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Drain-Extended FinFET Technology for RF Power Applications

Bo-Yuan Chen[1,2], Kun-Ming Chen[1], Chia-Sung Chiu[1], Guo-Wei Huang[1,3], Hsiu-Chih Chen[1], Chun-Chi Chen[1], Fu-Kuo Hsueh[1], Min-Cheng Chen[1] and Edward Yi Chang[2]

[1]National Nano Device Laboratories, No.26, Prosperity Rd. I, Science Park, Hsinchu 30078, Taiwan
Phone: +886-3-5726100 E-mail: bychen@narlabs.org.tw
[2]Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan
[3]Department of Electronics Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan

Abstract

The dc and high-frequency performances of drain-extended FinFETs are investigated. To reduce the drain resistance, wide drain-extension layouts are proposed. Experimental results show that power FinFETs with a wide drain extension exhibit a better high-frequency performance and a similar breakdown voltage compared with the conventional one, suggesting its feasibility for RF power applications.

1. Introduction

With scaling down to the sub-100-nm era, FinFETs or trigate FETs have been attracting considerable attention due to their high immunity to short channel effect [1]. Currently, FinFET devices are considered as a likely-to-merge structure for future VLSI technologies. Besides, with low cost and high performances, FinFETs are suitable for implementing the system-on-chip (SoC). The technological aspects and perspectives of FinFETs for digital and analog/RF applications have been widely investigated [2][3]. The high-voltage FinFET was less discussed [4], though it is an important part of SoC. In this work, the high-frequency characteristics of power FinFETs for wireless communication systems are presented for the first time. To improve the high-frequency performances, FinFETs with a wide drain extension are proposed.

2. Device Fabrication

The drain-extended FinFETs were fabricated using a bulk-Si FinFET process. First of all, the active region was pattern by the e-beam lithography. After etching of the Si fins, a 10-nm thermal oxidation was carried out to provide fin corner rounding and reduce the fin width. The oxide was then removed and the trench was refilled with the oxide grown by HDPCVD. Afterward 40-nm width and 45-nm height silicon fins were achieved (see Fig. 1). For the gate stack, a 2.6-nm-thick HfO_2 dielectric and a 50-nm-thick TiN metal gate were formed, followed by a low-doped drain extension implantation and a high-doped source/drain implantation.

For RF applications, the drain-extended FinFETs were design with a multi-fin and multi-gate layout. The total fin number is 480. Two types of devices are compared in this work, as shown in Fig. 2. One is the conventional drain-extended structure, and the other is a new design where the fin width in the drain extension is wider than that in the channel.

3. Results and Discussion

Fig. 3 compares the output characteristics and breakdown voltages of the standard (drain-extension length L_D=0 nm) and drain-extended FinFET. The devices under test have a nominal gate length of 90 nm. With introducing the low-doped drain extension, the breakdown voltages increase from 2.6 V to 7.3 V due to the reduced electric field near the drain. However, the on-resistances also increase with the increased drain resistance.

To reduce the resistance in the drain extension, one of the solutions is to increase the width of the drain extension (W_D). The measured output characteristics of FinFETs with different W_D are shown in Fig. 4. The devices with a wide drain extension exhibit higher drain currents compared to the conventional one (W_D=40 nm). Fig. 5 depicts the off-state breakdown voltage and the on-resistance (R_{ON}) of FinFETs with different W_D. The breakdown voltage is defined as the drain voltage at which the drain current reaches to 1μA/μm under the off-state condition. R_{ON} is improved by 16% for devices with W_D=100 nm compared to the conventional device, indicating the resistance in the drain extension is reduced. For breakdown voltage, it is nearly unchanged with increasing W_D.

Fig. 6 shows the cutoff frequency (f_T) of drain-extended FinFETs at drain voltage V_{DS} = 3 V. As compared to the conventional device, the enhancement of peak f_T is 56% for devices with a wider drain extension. Higher f_T in the wide drain-extension devices is mainly attributed to its lower drain resistance, since the transconductance and the gate capacitance are less influenced by changing drain-extension layouts.

4. Conclusions

The dc and high-frequency characteristics of power FinFETs with different drain-extension structures were presented. Higher breakdown voltages were obtained by introducing a low-doped drain extension between the channel and the drain contact. Moreover, the high resistance in the drain extension was reduced with increasing the drain-extension width. Therefore better high-frequency performances were achieved for devices with a wider drain extension, while its breakdown voltages were kept to a high value.

Acknowledgements

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References

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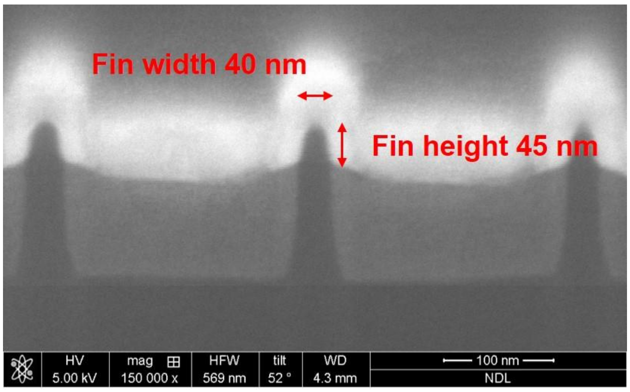

Fig. 1 TEM picture taken across fin structure with TiN gate.

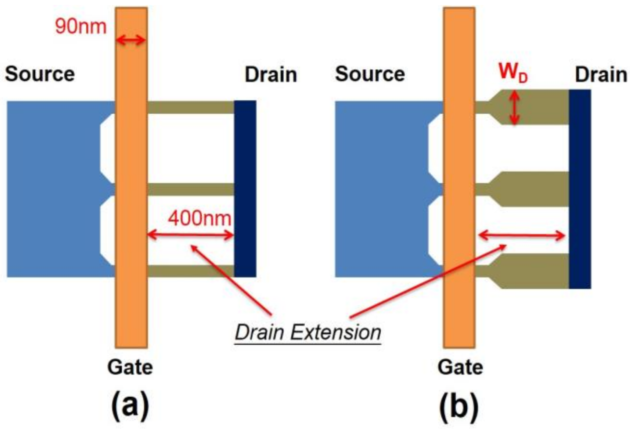

Fig. 2 Device layouts of (a) conventional drain-extended FinFET and (b) proposed FinFET with a wide drain extension.

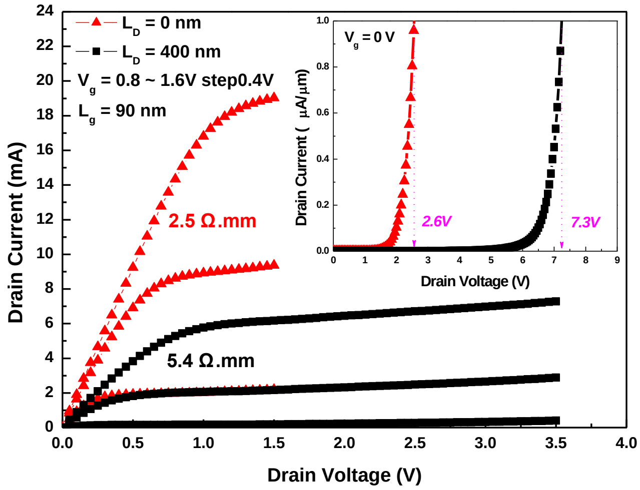

Fig. 3 Output characteristics and breakdown voltages of the standard and drain-extended FinFETs.

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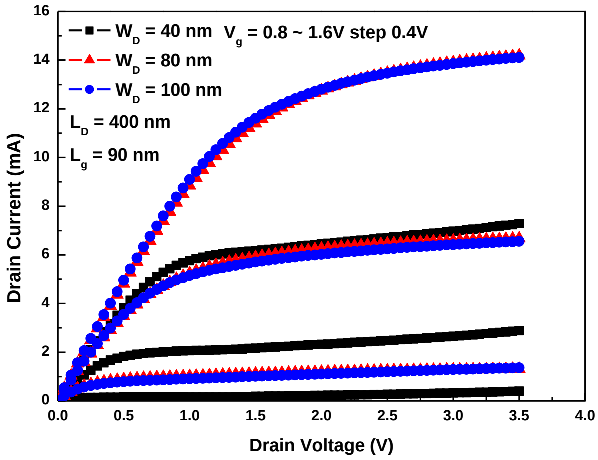

Fig. 4 Output characteristics of drain-extended FinFETs with different W_D.

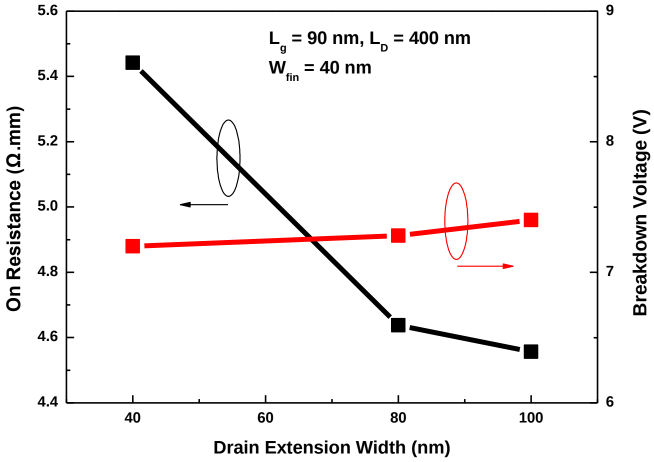

Fig. 5 Breakdown voltage and on-resistance of drain-extended FinFETs with different W_D.

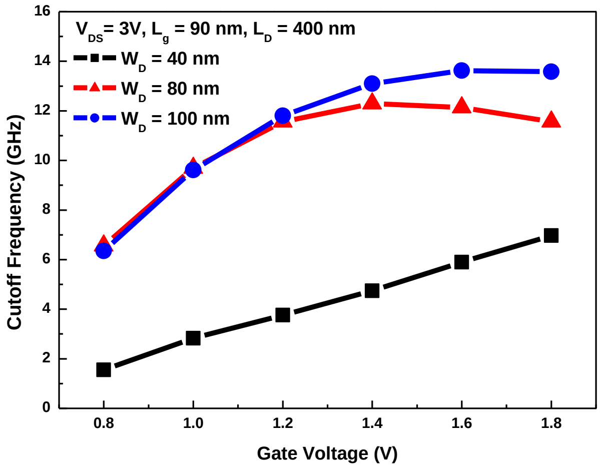

Fig. 6 Cutoff frequency of drain-extended FinFETs with different W_D.