Synthesis and Characterization of Electrophosphorescent Jacketed Conjugated Polymers

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Received 14 April 2012; accepted 22 May 2012; published online DOI: 10.1002/pola.26189

ABSTRACT: A monomer containing bent side chains with oxadiazole unit was synthesized. And it was copolymerized with polyfluorene at different ratios. The photophysical and electrochemical properties of the copolymers were characterized. The results show that the introduction of the oxidiazole-containing side chains into the polymer reduces the lowest unoccupied molecular orbital level. And the steric hindrance of the side groups can effectively suppress the aggregation of the polymer backbones. Electroluminescent devices were fabricated with a configuration of indium tin oxide (ITO)/poly(3,4-ethylenedioxythiophene (PEDOT):PSS/Sample/Ca/AI. All of the devices emit blue light. The device of the copolymer PFOXD50 shows the best performance with the maximum luminance of 1033 cd/m²

INTRODUCTION Recently, polymer light-emitting diodes (PLEDs) have attracted a lot of attention because of their good thermal stabilities, easy processing methods, such as spin-coating and inkjet-printing, and applications in flexible and large-area displays. The first polymer light-emitting material is poly(1,4-phenylene vinylene), discovered in 1990.¹ Most PLED materials emit fluorescent light from singlet exciting states. However, the maximum theoretical internal quantum efficiencies are limited to 25%. In 1998, Förrest discovered the first electrophosphorescent material.² Some heavy metal complexes can use the triplet exciting states, which account for the greater proportion in theory, to emit phosphorescent light. Electrophosphorescent materials make use of the triplet excitons, which allows for the theoretical internal quantum efficiencies to reach as high as 100%.³ Because of their relatively high quantum yields and short exciting lifetimes, iridium complexes are intensively researched.^{4,5}

Polyfluorene (PF) and its derivatives are highly efficient blue-light materials^{6,7} and good host materials.^{8,9} However, the planar structures of PFs may easily form intermolecular aggregation, leading to the undesirable changes of emitting colors.^{10,11} Therefore, some side groups with large steric hindrances are often introduced to suppress the aggrega-

and the maximum current efficiency of 0.29 cd/A. Then a cyclometalated iridium complex monomer (ppy)₂Ir(BrPhPyBr) was copolymerized with PFOXD50 at different ratios. The devices with the same configuration emit orange light. The efficiency generally increases with the increasing Ir content. Among them, the device of the copolymer PFOXDIr7 shows the best performance with the maximum luminance of 846 cd/m² and the maximum current efficiency of 0.61 cd/A. © 2012 Wiley Periodicals, Inc. J Polym Sci Part A: Polym Chem 000: 000–000, 2012

KEYWORDS: conjugated polymers; light-emitting diodes (LED); liquid-crystalline polymers (LCP)

tion.^{12,13} Besides, most PF materials are p-types, which have better abilities to transport holes than electrons. However, the balance of carrier transportation greatly affects the device efficiencies. A common way to solve this problem is to build mutilayered devices or to dope with other materials. However, problems, such as phase separation or crystallization, may occur. Another way is to introduce other moieties that have a different carrier-transporting property into the molecules to form bi-polar structures.¹⁴⁻¹⁷ Oxadiazole derivatives are well known electron-transporting and hole-blocking materials.^{18,19} The introduction of oxadiazole moieties in this work is expected to balance the carrier transportation. The backbones are expected to transport holes while the side groups transport electrons. This di-channel structure²⁰ should enhance the device performance. Besides, the oxadiazole side chains attached to the backbone can be viewed as a first-generation dendron. Dendronized polymers can selfassemble into interesting structures.^{21,22} By tuning the structure of the side group, such as changing the generation, different supermolecular structures occur.23-25 This will probably also benefit the electro-optic properties.²⁶

Mesogen-jacketed liquid crystalline polymers (MJLCPs) are first proposed as a special kind of side-chain liquid crystalline

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SCHEME 1 Syntheses of the monomer OXDBr2 and PFOXD series of polymers.

polymers with very short spacers or without spacers between the main chain and the side-on mesogen.^{27,28} Recently, jacketed structures are also applied to rigid, conjugated polymers.^{29,30} And researches on the functionalization of MJLCPs have been done in the past several years. The studies of MJLCPs in electroluminescent devices have proven that the jacketed structure can suppress the long-wavelength emissions, benefiting the electroluminescent properties.³¹⁻³³

This article focuses on a series of electroluminescent jacketed conjugated polymers. First, a series of PF copolymers containing different contents of bent side chains with oxadiazole moiety were synthesized. The polymer in this series with the best balance of carrier transportation was chosen as the host material and copolymerized with a monomer containing the iridium complex at different ratios to obtain phosphorescent polymers. The jacketed side groups are expected to prevent the iridium complexes attaching to the backbone from aggregating. To the best of our knowledge, these are the first jacketed conjugated polymers with iridium attached to the conjugated backbone.

EXPERIMENTAL

Materials

HC30XD-G1 was obtained using the previously reported method.¹⁷ 2,5-Dibromobenzene-1,4-diol and $(ppy)_2Ir(BrPh-PyBr)$ were synthesized according to the published procedures.^{34,35} All the other reagents were used as received.

Characterization and Device Fabrication

The characterization methods such as gel permeation chromatography, ¹H NMR spectroscopy, thermogravimetric analysis, differential scanning calorimetry, UV-vis spectrum, photoluminescent (PL) spectrum, and cyclic voltammetry (CV), and the device fabrication process were similar to those we used previously.³²

Synthesis

The synthetic routes of the PFOXD and PFOXDIr series of polymers are outlined in Schemes 1 and 2, respectively.



SCHEME 2 Synthesis of PFOXDIr series of polymers.

Synthesis of TsC3OXD-G1 (1)

HC3OXD-G1 (7.0 g, 10.7 mmol) and TsCl (2.7 g, 14.2 mmol) were dissolved in CH₂Cl₂ (200 mL). Et₃N (10 mL) was added. And the mixture was stirred at ambient temperature for 8 h. Then the solvent was removed by a rotary evaporator, and the residue was purified through silica gel column chromatography (CH₂Cl₂:EtOAc = 10:1) to give a white solid (6.5 g, 7.6 mmol) in a 72% yield. ¹H NMR (400 MHz, CDCl₃, δ , ppm): 0.86-0.89 (t, 6H, CH₃), 1.27-1.35 (m, 16H, CH₂), 1.45-1.47 (m, 4H, CH₂), 1.78-1.84 (m, 7H, OCH₂CH₂, phCH₃), 2.19-2.23 (m, 2H, OCH₂CH₂CH₂O), 4.02-4.05 (t, 4H, OCH₂), 4.12-4.15 (t, 2H, OCH₂), 4.28-4.31 (t, 2H, OCH₂), 7.01-7.05 (d, 4H, Ar-H), 7.24 (m, 2H, Ar-H), 7.67-7.68 (d, 2H, Ar-H), 7.76-7.77 (m, 2H, Ar-H), 8.08-8.12 (m, 4H, Ar-H), 8.38-8.39 (t, 1H, Ar-H). Mass spectroscopy (MS) (electrospray ionization (ESI)): m/z $[851.4 \ [M + H]^+$. Anal. Calcd. For $C_{48}H_{58}N_4O_8S$: C, 67.74; H, 6.87; N, 6.58. Found: C, 67.78; H, 6.86; N, 6.61.

Synthesis of OXDBr2 (2)

TsC30XD-G1 (6.2 g, 7.2 mmol) and 2,5-dibromobenzene-1,4-diol (0.93 g, 3.5 mmol) were dissolved in a mixed solvent

containing 100 mL of tetrahydrofuran and 200 mL of N,Ndimethyl formamide. K₂CO₃ (1.9 g, 13.8 mmol) and KI (0.2 g, 1.4 mmol) were added, and the mixture was heated at 70 $^\circ$ C under an Ar atmosphere for 8 h. After cooled to ambient temperature, the mixture was filtered, and the filtrate was concentrated. The pure product was obtained through silica gel column chromatography (CHCl₃:EtOAc = 8:1) as a white solid (5.0 g, 3.1 mmol) in a 88% yield. ¹H NMR (400 MHz, CDCl₃, δ, ppm): 0.88-0.91 (t, 12H, CH₃), 1.30-1.39 (m, 32H, CH₂), 1.44-1.50 (m, 8H, CH₂), 1.79-1.86 (m, 8H, OCH₂CH₂), 2.35-2.38 (m, 4H, OCH₂CH₂CH₂O), 4.03-4.06 (t, 8H, OCH₂), 4.20-4.23 (t, 4H, OCH₂), 4.39-4.42 (t, 4H, OCH₂), 7.02-7.04 (d, 8H, Ar-H), 7.16 (s, 2H, Ar-H), 7.83 (m, 4H, Ar-H), 8.08-8.11 (m, 8H, Ar-H), 8.41 (t, 2H, Ar-H). MS (matrix assisted laser desorption ionization (MALDI)-time of flight (TOF)): m/z 1647.6 $[M + Na]^+$. Anal. Calcd. For $C_{88}H_{104}N_8O_{12}Br_2$:C, 65.02; H, 6.45; N, 6.89. Found: C, 65.08; H, 6.46; N, 6.89.

General Procedure of Polymerizations

Typical Suzuki polycondensation was used in this work. Using PFOXD10 as an example, 9,9-dioctylfluorene-2,7-

TABLE 1 Molecular W	leights and	Thermal Properties	of PFOXD Series
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		Oxadiazole-Co C	Oxadiazole-Containing Monomer Content				
Polymer	Yield (%)	In feed (%)	In polymer (%) ^b	M _n (g∕mol)ª	PDI ^a	<i>T</i> _d (°C) ^c	τ _g (°C) ^d
PF	73	0	0	8,000	4.29	428	60
PFOXD10	84	10	9	9,100	4.38	413	67
PFOXD30	82	30	32	10,800	1.65	417	74
PFOXD50	94	50	55	10,600	1.71	417	77

^a Determined by GPC using polystyrene standards.

^b Calculated from ¹H NMR data.

 $^{\rm c}$ The temperature of 5% weight loss of the polymer determined from TGA under a nitrogen atmosphere at a heating rate of 20 $^{\circ}C/min.$



 $^{\rm d}$ Glass transition temperature determined by DSC in the second heating process at a heating rate of 20 $^\circ {\rm C/min}.$



FIGURE 1 ¹H NMR spectra of the PFOXD series of polymers.

bis(ethyleneborate) (0.13 g, 0.25 mmol), 2,7-dibromo-9,9dioctylfluorene (0.11 g, 0.20 mmol), OXDBr2 (0.08 g, 0,05 mmol), and Pd(PPh₃)₄ (0.02 g, 0.002 mmol) were added in a schlenk tube. Toluene (5 mL) and an aqueous solution of K_2CO_3 (3 mL, 1 mol/L) were used as the mixed solvent. After three times of freeze-pump-thaw cycles, the tube was heated at 80 °C under an Ar atmosphere for 72 h. A small amount of bromobenzene was added to remove the boric acid ester end groups. After 4 h, a small amount of phenylboronic acid was added to remove the bromine end groups. The reaction mixture was diluted by $CHCl_3$ (150 mL) and then washed with water (100 mL \times 3). The organic layer was concentrated after dried by $MgSO_4$. The residual solution was passed through an alumina column and precipitated in acetone. The same precipitation process was done two more times.

¹H NMR (400 MHz, CDCl₃, δ , ppm)

PF: 0.75–1.25 (m, CH₃, CH₂), 1.95–2.30 (br, fluorene–CH₂), 7.32–8.04 (m, Ar–H).



FIGURE 2 Normalized UV-vis absorption spectra of PFOXD series in CHCl₃ (a) and in films (b).



FIGURE 3 Normalized PL spectra of PFOXD series in $CHCl_3$ (a) and in films (b).

PFOXD10: 0.70–1.50 (m, CH₃, CH₂), 1.70–1.90 (br, fluorene–CH₂), 1.90–2.40 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.85–4.45 (m, OCH₂), 6.90–8.45 (m, Ar—H).



FIGURE 4 Normalized PL spectra of PFOXD series in films after annealing.

TABLE 2 UV-vis and F	PL Spectra I	Data of PFOXD	Series
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	In C	HCI ₃	In Film			
	UV-vis (nm)ª	PL (nm) ^{b,c}	UV-vis (nm) ^d	PL (nm) ^{c,e}	PL (nm) ^f	
PF	377	422, 441	375	424, 446	439, 466	
PFOXD10	375, 310	420, 439	378, 300	425, 449	440, 465	
PFOXD30	366, 307	417	376, 301	451	450	
PFOXD50	365, 305	415	382, 330, 302	430, 440	442	

^a Solution concentration: 10⁻⁵mol/L.

^b Solution concentration: 0.1 mg/ml.

^c Excited at 300 nm.

 $^{\rm d}$ Films were spin-coated from ${\rm CHCl}_3$ solutions (0.1 mg/ml) and dried at ambient temperature.

 $^{\rm e}$ Films were cast from ${\rm CHCl}_3$ solutions (10 mg/ml) and dried at ambient temperature.

^f Annealed at 100 °C for 24 h.

PFOXD30: 0.70–1.50 (m, CH₃, CH₂), 1.70–1.90 (br, fluorene–CH₂), 1.90–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.85–4.45 (m, OCH₂), 6.90–8.50 (m, Ar—H).

PFOXD50: 0.65–1.50 (m, CH₃, CH₂), 1.70–1.85 (br, fluorene–CH₂), 1.85–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.85–4.45 (m, OCH₂), 6.85–8.45 (m, Ar—H).

PFOXDIr1: 0.65–1.50 (m, CH₃, CH₂), 1.70–1.85 (br, fluorene–CH₂), 1.85–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.85–4.50 (m, OCH₂), 6.88–8.45 (m, Ar—H).

PFOXDIr3: 0.65–1.50 (m, CH₃, CH₂), 1.70–1.85 (br, fluorene–CH₂), 1.85–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.90–4.52 (m, OCH₂), 6.90–8.45 (m, Ar—H).

PFOXDIr5: 0.65–1.50 (m, CH₃, CH₂), 1.70–1.85 (br, fluorene–CH₂), 1.85–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.92–4.52 (m, OCH₂), 6.91–8.44 (m, Ar—H).

PFOXDIr7: 0.65–1.50 (m, CH₃, CH₂), 1.70–1.85 (br, fluorene–CH₂), 1.85–2.45 (m, OCH₂CH₂CH₂O, fluorene–CH₂), 3.85–4.45 (m, OCH₂), 6.80–8.50 (m, Ar—H).



FIGURE 5 Cyclic voltammograms of PF and PFOXD30.

	HOMO (eV)ª	LUMO (eV) ^a	LUMO (eV) ^b
PF	-5.87	-	-3.06
PFOXD10	-5.90	-	-3.09
PFOXD30	-6.07	-2.51	-3.16
PFOXD50	-6.19	-2.51	-3.23

TABLE 3 Energy Levels of PFOXD Series

^a Calculated from CV.

^b Calculated from optical band gap.

RESULTS AND DISCUSSION

PFOXD Series

The number-average molecular weights (M_n s) and polydispersity indexes (PDIs) are summarized in Table 1. Their M_n values are 8000-10,800 g/mol, with PDIs of 1.65-4.38. The contents of the oxadiazole in the polymers can be obtained from ¹H NMR data (Fig. 1). The chemical shift at around 4 ppm is attributed to the OCH₂ in the oxadiazole monomer. The chemical shift at around 2 ppm is attributed to both the OCH₂*CH*₂ in the oxadiazole-containing monomer and CH₂ directly connecting the fluorene. Therefore, the ratio of the two monomers can be calculated by the integral area. The results (shown in Table 1) are close to the designed values. And all the polymers exhibit good thermal stabilities with the 5% weight loss temperatures (T_d s) higher than 400 °C. The glass transition temperature (T_g) increases slightly because of the rigid structure of oxadiazole side groups.

Figure 2 is the UV-vis absorption spectra of the polymers in solution and in films. With the increase of the oxadiazole content, the absorption peak at about 300 nm attributed to oxadiazole³⁶ increases in intensity, and the peak at about 380 nm attributed to the backbone²⁹ decreases in intensity. This result is as expected.

Excited at 300 nm, all the polymers emit typical blue light of the backbone (Fig. 3).²⁹ The most remarkable is that the PL spectra of PF, PFOXD10, and PFOXD30 change dramatically after annealed at 100 °C for 24 h. However, the spectrum of PFOXD50, which had the highest oxadiazole content in the series, almost remains the same as before annealing (Fig. 4). This suggests that the steric hindrance of the side groups can effectively suppress the aggregation, which leads to changes of the spectra, of the polymers during annealing. And it also implies that PFOXD50 may be the best polymer to build high-performance devices. The photophysical data are summarized in Table 2.



FIGURE 6 EL spectra of PFOXD series.

Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) levels are important properties for organic light-emitting diode materials. They can be determined from the onset reduction potential and onset oxidation potential in CV spectra according to the formulae $E_{\text{HOMO}} = -e[U_{\text{onset}(\text{ox})} + (4.8 \text{ V} - U_{1/2,\text{FOC}})]$ and E_{LUMO} $= -e[U_{\text{onset(red)}} + (4.8 \text{ V} - U_{1/2,\text{FOC}})]^{.32}$ In the CV spectra of the polymers (Fig. 5, showing PF and PFOXD30 as examples), the onset reduction potentials of PF and PFOXD10 are not observed. This is probably because of the low oxadiazole contents. Therefore, for these two samples, their LUMO levels were calculated from the onset absorption in their UV-vis spectra. The results are listed in Table 3. By introducing the oxadiazole moieties into the polymers, the LUMO levels decrease, which indicates the improvement of the electrontransporting property. The backbones may act as the holetransporting part, while the side groups may act as the electron-transporting part. Such a bi-channel structure may be beneficial for balancing the carrier transportation in devices.20

Electroluminescent devices were fabricated with a configuration of indium tin oxide (ITO)/poly(3,4-ethylenedioxythiophene (PEDOT):PSS/Sample/Ca/Al. All of the devices emit blue light (Table 4). The efficiencies generally increase with the increase of the oxadiazole content. Because the introduction of oxadiazole moiety enhances the electron-transporting abilities, which makes the carrier transportation more balanced, the device with PFOXD50 shows the best performance

	$U_{\rm onset}$ (V)	$L_{\rm max}~({\rm cd}/{\rm m}^2)$	η _{Imax} (cd/A)	η _{Lmax} (Im/W)	CIE Coordinate	λ (nm) ^a
PF	5.6	488	0.0685	0.0279	0.19, 0.13	423, 438, 481
PFOXD10	5.5	864	0.2050	0.0879	0.18, 0.13	421, 442, 481
PFOXD30	5.7	549	0.1400	0.0528	0.20, 0.12	420
PFOXD50	4.9	1033	0.2890	0.1140	0.18, 0.10	418

TABLE 4 Electroluminescent Properties of PFOXD Series

^a At low voltage.

TABLE 5	Molecular	Weights	and	Thermal	Properties	of
PFOXDIr	Series					

Polymer	Yield (%)	<i>M</i> _n (g/mol) ^a	PDI ^a	$T_{d} (^{\circ}C)^{b}$	T _g (°C) ^c
PFOXDIr1	90	8,400	1.28	412	77
PFOXDIr3	95	8,300	1.35	406	75
PFOXDIr5	95	8,600	1.42	401	76
PFOXDIr7	97	11,700	1.51	405	82

^a Determined by GPC using polystyrene standards.

^b The temperature of 5% weight loss of the polymer determined from

TGA under a nitrogen atmosphere at a heating rate of 20 °C/min.

 $^{\rm c}$ Determined by DSC in the second heating process at a heating rate of 20 $^{\circ}\text{C/min}.$

with the maximum luminance of 1033 cd/m^2 and the maximum current efficiency of 0.29 cd/A. And in the electroluminescent (EL) spectra (Fig. 6), the shoulder peaks at about 500 nm decrease with the increase of the oxadiazole content. This is in agreement with the PL spectra. All these results reveal that PFOXD50 has the best properties among this series of copolymers and is the most possible one as the host material for the phosphorescent guest in the next step.



FIGURE 7 Normalized UV-vis absorption spectra of PFOXDIr series in $CHCl_3$ (a) and in films (b).



FIGURE 8 Normalized PL spectra of PFOXDIr series in $CHCI_3$ (a) and in films (b).

PFOXDIr Series

On the basis of the above study, PFOXD50 is the best among the PFOXD series of copolymers. We introduced iridium complexes into this polymer by copolymerizing with $(ppy)_2Ir(BrPh-$ PyBr) at different ratios. As listed in Table 5, the M_ns of the

TABLE 6 UV-vis and PL Spectra Data of PFOXDIr Series

	In	CHCI ₃	In Film		
	UV-vis (nm)ª	PL (nm) ^{b,c}	UV-vis (nm) ^d	PL (nm) ^{c,e}	
FOXDIr1	304	418	300	445, 568	
FOXDIr3	304	418	306	451, 571	
FOXDIr5	304	418	305	461, 574	
FOXDIr7	304	418	299	463, 579	

^a Solution concentration: 10^{-5} mol/L.

^b Sulution concentration: 0.1 mg/mL.

^c Excitation wavelength was 300 nm.

 $^{\rm d}$ Films were spin-coated from CHCl_3 solutions (0.1 mg/mL) and dried at ambient temperature.

 $^{\rm e}$ Films were cast from ${\rm CHCI}_3$ solutions (10 mg/mL) and dried at ambient temperature.



FIGURE 9 Cyclic voltammogram of PFOXDIr7.

polymers are 8300-11,700 g/mol, with PDIs of 1.28-1.51. They have similarly good thermal properties as PFOXD50.

Because the contents of the iridium complexes are small in the copolymers, their absorption spectra are similar (Fig. 7). For PL emission in solution, all the polymers are similar to PFOXD50 with the maximum emission peaks at around 420 nm (Fig. 8). No obvious emission peaks from the guest are observed, which indicates that there is no energy transfer from the host to the guest. However, the situation in films is quite different (Table 6). As the Ir content increases, the intensity of the emission peak from the guest at about 570 nm increases, while that of the emission peak from the host at about 450 nm decreases. This suggests that energy transfers from the host to the guest. For PFOXDIr7, there is only one emission peak at 579 nm, indicating nearly complete energy transfer.



FIGURE 10 Energy levels of the host and guest materials.

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TABLE 7 Electroluminescent Properties of the PFOXDIr Series

	U _{onset} (V)	L _{max} (cd/m²)	η _{Imax} (cd/A)	ղ _{Lmax} (Im/W)	CIE Coordinate	λ (nm)ª
PFOXDIr1	5.9	619	0.4046	0.1414	0.46, 0.46	416, 569
PFOXDIr3	6.0	352	0.3682	0.1456	0.48, 0.47	417, 577
PFOXDIr5	5.7	931	0.4886	0.1792	0.51, 0.48	580
PFOXDIr7	5.4	846	0.6118	0.2394	0.53, 0.47	585

^a At low voltage.

The HOMO and LUMO energy levels of the polymers calculated from CV spectra (CV curve of PFOXDIr7 is shown in Fig. 9 as an example) are also quite close. The energy diagram (Fig. 10) shows that the HOMO and LUMO levels of $Ir(ppy)_3$ are in between those of PFOXD50. This indicates that the complexes may act as the traps of the carriers in light-emitting devices.

Devices with the same configuration for the PFOXD series were fabricated. They emit orange light (Table 7). The change of the EL spectra (Fig. 11) is similar to that of the PL spectra. Emissions from both the host and the guest can still be observed in devices with PFOXDIr1 and PFOXDIr3 that have relatively low Ir contents. However, in devices with PFOXDIr5 and PFOXDIr7, there are only single peaks at around 580 nm. The device efficiencies generally increase from PFOXDIr1 to PFOXDIr7. No obvious decrease of the efficiencies caused by quenching of triplet excitons at the high Ir concentration is observed. This can be attributed to the "jacketing" effect. The big side groups can efficiently separate the iridium complexes from each other and suppress the triplet annihilation. The device with PFOXDIr7 has the best performance with the maximum luminance of 846 cd/ m^2 and the maximum current efficiency of 0.61 cd/A.

CONCLUSIONS

A series of electroluminescent jacketed conjugated polymers with different contents of oxadiazole moeity were



FIGURE 11 EL spectra of PFOXDIr series.

successfully synthesized. The contents of oxadiazole determined by ¹H NMR are close to the designed values. And variation in the absorption spectra is expected. With the increase of the oxadiazole content, the LUMO levels decrease, and the performance of the simple device with a configuration of ITO/PEDOT:PSS/Sample/Ca/Al enhances, with the device containing PFOXD50 having the best properties. And PFOXD50 was chosen as the host material and copolymerized with (ppy)₂Ir(BrPhPyBr) at different ratios. The absorption spectra and the CV spectra do not change much at different Ir contents. However, the intensity of the orange-light emission of the PL spectra in films from the guest increases, while the emission from the host decreases. There is an energy transfer between the host and the guest. With the same configuration as with the PFOXD series, they all emit orange light. The efficiencies generally increase with increasing Ir content, which indicates that the bulky side groups containing oxidiazole can not only balance the carrier transportation but also separate the iridium complexes and suppress the triplet annihilation because of the "jacketing" effect. All of these devices have higher current efficiencies than that of the device with PFOXD50. Among them, the device with PFOXDIr7 shows the best performance with the maximum luminance of 846 cd/m² and the maximum current efficiency of 0.61 cd/A.

ACKNOWLEDGMENT

This research was supported by the National Natural Science Foundation of China (Grants 20974002 and 21134001) and the 973 National Basic Research Program (2011CB606004).

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