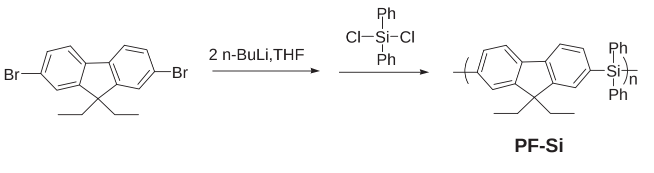
Blue Electrophosphorescent Light-emitting Device Using a Novel Nonconjugated Polymer as Host Materials

Ke-Feng Shao,[1,3] Xin-Jun Xu,[2,3] Gui Yu,[2] Yun-Qi Liu,[2] and Lian-Ming Yang*,[1]
[1]*New Materials Laboratory, Institute of Chemistry, Chinese Academy of Sciences, Beijing 100080, P. R. China*
[2]*Organic Solids Laboratory, Institute of Chemistry, Chinese Academy of Sciences, Beijing 100080, P. R. China*
[3]*Graduate School, Chinese Academy of Sciences, Beijing 100080, P. R. China*

(Received January 23, 2006; CL-060093; E-mail: yanglm@iccas.ac.cn)

Blue electrophosphorescent organic light-emitting devices (PHOLEDs) were fabricated by doping a phosphorescent iridium complex, bis[(4,6-difluorophenyl)pyridinato-N,C^2]-(picolinato)iridium(III) (Firpic) into a novel nonconjugated polymer, poly[(9,9-diethylfluoren-2,7-ylene)diphenylsilylene] (PF-Si). A device with the same configuration using the widely applied poly(9-vinylcarbazole) (PVK) as the host material was also prepared under the identical conditions for comparison. The luminance and current efficiency of the PF-Si:Firpic device were over four times higher than those of the PVK–Firpic device at a current density of 200 mA/cm^2 (1260 cd/m^2 vs 275 cd/m^2, 0.61 cd/A vs 0.13 cd/A).

Recently, there have been a number of studies on organic light-emitting devices (OLED) using heavy-metal phosphorescent materials as emitters.[1–3] Most of the electrophosphorescent devices (so called PHOLED) have a composite guest/host emitter layer, where the guest is a phosphorescent dye with efficient intersystem crossing and the host is a suitably chosen fluorescent organic molecule.[4,5] Both singlet and triplet excitons formed in the host material can be transferred to the phosphorescent dopant,[6–8] resulting in very high external quantum efficiency of PHOLEDs.[9–11] However, as the triplet energy of the phosphor is shifted to blue, it becomes increasingly difficult to find an appropriate host with a suitable high-energy triplet state. Some low molecular weight host materials with high triplet energy, such as *m*-bis(*N*-carbazolyl)benzene (mCP) and bis(triphenylsilane) benzene (UGH2), were applied in blue PHOLEDs to achieve high external quantum efficiency ($\eta_{\mathrm{ext}} = 7.5$[12] and 9.1%,[13] respectively). To our knowledge, polymer-based high energy host materials suitable for blue PHOLEDs have not been well developed, although poly(9-vinylcarbazole) (PVK)-based host–guest systems were reported.[14–17] The using of nonconjugated polymer host result to PHOLEDs with good external quantum efficiencies, due to the less favorable phosphorescence quenching because of the absence of low-energy triplet state.[15,16] In this letter, we present a blue phosphorescent device using a novel nonconjugated polymer, poly[(9,9-diethylfluoren-2,7-ylene)diphenylsilylene] (PF-Si)[18] as the host material doped with iridium(III) bis[(4,6-difluorophenyl)pyridinato-N,C^2]picolinate (Firpic) as an emitter.



Scheme 1. Synthetic route of the polymer.

The electrophosphorescent polymer light-emitting devices (PHPLEDs) was prepared as follows: A pre-cleaned ITO-coated glass substrate was first coated with a 30 nm-thick layer of poly(ethylenedioxythiophene):poly(styrenesulfonic acid) (PEDOT:PSS) in order to enhance hole injection and improve smoothness of the substrate; Next, a mixture of blue phosphorescent emitter, Firpic, and polymer host, PF-Si, was spin coated from toluene solution, with a doped ratio of 5% (by weight), resulting in a 60 nm-thick emitting layer; After removal of solvent, a 20 nm-thick 2,2′,2″-(1,3,5-benzenetriyl)-tris(1-phenyl-1*H*-benzimidazole) (TPBI) hole-blocking layer was applied by thermal vacuum evaporation at a pressure of $<10^{-6}$ Torr; Finally, a 100 nm-thick Al cathode was deposited in vacuum through a shadow mask with 1 mm-diameter circular openings. For comparison, we also fabricated a device with the same configuration using PVK as a host material under the identical conditions. The layer thickness was determined using a crystal thickness monitor, and an ellipsometer for the evaporated and spin-coated films, respectively.

The EL spectra of the devices are shown in Figure 1. A small emission peak (424 nm) was found in the EL spectra of PVK:Firpic device, indicating that the energy transfer from PVK to Firpic was not very completed because that the triplet energy level of Firpic (2.62 eV)[19] is much higher than that of PVK (~2.5 eV).[20] On the other hand, no emission from PF-Si was observed in the PF-Si:Firpic device, indicating that more efficient energy transfer from PF-Si to Firpic was achieved. The Commission International de L'Eclairage (CIE) coordinates (x and y values, respectively) for PVK and PF-Si devices are (0.15, 0.28) and (0.17, 0.33), respectively.

Figure 2 shows the luminance–voltage (L–V), current–volt-

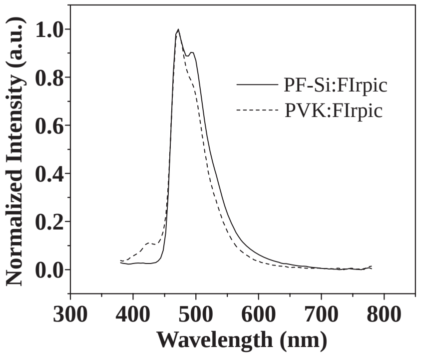


Figure 1. Normalized electroluminescence (EL) spectra of the devices.

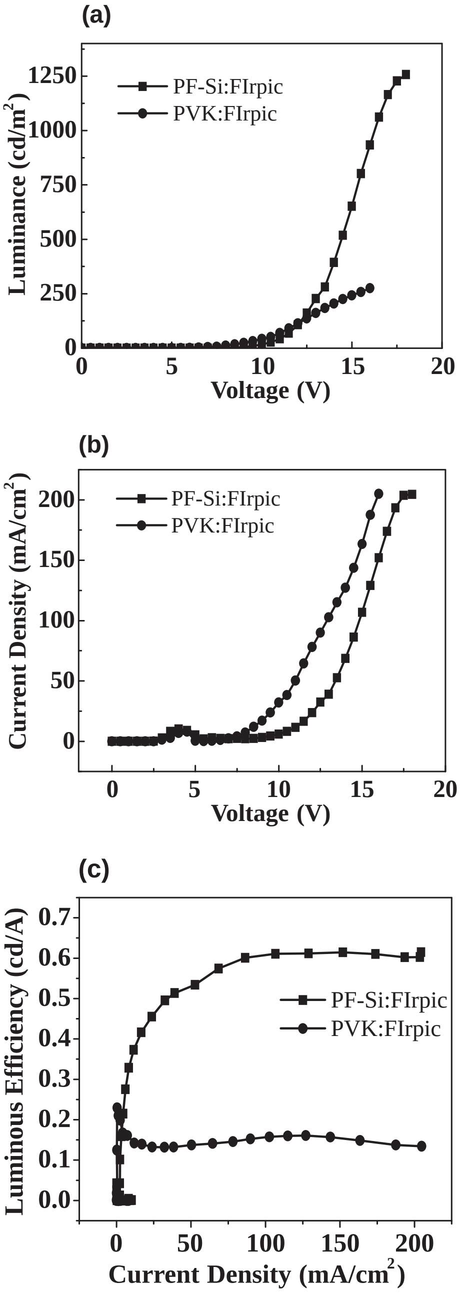


Figure 2. (a) Luminance–voltage, (b) current density–voltage, and (c) luminous efficiency–current density characteristics of ITO/PEDOT:PSS/polymer:FIrpic/TPBI/Al devices.

age (I–V) characteristics, and the luminous efficiency of these devices. The PF-Si:Firpic device produces a luminance of 1260 cd/m^2 and a luminous efficiency of 0.61 cd/A at a current density of 200 mA/cm^2, which were over four times higher than those of the PVK:Firpic device (275 cd/m^2 and 0.13 cd/A, respectively).

In conclusion, a blue electrophosphorescent organic light-emitting device with phosphorescent emitter doped into a novel nonconjugated polymer, PF-Si, was fabricated. Over four times higher luminance and luminous efficiency than those of the PVK:Firpic device was achieved. It may be attribute to a more efficient energy transfer from the polymer host to the phosphorescent guest in the PF-Si:Firpic device than in the PVK:Firpic device. This new polymer could be a potential candidate for the application as host materials in PLEDs, especially for blue PLEDs.

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