

Surface Effects on Anchoring and Dynamical Interactions of Liquid Crystalline Films

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Liquid crystalline (LC) systems evoke much interest in the scientific community because they possess such unique qualities as birefringence and electric and magnetic susceptibilities, which allow them to be utilized in a wide variety of technological applications. These complex fluids are also very sensitive to interactions at the boundary regions contacting the surface;^{1,2} thus there is much interest in driving the anisotropy of these phases via these interfacial interactions. In our research, we focus on understanding the thin film-substrate interactions that govern the anchoring and dynamic transitions of these materials, which is critical to the development of reliable, energy-efficient, and low-cost devices.

4-n-pentyl-4'-cyanobiphenyl (5CB),³ a prototypical nematic liquid crystalline material, is studied in our research. 5CB is entrapped in a confinement geometry⁴ determined by Au electrodes and ZnSe substrate surfaces as indicated in Figure 1. An interdigitated electrode array (IDEA) is microfabricated onto a ZnSe substrate, onto which 5CB is placed; an unpatterned ZnSe is then placed on top to confine the LC material. Surface effects are then studied via polarized Fourier-transform infrared (FTIR) and step-scan time-resolved FTIR (TRS) spectroscopies.

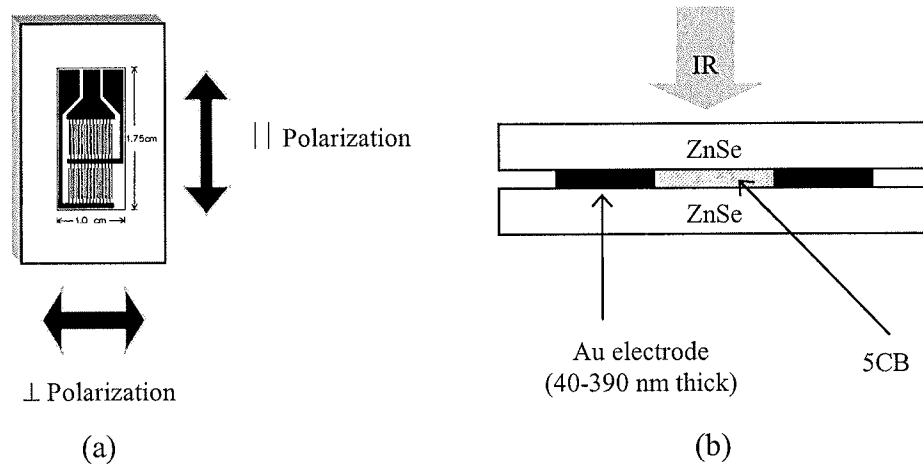


Figure 1. The liquid crystal electro-optical cell utilized in our research: (a) the interdigitated electrode array (IDEA) microfabricated onto a ZnSe substrate and (b) a cross-sectional view of the assembled liquid crystalline cell. IR radiation is incident in a transmission geometry in the experimental setup, with the IR radiation polarizations defined with respect to the electrodes as indicated in (a).

Experimental results reported in literature indicate that the anchoring and dynamics of liquid crystalline systems may be driven by many factors, both physical and chemical in nature.^{1,2} In our own experiments, we find that nanoscale morphological

features of the surface can effectively direct the initial anchoring of 5CB.⁵ Spicular corrugated texture of the ZnSe surface induces a homeotropic alignment of a 40 nm 5CB film, while a grooved texture induces a planar alignment of the same film, with the director parallel to the groove directions. There is also evidence that geometrical constraints can also drive the anchoring in these systems when the nanoscale textures of the ZnSe surface are softened by coating the surface with a polymeric (polyimide) film.⁶ The initial anchoring induced by the surface textures and confinement effects determines the mechanism via which the liquid crystalline molecules reorient in an electric field-induced Fredericksz transition, thereby also determining the dynamic rates of electric field-induced reorientation and thermal relaxations via elastic intermolecular interactions.

Thermal perturbations also mediate the initial anchoring and dynamics of LC systems.⁷ Temperature affects the elastic intermolecular interactions directly in these systems,^{8,9} and thereby determines the initial alignments of the LC films. The initial anchoring may be pictured as a thermodynamically stable state that results from the competition between surface effects and intermolecular forces. The balance between the two competing forces alters when the temperature influences the elastic constants that govern the intermolecular interactions between the LC molecules, thereby modifying the initial LC alignment. The orientational dynamics in these systems can then be correlated directly with the initial alignments, as illustrated in Figure 2.

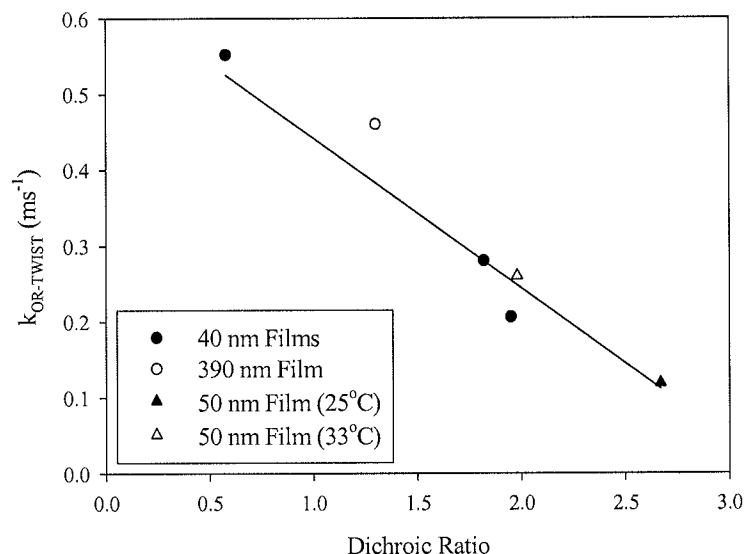


Figure 2. Twist components of the orientation dynamics as a function of the initial dichroic ratios of LC films. The dichroic ratios serve to indicate the dipole moments of domains that interact with the applied electric field.

The LC systems in our studies were modeled by comparing them with an overdamped harmonic oscillator.⁶ This theory-based framework explains the results obtained in our research very well, including the direct orientation rate dependence on the initial orientations as indicated in Figure 2. Overall, external perturbations appear to act

on the viscoelastic properties of the LC phases, which determine both the initial alignments and the electric field-induced dynamics.

References

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