Morphological Studies of Room Temperature Ferroelectric Liquid Crystal Mixture

Dr. Neeraj Puri[a*], *Dr. K. K. Raina*[b]

[a]Assistant Professor, Faculty of Natural Sciences, GNA University, Phagwara-144001, India
[b]Vice Chancellor, DIT University, Dehradun, Uttarakhand- 248009, India

Abstract

We examined the effect of rubbing and cell thickness on the morphology of a room temperature ferroelectric liquid crystal (FLC) mixture ZLI-3651 by performing the polarizing microscope studies. The cells thicknesses of 5µm with parallel rubbing and 10 µm with both parallel and anti parallel rubbing were used in the experiment. We found that decrease in thickness reduces the defects and improve the electro-optic properties of ferroelectric liquid crystals.

Keywords : Liquid Crystal, Ferroelectric, Electro-optic properties

1. Introduction

Liquid crystal displays (LCDs) are widely used in displays for computers, television sets, calculators, cameras and other such devices. The images are displayed by scheming light which is done by altering the molecular orientation of the liquid crystals using applied voltage. Initial orientations of liquid crystals (orientation when no voltage is applied) are controlled by polymer films called liquid crystal alignment films. Rubbed polyimide films are widely used for this purpose. The discovery of ferroelectric liquid crystals (FLCs) by Meyer[1] in 1975 broadens the research area of liquid crystals because of the tremendous applications in fast electro-optic devices[2,3]. However, formation of zigzag lines in FLCs results in their poor electro-optic performance and hence is an obstacle for their use in display applications. These zigzag lines are optical appearance of defects within domain walls that separate the chevrons of opposite bending directions. By using proper alignment technique and applying a low frequency bias field, these zigzag defects can be controlled or eliminated which definitely influence the electro optic properties of FLCs. Thus alignment of liquid crystal director plays an important role in the function of liquid crystal displays. In the last years, a number of procedures such as Langmuir Blodgett films, lithography micro patterned polymers, nano patterned surfaces using an atomic force microscope or ion beam etching surfaces, SiOx films, mechanically rubbed polymer layers and photo aligned light sensitive polymers etc have been employed to align the surfaces of conducting glass substrates. We used the easiest and common mechanical rubbing technique of polymer layers in our studies[4-7]. It produces grooves on polyimide surface and breaks the original uniformity in surface topography of polyimide thin film and cause a preferential direction which is parallel to rubbing direction on the surface. The change in surface topography changes the other chemicophysical properties at the polymer surface.

We have compared textures of a room temperature ferroelectric liquid crystal by constructing 10 µm thickness cells with parallel and anti parallel alignment. In parallel rubbed FLC cells both the rubbing directions of alignment films on two substrates are same whereas in anti-parallel rubbed cells, rubbing directions of alignment films are opposite. Also we have used a planer aligned parallel rubbing 5 µm thickness cell to show that how cell thickness influence the morphology of FLCs.

2. Experimental

In the present study we have used the mechanical rubbed polymer technique to align the surfaces. A uniform coating of polyimide (nylon/ m-cresol/ methanol) was done using spin coating unit at a speed of 1400 rotations per minute on the ITO coated glass substrates. Such coated substrates were baked in the oven at 130°C for one hour. Then rubbing was done in one direction using a nylon cloth on these polyamide coated substrates[8]. The parallel rubbing cell was constructed by putting two substrates together in such a way that rubbing directions on each polymer surface orient in the same direction. However anti parallel rubbing cells were constructed by putting these polymer surfaces orienting in the opposite direction. The cell gap was considered 10 µm. A parallel aligned cell of 5 µm thickness was also prepared. A room temperature short pitch ferroelectric liquid crystal mixture ZLI-3651 FLC was filled using capillary action in two polyimide rubbed ITO coated glass plates at its isotropic temperature. The alignment and textures of the FLC material were studied by slow cooling at a rate of 0.1°C/min. in the presence of an electric field at 50Hz using thermal optical polarizing microscope (OLYMPUS model BX-51P) interfaced to temperature controller model LINKAM-TP94 and THMS600 coupled to hot stage at an accuracy of ±0.1°C.

2.1. Theoretical considerations

Ferroelectric liquid crystals are chiral smectic C phases where the director of each planer layer is tilted from the layer normal z by a fixed angle, called tilt angle θ as shown in **figure 1**. The projection of the director in the smectic plane and x-axis give the azimuthal angle. When the molecule is chiral, successive smectic C layers show a gradual change in the direction of tilt, such that the director processes about the z-axis from layer to layer, always lying on the surface of a hypothetical cone of angle 2θ. Chirality causes helical structure in the chiral smectic C meso phase with pitch being the distance along the z-axis and spontaneous molecular polarization vector, which is perpendicular to the molecule and contained in the layer plane. Thus all possible directions for the vector are tangent to the circle of intersection of cone with the plane.[9]

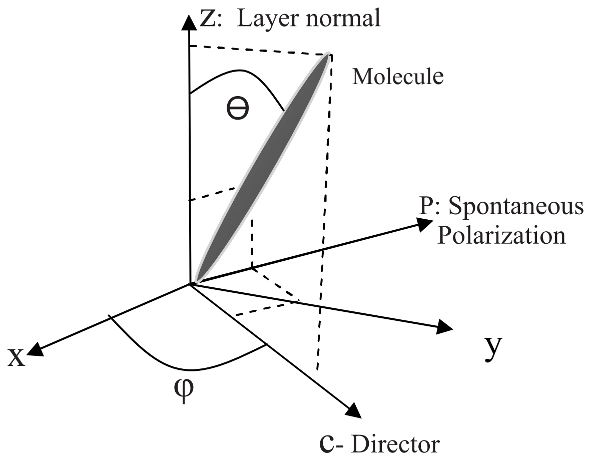

Figure 1. Projection of molecule in SmC* phase

3. Results and Discussion

3.1. FLC morphology

The optical textures of FLC ZLI-3651 sandwiched between various cells have been investigated under crossed polarizers from its isotropic state to room temperature at the rate of 0.1°C/min. Since the helical pitch (1.5μm) is smaller than the thickness of the sample cell a short pitch geometry is observed. In short pitch FLC cells, the pitch of the liquid crystal director is less than the cell gap. Moreover, here the surface anchoring is kept weak using surface treatment of both the ITO coated surfaces so that the helix is retained within cell boundaries and the bookshelf structure is generated where smectic planes are oriented perpendicular to glass plates. The transition temperature of the sample was measured using hot stage cum temperature controller and POM and further confirmed by differential scanning calorimeter (DSC L63, LINSEIS).

On heating LC material to its isotropic temperature, it was found that isotropic phase appeared dark above 86°C. On cooling further cholesteric phase appeared at 86°C. Then appeared SmA phase at 75°C and SmC* phase was observed at a temperature 60°C. The various microscopic textures obtained at a magnification of 10X are shown in **figure 2** and **figure 3**.

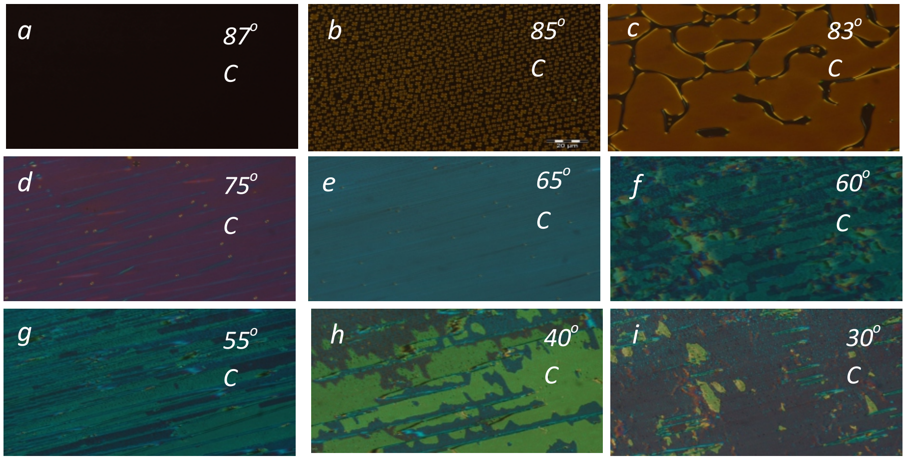

Figure 2. (a) Microscopic textures of ZLI 3651 obtained during cooling below isotropic temperature in 5 μm thickness cell shows (a) Isotropic phase (b) & (c) nucleation growth (d) Cholesteric phase (e) hair pin defects (f) SmA phase (g) SmC* phase (h) formation of domains and (i) microscopic texture at room temperature.

Figure 2(a) shows the microscopic textures appeared dark of an isotropic phase above the transition temperature in a 5 μm thickness cell. Nucleation started at 86 °C and it grows as the temperature is further decreased as shown in **Figure 2 (b)** and **Figure2(c)** respectively. **Figure 2(d)** shows the cholesteric phase obtained on further cooling. Hair pin defects were observed as shown in **Figure 2(e)** in SmA phase **Figure 2(f). Figure 2(g)** show SmC* phase. A domain formation was observed in **Figure 2(h). Figure 2(i)** shows micro texture of SmC* phase at 30°C. The various LC phases are also observed in 10 μm thickness cell from its isotropic temperature in cooling as shown in **Figure 3**, which are more clearly visible as compared to 5 μm cell.

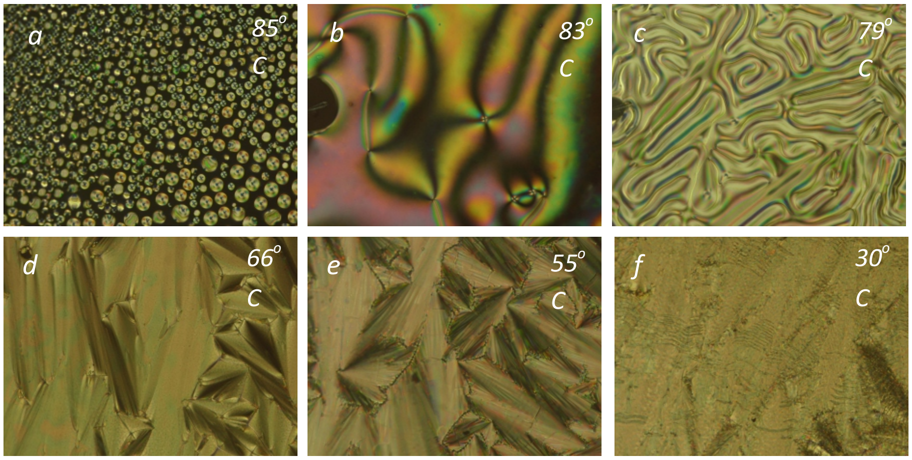

Figure 3 : Micrographs of FLC in 10 µm cell with anti parallel rubbing at different temperature showing (a) Formation of nucleation (b) nematic phase (c) cholesteric phase (d) Sm A phase (e) focal conic texture (f) SmC* phase.

Figure 4 : shows the DSC graph for ZLI 3651 FLC material. The phase sequence of the material can be obtained by identifying various phases of LCs as shown below:

$$\text{SmC*} \xrightarrow{60^\circ\text{C}} \text{SmA} \xrightarrow{75^\circ\text{C}} \text{Cholesteric} \xrightarrow{86^\circ\text{C}} \text{Isotropic}$$

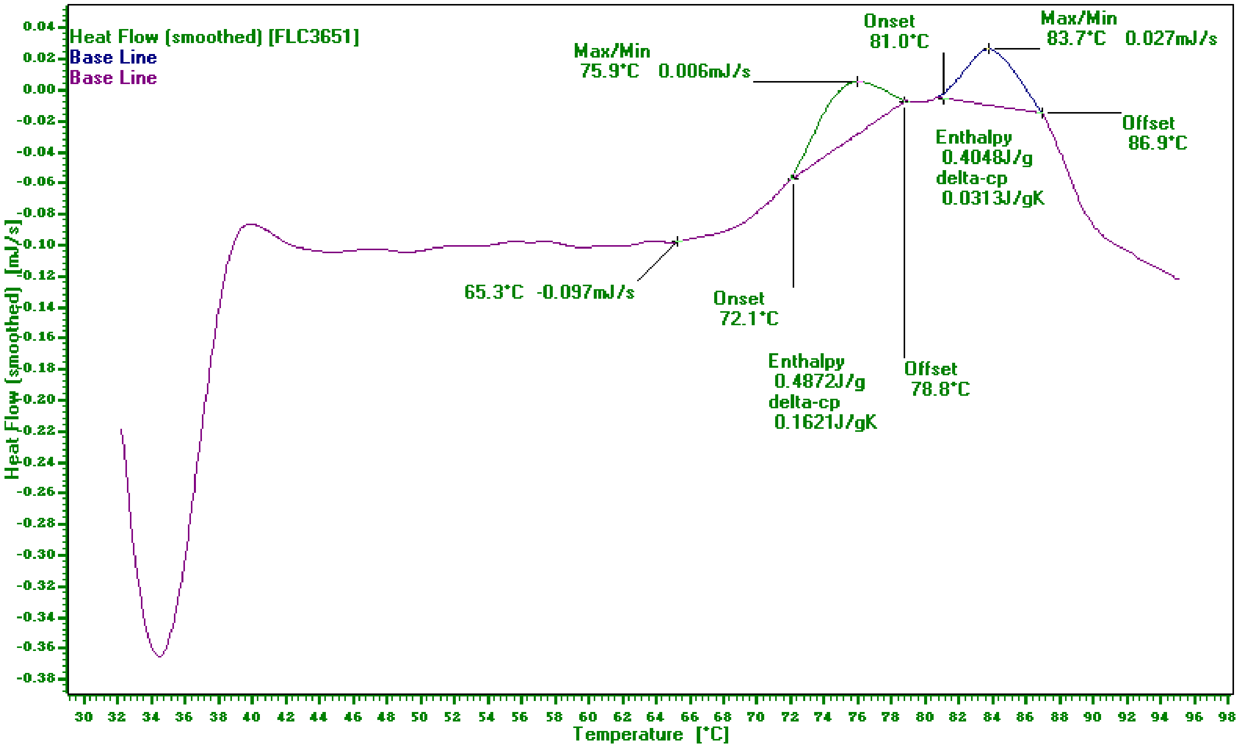

Figure 4. DSC graph of the phase sequence for ZLI 3651 sample

4. Conclusions

ZLI-3651 has short pitch geometry (~1.5 um). It shows various phases i.e. SmC*, SmA, cholesteric and nematic phases at different temperatures. Rubbing of sample cells reduces the defects, however the 5 um thickness cell has less defects and are more aligned as compared to 10 um cell. This shows that defects decreases with reducing thickness of cells.

5. References

1. Meyer, R.B., Liebert, L.L., Keller, P.L & Strzelecki (1975). Ferroelectric Liquid Crystals. *J de Physique,* 36 ,69-71.
2. Clark, N.A. & Largewall, S.T. (1981). Physics of Ferroelectric Fluids Physics of Ferroelectric Fluids: The Discovery of a High-Speed Electro-Optic Switching Process in Liquid Crystals. *Recent Developments in Condensed Matter Physics*, Springer 4, 309-319.
3. Mikhailenko V., Krivoshey A., Pozhidaev E.P., Popva E.V., Fedoryako A., Gamzaeva S., Srivastava A.K., Kwok H. S. & Vashchenko V.V. (2019). The nano-scale pitch ferroelectric liquid crystal materials for modern display and photonic application employing, highly effective chiral components: Trifluoromethylalkyl diesters of p-terphenyldicarboxylic acid. *Journal of Molecular Liquids*, 281, 186-195.
4. Williams, D. & Davis, L.E. (1986). Alignment of Chiral Smectic liquid Crystals. *J Phys D Appl Phys*, 19, L37-L41.
5. Frunza, S., Beica, T., Moldovan, R., Zgura, I. & Frunza, L. (2005). Peculiar Orientation of Nematic Liquid Crystals on Rubbed Polyvinylimidazole. *Journal of Optoelectronics and Advanced Materials,* 7, 2149-2157.
6. Yang, F., Zoriniants, G., Ruan, L. & Sambles, J.R. (2007). Optical anisotropy and liquid crystal alignment properties of rubbed polyimide layers. *Liquid Crystals,* 34, 1433-1441
7. Malone, S. M. & Schwartz, D. K. (2008). Polar and azimuthal alignment of a nematic liquid crystal by alkylsilane self-assembled monolayers: Effects of chain-length and mechanical rubbing. *Langmuir.* 24, 9740-9794.
8. Baawa, S.S., Biradar, A. M. & Chandra, S. (1987). Molecular reorientation processes and dynamics of polarization reversal in thin surface stabilized ferroelectric liquid crystal DOBAMBC. *Ferroelectrics*, 76, 69-80.
9. Andrienko, D. (2018). Introduction to Liquid Crystals*, Journal of Molecular Liquids*, 267, 520-541.