

國立交通大學
應用化學研究所
博士論文

高效率上發光有機發光元件的開發

Development of Highly Efficient Top-Emitting Light-Emitting Devices



研究生：徐士峯

指導教授：陳金鑫 教授

中華民國九十五年九月

高效率上發光有機發光元件開發
Development of Highly Efficient Top-Emitting Light-Emitting Devices

研究生：徐士峯

Student : Shih-Feng Hsu

指導教授：陳金鑫

Advisor : Chin H. Chen



Submitted to Department of Applied Chemistry
College of Science
National Chiao Tung University
in partial Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy

Sep. 2006

Hsinchu, Taiwan

中華民國九十五年九月

Development of Highly Efficient Top-Emitting Light-Emitting Devices

Student : Shih-Feng Hsu

Advisors : Dr. Chin H. Chen

Department of Applied Chemistry
National Chiao Tung University

ABSTRACT

We have developed highly efficient red, green and blue top-emitting organic light-emitting devices by using Ag as the anode and cathode. We optimized microcavity effect in the devices by tuning suitable optical length for RGB emissions. A very saturated RGB color with Commission Internationale d'Eclairage (CIE) coordinates of (0.646, 0.353), (0.227, 0.721) and (0.135, 0.056) for RGB respectively were demonstrated and shown to display a color gamut of NTSC 102%. We also introduced a new hole-injection layer to get better carrier balance in the TOLEDs with which one of the best electroluminescence (EL) efficiencies for red was achieved at 37.5 cd/A .

We have also developed highly efficient white top-emitting organic light-emitting devices with broad emission by modifying both the anode and cathode. To alleviate the undesirable microcavity effect and obtain "broad" white emission, a CF_x -coated Ag anode and an index-matching layer (SnO_2) capped on a thin Ca/Ag cathode with a maximum transparency of 80% were employed. A top-emitting broad white-light device, based on the dual-layer architecture of light blue and yellow emitters with one of the highest EL efficiencies of 22.2 cd/A (9.6 lm/W) at 20 mA/cm² and 7.3 V with CIE coordinates of (x=0.31, y=0.47), has been demonstrated.

Contents

Chapter 1	Introduction	1
1.1	Overview of OLED devices and displays.....	1
1.2	Motivation.....	3
1.3	Thesis outlines.....	5
Chapter 2	Color-saturated top-emitting organic light-emitting devices	7
2.1	Introduction.....	7
2.2	Experimental	9
2.3	Results and discussions.....	11
2.3.1	<i>Alq-based devices with various thickness of ITO.....</i>	<i>11</i>
2.3.2	<i>Optimized TOLEDs with RGB emissive colors.....</i>	<i>13</i>
2.3.3	<i>Viewing angle of Alq-based and RGB TOLEDs</i>	<i>17</i>
Chapter 3	Highly efficient top-emitting organic light-emitting devices	21
3.1	Optical simulation.....	21
3.2	High efficiency TOLED devices.....	23
3.2.1	Ca/Ag system.....	24
3.2.2	<i>N-doping ETL/Ag system.....</i>	<i>25</i>
3.2.3	<i>New HIMs system.....</i>	<i>28</i>
3.3	Power consumption simulation of TOLEDs.....	32
3.4	WTOLEDs on TFT array.....	37
Chapter 4	White light top-emitting organic light-emitting devices	38
4.1	Introduction.....	38
4.2	White light top-emitting organic light-emitting devices with a dual-cavity structure.....	41
4.2.1	<i>Single-cavity WTOLEDs.....</i>	<i>42</i>
4.2.2	<i>Simulation and experimental comparisons of single-cavity WTOLEDs.....</i>	<i>46</i>
4.2.3	<i>Using Al/ITO as the separating layer in a dual-cavity structure.....</i>	<i>48</i>
4.2.4	<i>Using Ni as the separating layer in a dual-cavity structure.....</i>	<i>51</i>

4.3	White light top-emitting organic light-emitting devices with a highly transparent cathode.....	56
4.4	Highly efficient top-emitting white organic electroluminescent devices....	63
4.4.1	<i>Device characteristics of WTOLEDs</i>	64
4.4.2	WTOLEDs on TFT array.....	69
Chapter 5	High-efficiency and easily manufactured top-emitting white organic electroluminescent devices	73
5.1	WTOLEDs with a single blue dopant.....	73
5.2	WTOLEDs with a stacked structure.....	81
Chapter 6	Summary and future prospects	85
6.1	Summary.....	85
6.2	Future prospects.....	86
	Materials	87
	Publication list	90
	Author's autobiography	93



謝誌

首先，感謝口試委員陳金鑫教授、謝宗雍教授、陳錦地副所長、利錦洲處長、吳忠幟教授和陳皇銘教授對學生口試和論文的指導。

從 2000 年大二升大三的暑假，在電資大樓辦公室中伴隨爽朗笑聲，一隻手和我緊緊握住之後，開始了我 OLED 生活。從此黏住了 fred 和 OLED 實驗室，怎麼趕也趕不走。一轉眼已經 06 年了，六年的精采生活。從傻傻的拿到 $\text{Ir}(\text{acac})_3$ 和 IrCl_3 開始、到玩具越玩越大玩 Solciet coater、每年和 Ching Tang 除了討論 OLED 也討論政治問題、去美國 SID oral 發表一下、到德國 Prof. Selback 實驗室混一下、到處參加 conference—“We travel around the world”。陳金鑫教授您帶我真正體驗了 OLED 的種種過程，真的除了感謝還是感謝。

感謝所有 OLED 實驗室的成員，從草創成員到現在人數實在龐大。我要特別感謝帶我合成的 Banumathy Balaganesan、一起做實驗動腦筋又特別照顧我的孝文 Jesse 和 重君 CC 學長，沒有你們我真的不行。還有兼任室友的生活伴侶土撥 Sam、赤木 Oliver 和 小何 Kinneas，你們豐富了我的人生。也感謝嘉偉 Pony 和 圃成 Epson 還有所有族繁不及備載的大大小小學長學弟給我的幫助和刺激。最後也要特別謝謝朱媽媽美貞大大小小事情的照顧。

還要感謝友達光電 JJ、CF、Mike 和 pete 學長對我的照顧。昱鐳光電黃董、Serge 和 Simon 學長的材料支持。好朋友佩珍、琇苓一路的陪伴和鼓勵。要感謝的人太多，真的謝謝大家。

最後，感謝默默支持我的家人。

在此將本論文獻給所有關心我的人。