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A Comparison Between a-Si:H TFT and Poly-Si TFT for a Pixel in AMOLED

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We have demonstrated that both hydrogenated amorphous silicon (a-Si:H) and polycrystalline silicon (poly-Si) TFTs can be used as switching and driving TFTs for an active matrix organic light emitting diode (AMOLED). However, the a-Si:H TFT should have a channel width to length ratio of at least 50. The off-current level of switching TFT should be less than 1 pA to keep the brightness within 3% during one frame. An AMPLED has less power consumption compared to AMOLED.

I. INTRODUCTION

Organic electro-luminescence materials have been studied extensively since 1987 in order to enhance the light emission properties of a first invented small molecule organic system by Tang *et al.* [1] Since that there has been a very rapid progress in organic light emitting diode (OLED) technology [2]. Actually OLED are presently of great interest due to its potential applications because of its low cost, low power consumption, wide viewing angle, and the possibility to be made on flexible substrates. One application for these devices is the light emitting component in a passively addressed display. However passive matrix addressed display needs high current and high voltage level to obtain high brightness [3]. These high operating levels reduce the OLED efficiency.

In an active matrix OLEDs (AMOLEDs), the pixel provides a lower constant current than passive display of an equivalent brightness. Therefore, in past years, many experts have concentrated to develop active matrix techniques for the OLEDs [3–6]. Among all the pixel circuit designs for AMOLEDs, the two-TFT (thin-film transistor) circuit is the simplest and most widely employed configuration [3,4].

In this work we calculated the applied voltages to the OLED and to the TFT in a pixel using a two-TFT driving circuit. The comparison between an a-Si:H TFT and a poly-Si TFT for a pixel in AMOLED has been studied. In addition, the use of PLED (Polymer Light Emitting Diode) for an active matrix light emitting diode has been investigated for a comparison with OLED.

II. SIMULATION

The simulations are performed with a version of the circuit simulation package AIM-SPICE (Automatic Integrated Circuit Modeling Simulation Program with Integrated Circuit Emphasis) computer aided circuit simulator. PLED modeling for AIM-SPICE is carried out using the data taken from a work reported by T. Shimoda *et al.* [3]. Figure 1 shows the emulating configuration of the PLED and OLED (a) and their I-V characteristics (b). In the present work the pixel of PLED and OLED was designed for a 2-inch QVGA (320 × 240, pixel pitch=125 μm × 125 μm) monochrome display. In Fig. 1(a), R_{ito} is the sheet resistance of ITO, R_{tot} is the series resistance of an OLED, and C_{cell} is the capacitance of an OLED. The simplest analog circuit that performs the tasks required of an AMOLED pixel is the two-TFT circuits [4]. Figure 2 shows the equivalent circuit diagrams of the AMOLED (a) and driving voltages (b). It includes a switching TFT (T_{sw}) and a driving TFT (T_{dr}), a storage capacitor (C_{st}) and an OLED. The circuit relies on a T_{dr}, trans-conductance properties to produce a voltage controlled current source. The C_{st} is used to retain

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Table 1. Characteristics of a-Si:H and poly-Si TFTs.

	a - Si : H TFT	poly-Si TFT
switching TFT (W/L)	70 μm/4 μm	15 μm/10 μm
Driving TFT (W/L)	200 μm/4 μm	60 μm/10 μm
Mobility	0.56 cm^2/Vs	50$\sim$70 cm^2/Vs
Slope	0.68$\sim$0.76 V/dec.	0.50$\sim$0.59 V/dec.
V_{th}	3.3 V	1.7$\sim$1.9 V
I_{on} (V_d=5V)	$> 1\times10^{-5}$ (V_g = 15 V)	$> 1\times10^{-4}$ (V_g = 10 V)
I_{off} (V_d=5V)	$< 1\times10^{-12}$ (V_g = -3.5 V)	$< 1\times10^{-12}$ (V_g = -2.5 V)

video information in the form of T_{dr} gate-source voltage, between pixel addressing periods. The T_{sw} is used as an addressing switch. The characteristics of a-Si:H and poly-Si TFTs used in this study are shown in Table 1.

III. RESULTS AND DISCUSSION

Figure 3 shows the voltage dependence of C_{st} versus time for a-Si:H TFT with a PLED. The ratio of channel width to channel length, W/L, of a switching TFT was 70 μm/4 μm, W/L of driving TFT was 200 μm/4 μm and the C_{st} was 0.3pF. It indicates that data voltage, such as video information, has maintained after pixel addressing caused by C_{st}.

The mechanism to apply a data voltage to C_{st} is similar to that adopted in AMLCD. The only difference is that the capacitor stores only the DC signal, which controls the conductance of T_{dr} by applying the data voltage to T_{dr} gate. The diode current from V_{dd} line passing through T_{dr} can be modulated by varying the data voltage stored on the capacitor.

Figure 4 shows the retention ratio of C_{st} voltage, PLED voltage and PLED current related to off-current level of T_{sw}, respectively. The off-currents for the TFTs are 0.1pA, 1pA and 10 pA, respectively. Figure 5 shows the retention ratio of C_{st} voltage, OLED voltage and OLED current related to off-current level of T_{sw}, respectively. Retention ratio, R_r, is defined as the following formula:

$$R_r(\%) = \frac{P_1 - \mid P_1 - P_2 \mid}{P_1} \times 100 \tag{1}$$

where P_1 is an initial point voltage just after addressing period and P_2 is a final point voltage of frame time. The P_1 and P_2 are shown in the inset of Fig. 3.

In the case of PLED with an a-Si:H TFT when the off-current level of T_{sw} is less than 10^{-12} A, C_{st} voltage maintains within a frame time. But when the off-current level of T_{sw} is 10-11 A, retention ratio of C_{st} voltage is $\sim$ 90 % at the end of a frame time. However, when the off-current level of T_{sw} is 10^{-10} A, the current deviation of a PLED drops to 57 % of its initial point current even

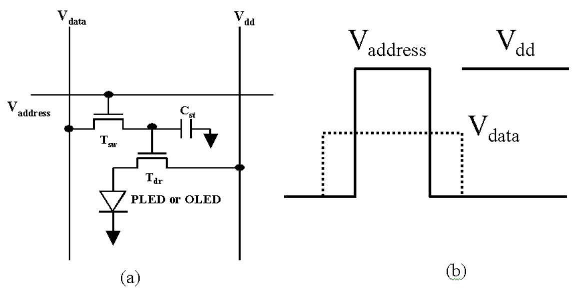

Fig. 2. The equivalent circuit diagrams of an AMOLED (a) and driving voltages (b).

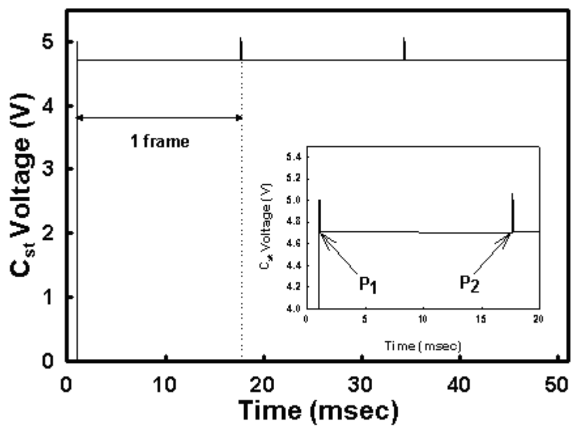

Fig. 3. The voltage dependence of C_{st} versus time in the case of a-Si:H TFT with a PLED.

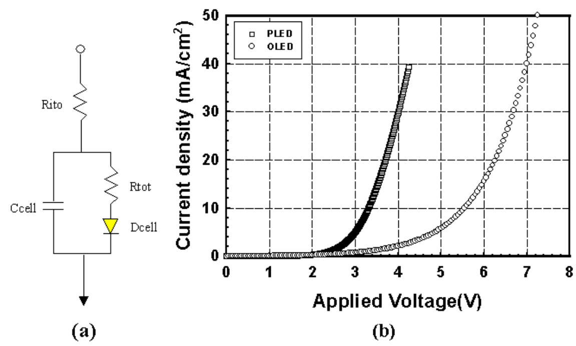

Fig. 1. The emulating configuration of the PLED and OLED (a) and its I-V characteristics (b).

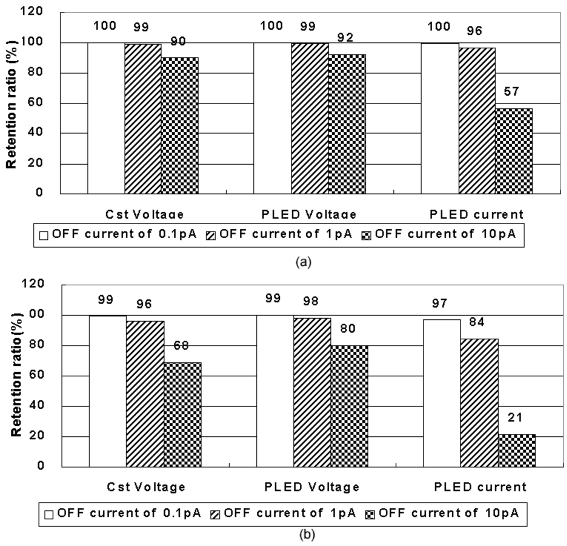

Fig. 4. The retention ratio of C_{st} voltage, PLED voltage and PLED current related to off-current level of T_{sw} (a) a-Si:H TFT (b) poly-Si TFT.

though the voltage of a PLED changes by 10 %. This means that small deviation of C_{st} voltage leads to big change in the brightness of PLED during a frame time.

As can be seen in Figs. 4 and 5, PLED and OLED with poly-Si TFT or with a-Si:H TFT show similar results. T_{sw} retention ratio decreases with increasing the off-state current. From these results, off-current level of T_{sw} should be less than $\sim 10^{-12}$ A.

Figure 6 shows the current density of a PLED versus data voltage, V_{data}. The data voltage is applied through the driving TFT in case of AMOLED.

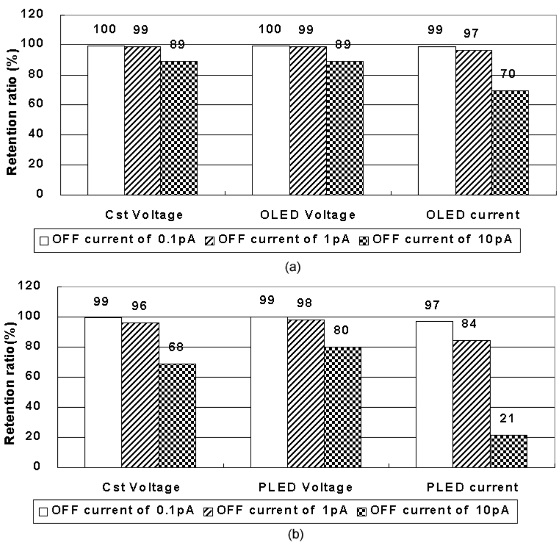

Fig. 5. The retention ratio of C_{st} voltage, OLED voltage and OLED current related to off-current level of T_{sw} (a) a-Si:H TFT (b) poly-Si TFT.

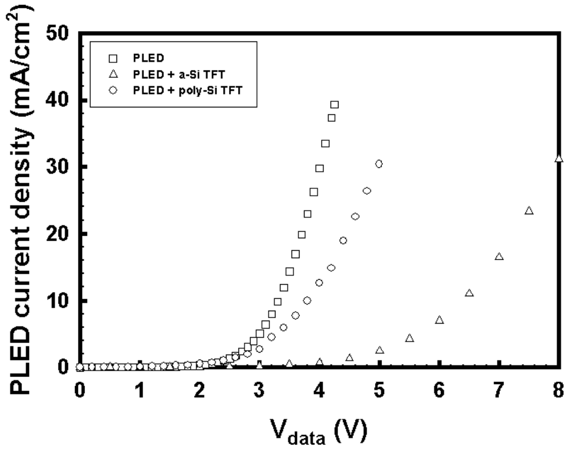

Fig. 6. The current-voltage characteristics for a PLED. The voltage is applied through the driving TFT in case of AMPLED.

Figure 7 shows the current-voltage characteristics of AMOLED. In general, a luminance and current density of OLED has a linear relationship. In Fig. 6, if the pixel configuration of Fig. 2 (a) is adopted to provide a maximum brightness with a current density of 10 mA/cm^2 for an a-Si:H TFT, then the data voltage for the maximum brightness is 6.5 V. On the other hand, in the case of poly-Si TFT the data voltage corresponding to the maximum brightness is 3.8 V. In Fig. 7, if the pixel of an OLED was designed to provide the maximum brightness at the current density of 10 mA/cm^2 with an a-Si:H TFT, the data voltage is 8.5 V. On the other hand, in the poly-Si TFT data voltage is 6 V at the same current density. Note that the poly-Si TFT needs less driving voltage than a-Si:H TFT for an AMOLED.

Figure 8 shows the T_{dr} voltage, PLED voltage and PLED current calculated for both a-Si:H TFT and poly-

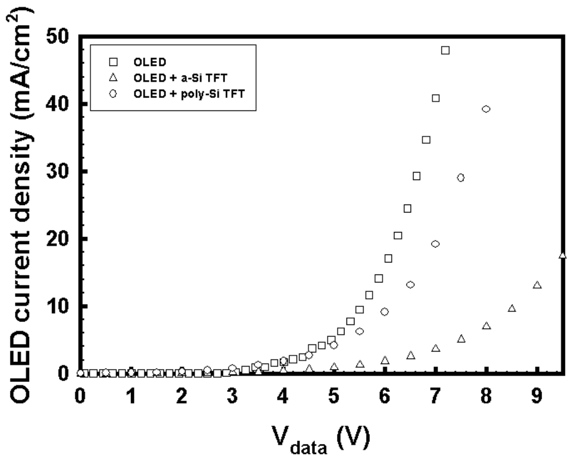

Fig. 7. The current-voltage characteristics for an OLED. The voltage is applied through the driving TFT in case of AMOLED.

Table 2. Power consumption of AMPLED and AMOLED.

	Power consumption(total)	TFT power consumption(a-Si:H TFT, Poly-Si TFT)
AMPLED	600 mA	216 mA
AMOLED	960 mA	288 mA

Si TFT as a function of data voltage for V_{dd} = 5V. Figure 9 shows the T_{dr} voltage, OLED voltage and OLED current calculated for both a-Si:H TFT and poly-Si TFT as a function of data voltage for V_{dd} = 8V. The TFT power consumption is determined principally by the product of the OLED current and voltage across the T_{dr}. In Fig. 8 if the pixel used in this study is required the current density of 10 mA/cm^2 to achieve the required brightness, then T_{dr} voltage is approximately 1.8 V for both a-Si:H TFT and poly-Si TFT. Then, PLED voltage becomes ∼3.2 V. Therefore, TFT power consumption using a-Si:H and poly-Si devices will be ∼56 % of the power consumed in the PLED devices. In Fig. 9 if the pixel requires the current density of 10 mA/cm^2 to achieve the same brightness, then T_{dr} voltage is approximately 2.4 V for a-Si:H TFT and poly-Si TFT.

Table 2 shows the TFT power consumptions of AMPLED and AMOLED at the current density of 10 mA/cm^2. From the simulation results AMOLED has higher power consumption than AMPLED. Then TFT power consumption of AMOLED has also higher than that of AMPLED. In the simulation, the W/L of a-Si:H TFT was much higher than that of poly-Si TFT for both AMOLED and AMPLED to achieve enough current to drive an OLED and a PLED.

IV. CONCLUSION

In this paper, we have shown that both a-Si:H and poly-Si TFTs can be used as pixel elements for active-matrix OLED. In the two-TFT circuits the off-current level of a switching TFT should be less than ∼10^{-12} A to keep the brightness during a frame time. We have achieved enough current to drive an OLED by suitable choice of W/L of an a-Si:H TFT.

ACKNOWLEDGMENTS

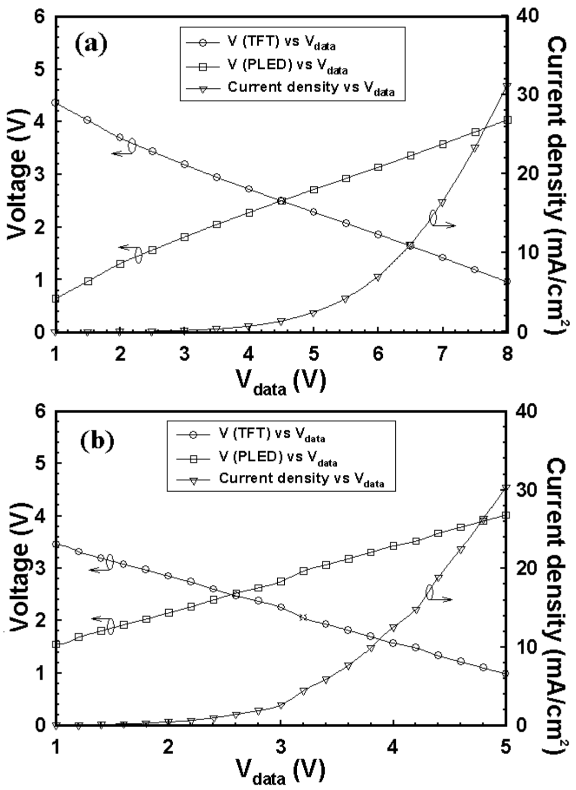

Fig. 8. The T_{dr} voltage, PLED voltage and PLED current calculated for both a-Si:H TFT (a) and poly-Si TFT (b) as a function of data voltage for V_{dd}=5V.

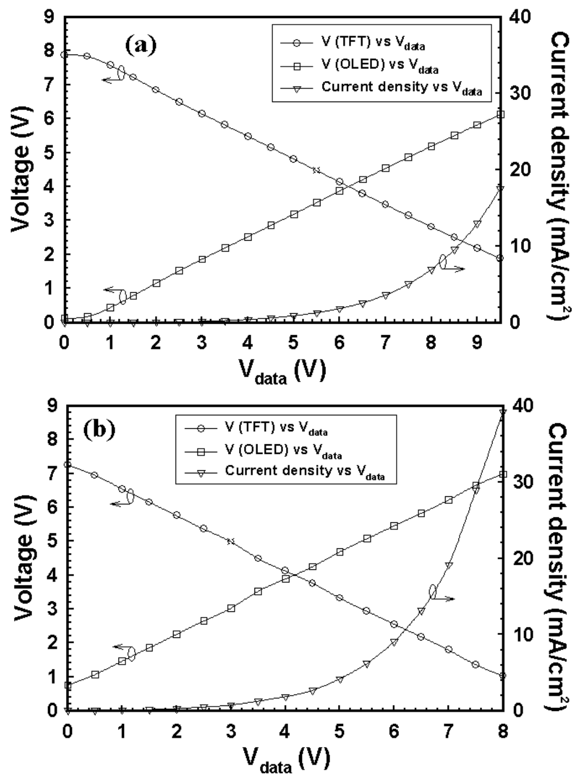

Fig. 9. The T_{dr} voltage, OLED voltage and OLED current calculated for both a-Si:H TFT (a) and poly-Si TFT (b) as a function of data voltage for V_{dd}=8V.

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