A New Pixel Structure for Active-Matrix Organic Light Emitting Diode

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Abstract

We propose a new pixel structure for Active Matrix OLED (AMOLED). The proposed pixel structure can display full color images by compensating threshold voltage (Vth) variation of driving TFTs. And we obtain an improved contrast ratio(C/R) of higher than 600:1

1. Introduction

Liquid-crystal display(LCD) is currently the dominant flat-panel display(FPD) technology because of its portability, low power consumption and mature manufacturing technology. But LCD needs back-light and it is difficult to realize fast moving video images due to slow response time of liquid crystal. To overcome above limitations, organic light-emitting diode (OLED) for FPD applications has been studied. OLED is a monolithic and semi-conductive device that emits light when current is flown to it. It has various advantages such as simple structure, fast response time, emissive nature and wide viewing angle.

There are two kinds of pixel addressing method for OLED. One is passive matrix addressing method and the other is active matrix addressing method. In case of active matrix OLED(AMOLED) display, because light is emitted during frame time, emission current is lower than that of passive matrix OLED. However it still has non-uniformity problems of display images, because of Vth variations of poly-Si TFT, an element of inner pixel current source.

Recently, AMOLED displays demonstrated with several solutions to obtain uniform images, such as Vth compensated voltage programming method[1,2], current programming method[3,4] and digital driving method[5~7]. Digital driving method can reduce the Vth sensitivity of displayed images, but it needs fast addressing speed[5~7]. so that may not be the good solution for high resolution and large size panel. The voltage programming method, reported by Dawson et al. [1], can compensate the Vth variation of TFTs. But this method requires two pixel capacitors and three control signal lines with complex control signals for driving. Another voltage programming method needs relatively simple pixel structure, but it may occur low C/R problems if there is no additional control line and TFT [2][8].

We propose an improved AMOLED pixel structure which has no additional horizontal line by reducing discharging line of previous reported structure [2].

2. Proposed pixel structure

Figure 1 shows the previously reported pixel structure for AMOLED [2]. It can compensate the Vth variation of poly-Si TFT. Figure 2 also shows the voltage programmed pixel structure[8] which can compensate Vth variations by similar operation to Figure 1. This structure reduced one metal line(VI) of Figure 1 by initializing through data line and dividing row line time. But unwanted emission which occurs during initializing time make it difficult to obtain high C/R for those structure. Under PMOS only process for TFT, one solution for that problem is to add one control line and one TFT for blocking

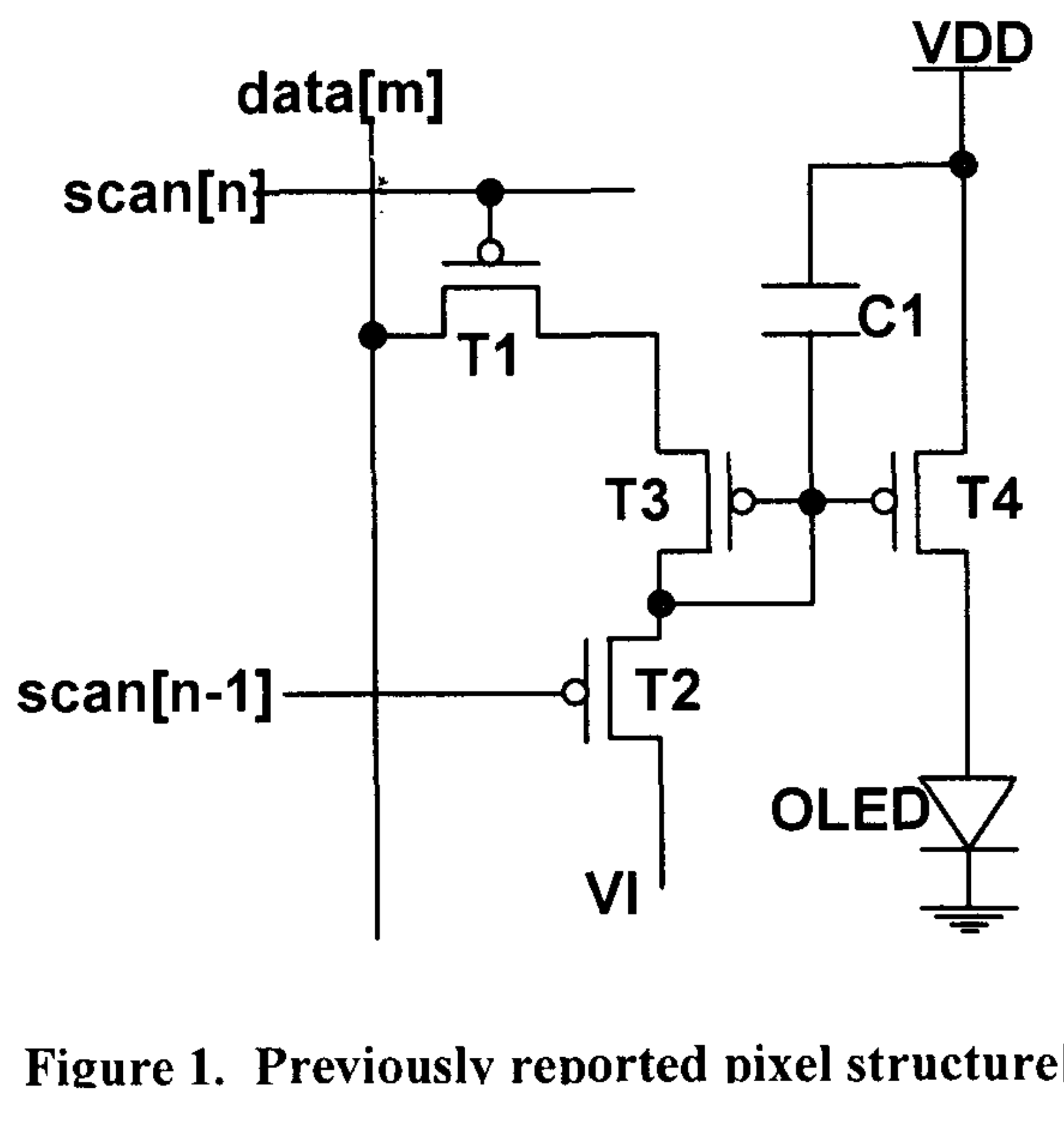

Figure 1. Previously reported pixel structure[2].

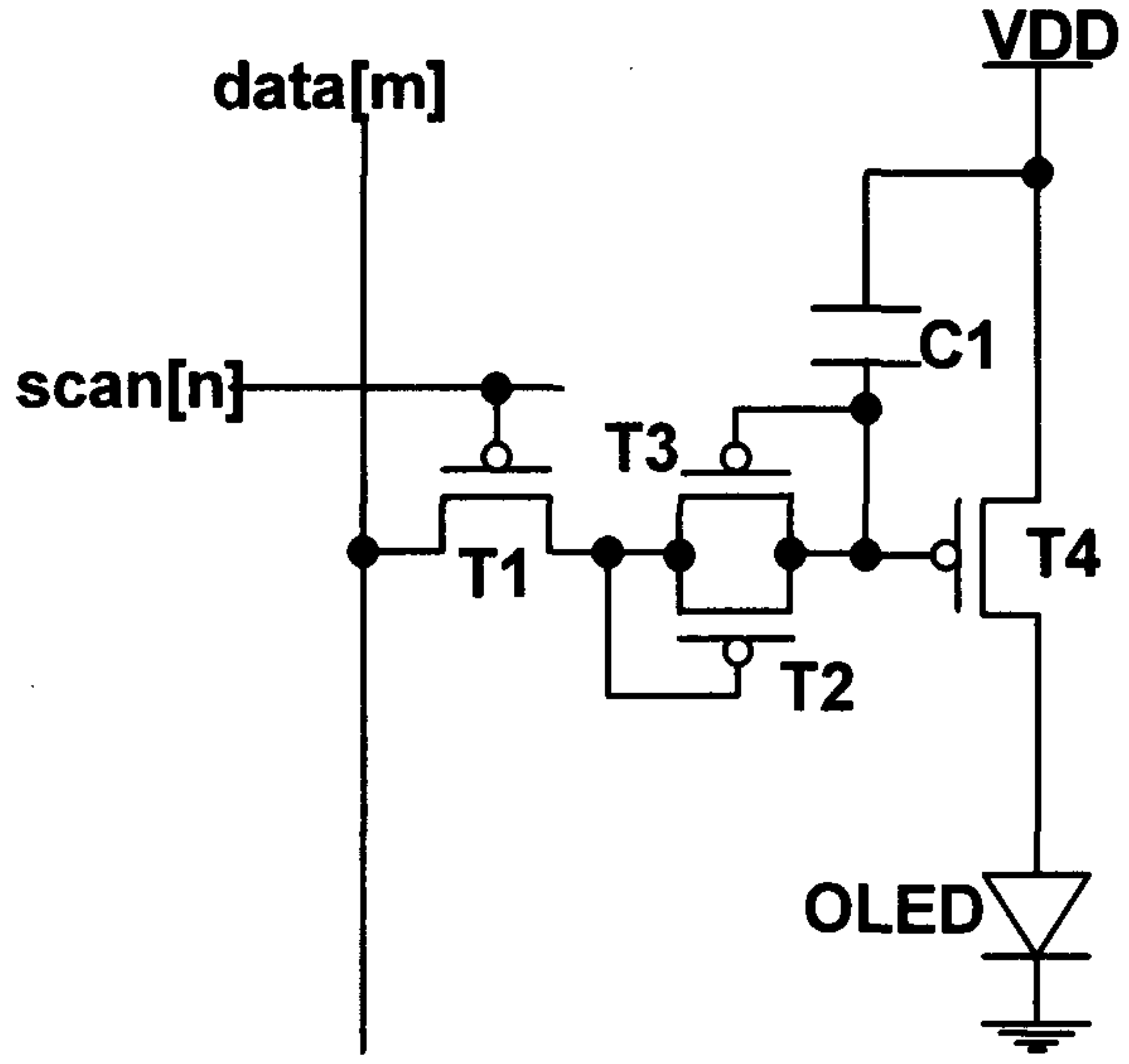

Figure 2. Previously reported pixel structure [8].

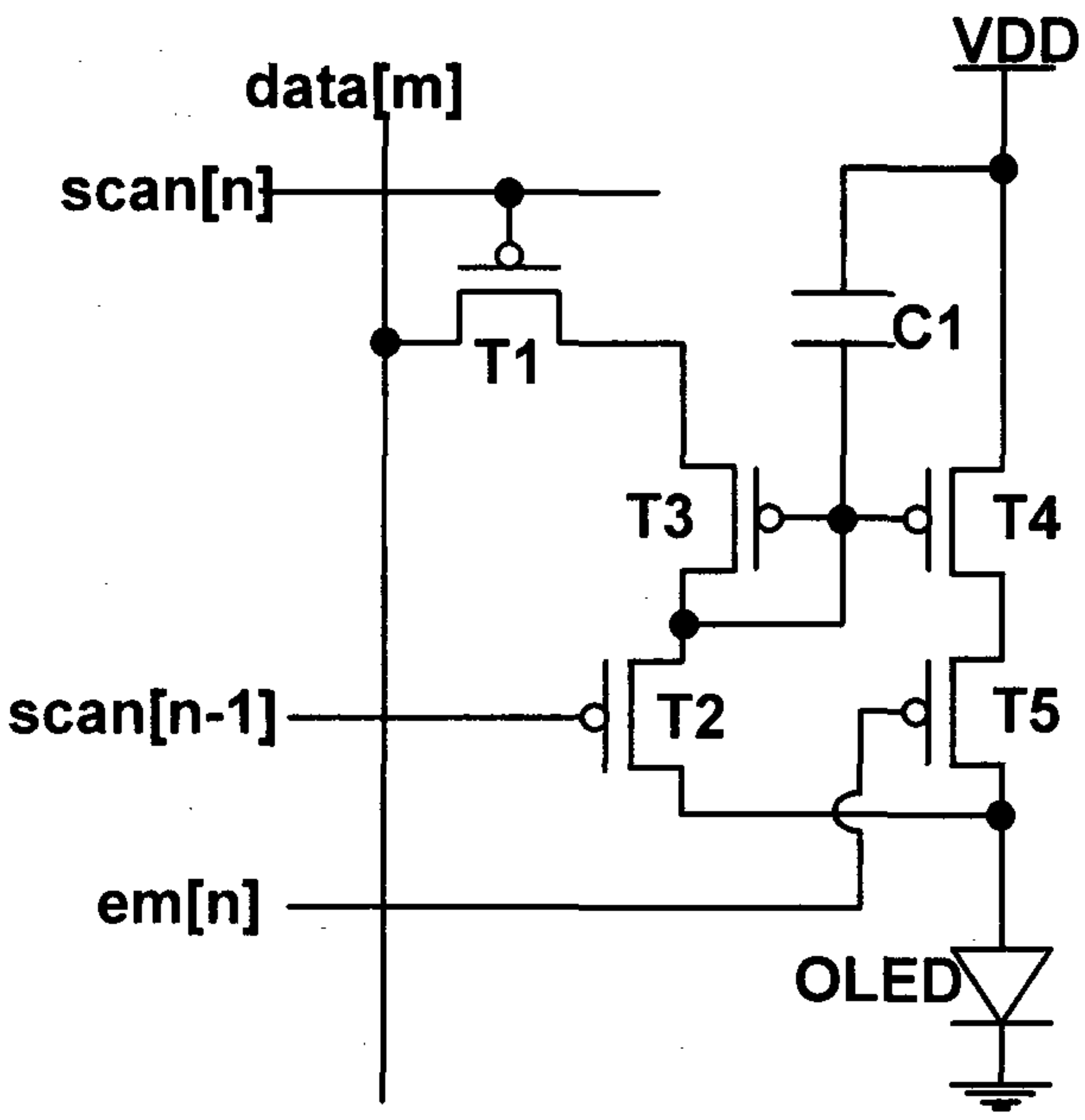

Figure 3. Proposed pixel structure.

current flow during initializing period[9]. But additional control line generates larger parasitic elements and reduces pixel aperture ratio. So we propose an advanced pixel structure that can obtain much better C/R without additional metal line and complexity of driving method.

Figure 3 shows the proposed pixel structure of

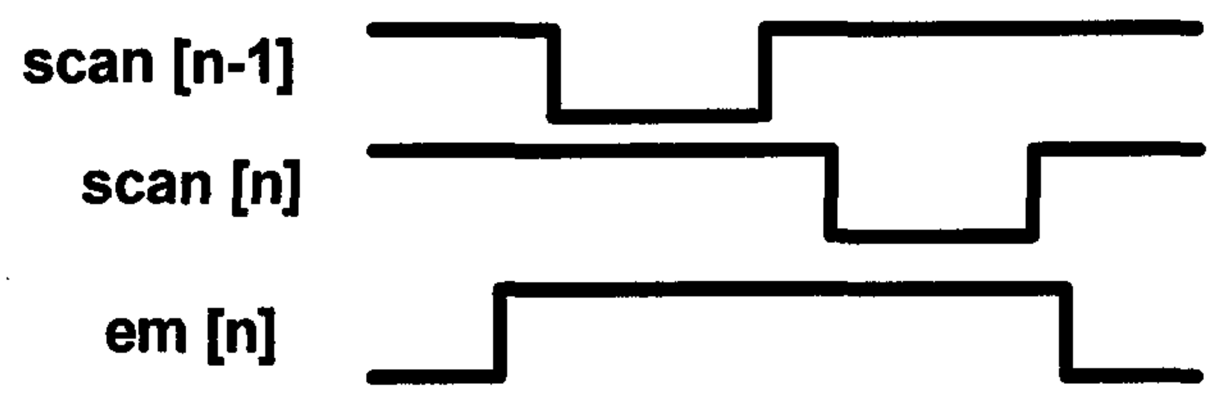

Figure 4. Timing diagram of proposed pixel structure.

AMOLED having 5 TFTs, 1 capacitor and 2 horizontal control lines. T1, T2 and T5 are switching TFTs, and T4 is driving TFT, which supplies constant current to OLED for a frame time. C1 is a storage capacitor, which storing gate voltage of T4. And T3 compensates the Vth variation of driving TFT, T4. We add one TFT to block the emission current and control signal line, em[n], to control the operation of the TFT, however there is no initializing line(VI of previously reported structure[2]). So, total number of metal line, cross the panel, is equal to previous one of Figure 1. In this structure, the gate node of T4 is initialized through T2 to low level previous line scan period (scan[n-1]) enough to program next data voltage during. As a results, there is only one additional component, T5, to eliminate the unwanted emission compared with previous one [2].

After initializing the gate node voltage, T1 is turned on by scan[n] so that data voltage is applied. Here the threshold voltage variation of T4 is compensated by diode connected T3. If the threshold voltage of T3 and T4 are same, each threshold voltage is canceled. So it is possible to control OLED current independent of threshold voltage variation of driving TFT, as shown in equation (1). And lights from OLED are emitted as programmed data only when blocking TFT T5 is turned on. Figure 3 show the timing diagram of proposed pixel structure.

$$I_{OLED}=\frac{\beta}{2}(|V_{GS\_4}|-|V_{th\_4}|)^2=\frac{\beta}{2}\{(VDD-(V_{DATA}-|V_{th\_3}|))-|V_{th\_4}|\}^2$$
$$=\frac{\beta}{2}(VDD-V_{DATA})^2 \qquad (1)$$

Where the V_{GS_4} is voltage difference between the gate node and source node of the T4, V_{th_3} and V_{th_4} are the threshold voltage of T3 and T4, respectively, and V_{DATA} is the input data voltage.

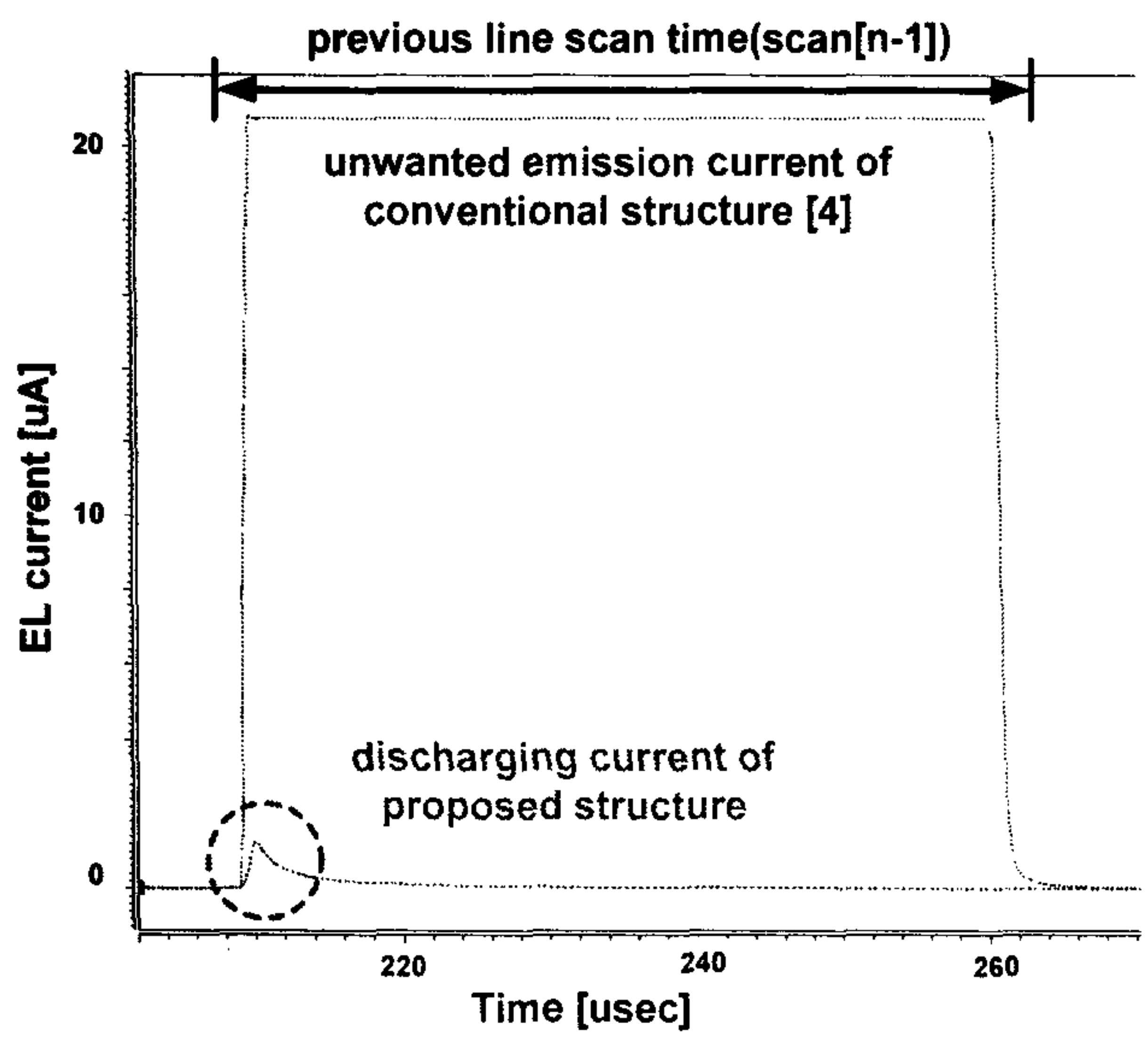

Figure 5. HSPICE simulation results of unwanted pixel emission current during previous line scan time.

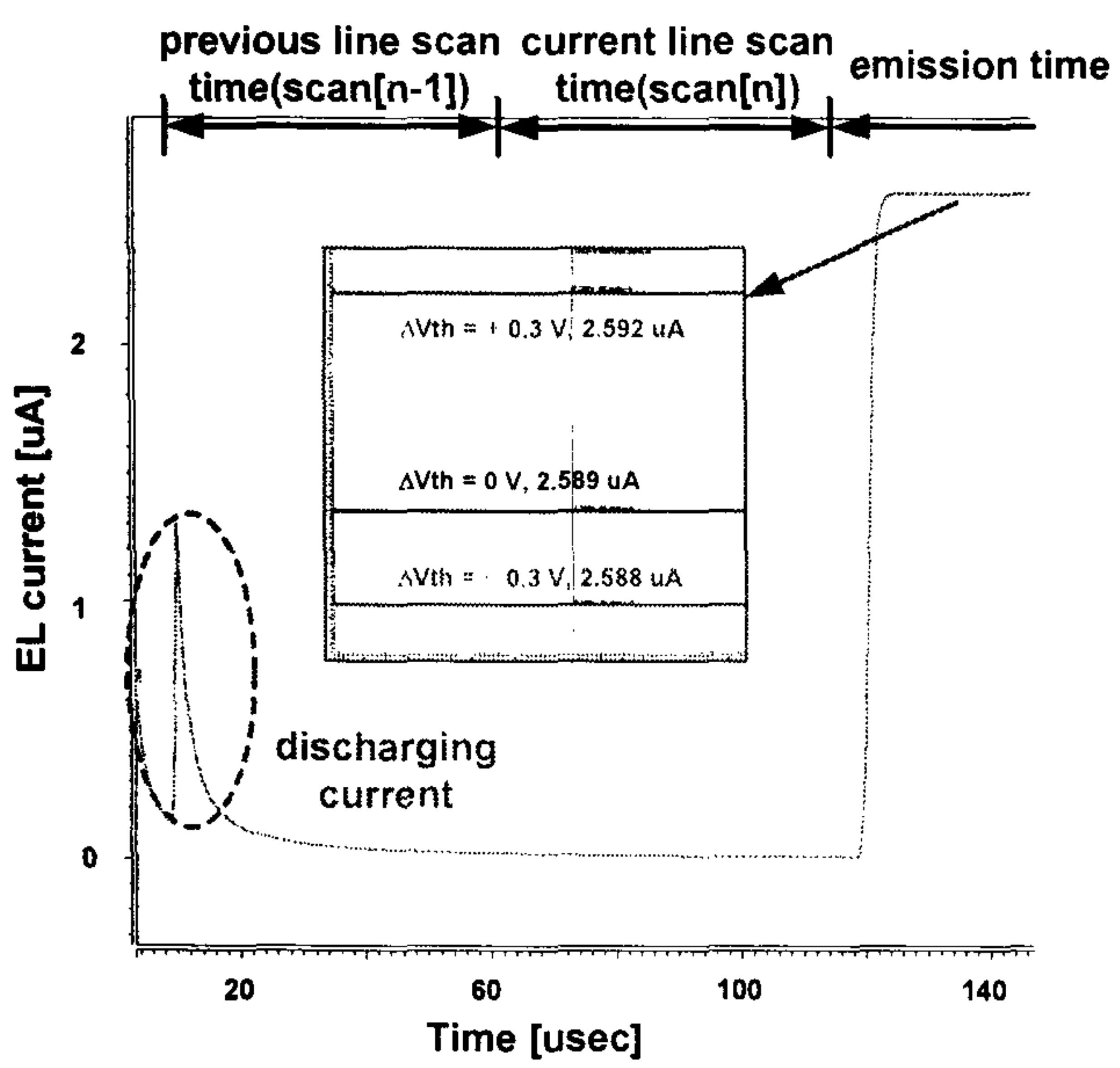

Figure 6. HSPICE simulation results of EL current for Vth variation of p-Si TFT.

3. Simulation results

Figure 5-7 show the HSPICE simulation results of conventional structure and proposed one in case of QVGA resolution. If pixel current of white level is 2.5 uA, then the calculated C/R is about 39:1 and 625:1 for conventional structure[4] and proposed one, respectively. For proposed pixel structure, the pixel current variation due to Vth variation is under 0.1 gray

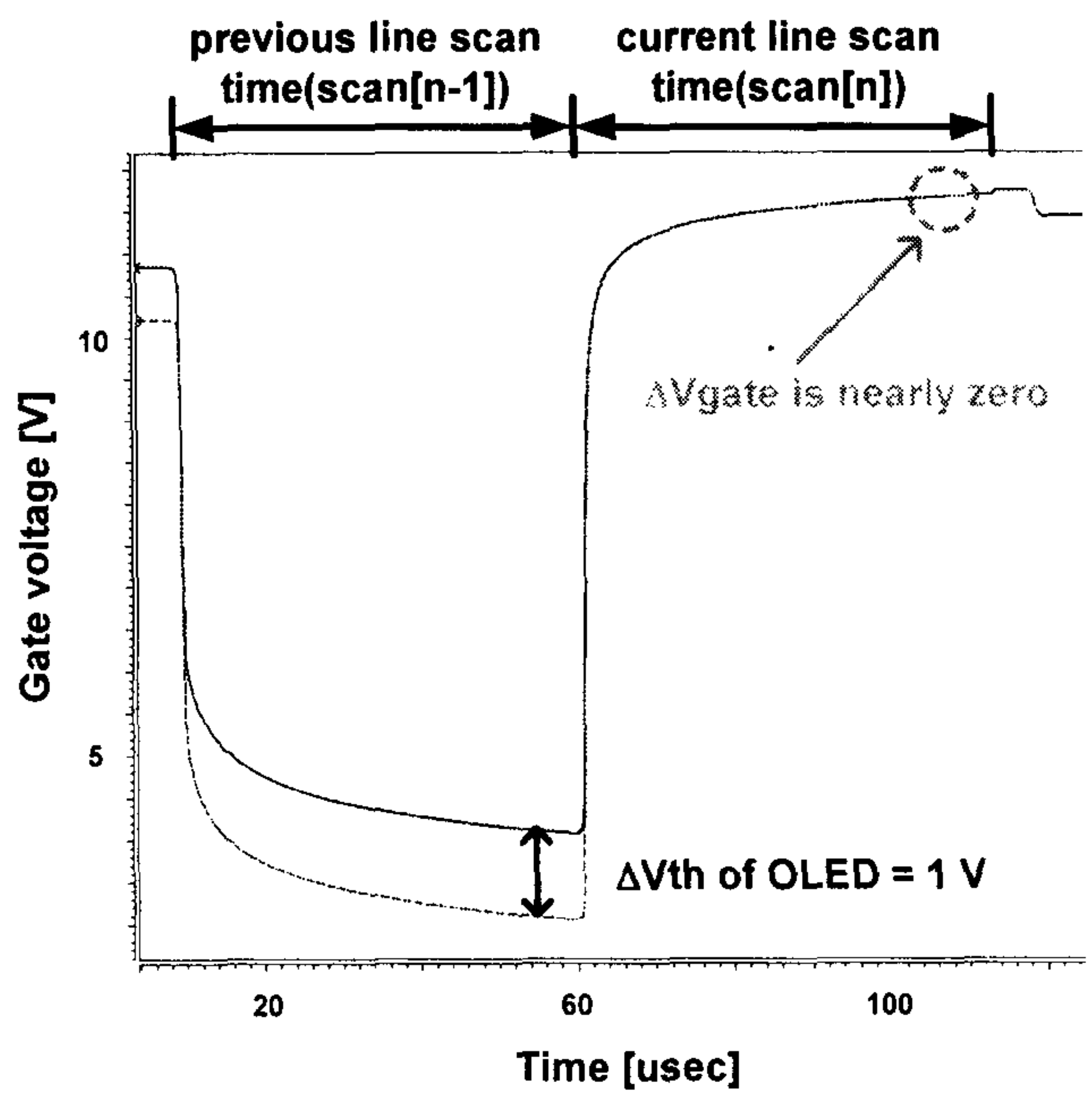

Figure 7. HSPICE simulation results of EL current for Vth variation of OLED.

on an average through full 64 gray range when the deviation of Vth is 0.6 V. EL current from discharging of proposed structure is also observed from the result, as shown in Figure 5. But the average value of that through a frame time is so small that the calculated C/R is high without regard to the discharging current.

There can be also some variations of initializing voltage from Vth variation of organic EL materials. As shown in Figure 7, the variation of programmed data voltage is almost zero, when ΔV_{th_OLED} is 1.0V. And that fact shows that the proposed pixel structure is insensitive over Vth variation of OLED.

4. Conclusions

We propose an improved pixel structure for AMOLED panel and verified its performance by HSPICE simulation. We can solve the low C/R problem and Vth variation problem by using 5 TFTs, 2 control lines and simple signal pattern of data line without a loss of row line time.

5. Acknowledgement

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