Molecular Engineered Conjugated Polymers for High - Performance Light-Emitting Diodes (LEDs)

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Project Summary:

The objective of this project is to develop novel luminescent copolymers for highly efficient light-emitting diodes (LEDs).

The first approach we adopted is to maximize the confinement of the charge carrier in the luminescent polymers from both molecular design and device engineering. Molecular engineered conjugated polymers containing randomly distributed lower-energy segments are designed to provide electrons and/or holes trapping sites. In addition to directly or sequentially trap electrons and holes on these lower-energy sites, the excitons formed on higher-energy segments could also be transferred to these lower-energy sites through the Förster energy transfer mechanism. This will increase device efficiency due to lower self-absorption loss. By further introducing hole/exciton blocking layer in the LED devices to block the hole migration to the electrode, this will also significantly enhance the charge capture efficiency and prevent the luminescence quenching. Based on these concepts, we have developed a series of fluorene based copolymers with a small amount (less than 10 mol-%) randomly distributed electron-deficient low bandgap moieties to improve the device performance (Figure 1). These low-energy moieties with electron-deficient nature are designed to increase electron-affinity of the resulting polymers and to facilitate charge-recombination through their function as charge trapping sites for both holes and electrons. The emission colors of these polymers are green, yellow and red, respectively. Future work will be focused on engineering the device structure through the introduction of hole/exciton blocking layer, and optimization of thickness of individual layers to further improve the LED performance. This will be conducted at Dr. Burrow's group in PNNL.

Hole-electron recombination in organic LEDs leads to the formation of both singlet and triplet excitons, the efficiency of LEDs based on fluorescent conjugated polymers is limited because only 25 % of the singlet excitons are emissive. Another approach we employed in this project to improve the device performance is to utilize the phosphorescence emission; the phosphorescent compounds will be incorporated into conjugated polymer matrix to harvest both singlet and triplet excitons. However, phosphor-doped organic LEDs usually exhibit low quantum efficiencies in conjugated polymers comparing to nonconjugated polymers due to the low triplet energy level of these conjugated polymers. The back transfer of the exciton to the polymer host from the phosphor leads to phosphorescence quenching and lower device efficiency. In order to overcome this problem, blue-emitting materials having short conjugated segments with ether linkage will be synthesized to elevate their triplet energy level, while still maintain the good charge-transporting properties (Figure 2). This type of materials will be used as the host to achieve highly efficient phosphorescent emission for white LED applications.

Publications, Presentations, and Proposals*:*

1. M. S. Liu, J. Luo, A. K-Y. Jen, **"**Efficient Green Light-Emitting Diodes from Silole-Containing Copolymers", *Chem. Mater*. **15**, 3496 (2003).
2. J.-H. Kim, M. S. Liu, A. K–Y. Jen, B. Carlson, L. R. Dalton, R. Dodda, C. F. Shu, "Bright Red-Emitting Electrophosphorescent Device Using Osmium Complex as a Triplet Emitter", *Appl. Phys. Lett.* **83**, 776 (2003).
3. C. F. Shu, R. Dodda, F. I. Wu, M. S. Liu, A. K-Y. Jen, "Highly Efficient Blue Light-Emitting Diodes from Polyfluorene Containing Bipolar Pendent Groups", *Macromolecules* **36**, 6698 (2003).
4. F-I. Wu, D. S. Reddy, C. F. Shu, M. S. Liu, A. K-Y. Jen, "A Novel Oxadiazole-Containing Polyfluorene with Efficient Blue Electroluminescence", *Chem. Mater*. **15**, 269 (2003).
5. P. Herguth, J.-H. Kim, X. Z. Jiang, M. S. Liu, A. K.-Y. Jen, "Absorption and luminescence properties of sequentially random- and defined copolymers based on poly(fluorene-benzothiadiazole)", *MRS Proc.* **771**(Organic and Polymeric Materials and Devices), 357 (2003).

6. M. S. Liu**,** X. Z. Jiang, P. Herguth, S. Liu, A. K.-Y. Jen, "Development of Efficient Electron-Transporting Polymers for Light-Emitting Diodes"**,** *Proc. SPIE* **4800**, 130 (2003).
7. P. Herguth, X. Z. Jiang, M. S. Liu, A. K.-Y. Jen, "Poly(fluorene-co-benzothiadiazole)s: Effect of Structure, Molecular Weight and Polydispersity on Their Performance in Polymer Light-Emitting Diodes"**,** *Proc. SPIE* **4800**, 138 (2003).

Fundings that has resulted from this research:

We are in the process of preparing a proposal to be submitted to the Air Force Office of Scientific Research (AFOSR) based on the preliminary results and concepts derived from this JIN supported work. It will be submitted in the beginning of next year.

Figures:

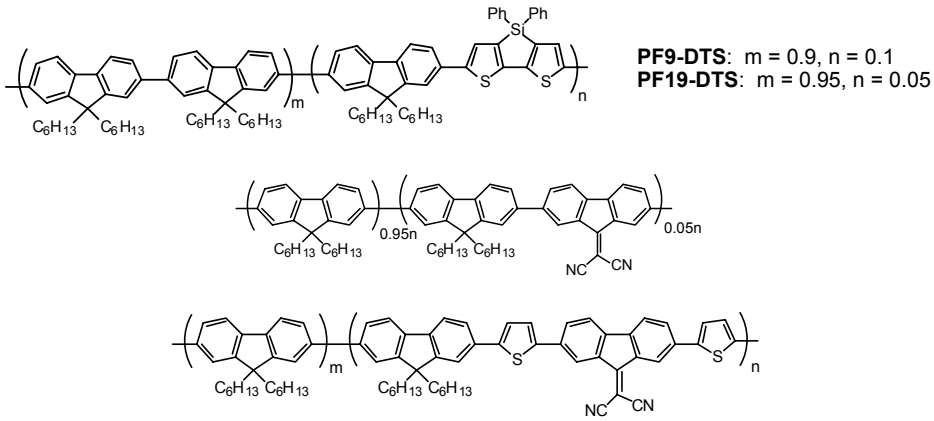

Figure 1. Chemical structure of conjugated polymers with lower-energy segements.

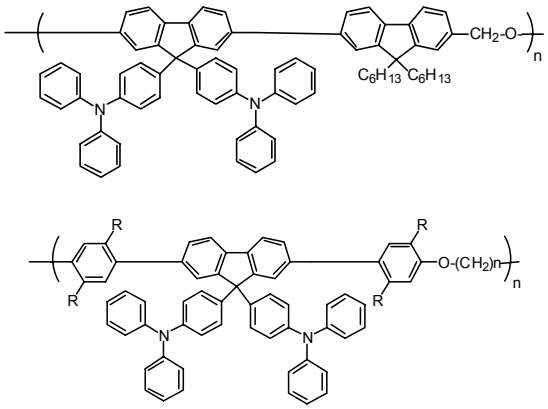

Figure 2. Chemical structure of polymers with breaking conjugation length.