

Synthesis and characterization of a novel blue electroluminescent polymer constituted of alternating carbazole and aromatic oxadiazole units

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A novel copolymer poly[*N*-(2'-ethylhexyl)-carbazole-3,6-diyl-1'',3'',4''-oxadiazole-2'',5''-diyl-2''',5'''-dioctyloxy-1''',4'''-phenylene-1''',3''',4'''-oxadiazole-2''',5'''-diyl] (PCOPO) containing an electron rich carbazole moiety and an electron deficient aromatic oxadiazole unit is synthesized by a polycondensation reaction. The structure of the polymer is confirmed by FT-IR, NMR, and elemental analysis. PCOPO can be partially dissolved in THF, CHCl₃, xylene, and DMSO while it can be completely dissolved in chloroform with a small amount of trifluoroacetic acid (TFA). The optical and electronic properties of the polymer are investigated by UV-Vis absorption and photoluminescence spectroscopy as well as cyclic voltammetry. The results show that the polymer films emit greenish-blue light (475 nm). The bandgap energy of the polymer is estimated by the optical method (2.82 eV) and the electrochemical measurement (2.94 eV), respectively. Both p-doping and n-doping processes are observed in cyclic voltammetric investigation. The HOMO and LUMO energies of the polymer are estimated to be 5.60 and 2.66 eV, respectively. The photophysical and electronic properties as well as the preliminary electroluminescent device result of the polymer demonstrate that it may be a promising candidate material for the fabrication of an efficient polymer light-emitting device.

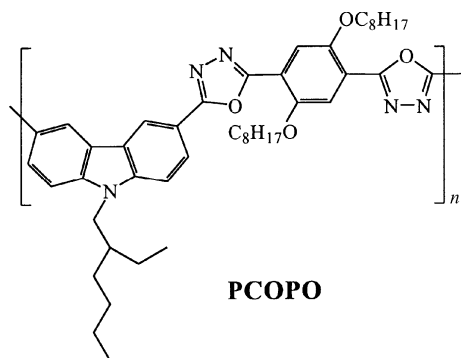
Introduction

In the past few years, many efforts have been devoted to the design and synthesis of new electroluminescent (EL) polymers for the fabrication of blue polymer light-emitting diodes (PLEDs) with high efficiency.^{1–3} Blue light generation from emissive polymers is much more promising for display technology because inorganic semiconductors such as GaN, SiC, and ZnSe are proven so far to be difficult for large-area flat panel applications. Several polymer systems have been developed for blue light emission. Among them, polyfluorenes (PFs),⁴ polycarbazoles (PCs),⁵ and polythiophenes (PTs)⁶ as well as polyoxadiazoles (POs)⁷ are some examples. Carbazole-based conducting polymers have been paid increasing attention recently because of their interesting optical properties and strong hole-transporting ability in the optoelectronic devices.^{8,9} On the other hand, oxadiazole-based polymers have played an important role in the fabrication of multilayer LED devices as good electron-transporting materials.^{10,11} Both carbazole and oxadiazole based luminescent polymers demonstrate quite different charge injection and transporting abilities for holes and electrons in PLED devices.

It is reported that the obstacle to improving the electroluminescence efficiency of LED devices is mainly due to the imbalance of the charge injection rates from opposite contacts into the emission layer. Consequently high quantum efficiencies are difficult to obtain using either carbazole or oxadiazole based polymers alone. For most of the electroluminescent polymers investigated so far, the barrier for electron injection from the metal contact is much bigger than

that for hole injection, which leads to charge capture near the metal contact. This results in poor quantum efficiency. To overcome this problem, two approaches have been developed. One is to use the low work function metals such as Ca or Mg as the cathode so as to improve the ability of electron injection. The other is to introduce the electron transporting and hole blocking layer to provide an intermediate area for charges to capture each other. However, there are some technical problems associated with making the device utilizing these above two approaches. Alternatively, polymers with well-matched HOMO and LUMO energy levels with the respective electrode energy barrier heights will lead to high efficiency for light-emitting device application. Combining a typical hole injection moiety and an electron injection unit into the same polymer backbone might meet this requirement.

Our previous work, based on combined thiophene and oxadiazole units as functional materials for blue light emission LED devices, has demonstrated good results.^{12–14} In this paper, we present the work of synthesis and characterization of a new polymer, poly[*N*-(2'-ethylhexyl)-carbazole-3,6-diyl-1'',3'',4''-oxadiazole-2'',5''-diyl-2''',5'''-dioctyloxy-1''',4'''-phenylene-1''',3''',4'''-oxadiazole-2''',5'''-diyl] (PCOPO) (Scheme 1), in which the oxadiazole moiety as the electron injection and transporting unit is incorporated into the carbazole main chain to form a p–n diblock structure. Based on this concept, it is expected that the designed polymer will possess good charge injection and transporting properties for both holes and electrons. The work described here reinforces our previous idea towards the design of p–n diblock copolymers for promising optoelectronic applications.



Scheme 1 Chemical structure for PCOPO.

Experimental

Measurements

NMR spectra were collected on a Bruker ACF 300 spectrometer with chloroform-*d* as solvent and tetramethylsilane as internal standard. FT-IR spectra were recorded on a Bio-Rad FTS 165 spectrometer by dispersing samples in KBr disks. UV-Vis and fluorescence spectra were obtained on a Shimadzu UV 3101PC UV-Vis-NIR spectrophotometer and a Perkin Elmer LS 50B luminescence spectrometer with a xenon lamp as light source, respectively. Elemental analyses were performed on a Perkin-Elmer 240C elemental analyzer for C, H, N, and S determinations. Cyclic voltammetry was performed using an EG&G Model 273A potentiostat/galvanostat under argon atmosphere. All potentials were measured against a Ag/Ag⁺ (0.1 M in acetonitrile) electrode (0.34 V *vs.* SCE) and all of the experimental values in this report were corrected with respect to SCE. Gel permeation chromatography (GPC) analysis was conducted with a Perkin Elmer Model 200 HPLC system equipped with Phenogel™ MXL and MXM columns using polystyrene as standard and THF as eluent.

LED device fabrication

In the fabrication of single layer LED devices, indium tin oxide-coated (ITO) glass with a resistivity of 250 Ω⁻¹ was used as substrate. A uniform film (thickness about 1200 Å) of the polymer was obtained by spin-coating from the polymer solution dissolved in trifluoroacetic acid (TFA)–CHCl₃ at a rate of 5000 rpm for 2 min. The film was dried in a vacuum oven at 30 °C before the device fabrication. Aluminum was vapor-deposited (JEOL-400 Vacuum Evaporator) through a mask as the top electrode at a pressure of around 3 × 10⁻⁴ Torr, yielding a 1200 Å layer (Thickness Monitor Model TM-200R, Maxtek Inc.). An active area of the LED device is about 1 mm². Electrical contacts were fixed using a conductive epoxy 14G adhesive. Sample processing and handling was done under ambient atmosphere. Electrical and optical characterizations were also carried out under ambient atmosphere. Current–voltage (*I*–*V*) characteristics were measured with a Keithley 238 High Current Source Measure unit. Voltages are given as the potential of the ITO electrode with the aluminum contact grounded; forward bias denotes ITO contact positive.

Materials

Triethylamine was purchased from Aldrich and was redistilled prior to use. Carbazole, 2-ethylhexyl bromide, aluminum chloride, *N,N*-dimethylcarbamoyl chloride, ethylene chloride, thionyl chloride were used as received (Fluka or Aldrich chemicals).

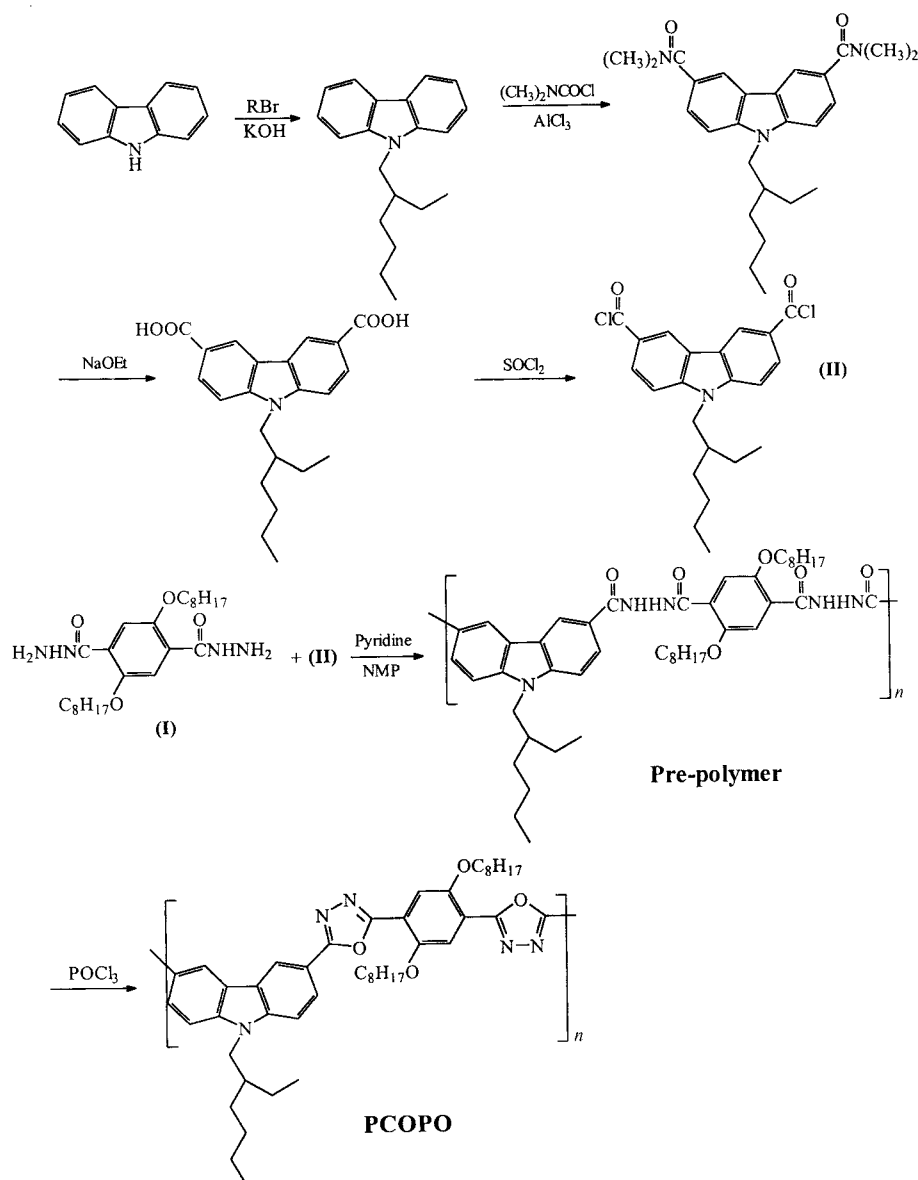
The detailed synthetic route to the target polymer is depicted in Scheme 2.

2,5-Dioctyloxylterephthalic dihydrazide (I). 7.2 g (0.015 mol) of diethyl 2,5-dioctyloxylterephthalate was added to a solution of 10 ml of hydrazine monohydrate (99%) in 60 ml of CH₃OH. The reaction mixture was refluxed for 24 h. Then the mixture was cooled and filtered to give a white precipitate. The precipitate was recrystallized from ethanol and dried in vacuum at 60 °C to yield 6.4 g (95%) white crystals. Mp 98.0–99.0 °C. MS: *m/z* 450. ¹H NMR (CDCl₃) δ 9.19 (broad, 2 H, NH), δ 7.84 (s, 2 H), 4.19–4.16 (t, *J* = 6.7, 4 H), 4.18–4.16 (d, 4 H, NH₂), 1.92–1.82 (m, 4 H), 1.48–1.28 (m, 20 H), 0.88–0.86 (t, *J* = 6.8, 6 H). ¹³C NMR (CDCl₃) δ 165.24, 150.70, 122.97, 115.66, 69.80, 31.61, 29.08, 29.02, 28.97, 25.88, 22.50, 13.95. Analysis calculated for C₂₄H₄₂N₄O₄: C, 63.97; H, 9.39; N, 12.43. Found: C, 63.78; H, 9.29; N, 12.22.

***N*-(2'-ethylhexyl)carbazole.**¹⁵ To the mixture of 16.7 g (0.1 mol) of carbazole dissolved in 120 ml of ethanol was added 11.2 g (0.2 mol) of potassium hydroxide. The mixture was refluxed for 0.5 h, and then 38.6 g (0.2 mol) of 2-ethylhexyl bromide was added dropwise over a period of 1 h. The mixture was further refluxed for 6 h. After cooling to room temperature, the mixture was poured into water (250 ml) and extracted with ether three times (60 ml each), then dried with anhydrous magnesium sulfate. The solvents were removed by rotary evaporation and the residue was distilled to remove the excess 2-ethylhexyl bromide. The residue was purified by silica-gel column chromatography using hexane : ethyl acetate (10 : 1) as the eluent. The yield is 81%. MS: *m/z* 279. ¹H NMR (CDCl₃) δ 8.21–8.18 (m, 2 H), 7.57–7.34 (m, 4 H), 7.31–7.29 (m, 2 H), 4.23–4.20 (d, *J* = 7.2, 2 H), 2.18–2.14 (m, 1 H), 1.51–1.33 (m, 8 H), 1.02–0.94 (m, 6 H). ¹³C NMR (CDCl₃) δ 141.07, 125.65, 122.97, 120.39, 118.82, 109.08, 47.42, 39.49, 31.15, 28.95, 24.55, 23.20, 14.18, 11.03. Analysis calculated for C₂₆H₂₅N: C, 86.02; H, 8.96; N, 5.02. Found: C, 85.79; H, 9.09; N, 5.27.

3,6-Bis(*N,N*-dimethylcarbamoyl)-9-(2'-ethylhexyl)carbazole.¹⁶ To a stirred mixture of 9.6 g (0.070 mol) of aluminum chloride and 30 ml of ethylene chloride under nitrogen was added a solution of 9.8 g (0.035 mol) of *N*-(2'-ethylhexyl)carbazole dissolved in 30 ml of ethylene chloride. Then a solution of 7.5 g (0.070 mol) of *N,N*-dimethylcarbamoyl chloride in 30 ml of ethylene chloride was added dropwise over 20 min. The mixture was heated under reflux for 24 h under nitrogen, then cooled and poured into 50 ml water and extracted with chloroform three times (20 ml each). The combined organic layer was washed with water, until the washings were neutral to litmus paper, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure and the residue was purified by silica-gel column chromatography using ethyl acetate as the eluent. Yield 73%. Mp 55.0–57.0 °C. MS: *m/z* 421. ¹H NMR (CDCl₃) δ 8.18–8.17 (m, 2 H), 7.60–7.56 (m, 2 H), 7.40–7.38 (m, 2 H), 4.17–4.16 (d, *J* = 7.2, 2 H), 3.12 (s, 12 H), 1.85–1.80 (m, 1 H), 1.37–1.20 (m, 8 H), 0.93–0.81 (m, 6 H). ¹³C NMR (CDCl₃) δ 172.32, 141.80, 127.01, 125.63, 122.10, 120.00, 108.86, 47.57, 39.24, 30.86, 28.66, 24.26, 22.86, 13.89, 13.85, 10.76. Analysis calculated for C₂₆H₃₅N₃O₂: C, 74.07; H, 8.37; N, 9.97. Found: C, 74.05; H, 8.35; N, 9.33.

***N*-(2'-ethylhexyl)carbazole-3,6-dicarboxylic acid.**¹⁶ A mixture of 6.0 g (0.014 mol) of 3,6-bis(*N,N*-dimethylcarbamoyl)-9-(2'-ethylhexyl)carbazole and 40 ml of 20% ethanolic potassium hydroxide was refluxed for 6 h. The solvent was evaporated and the residue was poured into water, then the solution was acidified with concentrated hydrochloric acid. The precipitate was collected by filtration and washed with water. Recrystallization from ethanol gave the white powder product. Yield 70%. Mp 310–313 °C. MS: *m/z* 367. ¹H NMR (DMSO-*d*₆) δ 12.66 (s, br, 2 H), 8.87 (s, 2 H), 8.11–8.09 (d, *J* = 8.9, 2 H), 7.70–7.67 (d, *J* = 8.7, 2 H), 4.35–4.32 (d, *J* = 7.4, 2 H), 2.01–1.97 (m, 1 H), 1.35–1.14 (m, 8 H), 0.86–0.72 (m, 6 H). ¹³C



Scheme 2 Routes of synthesis of monomers and polymers.

NMR ($\text{DMSO-}d_6$) δ 167.68, 143.54, 127.54, 122.62, 122.12, 121.80, 109.69, 40.28, 38.46, 29.99, 27.83, 23.50, 22.33, 13.64, 10.53. Analysis calculated for $\text{C}_{22}\text{H}_{25}\text{NO}_4$: C, 71.91; H, 6.86; N, 3.81. Found: C, 72.27; H, 7.00; N, 4.22.

***N*-(2'-ethylhexyl)carbazole-3,6-dicarbonyl chloride (II).**¹⁶ A mixture of 1.0 g (2.72 mmol) of *N*-(2'-ethylhexyl)carbazole-3,6-dicarboxylic acid and 15 ml of thionyl chloride under nitrogen was refluxed for 8 h. The excess thionyl chloride was removed by distillation. The residue solid was purified by recrystallization from hexane and dichloromethane to afford a light yellow powder. Yield 79%. Mp 147.0–149.0 °C. MS: m/z 404. ^1H NMR (CDCl_3) δ 8.91 (s, 2 H), 8.28–8.26 (d, $J = 8.2$, 2 H), 7.50–7.47 (d, $J = 8.7$, 2 H), 4.26–4.23 (d, $J = 7.4$, 2 H), 2.10–1.99 (m, 1 H), 1.44–1.22 (m, 8 H), 0.96–0.83 (m, 6 H). ^{13}C NMR (CDCl_3) δ 167.72, 143.53, 129.98, 125.71, 125.28, 122.80, 109.83, 48.13, 39.35, 30.83, 28.60, 24.27, 22.82, 13.83, 10.73. Analysis calculated for $\text{C}_{22}\text{H}_{23}\text{Cl}_2\text{NO}_2$: C, 65.35; H, 5.69; N, 3.47, Cl, 17.57. Found: C, 65.00; H, 5.79; N, 3.95; Cl, 17.38.

Preparation of the precursor polymer polyhydrazide.¹³ To a stirred solution of monomer I (0.424 mmol as a representative) in *N*-methylpyrrolidinone (NMP) (20 ml) containing 0.1 g of LiCl and two equivalents of pyridine (0.070 ml) or triethylamine (TEA) (0.120 ml) was added monomer II at room temperature. The reaction mixture was then heated to 80 °C

and was stirred at this temperature for 3 h. After cooling to room temperature, the pre-polymer was precipitated in methanol and washed with water and ethanol. Further purification of the pre-polymer was carried out by dissolving the polymer in NMP and precipitated in methanol again. Drying under vacuum at 60 °C for 24 h afforded a high yield (90%) of a polyhydrazide. ^1H NMR ($\text{DMSO-}d_6$) δ 10.92 (s, 2 H), 10.32 (s, 2 H), 8.93 (s, br, 2 H), 8.14 (s, br, 2 H), 7.77 (br, 2 H), 7.53 (br, 2 H), 4.41 (br, 2 H), 4.21 (br, 4 H), 2.05 (br, 1 H), 1.86 (br, 4 H), 1.72–1.23 (m, 28 H), 0.88–0.77 (m, 12 H). Analysis calculated for $(\text{C}_{46}\text{H}_{63}\text{N}_5\text{O}_6)_n$: C, 70.68; H, 8.07; N, 8.96. Found: C, 69.51; H, 7.56; N, 8.61.

Preparation of polymer PCOPO.¹³ 0.6 g of polyhydrazide was dispersed in 20 ml of POCl_3 at room temperature. The mixture was refluxed for 8 h. After cooling to room temperature, the reaction mixture was poured into water. The precipitate was collected by filtration and washed with water, ethanol and then ether and finally dried under vacuum at room temperature to afford a greenish-yellow solid. The yield is 83%. ^1H NMR (CDCl_3 ; TFA- $d = 20 : 1$): δ 8.9 (br, 2 H), 7.8 (br, 2 H), 7.1 (br, 2 H), 6.9 (br, 2 H), 4.40 (br, 4 H), 3.87 (br, 2 H), 1.83–0.56 (br, 43 H) ppm. Analysis calculated for $(\text{C}_{46}\text{H}_{57}\text{N}_5\text{O}_4)_n$: C, 74.26; H, 7.72; N, 9.42. Found: C, 74.01; H, 7.31; N, 9.09.

Results and discussion

The polymer is synthesized by the polycondensation method as reported in our previously published papers.^{13,14} The disubstituted aromatic hydrazine reacts with the bischlorocarbonyl of *N*-(2'-ethylhexyl)-carbazole in the presence of pyridine or triethylamine as a base, which acts as an acid absorbent reagent to promote the polymerization. *N*-(2'-ethylhexyl)-carbazole was synthesized using a modified method reported by Lee *et al.*¹⁵ We tried several times by using K_2CO_3 as the base in acetone to synthesize the *N*-alkylated carbazole, however, only 60% of yield can be obtained after a long time of reaction (3 d). By changing the base to KOH with ethanol as the solvent, we obtained the product with a relatively higher yield (73%) after only 3 h of reaction. Obviously, using a strong base in this step can accelerate the alkylation reaction and can also improve the yield. Other materials were successfully synthesized according to the literature cited.

The synthesized pre-polymer is light yellow in color and can be dissolved in DMSO, NMP, and DMF. Cyclodehydration of the polyhydrazide to the final poly-oxadiazole was performed by employing $POCl_3$ as both the solvent and the dehydrating reagent. The final polymer was obtained as a greenish-yellow solid. The polymer is partially soluble in common organic solvents such as chloroform, tetrahydrofuran, xylene, and DMSO. However, it is readily dissolved in chloroform with a little amount of TFA. The complete conversion of pre-polymer to final polyoxadiazole can be confirmed by FT-IR. The FT-IR spectra are shown in Fig. 1. Both the absorption peak at 1620 cm^{-1} owing to the carbonyl group and the broad absorption peak in the range of 3300 cm^{-1} due to the amide groups of the polyhydrazide disappeared after treatment with $POCl_3$, while a new peak at 1540 cm^{-1} attributed to the C=N in the oxadiazole ring clearly appeared in the spectra of the final polymer. These results indicate that the cyclodehydration reaction was completed.¹⁴ It is well known that high purity of electroluminescent materials is a crucial factor for good performance in PLED devices. Impurities existing in the emission and/or transporting layers will quench the excitons, which will lower the electroluminescent quantum efficiency. During conversion of the pre-polymer to the final polymer, a complete cyclization ensures the required purity for PLED application and also clears up quench sites of carbonyl groups in the final polymer.

The absorption and photoluminescence (PL) spectra of the polymer both in a solution of chloroform containing a small amount of TFA and as thin films which were prepared by spin-coating the solution on quartz plate, were measured at room temperature. The spectra are displayed in Fig. 2. In solution, the polymer gives a main absorption peak at 398 nm and a shoulder at 418 nm, while the main absorption peak of the solid films of the polymer appears at 418 nm with a shoulder at 398 nm. The relatively identical absorption spectra of the polymer in solution and as solid films indicates that there

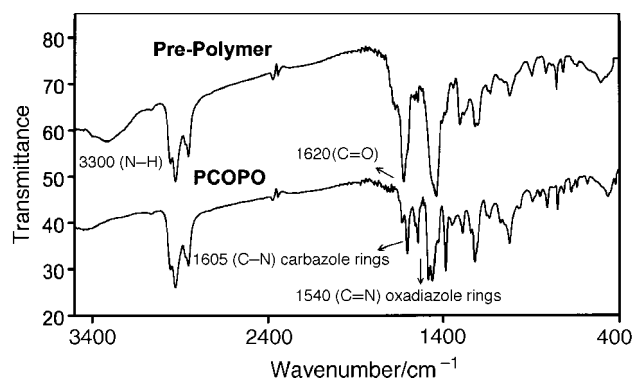


Fig. 1 FT-IR spectra of PCOPO and its pre-polymer.

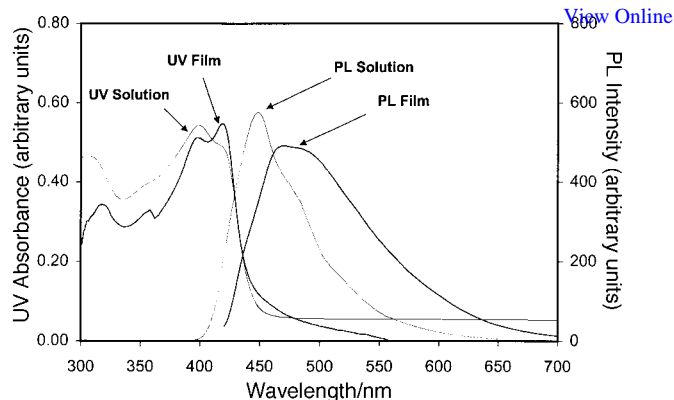


Fig. 2 UV-Vis spectra and fluorescence spectra of the polymer in solution and as films.

is little difference in the conformations of the polymer in the two states.¹⁷ However, the emission spectra of the polymer in solution and as solid films are quite different. In comparison with its solution emission peak at 448 nm, the main emission peak in the solid films shifted about 25 nm towards longer wavelength. This may be due to the intrachain and/or interchain mobility of the excitons and excimers generated in the polymer in the solid state.

Cyclic voltammetry (CV) was employed to investigate the redox behavior of the polymer and to estimate the HOMO and LUMO energy levels of the polymer.¹⁷ The polymer film on Pt electrode was scanned anodically and cathodically separately in an acetonitrile solution of *n*- Bu_4NClO_4 . Fig. 3 depicts the *C-V* spectra of both p-doping and n-doping processes.

During the cathodic scan, the polymer exhibits a reversible n-doping process. The cathodic peaks appear at -1.90 V (*vs.* SCE) with corresponding anodical peaks at -1.78 V (*vs.* SCE). The onset potential of the reduction is -1.74 V (*vs.* SCE). The reduction potential is comparable to that of 2-(4-biphenyl)-5-(4-*tert*-butylphenyl)-1,3,4-oxadiazole (PBD) (-1.95 to -1.94 V vs. SCE),¹⁴ which is one of the most widely used electron-transporting/hole-blocking materials. The onset potentials of n-doping and p-doping processes can be used to estimate the HOMO and LUMO energy levels of a conjugated polymer.¹⁸ According to the equations reported by de Leeuw *et al.*,¹⁸ $E_{LUMO} = [E_{\text{onset}}^{\text{red}} \text{ vs. SCE}] + 4.4\text{ eV}$ and $E_{HOMO} = [E_{\text{onset}}^{\text{ox}} \text{ vs. SCE}] + 4.4\text{ eV}$, where $E_{\text{onset}}^{\text{ox}}$ and $E_{\text{onset}}^{\text{red}}$ are the onset potentials *vs.* SCE for the oxidation and reduction processes of a polymer. The onset potentials were determined from the intersection of the two tangents drawn at the rising current and base line charging current of the *I-V* curves. The LUMO energy of the polymer is thus

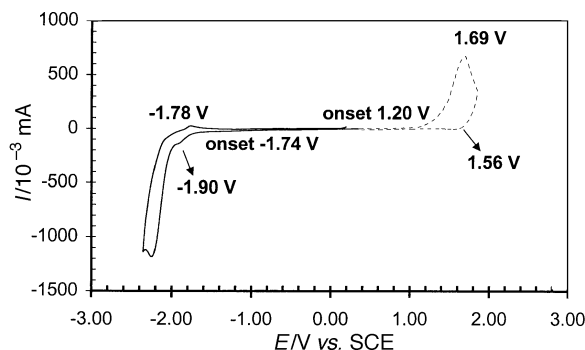


Fig. 3 Cyclic voltammogram of PCOPO coated on Pt electrodes in acetonitrile containing $0.1\text{ M } n\text{-Bu}_4NClO_4$ at a scan rate of 50 mV s^{-1} .

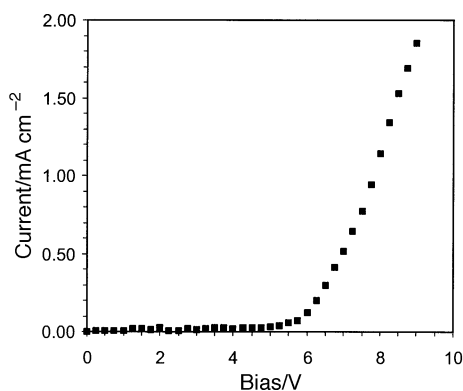


Fig. 4 Current-voltage characteristics of the ITO/polymer PCOPO/Al device.

determined to be 2.66 eV. This value is almost the same as that of poly[2-methoxy-5-(2'-ethylhexyloxy)-*p*-phenylenevinylene (MEH-PPV) (2.6 eV) reported by Cervini *et al.*¹⁹ It implies that the polymer may have similar electron-injection property with MEH-PPV when it is used as the emitter in PLEDs. However, the LUMO energy level of 2.66 eV is smaller than those of poly(cyanoterephthalidene) (CN-PPV) (3.02 eV) and some poly(aromatic oxadiazoles) (2.8–2.9 eV),¹⁹ which all exhibit good electron-injection properties.

When we scanned the polymer films anodically, the polymer showed a partially reversible anodic peak at 1.69 V with a cathodic peak at 1.56 V (*vs.* SCE). The onset potential was determined to be 1.20 V, so that the HOMO energy level could be estimated to be 5.60 eV. This value is almost the same as that of CN-PPV (5.55 eV), but is bigger than that of MEH-PPV (4.87 eV).¹⁹ This means that the polymer has similar hole-injection ability with CN-PPV when it is used in PLEDs, but the hole-injection ability is poorer than that of MEH-PPV.

In order to increase the quantum efficiency of PLEDs, it is necessary to balance the injection rates of electrons and holes into the polymer layers from the opposite contacts. However, most of the current existing EL polymers, *e.g.*, MEH-PPV, the best soluble EL polymer so far, are more favorable for hole injection when a stable metal, *e.g.* aluminum, is used as the cathode. The new blue EL polymer has a similar LUMO but a higher HOMO energy level when compared to MEH-PPV. Therefore, it could be expected to give an improved EL quantum efficiency when this polymer is used to fabricate single-layer PLEDs using stable metals as cathodes.

A light-emitting diode was successfully fabricated with polymer PCOPO as active material. The stable electrode aluminum metal was used as the top electrode. Under a bias in the forward direction, the single-layer diode begins to emit visible blue light (observable in a dark room) at about 8 V with a current density of 1.14 mA cm⁻². The current-voltage (*I*-*V*) characteristics of the ITO/PCOPO/Al device is displayed in Fig. 4, showing a typical diode character. When the forward bias increases, both the current and the emitting light intensity increase rapidly after 6 V. The preliminary results show that the new polymer could be a potential novel active material to be used in PLEDs. Because the performance and characterization of the fabricated PLED were measured in ambient conditions, higher performance PLEDs made out of this new polymer could be expected under the optimized

device fabrication conditions. Further study on the EL properties of the polymer is still in progress.

Conclusion

A new conjugated polymer constituted of alternating *N*-(2'-ethyl hexyl)carbazole and 1,4-bis(1,3,4-oxadiazole-2-yl)-2,5-dioctyloxybenzene was synthesized and characterized. Photoluminescence spectra of the polymer films indicate that the polymer is a blue light emitting material. The LUMO and HOMO energy levels of the polymer are determined by cyclic voltammetry. A single layer LED device with stable aluminum metal as negative electrode was successfully fabricated, suggesting that the new polymer has better balanced injection of electrons and holes in PLEDs compared to MEH-PPV, and thus gives an improved EL quantum efficiency.

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