Stressed Liquid Crystals

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Abstract

Stressed liquid crystals, SLCs, consist of a low-density polymer network dispersed in a nematic host. We induced stress by shearing the material. Alignment layers are not required because the liquid crystal director uniformly aligns along the direction of shear. The shearing stress also eliminates light scattering and results in sub-millisecond switching speeds, making them good candidates for video display applications.

1. Introduction

Dispersions of liquid crystals and polymers possess many properties that make them interesting for research and attractive for a variety of applications [1]. Typical examples of these materials are polymer dispersed liquid crystals (PDLC) and polymer network liquid crystals. These systems have a wide variety of potential uses, including light shutters, displays, and switchable windows. The electro-optic performance of these materials depends on the size of the liquid crystal domains and the initial orientation of the liquid crystal inside the droplets. PDLC films have been stretched to impose a preferred orientation on the liquid crystal within the droplets [2]. For instance, this technology was successfully used to produce electrically controlled polarizers [3].

In this paper, we present the main characteristics of stressed liquid crystal (SLCs) films and their use as a new high-speed electro-optical material. These films do not scatter light, produce a large electrically controlled shift in the refractive index, and switch with sub-millisecond speeds.

2. Experimental

We made SLC films using Norland optical adhesive NOA65 as a photopolymerizable monomer mixed with the liquid crystal E7. We utilized a concentration of the polymer (about 14 wt %) intermediate between polymer dispersed liquid crystals and the much more dilute polymer stabilized liquid crystals. The material was sandwiched between glass plates coated with indium tin oxide (ITO). The gap between these substrates was controlled by using film or particle spacers. The cells were capillarly filled and maintained at uniform temperatures during UV exposure. It should be noted that the applied stress, rather than an alignment layer, provides uniform orientation of the liquid crystal.

Unidirectional alignment of the droplets was produced by a shearing deformation. This was accomplished by fixing one substrate of the cell to a support while the other substrate was moved. The distance of shearing was controlled with a micro-screw (accuracy of about 5 μm).

In order to study the internal structure of the SLC films by SEM, we used sodium chloride substrates that were dissolved after the UV polymerization process. This method reduces the mechanical disturbance to the film and allowed visualization of the pristine polymer structure.

To demonstrate the high speed, high contrast, operating voltage and shift of the phase retardation achievable with the film we placed the 20 mm thick cell between two crossed polarizers. The optical axis of the cell was set at 45 deg to the polarization direction of the polarizers. We measured and analyzed the intensity of a He-Ne laser beam passing normally through the cell.

3. Results and discussion

The SEM image of the film (Figure 1) shows an interpenetrating structure of polymer films and liquid crystal domains. The polymer forms thin films that separate the liquid crystal domains which range in size from 0.5-2 μms.

We discovered that the initial scattering of these films decreased dramatically upon application of the shearing deformations (Figure 2). For comparison, it was not possible to achieve complete transparency for traditional PDLC films even with application of much higher shearing deformations (Figure 3).

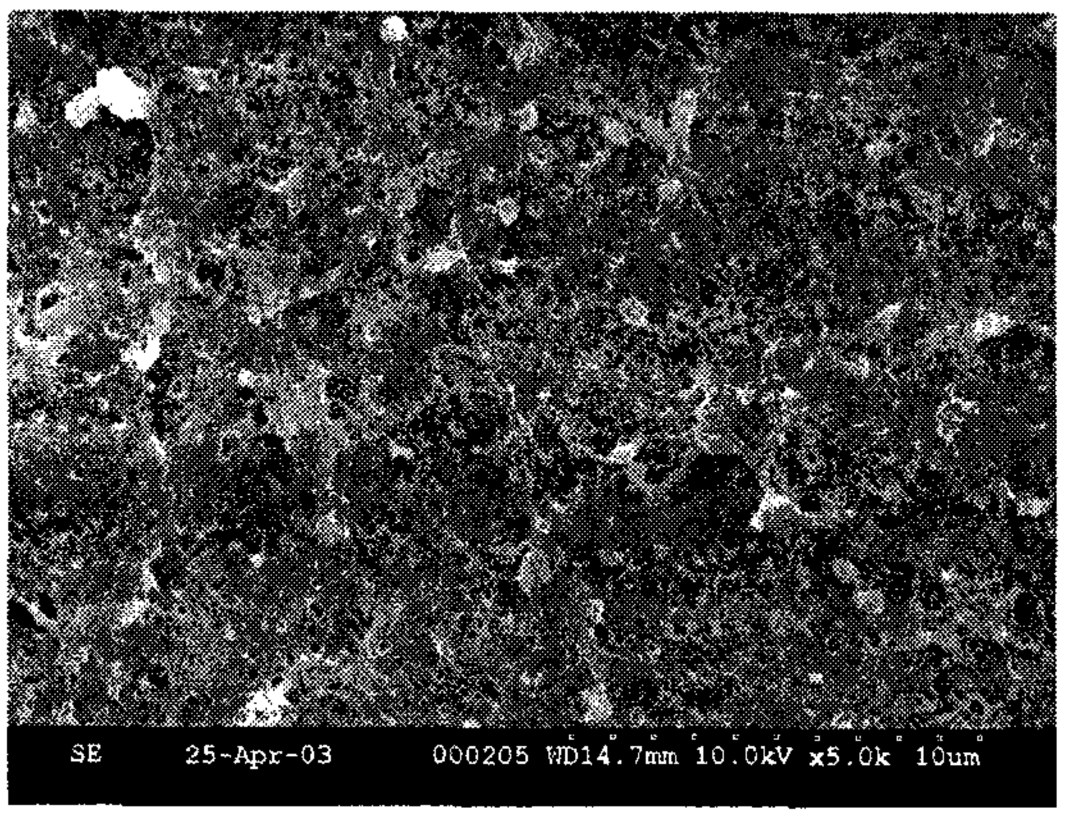

Figure 1. The SEM image of the film. The image reveals the interconnected liquid crystal domains separated by the rigid polymer chains.

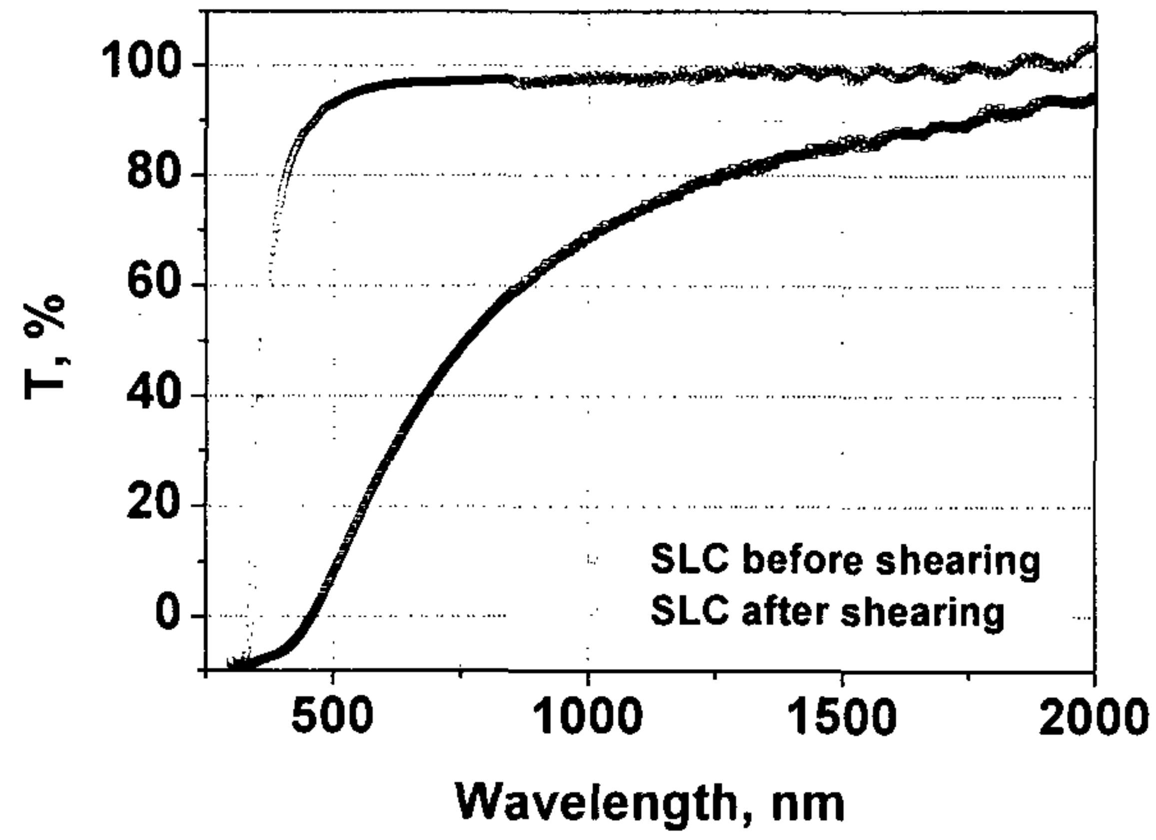

Figure 2. Transmittance of the SLC film before and after application of a shearing deformation.

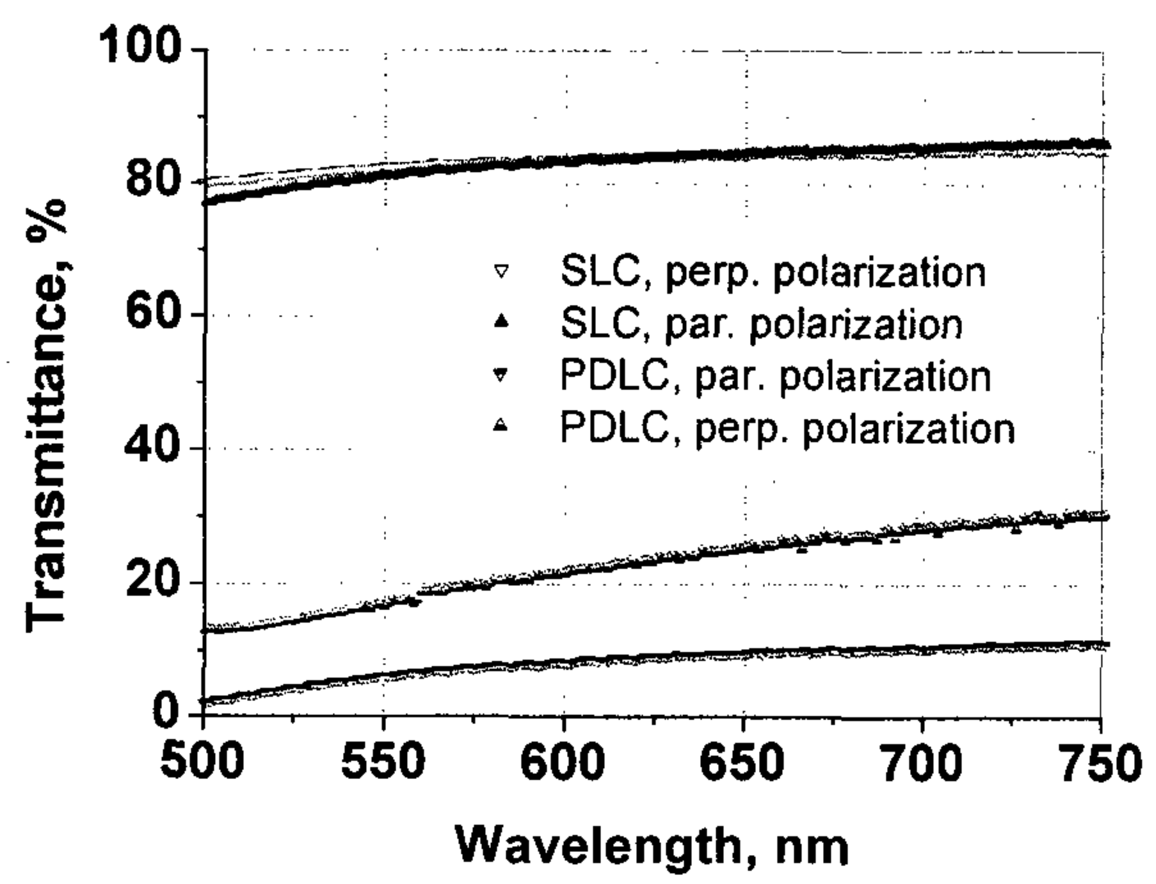

Figure 3. Comparison of the actual transmittance spectra of the traditional PDLC and SLC films placed between two ITO-glass substrates; an equivalent shearing deformation was applied to the both cells.

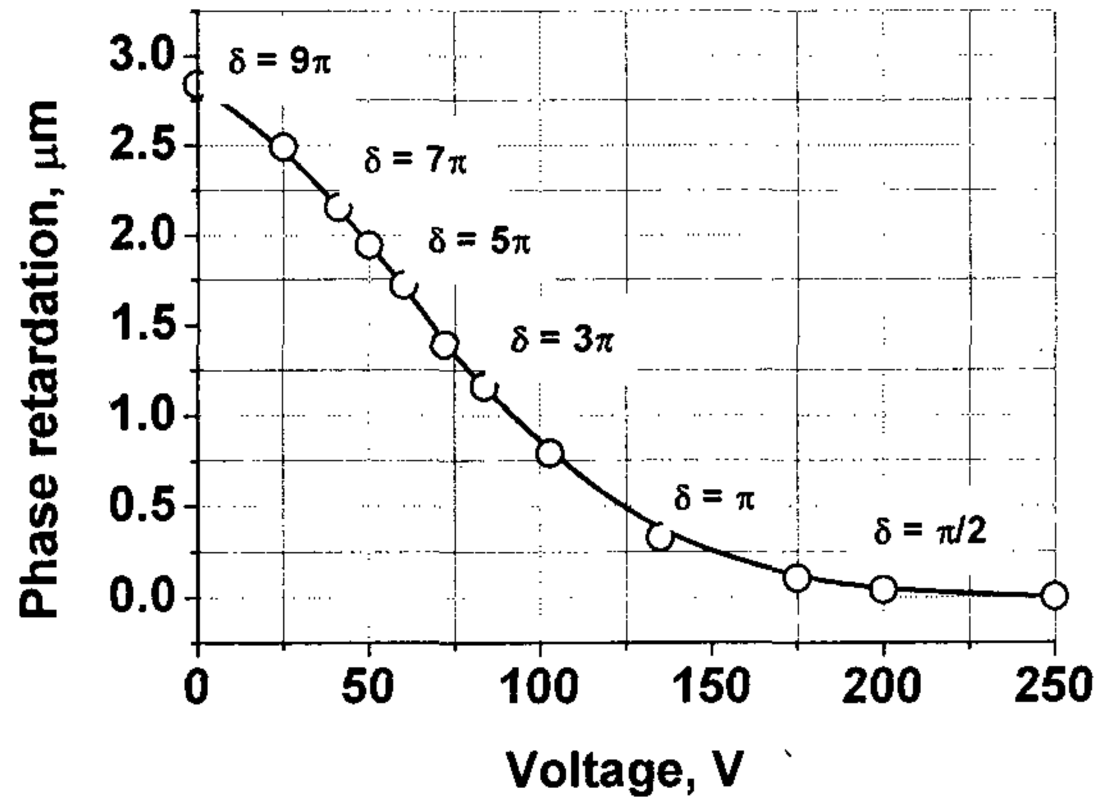

Figure 4. The dependence of the phase retardation in the cell as a function of an applied electric field.

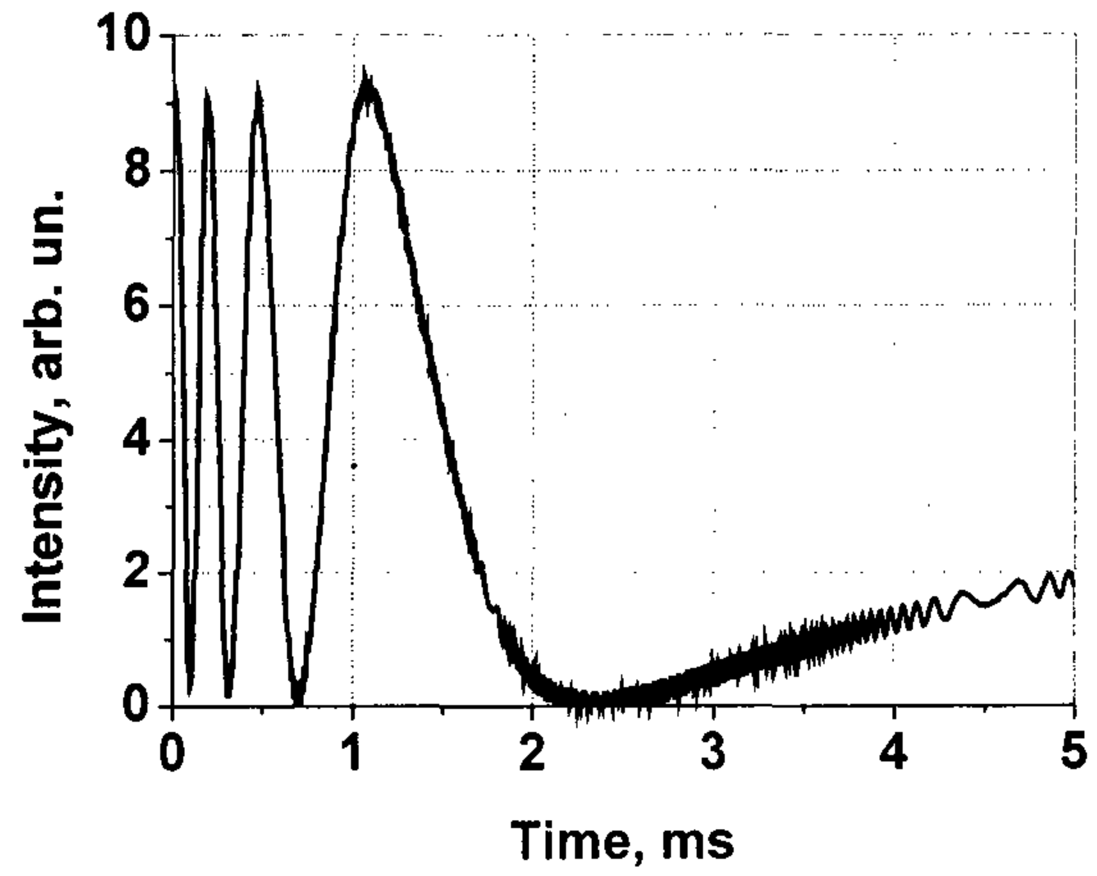

Figure 5. The dynamics of the cell relaxation after removing 135V applied to the cell (referenced to the figure 4)

The dependence of the phase retardation as a function of an applied voltage is shown in figure 4. Shearing of such a SLC film greatly reduced the relaxation time of the material. The dynamics of the cell relaxation is shown in figure 5. The phase retardation shift of ~ 2 µm occurred within 1 ms. Another attractive feature of the SLCs is the absence of hysteresis, common in other heterogeneous liquid crystal systems. Figure 6 demonstrates the results of the hysteresis measurement of the SLC film at different shearing deformations.

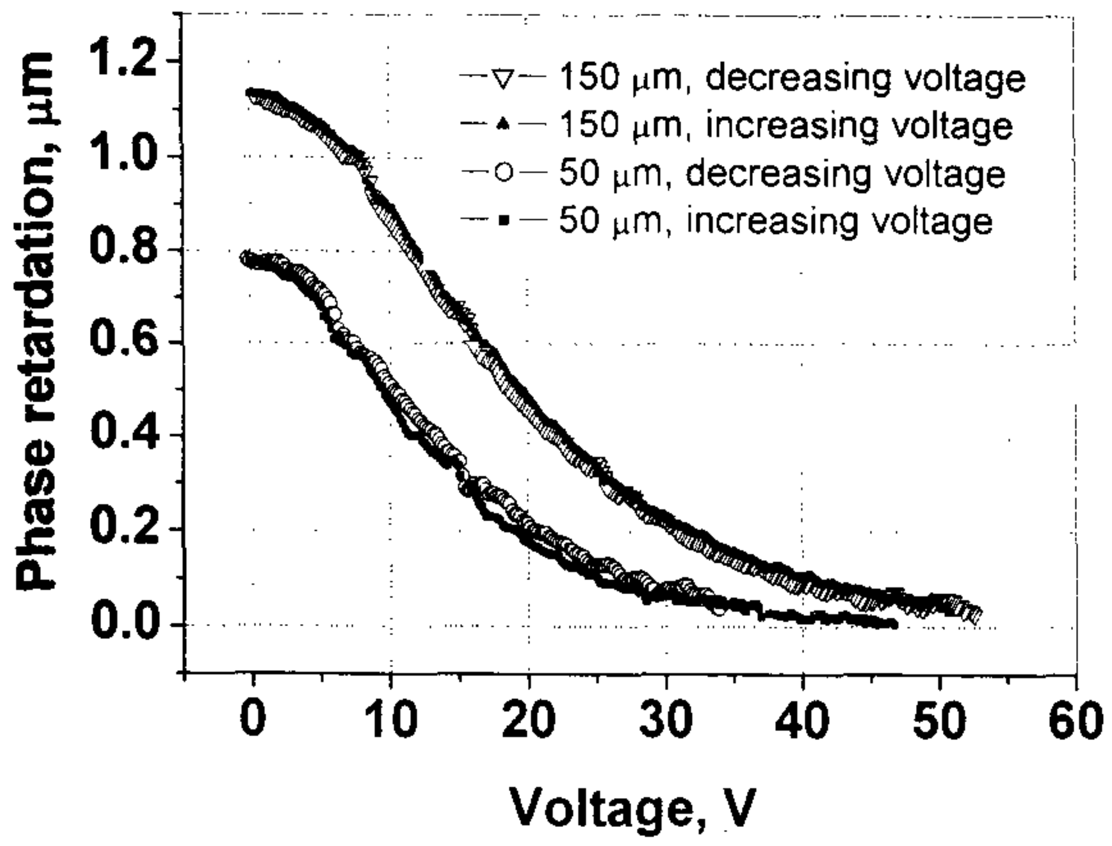

Figure 6. The hysteresis measurement results of the SLC film under application of different shearing deformations.

a

b

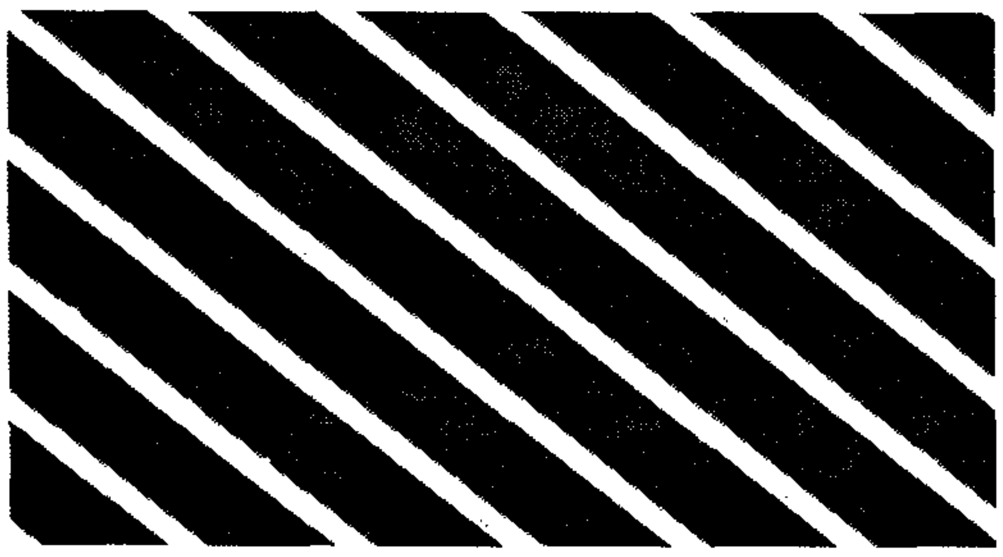

Figure 7. Microphotographs of the display pixels between crossed polarizers: a, an initial state; b, electric field is applied to each electrode.

The SLC materials may be used for fast switching displays. Figure 7 shows a microphotograph of a display prototype with line electrodes. We achieved the switching time (time ON) of this display 20 microseconds, and the relaxation time (time Off) 40 microseconds.

4. Conclusion

Stressed liquid crystals (SLCs) consist of unidirectionally oriented domains of liquid crystal separated with polymer chains. The applied stress eliminates scattering in the film, and increases the switching speed and contrast. The film can be adapted for displays having high contrast, good gray scale and switching speeds as fast as ferroelectrics. No alignment layers are required, greatly simplifying cell preparation.

5. Acknowledgements

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6. References

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