Preparation of Polymer Light-Emitting Diodes based on Poly(3-alkylthiophene)

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Introduction

Since Burroughes et al. first reported light-emitting diodes(LEDs) based on semiconducting conjugated polymers in 1990, there has been much interest in the development of efficient polymeric LEDs. Polymeric LEDs have some important advantages over conventional inorganic semiconductors for LEDs such as in processing, mechanical properties and the choice of geometry, etc. Nowadays, applications for semiconducting polymeric materials include their use in transistor, diode, optoelectronic and photovoltaic devices. Although rapid progress has been made in research on polymer LEDs, the number of soluble conjugated polymers with relatively high luminescence efficiency is limited. The poor device characteristics have been explained by the material's high degree of amorphicity and large trap concentration.

For overcoming this poor structural ordering that occurs within conjugated conducting polymers, we tried to improve the degree of crystallinity of the polymer. Annealing polymer would be one method to improve the degree of crystallinity of the polymer[1]. We used poly(3-hexylthiophene)(P3HT) as emissive layer that is semicrystalline, and annealed it at different temperature schemes to vary the degree of crystallinity.

As well as the crystallinity, the orientation effect on the device performance and the effective thickness of the polymer layer was investigated

Experiments

Poly(3-hexylthiophene)s were prepared from 3-hexylthiophene utilizing $FeCl_3$ as a catalyst[2]. That is, 3-hexylthiophene and $FeCl_3$ were dissolved in chloroform at room temperature. After the reaction mixture was kept at room temperature for 2hours, the reaction mixture was poured into methanol and filtered. Filtered polymer was dedoped by conc. NH_4OH. The head-to-tail linkages of the polymer determined by proton NMR integration is 60-70%.

Thin film was spin coated on the glass covered by a transparent indium-tin-oxide(ITO) layer from the chloroform solution of various concentration. The effective thickness

of the device was determined by the electroluminescence intensity at the same current density.

For annealing, thin films were made by spin-coating from 2wt% chloroform solution at 2000rpm on the ITO-glass. These films were annealed at 240°C, 170°C, 150°C, 120°C for 30min and cooled to the room temperature in nitrogen atmosphere.

For orienting the emissive polymer film, the polymer was spin coated(~50nm) from 0.5wt% solution onto a thick polyethylene(PE) film(house hold plastic foil). The PE/P3HT bilayer film was oriented by mechanical stretching, to 2-3 times the initial length. And the same polymer(P3HT) was spin coated on the top of the ITO-glass, in order to enhance the adhesion of the oriented layer to the ITO contact. The oriented polymer film was transferred to the ITO-glass by pressing the PE/P3HT bilayer to the substrate during heating. Then we peel the PE film off and the oriented P3HT layer remains on the substrate. Aluminum is then vacuum evaporated onto the surface. The device structure is shown in Figure 1.

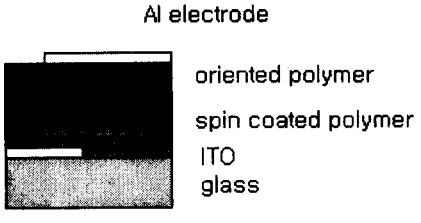

Fig. 1. Cross section of the device.

Results and discussion

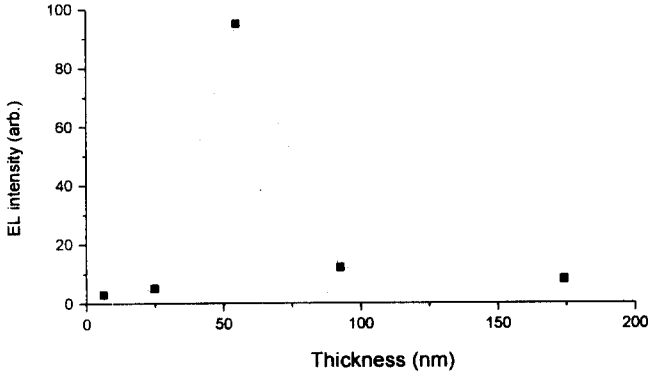

Fig. 2

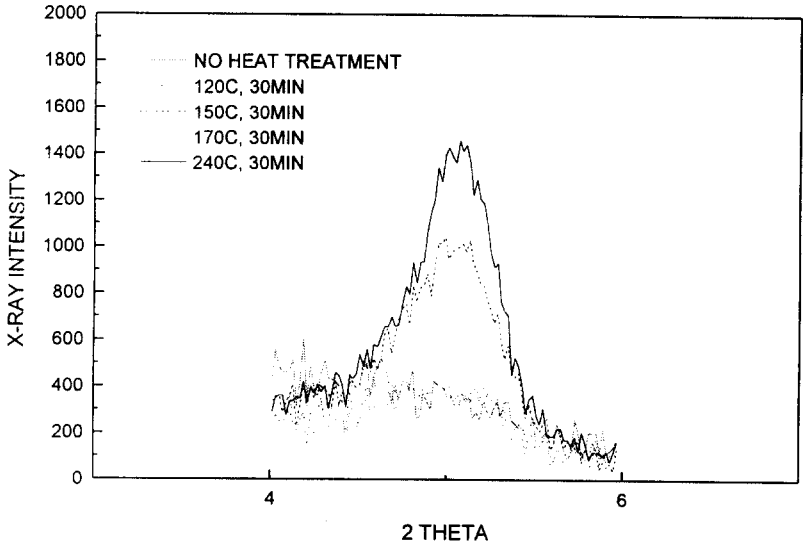
NO HEAT TREATMENT
120C, 30MIN
150C, 30MIN
170C, 30MIN
240C, 30MIN
X-RAY INTENSITY
2 THETA
2000
1800
1600
1400
1200
1000
800
600
400
200
0
4
6

Fig. 3

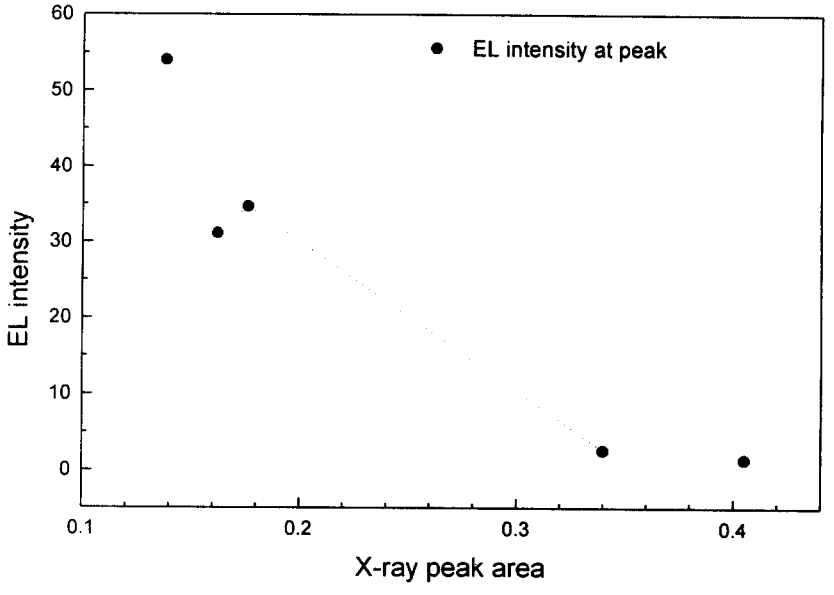
EL intensity at peak
EL intensity
X-ray peak area
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4

Fig. 4

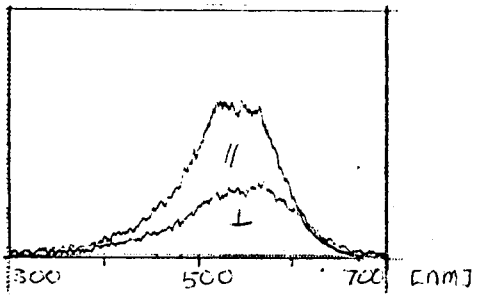

Fig. 5 Electroluminescence intensity, parallel and perpendicular to the direction of orientation. Draw ratio is 2.6 and the intensity ratio between light emitted parallel and perpendicular is 2.1.

References

1. S. Marchant and P. J. S. Foot, Polymer, 38, 1749 (1997)
2. Yosino et al, Chem. Exp. 1,11, 635, 1986
3. K. Tashiro, K. Ono, Y. Minagawa, M. Kobayashi, T. Kawai and K. Yoshino, J. of Polymer Sci. Part B, **29**, 1223 (1991)