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Organic TFT를 이용한 AM-OLED 구동용 Pixel 보상회로 설계에 관한 연구

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Organic Thin-Film Transistor-driven Current Programming Pixel Circuit for Active-Matrix OLEDs

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Abstract - A new current-programmed pixel circuit for active-matrix organic light emitting diodes (AMOLEDs), based on Organic TFTs (OTFTs), is proposed and verified by SPICE simulations. The simulation results show that the proposed pixel circuit, which is a current mirror structure consisting of five Organic TFTs and one capacitor, has reliable linear characteristics between input current and output OLED current. Also, the threshold voltage degradation of Organic TFTs due to long time operation stress is well compensated to reliable values.

1. Introduction

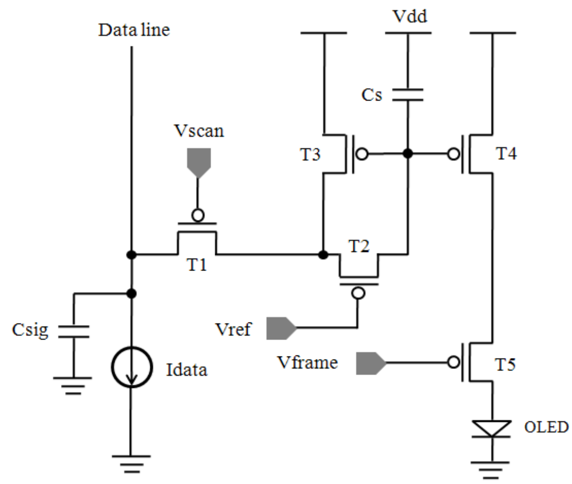
Organic light-emitting diode(OLED) displays have gained much attention due to their potential for thin, light-weight, low-power, and possibly flexible displays[2]. Recently, a-Si:H TFTs and poly-Si TFTs have been considered as the pixel element of AMOLEDs due to low manufacturing cost and its stable physical characteristics. When applying conventional 2-TFT pixel circuit to AMOLED panels, the OLED current varies substantially due to the threshold voltage variations of the driving TFTs. In order to solve the above problem, various pixel compensating circuits have been proposed[3,4]. The driving mechanisms for AMOLED are classified into two types; voltage programming method and current programming method. The voltage programming method compensates the problem of the threshold voltage degradation and is possible to employ the data drivers of current AMLCDs. However, the compensation of mobililty degradation is difficult to solve and an additional signal is needed in order to periodically refresh the gate voltage of the driving TFT. Current programming method compensates both the problem of threshold voltage degradation and mobility degradation. Also, influence of the voltage drop at the power supply line is neglected by self-compensation. Therefore, current programming method would be an attractive solution for AMOLED pixel structure design.

In this work, progress is made in driving AMOLED displays with organic TFTs, using a current mirror structure. This will be set as basic studies on using organic TFTs in AMOLED displays with some problems and its solution mentioned. Also, for future low cost displays, the results are based on soluble-processed Organic TFTs. With further improvements to be made on organic TFT devices, we can expect the performance and design margins to be improved. This work could be both set as a goal and as basic research information for future OTFT-AMOLED display development[5].

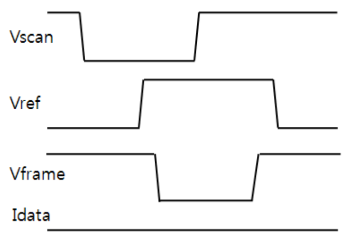
2. The Proposed Pixel Structure

2.1 Proposed Pixel Circuit

Fig. 1 shows our proposed pixel circuit based on organic TFTs and the timing diagram to operate the pixel structure. The switching and driving TFTs are all soluble-processed p-type organic TFTs. The proposed pixel circuit shows high linearity between input data current and output OLED current. Also, the compensation of threshold voltage(Vth) degradation of organic TFTs is effectively achieved by employing a current mirror scheme. This solves the problem of long programming time for driving low-luminance image by properly scaling the mirror TFTs(Transistors T3 and T4). However, this current mirror scheme operates only when the two mirror TFTs are matched.



(a)



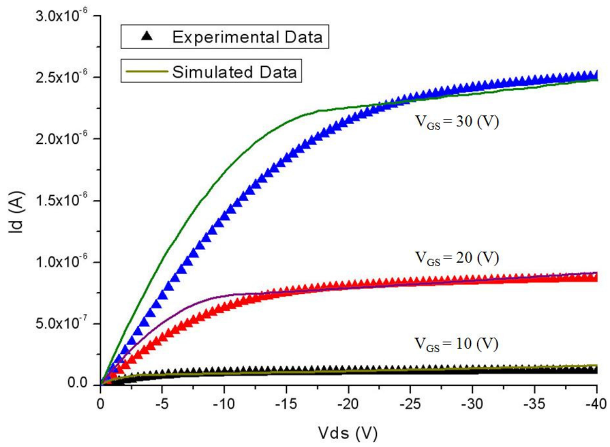
(b)

<Figure 1> Schematic of the proposed pixel structure(a) and Timing diagram(b)

The proposed pixel circuit consists of four switching Organic TFTs and one driving Organic-TFT(T4) with one storage capacitor(Cs). The operation of the proposed pixel circuit is as follows. First, in the initial state, only the refresh voltage(Vref) is set low so as to diode connect the transistor T3. Second, the scan voltage(Vscan) is set low to make a current path from the data current(Idata) to Transistors T1 and T3. This programs the gate voltage of Transistors T3 and T4 to the applied data current, which is stored by the storage capacitor(Cs). Third, Vref is set high which turns off Transistor T2 and by setting Vframe low, the current path from T4 to T5 and the OLED is formed which supplied the OLED with uniform current.

2.2 Circuit Simulation

To verify the proposed pixel circuit, we have performed circuit simulation using HSPICE circuit simulator. By measuring the device characteristics of the Organic TFT by using HP4156B, the model parameters were extracted by precise curve fitting. Fig. 2 shows the measured and simulated output characteristics of organic TFT, which was matched to HSPICE level 3 MOSFET model. We employed these modeling results for further SPICE circuit simulation.



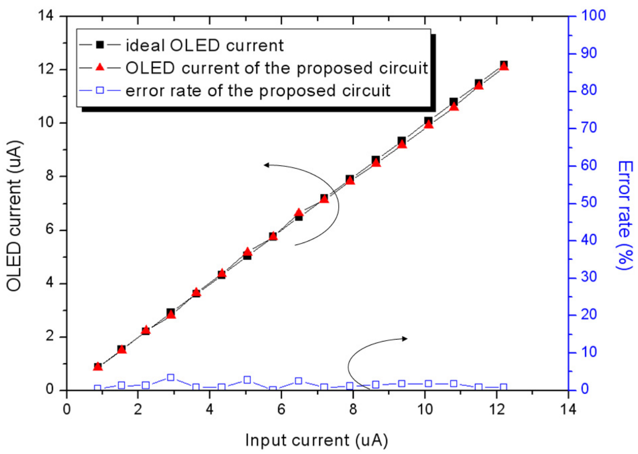
<Figure 2> The measured and simulated output characteristics of Organic TFT

The soluble-processed organic device parameters are listed on Table 1. Since the active layer is a soluble material for low temperature manufacturing, the characteristics are deteriorated compared to state-of-the-art pentanece active layer devices. However, we expect the characteristics to improve process development.

<Table 1> Device parameters of Organic TFT

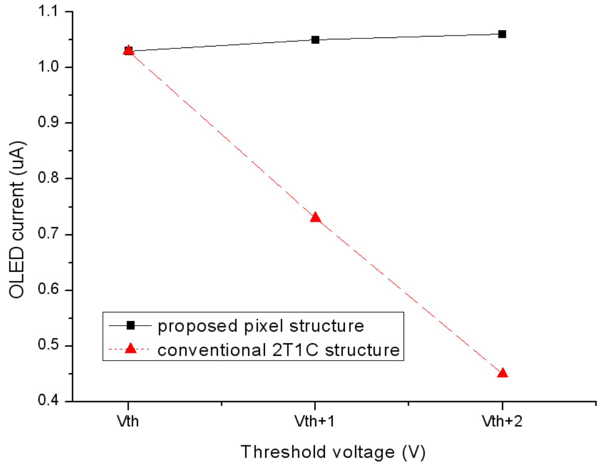
parameters	mobility	on/off ratio	s-factor	Vth
value	0.2	1.03E05	2.28	-5
dimension	cm^2/Vs	-	V/dec	V

Fig. 3 represents the linearity characteristics between input current and output OLED current for optimized design parameters of the pixel circuit. As can be seen from the results, high linearity is achieved at all input current levels of interest(1uA-12uA). Also, error rate is measured from $\triangle I_{OLED}/I_{OLED}(\%)$ which shows less than 5% error rate in all input current levels. Thus, the proposed pixel circuit can be applied to pixels requiring high accuracy input levels.



<Figure 3> Linearity characteristics between input current and output OLED current with difference from the ideal

Simulation was conducted with stress induced to the organic TFTs in order to see the stability of the pixel circuit during long time operation. This could be carried out by modifying the organic TFT device parameters. The results of modifying the mobility and operating temperature had insignificant influence on the output OLED current. Therefore, we conclude that the main stress factor is the threshold voltage shift of the organic TFT. This will have the most influence on AMOLED operation and thus, focus on the compensation of threshold voltage shift of the transistors. The threshold voltage deviation poly-Si is reported to be around 0.33 V[3], therefore, in this work we have set the values to 1 V for organic TFT worst case operation.



<Figure 4> OLED current variation of the proposed and conventional pixel structures with threshold voltage shift

Fig. 4 shows the OLED current variation of the proposed pixel structure and conventional pixel structure, with threshold voltage shift from 1V to 2V. As can be seen from the results, the proposed pixel circuit successfully compensates the threshold voltage degradation of organic TFTs, while the conventional 2T1C structure highly degrades the OLED current with threshold voltage shift.

3. Conclusion

We propose a new active-matirx organic light emitting diode (AM-OLED) pixel design based on organic TFTs, which consists of five organic TFTs and one capacitor, and verify the proposed pixel circuit using SPICE simulation. The simulation results, based on the measurement of organic-TFT's electrical characteristics, exhibit reliable linear characteristics between the input current and output OLED current. Also, the proposed pixel structure successfully compensates the threshold voltage degradation of TFTs and OLED. The proposed circuit may be suitable for future organic TFT based AMOLED display development.

4. Acknowledgements

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