Materials Science & Engineering Doctoral Defense

Organic Optoelectronic Devices Employing Small Molecules

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abstract

Organic optoelectronic devices have remained a research topic of great interest over the past two decades, particularly in the development of efficient organic photovoltaics (OPV) and organic light emitting diodes (OLED). In order to improve the efficiency, stability, and materials variety for organic optoelectronic devices a number of emitting materials, absorbing materials, and charge transport materials were developed and employed in a device setting. Optical, electrical, and photophysical studies of the organic materials and their corresponding devices were thoroughly carried out.

Two major approaches were taken to enhance the efficiency of small molecule based OPVs: developing material with higher open circuit voltages or improved device structures which increased short circuit current. To explore the factors affecting the open circuit voltage (V_{OC}) in OPVs, molecular structures were modified to bring V_{OC} closer to the effective bandgap, ΔE_{DA}, which allowed the achievement of 1V V_{OC} for a heterojunction of a select Ir complex with estimated exciton energy of only 1.55eV. Furthermore, the development of anode interfacial layer for exciton blocking and molecular templating provide a general approach for enhancing the short circuit current. Ultimately, a 5.8% PCE was achieved in a single heterojunction of C_{60} and a ZnPc material prepared in a simple, one step, solvent free, synthesis.

OLEDs employing newly developed deep blue emitters based on cyclometalated complexes were demonstrated. Ultimately, a peak EQE of 24.8% and nearly perfect blue emission of (0.148,0.079) was achieved from PtON7dtb, which approaches the maximum attainable performance from a blue OLED. Furthermore, utilizing the excimer formation properties of square-planar Pt complexes, highly efficient and stable white devices employing a single emissive material were demonstrated. A peak EQE of over 20% for pure white color (0.33,0.33) and 80 CRI was achieved with the tridentate Pt complex, Pt-16. Furthermore, the development of a series of tetradentate Pt complexes yielded highly efficient and stable single doped white devices due to their halogen free tetradentate design. In addition to these benchmark achievements, the systematic molecular modification of both emissive and absorbing materials provides valuable structure-property relationship information that should help guide further developments in the field.

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