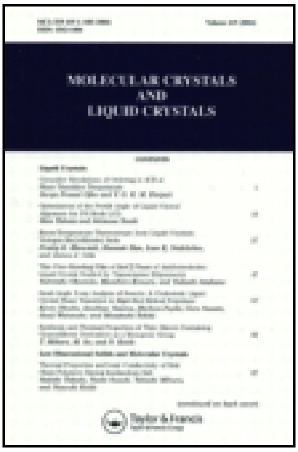

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Microcavity Effect in Light-Emitting Device Based on PPV Having Oxdiazole Pendant

G. J. Lee [a] , D. -W. Lee [b] , J.-I. Jin [a b] , H. Kang [c] , K. Park [c] , J. Joo [a c] , J. S. Yoon [d] , B. Y. Jung [e] & C. K. Hwangbo [e]

[a] Center for Electro- & Photo-Responsive Molecules, Korea University, Seoul, 136-701, Korea

[b] Department of Chemistry, Korea University, Seoul, 136-701, Korea

[c] Department of Physics, Korea University, Seoul, 136-701, Korea

[d] Department of Physics, Kangnung National University, Kangnung, 210-702, Korea

[e] Department of Physics, Inha University, Incheon, 402-751, Korea

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Microcavity Effect in Light-Emitting Device Based on PPV Having Oxdiazole Pendant

G. J. LEE[1,*], D. -W. LEE[2], J.-I. JIN[1,2], H. KANG[3], K. PARK[3], J. JOO[1,3], J. S. YOON[4], B. Y. JUNG[5], C. K. HWANGBO[5]

[1]*Center for Electro- & Photo-Responsive Molecules,*
[2]*Department of Chemistry,*
[3]*Department of Physics, Korea University, Seoul 136-701, Korea,*
[4]*Department of Physics, Kangnung National University, Kangnung 210-702, Korea and*
[5]*Department of Physics, Inha University, Incheon 402-751, Korea*

We found that the microcavity light-emitting device (LED) shows the emission enhancement having a higher photoluminescence intensity and a narrower linewidth when compared with those of the noncavity LED. We designed the microcavity LED that located the emissive layer and the filler layer between a distributed-feedback mirror and a metal mirror, and fabricated the microcavity LED using a single layer of OxdEH-PPV as emissive material, and measured its photoluminescence characteristics. The experimental results are well fitted to the model that regards the emissive material as the assembly of emitting dipoles.

Key words: microcavity, distributed-feedback mirror, photoluminescence, PPV, oxadiazole.

INTRODUCTION

Recently, polymer light-emitting devices (PLEDs) have attracted considerable attention due to high luminescence quantum yields, a wide wavelength-tunability and easy processibility, despite of the problems associated with the long-term stability. There have been many efforts to understand of the underlying mechanism of electroluminescence (EL) and also to enhance of the EL performance.[1-9] There have been various approaches to raise the EL efficiency, to lower the driving voltage and to improve the structural stability.

*Present address: E-mail: geonjoon@chollian.net. Department of Applied Physics & Chemistry, University of Electro-Communications, Chofu, Tokyo 182-8585, Japan.

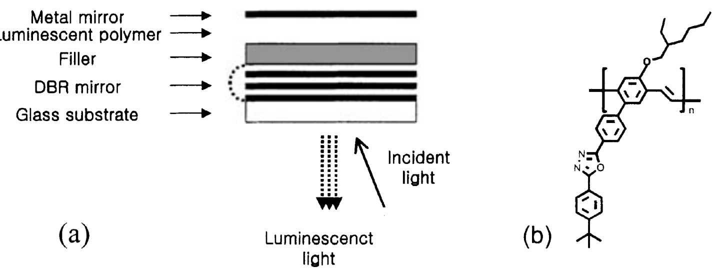

FIGURE 1. Microcavity structure (a) and OxdEH-PPV structure (b).

Tang *et. al* and Forrest *et. al* have studied the EL devices using vacuum-deposited materials as the emitting elements.[1-2] Friend *et. al* and Heeger *et. al* have investigated the characteristics of the PLEDs made from conjugated polymer.[3-6] Neher *et. al,* Fisher *et. al* and Saito *et. al* have studied the emission characteristics of PLEDs prepared using a microcavity structure.[7-9] A microcavity structure provides control over photoluminescence /electroluminescence characteristics such as the peak emission wavelength, the spectral width, the PL peak intensity and the spatial distribution of spontaneous emission intensity of embedded emitter by altering the photon density of states inside the cavity.

In this report, we have studied the microcavity effects in the LED having OxdEH-PPV as emissive material. We designed and fabricated the microcavity LED that consists of the emissive layer, the filler layer and the resonator mirrors. To find the microcavity effect for LED, we measured photoluminescence (PL) spectrum of the microcavity LED as well as that of the noncavity LED. Since the nature of the radiative transition involved in EL and PL is thought to be the same singlet exciton, the results of PL investigations can be used as a guideline to develop high performance PLED.

EXPERIMENTAL RESULTS AND DISCUSSION

The microcavity LED was fabricated by sandwiching a single layer of OxdEH-PPV and the filler layer between a metal mirror and a distributed-feedback (DFB) mirror. First, DFB mirror was prepared by evaporating $TiO_2(n_H)$ and $SiO_2(n_L)$ layers alternatively onto the glass plate. Each layer has the optical thickness of a quarter wavelength near the maximum emission. The number of layers in DFB mirror is 6. $[G(n_H\ n_L)^3]$. After that, the filler layer of 163 nm thickness is deposited on the sixth layer by thermal evaporation $[G(n_H\ n_L)^3\ /n_f(d_f)]$. The filler layer is used to control the resonator wavelength of the microcavity LED. Next, the OxdEH-PPV film of 177 nm thickness was spin coated onto the filler layer-deposited DFB mirror $[G(n_H\ n_L)^3\ /n_f(d_f)\ n_p(d_p)]$. Finally, the aluminum layer was thermally evaporated onto the polymer film. $[G(n_H\ n_L)^3/\ n_f(d_f)\ n_p(d_p)\ /Al]$.

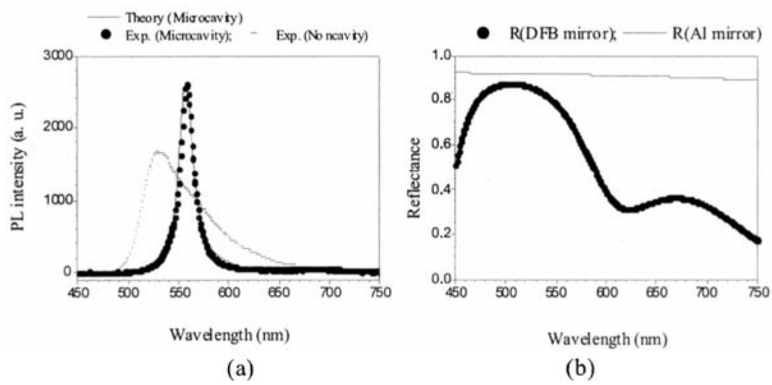

FIGURE 2. Photoluminescence spectra of the microcavity LED (a) and the reflectance spectra of the DFB & aluminum mirrors (b).

To find the microcavity effect for LED, we measured PL spectrum of the microcavity LED and that of the noncavity LED. Recordings of PL spectra were performed using a spectrophotometer. The excitation wavelength was 420 nm. The incidence angle was 22.5° and the detection angle for collecting PL was 0°. The emission signal was collimated by 5-cm focal length lens, focused onto a band pass filter by 5-cm focal length lens, and detected with photomultipler tube

Figure 2(a) is the photoluminescence spectra for the microcavity LED and the noncavity LED, and Fig. 2(b) is the reflectance spectra of the front and back mirrors used in the microcavity LED. The PL spectrum of microcavity LED shows the emission enhancement having a higher PL and a narrower linewidth when compared with that of noncavity LED. The linewidths of the microcavity and the noncavity LEDs are 17 nm and 67 nm, respectively. The ratio of the peak PL intensity of the microcavity and that of the noncavity is 1.44. We can understand these results with cavity mode selection by planar resonator. As an incident beam undergoes a series of partial reflections and transmissions at each mirror, the resonant photon mode is increased by a quality factor, $Q=4/(1-R)$. Conversely, the nonresonant photon mode is suppressed by a quality factor, $Q'= 1-R$. In order to find more the microcavity effect for the emission profile in LED, we analyzed the PL spectrum of the microcavity LED using the model that regards the emissive material as the assembly of emitting dipoles,

$$I^{(mc)}(\lambda)=\frac{\eta(1-R_d(\lambda))\,(1/N_d)\sum_i[1+R_m(\lambda)-2(R_m(\lambda))^{0.5}\cos(2kz_i)]}{[1+R_m(\lambda)R_d(\lambda)-2(R_m(\lambda)R_d(\lambda))^{0.5}\cos(2kL)]}\,I^{(nc)}(\lambda). \quad (1)$$

Here, $I^{(nc)}(\lambda)$ is the PL spectrum of the noncavity, $R_m(\lambda)$ and $R_d(\lambda)$ are the reflectivity spectra of the metal and dielectric mirrors, respectively, L is the total optical thickness of the cavity, and η is the coupling factor that depends on the spatial distribution of the emitted radiation and the size of the active area in the photo detection device. z_i is the distance of the emitting dipole from metal mirror and N_d is the number of sublayers. In eq.(1), the denominator explains the cavity mode selection by planar resonator, and the numerator expresses the alternation of emission spectrum by the interference of the oppositely propagating waves inside the cavity. In the numerical simulation, we divided the emissive layer as 20 sublayers and summed up the contribution of individual sublayers. Also the spatial distribution of the emitted radiation is angular averaged along the direction normal to the mirror surface. The calculated spectrum is designated as the solid line in Fig. 2(a). The experimental data are well fitted to the theoretical curve.

In conclusion, we found that the microcavity LED shows the emission enhancement having a higher photoluminescence intensity and a narrower linewidth when compared with those of noncavity LED. We designed and fabricated the microcavity LED using a single layer of OxdEH-PPV as emissive material, and measured its PL spectrum. The experimental results are well fitted to the model that regards the emissive material as the assembly of emitting dipoles.

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