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RF Characteristics of Trigate Poly-Si Thin-Film Transistors with Different Layout Geometries

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Abstract

The dc and RF characteristics of trigate poly-Si thin-film transistors with different layout geometries are investigated. To achieve the optimal RF performance, devices with different layout geometries are compared. A new tapered channel is also demonstrated for improving high-frequency parameters in the saturation region.

1. Introduction

Owing to the low-temperature and low-cost processes, polycrystalline silicon (poly-Si) thin-film transistors (TFTs) have been extensively studied for applications to large area electronics and 3-D stackable circuit [1][2]. For higher driving current and better RF performance, the gate length of TFTs has to be scaled down, which leads to serious short channel effect. Recently multi-gate TFT structures were presented to enhance the gate controllability and suppress the short channel effect [3]. Excellent electrical performance was revealed for devices with the gate length scaled down to 120 nm [3]. Moreover, with utilizing the laser-processed and CMP-thinned techniques in the poly-Si TFT process, a 6.8 GHz voltage-controlled oscillator was reported [4]. It demonstrates that the poly-Si TFT technology is feasible for low-cost RFIC application such as RF identification (RFID) and wireless transceivers in Internet of Things (IoT). In this work, we experimentally examine the dc and RF characteristics of trigate poly-Si TFTs with different layout geometries.

2. Device Structure

Trigate poly-Si TFTs were fabricated using a through-silicon-via (TSV) free monolithic 3D-IC process with a sub-20nm-thick channel [4]. For RF applications, trigate TFTs were designed with a multi-finger gate and multi-channel layout to reduce the gate resistance. The device under test features 20 gate fingers, each of which crosses over 5 channels; thereby, the total channel number is 100. Two type of devices are compared in this work. Fig. 1(a) shows the standard multi-channel TFT structure, which has uniform channel width. To improve the RF performance, we propose a tapered channel layout, where the channel width increases gradually from source to drain. Owing to the channel potential modulation, the carrier velocity can be increased in the saturation region.

3. Results and Discussion

Fig. 2 shows the dc characteristics of trigate TFTs with different source/drain (S/D) extension designs. These devices exhibit excellent gate controllability (subthreshold swing SS~100 mV/decade) with gate length of 120 nm. It is the main merit of multi-gate devices. Additionally, we find the drain current increases with increasing the extension width (W_E) or decreasing the extension length (L_E), owing to the reduction of parasitic S/D resistance. Lower parasitic resistances also enhance the cutoff frequency (f_T) and the maximum oscillation frequency (f_{max}), as depicted in Fig. 3. Less improvement is observed in devices with a larger W_E, indicating the parasitic capacitances between gate and S/D contact might be increased with W_E. Compared to the state-of-the-art RF planar TFTs (f_T=17 GHz, SS~300 mV/decade) [5], better gate controllability and RF performances are obtained simultaneously in trigate devices.

Fig. 4 compares the output characteristics of trigate TFTs with standard and tapered channel structures. The average channel width is kept to the same for these two samples. Higher drain currents in the saturation region are observed in the tapered one because of the increase of channel carrier velocity. The values of f_T and f_{max} have also been boosted in devices with the tapered channel (see Fig. 5). Compared to the standard device, the enhancements of peak f_T and peak f_{max} are 5% and 17%, respectively. More improvement in f_{max} is related to the reduction of gate-drain capacitance. It is another attribute of the tapered channel with the channel potential modulation [6].

4. Conclusions

Trigate poly-Si TFTs exhibit better gate controllability while retain as good high-frequency properties compared to the planar counterpart. To further improve the RF performance, one can reduce the L_E or utilize the tapered channel structure according to our experimental results. The high f_T and f_{max} in our devices indicate the poly-Si TFT could be a suitable candidate for low-cost RFIC applications.

Acknowledgements

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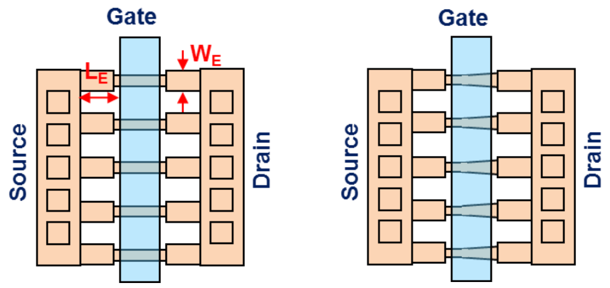
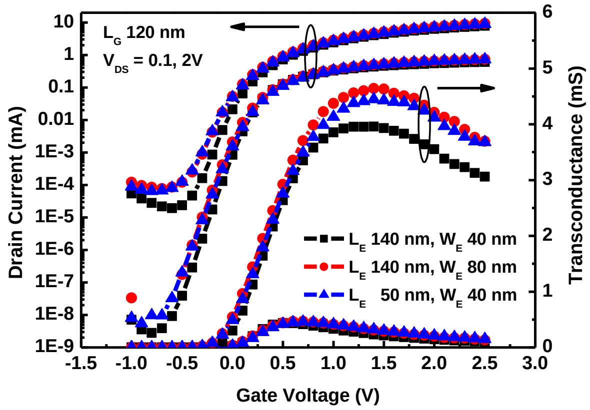
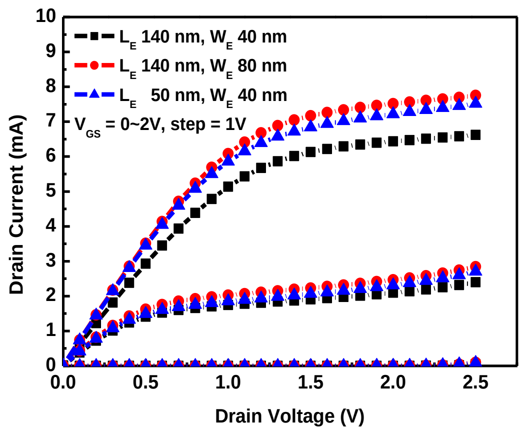


(a) (b)

Fig. 1 Layout structure of multi-channel trigate TFTs in a unit cell with (a) standard and (b) tapered channel structures.



(a)



(b)

Fig. 2 (a) Transfer and (b) output characteristics of trigate TFTs with different S/D extension lengths and widths. The gate length and unit channel width are 120 nm and 40 nm, respectively.

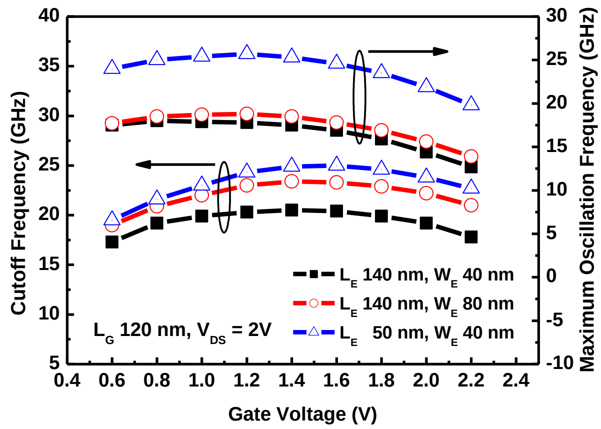


Fig. 3 Cutoff frequency and maximum oscillation frequency of trigate TFTs with different extension lengths and widths. The gate length and unit channel width are 120 nm and 40 nm, respectively.

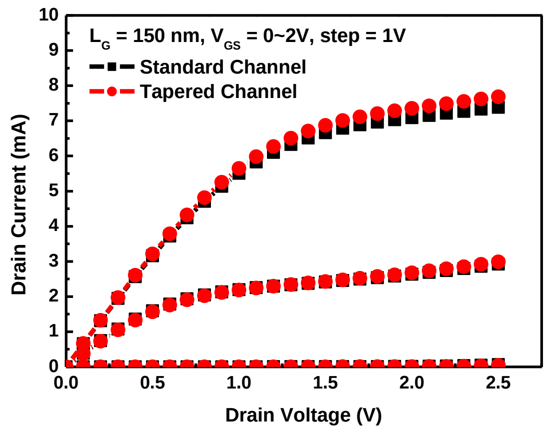


Fig. 4 Output characteristics of trigate TFTs with different channel layout designs. The gate length and unit average channel width are 150 nm and 50 nm, respectively.

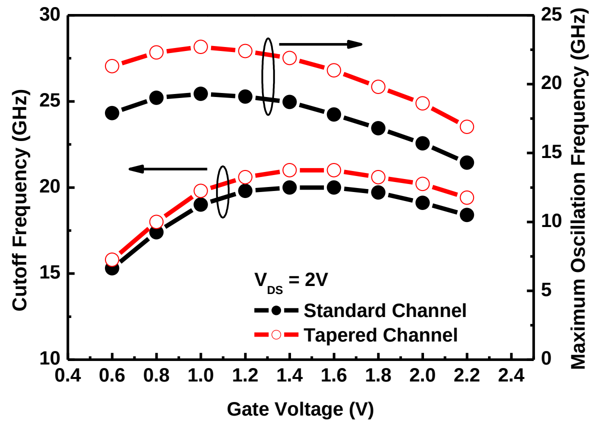


Fig. 5 Cutoff frequency and maximum oscillation frequency of trigate TFTs with different channel layout designs. The gate length and unit average channel width are 150 nm and 50 nm, respectively.