A New Evaluation Method of the Threshold Voltage for a Low Temperature Poly-Silicon Thin Film Transistor in a Source Follower Configuration

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Abstract

A new evaluation method of the output voltage for the source follower composed of a LTPS TFT is proposed. This method provides an effective and more precise description about the unsaturated output voltage behavior of the source follower with a LTPS TFT. A new interpretation of the threshold voltage of LTPS TFT is also provided.

1. Introduction

The LTPS TFT (Low Temperature Poly-Silicon Thin Film Transistor) is taken as a promising technology for its larger current, brighter and higher resolution used in the pixel as compared to amorphous-silicon TFT. Besides, owing to its high mobility, LTPS TFT has the compatibility of consisting the peripheral circuits to realize the dream of SOG (System On Glass). However, the special behavior of the transition region of the LTPS TFT makes it difficult to design the circuit. Many researches[1-4] have been made to interpret the "threshold voltage" of the LTPS TFT, while circuit designers nowadays are still using the device parameters extracted from LTPS TFT with the method applied originally to MOSFET[5]. These parameters of TFTs might not be able to properly represent the TFT characteristics and they will bring extra difficulties to the designers to predict the performance of the TFT circuit.

A source follower configuration as shown in Fig.1 is widely used in analog circuits and its application is directly related to the definition of threshold voltage (Vth) of the TFT. A typical way to specify a source follower is by the voltage drop between the gate Vg and source electrode Vs of the transistor as the source follower stops charging. Conventionally, when the source follower stops charging, the voltage difference between gate and source will reach the Vth of the transistor. In this work, it is found that as the transistor is changed to a LTPS TFT, the charging characteristics of the capacitance is much different from our expectation and a new evaluation method of the output voltage is proposed.

2. Simulation Results

Figure 2 (a) shows the drain current dependence on the gate voltage, namely the Id-Vgs curves, of three typical LTPS TFTs. From the widely used extraction method, e.g., "Constant Current Method" which extracts threshold voltage at the gate voltage at the normalized current at Id/ (W/L) =100nA, these three TFTs have the same threshold voltage. However, from Fig. 2(b), it can be seen that the output voltages do not stop at the voltage of Vgs-Vth, namely around 3.5V, which is much different from our expectation. Furthermore, their output voltages show an unsaturated behavior. The reason the output voltages do not swiftly saturate is that LTPS TFTs have more gradual subthreshold transition behaviors than MOSFETs do. Furthermore, it is noticed that this special transition region is just where the typical constant current method designates. Thus, the concept of "threshold" for a LTPS TFT should be modified to a region instead of a specific point.

Since in source followers the voltage drop of gate to source (Vgs) and drain to source (Vds) keeps changing, it would be more appropriate to examine the current behavior with the changing Vs and fixed Vd and Vg. In Fig. 3, the characteristics of the TFTs are reexamined by their Id-Vs curves, which exhibit the dependence of Id on the source voltage Vs with Vg and Vd are kept constant. Comparing the source voltage in the Id-Vs curves and the voltage drop in the source follower charging curves, it depicts that the output voltage of the source follower is related to the current behavior of region B in the Id-Vs curves.

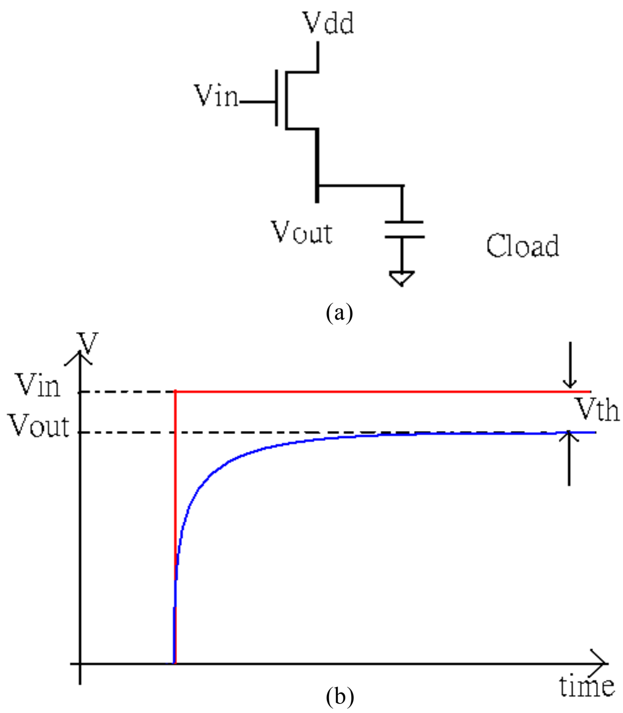
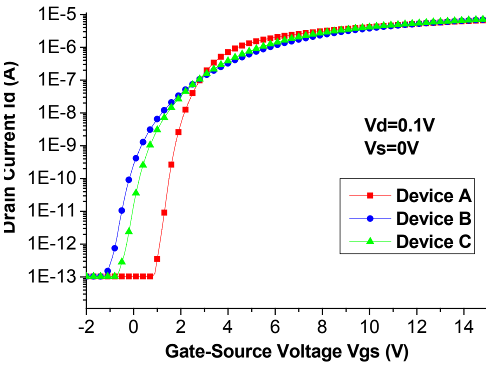
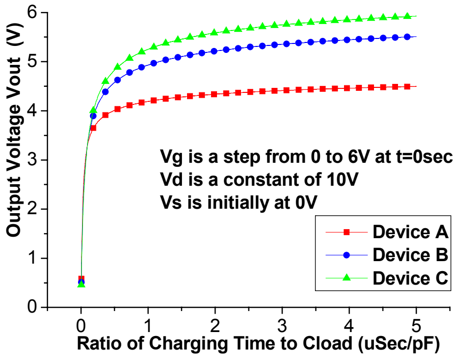


Fig.1 (a) the typical configuration of a source follower.
(b) The charging characteristics of the typical source follower



(a)



(b)

Fig. 2. (a) The Id-Vgs of the three poly-Si TFT curves with the same threshold voltage. (b) The charging behavior of the source followers using the three TFTs.

To verify the relation of the charging behavior and the device characteristics in region B, we modify the zero-bias threshold voltage parameter Vto of the previous three devices and name them as Device D, E and F, respectively. In Fig. 4, it can be seen that these devices have different threshold voltage and their Id-Vs curves coincide with the constant current at normalized drain current Id/(W/L)=100nA. As illustrated in Fig. 5, these devices have almost the same output voltage. Intuitionally, devices having the same threshold voltage should have the same output voltage in the source follower. However, in LTPS TFT source followers, we do not observe this nature. Besides, comparing Fig. 4(b) and Fig. 5, it is proposed that the Vth can be extracted by the voltage difference between the constant Vg and the Vs at the normalized current in the Id-Vs curves. This new extraction method is straightforward and can be applicable in measurement apparatus.

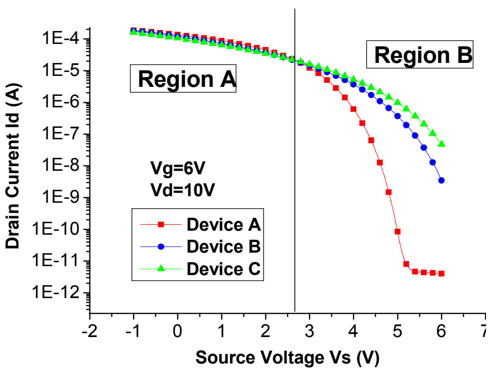
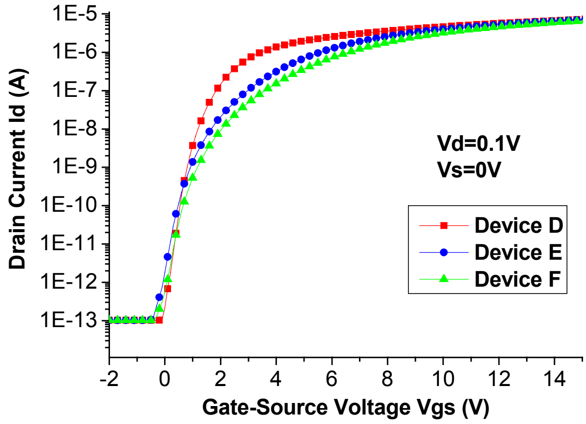
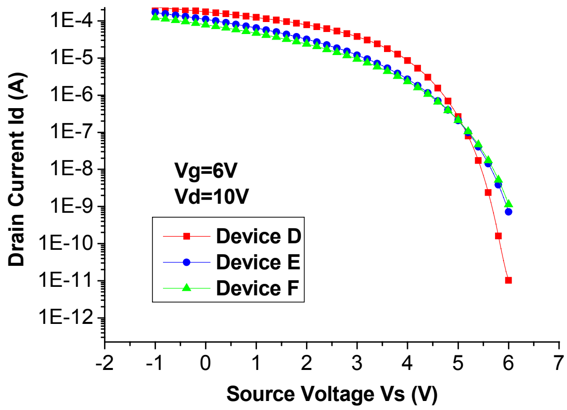


Fig. 3 The Id-Vs curves of the device A, B, and C which have the same Vth with the typical extraction method.



(a)



(b)

Fig. 4. (a) The Id-Vg curve of the other three devices. They have almost the same different Vth. (b) The Id-Vs curves.

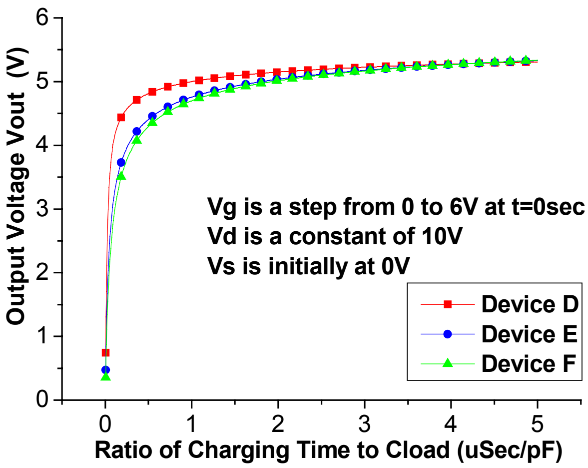


Fig. 5 The charging curves of the source follower for three TFTs corresponding to Fig 4(b).

In order to compare the Id-Vs curves of the MOSFET and the LTPS TFT, Fig.6 shows the Id-Vg and Id-VS curves of a typical MOSFET. In Fig.6(a), it can be seen that for MOSFET, the device is swiftly turned on as Vg is changed above zero volt and the drain current increase rapidly. Using the extrapolation method, the threshold voltage can be extracted and the value is just about 1V. This rapidly-increase current characteristic can also be seen in the Id-Vs curve. In Fig.6 (b), the drain current is gradually reducing as the voltage drop Vg-Vs approaches the threshold voltage, namely Vs=1V in Fig.6 (b). When the source voltage is increased beyond 5V, namely the voltage drop Vg-Vs is smaller than Vth, the current quickly decreases and the device can be taken as turned off. In MOSFET, the switching behavior about the threshold voltage is clear and rapid, therefore extracting the threshold voltages from these two curves are both proper. However, for LTPS TFT, owing to its special transition characteristics, the threshold voltage extracted from Id-Vg and Id-Vs may lead to different value and may bring difficulties to circuit designers. For this reason, it is proposed that as used in source followers, the threshold voltage of the LTPS TFT should be extracted from the Id-Vs curves with Vg and Vs kept constant, since this proposed method can give a more precise output voltage.

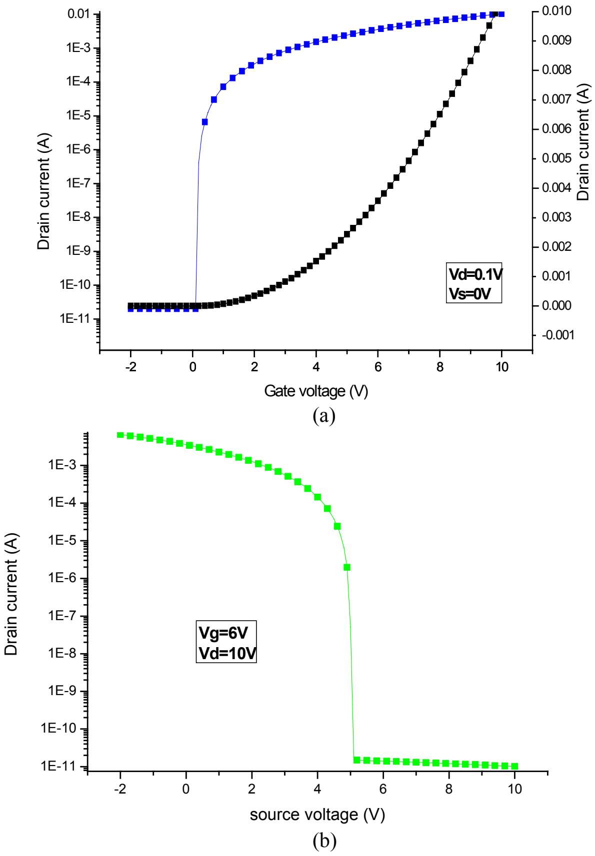


Fig. 6 (a) The Id-Vg curves of a typical MOSFET. (b)The Id-Vs curves of the typical MOSFET with Vg and Vd kept constant.

3. Conclusions

We have proposed a new method to predict the output voltage for the source follower including a LTPS TFT. Although LTPS TFTs have more gradual transition characteristics than MOSFETs, usage of this method can still provide a precise way to estimate the output voltage. This method also provides a new interpretation of the Vth for LTPS TFTs.

4. Acknowledgements

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