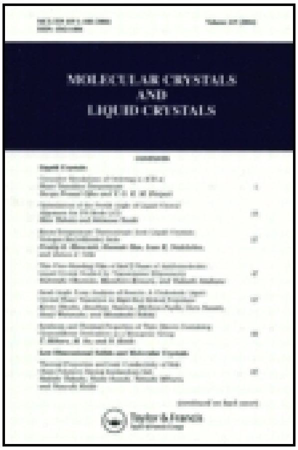

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Features of Conductivity and Electroluminescence of New Poly (9,9-Dioctylfluorenyl-2,7-Diyl) - End Capped With Polyhedral Oligomeric Silsesquioxanes

Larisa Fenenko [a], C. Adachi [a], Yoichiro Nakanishi [c], Petro Smertenko [b] & Sergey Svechnikov [b]

[a] Center for Future Chemistry, Kyushu University, Nishi, Fukuoka, Japan

[b] V. E. Lashkarev Institute of Semiconductor Physics of NASU, Kyiv, Ukraine

[c] Research Institute of Electronics, Shizuoka University, Hamamatsu, Japan

Version of record first published: 22 Sep 2010

To cite this article: Larisa Fenenko, C. Adachi, Yoichiro Nakanishi, Petro Smertenko & Sergey Svechnikov (2007): Features of Conductivity and Electroluminescence of New Poly (9,9-Dioctylfluorenyl-2,7-Diyl) - End Capped With Polyhedral Oligomeric Silsesquioxanes, Molecular Crystals and Liquid Crystals, 467:1, 303-309

To link to this article: http://dx.doi.org/10.1080/15421400701224678

Mol. Cryst. Liq. Cryst., Vol. 467, pp. 303–309, 2007

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400701224678

Features of Conductivity and Electroluminescence of New Poly (9,9-Dioctylfluorenyl-2,7-Diyl) – End Capped With Polyhedral Oligomeric Silsesquioxanes

Larisa Fenenko
Center for Future Chemistry, Kyushu University, Nishi, Fukuoka, Japan; V. E. Lashkarev Institute of Semiconductor Physics of NASU, Kyiv, Ukraine

C. Adachi
Center for Future Chemistry, Kyushu University, Nishi, Fukuoka, Japan

Yoichiro Nakanishi
Research Institute of Electronics, Shizuoka University, Hamamatsu, Japan

Petro Smertenko
Sergey Svechnikov
V. E. Lashkarev Institute of Semiconductor Physics of NASU, Kyiv, Ukraine

The emission and conductivity of a new polymer poly (9,9-dioctylfluorenyl-2,7-diyl) end capped with polyhedral oligomeric silsesquioxanes (PFO-POSS) have been investigated by the differential approach. Thin films of PFO-POSS showed pure blue photoluminescence (PL) with structured spectrum and a maximum at $\lambda_{PL} = 423$ nm. However, the OLED structures formed on the PFO-POSS base emitted green light with broadened spectrum and a maximum at $\lambda_{EL} = 510 \sim 529$ nm. The electroconductivity and electroluminescence have shown that the greatest influence on the current voltage and luminance current characteristics is rendered by introducing the electron transport layer to the multilayer OLED structure under investigation.

Keywords: Electroconductivity; electroluminescence; polymer; poly (9,9-dioctylfluorenyl-2,7-diyl); polyhedral oligomeric silsesquioxanes

Address correspondence to Petro Smertenko V. E. Lashkarev Institute of Semiconductor Physics of NASU 41, Nauky Ave, Kyiv 03128 Ukraine. E-mail: smertenko@isp.kiev.ua

INTRODUCTION

The search of the effective emitting polymer structures in various spectral ranges is under way yet [1–7]. For this purpose, some approaches are used:

(i) combination of polymer or organic materials [8,9];
(ii) various constructions from a single layer to multilayer structures [10,11];
(iii) set of a contact material [12,13];
(iv) technological variety [14,15];
(v) post preparation treatment.

In spite of the obvious progress in this field, there is the problem to enhance the effectiveness of organic light emitting diodes (OLEDs). The fine features of the current voltage and luminance current characteristics can indicate the ways to improve the main OLED's parameter.

The aim of this article is to investigate the current-voltage and luminance-current characteristics (CVC and LCC, respectively) of some new light emitted organic multilayer structures on the base of poly (9,9-dioctylfluorenyl-2,7-diyl) end capped with polyhedral oligomeric silsesquioxanes (PFO-POSS) by the differential and injection approaches [16,17].

EXPERIMENTAL

The new polymer poly (9,9-dioctylfluorenyl-2,7-diyl) (PFO) end capped with polyhedral oligomeric silsesquioxanes (POSS) (Fig. 1) was used for the preparation of OLED.

In addition, poly(ethylenedioxythiophene):poly(styrene sulfonic acid) (PEDOT:PSS) as a hole-transport layer (HTL) and aluminum

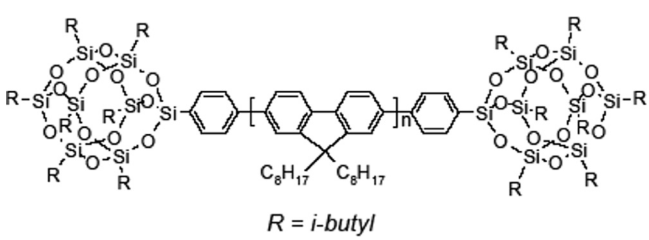

FIGURE 1 Poly (9,9-dioctylfluorenyl-2,7-diyl) – end capped with polyhedral oligomeric silsesquioxanes.

(III) tris(8-hydroxyquinoline (Alq3) as an electron-transport layer (ETL) were used to improve the device performance.

Four types of OLED structures were prepared:

type I: ITO(110 nm)/PFO-POSS(100 nm)/Mg:Ag(100 nm)/Ag(20 nm);
type II: ITO(110 nm)/PEDOT: PSS(50 nm)/PFO-POSS(100 nm)/Mg:Ag(100 nm)/Ag(20 nm);
type III: ITO(110 nm)/PFO-POSS(100 nm)/Alq3(50 nm)/Mg:Ag(100 nm)/Ag(20 nm);
type VI: ITO(110 nm)/PEDOT: PSS(50 nm)/PFO-POSS(100 nm)/Alq3 (50 nm)/Mg:Ag(100 nm)/Ag(20 nm)

A 50-nm-thick layer of poly(ethylenedioxythiophene):poly(styrene sulfonic acid) (PEDOT:PSS) was spin coated on the pre-cleaned ITO-coated (110 nm) glass substrates at 2000 rpm and dried in air on a hot plate at 200°C for 10 min. Next, the 1 wt% solutions of ADS229BE in chloroform were spin coated at 2000 rpm at room temperature and dried in a glove box on a hot plate at 60°C for 1 h. An Alq3 layer was successfully deposited in vacuum on the top of an ADS229BE layer.

The Mg:Ag alloy layer (10:1) capped with a silver layer was deposited on the top of the organic layers (the work area $\sim$ 1 mm^2).

The current density-voltage-luminance (J-V-L) characteristics were measured using a semiconductor parameter analyzer (Agilent, HP4155C) with an optical power meter (Newport, Model 1835-C). The optical absorption spectra were measured using a UV-VIS-NIR spectrometer at room temperature.

The experimental data $y = f(x)$ were processed in the form [16] of the dimensionless differential slope $\alpha = d(lg\,y)/d(lg\,x)$. With such a definition, the ranges of constancy of the $\alpha(x)$ dependence correspond to the power behaviour ($y \sim x^{\alpha}$).

RESULTS AND DISCUSSION

The absorption and PL spectra of PFO-POSS and the EL spectra of the OLED structures prepared are shown in Figure 2. The spectra were obtained at a current density of 100 mA/cm^2.

The thin films of PFO-POSS showed pure blue photoluminescence (PL) with structured spectrum and a maximum at $\lambda_{PL} = 423\,nm$. However, the OLED structures formed on the PFO-POSS base emitted green light with broadened spectrum and a maximum at $\lambda_{EL} = 510 \sim 529\,nm$. The green EL emission was identified as the emission from defects caused by the oxidation degradation and the cross-linking of polymer chains. Thus suggests that the energy traps

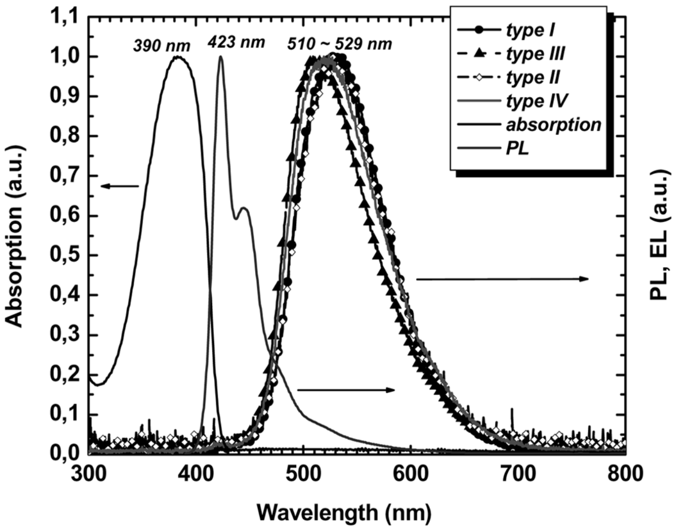

FIGURE 2 Absorption and PL spectra of PFO-POSS and EL spectra of the OLED structures prepared.

on the cross-linked chains play an important role in the PFO-POSS emission, and their formation cannot be completely suppressed by the end capping of the PFO backbone with POSS bulky groups.

The current voltage characteristics of the OLEDs structures under investigation and their differential image are shown on Figure 3.

From Figure 3, we can see the main features of the current-voltage characteristics.

1. Low voltage regions (0.1 V–3 V) are different for all samples. We can see the range with $\alpha = 1.5$ (Figs. 3b, e), what is proper to the bimolecular recombination for structures of types I and IV. In this case, there are the approximately equal quantities of both types of charge carriers. The linear range with $\alpha = 1$ (Fig. 3c) corresponds to the structure of type II. Such a behaviour occurs with the additional HTL. The sublinear range with $\alpha = 0.5$ (Fig. 3d) is presented for the structure of type III. It shows a rectifying barrier that is overcome at high voltages.
2. High voltage region (5 V–50 V) has two peculiarities. For structures of types I and II (Fig. 3b, c), we can see the range with $\alpha = 7$, and then α increases up to $\alpha = 15$. Probably, such a behaviour is due to the field emission of carriers (FEC) [18]. For structures of type II, the additional HTL does not make for the increase of FEC.

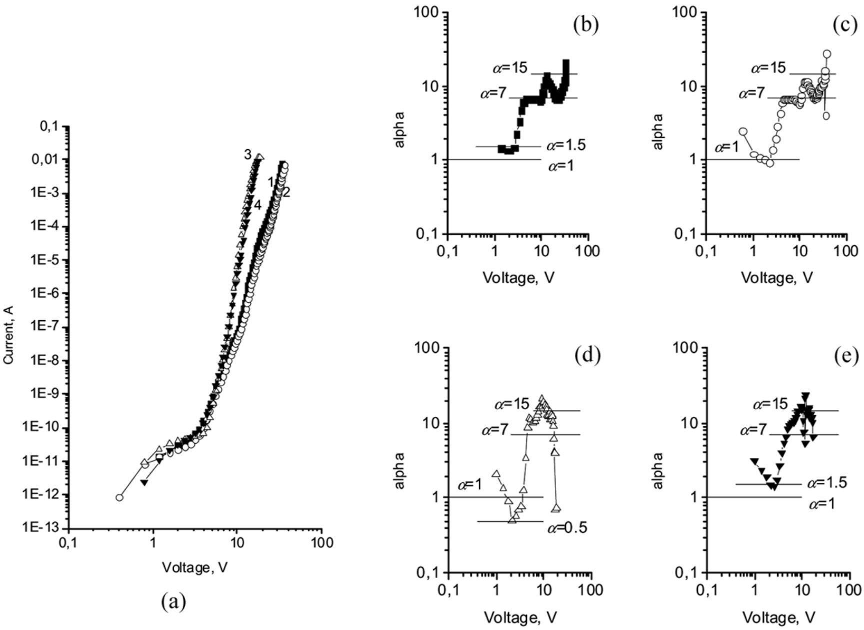

FIGURE 3 Current-voltage characteristics of four types of the structures under investigation (a) (curves 1–4, respectively) and their differential image for type I (b), type II (c), type III d), and type IV (e).

For structures of types III and IV (Fig. 3d, e), the range with $\alpha = 15$ is broader. Just the use of (ETL) Alq3 increases the rate of change of the current-voltage characteristic. It is necessary to note that HTL both in types II and IV reduces a little the growth of the current voltage characteristic (curve 4, Fig. 3a and 3e).

From Figure 4, we can see the main features of luminance-current characteristics.

1. All characteristics are remarkable mainly for the quasilinear range width (R) with $0.9 < \alpha < 1.1$. This range decreases in the row of type IV ($R = 8685$), type III ($R = 3083$), type I ($R = 31.67$), and type II ($R = 2.49$).
2. Luminance efficiency for the low-current region (10^{-10} – 10^{-6} A) decreases in the row of type I, type II, type III, and type IV (Fig. 4a).
3. Luminance efficiency for the high current region (10^{-4} – 10^{-2} A) decreases in the row of type III, type IV, type I, and type II (Fig. 4a).

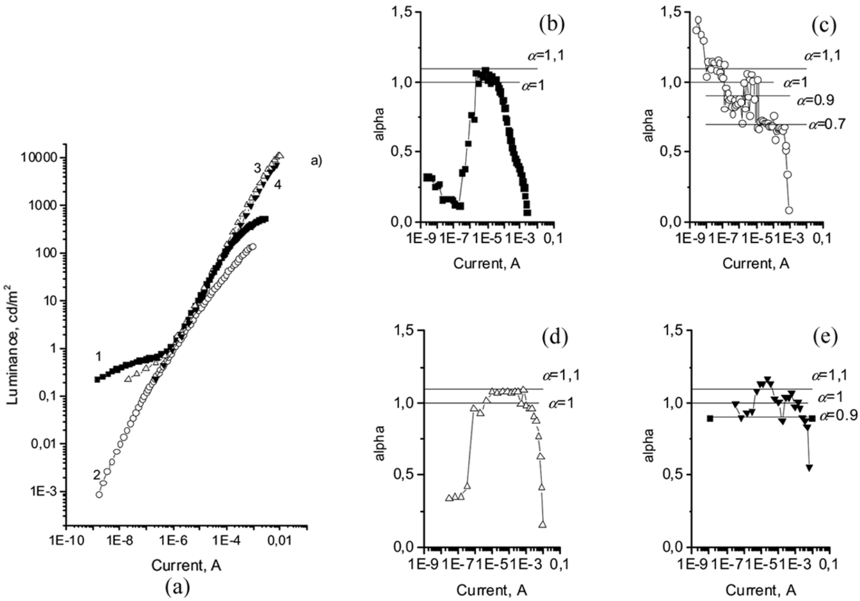

FIGURE 4 Luminance-current characteristics of four types of the structures under investigation (a) (curves 1–4, respectively) and their differential image for type I (b), type II (c), type III (d), and type IV (e).

4. For the structure of type II, there is the cascade of differential slopes with the clear regions with $\alpha = 1.1$, $\alpha = 0.9$, and $\alpha = 0.7$ (Fig. 4c). Probably, the PEDOT: PSS/PFO-POSS interface is responsible for such a behaviour of LCC. This interface in the type-IV structure restructures the differential slope too (Fig. 4e).

CONCLUSION

The greatest influence on the current voltage and luminance current characteristics is rendered by introducing the ETL to a multilayer OLED structure. The structures of type IV and type III are more appropriate for efficient OLED.

The type-IV structure has the widest quasilinear range of luminance among the investigated structures.

This is the first detailed study of the influence of different layers on the current voltage and luminance current characteristics. That is why the further study of different layers on CVC and LCC is necessary.

REFERENCES

[1] Friend, R. H., Gymer, R. W., Holmes, A. B., Burroughes, J. H., Marks, R. N., Taliani, C., Bradley, D. D., Dos Santos, D. A., Breads, J. L., Logdlung, M., & Salaneck, W. R. (1999). *Nature*, *397*, 121.
[2] Bernius, M. T., Inbasekaran, M., O'Brien, J., & Weishi, W. (2000). *Adv. Mater.*, *12*, 1737.
[3] Friend, R. (2001). *Pure Appl. Chem.*, *73*, 425.
[4] Xiao, S., Nguen, M., Gong, X., Cao, Y., Wu, H., Moses, D., & Heeger, J. (2003). *Adv. Funct. Mater.*, *13*, 25.
[5] Zhao, W., Cao, T., & White, J.M. (2004). *Adv. Funct. Mater.*, *14*, 783.
[6] Carpi, F. and De Rossi, D. (2006). *Optics & Laser Technology*, *38*, 292.
[7] Fenenko, Larysa, Nakanishi, Yoichiro, Tokito, Shizuo, & Konno Akinori, (2006). //*Japanese Journal of Applied Physics*, *45*, 550.
[8] Tsuzuki, Toshimitsu, Shirasawa, Nobuhiko, Suzuki Toshiyasu, & Tokito, Shizuo, (2005). *Japanese Journal of Applied Physics*, *44*, 4151.
[9] www.adsdyes.com.
[10] Qiu, C. *et al.* (2004). *IEEE Trans. On Elec. Device*, *51*, 1207.
[11] Braun, D. (2002). *Materials Today*, *5* (6), 32.
[12] Lee, J., Park, Y., & Kim, D. Y. (2002). *J. Phys. D: Appl. Phys.*, *35*, 3171.
[13] Hsu, Ching-Ming, Liu, Ching-Fong, Cheng, Hsyi-En, & Wu, Wen-Tuan, (2006). *Journal of Electronic Materials*, *35*, 383.
[14] Yamashita, K., Mori, T., & Mizutani, T. (2001). *J. Phys. D: Appl. Phys.*, *34*, 740.
[15] Zhang, X. H., Chua, S. J., Wang, H., Huang, W. (1992). *Nature*, *357*, 477.
[16] Smertenko, P., Fenenko, L., Brehmer L., & Schrader, S. (2005). *Advantages in Colloid and Interface Science*, *116*, 255.
[17] Ciach, R., Dotsenko, Yu. P., Naumov, V. V., Shmyryeva, A. N., & Smertenko, P. S. (2003). *Solar Energy Materials & Solar Cells*, *76/4*, 613.
[18] Zyuganov, A. N. & Svechnikov, S. V. (1981). *Injection Contact Phenomena in Semiconductors*, Kyiv, Naukova Dumka.