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# Solution processed multi-color organic light emitting diodes for application in telecommunications

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ABSTRACT

In this work we present an all solution processing scheme for the fabrication of the three primary colors, (R–G–B), emitting organic light-emitting diodes (OLEDs) via efficient color tuning of a blue organic semiconducting (OSC) thin film, in particular the poly[9,9-di-(2′-ethylhexyl)fluorenyl-2,7-diyl] (PF), in which different color fluorescent emitters are dispersed to define the final emitting color and thus to simplify the different color device fabrication. The transmission speed of the fabricated OLEDs was also examined for possible application in interactive telecommunications. To increase the response speed of the different color devices we altered both the device geometry and the electron injection efficiency. To this end we increased the emissive layer thickness and decreased the device emissive area and we also performed engineering of the cathode interfaces through the incorporation of solution processed porphyrin interlayers in order to lower the electron injection barrier height. The final devices exhibited improved operational characteristics and, consequently, modulation speeds.



## 1. Introduction

Organic light-emitting diodes (OLEDs) have recently drawn much attention in the flat panel display and lighting technology due to their potential for low cost, solution processability, no viewing-angle dependence, and full-color capability. Since the first OLED reported in 1987 by Tang and Van Slyke [1], a great deal of research has been carried out to realize devices emitting at different color and exhibiting higher brightness and luminous efficiency [2–5]. In the context of this research effort substantial progress has been made in the areas of device fabrication [6–8] and materials synthesis [9–11]. Several techniques have appeared for realizing the different color devices which usually involves the formation of multi-layer structures using deposition and patterning of different polymeric or small organic molecule based layers one over the other, where each one is capable of emitting one of the main colors [12]. Nevertheless, the deposition and patterning of each individual layer involves quite a few processing steps and in addition risks for performance degradation of the pre-existing layer during the deposition and patterning of the new layer. Several schemes have been proposed for the simplification and/or improvement of the whole process including selective diffusion of green and red fluorescent/phosphorescent dyes into adjacent regions, deposition of different materials by ink-jet printing and optical filtering of a single white-emitting OLED [13–15]. An alternative route, especially for white light applications, is to physically mix different spectrum emitters inside the materials of the emitting layers and achieve tuning of the emitting color depending on the materials combination [16–18].

Our group has previously demonstrated efficient color tuning of a wide-band gap semiconducting polymer, namely the poly-9-vinylcarbazole (PVK), through the addition of appropriate emitting dyes within the polymer matrix [19,20]. However, PVK suffers from extremely low mobility values which make it hard to interpret the improved device performance needed for practical

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applications [21]. By expanding our previous work, OLEDs emitting different colors, such as red–green–blue (R–G–B) are demonstrated here by using a higher conductivity polyfluorene derivative, in particular poly[9,9-di-(2′-ethylhexyl)fluorenyl-2,7-diyl] (PF) [22], as the semiconducting host and blue-emitting material and appropriate fluorescent dyes to achieve the green and red emission via efficient energy transfer from the host matrix to the emitter (guest). With the dispersion of either the green 1-[4-(dimethylamino)phenyl]-6-phenylhexatriene (DMA-DPH) or the red 4-dimethylamino-4′-nitrostilbene (DANS) emitter within the blue emitting polymer (PF), green and red emission, respectively, was obtained allowed via efficient energy transfer from the host polymer to the guest emitter. Note that red, green, and blue OLEDs with PF as the invariant semiconducting host/blue emissive material have not yet been reported. In addition, the use of similar material combinations for different-color OLEDs has the benefit of enhancing the production throughput and process controllability in the manufacture of multi-color OLED devices. In addition, for the practical use of OLEDs in the field of interactive telecommunications, the fast transmission speed of the device is of paramount importance [23]. The prerequisites for a fast response OLED are to exhibit a low capacitance which critically depends on the device parameters (active area, thickness of the organic layer) and reduced charge injection barriers in order to achieve increased/balanced charge injection/transport from the metallic contacts to the emissive layer [24–30]. Especially in OLEDs using large work function air-stable cathode electrodes (such as Aluminum, Al) it is important to develop effective cathode interfacial layers to

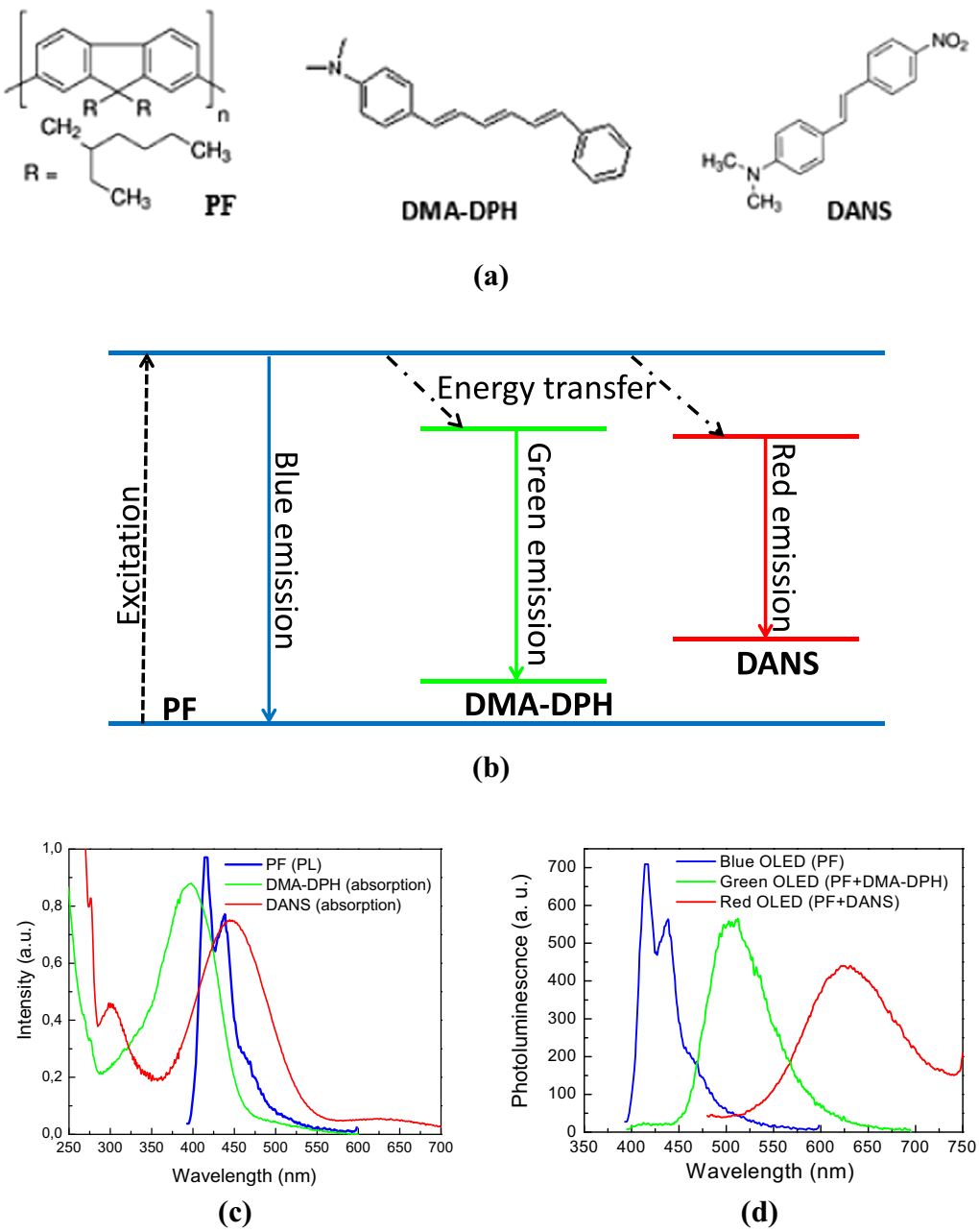


**Fig. 1.** (a) Chemical structures of the blue-emitting semiconducting polymer matrix (PF) and the green (DMA-DPH) and red (DANS) emitting dyes. (b) Illustration of the energy transfer processes occurring after excitation of the polymer matrix. (c) The overlap of the absorption spectra of the emitting dyes with the photoluminescence spectrum of the polymer matrix (PF film). (d) Photoluminescence spectra of pristine PF film (blue emission), PF incorporating 2% w/w DMA–DPH (green emission) and 2% w/w DANS (red emission). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)