Materials Science & Engineering Doctoral Defense

Phosphorescent Metal Complexes and Their Molecular Aggregates for Stable and Efficient Organic Light-Emitting Diodes

School for Engineering of Matter, Transport and Energy

Linyu Cao
Advisor: Jian Li

Abstract

Over the past three decades, significant progress in the development of organic light-emitting diodes (OLEDs) has been achieved, enabling OLEDs to become a main component in state-of-the-art displays and next generation solid-state lighting. As this technology advances, it is highly desirable to further improve the device efficiency and operational stability to drive the success of OLEDs in future display and lighting applications. This dissertation aims at developing novel organic emitting materials covering visible and near-infrared (NIR) emissions for efficient and table OLEDs.

Firstly, a series of tetradentate Pd(II) complexes, which have attractive phosphorescent aggregate emission performance especially at high brightness level in device settings, have been developed. The luminescent lifetime of Pd(II) complex aggregates was demonstrated to be shorter than 1 μs with a close-to-unity photoluminescence quantum yield. Moreover, a systematic study regarding structure-property relationship was conducted on four tetradentate Pd(II) complexes, i.e., Pd3O3, Pd3O8-P, Pd3O8-Py2, and Pd3O8-Py5, featuring aggregate emission. As a result, an extremely efficient and stable OLED utilizing Pd3O8-Py5 was achieved. It demonstrated a peak external quantum efficiency (EQE) of 37.3% with a reduced efficiency roll-off retaining a high EQE of 32.5% at 10000 cd m-2, and an estimated LT95 lifetime (time to 95% of the initial luminance) of 48246 h at 1000 cd m-2.

Secondly, there is increasing demand for NIR OLEDs with emission spectra beyond 900 nm to expand their applications in biometric authentication, night vision display, and telecommunication, etc. A stable and efficient NIR Pt(II) porphyrin complex named PtTPTNP-F8 was developed and exhibited an electroluminescent spectrum at 920 nm. By carefully choosing the host materials, an PtTPTNP-F8 based NIR OLED achieved a EQE of 1.9%. Furthermore, an PtTPTNP-F8 OLED fabricated in a stable device structure demonstrated extraordinary operational stability with LT99 of >1000 h at 20 mA cm-2.

Lastly, a series of imidazole-based blue Pt(II) complexes were developed and studied. Results indicated that structural modification of ligand molecules effectively tuned the emission spectral wavelength and bandwidth. Two blue complexes, i.e., Pt2O2-P2M and Pt2O2-PPy5-M, emitting at 472 and 480 nm respectively, exhibited narrow-band emission spectra with a full width at half maximum of 16 nm.

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