

Organic Materials for Electronic Devices

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To my family

CURRICULUM VITAE

Lichang Zeng was born in 1978 in Fujian, China. In 2001, he received a Bachelors of Engineering degree in Polymer Materials from Zhejiang University, Hangzhou, China. He continued on at Zhejiang University receiving his Master of Science degree in 2004. He then moved to the University of Rochester to pursue his doctorate in Chemical Engineering under the joint supervision of Professors Shaw H. Chen and Ching W. Tang, receiving a Master of Science degree in 2009. His field of research was in organic electronic materials and devices.

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3. Zeng, L. C.; Lee, T. Y. S.; Merkel, P. B.; Chen, S. H. "A New Class of Non-Conjugated Bipolar Hybrid Hosts for Phosphorescent Organic Light-Emitting Diodes." *Journal of Materials Chemistry* **2009**, *19*, 8772.
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ABSTRACT

Through light absorption and emission as well as charge carrier generation, transport and recombination, π -conjugated molecules are central to electronic devices including organic field-effect transistors, organic light-emitting diodes, and organic solar cells. This thesis reports on materials development via molecular design, material synthesis and processing, device fabrication and characterization. Major accomplishments are summarized as follows.

A series of oligo(fluorene-*co*-bithiophene)s, **OF2Ts**, have been synthesized and characterized for an investigation of the effects of oligomer length and pendant aliphatic structure on thermotropic properties, light absorption and emission, and anisotropic field-effect mobilities. Solvent-vapor annealing at room temperature was shown to be capable of orienting **OF2Ts** into monodomain glassy-nematic films with an orientational order parameter emulating that achieved with conventional thermal annealing on a rubbed polyimide alignment layer.

Comprising hole- and electron-transporting moieties with flexible linkages, non-conjugated bipolar compounds have been developed for use as hosts for electrophosphorescence. These materials are characterized by an elevated glass transition temperature, morphological stability against crystallization, LUMO and

HOMO levels unaffected by chemical bonding, and triplet energy unconstrained by the electrochemical energy gap. Phosphorescent OLEDs containing solution-processed emitting layers were fabricated with **TRZ-3Cz(MP)2**, **TRZ-1Cz(MP)2** and **Cz(MP)2** hosting Ir(mppy)₃ for an illustration of how chemical composition and hence charge transport properties affect device performance.

Bulk heterojunction organic solar cells comprising an active layer of **P3HT:PCBM** blend at a 1:1 mass ratio with thickness from 130 to 1200 nm have been fabricated and characterized before and after thermal annealing. Before thermal annealing, both short circuit current density and power conversion efficiency decrease with an increasing film thickness, resulting in an inverse spectral response for thick-film devices. Thermal annealing decreases the thin-film device efficiency but substantially increases that of the thick-film devices while eliminating the inverse character of spectral response therefrom.

A conjugated oligomer-C₆₀ **Dyad** has been synthesized to demonstrate its ability to modulate the extent of phase separation between rod-like **OFTB** and spherical **PCBM**. While thermal annealing of the **OFTB:PCBM** at a 1:1 mass ratio results in a eutectic mixture, **OFTB:Dyad:PCBM** film at a 9:2:9 mass ratio undergoes phase separation into interspersed 30-nm amorphous domains at approximately equal fractions upon thermal annealing. Geometric surfactancy is

inferred by analogy to the widely reported formation of microemulsions in traditional oil-surfactant-water systems and ternary polymer blends.

TABLE OF CONTENTS

Curriculum Vitae	iii
Acknowledgements	v
Abstract	viii
List of Charts	xiv
List of Reaction Schemes	xv
List of Figures	xvi
List of Tables	xxviii
Forward	xxix
Chapter 1 Background and Introduction	1
1.1 Organic Semiconductors	1
1.2 Organic Field-Effect Transistors	4
1.3 Organic Light-Emitting Diodes	8
1.4 Organic Photovoltaic Cells	13
1.5 Formal Statement of Research Objectives	19
References	22
Chapter 2 Synthesis and Processing of Monodisperse Oligo (fluorene-co-bithiophene)s into Oriented Films by Thermal and Solvent Annealing.	42
2.1 Introduction	42

2.2	Experimental	45
2.3	Results and discussion	59
2.4	Summary	71
	References	74
Chapter 3	Development of Non-Conjugated Bipolar Host Materials for Phosphorescent Organic Light-Emitting Diodes	80
3.1	Introduction	80
3.2	Experimental	83
3.3	Results and discussion	95
3.4	Summary	111
	References	113
Chapter 4	Effects of Active Layer Thickness and Thermal Annealing on the P3HT-PCBM Photovoltaic Cells	119
4.1	Introduction	119
4.2	Experimental	120
4.3	Results and discussion	122
4.4	Summary	132
	References	134

Chapter 5	Modulation of Phase Separation Between Spherical and Rod-Like Molecules Using Geometric Surfactancy	136
5.1	Introduction	136
5.2	Experimental	137
5.3	Results and discussion	144
5.4	Summary	154
	References	156
Chapter 6	Conclusions and Future Studies	158
6.1	Conclusions	158
6.2	Future studies	161
Appendix 1	¹ H NMR and MALD/I-TOF Mass Spectra for Chapter 2	164
Appendix 2	¹ H NMR and MALDI/TOF Mass Spectra for Chapter 3	181
Appendix 3	¹ H NMR and MALD/I-TOF Mass Spectra for Chapter 5	188
Appendix 4	POM Images for Chapter 5	193

LIST OF CHARTS

2.1	Molecular structures of OF2T-1 through -8 and PF2T	45
3.1	Representative non-conjugated bipolar compounds as well as independent electron- and hole-transport moieties with their thermal transition temperatures determined by DSC heating scans. Symbols: <i>G</i> , glassy; <i>K</i> , crystalline; <i>I</i> , isotropic.	83
5.1	Molecular structures of OFTB , PCBM , and Dyad used in this study. Symbols: <i>G</i> , glassy; <i>K</i> , crystalline; <i>I</i> , isotropic.	138

LIST OF REACTION SCHEMES

2.1	Synthesis of OF2T-1 through -8	46
3.1	Synthesis scheme of non-conjugated bipolar hybrids, TRZ-1Cz(MP)2 , TRZ-3Cz(MP)2 , OXD-2Cz(MP)2 , and hole-transporting Cz(MP)2 .	85
5.1	Synthesis schemes for OFTB and Dyad .	138

LIST OF FIGURES

- 1.1 Schematic diagram of organic field-effect transistors in a top-gate configuration. 41
- 1.2 Typical J-V characteristics under dark and illuminated conditions accompanied by device performance parameters. 42
- 2.1 DSC thermograms at ± 20 °C min⁻¹ for samples of **OF2Ts** and **PF2T** preheated to above T_c or T_m (whichever is higher) and then quenched to -30 °C at -100 °C min⁻¹ before recording the reported second heating and cooling scans. Vertical arrows on the thermograms of **OF2T-3** locate transition temperatures identified by hot-stage polarizing optical microscopy. Symbols: *G*, glassy; *K*, crystalline; *N*, nematic; *I*, isotropic. 58
- 2.2 (a) UV-vis absorption spectra in molecular extinction coefficient, ϵ , and (b) fluorescence (with excitation at 430 nm) spectra of **OF2T-1**, **OF2T-4**, **OF2T-7** and **OF2T-8** in toluene at 10^{-7} to 10^{-6} M. 61
- 2.3 Cyclic voltammetric scans of (a) **OF2T-4**, (b) **OF2T-5**, (c) **OF2T-7** and (d) **OF2T-8** in anhydrous CH₂Cl₂ at 2.5×10^{-4} M with 0.1 M tetraethylammonium tetrafluoroborate as the supporting electrolyte. 62
- 2.4 Polarizing optical micrographs of **OF2T-8** films spin-cast from chloroform on a rubbed polyimide alignment layer observed at 45 degrees with respect to rubbing direction: (a) pristine, and (b) after thermal annealing at 140°C for 5 min. 63
- 2.5 (a) Schematic diagram of the organic field-effect transistors constructed for this study, where S and D denote source and drain, respectively; output (b) and transfer (c) curves for the OFETs

- comprising **OF2T-8** with chain alignment parallel to current flow. 64
- 2.6 Polarized absorption spectra of films spin-cast from 0.8 wt% solutions at 3000 rpm for 65 s on rubbed polyimide alignment layers: (a) **OF2T-8** film from chlorobenzene and then vacuum-dried at room temperature for up to 48 h; (b) **OF2T-8** film from chloroform or chlorobenzene, thermally annealed at 140°C for 5 min, and then cooled to room temperature; (c) **OF2T-8** film from chloroform and then vacuum-dried at room temperature for 12 h; and (d) **PF2T** film from chlorobenzene, and then vacuum-dried at room temperature for up to 48 h. The reported S_{ab} values are accompanied by an experimental error of ± 0.02 . Symbols A_{\parallel} and A_{\perp} represent absorbance parallel and perpendicular to rubbing direction, respectively. 67
- 2.7 Polarized absorption spectra of films spin-cast from 0.8 wt% solutions at 3000 rpm for 65 s on rubbed polyimide alignment layers: (a) **OF2T-7** film from chlorobenzene and then vacuum-dried at room temperature for up to 48 h; (b) **OF2T-4** film from chlorobenzene and then vacuum-dried at room temperature for up to 48 h; (c) **OF2T-7** film from chlorobenzene, followed by exposure to saturated chlorobenzene vapor for 30 s, and then vacuum-dried for up to 48 h, all at room temperature; (d) **OF2T-4** film from chlorobenzene, followed by exposure to saturated chlorobenzene vapor for 30 s, and then vacuum-dried for up to 48 h, all at room temperature. The reported S_{ab} values are accompanied by an experimental error of ± 0.02 . Symbols A_{\parallel} and A_{\perp} are as defined in Figure 2.6. 69
- 3.1 TGA thermograms of hybrid compounds recorded at a heating rate of 10 °C/min under nitrogen atmosphere. The decomposition

- temperatures at a weight loss of 5% are 399, 403 and 407 °C for **TRZ-1Cz(MP)2**, **TRZ-3Cz(MP)2** and **OXD-2Cz(MP)2**, respectively. 96
- 3.2 DSC heating and cooling scans at ± 20 °C/min of samples comprising (a) hole- and electron-transport moieties, (b) mixtures thereof, and (c) non-conjugated bipolar compounds that have been preheated to beyond their melting points followed by quenching to -30 °C. Symbols: *G*, glassy; *K*, crystalline; *I*, isotropic. 97
- 3.3 Polarizing optical micrographs of films from spin-cast chlorobenzene of **OXD:2Cz(MP)2** mixture (a) before and (b) after thermal annealing at 32 °C for 3 days; (c) that of an **OXD-2Cz(MP)2** film before and after thermal annealing at 100 °C for 3 days; and (d) that of an **OXD:PVK** mixture at 30:70 mass ratio after thermal annealing at 100 °C for 3 days. 98
- 3.4 Cyclic voltammetric scans of compounds in acetonitrile/toluene (1:1 by volume) at 10^{-3} M with 0.1 M tetrabutylammonium tetrafluoroborate as the supporting electrolyte. 100
- 3.5 Fluorescence spectra with excitation at 360 nm of approximately 45-nm-thick, spin-cast films of **Cz(MP)2**, **TRZ-1Cz(MP)2**, and **TRZ:1Cz(MP)2**; thermal annealing was performed at 20 °C above T_g under argon for ½ h. 101
- 3.6 (a) UV-vis absorption spectra in molecular extinction coefficients, ϵ , of **OXD-2Cz(MP)2**, **Cz(MP)2** and **OXD**. Phosphorescence spectra of (b) **Cz(MP)2**, (c) **OXD**, and (d) **OXD-2Cz(MP)2** at 77 °K in ethyl acetate at 10^{-4} M, for which the E_T values were determined by the 0-0 transitions as indicated by arrows. 105
- 3.7 (a) Molecular structure and energy diagram of a conjugated bipolar compound **CzOXD**, and (b) Molecular structure and

- energy diagram of a non-conjugated bipolar compound **TRZ-1Cz(MP)2** accompanied by those of **Cz(MP)2** and **TRZ**. 107
- 3.8 (a) Current density as a function of driving voltage for phosphorescent OLEDs with emitting layers comprising **Cz(MP)2**, **TRZ-3Cz(MP)2**, and **TRZ-1Cz(MP)2** doped with Ir(mppy)₃ at a 10:1 mass ratio. Inset: electroluminescence (EL) spectrum with **TRZ-3Cz(MP)2** as the host. (b) Luminance and current efficiency as functions of current density for the same phosphorescent OLEDs as described in (a). 109
- 4.1 Schematic diagram of the BHJ-OPV device architecture and chemical structures of **P3HT** and **PCBM** 123
- 4.2 *J-V* characteristics under 100 mW/cm² light illumination before and after thermal annealing at 110°C for 20 min of 130-nm BHJ-OPV devices without the LiF layer to improve electron collection-efficiency over Al cathode alone. 123
- 4.3 *J-V* characteristics under 100 mW/cm² light illumination of BHJ-OPV devices with varying active layer thicknesses before thermal annealing. 124
- 4.4 (a) UV-vis absorption spectra of P3HT:PCBM blend films with varying active layer thicknesses before thermal annealing, and (b) Spectral responses from BHJ-OPV devices with varying active layer thicknesses before thermal annealing; the dotted curve represents the spectral response from a 1200-nm device under illumination through the semitransparent cathode. 125
- 4.5 *J-V* characteristics under 100 mW/cm² white light illumination of a 1200-nm BHJ-OPV device thermally annealed at 110°C up to 120 min. 128
- 4.6 (a) UV-vis absorption spectra of a 1200-nm film before and after

- thermal annealing at 110 °C for 20 min, and (b) Spectral responses of a 1200-nm BHJ-OPV device thermally annealed at 110°C up to 120 min. 129
- 4.7 *J-V* characteristics in dark of BHJ-OPV devices with a 130- and 1200-nm active layer thermally annealed at 110°C for 20 min. The dotted curve represents the *J-V* characteristics of a 130-nm device without a LiF layer. 131
- 4.8 Electric-field dependence of spectral responses under reverse bias of a 1200-nm BHJ-OPV device after thermal annealing at 110°C for 20 min. 132
- 5.1 DSC heating scans of **OFTB:Dyad:PCBM** at three compositions as indicated. Dashed curves: samples preheated to 310°C and quenched to -30°C before heating at 20°C/min. Solid curves: samples preheated to 310°C and quenched to -30°C before annealing at 10°C above respective T_g s, as determined with dashed curves, for 12 h and then cooled to room temperature before heating at 20°C/min. Complete transition to isotropic liquid for the annealed 10:0:10 blend occurred at 242°C as indicated by an arrow. Symbols: *G*, glassy; *K*, crystalline; *I*, isotropic. 145
- 5.2 Samples of **OFTB:Dyad:PCBM** at 10:0:10 mass ratio, pure **PCBM** and **OFTB** were preheated to 310°C and then quenched to room temperature before annealing at 103°C for 48 h followed by cooling to room temperature for powder XRD analysis. Weaker crystalline diffraction peaks resulted from a shorter annealing time, *e.g.* 12 h. The annealing temperature was placed at 10 and 22°C above T_g of the blend and **OFTB**, respectively, and 189°C below the T_m of **PCBM**. A quenched but unannealed 10:0:10

blend was also characterized for identification of broad amorphous peaks.

146

- 5.3 The **OFTB:PCBM** phase diagram constructed with the DSC thermograms at 20°C/min and hot-stage POM for phase identification. With the exception of **PCBM**, all samples were preheated to 310°C, quenched to -30°C, and then annealed at 10°C above their respective T_g s for 12 h to maximize crystallization. The samples were then cooled at -20°C/min to room temperature for collecting heating scans at 20°C/min. Preheating **PCBM** to 310°C followed by quenching to -30°C did not result in glass transition, thereby obviating thermal annealing at 10°C above its T_g to further induce crystallization. The liquid lines were constructed with the end melting (open circles) and end dissolution (solid circles) temperatures for neat and excess components, respectively. Open triangles represent crystallization temperatures for the specified compositions. Symbols S and L represent solid and liquid regimes, respectively.

147

- 5.4 XRD patterns (collected at 0.02°/step), 10 s per step and POM micrographs as the insets for 100-nm-thick spin-cast films of **OFTB:Dyad:PCBM** blends at (a) 10:0:10 mass ratio and (b) 9:2:9 mass ratio after thermal annealing at 10°C above their respective T_g s for 12 h followed by cooling to room temperature. Essentially the same XRD and POM results were observed for the 7:6:7 film as reported in (b) for the 9:2:9 film. Preheating to 310°C as conducted for powders was avoided to preserve film integrity. No diffraction peaks are visible at 2θ between 10 and 30° as shown in Figure S.5.

149

- 5.5 AFM phase images of 100-nm-thick spin-cast films of **OFTB:Dyad:PCBM** at three compositions before (a, b, c) and after (d, e, f) thermal annealing for 12 h at 10°C above their respective T_g s followed by cooling to room temperature. Preheating to 310°C as conducted for powders was avoided to preserve film integrity. Featureless phase images of (a), (b), (c), and (f) represent the absence of phase separation down to about 1 nm. 151
- 5.6 Section analysis of the phase image of a 100-nm-thick spin-cast film comprising **OFTB:Dyad:PCBM** at a mass ratio of 9:2:9 after thermal annealing at 10°C above T_g for 12 h followed by cooling to room temperature. Preheating to 300°C as conducted for powders was avoided to preserve film integrity. The domain sizes are typically between 30 and 40 nm. 152
- 5.7 A schematic diagram of **Dyad** acting as a geometric surfactant to modulate phase separation between **OFTB** and **PCBM**. 153
- 5.8 AFM topographic images of 100-nm-thick spin-cast films of **OFTB:Dyad:PCBM** at three compositions before (a, b, c) and after (d, e, f) thermal annealing at 10°C above their respective T_g s for 12 h followed by cooling to room temperature. Preheating to 300°C as conducted for powders was avoided to preserve film integrity. The root-mean square protrusions are 0.33, 0.25, and 0.21 nm for a, b, and c, respectively, and 5.6, 3.1, and 0.23 nm for d, e, and f, respectively. 154
- A1.1 ^1H NMR (400 MHz) spectrum of **OF2T-1** in CDCl_3 at 298 K. 165
- A1.2 ^1H NMR (400 MHz) spectrum of **OF2T-2** in CDCl_3 at 298 K. 166
- A1.3 ^1H NMR (400 MHz) spectrum of **OF2T-3** in CDCl_3 at 298 K. 167

A1.4	¹ H NMR (400 MHz) spectrum of OF2T-4 in CDCl ₃ at 298 K.	168
A1.5	¹ H NMR (400 MHz) spectrum of OF2T-5 in CDCl ₃ at 298 K.	169
A1.6	¹ H NMR (400 MHz) spectrum of OF2T-6 in CDCl ₃ at 298 K.	170
A1.7	¹ H NMR (400 MHz) spectrum of OF2T-7 in CDCl ₃ at 298 K.	171
A1.8	¹ H NMR (400 MHz) spectrum of OF2T-8 in CDCl ₃ at 298 K.	172
A1.9	MALD/I TOF MS spectrum of OF2T-1 using DCTB as the matrix.	173
A1.10	MALD/I TOF MS spectrum of OF2T-2 using DCTB as the matrix.	174
A1.11	MALD/I TOF MS spectrum of OF2T-3 using DCTB as the matrix.	175
A1.12	MALD/I TOF MS spectrum of OF2T-4 using DCTB as the matrix.	176
A1.13	MALD/I TOF MS spectrum of OF2T-5 using DCTB as the matrix.	177
A1.14	MALD/I TOF MS spectrum of OF2T-6 using DCTB as the matrix.	178
A1.15	MALD/I TOF MS spectrum of OF2T-7 using DCTB as the matrix.	179
A1.16	MALD/I TOF MS spectrum of OF2T-8 using DCTB as the matrix.	180
A2.1	¹ H NMR (400 MHz) spectrum of TRZ-2Cz(MP)2 in CDCl ₃ at 298K	182
A2.2	¹ H NMR (400 MHz) spectrum of TRZ-3Cz(MP)2 in CDCl ₃ at 298 K.	183
A2.3	¹ H NMR (400 MHz) spectrum of OXD-2Cz(MP)2 in CDCl ₃ at 298 K.	184
A2.4	MALD/I TOF MS spectrum of TRZ-1Cz(MP)2 using DCTB as	

	the matrix.	185
A2.5	MALD/I TOF MS spectrum of TRZ-1Cz(MP)2 using DCTB as the matrix.	186
A2.6	MALD/I TOF MS spectrum of TRZ-1Cz(MP)2 using DCTB as the matrix.	187
A3.1	¹ H NMR (400 MHz) spectrum of OFTB in CDCl ₃ at 298 K.	189
A3.2	¹ H NMR (400 MHz) spectrum of Dyad in CDCl ₃ at 298 K.	190
A3.3	MALD/I TOF MS spectrum of OFTB using DCTB as the matrix	191
A3.4	MALD/I TOF MS spectrum of Dyad using DCTB as the matrix	192
A4.1	Polarizing optical micrographs of 100-nm-thick films comprising OFTB:Dyad:PCBM at three compositions before (a, b, c) and after (d, e, f) thermal annealing at 10°C above their respective T_g s for 12 h followed by cooling to room temperature. Preheating to 300°C as conducted for powders was avoided to preserve film integrity.	194

LIST OF TABLES

2.1	Highest occupied molecular orbital, HOMO, energy levels, orientational order parameters, S_{ab} , and anisotropic field-effect hole mobilities, μ_{\parallel} and μ_{\perp} , for OF2Ts and PF2T	69
2.2	Orientational order parameters, S_{ab} , of monodomain films comprising OF2T-4 , -7 and -8 achieved through thermal, quasi-solvent and solvent-vapor annealing	71
3.1	Electrochemical properties of compounds determined by the oxidation and reduction scans presented in Figure 3.4.	102
4.1	Performance parameters of BHJ-OPV devices with varying active layer thicknesses before and after thermal annealing at 110 °C for 20 min.	126
4.2	Performance parameters of the 1200-nm BHJ-OPV device after thermal annealing at 110 °C up to 120 min.	130

FORWORD

This thesis summarizes my PhD research in collaboration with my advisers, my fellow students, and scientists within and outside the University of Rochester. My participation and contributions to the research are as what follows.

Chapter 1 of my thesis is to introduce the background information pertinent to the researches discussed in the following chapters. I did the literature study and wrote this chapter.

I'm the leading author of Chapter 2 and have collaborated with Professor Shaw H. Chen, Feng Yan, Sean W. Culligan, and Simon K. H. Wei. Feng Yan synthesized compound **OF2T-1**, **-2**, **-3**, **-4**, **-5**, and **-7**. Sean W. Culligan measured the hole mobilities for **OF2T-4** and **-5**. This chapter has been published in *Advanced Functional Materials* **2009**, *19*, 1978

Chapter 3 of my thesis was co-authored with Professor Shaw H. Chen, Thomas Y. H. Lee, and Paul B. Merkel. The low-temperature phosphorescence spectra were collected by Paul B. Merkel. I'm the leading author for this chapter published in the *Journal of Materials Chemistry* **2009**, *19*, 8772

Chapter 4 of my thesis originates in the joint efforts with Professor Ching W. Tang and Professor Shaw H. Chen. I carried out all the experiments reported in this chapter, and it has been published in *Applied Physics Letters* **2010**, *97*, 053305.

Chapter 5 of my thesis was co-authored with Professor Shaw H. Chen, and

Thomas N. Blanton of the Eastman Kodak Company. All the X-ray diffraction data were collected by Blanton, and I'm responsible for all other data. This chapter has been published in *Langmuir* **2010**, *26*, 12877.