Tandem reflective LCD and OLED

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Abstract

We demonstrate a hybrid device with high ambient-contrast-ratio (>133.8:1) under any ambient conditions by vertically integrating a reflective LCD and a transparent OLED. The twisted nematic LC cell is placed beneath the OLED to improve device transmittance by 53.8% due to the asymmetric emission from both-sides of the transparent OLED.

1. Introduction

Transflective LCDs have been widely used for mobile displays since it is suitable for indoors and outdoors by splitting each pixel into transmissive (T) and reflective (R) sub-pixels. The T-mode is intended for dark ambient and R-mode for bright ambient for obtaining a high ambient contrast ratio (A-CR) independent of ambient light conditions [1]. However, the planar integration of T- and R-modes of the transflective LCD limits the aperture ratio which, in turn, degrades the display resolution and brightness. To overcome this shortcoming, a tandem structure which vertically integrates an organic light-emitting display (OLEDs) and a normally black reflective LCD (NB-RLCD) was proposed [2]. This device not only increases the aperture ratio but also enhances the A-CR, as compared to the conventional transflective LCD. In such a structure, OLED (T-mode) is placed underneath the RLCD (R-mode) where the anode of the OLED is also used as the reflector for the R-mode operation, as Fig. 1(a) shows. In such a design, the polarizer of the RLCD filters one half of the output light from the OLED and decreases the transmittance of the T-mode. In this paper, we propose to place a transparent OLED (TOLED) on top of the RLCD as Fig. 1(b) shows in order to decrease the optical loss from the RLCD [3]. In theory, the transmittance should increase by 50% provided that the OLED emission is Lambertian. Due to the micro-cavity effect in such a device, the forward- and backward- emission can be engineered by varying the layer structure of the TOLED which improves the transmittance by 53.8% in our new device structure.

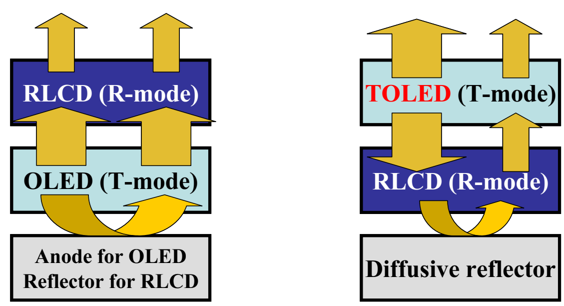
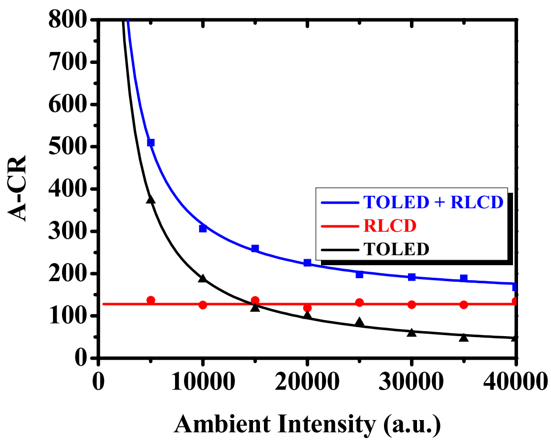


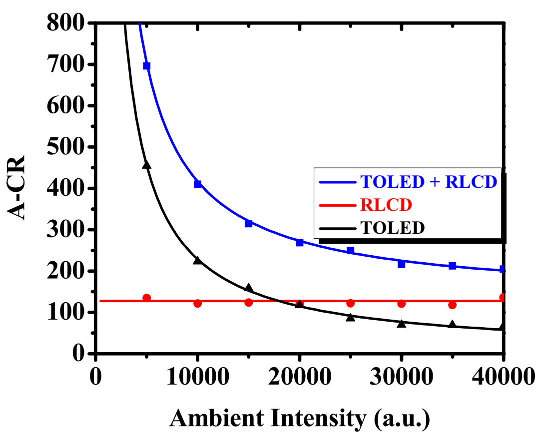
Fig. 1: Configurations of the tandem OLED and RLCD.

2. Experimental

Our TOLED structure consists of ITO glass/ PEDOT:PSS (70 nm) / PFO (70 nm) / LiF (1.5 nm) / Ag (1 nm) / ITO (120 nm) layers. The silver layer in our TOLED can prevent the underlying emitting layer from the bombard damage during ITO sputtering. Besides, it helps to increase the Li concentrations in the polymer which enhances its electron injection and transport capabilities [3]. Optical intensity from the top is 60% more than that from the bottom side which results from the micro-cavity effect of the thin film structures. In this study, the LC employed is Merck MLC-13900-100 with 5 μm cell gap. Under constant input optical power, maximum reflection is achieved at 4.314 V_{rms} and 1 kHz. A He-Ne laser was used as the light source and the output power is monitored by a photodiode detector [2]. The reflectance of the RLCD at bright state and dark state is 21.11% and 0.16%, respectively, which leads to CR=133.8:1. By placing the TOLED on top of the RLCD (Fig. 1(b)), the transmittance shows an 21.6% and 53.8% increase when the R-mode is turned off and on, respectively, compared to the device configuration in Fig. 1(a).



(a)



(b)

Fig. 2 (a) and (b): Measured (symbols) and fitted (lines) A-CR under different ambient intensities for the device structures shown in Fig. 1(a) and (b).

3. Results and discussion

Figure 2(a) and 2(b) show the measured A-CR at normal incidence for the RLCD- TOLED-, and (RLCD+TOLED)-mode of operation corresponding to the device structures of Figs. 1 (a) and 1(b), respectively. Under low ambient, the A-CR of the OLED is extremely high, but decreases sharply as the ambient intensity increases. On the other hand, the A-CR of the RLCD keeps at ~133.8:1, insensitive to the ambient light intensities for both device configurations. The A-CR in Fig. 2(b) is improved for both T- and (R+T)-modes since the TOLED is placed upon the polarizer of the RLCD which decreases the optical loss and increases the transmission of the T-mode operation.

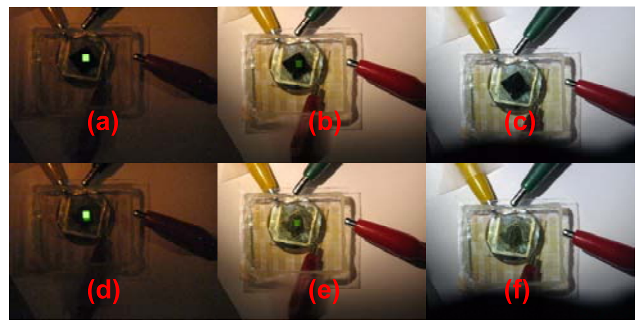


Fig. 3
Photographs showing the operation of the tandem device: (a)-(c) RLCD is off; (d)-(f) RLCD is on; (a) and (d) a re low ambient; (b) and (e) are medium ambient; and (c) and (f) are high ambient. Note that OLED is always on in all cases.

Fig. 3 shows the photos illustrating the operation principles of the tandem device. A mirror with 1-inc h diameter was placed under the tandem device a s the reflector. OLED with green emission is alw ays lit on for all the cases. Figures 3(a)-3(c) show the examples from dark to bright with RLCD turne d off. We can see that OLED is quite bright und er dark, dimmer under medium ambient, and was hed out severely under high ambient. The black s quare region is attached by a λ/4 and polarizer fi l m . Figures 3 (d)- 4 (f) demonstrate the device appearance with RLCD turned on. Comparing Figs. 3(f) to 4(c) (high ambient case), we can clearly s ee that the RLCD becomes brighter. However, the difference is not so obvious when the ambient is medium (Figs. 3(b) and 3(e)). When the ambient is low, as shown in Figs. 3(a) and 3(d), there is nearly no difference.

4. Summary

We have demonstrated a preliminary tandem display device consisting of a normally black TN-

RLCD and a TOLED which exhibits a high ambient contrast ratio and high transmittance. The A-CR over 100:1 and 53.8% transmittance enhancement are achieved experimentally by our tandem device regardless of the ambient light intensity. This new tandem device will be useful for mobile displays, such as cell phones and PDAs.

4. Acknowledgements

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5. References

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