Dual Mode AMOLED Pixel Circuit

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Abstract

We proposed dual mode pixel circuit in AMOLED (active matrix organic light emitting device). After light emitting period of OLED, we used it as a photo sensor. We measured photo current of OLED and simulated the proposed pixel circuit to verify it's function of dual mode, that is lighting and sensing.

1. Introduction

Low temperature poly silicon (LTPS) thin film transistors (TFTs) are being used for AMLCD (active matrix liquid crystal display) and AMOLED (active matrix light organic emitting device). PMOLED (passive matrix organic light emitting device) is already being used for mobile-phone which use small size display around 2 inch diagonal.

There were attempts to integrate photo sensor in each pixel using TFT fabrication process in AMLCD [1, 2]. In AMOLED, photo-sensors have also been proposed for controlling light output from OLEDs [3, 4]. Integration of photo sensor enables to add new functions in display such as touch panel, digitizer, and image capture.

For detecting ambient illumination in AMOLED, integration of photo sensors are necessary. However, integration of image sensors reduces the light emission area, and photo sensor area is limited by the light emission devices.

To avoid the reduction of light emission area we suggested a dual mode pixel circuit which use organic light emitting device as a photo sensor. After light emitting period of OLED, we use it as a photo sensor. To do this, we proposed a new driving method which provides a means for the dual mode operation.

In the organic light emitting diode, electrons and holes are injected into the semiconducting polymer film at the cathode and anode, respectively. The electrons and holes subsequently recombine radiatively, and photons are emitted. The inverse process which is photo generation of electric current offers promise for photosensing with OLED and there were photoconductor researches with polymer [5, 6, 7].

2. Proposed circuit

Proposed circuit is shown at figure 1 where photo sensing and light emitting is accomplished by the same OLED. For the light emitting mode, the circuit operates the same as the conventional 2 transistors and 1 capacitor pixel circuit.

During light emitting mode, transistor M2 is off-state. Therefore, data voltage is written onto the storage capacitor (C_{st}) through the switching TFT. Stored data voltage is applied to the gate of drive TFT (M1) and the current flows through the OLED proportional to the gate voltage. After a frame time, we read out the light sensing signal through the amplifier M1 and selection TFT M2, just before re-write a light emitting data voltage to the C_{st}.

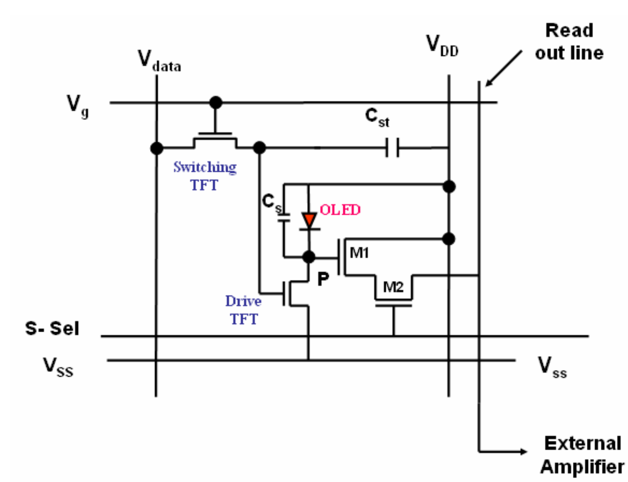

Fig. 1. Proposed pixel circuit for a dual mode OLED. Light emitting and photo sensing are accomplished by the same OLED.

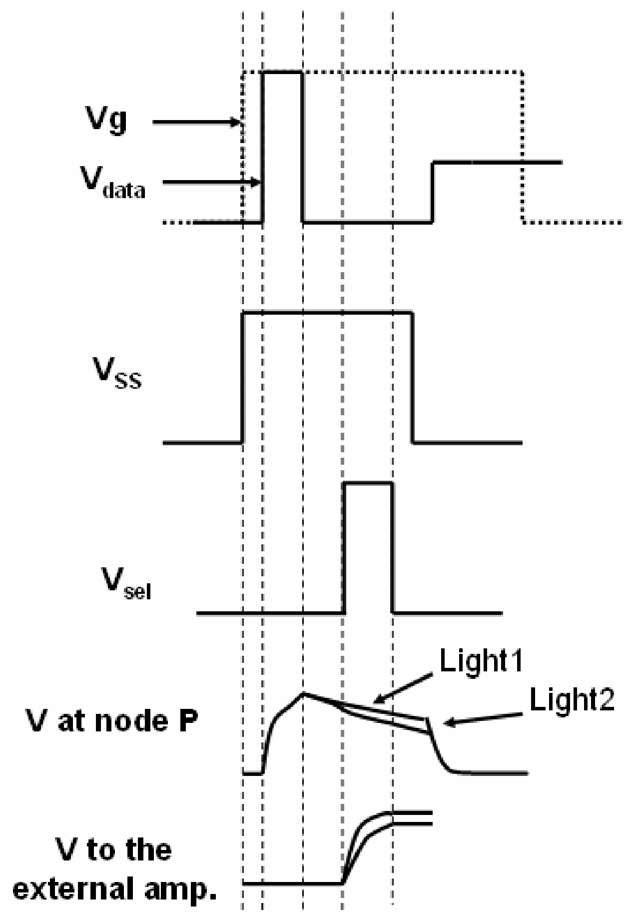

Fig. 2. Time chart for the dual mode pixel circuit. While V_{sel} is high, output is integrated at the read out capacitor of external amplifier as shown at the bottom.

The time chart for read out of light sensing signal is shown at figure 2. At first, V_{SS} is brought high for the reverse biase operation of OLED.

At the same time, switching TFT becomes on-state by applying high gate voltage (Vg), and then, V_{data} is high for a short period. For a short period drive TFT becomes on due to high data voltage to the gate of drive TFT, which allows the high V_{SS} is written onto the node P. This high voltage of node P becomes reset voltage for sensing of the incident light illumination.

Since V_{SS} at node P is larger than V_{DD}, the OLED is reversely biased. Drive TFT becomes off because gate voltage is low after a short period of high data voltage (V_{data}). Reset charge at node P is stored at the C_s which is connected parallel with OLED.

Since photo current flows through reverse bias OLED, stored charge into the C_s discharges through the OLED. The discharge current depends on the incident light intensity. A voltage at the node P after a defined integration time is determined by illuminated light intensity.

Photocurrent discharges C_s by ΔQ and decreases the potential on C_s by a small signal voltage ΔVp [8, 9]. ΔVp is described as

$$\Delta Vp = \frac{\Delta Q}{C_s}$$

After integration, the selection TFT (M2) switch is turned on for a selection time, which connects pixel to the external charge amplifier and an output voltage is developed across the read out capacitor of an operational amplifier.

The output voltage at the external amplifier input is shown at the bottom of figure 2. The current through selection TFT M2 is integrated at the read out capacitor of the external amplifier.

3. Photo Currents and Output Voltages

With conventional OLED, we measured photocurrent according to the incident light illumination. Reverse current of OLED increased with light illumination and photo currents are shown at figure 3.

At the reverse bias region, photosensitivity is rather large, and the photo current at -4V is shown at figure 4 which shows the current dependence on incident light illumination from 0 to 250 lx.

For higher light illumination we can get larger value of photo current which is necessary for the large photo sensing output voltages.

Due to photo sensitivity of OLED we can use OLED as a photo sensing device. For this, we need dual mode pixel circuit which can do both writing of a data onto the pixel and reading a sensing output voltage.

The proposed dual mode pixel circuit composed of N channel TFTs, however, P channel TFT pixel circuit is also possible.

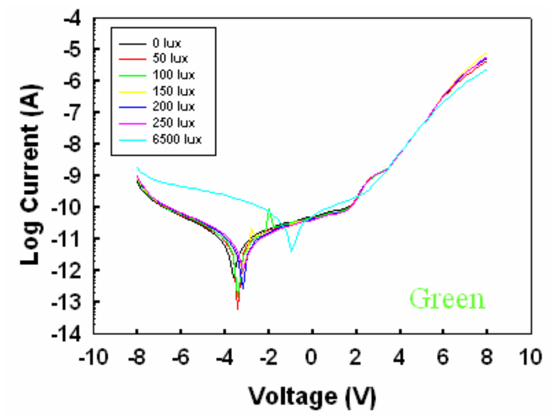

Fig. 3. The reverse photo current of green OLED according to the voltages and incident light illuminations.

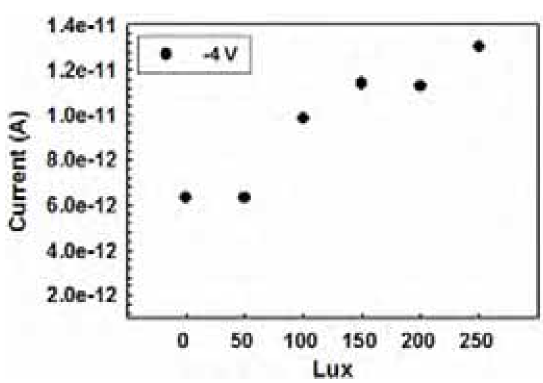

Fig. 4. The reverse current of green OLED according to the incident light illuminance. The bias voltage was - 4 V.

Proposed pixel circuit is shown at figure 1. The writing scheme is conventional 2 transistors and a capacitor. For the read out scheme, we added two transistors, one is for the amplifier and the other is for the selection transistor.

The reading is operated before writing a new data onto the C_{st} of figure 1. After reading a light sensor output, display data is written onto the C_{st} and OLED emits light for a frame time.

The simulation result of dual mode pixel circuit is shown at figure 5. The voltage at the node P depends on light illuminance on OLED. We used typical N-channel LTPS TFT parameters for the TFT characteristics.

The sensor output reading is completed within 10 μs. The simulation shows that voltage of node P reaches reset voltage during a short period of high data voltage. This period is 2 μs. After that V at node P becomes low and the simulation shows that voltage of node P decreases due to OLED photo leakage. For a higher light illumination (light 2), the voltage decrease is more significant.

After a certain integration time, selection TFT is on and the simulation shows the increase of read out voltages which is the voltage along the read out capacitor connected in parallel with an external operational amplifier.

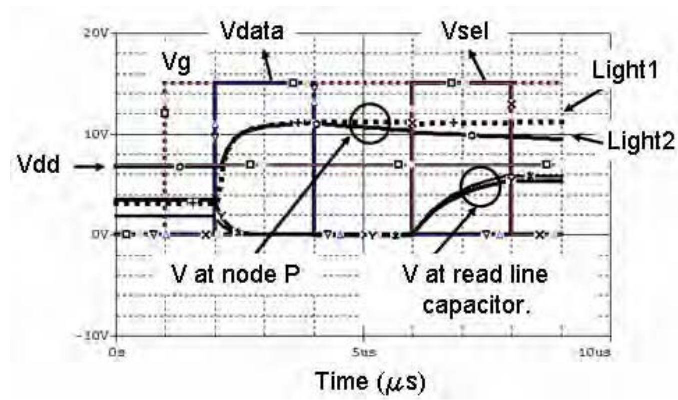

Fig. 5. Simulation result of the proposed pixel circuit during a sensing period.

3. Summary

In this paper, we verified the reverse photo current of OLED according to the incident light illumination. For the reverse biased OLED, the photocurrents were observed proportional to the input light illumination. For dual mode operation of reading and writing, we simulated dual mode pixel circuit based on LTPS TFT.

As shown at figure 4, photo sensitive output voltage was appeared at the read output capacitor. Which enable to sense incident light without additional photo sensor. After light emitting period of OLED, we used it as a photo sensor, which provides large sense area.

4. References

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