

新廣 SmC*液晶相溫度之玻璃態鐵電型液晶

**Novel Ferroelectric Glassy Liquid Crystal and
Mixtures with Wide SmC* Mesophase**

研究生：林淇文

指導教授：陳皇銘 博士

國立交通大學 電機資訊學院

顯示科技研究所

碩士論文

A Thesis
Submitted to Display Institute
College of Electrical and Computer Engineering
National Chiao Tung University
In Partial Fulfillment of the Requirements for the Degree of Master
In
Display Institute
June 2006
Hsinchu, Taiwan, R.O.C.

中華民國九十五年六月

新廣 SmC*液晶相溫度之玻璃態鐵電型液晶

研究生：林淇文

指導教授：陳皇銘 博士

國立交通大學顯示科技研究所

摘要

表面穩定鐵電型液晶最早於西元 1980 年被提出，此模態之鐵電型液晶在反應速度及視角上都有優異的表現並有雙穩態之特性。在此研究中，我們將玻璃態鐵電型液晶 (ferroelectric glassy liquid crystals) 摻雜至 W206A 液晶中，欲調配出廣 SmC* 液晶態工作溫度之鐵電型液晶材料以利於液晶顯示器之運用。

在合成的材料中，FGLC-3 compound 具有相當廣之 SmC* 液晶相 (15.7°C-115.4°C)，將 FGLC-3 compound 參雜至 W206A 中可成功地將 SmA 液晶態去除。其中 12% FGLC-3 mixture 含有最廣之 SmC* 液晶態 (16.9°C -97.9°C)。液晶排列狀態是由偏光顯微鏡拍攝所得，2% FGLC-1 mixture 在未經特殊表面處理之 2 μ m 液晶盒中表現出最佳的排列，沒有鐵電型液晶常出現的鋸齒狀缺陷 (zigzag defects)。2% FGLC-1 mixture 的反應速度 τ_{10-90} 和 τ_{90-10} 分別是 680 μ s 和 1.1ms 而 4.3% FGLC-3 mixture 之反應速度分別是 580 μ s 和 760 μ s。此兩種材料之廣 SmC* 溫度與排列皆有利於快速反應表面穩定電鐵型液晶材料之應用。

Novel Ferroelectric Glassy Liquid Crystal and Mixtures with Wide SmC* Mesophase

Student: Chi-Wen Lin

**Advisor: Prof. Huang-Ming Philip
Chen**

**NATIONAL CHIAO TUNG UNIVERSITY
Display Institute**

Abstract

A series of ferroelectric glassy liquid crystals (FGLCs) were synthesized and evaluated their potential for fast switching ability less than 1 ms. The latest developed FGLC possesses wide chiral smectic C mesophase over 100 °C. The diluted FGLCs mixtures were also investigated using W206A as host. In particular, the 2% FGLC-1 mixture obtains better alignment with than R2301 (Clariant, Japan) in the same pre-made 2μm cell (from EHC). In the series of FGLC-3 mixtures, the chiral smectic A phase was completely suppressed within all concentrations. These results provide new promising LC materials for fast switching, field sequential color LC display.

The novel FGLCs have potential to prepare a relatively good domain in SSFLC. They can be either prepared by pure component or used as chiral dopant in FLC mixtures. FGLCs as chiral dopant showed great ability maintaining chiral smectic C mesophase. Several groups have obtained mono-domain with FLC material R2301 by utilizing hybrid alignment or asymmetrical cell with liquid crystal polymers (LCPs) and linearly-photo-polymerized polymers (LPPs). Since larger domain sizes were able to achieve by 2% FGLC-1 cell and 4.3% FGLC-3 cell, we believe that the criteria to obtain mono-domain FGLC or FGLC mixture could be less strict than R-2301. These advantages may lead to a simpler manufacturing process or simpler cell structure in the future.

誌謝

在碩士班的研究期間，首先要感謝指導教授 陳皇銘老師在這兩年來細心及嚴厲的指導，在實驗的設計，邏輯的思考上給了我很大的幫助及改善。在於液晶的專業研究中更引導我們直到深入的研究與了解。並感謝師母於英語能力的細心指導。

在於研究生活中，首先要感謝 Dr. Pani Kumar 在於光電量測系統的教學以及鐵電式液晶驅動的指導。感謝鄭榮安 博士於化學實驗以及寫作上的建議。感謝呂志平學長讓我有機會合作參與顯示專題競賽並取得佳績。而所上其他學長姐們，黃文奎、韋安琪、陳均合、鄭裕國、楊柏儒 等人亦在研究及生活上提供了寶貴的經驗。同時並感謝昀諺陪我共度兩年的研究生活，在於課程，實驗，生活上得以一起討論與分享。並感謝所上的助理小姐在於學生教務上熱心的幫助以及感謝學弟妹在於研究上的協助並為實驗室帶來歡愉的氣氛。

最後，對於我摯愛的家人，感謝你們的關懷，陪伴及鼓勵讓我能順利完成這兩年的學業。並感謝好友們於生活的分享，關心讓我能快樂的研究，度過低潮。希望將這份喜悅與所有曾幫助我、關心我的人分享。

Table of Contents

Abstract (Chinese)

Abstract (English)

Table of Contents

Figure Caption

List of Tables

<i>Chapter 1 Introduction</i>	1
1.1 Introduction of Liquid Crystal Displays	1
1.2 Liquid Crystals Phase	2
1.3 Chirality	3
1.4 Ferroelectric Liquid Crystal	4
1.5 Surface Stabilized Ferroelectric Liquid Crystal (SSFLC)	7
1.6 Motivation and Objective of This Thesis	8
1.7 Organization of This Thesis	9
<i>Chapter 2 Ferroelectric Liquid Crystal Devices</i>	10
2.1 Spontaneous Polarization	10
2.1.1. Thickness and Temperature Dependency of the Spontaneous Polarization.	10
2.2 Display Operation Principle	13
2.2.1 Advantage of SSFLC Devices.....	14
2.2.2 Disadvantage of SSFLC Devices.....	16
2.3 Ionic Effects in FLC Display	18
2.4 Gray Scale	19
2.4.1 Spatial dither technique.....	19

2.4.2 Temporal dither technique.....	20
2.4.3 Polymer Stabilized Method.....	20
2.5 Field Sequential Full Color LCDs.....	22
2.6 Case Study.....	23
<i>Chapter 3 Fabrication Process, Instruments and Principle.....</i>	<i>27</i>
3.1 Introduction.....	27
3.2 Fabrication Process.....	27
3.2.1 FGLC Mixture Preparation.....	27
3.2.2 Measurement	28
3.3 Instruments and Principle.....	28
3.3.1 Differential Scanning Calorimetry (DSC).....	29
3.3.2 Polarizing Optical Microscope.....	30
3.3.3 Hot Stage.....	30
3.3.4 UV-VIS Spectroscopy.....	31
3.3.5 Optical System.....	33
3.3.6 Measurement of Spontaneous Polarization.....	34
<i>Chapter 4 Experimental Results and Discussion.....</i>	<i>37</i>
4.1 Introduction.....	37
4.2 Thermal Properties.....	37
4.2.1 Thermal Properties of FGLC Compounds and SmC Host.....	37
4.2.2 Thermal Properties of FGLC Mixtures.....	39
4.3 Alignment.....	40
4.4 Response Time.....	41
4.5 Electro Optical Characteristics of the 2% FGLC-1 Mixture.	42

4.6 Spontaneous Polarization.....46

4.7 Summary.....48

Chapter 5 Conclusion.....50

5.1 Conclusions.....50

5.2 Future Work.....50

Reference



Figure Caption

Fig. 1.1 Description of rod-like LC molecule.....	2
Fig. 1.2 Molecular arrangement in nematic, smectic A and smectic C phase.....	3
Fig. 1.3 Molecular arrangement in chiral smectic C phase.....	4
Fig. 1.4 EO characteristics of FLC device varies with temperature.....	5
Fig. 1.5 Two stable states in surface stabilized FLC device, molecule reorients with its spontaneous polarization follows electric field.....	8
Fig. 2.1 cell gap dependent spontaneous polarization.....	11
Fig. 2.2 The magnitude of spontaneous polarization determined as a function of temperature and cell thickness.....	11
Fig. 2.3 black (a.) and white (b.) display states of SSFLC under crossed polarizers..	13
Fig. 2.4 FLC switching modes (a) half-V mode (b) V-mode.....	16
Fig. 2.5 (a) Zigzag defects of a surface stabilized ferroelectric liquid crystal in the chevron geometry. (b) Texture of a field induced horizontal chevron structure. (c) double domains with opposite polarization.....	17
Fig. 2.6 Schematic diagram of spatial dither method.....	19
Fig. 2.7 Schematic diagram of temporal dither method.....	20
Fig. 2.8 Schematic diagram of gray scales PSFLC	21
Fig. 2.9 Photographs of PSFLC device driven by (a) 0V, (b) 3V and (c) 5V respectively, and the texture of Fig. 2.9 (b) is captured under POM	21
Fig. 2.10 The driving schemes of field sequential full color FLC of half-V and V modes materials.....	22
Fig. 2.11 Chemical structures of MD _n 2NA, MD _n 2NB and MD _n 2NB.....	24
Fig. 3.1 Photo of PerkinElmer Diamond DSC and its liquid nitrogen cooling system.....	29

Fig. 3.2 Instrument photo of Polarizing Optical Microscope, OLYMPUS BX51	30
Fig. 3.3 Instrument photos of Hot Stage together with its center controller.....	31
Fig. 3.4 Instrument photo of UV-VIS Spectroscopy, LAMBDA 650 PerKin Elmer...31	
Fig. 3.5 Interference data of one EHC cell by UV-Visible.....	32
Fig. 3.6 Diagram of optical system.....	33
Fig. 3.7 Spontaneous polarization experimental circuit set-up.....	34
Fig. 3.8 Schematic illustration of the current induced by (a) applying a square wave. (b) applying a triangular wave. Three contributions I_c , I_p , I_i , to the overall current I	35
Fig. 4.1 Thermal properties FGLC-1 mixtures measured by DSC.....	40
Fig. 4.2. Thermal properties of FGLC-3 mixtures measured by DSC.	40
Fig. 4.3 Microscopic textures of alignment and ON/OFF state of (a) FGLC-2, 120°C; (b) 2% FGLC-1, 25°C (c) 4.3% FGLC-3, 25°C; (d) R2301, 25°C	41
Fig. 4.4 (a) Driving scheme of response time measurement (b) Optical response of FGLC2 with over drive and high frequency driving scheme.....	42
Fig. 4.5 (a) EO characteristics of the 2% FGLC-1 mixture driven by 60 Hz bi-polar square wave at different temperature. (b) frequency dependent EO characteristics at 25 °C.....	43
Fig. 4.6 Electro optical characteristics of 2%FGLC-1 mixture driven by single pulses. (a) 23 V, 2 ms. (b) 23 V, 400 μ s. (c) 28 V, 400 μ s.....	44
Fig. 4.7 Electro-optical characteristics of the 2% FGLC-1 mixture applied by (a) 10 Hz, (b) 0.5 Hz triangular wave.	44
Fig. 4.8 (a) dark state without applying voltage. (b-e) the transition states by applying V_{DC} , 6V, (f) texture after applying V_{DC} , 15V.....	46
Fig. 4.9 Spontaneous polarization results of 2% FGLC-1 mixture, (a) 25Hz, 100V	

triangular wave, at 25 °C. (b) 25Hz, 100V triangular wave, at 120 °C
(isotropic).....47
Fig. 4.10 Ps value of FGLC-1 mixtures doped in R3206.....48
Fig. 5.1 Circuits of Diamant bridge method.....52



List of Tables

Tab. 2.1 Chemical Structure and Phase Transitions and Phase Transition Enthalpies for Polymers IP- IIIP.....	23
Tab. 2.2 Transitions temperatures for the series MD _n 2NA, MD _n 2NB, MD _n 2NC.....	25
Tab. 3.1 Filling temperatures of FGLC mixtures.....	28
Tab. 4.1 Phase Transition and Phase Transition Enthalpies for pure compounds obtained from DSC at heating and cooling rate at 20°C/min.....	38
Tab. 4.2 Thermal property of FGLC-1 and FGLC-3 mixtures.....	38
Tab. 4.2 Response time of various FLC samples in 2±0.5 μm cell, driven by 1 kHz 30V square wave.....	41

