

Design of Electroluminescent Polymer for Polymer Light Emitting Diode

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Introduction

Conjugated polymers are those polymers in which their main chains are composed of alternating single and double bonds. The polymer molecule has an energy gap (band gap, E_g) in the semi-conducting range 1.0~3.5eV and is thus termed organic semi-conducting polymer. It can be used for applications in light emitting diode (PLED), polymer field effect transistor (PFET), opto-electronic sensor, solar cell, and polymer laser. The first two applications are now in the way toward commercialization, especially for the first one. The requirements for PLED to be practically useful are: long life time, close decay rates of RGB colors, high quantum efficiency, and low operating voltage. In this presentation, research results mainly from our group are reported.

Results and discussion

Three approaches for the design of polymers are included. The first, single chain consideration: for which a modification with multiple charge transport moieties on ends of side chains is found to be an effective way to improve device efficiency for pure blue emitting spiro-fluorene polymers. The EL device based on this material shows ultra high efficiency (luminous efficiency~ 4.6 Cd/A, which is the highest so far among the PLEDs reported in literatures) and ultra high luminance ($22,000 \text{ Cd/m}^2$) with pure blue emission (C.I.E. color coordinate $x=0.16, y=0.10$). Such approach is also applied to a carbazole-based high triplet energy polymer. Upon doping with green and red emission Ir-complexes, it gives devices with high luminous and external quantum efficiencies for green emission ($23.7 \text{ cd/A}, 6.57\%$) and for red emission ($5.1 \text{ cd/A}, 4.23\%$), respectively (Fig. 1).

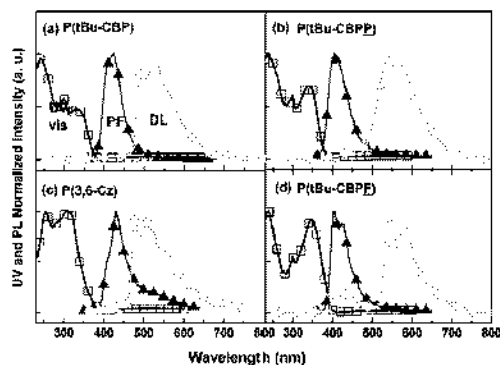
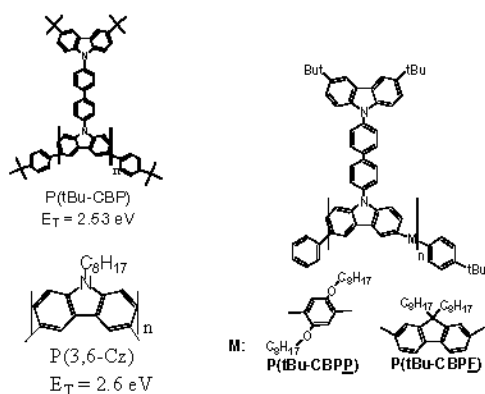


Figure 1. UV-vis (□) and prompt fluorescence (PF) (▲) at room temperature, and delay luminescent (DL) with delay time of 5 ms after photoexcitation (◆) spectra at 4 K of P(tBu-CBP), P(3,6-Cz), P(tBu-CBPP) and P(tBu-CBPF) thin solid films.

The second, supramolecular structure consideration: for which we found that, for polyfluorenes (PFs), main chain/main chain interaction, side chain moiety/moiety interaction and moiety/main chain interaction play a very important role in the molecular design of electroluminescent polymers (Fig. 2). It not only affects the device performance, but also the emission color. The following sub-topics will be included: (a) main chain/side chain interaction and energy transfer, and (b) integrated consideration on interactions among side chain, main chain, and dopant for color tuning.

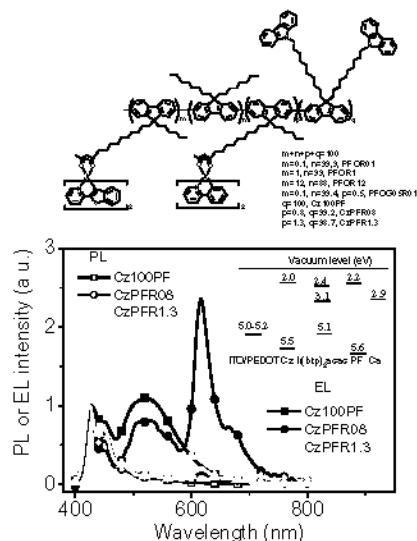


Figure 2. PL and EL spectra of CzPF and Ir-Red complex modified CzPFs

The third, conformation manipulation: for which we introduced electron deficient moiety on both ends of poly(di-octyl fluorene) chains, such as oxadiazole and triazole, and found that conjugation length along the chain ends increases such that a new phase called β phase is formed (Figs. 3 and 4). Even though the amount of this new phase is extremely small, its effect on emission color is significant and causes an emission of high purity blue emission with CIE coordinates $x+y$ far less than 0.3. This is due to an incomplete energy transfer from the amorphous phase to β phase, by which the main blue emission peaks in both phases dominate the resulting emission spectrum. Other method for a generation of β phase is also to be reported, which provides a similar improvement.

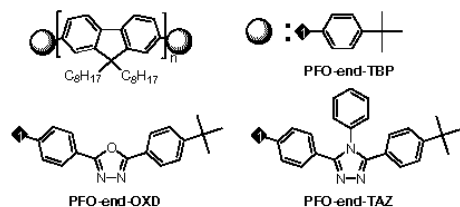


Figure 3. The absorption spectra of PFOs with the enlargement in the inset (a) and the PLE spectra (monitored at 470 nm) and the PL spectra excited at 436 nm (b).

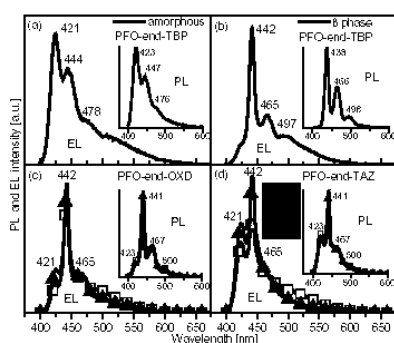


Figure 4. The PL and EL spectra of spin-cast films of PFO-end-TBP, -OXD and -TAZ: TBP amorphous phase (a) and β phase (b); OXD (c) and TAZ (d) both with their spectral summations from spectra in (a) and (b) (\blacktriangle : experimental, \square : spectral summation). The picture of emission in (d) is from PFO-end-TAZ based device operated at 4 V.

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