strong enough that the AFM needle is unable to tear it. Though for the moment we do not know the exact thickness of the film, we observe that it exhibits a slight unidirectional roughness [3]. This is a first indication that the film has an anisotropic structure that may be sufficient to impress an azimuthal anchoring to the nematic liquid crystal. To test this property, we first melt the sample into the isotropic phase, at least 5°C above the transition temperature (34°C). This ensures that the nematic phase is completely melted, including the nematic film that is normally induced at the surface of the substrate, and washes out the lattice of the virtual defects that is characteristic of the nematic phase (Fig. 3a). We then cool down the sample in the nematic phase. As shown in Figure 3b, a new lattice of disclination lines is formed, but very surprisingly the previous lattice is also restored, and appears as overwritten onto the new one. This photograph directly indicates:

1. that a polymer film has been photosynthesized onto the substrates in the presence of the nematic phase as discussed above;
2. that the director orientation has been written in the film, probably by means of the average direction of the polymer molecules themselves;
3. and finally, that the nematic liquid crystal is able to read the inscribed polymer film when again in contact to it.

In summary, we have shown in our experiments, that the nematic phase may be used as a template that imprints its orientation onto *in-situ* synthesized polymer films, and that in a second step, it is able to read it. Keeping a memory of the nematic orientation onto the substrates moreover comes to recording the director orientation all over the sample. This explains that we are able to keep a memory of the virtual defect lines just on synthesizing a thin polymer film onto the substrates.



(a)



(b)

FIGURE 3 a) Virtual disclination lines observed between crossed polarizers, before UV polymerization. b) After polymerization, the network of the disclination lines is washed out on heating the sample into the isotropic phase. On coming back again in the nematic phase, a new lattice of disclination lines is created, but the previous one keeps visible.

Similar memory effects have already been reported, however, in different systems, and using different mechanisms from the one described here. For instance, the imprinting mechanism may use a plastic coupling between the nematic director and a polymer-coated

substrate as shown in References [4]–[6], or the polymer film may be localized onto the surface by means of a strong gradient in the UV intensity across the sample thickness [7].

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