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Doctoral Dissertation

High Efficiency Circularly Polarized Electroluminescence Induced by Sublimable Axially Chiral Inducers

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Abstract

Organic light-emitting diodes (OLEDs) capable of emitting circularly polarized (CP) light have attracted significant interest from researchers due to their potential applications, such as 3D display and optical information storage. One of the effective approaches to fabricate CP-OLEDs is to construct chiral light-emitting layers by chiral induction, where chiral small molecules are doped as chiral inducers into achiral luminescent polymers. Due to the chiral transfer, strong circularly polarized luminescence (CPL) of the polymer can be achieved. While this method can yield high asymmetry factor g, the presence of chiral inducers within the films can decrease the device performance of the CP-OLEDs. To solve this problem, it may be important to remove the chiral inducers from polymer after chiral induction is complete.

In this study, we doped the axially chiral inducers into thin films of the achiral conjugated polymers. Upon annealing the films, a clear circular dichroism (CD) signal from emitting polymer appeared, indicating the induction of chiroptical properties. Nuclear magnetic resonance (NMR) spectra of the samples before and after annealing confirmed the complete removal of chiral inducers by sublimation during annealing, resulting in the formation of neat polymer films. The red shift in absorption spectra and the fibrous morphology in atomic force microscope (AFM) after annealing indicated that the chiroptical properties were caused by intermolecular exciton coupling due to aggregation. The photoluminescence quantum yield (PLQY) of as-prepared films was remarkably low but after annealing it increased to that of neat films, suggesting that the removal of chiral inducers by high-temperature sublimation realized both high g factor and PLQY simultaneously. We applied this thin film to the emitting layer of CP-OLEDs. The device achieved a maximum external quantum efficiency (EQE) of 1.20%, The $|g_{EL}|$ of 7×10^{-3} was achieved without any optimization of the device structures. This study demonstrates for the first time a way to realize CP-OLEDs by sublimable chiral inducers.

Furthermore, the generality of the sublimation-assisted chiral induction strategy was also investigated. We confirmed that BINOL is capable of inducing CPL not only in F8BT but also in PFO. Compared to F8BT, PFO exhibited a g_{lum} value one order of magnitude lower. In addition, the CPL emission of PFO could be further red-shifted after solvent vapor annealing, which induced the β-phase crystalline structure. The chiral F8BT system was further extended to realize circularly polarized Förster resonance energy transfer (C-FRET). By replacing BINOL with a more efficient chiral inducer, R5011, and doping the blend with a red-emitting molecule DBP as both the energy and chirality acceptor, red CPL emission was successfully achieved. Notably, we also discovered that R5011 contributed to a significant enhancement in the PLQY of the films. These studies provide a new method for the preparation of high-efficiency CP-OLEDs.

Keywords: Chiral induction, Circularly polarized organic light-emitting diodes, BINOL, Polyfluorene, Circularly polarized fluorescence resonance energy transfer.