Invited: Novel LCD structures with OLED backlight integration for mobile display applications

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Abstract

This paper reviews the state of the art of critical processes and proposes novel structures of an integrated device comprising LCD and OLED backlight that increases the compactness and decreases the assembly time of hand-held mobile display units like the hand-sets of mobile phones

1. Objective and Background

Mobile hand-held electronic units like cell phones have critical demand for simplicity in assembly and compactness. Currently LCDs in mobile phones are assembled with discrete white LED light source with many optical components that are held by rigid plastic frame. Thus the LCD assembly with backlight does not result in slimness. The assembly of discrete optical components and the components themselves can be eliminated by replacing discrete LEDs with slim flat light source. Further the slim flat slight source could be integrated to LCD with ingenious process techniques that are practical and have been demonstrated elsewhere. The LCD and the backlight becomes one integral unit saving space and assembly time.

With the above objective, critical processes needed for LCD and OLED have been reviewed and the practicality of novel integrated structures have been arrived at.

1.1. Internal polarizer for LCD

Liquid crystal thin film [1] polarizers have been demonstrated by Optiva Inc. The thin film polarizer is internal to LCD and thus eliminates any lamination of plastic film outside the glass substrate of LCD. This facilitates integrating OLED backlight to the external surface of the bottom substrate of LCD as can be seen in the figures appearing in the next section.

1.2. Thin film passivation- seal for OLED

Latest technique of preventing permeation of oxygen and moisture through the sealing of OLED devices is to encapsulate OLED by employing the technique of thin film seal. This thin film seal ought to be conformal and pore-free. The process that has been found very effective in encapsulating OLED through thin film seal is described in Ref 2 and 3. This seal could be formed at temperatures below 110C. Many conformal pore-free dielectric oxide films such as SiO_2, Al_2O_3, TiO_2, ZrO_2, Ta_2O_5, HfO_2, Nb_2O_5, Y_2O_3, and MgO can be formed [4] by employing the process known as 'Atomic Layer Epitaxy' (ALE) which has been proven well in semiconductor industry and EL display technology. This process enables the integration of OLED to LCD. For example, the process for depositing TiO_2 is broadly explained below:

1.2.1 Deposition of TiO_2 by ALE

The precursors for TiO_2 deposition are: (i) Titanium tetrachloride and (ii) Ozone. The temperature of the chamber is set around 100^0 C. Report [5] has appeared on the formation of TiO_2 even at room temperature through ALE process. The chemical reaction that takes place at this temperature is as shown below:

$$TiCl_4 + O_3 \longrightarrow 2\,TiO_2 + 2ClO_2$$

$2ClO_2$ is flushed out of the chamber by a pulse of N_2 gas injected in to the chamber and pumping it out. As the growth rate of ALE is a maximum of 10 nm/min, a thickness of only 500^0 A of TiO_2 is contemplated. Similar processes exist for Al_2O_3 and other oxides.

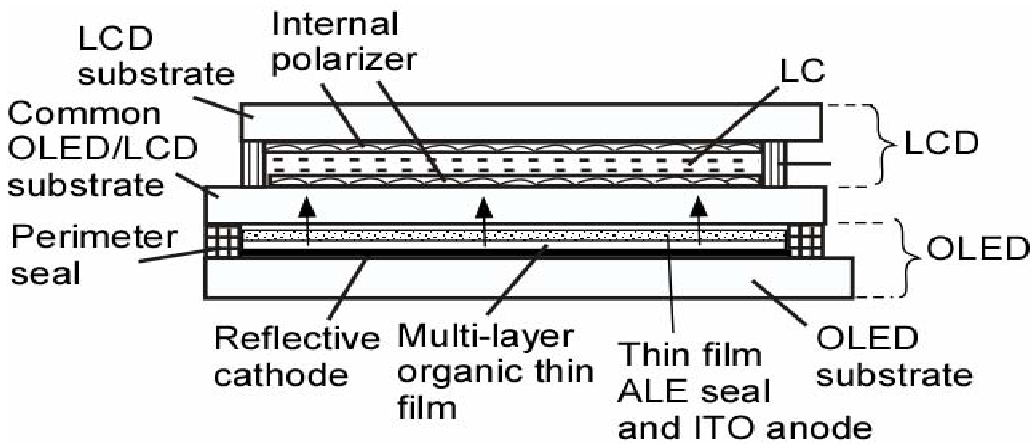

Fig. 1: Three substrate LCD/OLED integrated structure

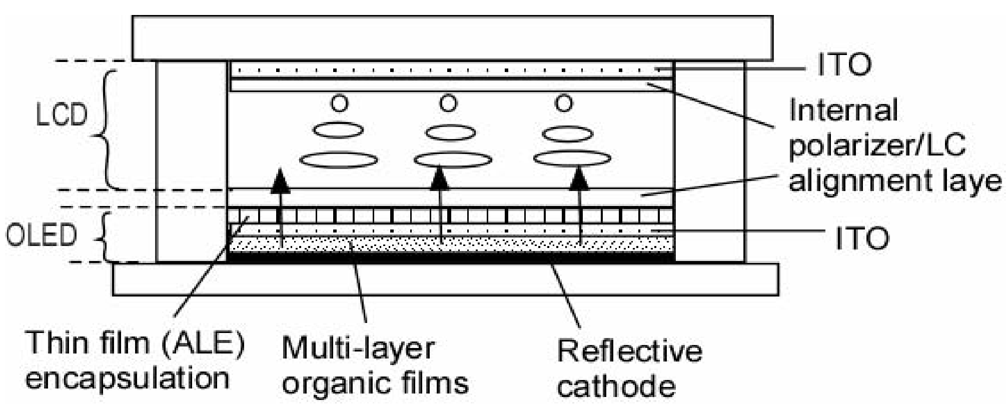

Fig. 2: OLED backlight inside LCD

2. Results

2.1 Three substrate integrated structure

By employing the critical processes stated in section 1.1 and 1.2, novel integrated structures are realizable. Figure 1 shows the integrated structure employing three substrates of which one substrate is shared by OLED and LCD. This structure is realizable and practical because of the 'in-cell polarizer' of Optiva Inc. OLED processes are low temperature compatible. OLED has a dielectric encapsulation layer formed out of ALE process. This structure is practical even with the traditional perimeter seal process. It can be noted that the OLED employs 'up-emitting' mode. Light coupling is efficient to LCD and the device is a single unit that has simplicity of assembly in to mobile phone hand-set. As there are only three substrates, the overall thickness is reduced.

2.2 OLED backlight inside LCD

Figure 2 shows further integration of OLED-LCD integrated structure. For the sake of simplicity, TFT, color filter and other layers of LCD are not shown in Fig. 2. The ALE film is so hard and robust enough for LC alignment layer formation and treatment. All the OLED processes are low temperature compatible. In this configuration TFT, color filters and black matrix are not on OLED side but on the opposite side i.e, the top substrate of LCD contains the TFT, color filters with black matrix.

3. Impact

The LCD-OLED integrated device has major advantages in Mobile display applications and they are (1) simplicity in assembly and reduced assembly cost (2) compactness that is highly desirable in hand-held applications (3) single device instead of two separate devices (4) coupling of light to LCD is very efficient.

4. References

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