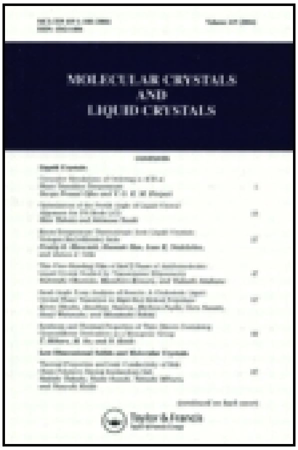

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Transient Response and Carrier Mobility in Electroluminescent Device

Yutaka Ohmori [a], Norio Tada [a], Yoshitaka Kurosaka [a] & Katsumi Yoshino [a]

[a] Department of Electronic Engineering, Osaka University, 2-1 Yamada-Oka, Suita, Osaka, 565-0871, Japan

Version of record first published: 24 Sep 2006

Mol. Cryst. Liq. Cryst., 1999, Vol. 327, pp. 213-216
Reprints available directly from the publisher
Photocopying permitted by license only

Transient Response and Carrier Mobility in Electroluminescent Device

YUTAKA OHMORI, NORIO TADA, YOSHITAKA KUROSAKA and KATSUMI YOSHINO

Department of Electronic Engineering, Osaka University, 2–1 Yamada-Oka, Suita, Osaka 565–0871 Japan

(Received June 30, 1998; In final form July 15, 1998)

Transient response and carrier transport in electroluminescent (EL) devices have been discussed for those consisted of poly(3-alkylthiophene) (PAT) containing dye molecules as a function of alkyl-side-chain length, and for those of multi-layered dye molecules as multi-color emission devices.

Keywords: organic electroluminescent device; poly(3-alkylthiophene); dye molecules; multi-color electroluminescent device; carrier mobility

INTRODUCTION

Organic electroluminescent (EL) devices utilizing fluorescent dyes or conducting polymers have attracted great interest because of their advantage for an emission in wide visible spectral range and for low driving voltages.

In this paper, we discuss transient response and unique enhancement of EL in poly(3-alkylthiophene) (PAT) devices containing dye molecules of 2-(4-biphenylyl)-5-(4-*tert*-butylphenyl)-1,3,4-oxadiazole(PBD), and discuss carrier mobilities of PAT as a function of alkyl-side-chain length. We also discuss transient characteristics and carrier transport in multi-color EL device.

TRANSIENT RESPONSE AND CARRIER MOBILITY IN DYE DOPED POLY(3-ALKYLTHIOPHENE) EL DEVICE

The EL devices consist of an indium-tin-oxide (ITO)-coated glass substrate, an emissive layer of dye-doped PAT and an magnesium containing indium (Mg: In) cathod. The layer thickness of the spin-coated PAT was about 100-

500 nm. PAT and dye molecules, the structures of which are shown in Fig. 1, of appropriate molar ratio were dissolved in toluene, and the films were fabricated by spin-coating method. The active area of the device was 4 mm^2.

In the dye-doped PAT diode[1], the forward bias current was quenched as the concentration of PBD increased. The resistivity of the diodes increases as increasing the molar ratio of PBD to PAT, and it was maximum in the diodes with the ratio of PAT to PBD as 10:5. Upon over doping of PBD, the resistivity decreased again due to the high electronic conductivity of PBD.

Emission spectra of PBD doped poly(3-hexylthiophene) (PAT-6) are shown in Fig. 1(c). The emission intensity increased with doping of the dye molecule. Similar effect was observed in PAT diodes with different alkyl-side-chain length. The emission efficiency in the diodes of the ratio of PAT to PBD as 10:5 is the highest among the other concentration of the dye-doped diodes.

The response of PBD-doped PAT-6 diodes is shown in Fig. 2. From the response time of the emission, the carrier mobility is estimated using Eq. (1), where V, e, T, L, μ and σ, applied voltage, electronic charge, transit time, layer thickness, carrier mobility and conductivity, respectively.

$$T = L^2 / (\mu V) \quad \text{---} \quad (1)$$

$$\sigma = n\, e\, \mu \quad \text{---} \quad (2)$$

The carrier mobilities for the undoped and doped PATs are estimated as 2.5×10^{-6} and 1.2×10^{-6} cm^2/Vs, respectively, where L and V are 0.3μm and 6V, respectively. Differential conductivity σ is estimated as 2.0×10^{-4} $(\Omega cm)^{-1}$ and 1.1×10^{-4} $(\Omega cm)^{-1}$ for undoped and doped PAT, respectively. The results show that the carrier concentrations are the same, and that the mobility of dye-doped PAT is low.

Carrier mobilities of PAT films of different alkyl-side-chain length were obtained

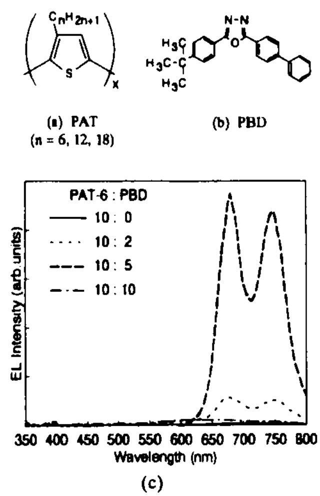

FIGURE 1 Molecular structures (a), (b) and the emission spectra (c) of dye doped PAT.

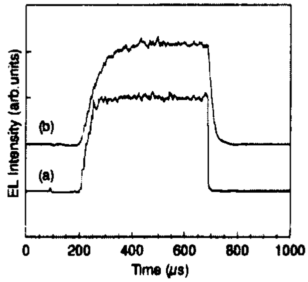

FIGURE 2 The time response of PBD-doped PAT diodes. (a) for the undoped, and (b) for the PBD-doped PAT diode where the ratio of PAT to PBD is 10:5.

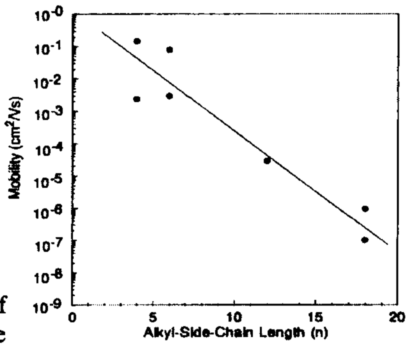

FIGURE 3 Carrier mobility of PAT as a function of alkyl-side-chain length.

from field effect transistors (FET), which are shown in Fig. 3. The carrier mobilities of PAT are in the range between 10^{-1} to10^{-7} cm^2 /Vs depending on the alkyl-side-chain length. Exciton confinement is strong in the main-chain of PAT with long alkyl-side-chain, resulting in the increase of EL efficiency, due to the conformational change by the long side-chain. Doping of dye molecules into PAT has the same effect to increase the confinement of excitons in the main chain of PAT.

TRANSIENT RESPONSE IN MULTI-COLOR EL DEVICE

Transient response and carrier transport in multi-color device [2] are discussed. Figure 4 shows the molecular structure and a schematic of multi-color EL device. The single-color emission part is constracted on a two-color emission part, and the half-transparent Al electrode, 17%-transmittance at 515nm, plays roles as electrodes to the two-color and to the single color emission parts, simultaneously.

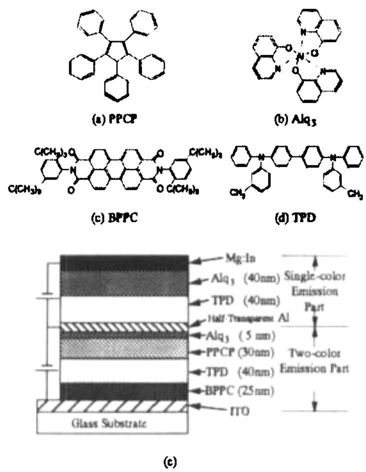

FIGURE 4 Molecular structure and schematic description of multi-color EL device.

In the two-color emission part, it emits blue light at its peak of 450nm originating from PPCP in the forward bias, and red light at its peak of 640nm from BPPC in the reverse bias case. The single-emission part emits green light at its peak of 520nm originated from Alq_3, only in the forward bias. The EL device can emit three different colors of R-G-B.

The responses of EL from multi-color device are shown in Fig. 5. The response in the forward bias case is slower than that in the reverse bias, and is also slower than that of the device with only the emissive and the carier transporting layers. The results shows that the response depends upon the total carrier transport in the emissive and the carrier transporting layers. The response time of the device is high enough for full-color display, since the response is more than 100kHz.

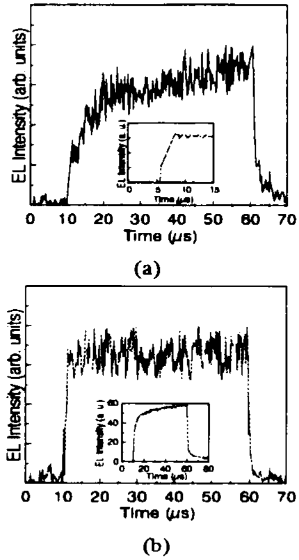

FIGURE 5 Transient response of two-color emission part. Emission in the forward (a) and in the reverse (b) bias conditions.

SUMMARIES

1) The transient response and carrier mobility in dye-doped PAT diodes are discussed. Carrier mobilities of the PAT films are in the range between 10^{-1} to 10^{-7} cm^2/Vs depending on the alkyl-side-chain length.

2) The transient response of the multi-color EL device depends upon the layer structure, and the response is high enough for display applications.

Acknowledgements

A part of this work was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, Sports and Culture.

References

[1] M. Yoshida, H. Kawahara, A. Fujii, Y. Ohmori and K. Yoshino, *Jpn. J. Appl. Phys.*, **34**, L1237 (1995).

[2] N. Tada, A. Fujii, Y. Ohmori, and K. Yoshino, *IEEE Trans. Electron Device*, **44**, 1234 (1997).