

Chapter 1

Introduction

1.1 Introduction of Liquid Crystal Displays

Liquid crystal displays (LCDs) provide the desired features of thin format, compact size, light weight, and high image quality. They are also widely used in cell phones, PDA, computers, note books, high definition TV (HDTV) and so on. Twist nematic (TN) LCD is first adopted in the liquid crystal devices for its low driving voltage and gray scales capability. The slow response time and confined viewing angle limit their application for TV. To solve aforementioned issues, several LCD modes have been developed such as: in-plane switching (IPS), multi-domain vertical alignment (MVA), optically compensated bend (OCB) and ferroelectric liquid crystal (FLC) displays. Among these modes, the advanced FLC displays have been actively researched for the advantages of fast response, wide viewing and bistable capability. In particular, FLCs have the shortest response time (i.e. less than 1 ms). This character can be applied effectively to reduce the blur image from moving picture, and to suppress color break-up phenomenon in field sequential color (FSC) display. However, the issues such as working temperature and voltage, defect free structures, and assembly processes are hindered the applications of FLC. Thus, to realize FLC in display application remains great technical and scientific challenges.

1.2 Liquid Crystal Phase

Liquid crystal phases are classified by several configurations of molecules which widely differ in their structure. The rod-like LC molecules can be described by introducing two axes, one parallel to the molecule is long axis, and the other one perpendicular to the molecule is short axis as shown in Fig. 1.1. Generally, rod-like molecules tend to orient themselves around the rubbing direction and align parallel to each other to a preferred direction which is so called *self-assembly*. Depending upon the amount of the order in the materials, there are several types of LC states. Molecules in nematic, smectic A and smectic C phase [1] are shown in Fig. 1.2, the nematic phase possesses an orientational order without positional order, and the smectic A phase possessed not only the orientational order but also the positional order, the orientation can be determined by the formation of smectic layers and the director. In the smectic A phase, molecules are oriented normal to the smectic layers and determines the optic axis of the system. The molecules with smectic C phase are still arranged in smectic layers, and the long axis of molecules are tilted in one preferred direction, the angle between layer normal and the long axis of molecule is known as so called *smectic cone*.

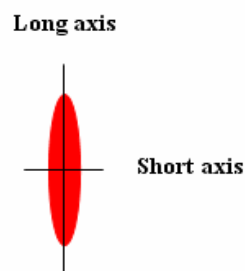


Fig. 1.1 Description of rod-like LC molecule.

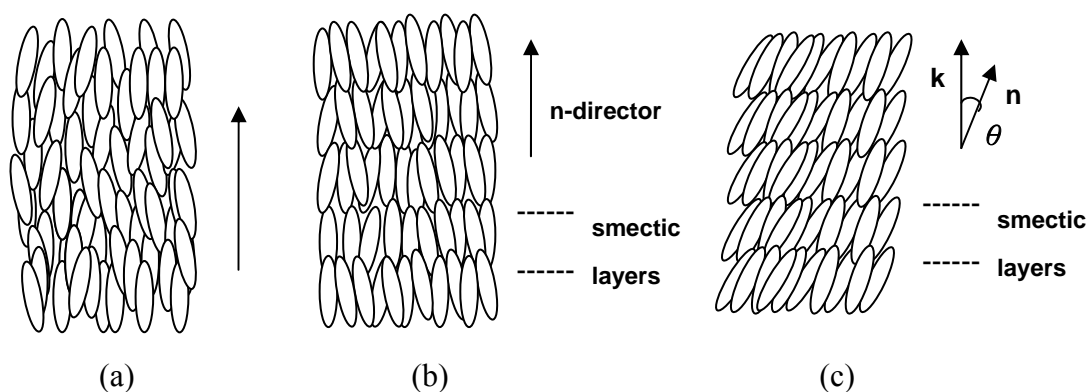


Fig. 1.2 Molecular arrangement in (a) nematic (b) smectic A (c) smectic C phase.

1.3 Chirality

Chiral molecules dissolved in nematic or smectic phases will induce chirality in the phase and generate the properties of chiral nematic or smectic phase, respectively. An object is chiral if the symmetry elements like mirror planes, such as one's left and right hands, the chiral object and its mirror image cannot be superimposed by rotating. Molecules can not be superimposed onto their mirror image usually due to presence of an asymmetry carbon atom, chiral center, bonded to four distinct groups. Chiral molecules induced the chirality in nematic or smectic phases usually due to intramolecular and intermolecular chirality transfer [2], intramolecular chirality transfer means the chiral center leads to a chiral distortion in the structure of compounds and leads to the formation of various chiral conformers. Intermolecular chirality transfer may result in a variation of the orientational distribution function of the molecules. Helical twisting power (HTP) can be generalized for the induction in chiral phases, approximately a linear function of HTP is

$$HTP = p^{-1}x^{-1} \tag{1.1}$$

Where, p is the helical pitch,

x is the concentration of chiral dopant.

1.4 Ferroelectric Liquid Crystal (FLC)

Chiral smectic C phase is composed by doping chiral molecules in achiral smectic C molecules. The orientation of chiral smectic C phase is shown in Fig. 1.3, the helix structure is formed by twisting smectic layers with chiral dopant induced chirality, the distance over which the director rotates through a full cone (360 degree) is called one pitch, and the pitch length can be adjusted with the concentration of chiral dopant.

FLCs have been studied since 70's, and many research teams have devoted to the development of ferroelectric liquid materials for the potential of display, optical storage system and other applications. The requirements of FLC material [3] are summarized in the following:

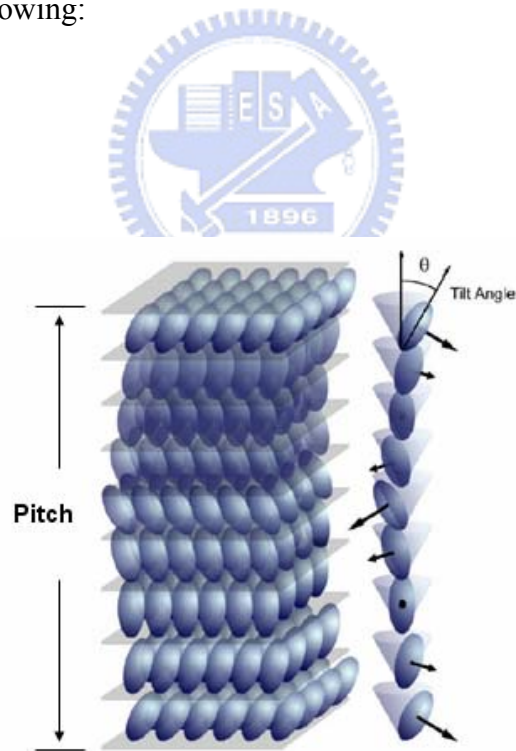


Fig. 1.3 Molecular arrangement in chiral smectic C phase.

a. Wide chiral smectic C mesophase

Liquid crystal mesophases, depending upon the amount of order in the material, mostly, from high to low temperature, FLC material begins in the isotropic state and transforms to chiral nematic phase, smectic A phase, smectic X phase, chiral smectic C phase, which is the FLC working phase. And a FLC material with wide chiral smectic C phase including room temperature is desired for a FLC device to work at different region.

b. Thermal stability

Liquid crystals are usually sensitive with temperature, For example, FLC material is thermal dependent as shown in Fig. 1.4 [4], and the transmittance is decreased with increasing temperature. A superior FLC material requires not only wide chiral smectic C operation temperature but also its thermal and chemical stability, of course, a temperature independent V-T curve is also desired.

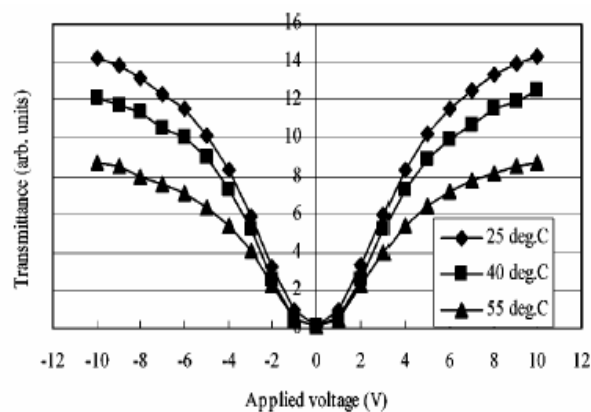


Fig. 1.4 Electro-optical characteristics of FLC device varies with temperature [4].

c. Long helical pitch in chiral smectic C and chiral nematic phase

Surface stabilized ferroelectric liquid crystal (SSFLC) [5] device is mostly used for FLC displays. Typically a SSFLC device is produced by unwinding the helix of a chiral smectic C material when the cell spacing is less than 2 μm and it requires a relatively large helix pitch FLC material.

d. Alignment ability

The alignment of FLC is extremely important for display applications and the elucidation of its physical properties. The conventional technique for producing homogeneous alignment is confining liquid crystal molecules under rubbed polyimide thin film [6]. However, smectic liquid crystals are more difficult to be orient, in chiral smectic C phase, zigzag defect and different domains are usually exhibited which are related to the chevron layer structures [6], and the defects will cause light leakage.

e. Fast response time

FLC has the potential and advantage of fast response time which is governed by the strong ferroelectric torque. Mostly, the response time of ferroelectric liquid crystal is less than 1 ms, which is faster than twist nematic LC for more than one order. With the fast response, more display applications such as field sequential color liquid crystal display [4] are capable.

f. Low viscosity and high purity

High viscosity FLC material affects not only the filling process but also the response time. For large panel displays, high viscosity LC materials are hardly filled in conventional vacuum filling process. To take it over, one drop fill (ODF) process [7] is highly concerned. The rise time of FLC can be describe as $\tau = \eta / P \cdot E$, where, η is the viscosity, P is the spontaneous polarization and E is the electric field. Reorient

speed of molecules is decreased in high viscosity LC material, to increase the response time, a low viscosity FLC material is required.

Ions affect the LC devices, upon the spontaneous polarization, SSFLC device is stabilized at one of the bistable state, and ions form an opposite field in order to erase the polarization, as a result, the stable state is destroyed. Ion effects are an important issue in LCDs, it will be further discussed in section 2.3.

g. Appropriate and large cone angle

Surface stabilized FLC device orients at the bistable states, a FLC material with 45° cone angle provides the 180° retardation and the relatively brightest state under crossed polarizers. To get the superior contrast ratio, not only a well aligned cell without light leakage but also the 45° cone angle for 180° retardation is required.

1.5 Surface Stabilized Ferroelectric Liquid Crystal (SSFLC)

SSFLC was first proposed by Clark and Lagerwall [5] in 1980. Typically a SSFLC device is produced by unwinding the helix of a chiral smectic C material when the cell spacing is less than $2\ \mu\text{m}$, since the cell gap is quite small compared with the helix pitch of FLC material. The spontaneous polarization (P_s) vector is perpendicular to the cell surfaces, and the bistable states are in opposite directions. FLC molecules are reoriented with electric field where the P_s vector will follow the electric field direction. And SSFLC device can be stabilized at both states when the applied voltage is removed, the bistable property can be utilized for not only display applications but also optical storage systems.

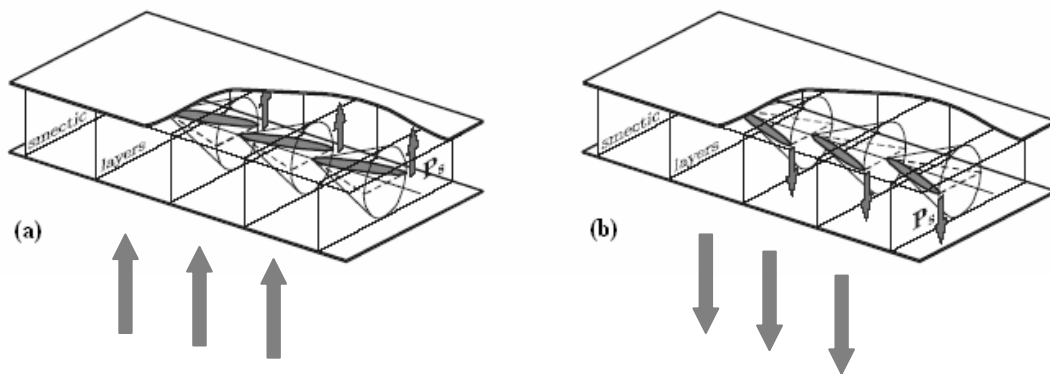


Fig. 1.5 Two stable states in surface stabilized FLC device, molecule reorients with its spontaneous polarization follows electric field.

1.6 Motivation and Objective of This Thesis

FLC is actively studied because of its advantages of fast response time, wide viewing angle and bistable capability. The fast response time under 1 ms makes the field sequential color LCD practicable. In field sequential color LCD, three colors (R, G, B) LEDs are utilized instead of the conventional CCFL. In this way, it follows the advantages, such as, good color saturation due to LED back light, and high luminance, high resolution and low cost for production due to color filterless.

For display applications, a monodomain cell and wide chiral smectic C mesophase are required. Unfortunately, zigzag defects and stripe domains usually exhibit in SSFLC device for most FLC materials. The defects lead to light leakage causing low contrast ratio. In addition, most commercial FLC materials have limited chiral smectic C phase, which also means the confined working temperature.

In this thesis, we proposed new glassy liquid crystals targeting applications in ferroelectric liquid crystal (FLC). Pure component of FGLCs and FGLCs as chiral

dopant were examined in this study. In all FGLC mixtures, rise time were under 700 μs and fall time were around or less than 1 ms without over driving technique. Thus, FGLC mixtures with large domain size and fast response time are suitable for color sequential display.

1.7 Organization of This Thesis

This thesis is organized as following: introduction of FLC is presented in Chapter 1. The properties and features of ferroelectric liquid crystal and SSFLC devices will be presented in Chapter 2. The experimental process for the preparation of FLC mixtures, and the introduction of instruments and their principles will be given in Chapter 3. The detail experimental results of FGLCs are discussed and presented in Chapter 4. Finally, the conclusion is summarized in Chapter 5.

