Self-heating Induced Linear Kink Effect in Poly-Si TFTs

***Seok-Woo Lee**, HoChul Kang, Kum Mi Oh, Eugene Kim, Soo-Jeong Park, Kyoung Moon Lim, Chang-Dong Kim, and In-Jae Chung*

LG. Philips LCD R&D Center, Kyongki-do, 431-080 Korea, ardorsu@lgphilips-lcd.com

Abstract

Linear kink effect (LKE) induced mainly by self-heating on the reliability of divided-channel poly-Si TFTs has been studied. The LKE was enhanced for compact designed structure to achieve narrow bezel, which was explained by the difference in heat dissipation capability, thus self-heating immunity in TFT.

1. Introduction

Low-temperature polycrystalline silicon (LTPS) thin-film transistor (TFT) is widely attracted for the integration of system on panel (SOP). Compact designed "narrow bezel" is one of the requirements to develop value-added SOP. Degradation caused by self-heating is one of the critical reliability issues of poly-Si TFTs [1], which is enhanced as TFT width is increased. Divided-channel was proposed to improve self-heating induced degradation of large-width TFT [2].

Self-heating induced linear kink (SHLK) effect, occurring in the linear operation regime [3], was studied and SHLK effect on device reliability was also examined with respect to TFT area with same width/length (W/L) dimension. The trade-off, shown in this paper, between suppression of self-heating effect and reduction of TFT area will give an insight for designing compact-designed SOP with increased reliability.

2. Experimental

Top gate CMOS poly-Si TFTs with W/L dimension of 72/6 ㎛/㎛ were fabricated using low temperature process, where TFT types with same device dimension but different area were split as a function of divided-channel W/L ratio (DCR) from 1 to 12.

Firstly, stacked SiN_x and SiO_2 buffer layers were deposited sequentially on a glass substrate by plasma enhanced chemical vapor deposition (PECVD) not only to suppress mobile charge diffusion from glass substrate but also to reduce the self-heating effect by using SiN_x. Then, poly-Si layer with average grain length of 2 ㎛ was crystallized by sequential lateral solidification (SLS) method with laser energy density over 1000 mJ/cm^2. The thickness of dehydrogenated precursor PECVD amorphous silicon was 50 nm. Channel doping was applied to achieve symmetrical adjustment of V_{th} between N-TFT and P-TFT. After the poly-Si active layer patterning, diluted HF cleaning was applied to remove native oxide and residual impurities, and a 75 nm-thick SiH_4-based gate oxide was deposited. After that, gate metallization and source and drain (S/D) doping was followed. A 500 nm-thick interlayer was deposited and the S/D doped region was thermally activated. Finally, passivation layer was deposited after S/D metallization, and thermal anneal was applied to improve hydrogenation efficiency.

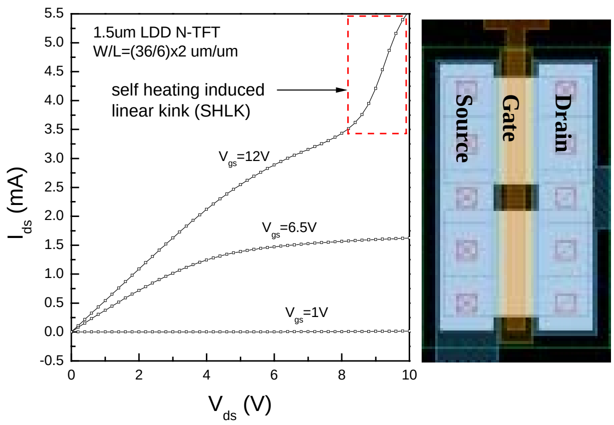

Fig. 1 Output characteristics with self-heating induced linear kink and layout image of 2-channel-devided structure.

3. Results

Fig. 1 shows output curve and TFT layout image of LDD N-TFT with W/L=72/6 ㎛/㎛ adopting 2-channel-divided structure, which is composed of parallel-connected 2 TFTs with an evenly-divided-channel of W/L=36/6 ㎛/㎛, thus the DCR is defined here as 6.

Abnormal kink was observed and started at linear regime of V_{ds}=8V and V_{gs}=12V, considering V_{th} to be around 1V. No noticeable kink phenomena were found at lower V_{gs} curve including saturation region, thus the kink was categorized as linear kink. It was assumed that the linear kink was induced by combined effect of the generally known drain avalanche induced floating body effect [4], and self-heating effect. The latter was thought to play the more important role to the linear kink because the linear kink was started at high power operation regime, thus self-heating region.

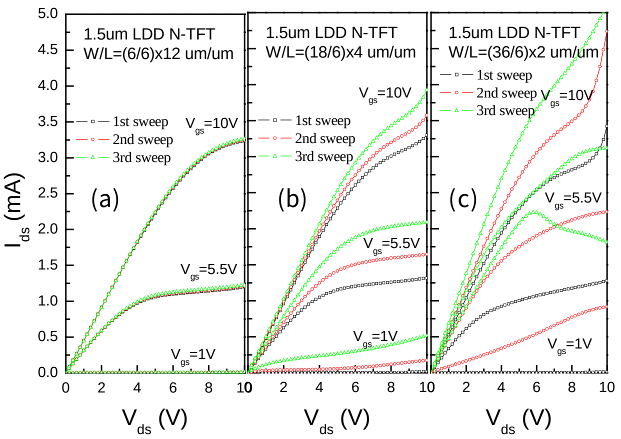

Fig. 2 3-times repeated output curves as a function of divided-channel W/L ratio (DCR), where (a) DCR=1, (b) DCR=3, and (c) DCR=6.

To find out the self-heating effect on the linear kink, repeated output curves were compared as a function of DCR. Fig. 2 shows 3-times repeated output curves as a function of DCR. Drastic degradation of output curve with repeated sweep was observed as the DCR increased, where the increase of DCR means TFT area reduction because the number of active-removed-dividing-region is decreased as DCR is increased.

The linear kink phenomena became aggravated as TFT area was decreased. It was also found that the self-heating effect was enhanced with increasing W/L ratio of TFT, but decreased with increasing TFT area with the same TFT W/L dimension. These results explain that the linear kink was enhanced by self-heating effect, thus named as self-heating induced linear kink (SHLK), and strongly depended on TFT area.

To examine the dependence of SHLK on TFT area, linear kink starting power (P_{kink}) was compared as a function of DCR, where the P_{kink} was defined by $I_{ds} \times V_{ds}$ at the starting point of the linear kink. Fig. 3 shows P_{kink} and normalized TFT area ($A_{normalize}$) as a function of DCR. P_{kink} was drastically decreased as DCR was increased, which could be explained by the dependence of self-heating induced degradation on TFT area. $A_{normalize}$ was also reduced as DCR was increased. Considering the same device dimension of test samples but TFT area, self-heating induced degradation monitored here with P_{kink} became aggravated as TFT area decreased because applied power density causing self-heating increased as TFT area was reduced.

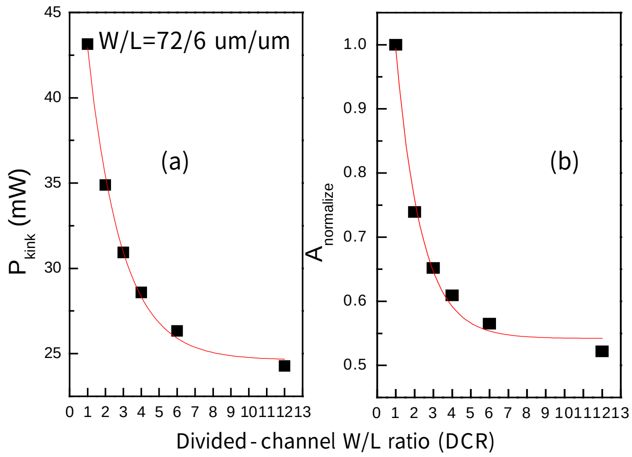

Fig. 3 Divided-channel W/L ratio (DCR) dependence of (a) SHLK starting power (P_{kink}), and (b) normalized TFT area ($A_{normalize}$).

To analyze the P_{kink} dependence on TFT area in more detail, P_{kink} normalized to TFT area ($P_{kink}/A_{normalize}$) was compared in Fig. 4 with respect to DCR. The

$P_{kink}/A_{normalize}$ was almost same regardless of DCR, which enabled the explanation that the linear kink was mainly caused by self-heating effect.

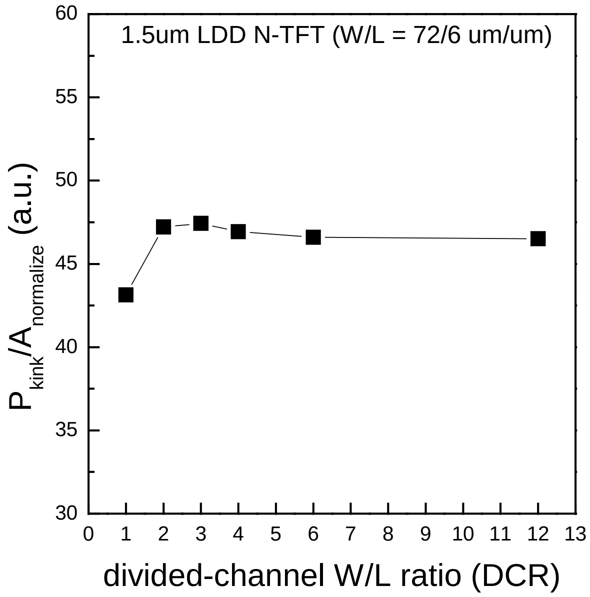

Fig. 4 P_{kink} normalized to TFT area ($P_{kink}/A_{normalize}$) as a function of DCR

4. Conclusions

Linear kink phenomenon was studied with respect to TFT design scheme to achieve narrow bezel. It was found that the linear kink was mainly caused by self-heating effect, because the kink stated at high power region and the linear kink became aggravated as TFT area was decreased. There exists a trade-off between achieving narrow bezel by reducing TFT area and improving self-heating induced degradation by increasing TFT area, which should be considered in designing to integrate circuit on a glass substrate.

5. References

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