

MASTER'S THESIS

Multicolor organic light-emitting devices based on hydroxyquinoline complexes

Lee, Ka Man

Date of Award:
2001

[Link to publication](#)

General rights

Copyright and intellectual property rights for the publications made accessible in HKBU Scholars are retained by the authors and/or other copyright owners. In addition to the restrictions prescribed by the Copyright Ordinance of Hong Kong, all users and readers must also observe the following terms of use:

- Users may download and print one copy of any publication from HKBU Scholars for the purpose of private study or research
- Users cannot further distribute the material or use it for any profit-making activity or commercial gain
- To share publications in HKBU Scholars with others, users are welcome to freely distribute the permanent URL assigned to the publication

**Multicolor Organic Light-emitting Devices based on
Hydroxyquinoline Complexes**

LEE Ka Man

**A thesis submitted in partial fulfillment of the requirements
for the degree of
Master of Philosophy**

December 2001

Hong Kong Baptist University

Abstract

Significant advances have occurred in the development of organic light emitting diodes (OLEDs) in past-few years. For applications on display technology, the highly efficient blue and red light emitters are still under search. In this thesis, we fabricated blue and red OLEDs by using new blue organic light emitters and by dye-doping method respectively.

A bright blue light emitting material, bis(2-methyl-8-quinolinato) aluminum(III) hydroxide complexes (Almq_2OH), was first introduced. Almq_2OH was an efficient emitter and its OLEDs exhibited excellent electroluminescent ability. Its emission exhibited a peak at 485nm. The electrical and optical performance of Almq_2OH based OLEDs were studied in details and was compared to Alq_3 based OLEDs. We also studied in details the intra-molecular properties of Almq_2OH by quantum chemistry analysis. Moreover, a series of bis(2-methyl-8-quinolinato) aluminum(III) complexes (Almq_2OL), were also reported. Their properties were studied and compared to the performance of the multi-layer OLEDs

Doping technique was applied on OLEDs for tuning the colour of OLEDs. The idea originated from the concept of Förster Energy Transfer- a host light emitting material donates energy non-radiatively to dopant molecules. Three laser dyes: DCM II, coumarin 540 and perylene, were doped in the light emitting layer by co-evaporation. The electrical and optical properties of the doped OLEDs were discussed. After doping, the OLEDs had colour change and luminance enhancement. The performance of the doped OLEDs was also optimized by modifying on device structure, by selecting suitable host material and by finding the optimum dopant concentration.

Table of Contents

<i>Declaration</i>	<i>i</i>
<i>Abstract</i>	<i>ii</i>
<i>Acknowledgements</i>	<i>.iii</i>
<i>Table of Contents</i>	<i>iv</i>
<i>List of Tables</i>	<i>vii</i>
<i>List of Figures</i>	<i>viii</i>

Chapter 1 <i>Background Review</i>	<i>1</i>
1.1 Historical Background.....	1
1.2 Characteristics and Applications.....	4
1.3 Colour Modification.....	6
1.3.1 Chemical Structure Modification.....	6
1.3.1.1 Replacement of Central Metal Atom.....	6
1.3.1.2 Ligand Modification.....	7
1.3.2 Dye-doping Method.....	12
1.4 Motivation.....	16
Chapter 2 <i>Theory</i>	<i>17</i>
2.1 Electroluminescent Mechanism.....	17
2.1.1 Basic Description of EL Mechanism.....	17
2.1.2 Description of Chemical Items.....	19
2.1.2.1 Molecular Orbital.....	19
2.1.2.2 Exciton.....	23
2.1.2.3 Decay of Exciton.....	25
2.2 Carrier Transfer Mechanism.....	26
2.2.1 Injection Limiting Factor.....	26
2.2.2 Bulk Limiting Factor.....	27
2.3 Energy Transfer.....	35
2.3.1 Radiative Energy Transfer.....	35
2.3.2 Non-radiative Energy Transfer.....	35

2.3.2.1 Förster Energy Transfer.....	38
2.3.2.2 Carrier Transfer-Electron Exchange.....	40
2.3.2.3 Comparison between Förster Energy and Carrier Transfer.....	41
Chapter 3 Experimental Details.....	42
3.1 Material Preparation.....	42
3.1.1 Synthesis of Material.....	42
3.1.1.1 Synthesis of Almq_2OH Raw Material.....	43
3.1.1.2 Synthesis of Almq_2OL Raw Material.....	43
3.1.1.3 Chemical Structure Confirmation of Raw Material.....	45
3.1.2 Purification of Material.....	45
3.1.2.1 Purification Set-up.....	45
3.1.2.2 Purification Time Schedule.....	47
3.2 Sample Fabrication.....	49
3.2.1 Sample Structure.....	49
3.2.2 Cleaning Procedure.....	54
3.2.3 Coating Procedure.....	55
3.2.4 Encapsulation Procedure.....	59
3.3 Sample Measurement.....	60
3.3.1 <i>J-V-L</i> Characteristics Measurement Setup.....	60
3.3.2 Electro-luminescence Spectra and Photo-luminescence Spectra Measurement Setup.....	62
Chapter 4 Blue OLEDs.....	64
4.1 Blue OLEDs based on Bis(2-methy, 8-quinolinato).....	68
Aluminum Hydroxide Complex (Almq_2OH)	
4.1.1 Standard Performance of Almq_2OH based OLEDs.....	70
4.1.2 Comparison between Almq_2OH based and Alq_3 based OLEDs.....	73
4.1.3 Quantum Chemistry Analysis of Almq_2OH	77
4.1.4 Thickness Effects on Almq_2OH based OLEDs.....	86
4.2 Blue OLEDs based on Bis(2-methyl-8-quinolinato)	

Aluminum Complexes (Almq ₂ OL).....	91
4.2.1 Investigating a Stable and Efficient Almq ₂ Material.....	91
4.2.2 Improving the Almq ₂ based OLEDs by Dye-doping.....	105
Chapter 5 Red OLEDs	110
5.1 Reliability of Our Doping Method.....	113
5.2 Fabrication of Red OLEDs by Doping DCM II.....	123
5.2.1 Choice of Host Material.....	123
5.2.2 Improvement on DCM II Doped Znq ₂ OLEDs by Adding an Electron Transporting Layer.....	136
Chapter 6 Conclusion.....	143
Chapter 7 Bibliography.....	144
Chapter 8 Appendices.....	151
Appendix A – NMR Results of Homemade Blue Emitters.....	151
Appendix B – Purification Time Schedule.....	156
Appendix C – Details of Quantum Mechanical Calculation and Simulation...	157
8.c.1 The Molecular Hamiltonian.....	157
8.c.2 Wavefunction of Molecular Orbitals.....	158
8.c.2.1 Nature of Wavefunction.....	158
8.c.2.2 Selection of Basis Sets.....	159
8.c.3 Ab Initio Calculations.....	160
8.c.3.1 Expectation Value of Energy.....	160
8.c.3.2 Derivation of Hartree-Fock Equation.....	162
8.c.3.3 Simulation Procedure	165
Appendix D – Micro-cavity Interference Effect.....	166
Appendix E – Hammett Value.....	169
Appendix F – Excimer and Exciplex.....	170
<i>Publications and Conference Presentation.....</i>	<i>172</i>
<i>Curriculum Vitae.....</i>	<i>173</i>