Organic Electronics 15 (2014) 2802–2809

Contents lists available at ScienceDirect

Organic Electronics

journal homepage: www.elsevier.com/locate/orgel

Thermal buffer materials for enhancement of device performance of organic light emitting diodes fabricated by laser imaging process

Joon Ho Jeon [a], Seung Ji Cha [a], Young Min Jeon [b], Ji-Hoon Lee [c], Min Chul Suh [a,*]

[a] Department of Information Display and Advanced Display Research Center, Kyung Hee University, Dongdaemoon-Gu, Seoul 130-701, Republic of Korea
[b] Daejoo Electronic Materials Co., Ltd., Sihwa Ind. Complex. 1Ra. 110, Jeongwang-Dong, Siheung-Si, Gyeonggi-Do 429-848, Republic of Korea
[c] Department of Polymer Science & Engineering, Korea National University of Transportation, 50 Daehak-ro, Chungju-Si, Chungbuk 380-702, Republic of Korea

ARTICLE INFO

Article history:
Received 2 May 2014
Received in revised form 21 July 2014
Accepted 3 August 2014
Available online 19 August 2014

Keywords:
Display patterning process
LITI
Thermal buffer layer
Organic light emitting device
Relative efficiency

ABSTRACT

Laser Induced Thermal Imaging (LITI) is a laser addressed thermal patterning technology with unique advantages such as an excellent uniformity of transfer film thickness, a capability of multilayer stack transfer and a possibility to fabricate high resolution as well as large-area display. Nevertheless, it has been an obstacle to use such a laser imaging process as a commercial technology so far because of serious deterioration of the device performances plausibly due to a re-orientation of the molecular stacking especially in the emitting layer during thermal transfer process. To improve device performances, we devised a new concept to suppress the thermal degradation during such kind of thermal imaging process by using a high molecular weight small molecular species with large steric hindrance as well as high thermostability as a thermal buffer layer to realize highly efficient LITI devices. As a result, we obtained very high relative efficiency (by EQE) up to 91.5% at 1000 cd/m^2 from the LITI devices when we utilize 10-(naphthalene-2-yl)-3-(phenanthren-9-yl)spiro[benzo[ij]tetraphene-7,9′-fluorene] as a thermal buffer material.

1. Introduction

Since the discovery of electroluminescence (EL) in amorphous organic molecular materials in the late 1980s, organic light emitting diodes (OLEDs) have been under extensive development in a number of academic and industrial laboratories [1–3]. As a result, the research of the last decade has led to a number of breakthroughs in OLED technology, which made the commercialization of OLED displays very successful. Nevertheless, some serious drawbacks still exist on the path of realization of large-area and high-resolution displays. This is because a fine metal mask (FMM) method, currently a sole mass production technology for active-matrix OLEDs (AMOLEDs), has proved to be a very poor color patterning technology with a low patterning accuracy (± 10–12.5 μm) as compared to the conventional photolithography process [4,5]. Nevertheless, as photolithography process requires the use of wet etchant, developer, stripper, etc., all of which can damage organic layers, there has been no other option except for using such thermal evaporation-based technology [6–14]. In the meanwhile, the Laser Induced Thermal Imaging (LITI) process has been developed to become the most promising alternative for OLED fabrication, because it yields a much higher process accuracy (about ±3 μm) and provides the possibility of large-area processing applicable to active matrix OLED fabrication [15].

However, the device characteristics obtained by LITI process generally degrade compared to those fabricated

* Corresponding author. Tel.: +82 2 961 0694; fax: +82 2 968 6924.
E-mail address: mcsuh@khu.ac.kr (M.C. Suh).

http://dx.doi.org/10.1016/j.orgel.2014.08.009
1566-1199/

by the most common evaporation process. Thus, it has so far been difficult to commercialize it as a main OLED fabrication technology. Indeed, laser imaging process normally causes a temperature increase up to several hundred degrees centigrade during the transfer process of organic materials by thermal stimulation by laser source at light to heat conversion (LTHC) layer (as shown in Fig. 1(a)), although the duration time at the peak temperature is only within a millisecond [16,17]. Hence, the blue common layer (BCL) structure containing the blue layer on top of red and green layers (without using any interlayer in-between them as Fig. 1(b)) has been necessary to realize a reasonable device performance, comparable to the previously reported conventional thermally evaporated OLED devices [18–20]. By applying the concept of such blue common layer structure, we could realize the stable blue device, as well as red and green devices, with a high patterning accuracy. In this case, it is crucial to exclude the unexpected emission of blue emissive layer (EML), because blue EML materials are normally deposited directly on red or green emitters. The basic principle of the blue common layer approach is to use blue materials as an alternative component of hole-blocking layer (HBL), as they normally have much wider band gaps and much deeper highest occupied molecular orbital (HOMO) levels compared to those of red and green EMLs. Thus, the blue EML exhibits behaviors that are very similar to those of HBL, although they manifest a lower mobility level. Nevertheless, we must pattern for red and green emitters at least two times. To make matters worse, the red and green EML normally receives the greatest thermal stress, because, as shown in Fig. 1(a), it is deposited directly on the interlayer (IL) of donor film.

The temperature distribution through donor film – transfer layer – receptor layer was well illustrated in the previous report by Lamansky [21]. In this report, it was established that transfer layer could be heated up to ~200 °C. However, when we proceeded with such imaging process at a typical energy dose (~1.1 J/cm^2), the typical temperature observed close to the substrate level by a thermo-label test was about ~130 °C. This is another reason why blue materials cannot be transferred by such methods. In other words, blue materials which normally show a poor thermal stability (glass transition temperature T_g < 130 °C) cannot be transferred by LITI technology, because such materials (red and green EML) can be degraded mostly due to the change of the molecular stacking order through a strong π–π interaction during the heating by laser imaging. Indeed, such kind of a change could alter device properties when utilized during the device fabrication process. In addition, these kinds of bulk property change during LITI process are very similar to the phenomena observed after the annealing of evaporated devices [20]. Thus, it appeared to be very helpful if we could eliminate this thermal impact by introducing third materials, so-called, "a thermal buffer layer" (TBL) in between EML and IL of donor film. Those materials could be metallic materials, as they could dissipate heat very rapidly at such process interface. In addition, organic materials which have considerable amounts of steric hindrance could also

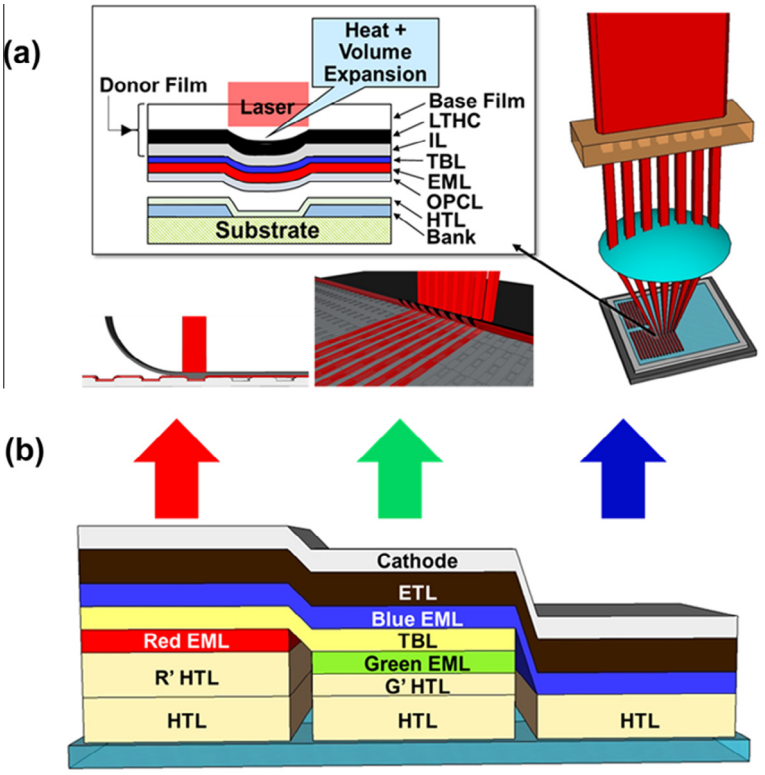

Fig. 1. (a) Schematic diagram of LITI process. (b) Schematic image of blue common layer device. This paper reports about devices with red BCL structure. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)