Abstract

Recent two decades have witnessed the burgeoning development of quantum dot (QD)-based light-emitting diodes (QLEDs) since its first demonstration in 1994. It has been regarded as one of the next-generation lighting and display technologies, mainly due to the testified extraordinary advantages such as tunable wavelength across the whole visible spectrum, narrow full-width at half-maximum (FWHM), superior colour saturation feature and economical manufacture accessibility. Although tremendous achievements in this research area have been made especially in these two to three years, which prove its comparable performance with organic LEDs (OLEDs), there still remain some deficiencies yet to be solved. This thesis will focus on the following topics regarding to the replacement of organic layer, the manipulation of carrier injection balance and the realization of full-inorganic prototype QLEDs.

Two inorganic materials, sol-gel prepared copper oxide (CuO) and commercially-available copper thiocyanate (CuSCN) were utilized as the replacements for polyethylene dioxythiophene: polystyrene sulfonate (PEDOT:PSS), respectively. For CuO-based QLED, the operation lifetime is enhanced due to the introduction of inorganic hole injection material, while the device performance is comparable with PEDOT:PSS-based ones. Furthermore, an inorganic CuSCN with simpler preparation method was applied, and the turn-on voltage of the corresponding QLED was dramatically decreased due to the better energy band alignment of CuSCN than PEDOT:PSS with comparable device performance.

Meanwhile, a novel cathode interfacial material (CIM) was introduced to improve the QLED performance by modulating the charge balance. With its promising electron transport behaviour and low processing temperature, the resultant devices demonstrate better features in terms of EQE, current (CE) and power efficiencies (PE). Furthermore, by incorporating this CIM with traditional LiF together as the cathode buffering layers, the corresponding device showed superior performance, which could be attributed to the better energy band alignment and more balanced charge injection due to the reduced barrier for electron injection from cathode.

Moreover, in order to further promote the stability of QLEDs, a series of all inorganic QLEDs with multiple emission wavelengths were proposed with specific design philosophy. By the insertion of thin lithium fluoride (LiF) as the insulating as well as buffering layer, the QD charging and carrier imbalance were suppressed in the working device, resulting in improved performance with an external quantum efficiency of 3.05% and a maximum brightness over 10,000 cd/m^2, which are among the best reported values to the best of our knowledge.

To sum up, this thesis mainly addresses three aspects of the current deficiencies in QLEDs. Two alternative inorganic materials have been introduced as the hole injection material for substituting PEDOT:PSS, resulting in improved device operation lifetime and lower turn-on voltage; On the other hand, a surpassing charge balance was achieved by the manipulation of cathode buffering layers, demonstrating the feasibility of the CIM in improving the device performance; Furthermore, all inorganic QLEDs with the reported highest performance so far were systematically fabricated with proper device engineering. We believe that our results could make contributions to the development and growth of QLEDs.