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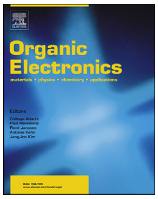

Great improvement of operation-lifetime for all-solution OLEDs with mixed hosts by blade coating

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ABSTRACT

We investigated some effective device designs and fabrication methods for long operation-lifetime all-solution-processed Phosphorescent OLEDs (PhOLEDs) and fluorescent OLEDs with mixed-hosts system and thin Poly [(9, 9-dioctylfluorenyl-2, 7-diyl)-*co*-(4, 4′-(*N*-(4-*sec*-butylphenyl) diphenylamine)] (TFB). The all-solution-processed green PhOLEDs had high current efficiency (30.3 cd/A) and long operation-lifetime. The best half-lifetime of green PhOLEDs with thin HTL, MH-hosts EML and optimized deposition was 310 h at an initial luminance 1000 cd/m^2, 250 h at an initial luminance 500 cd/m^2 for green PhOLEDs with thin HTL, and MH-hosts EML, and the lifetime of triple layer PhOLEDs device was only 0.5 h for the same materials. The red PhOLEDs exhibited a high current efficiency (10.93 cd/A) and half-lifetime with 157.9 h at an initial luminance 500 cd/m^2. For the blue fluorescent OLEDs, the thin polymer TFB, mixed-hosts EML, double EMLs and optimization deposition yield a high current efficiency (5.68 cd/A) and long operation-lifetime with 117.7 h at an initial luminance 500 cd/m^2. Single host fluorescent device had half-lifetime of 73.5 h only at an initial luminance 100 cd/m^2. Finally, by doping red emitter Rubrene into stable blue device, we achieved soft yellow OLEDs with high efficiency (10.87 cd/A) and 8 fold improvement operation-lifetime (1200 h). We believe that such all-solution-processed OLEDs which showed greatly improved operational lifetimes would be suitable for the indoor supportive lighting with natural colors.

1. Introduction

Organic Light-Emitting Diodes (OLEDs) technology produces flat light-emitting films, by placing a series of organic thin films between two conductors. When electrical current is applied to OLEDs, it emits a bright light. OLEDs can be used to make displays and lighting. Because OLEDs emit light, they do not require any backlights; therefore they are thinner and more efficient than LCD displays (which require white backlight). Yet the underlying issues of device lifetime and large-area fabrication have not been solved. The great majority of the scientific papers that address OLEDs only consider the efficiency levels of OLEDs with small areas; the problems of long-lasting devices and large-area devices are considered "non-academic". However, both of these problems are actually basic scientific challenges. The lack of study regarding these problems is one of the major reasons why organic semiconductor products have yet to the mainstream market. Long-lasting, large-area devices with low cost are the primary topic of this work. At present OLEDs are typically manufactured by a vacuum chamber evaporation process, which demands expensive vacuum chambers and has low material utilization. The lifetimes of vacuum-processed OLEDs have greatly improved over the past ten years; OLEDs have reached a level of quality suitable for commercial products. Several companies, such as Samsung Electronics Co. Ltd, and LG Display have launched products with full-color small-area mobile panels, and TVs with screens composed of OLEDs. The operational lifetimes for green and red phosphorescence as well as blue fluorescence are well over 100,000 h [1,2]. These lifetimes are

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acceptable but the cost of the vacuum process is exceedingly high [3–9]. However, several scientific literatures indicated that large-area solution-processed OLEDs had short lifetimes but potentially low costs in large area [7,10]. As the result, the operational lifetime improvement of solution-processed OLEDs would be paramount. In this study, therefore, we explained in detail how to improve the operational lifetimes of low-cost solution-processed OLEDs. There are several other important factors which may also limit the solution OLEDs lifetime including unstable electron transport materials [11,12], carrier accumulation at the interface, and a commonly used hole-injection conducting polymer PEDOT: PSS, etc. The degradation factors are shown in Fig. 1(a). OLEDs can be degraded by various internal and external effects. Aside from watertight encapsulation against moisture and using materials with intrinsically high stability, a crucial strategy for lifetime improvement is to avoid carrier accumulation at the interfaces of semiconductor heterojunctions [13]. In typical OLEDs design, the emission layer is confined by carrier-blocking layers. If the hole current exceeds the electron current, holes will accumulate at the interface between the emission layer and the hole-blocking layer, which is often also the electronic transport layer. The high hole density there could lead to the injection of some of the holes into the electron-blocking layer molecules, which may not be chemically stable with a positive charge. Furthermore, hole accumulation implies a concentrated electron-hole recombination zone at the interface, leading to high local exciton density. Two excitons may fuse into a highly excited state by, processes such as triplet-triplet annihilation. Such states may eventually decay through photo-chemical channels rather than the desired radiative channel. Long-lasting vacuum-processed OLEDs usually have balanced electron and hole currents. Such balance can be tuned by multiple electron transport and hole transport layers. In such device design, a single high-energy barrier is avoided and the current can be controlled by the thicknesses and the mobility levels of the individual layers. With a balanced current, the recombination zone can be in the middle of the emission layer without a high local carrier or exciton density at the interface [6,10,and14]. This multiple transport layer approach, however, is difficult to implement in solution-processed OLEDs. Even through

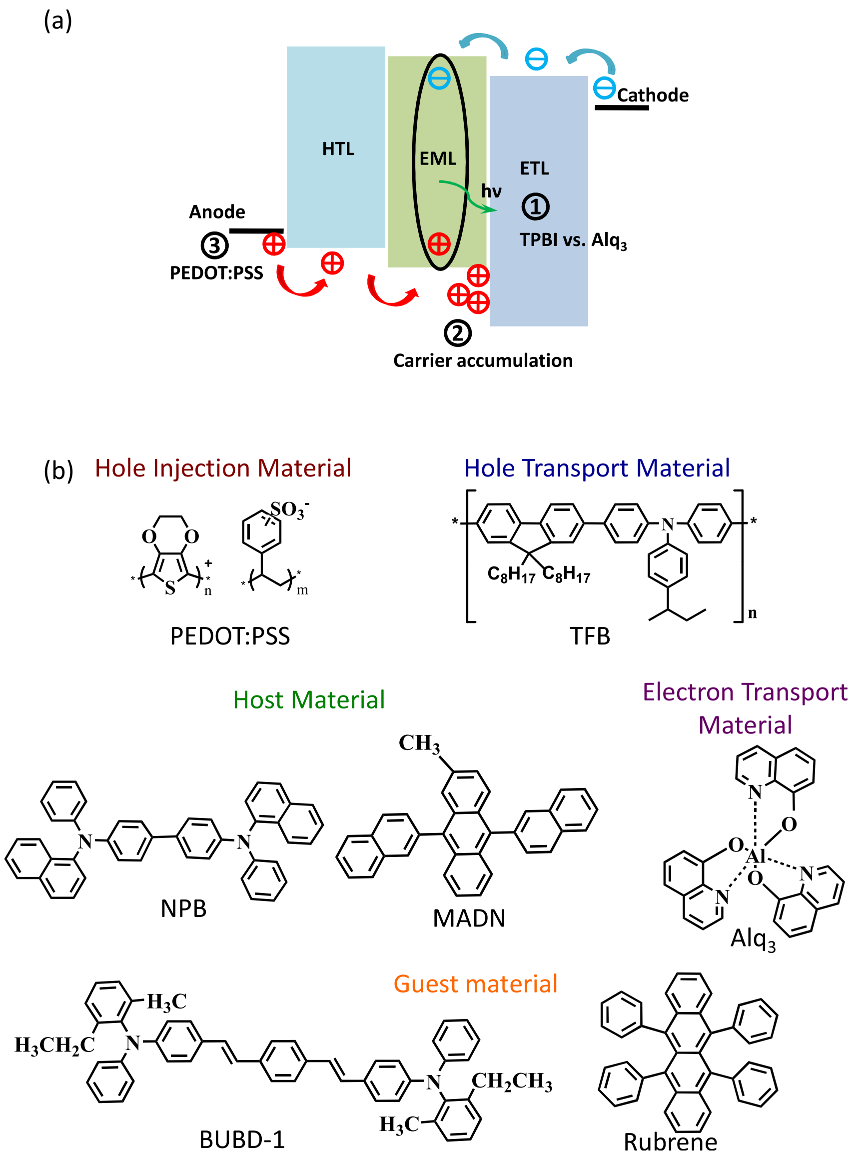

Fig. 1. (a) The degradation factor of solution-processed OLEDs including 1 unstable versus stable ETL material 2 carrier accumulation at the interfaces of semiconductor heterojunctions 3 PEDOT: PSS (b) The chemical structures of the organic materials used in the fluorescent OLEDs.