An a-Si:H TFT Pixel Circuit with Novel Threshold Voltage Compensation Technique for AMOLED Displays

Min-Seok Shin, Ung-Gyu Min, Jung-Hwan Choi, Junyong Song, Seung-Yong Lee, and Oh-Kyong Kwon[*]

Division of Electrical and Computer Engineering, Hanyang University, Haengdang-Dong, Seongdong-Gu, Seoul, 133-791, Korea
Phone: +82-2-2220-0359 , E-mail: okwon7@chol.com[*]

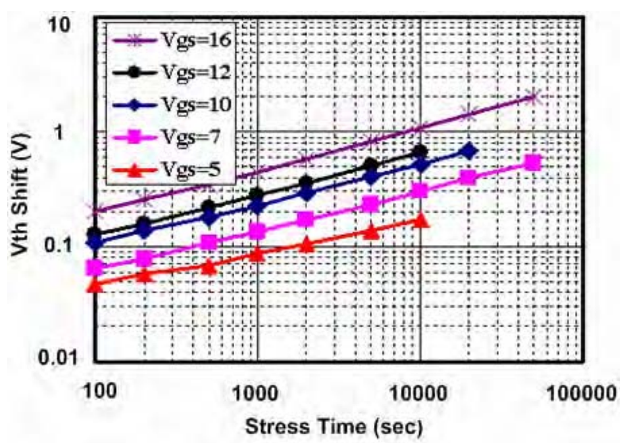
Abstract

A Novel pixel structure with a new threshold voltage compensation technique is proposed for large-size a-Si:H AMOLED panel application. The proposed pixel improves image quality with threshold voltage compensation and alleviates annealing technique for display-off time. Sensing the threshold voltage of driving TFT for 20-inch WUXGA panel is verified by the HSPICE simulation.

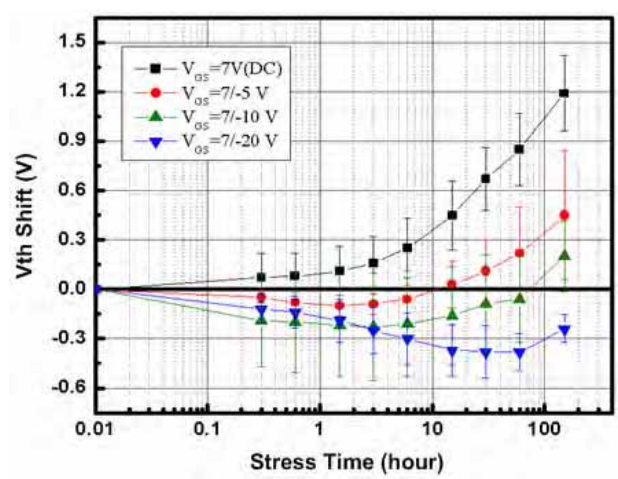
1. Introduction

AMOLED display based on a-Si:H TFTs is suffered from life time due to the threshold voltage shift problem. Furthermore, image quality get worse from differential aging that is caused by different stress to gate electrode in accordance with different pixel data.

Many pixel structures are studied to solve above problems. In case of current-programming pixel structures [1, 2], the independent current of TFT's threshold voltage flow to the OLED. But, current-programming time is limited by very low mobility of a-Si:H TFTs. Thus, current-programming method is not suitable for large-size and high-resolution display applications, whereas voltage-programming pixel structures [3, 4] can charge the data voltage to the pixel during the given line time. However, the voltage-programming method has differential aging problem since it cannot compensate for each threshold voltage of driving TFT. Feedback-type pixel structures [5] are proposed to reduce the dependence of the OLED current on the characteristics of TFTs. To sense the voltage of any node in the pixel, driving TFT of the pixel should charge parasitic capacitor of the sensing line. Large capacitance of the sensing line and low mobility of a-Si:H TFTs limit to sense the voltage of the node in the pixel for a given line time. Thus, new sensing scheme and threshold voltage compensation method need to solve above problems of prior pixel structures.

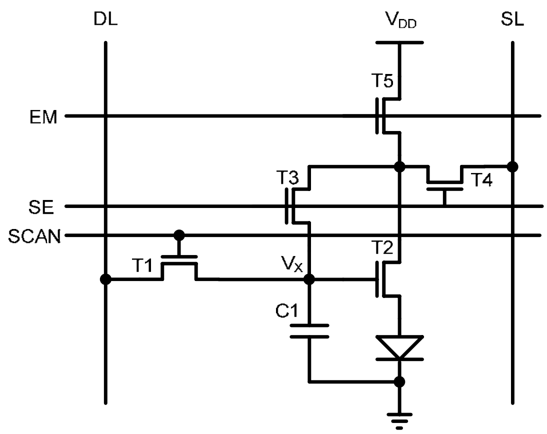


(a)



(b)

Figure 1. Measurement results of the threshold voltage shift in accordance with the stress time. (a) only positive bias to gate electrode, (b) positive and negative bias to gate electrode alternately.



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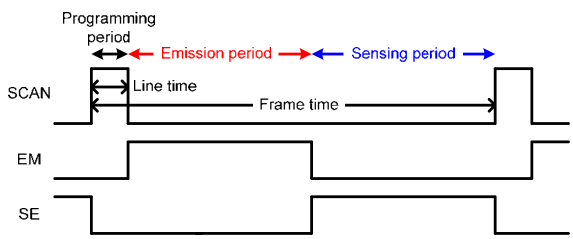
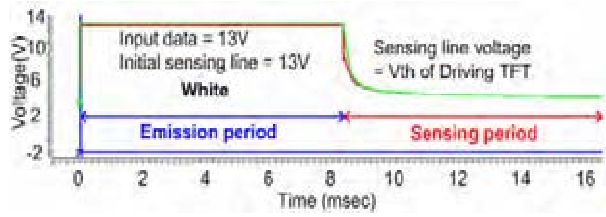


(b)

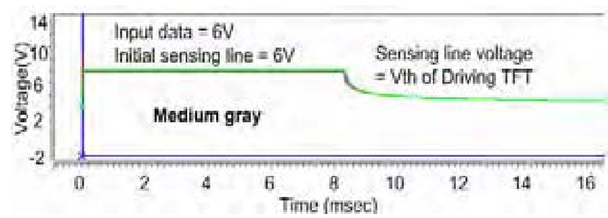
Figure 2. Proposed pixel. (a) circuit diagram, (b) timing diagram.

Proposed pixel circuit senses the threshold voltage of the driving TFT for half of frame time. The reason using the half of frame time is that the process of the threshold voltage compensation is not required in real time. From the measured data, shown in Figure 1, not only the threshold voltage of a-Si:H TFTs is slowly shifted in accordance with the stress time but also negative bias to gate electrode slow down threshold voltage shift of TFTs. Thus, the threshold voltage compensation of driving TFT doesn't need to be accomplished in real-time. In addition, negative bias to gate electrode is needed to slow down aging effect.

In this paper, proposed pixel structure programs the data voltage to the pixel, which is compensated by sensing the threshold voltage of driving TFT in the pixel for the period with half of one frame time. For the period of display-off time, when the data signal is not programmed to data line, proposed pixel structure programs the negative voltage to the driving TFT, which slow down the threshold voltage shift. And new driving



(a)



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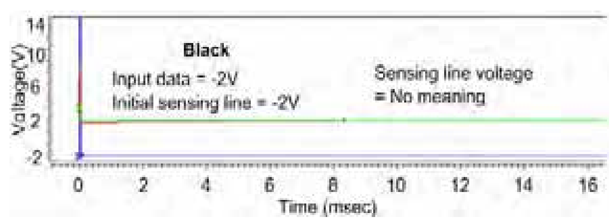

(c)

Figure 3. Simulation results of the threshold voltage sensing for driving TFT. (a) white gray, (b) medium gray, (c) black gray.

system makes the graphic data independent of the threshold voltage of driving TFT. Moreover, motion blur problem of conventional hold type display is reduced by emitting OLEDs during the half-frame time.

2. Proposed pixel circuit and simulation results

Figure 2 shows the proposed pixel circuit and timing diagram for sensing the threshold voltage of driving TFT. When 'Scan' signal is high, T1 is turned on. The data voltage is stored to C1. In this period, 'EM(Emmision)' signal should be low to prevent from emission of improper data voltage. And then, 'Scan' and 'EM' signal is low and high respectively, currents flow to OLED. When 'EM' and 'SE(Sensing)' signal change to low and high respectively in the center of frame time, then T5 is turned off. When T3 and T4 are turned on, sensing

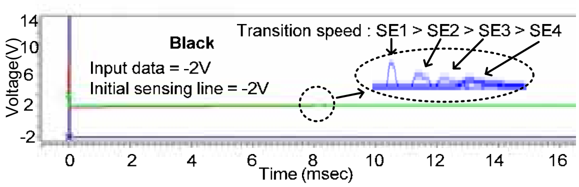

Figure 4. Simulation results of peak current in accordance with the transition speed of 'SE' control signal.

operation of the threshold voltage of driving TFT is carried out. T3 and T4 connect Vx to SL(Sensing Line) and T2 is changed to diode connected transistor. Accordingly charge of C1 and parasitic capacitor of SL is flow out to common cathode of OLED until T2 enters cut-off region. In this moment, the threshold voltage of T2, which equals to the voltage of SL, is sensed in external source driver IC. In the process of sensing the threshold voltage, additional current flows to OLED due to charge of large parasitic capacitance of SL. Additional current can get worse the contrast ratio because the light can flash in black gray scale. Therefore, SL is initially charged to the voltage of DL(Data Line). And if the transition of 'SE' control signal is sharp, Vx node voltage can be slightly increased by gate capacitive coupling of T3. Thus, the transition of 'SE' control signal should be slow to flow lower current to OLED.

Figure 3 are simulation results, which is sensing the threshold voltage of driving TFT. Panel load condition is for 20inch WUXGA. The value of load resistance and capacitance are 7.2kΩ and 79.5pF, respectively. Simulation is accomplished in accordance with 3 gray scale : white, medium gray, and black as shown in Figure 3. Simulation results, shown in Figure 4, are peak current in accordance with the transition speed of 'SE' control signal.

Another operation, which is annealing driving TFT, is performed during display-off time. When display turns off, 'SCAN' signal and data voltage is -6V and -20V respectively. Thus negative voltage is charged to gate electrode of driving TFT. All operations are shown in Figure 5 respectively.

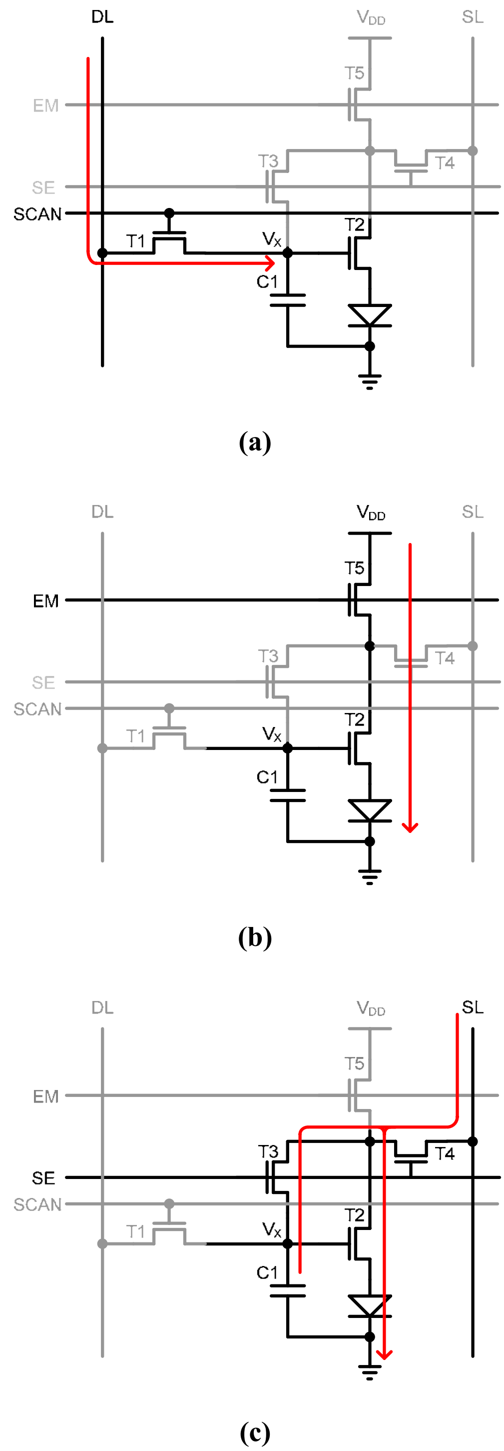

Figure 5. Operations of proposed pixel circuit. (a) data programming period, (b) emission period, (c) threshold voltage sensing period.

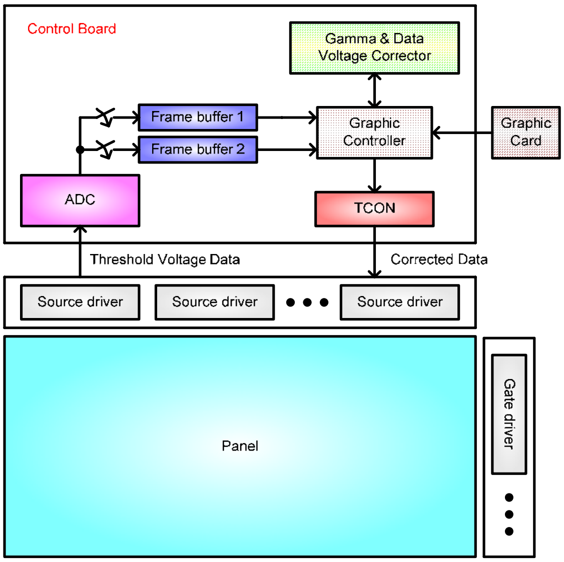

Figure 6. Proposed driving system.

3. Proposed driving system

Figure 6 shows the proposed threshold voltage compensation system for large-size AMOLED application. Control board consists of ADC (Analog-to-digital converter), frame buffers, timing controller, graphic controller, gamma generator and data corrector. Sensed threshold voltage of driving TFT from the proposed pixel circuit is converted to digital code using ADC, and then converted digital code is saved in frame buffer 2. Converted digital code is compared to pre-sensed threshold voltage in frame buffer 1. The difference between two digital codes changes graphic data that comes from graphic card. Changed graphic data is transferred to the panel according to the control signal of the timing controller.

4. Layout

Figure 7 shows layout of proposed pixel circuit. The size of unit pixel is 115.3μm×345.9μm as 20inch WUXGA. Storage capacitor is constructed with poly layer and power line(V_{DD}) to reduce layout area. In this result, aperture ratio comes to 35 percent.

5. Conclusion

A new pixel circuit is proposed for sensing the threshold voltage of driving TFTs for large-size

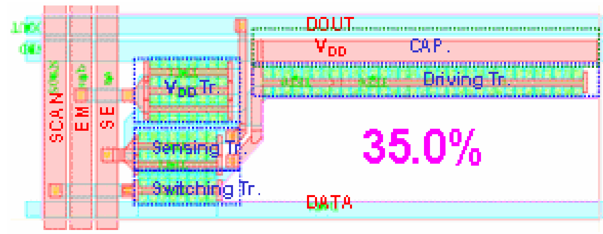

Figure 7. Layout of proposed pixel circuit.

a-Si:H AMOLED application. The proposed driving system modifies graphic data concerning the threshold voltage of driving TFTs and slows down it's threshold voltage shift by annealing process. In addition motion blur effect is reduced due to half-frame time emission. Sensing the threshold voltage of driving TFT for 20-inch WUXGA panel is verified by the HSPICE simulation. And the aperture ratio of proposed pixel structure is 35 percent.

5. References

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