Abstract: In poly-Si TFTs, the kink-effect much more pronounced than in bulk crystalline devices because of the floating body effect and the large voltage drops at the grain boundaries. In this paper, we propose a new kink effect model which expresses the multiplication factor as exponential functions of $V_{DS}$. Using the model, we obtained excellent agreements between the measured and calculated characteristics for TFT with channel lengths as short as 4um.

Keywords: LTPS TFT; I-V characteristics; Kink effect.

Introduction
Low Temperature Poly-Silicon (LTPS) Thin-Film Transistors (TFTs) are expected to play an important role in the next generation flat-panel display technology. In order to use LTPS TFTs in circuits, an accurate modeling of device characteristics is essential. In poly-Si TFTs, the kink effect is much more pronounced than in crystalline devices because of the large voltage drops at the grain boundaries. Therefore, proper modeling of the kink effect is very important for the accurate description of the I-V characteristics of poly-Si TFTs.

In this paper, we propose a new empirical model for the kink effect in poly-Si TFTs. The kink effect is expressed by defining a multiplication factor $M = \frac{I_{DS}}{I_a}$, where $I_{DS}$ and $I_a$ are drain currents with and without kink effect, respectively.

Model Formulation and Results
Above threshold, the drain current in the linear region of poly-silicon TFT can be expressed as

$$I_D = \mu C_{ox} \frac{W}{L} \left[ (V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2\alpha} \right], \quad (3)$$

where $\mu$ is the carrier mobility, $C_{ox} = \varepsilon_{ox} / t_{ox}$ is the gate-oxide capacitance per unit area, where $\varepsilon_{ox}$ is the dielectric permittivity and $t_{ox}$ is the thickness of the gate-oxide. $W$ and $L$ are the channel width and length, respectively. $V_{GS}$ and $V_T$ are gate-source voltage and the threshold voltage, respectively. $\alpha$ is the body-effect related parameter.

In the saturation region, the drain current can be described as,

$$I_D = \alpha \left( \frac{1}{2} \mu C_{ox} \frac{W}{L} (V_{GS} - V_T)^2 \right), \quad (2)$$

The Eqs (1) and (2) can be combined into one equation as follows[1],

$$V_{DSe} = \frac{V_{DS}}{1 + \left( \frac{V_{DS}}{V_{sat}} \right)^{M_{SS}}}^{\frac{1}{M_{SS}}}, \quad (4)$$

where $V_{sat}$ is above-threshold saturation voltage given as[4],

$$V_{sat} = \frac{1}{M_{SS}} \cdot \alpha \cdot V_{GT}, \quad (5)$$

and $M_{SS}$ is the fitting parameter which controls the transition between the triode region and the saturation region. For long-channel devices, we typically have $M_{SS} >> 1$ in which case $V_{sat} \approx \alpha \cdot V_{GT}$.

![Figure 1](image.png)

Figure 1. Comparison of the $I_{DS}$-$V_{DS}$ curves by measurement (solid) and the modeling not including the kink effect (dotted)

Figure 1 shows modeled $I_{DS}$-$V_{DS}$ curves which calculated with takes the saturation effect into consideration [5]. We can observe that the agreement between the measurement (solid line) and the model (dotted line) is quite good in the linear region. However, for large $V_{DS}$ the agreement between poor. This is due to kink effect.

We define multiplication factor $M$ due to kink effect as the ratio of measured $I_{DS}$ to the calculated $I_{DS}$ not including the kink effect.
Figure 2. Current multiplication factor $M$ defined as the ratio of measured $I_{DS}$ to the modeled $I_{DS}$ not including the kink effect (solid). Dotted lines represent exponential fit in the large $V_{DS}$ region.

Figure 2 shows the multiplication factor $M$ obtained from the $I_{DS}$ curves in Fig. 1 (solid lines). We can observe that $M$ is a strong function of both $V_{GS}$ and $V_{DS}$, and for large values of $V_{DS}$, $M$ can be modeled as

$$M = K_1(V_{GS}) \exp[K_2(V_{GS})V_{DS}],$$

where $K_1$ and $K_2$ are $V_{GS}$-dependent parameters. The dotted lines in Fig. 2 represent the results of this fitting.

Figure 3 shows the extracted $K_1$ and $K_2$. We can see that $K_2$, which is responsible for the large increase of current at large $V_{DS}$, is almost a linear decreasing function of $V_{GS}$. The solid lines in Fig. 3 (a) and (b) represent fittings to the extracted parameters.

Figure 3. Extracted kink effect parameters (a) $K_1$, (b) $K_2$

Figure 4. $I_{DS}$-$V_{DS}$ characteristics with $V_{GS}$-steps: 0.5V. (circles: measurement, solid line: calculation with kink effect, dotted lines: calculation without kink effect.)

Conclusion

In conclusion, we proposed a new kink effect model which expresses the multiplication factor as exponential functions of $V_{DS}$. Using the model, we obtained excellent agreements between the measured and calculated characteristics.

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