a-Si:H HEX-TFTs, a New Technology for Flat Panel Displays

Hojin Lee*, Juhn S. Yoo, C.-D. Kim**, In Byeong Kang**, and Jerzy Kanicki***

* Solid-State Electronics Laboratory, Department of Electrical Engineering and Computer Science,
University of Michigan, Ann Arbor, Michigan 48109, USA
** LG Philips LCD Research & Development Center, An-Yang, Korea

ABSTRACT

Single and multiple Hexagonal a-Si:H TFTs were designed and fabricated. It is shown that parallel connection of those devices increase the OLED output current to desirable value for give pixel electrode design. Enhanced electrical properties and stability of multiple Hexagonal TFTs are discussed in comparison to the single standard TFT.

1. INTRODUCTION

Due to its low carrier field-effect mobility, hydrogenated amorphous silicon thin-film transistor (a-Si:H TFT) has been suffering from a low drain current for a given gate / drain bias which becomes a critical factor in driving TFT for AM-OLEDs or in-plane gate drivers [1] for flat panel displays. In a-Si:H TFT, a high drain current can be achieved by simply increasing the channel width for a given length (i) using rectangular electrodes or (ii) comb-shaped electrodes [2]. However, it is known that the single transistor with large channel width results in not-acceptable TFT threshold voltage variations [3]. In this paper, to address above mentioned issues, we are proposing parallel-connected hexagonal a-Si:H TFTs for a given pixel circuit to achieve a high output current stable over time. We choose the hexagonal shape for multiple a-Si:H TFT structure since it represents an optimum shape to minimize the areal occupation when TFTs are integrated together in parallel in a given circuit.

First we report on single and multiple hexagonal a-Si:H TFTs (HEX-TFTs) electrical characteristics. We also discuss the impact of number of the HEX-TFT on the extracted key device electrical parameters such as sub-threshold slope, field-effect mobility, and threshold voltage. Then, we compare electrical properties of the multiple HEX-TFT connected in parallel with standard single a-Si:H TFT having different equivalent channel widths. To our best knowledge, this paper represents the first investigation of the electrical characteristics of single and multiple HEX-TFTs.

2. EXPERIMENTAL RESULT AND DISCUSSION

In this research, a series of a-Si:H TFTs connected in parallel, with a gate length of 5 μm, consisting of octuple (Hex-8), quadruple (Hex-4), double (Hex-2), and a single Hexagonal TFT (Hex-1), were fabricated as listed in Table I. All HEX-TFT structures were constructed of the identical single Hexagonal a-Si:H TFT as a base unit, Figure 1, and all gate, drain, and source electrodes of the a-Si:H HEX-TFTs are connected in parallel, respectively. To characterize the electronic properties of multiple HEX-TFT connected in parallel, we first measured the output characteristics for different configurations, Figure 1. The output current of multiple Hexagonal a-Si:H TFTs increases linearly with the increasing number of a-Si:H HEX-TFT unit in parallel. To check linearity of the total output current with the number of HEX-TFT, we calculated the total output current value for different multiple a-Si:H HEX-TFT configurations by multiplying the number of HEX-TFTs by the output current of a single a-Si:H HEX-TFT measured at V_{GS}=20V and V_{DS}=20V, and compared its magnitude with the actual output current values of multiple HEX-TFTs. The measured output currents are only slightly higher (>10%) than the calculated values but show a very good linearity with the number of multiple HEX-TFTs for both drain bias conditions. Therefore, using this unique advanced a-Si:H TFT technology, a desirable output current level per pixel can be obtained by just adjusting a number of HEX-TFTs for a given pixel design.

Figure 2 shows a variation of the threshold voltage (V_{TH}) and field-effect mobility (μ_{FE}) as a function of number of Hexagonal a-Si:H TFTs. Experimental results reveal that all HEX-TFTs yield almost the same μ_{FE} and V_{TH} values, indicating that the μ_{FE} and V_{TH} are not affected by numbers of the HEX-TFTs connected in parallel. For the comparison, we also fabricated the standard a-Si:H TFTs with different channel widths, 100, 200, 500, and 1000 μm, and channel length, L=6 μm. As shown in Fig. 3, for standard a-Si:H TFTs, μ_{FE} does not change but the V_{TH} increases with the increasing channel width. Hence, we expect that the V_{TH} increase will be more severe if the TFT channel width increases to value higher than 1000 μm to be comparable to the total width of Hex-4 or Hex-8 a-Si:H HEX-TFTs.

5. CONCLUSION

Considering excellent electrical properties of parallel-connected a-Si:H HEX-TFTs, we expect that this new advanced a-Si:H TFT technology is suitable for driving TFTs to be used in AM-OLED or gate-drivers which require high ON-currents and adequate electrical stability.

REFERENCES

[1] V. M. Da Costa et al, IEEE Journal of Solid-State Circuits, vol. 29, pp. 596-600 (1994).

[2] N. Matsuki et al, Thin Solid Film, vol. 486, pp. 210-213 (2005).

[3] A. T. Hatzopoulos et al, IEEE Trans. Electron Devices, vol. 54, pp. 1265-1269 (2007).

	Channel Lengh	Number of TFT	Effective Channel Width (W_{EFF})	
			Linear	Saturation
Hex-1	5 μm	1	285 μm	300 μm
Hex-2	5 μm	2	570 μm	600 μm
Hex-4	5 μm	4	1140 μm	1200 μm
Hex-8	5 μm	8	2280 μm	2400 μm

$W_{EFF\text{-}Linear}$ = Number of HEX-TFT × 6 × (R_1 + L/$3^{1/2}$)
$W_{EFF\text{-}Saturation}$ = Number of HEX-TFT × 6 × R_2

Table 1 Device dimensions of various multiple Hexagonal a-Si:H

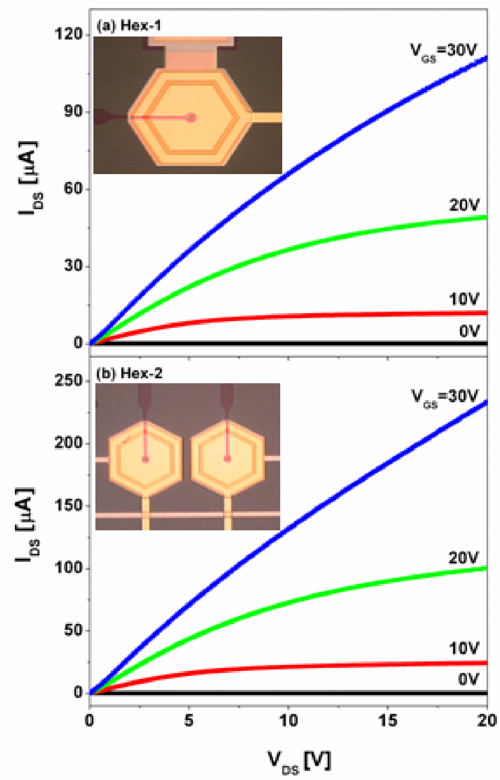

Figure 1 Output characteristics and top-views of multiple a-Si:H Hexagonal TFTs; (a) single (Hex-1) and (b) double (Hex-2)

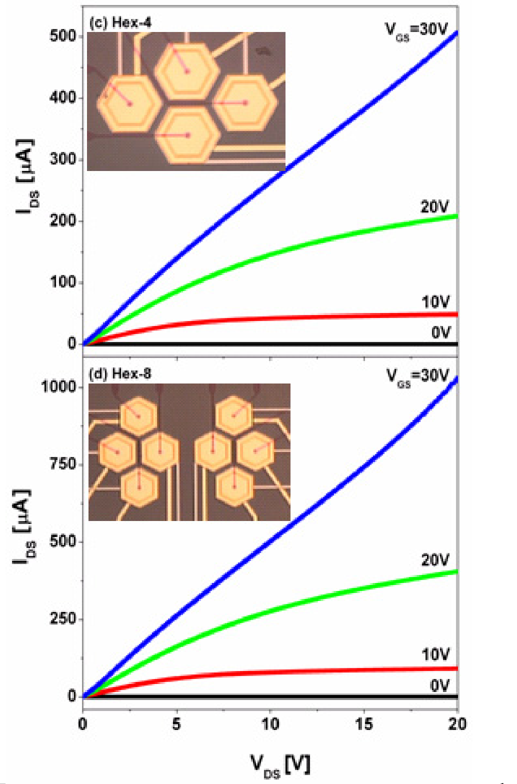

Figure 1 Output characteristics and top-views of multiple a-Si:H Hexagonal TFTs; (c) Quadruple (Hex-4) and (d) Octuple (Hex-8) a-Si:H HEX-TFTs.

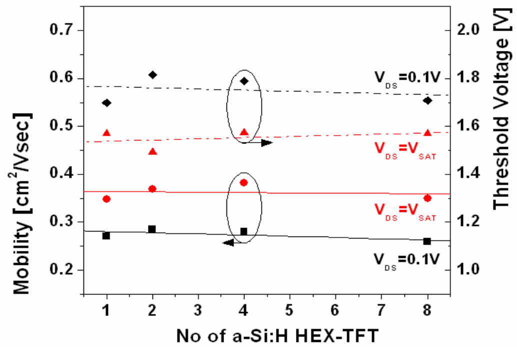

Figure 2 The trend of field-effect mobility and threshold voltage of multiple Hexagonal a-Si:H TFTs as a function of the number of TFTs.

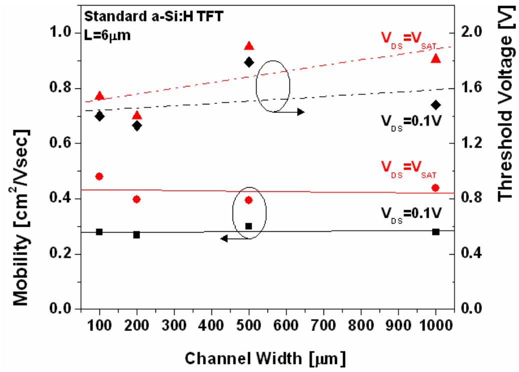

Figure 3 The trend of field-effect mobility and threshold voltage of standard TFT as a function of different channel widths.