A Novel Organic Light-Emitting Diode Having Dual Functionality of Front-Light and Touch Panel For Reflective Displays

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Abstract
We have proposed a novel OLED having dual functionality of front-light and touch-panel (OLFT) for reflective displays. OLFT uses a same process as conventional OLED front-light, but also simultaneously forms capacitive touch-panel function by optimizing the electrode patterns. Adopting OLFT to reflective displays as reflective LCDs, EPDs etc. achieve excellent visibility even in dark, thin, simple structure, and having touch-panel function.

Author Keywords
organic light emitting diode, OLED, front-light, touch-panel, OLED front-Light, capacitive touch-panel, reflective display, reflective LCD, EPD, organic light emitting diode having dual functionality of front-light and touch-panel, OLFT

1. Background
Reflective displays such as reflective LCDs (Liquid Crystal Displays) [1,2] and EPDs (Electro Phorenic Displays) [3-5] and so on have the advantages of low power consumption and excellent outdoor visibility. It has also been reported that EPDs have the advantage of being gentle on the eyes [5]. However, supplemental lighting is required to observe in dark environments. Front-lights are known as a form of supplemental lighting, however conventional front-lights which is an edge-light type have non-uniform brightness on the emitting surface, and the brightness changes significantly when viewed from oblique directions. In addition, when adopting to the reflective displays, there is also the issue of reduced contrast due to light leakage.

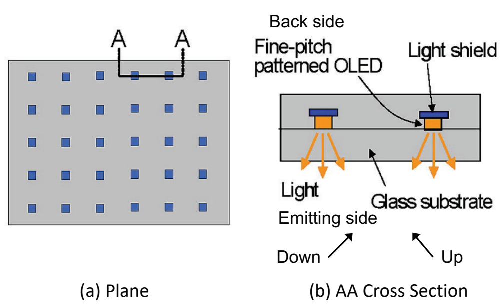

Figure 1. Principle of the OLED front-light

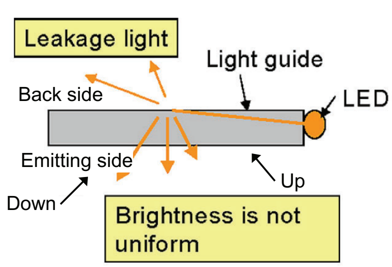

Figure 2. Schematic of the conventional front-light which is the edge-light type

An OLED (Organic Light Emitting Diode) front-light [6-9] have been proposed to solve these issues. Principle of the OLED front-light is shown in figure 1 [8]. Schematic of the conventional front-light which is an edge-light type is shown in figure 2 [8]. The OLED front-light consists of an OLED patterned with fine pitch and a light-shield formed on the light source at observer side. Light emitted from the light source is prevented from reaching the observer by the light-shield, which emits only light to the adopted reflective display.

Photographs of the front-lights observed at variable angles of emitting side are shown in figure 3 [8]. The distributions of light intensity as a function of viewing angle at the emitting side are shown in figure 4 [8]. Here, the light intensity at 0° of the emitting side is 100. The conventional front-light has a viewing-angle dependence of the light intensity, on the contrary the OLED front-light has no viewing angle dependence. Figure 5 show photographs of the front-lights observed at variable angles of back side [8]. The distributions of light intensity as function of viewing angle at the back side are shown in figure 6. The conventional front-light has light leakage. In contrast, the OLED front-light has no light leakage at any viewing angles. Figure 7 show the photographs of the reflective LCD which is adopted the OLED front-light [8]. Excellent display images are realized under both dark and bright ambient light.

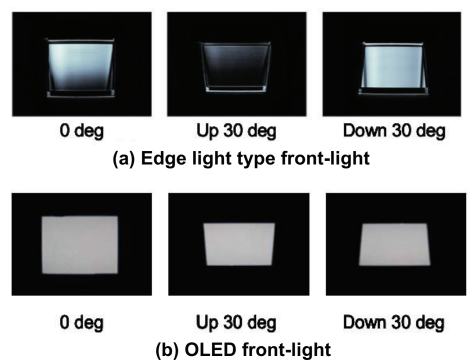

Figure 3. Photographs of the front-lights observed at variable angles of emitting side

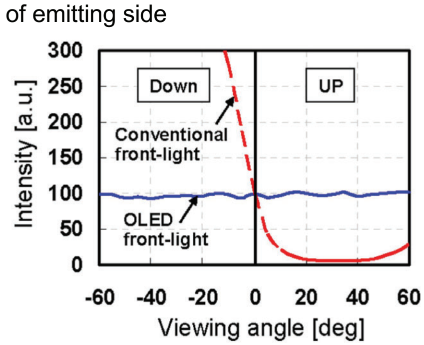

Figure 4. Distributions of the light intensity as a function of viewing angle at the emitting side

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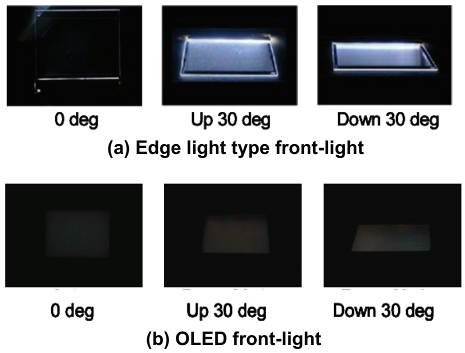

Figure 5. Photographs of the front-lights observed at variable angles of back side

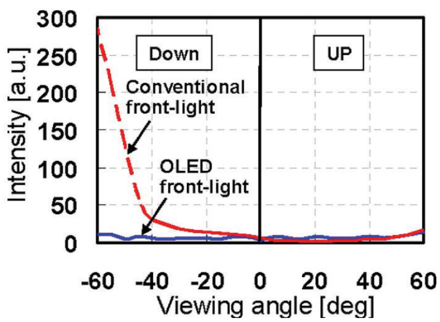

Figure 6. Distributions of the light intensity as a function of viewing angle at the back side

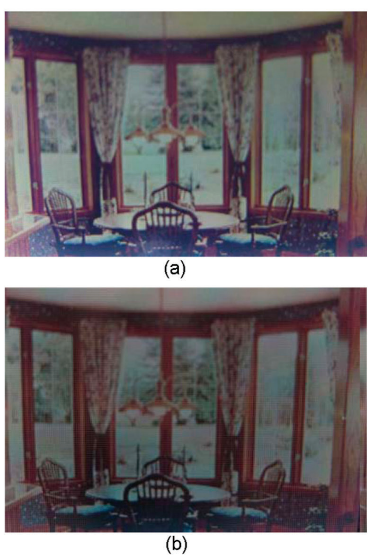

Figure 7. Photographs of the reflective LCD adopting the OLED front-light. (a) Under bright ambient light with OLED front-light off. (b) Under dark ambient light with OLED front-light on

On the other hand, many mobile displays have a touch-panel on the surface of the display as input means. Among them, capacitive touch-panels [10] [11] that are capable of multi-touch are widely used. However, arranging both a front-light and a touch-panel on a reflective display are bulky and complicated. To solve this problem, we have newly proposed a novel OLED having dual functionality of front-light and touch-panel (OLFT).

2. Principle of OLFT

2-1. Structure

Capacitive touch-panels place X and Y-electrodes through an insulation layer, and detect the touch position by detecting the change in capacitance of each electrodes. OLFT has a structure in which X and Y electrodes of the touch panel are placed without increasing the process by optimizing the electrode pattern of the OLED front-light. The specific structure is shown in figure 8-10. Figure 8 is a top view, figure 9 is a enlarged view of area C of figure 8. Figure10 (a) and (b) are AA and BB cross-sectional views of figure 8 respectively. X-electrode which also serves as the anode of the OLED front-light and Y-Electrode made of ITO (Indiuum Tin Oxside), are formed on the substrate. An organic layer which is consist of hole transport layer (HTL), emitting layer (EML) and electron transport layer (ETL) is formed on X electrode, and an Al layer which is the cathode is formed so as not to contact with the X-electrode through the organic layer. X and Y-electrodes are structured with alternating rhomboids in order to detect changes in capacitance. Al layer is then formed in contact with the Y-electrode made of ITO. In addition, an insulation layer made of SiO_2 and so on, and a black resin layer is formed to cover the cathode to prevent the reflection of ambient light from the cathode, and a transparent substrate is placed through an adhesive layer. The area where no cathode and black resin exists is the transparent area, and the ratio of the transparent area to the entire area (aperture ratio) is more than 80%, and the cathode pitch is bellow than 200μm. An AR (Anti Refrection) film is placed on the observer side of the OLFT via a UV (Ultra Violet) cut layer. The UV-cut layer protects the organic layers and the black resin layer from ambient light, and the AR film prevents surface reflections and improves the display quality. The conventional front-light which is edge-light type is not possible to install an AR layer, because the light leakage to the obserber side, on the contrary the OLED front-light is possible and also this effect provides an advantage for visivility.

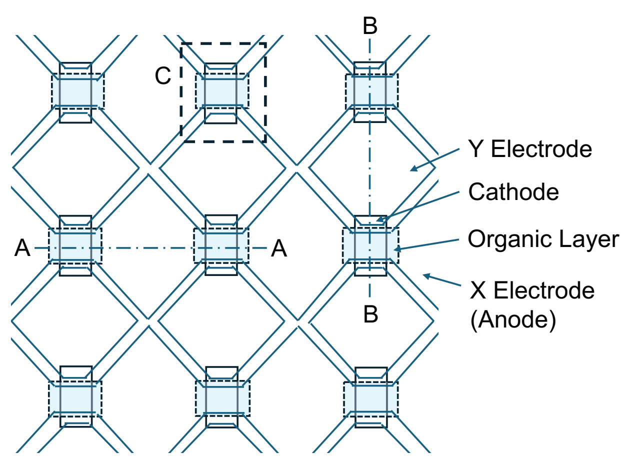

Figure 8. Structure of OLFT (plane)

When direct current is applied to the X and Y-electrodes, the organic layer illuminates, and the light emitted towards the cathode layer is reflected by the cathode layer and returned, resulting in light emission from only one side, and the area without cathodes transmit light, so it functions as an OLED front-light. Furthermore, by detecting changes in the capacitance of the X and Y-electrodes, the touch position can be detected, allowing it to function as a touch-panel. By lighting the OLED and detecting the capacitance in time-division as mentioned next section, OLFT that combines front-light and touch-panel functions can be realized.

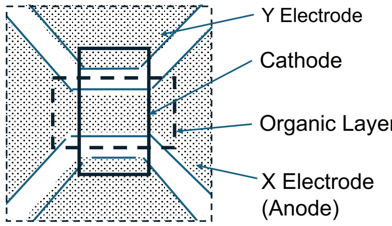

Figure 9. Enlarged View of area C of Figure 8

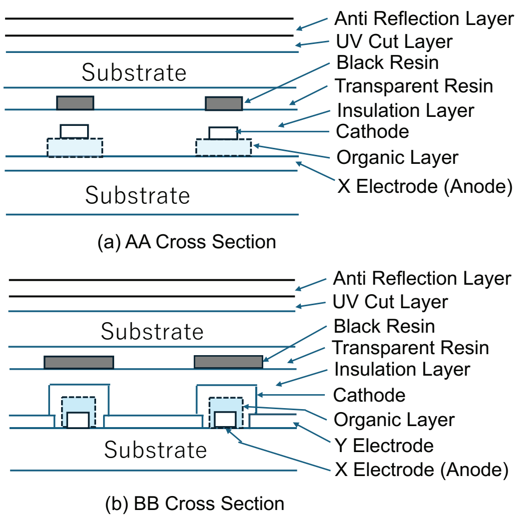

Figure 10. Structure of OLFT (AA and BB cross section of Figure 8)

2-2. Driving

Schematic of OLFT with driver is shown in figure 11. Timing chart of OFLT driving is shown in figure 12. A dedicated driver is prepared to drive the OLFT. Light emission and capacitance sensing are alternately performed within one frame of the adopted the reflective display. The frequency of lighting and sensing is 120 Hz (period: 8.333msec), which is twice the frame frequency of the reflective display. In this way, both lighting of the front-light and sensing of the touch-panel can be realized, and furthermore, the appearance of flicker when the front-light is turned on can be suppressed.

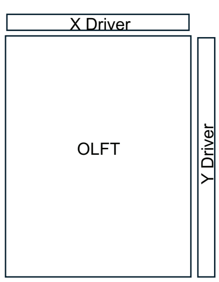

Figure 11. Schematic of OLFT with Driver

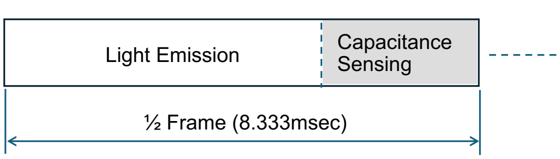

Figure 12. Timing Chart of OLFT

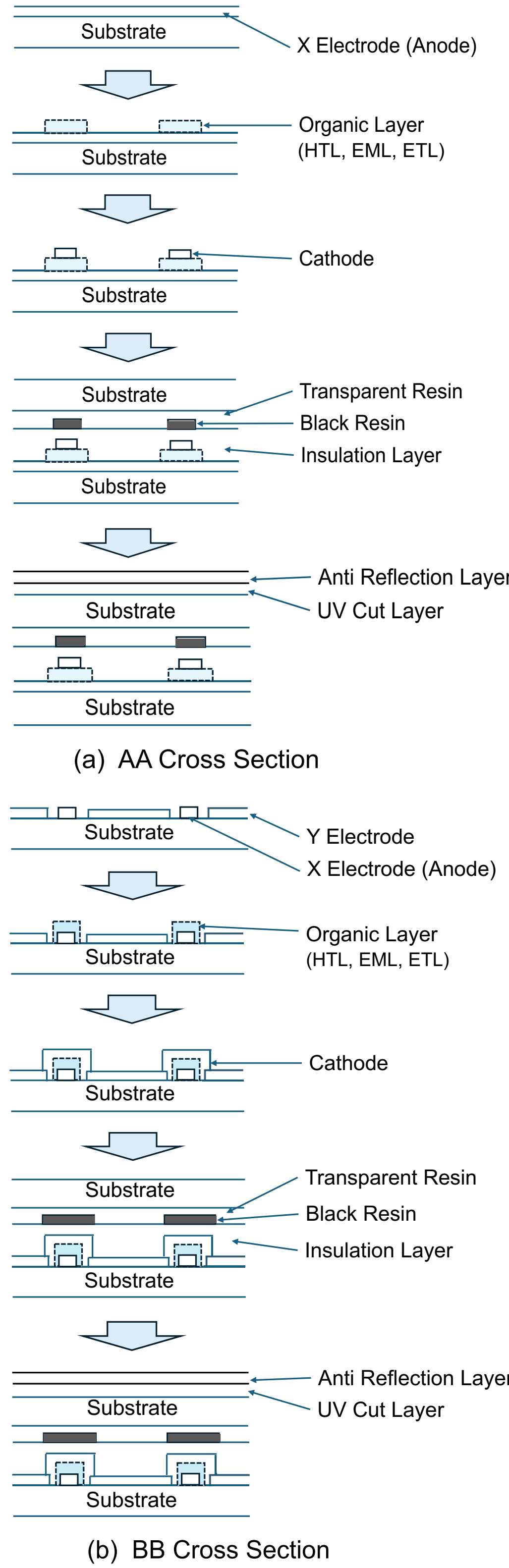

Figure 13. Process of OLFT obserbed from AA and BB cross sections of figure 8.

3. Process of OLFT

Manufacturing process of OFLT is shown in Figure 13. Figure 13(a) and (b) are the process of OLFT obserbed from AA and BB cross sections of figure 8. X-electrode which also serves as an anode, and Y-electrode made of ITO are simultaneously formed on a glass substrate. Next, an organic layer which is consist of HTL,EML and ETL, an Al layer, and an insulation layer are formed in consecutively. Next, a black resin layer is formed, and then an adhesive layer and a transparent substrate are arranged to complete the OLFT. Furthermore, the AR film is placed via the UV-cut layer.

4. Trial production

We have a plan to make two types of rial production of OLFT. The specifications of proto-types are shown in table 1.

Table 1. Specifications of Proto-types of OLFT

Proto-type	Size [inch] (Aspect ratio)	Pitch [μm]		Aperture ratio [%]
		X	Y	
OLFT-1	2.0 (4:3)	100	100	90
OLFT-2	6.0 (4:3)	150	150	90

Sizes are 2-inch and 6-inch. The pitch of the cathode (lighting part) of the 2-inch size is 100μm in both the X and Y directions, and the aperture ratio is 90%. For the 6-inch size, the pitch of the cathode is 150μm in both the X and Y directions, and the aperture ratio is 90%. The anode is ITO, the cathode is Al, and the insulation layer is SiO2. As the deposition equipment used to continuously deposit these materials will be use the product OASIS-C-E2T1-W8 made by Nagasu kogyo corporation. The black resin layer is fomed by exposing and developing black resist. The AR film and the UV cut layer are made by Tomoegawa corporation. The UV cut layer (product number: MK64UV03J) can efficiently cut UV light and light below 455 nm that is considered harmful to the eyes, while minimizing color sift. We are currently prototyping the OLFT.

5. Impact

The configuration of reflective displays using OFLT are shown in figure 14(b). For comparison, the configuration of reflective displays with conventional front-light and touch-panel are shown in figure 14(a). Reflective displays using OFLT have a simpler configuration and can be made thinner than conventional displays. We are also considering a film-type OLFT. Display system adoped the film-type OLFT will be even thinner and lighter as shown in Figure 14 (c).

6. Conclusion

We have proposed a novel OLED having dual functionality of front-light and touch-panel (OLFT) for reflective displays. OLFT uses a same process as conventional OLED front-light, but also simultaneously forms capacitive touch-panel function by optimizing the electrode patterns. Adopting OLFT to reflective displays as reflective LCDs, EPDs etc. achieve excellent visibility even in dark, simple structure, and having touch-panel function.

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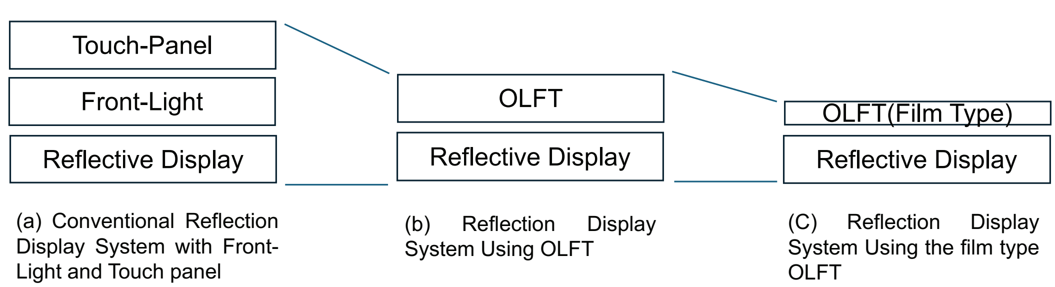

Figure 14. Comparison Reflection Display Systems Conventional and Using OLFT