P-115: Electrical, Optical, and ITO Characteristics of a Flexible OLED Display

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Abstract

For cyclic bending test (5000 times) on a flexible OLED, leakage current and luminance decreased , due to surface microcracks under bending process. Then we removing the organic layer to exhibit the surface of substrate and we find the OLED break down but the ITO layer still well .

1. Objective and Background

Flexible organic light-emitting diodes (OLEDs) have attracted much attention for display application owing to their advantages of robust, lightweight, and thin [1]. In this paper, we analyzed the electrical, optical, and storage lifetime characteristics of flexible OLED upon cyclic mechanical bending. Such an OLED was fabricated on a polyimide (PI) film with glass carrier substrate. Increase in current density was observed when removing the flexible OLED from the glass carrier. It resulted from the micro-contacts of ITO anode and cathode due to the formation of microcracks upon bending [2]. When bending for the first 50 times with a radius of curvature (Rc) of 14 mm, current density increased again, which came from the density increase of those microcracks. However, further bending resulted in a decrease of current density. That means: (1) density of microcrack stopped increasing, and (2) depth and width of microcracks increased which resulted in an open-circuit, rather than micro-contacts. After 1000 times bending, the current density was kept at low value until 5000 times bending. At the same time, luminance decreased to 64% of its initial value when bending for 300 times. After 700 times bending, the luminance was back to 92% of its initial one and kept until 5000 times bending. Besides, although there is microcrack formation, no obvious degradation in storage lifetime was observed. Dark spot has little change for the flexible OLED with and without mechanical bending.

2. Results

In this study, flexible OLED was fabricated upon the glass substrate with the size of 275 x 335 mm^2. PI film (with Tg>200^{o}C) was spun on the glass carrier then cured as the flexible substrate [3]. Before OLED fabrication, transparent passivation was formed on the PI film. Organic thin films and Al cathode was evaporated upon the low-temperature sputtered ITO anode. After OLED thin-film process, device was encapsulated with stainless cover. Test device was scribed from the mother glass with 50 x 60 mm^2. Dimension of each test pixel was 3 x 3 mm^2. Flexible OLED was detached from the glass substrate before bending tests.

Fig. 1 shows the J-V characteristics before and after detaching OLED from the glass carrier. One can see leakage current increase after peeling process, especially at low driving voltage, i.e. < 6V. Microcracks were also observed under microscope with the dimensions of several μm (not shown here). It may result from: (1) different thermal expansion properties between glass carrier and PI film, and (2) strain when peeling PI film from the glass. Although the macroscopic lit-on pictures before and after detaching from glass substrate look the same, as shown in the inset of Fig. 1, there are some defects formation at microscopic range. Those microcracks resulted in micro-short-circuits and increased the leakage current.

Then, we bent he devices to different Rc. When Rc=6 mm, open circuit was observed after 10 mins. ITO cracks across the device were formed from microscope image, which resulted in open-circuit failure. On the other hand, there was no obvious change was observed when Rc=14 mm for several days. Hence, we chose this condition for cyclic bending tests. Fig. 2 showed the current density and luminance variations under different bending cycles. One can see that current density increased and reached maximum when bending for 50 times. That came from the density increase of microcracks, resulting in the micro-short circuits. Then current density decreased to a minimum value and reached a steady state after 1000 times bending. The final current density is even lower than the initial one. With continuously bending the flexible OLED, depth and width of the microcracks increase, which resulted in partially open-circuit condition, which not only reduced the leakage current, but also impeded the current spreading path. In Fig. 2(b), luminance under constant voltage driving decreased from 570 cd/m^2 to 430 cd/m^2 after 300 times bending. However, luminance returned again to 620-630 cd/m^2 after 1000-5000 times bending. When bending for several tens to hundred times, the micro-shorts resulted in a local heating and yielded a reduction in current efficiency, which in turns reduced the luminance under constant voltage. With increasing bending cycles, short-circuits became open-circuits, which resulted in an increase in current efficiency, which boosted up the luminance.

3. Impact

We have demonstrated the electrical, optical, and lifetime performances of flexible OLED upon continuously mechanical bending. Leakage current increased then decreased, together with luminance reduction then recovery. It resulted from micro-short-circuit due to the density increase of microcrack at first stage. With further bending, the width and depth of microcracks increased, which resulted in micro-open-circuits. Although those defects did affect the electrical and optical characteristics, there has little effect on storage lifetime performances. For cyclic bending test (5000 times) on a flexible OLED, leakage current and luminance decreased, due to surface microcracks under bending process. Then we removing the organic layer to exhibit the surface of substrate and we find the OLED break down but the ITO layer still well.

4. References

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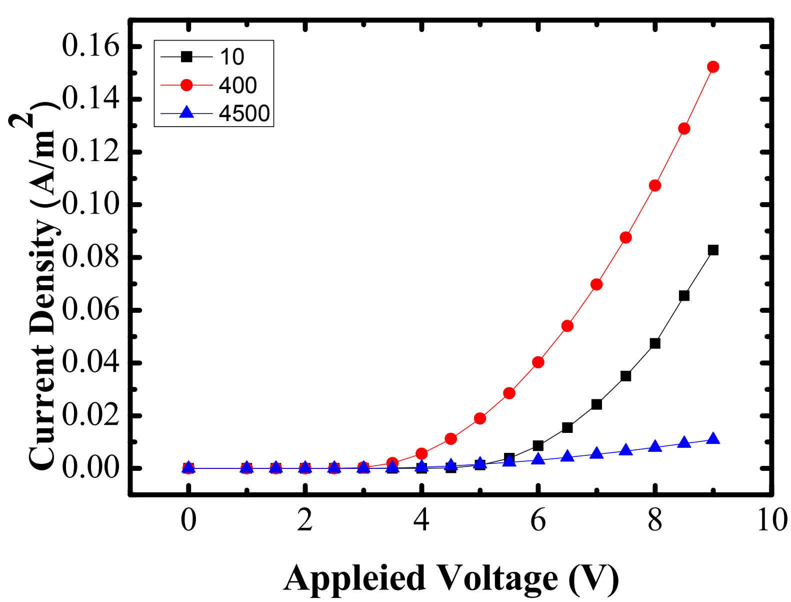

Fig. 1 J-V characteristic of flexible OLED before and after detaching from the carrier glass substrate. Inset: pictures of flexible OLED with pixel lit on.

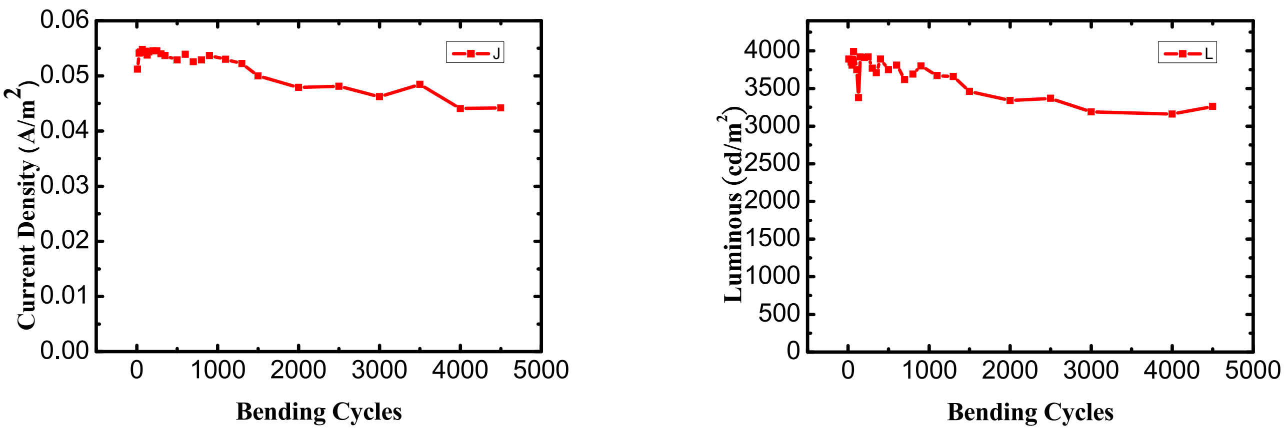

Fig. 2 (a) Current efficiency and (b) luminance under different bending cycles.

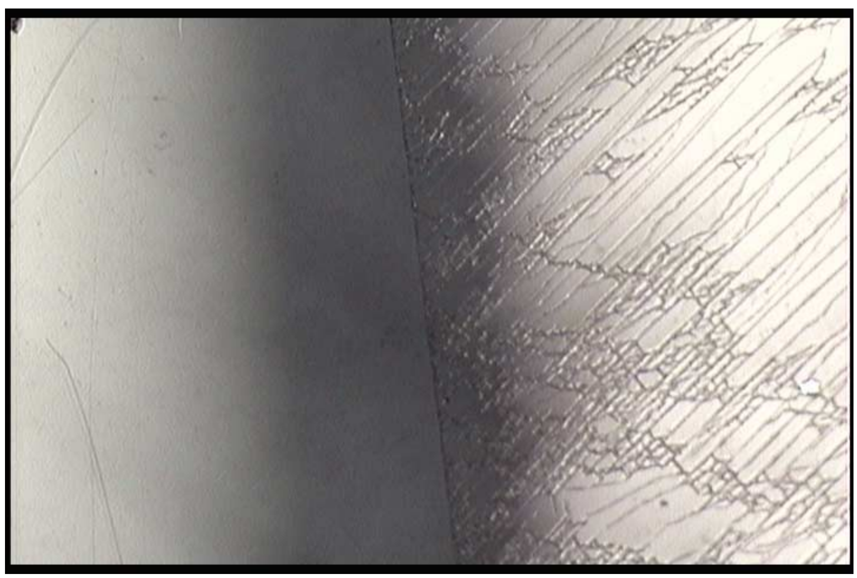

Fig. 3 Pictures of. Device surface . Left was ITO layer and right was flexible Substrate.