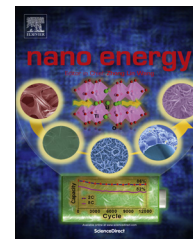




Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/nanoenergy



FULL PAPER

Charge trap assisted high efficiency in new polymer-blend based light emitting diodes



M.U. Hassan^{a,b,*}, Yee-Chen Liu^{a,1}, Kamran ul Hasan^c, H. Butt^d, Jui-Fen Chang^e, R.H. Friend^a

^a*Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom*

^b*COMSATS Institute Information Technology, Shehzad Town, Park Road, Islamabad 44000, Pakistan*

^c*Centers of Excellence in Science & Applied Technologies (CESAT), Islamabad, Pakistan*

^d*Nanotechnology Laboratory, School of Engineering, University of Birmingham, Birmingham B15 2TT, UK*

^e*Department of Optics and Photonics, National Central University, Chung-Li 32001, Taiwan*

Received 19 June 2015; received in revised form 22 December 2015; accepted 23 December 2015
Available online 13 January 2016

KEYWORDS

Polyfluorenes;
Poly(*para*-phenylene-
vinylenes);
Light emitting diodes;
Polymer-blend diodes

Abstract

Polymer blend system, F8_{1-x}SY_x, based on mixture of poly (9,9-dioctylfluorene) (F8) and a poly (*para*-phenylenevinylene) (PPV) copolymer, superyellow (SY), has been proven to be a high performance blend material in polymer light emitting diode (PLED). This blend system exhibits luminance (L) $> 10^4$ cd m⁻², luminous efficiency (η) > 21 cd A⁻¹ and low operating voltage (V) ~ 3 -10 V. The performance can be credited to the large difference (~ 0.6 eV) between the highest occupied molecular orbital (HOMO) levels of F8 (~ 5.8 eV) and SY (~ 5.2 eV), where, SY molecules serve as hole-traps in the F8 host polymer and reduce their mobility. This dictates a balanced charge injection into the emissive layer and results in overall increase in the device performance.

© 2015 Elsevier Ltd. All rights reserved.

*Corresponding author at: COMSATS Institute Information Technology, Shehzad Town, Park Road, Islamabad 44000, Pakistan.
E-mail address: muhammad_umair@comsats.edu.pk (M.U. Hassan).

¹Authors having equal contribution in this work.

Introduction

Organic semiconductors have been attracting immense attention for last two decades because of their unique features including easy tunability, viable processing, flexibility and excellent optoelectronic properties [1-10]. Device applications, such as polymer light-emitting diodes (PLEDs), photovoltaic cells and organic thin-film field-effect transistor (OTFTs) have already found their way towards commercialization [11-15]. With this immense success, further improvement in their performance is naturally a consistent goal. To achieve this, a range of strategies have been adopted. For example, in the field of PLEDs, making layered structures and using thick emissive layers have been proven very useful in increasing the device performance [16-20]. Using polymer blends as emissive layer is another powerful tool in order to enhance the efficiency as well tune the emission wavelength [21,22]. Various electrode schemes have also been exploited which allow efficient and balance charge injection in the emissive layer, an effective technique that has achieved the same goal [23].

Multiple emissive layers in polymer heterostructure devices are fabricated in layer-by-layer fashion, such that each layer uses a cross-linker as bonder which reduces the miscibility between the adjacent layers [8,24]. However, partial dissolution of the pre-deposited layer usually occurs with the deposition of the subsequent layer resulting roughness and film retention issues at the interface. Thermal layer stabilization and using orthogonal solvents have also been used to fabricate layered structure giving off blue emission [25]. Thick PLEDs (with emissive layer thickness of $\sim 1 \mu\text{m}$) are attractive as they are easy to fabricate and show high luminous efficiency [19,20]. However, they require very large operating voltage, limiting their use in many on-chip circuit applications. Such devices also consume more material. Using polymer-blends in PLEDs offers its own advantages because, a) fabrication of the emissive layer involves only one deposition step of the emissive layer and mixing of adjacent emissive layers is not applicable in contrast to heterostructure light emitting devices, b) these devices require low operating voltage, and c) very high efficiency can be achieved in blend based PLEDs (as reported here).

In the past, primary focus for blend based PLEDs remained on systems such as poly-fluorene (PF) blends, e.g. poly(9,9-dioctylfluorene) (F8)+poly(9,9-dioctylfluorene-*alt*-benzothiadiazole) (F8BT) [26-29], poly(9,9-dioctylfluorene-*alt*-N-(4-butylphenyl)-diphenylamine) (TFB)+F8BT, [30,31] and PFs+PPVs blends, e.g. poly[2-methoxy-5-(2'-ethyl-hexyloxy)-*p*-phenylenevinylene] (MEH-PPV) doped in F8 [32,33]. In this report, we purpose a polymer-polymer blend-system, $\text{F8}_{1-x}\text{SY}_x$ (where x signifies the weight fraction of SY in F8), a mixture of F8 and a PPV-copolymer known as superyellow (SY). F8 is an attractive polymer due to its efficient blue photoluminescence (PL) and electroluminescence (EL) [29,34,35]. It also serves as a backbone host in many white light-emitting copolymers because its emission can be tuned easily by copolymerization with different complimentary comonomers [29]. SY offers efficient and stable performance and long operational lifetime (100,000 h) [36-39]. It also offers much higher PL quantum

efficiency than other PPV derivatives, [37] making it a favorable material for light emitting devices. We chose to make this system firstly, because of strong spectral overlap between emission spectra of F8 and absorption spectra of SY - there is a potential of strong energy transfer between these molecules via Förster resonance energy transfer. Secondly, different charge transport properties of both polymers offer us an opportunity to see whether a balanced charge transport can be achieved within the emissive layer that could eventually lead to efficient devices.

We present our experimental findings for $\text{F8}_{1-x}\text{SY}_x$ based PLEDs as a function of increasing SY weight concentration, x . This blend system exhibits remarkable properties: luminance (L) $> 10^4 \text{ cd m}^{-2}$, luminous efficiency (η) $> 21 \text{ cd A}^{-1}$ and, low operating voltage (V) $\sim 3\text{-}10 \text{ V}$. We believe that the working principle lies in the large difference ($\sim 0.6 \text{ eV}$) between the highest occupied molecular orbital (HOMO) levels of F8 ($\sim 5.8 \text{ eV}$) and SY ($\sim 5.2 \text{ eV}$) [40-42]. SY molecules serve as hole-traps in the F8 host polymer and reduce their mobility. This dictates the charge balance/injection into the blend emissive layer and results in overall increase in the device performance. In order to understand the charge transport in $\text{F8}_{1-x}\text{SY}_x$ system, hole-only and electron-only devices for different values of x were also made. We use Mott-Gurney space-charge-limited current (SCLC) equation combined with field-dependent mobility [43,44] in order to estimate the hole mobility. Our findings support the hypothesis we made before this study that modified hole transport (due to SY traps) is responsible for very high efficiency of $\text{F8}_{1-x}\text{SY}_x$ based PLEDs. We anticipate that the system can pave the way for different device applications because of its superior electrical and optical properties as compared with the other well-known polymer blend systems. To the best of our knowledge, this is the first report for utilizing F8 and SY in a blend form for light emitting applications.

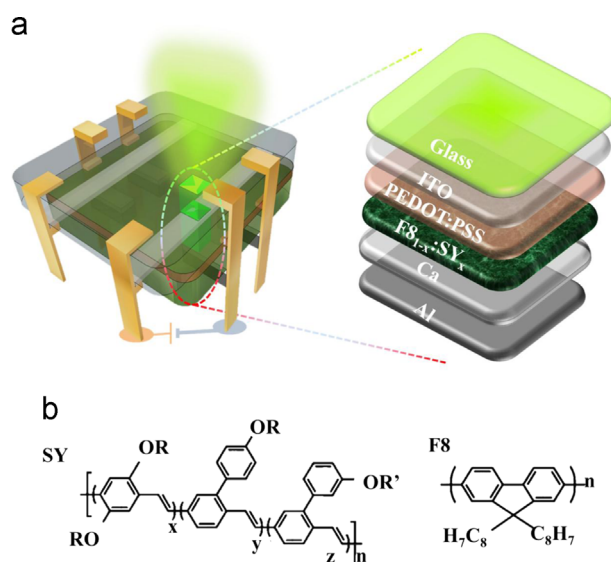


Figure 1 (a) Construction of $\text{F8}_{1-x}\text{SY}_x$ based polymer light emitting diode (PLED) pixels and different layers comprising the pixel, namely Glass/ITO/PEDOT:PSS/ $\text{F8}_{1-x}\text{SY}_x$ /Ca/Al. (b) Chemical structures of F8 and SY molecules.

Download English Version:

<https://daneshyari.com/en/article/1557187>

Download Persian Version:

<https://daneshyari.com/article/1557187>

[Daneshyari.com](https://daneshyari.com)