

P-12: A New a-Si:H TFT Pixel Design Compensating Threshold Voltage Degradation of TFT and OLED

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Abstract

A new active matrix organic light emitting diode (AM-OLED) pixel design, based on the a-Si:H TFTs, is proposed and verified by SPICE simulations. The simulation results show that the proposed pixel, which consists of 7-TFT and 1-capacitor and 1-additional signal line, compensates the problem of the threshold voltage degradation in the a-Si:H TFT and OLED.

1. Introduction

Organic light emitting diodes (OLEDs) have attracted a much attention due to high brightness, compactness and wide viewing angle [1]. Recently, hydrogenated amorphous silicon thin film transistors (a-Si:H TFTs) are considered as the pixel element of the active matrix organic light emitting diode (AM-OLED) due to low manufacturing cost and well matured technology. Although a-Si:H TFT exhibits an uniform threshold voltage, it is seriously degraded from its initial value after being subjected to the electrical stress [2,3]. When a conventional 2-TFT pixel circuit is applied to AM-OLED panel, the OLED current varies due to degradation of threshold voltage of driving a-Si:H TFT and OLED. Therefore, various pixel circuits are reported in order to compensate the problem of an inherent threshold voltage shift in the driving a-Si:H TFT [4,5]. Driving methods for AM-OLED are classified into 2-categories such as voltage and current programming. Current programming method compensates both a problem of threshold voltage shift and the voltage drop at the power supply line by self-compensation, but it may be a critical problem that the charging time for low data current is rather long [4,6]. In order to overcome the above problem, current scaling scheme is considered to scale a data current in the AM-OLED panel based on the excimer laser annealed poly-Si TFT. It reduces a charging time between data lines and pixel, and makes it possible to guarantee much wider current control margin at the data driver [7,8]. However, a-Si:H TFT would have been hard to consider the current scaling scheme because threshold voltage shift of each TFT in the pixel may be different. Voltage programming method compensates the problem of the threshold voltage shift and makes it possible to employ a data driver of the AMLCD. Therefore, voltage programming method would have been considered as an attractive solution due to compensation of threshold voltage shift in the driving a-Si:H TFT. However, it must also consider the threshold voltage degradation of OLED because OLED is usually placed on the source node of driving TFT, namely, the current of OLED.

The purpose of our work is to propose a new a-Si:H TFT pixel circuit, which compensates the problem of the threshold voltage shift in the a-Si:H TFT and OLED. The simulation result shows that it successfully reproduces almost identical OLED current regardless of the threshold voltage shift in the a-Si:H TFT and OLED.

2. Degradation of a-Si:H TFT

The a-Si:H TFTs were fabricated by the standard process and investigated when they were stressed by high drain and gate bias applied to driving a-Si:H TFT during each frame. Fig. 1 shows the stress induced changes in the a-Si:H TFT with dimensions of 200 μ m in width and 3.5 μ m in length, used as driving a-Si:H TFT for our proposed pixel. As shown in Fig. 1, after being subjected to the electrical stress, such as $V_{GS}=13V$ and $V_{DS}=13V$, threshold voltage shift was observed in the a-Si:H TFT. Therefore, the pixel design with compensation scheme would be necessary to drive AM-OLED based on a-Si:H TFT.

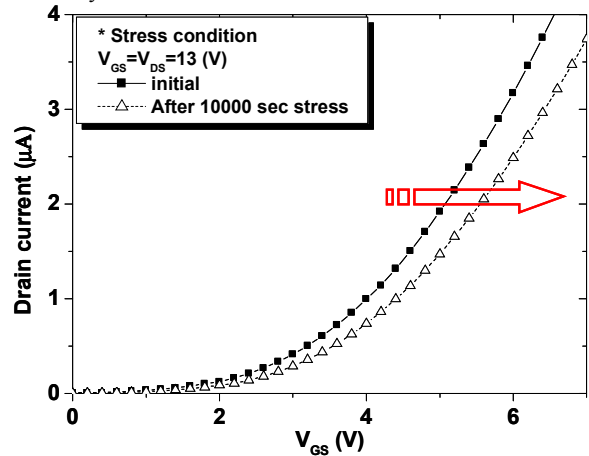


Figure 1. Stress induced changes in the driving a-Si:H TFT.

3. Pixel Design

Fig. 2 shows a comparison of n-type pixel and p-type pixel circuit.

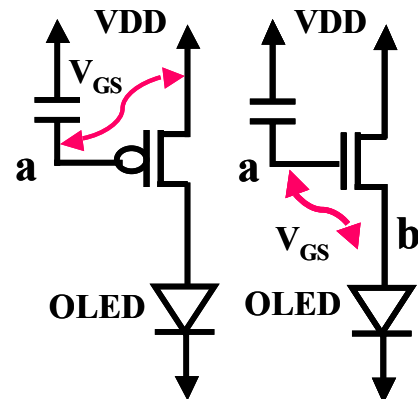


Figure 2. Comparison of n-type and p-type pixel circuit design.

While V_{GS} of p-type pixel circuit, widely considered in the AM-OLED based on poly-Si TFTs, is $(V_a - V_{DD})$, V_{GS} of n-type pixel circuit is $(V_a - V_b)$. When OLED degrades by a long time operation, the OLED current would be varied by threshold voltage degradation of OLED [9]. In other words, V_{GS} would be changed by a long time operation of OLED. Thus, n-type pixel design must consider the threshold voltage degradation of OLED because I_{OLED} is the saturation current of a-Si:H TFT, determined by V_{GS} .

Fig. 3 shows our proposed pixel circuit based on a-Si:H TFT and timing diagram of signal line. The proposed pixel compensates threshold voltage degradation of TFT by diode connection and OLED by bootstrapping.

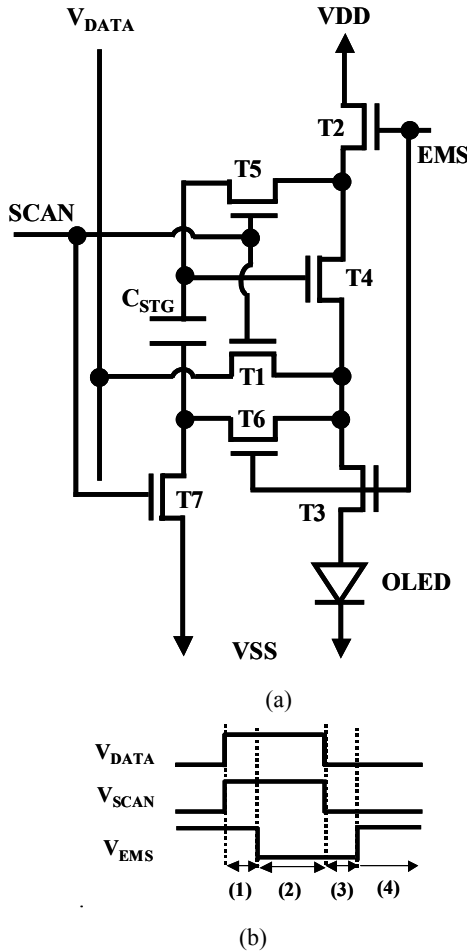


Figure 3. (a) Proposed pixel design, (b) Timing diagram of signal lines.

The proposed pixel circuit consists of six switching a-Si:H TFTs and one driving a-Si:H TFT (T4), one storage capacitor (C_{STG}) and includes an additional signal line entitled EMS line (emission). The operation of the proposed pixel circuit has the 4 stages. During (1) stage shown in Fig. 4 (a), pre-charging was performed. EMS is high, and gate scanning is high so that all TFTs in the pixel are on state. Thus, a gate node of T4 would be charged up in order to form a diode connection of T4 during the compensation period. Then, EMS is low, turning off T2, T3, T6, in order to store threshold voltage of driving TFT (T4). At this

time, during (2) stage shown in Fig. 4 (b), while V_{GS} of T4 is V_{TH} , V_{CSTG} is $V_{DATA} + V_{TH} - V_{SS}$. Stored voltage of C_{STG} is maintained until next pre-charging time. After pixel scanning time, during (3) stage shown in Fig. 4 (c), both EMS and scan signals are low. When an EMS signal goes high earlier before a scan signal goes low, stored charges in C_{STG} are changed by a charge injection from VDD. Thus, a scan signal goes low earlier before an EMS signal goes high. Thus, it precludes a charge injection from VDD to the storage capacitor.

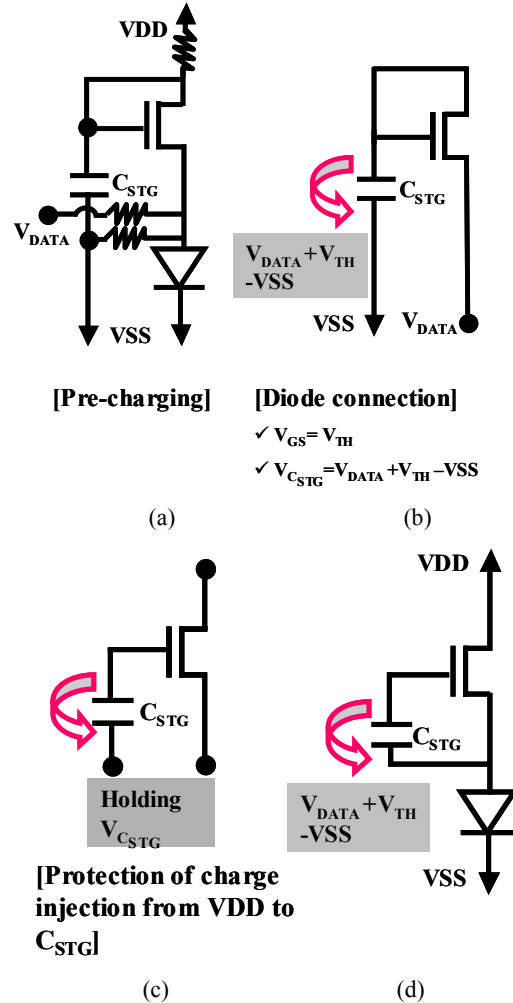


Figure 4. An equivalent circuit (T4) at each stage.

(a): (1) stage, (b): (2) stage,
(c): (3) stage, (d): (4) stage.

During (4) stage shown in Fig. 4 (d), driving TFT (T4) starts to drive the OLED. The C_{STG} holds the voltage, namely $V_{DATA} + V_{TH} - V_{SS}$, regardless of OLED load. I_{OLED} is also a saturation current of T4.

$$I_{OLED} = \frac{1}{2} k_4 (V_{GS} - V_{TH})^2 (k_4 = \mu C_{SIN} \frac{W}{L})$$

$$= \frac{1}{2} k_4 (V_{DATA} + V_{TH} - V_{SS} - V_{TH})^2 = \frac{1}{2} k_4 (V_{DATA} - V_{SS})^2$$

Therefore, I_{OLED} is an independent value about threshold voltage degradation of TFTs and OLED, only affected by data voltage.

4. Circuit Simulation

To verify the proposed pixel circuit, we performed a circuit simulation using SMART-SPICE. We measured the device characteristics of the a-Si:H TFTs for SPICE modeling. Simulation model parameters were extracted from measurement using HP4156B. Fig. 5 shows the output characteristics of a-Si:H TFT, which was matched to a-Si:H TFT model (RPI model level = 35). We employed these modeling results as SPICE simulation.

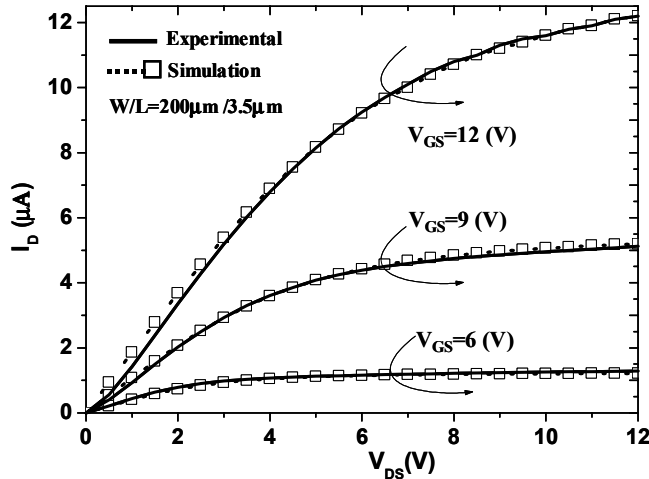


Figure 5. The measured and simulated output characteristics of a-Si:H TFT.

Fig. 6 shows the simulation results of the proposed pixel in case of threshold voltage degradation of driving TFT, which degrades from 2.5V to 3.5V.

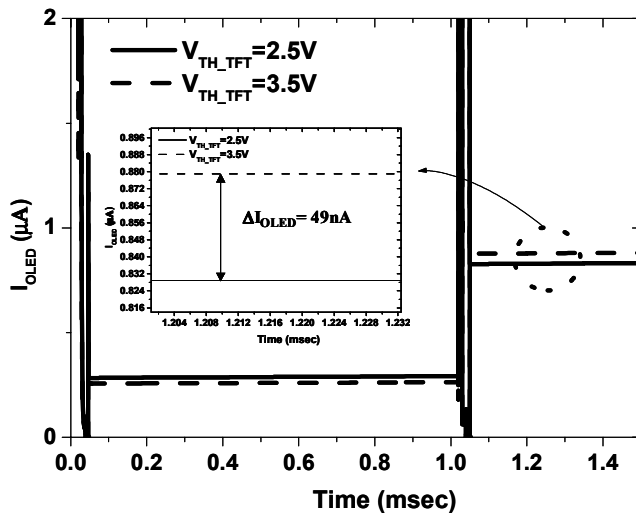


Figure 6. The simulation results of threshold voltage degradation of driving TFT.

In case of 1V threshold voltage degradation, OLED current variation is negligible as shown in the Fig. 6. These simulation data verify that the proposed AM-OLED pixel compensates threshold voltage degradation of a-Si:H TFT. Fig. 7 shows the each node's voltage of T4 when input data voltage is 2V and threshold voltage of TFT is 2.5V.

When data input stage ends, V_{GS} of T4 is V_{TH} of T4. However, at this time, stored voltage in the C_{STG} is $V_{DATA} + V_{TH} - V_{SS}$.

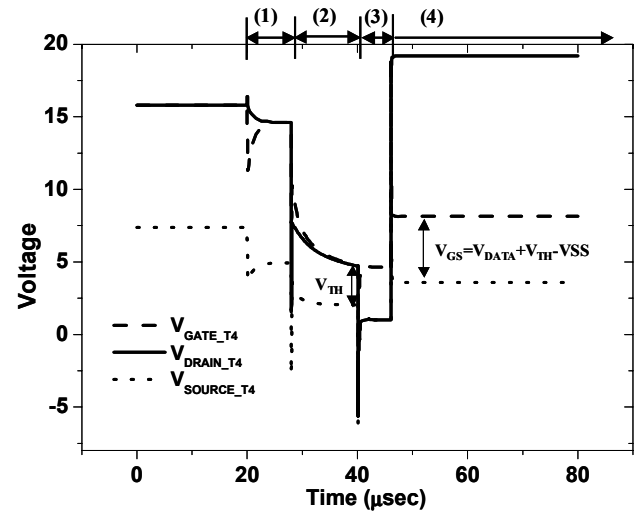


Figure 7. Gate, source, and drain node voltage of driving TFT (T4) with operation stage. (1): Pre-charging stage, (2): Data input and stored threshold voltage of T4, (3): For protection of stored charge in C_{STG} , (4): Emission stage.

Then, during (3) stage, V_{GS} is floating because source node of T4 is floating. However, a stored voltage in the C_{STG} is maintained due to the charge conservation law. After gate scanning time, EMS signal goes high, and emission stage begins. At the emission stage, V_{GS} is the same value of stored voltage in the C_{STG} . Thus, V_{GS} of emission stage is $V_{DATA} + V_{TH} - V_{SS}$. Even though threshold voltage of OLED degrades, V_{GS} of T4 wouldn't vary because stored voltage in the C_{STG} can't change. Thus, the proposed pixel circuit compensates threshold voltage degradation of TFTs and OLED.

Fig. 8 indicates the simulation results in case of threshold voltage degradation of OLED, which degrades from 3.0V to 3.5V.

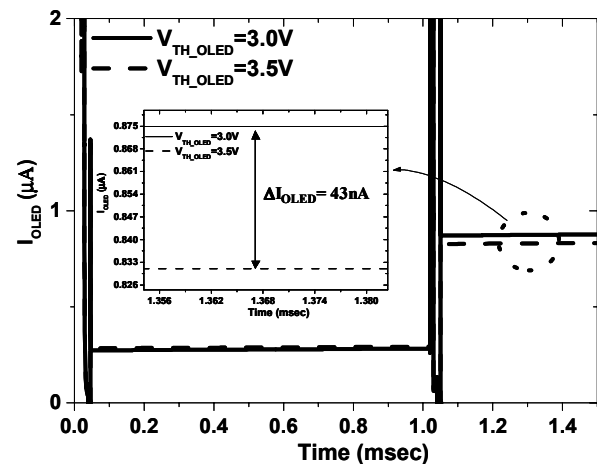


Figure 8. The simulation results of threshold voltage degradation of OLED.

Fig. 9 shows SPICE simulation results compared with a conventional two TFT pixel circuit.

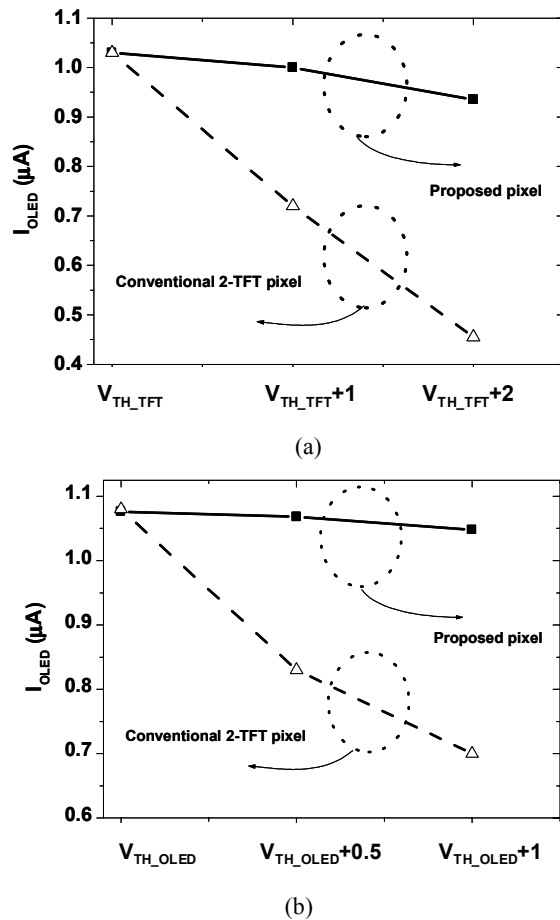


Figure 9. Simulation results : I_{OLED} variation in case of V_{TH} degradation of TFT (a) and OLED (b), compared with conventional 2-TFT pixel.

While I_{OLED} in the conventional 2-TFT pixel circuit would change in accordance with degradation of TFTs and OLED, I_{OLED} in the proposed pixel would be almost same value. Fig. 9 indicates the proposed pixel circuit successfully compensates V_{TH} degradation of TFTs and OLED. Thus, the uniformity of brightness would be improved in the AM-OLED displays.

Table I shows the simulation parameters used for the circuit simulation.

Table I. Circuit simulation parameters.

Devices			
W/L(T2,T4)	W/L(T3)	W/L(T1,T5,T6,T7)	C_{STG}
200/3.5	100/3.5	30/3.5	0.3pF
Signal lines			Time
VDD	VSS	EMS, SCAN	T(1) T(2) T(3)
20V	0V	0~25V	8 μ 12 μ 5 μ

5. Conclusion

We propose a new active matrix organic light emitting diode (AM-OLED) pixel design based on the a-Si:H TFTs, which consists of 7-TFT and 1-capacitor and 1-additional signal, and verify the proposed pixel by using SPICE simulation. The simulation results, based on the measurement of a-Si:H TFT's electrical characteristics, exhibit that the proposed pixel successfully compensates the threshold voltage degradation of TFTs and OLED. The proposed circuit may be suitable for large-size and low-cost AM-OLED panel.

6. References

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