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Application of Reversed Silicon Wafer Direct Bonding to Thin-Film SOI Power Ics

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Abstract

Reversed Silicon Wafer Direct Bonding (RSDB) has been applied to SOI power ICs. The SOI power ICs fabricated by RSDB are superior to those fabricated using conventional SOI substrates. RSDB is also demonstrated to be applicable to the high-side switch.

1. Introduction

SOI technology is significant for power ICs, which combine high-voltage power device and low-voltage MOSFET on the same silicon chip, because it can provide ideal dielectric isolation of low-voltage circuitry from high-voltage devices on the same chip with low leakage current [1]. The thin-film approach is attractive because devices can be easily made lateral isolation from each other and a high-voltage power MOSFET can be achieved without a deep diffusion process. Thus this approach is compatible with conventional LSI processes.

Reversed Silicon Wafer Direct Bonding (RSDB) has been proposed as a possible fabrication technique for future SOI LSIs [2]. RSDB has been applied to high-performance LSIs such as DRAMs and double-gate MOSFETs [3],[4], and it will be applied to a system-on-chip. Little attention, however, has been paid to the electrical characteristics of SOI power ICs that use RSDB.

This paper reports power ICs fabricated using RSDB for 30-V-class SOI power MOSFETs. The electrical characteristics of SOI power MOSFETs and nMOSFETs fabricated by RSDB are compared with those fabricated on the conventional SOI structure (SIMOX substrate).

2. Device Structure and Fabrication Process

A schematic cross-section of an SOI power IC is illustrated in Fig. 1. The power MOSFET and CMOS are formed in the same chip by RSDB. Applying RSDB to the power IC enables high-voltage devices to be completely isolated from the low-voltage CMOS devices. The thickness of the buried SiO_2 layer is changeable. This is because a thin buried SiO_2 layer improves the performance of the signal-circuit [5]. In addition, low-voltage CMOS devices can be fabricated in the thin buried SiO_2 layer on the same chip to suppress the short channel effect and reduce the saturation current caused by the thermal effect. RSDB also produces the shield effect of substrate bias. This means that it is suitable for high-side switches. RSDB also allows a quasi-SOI structure to be applied to the power device and this can suppress the parasitic bipolar effect [6]. The source-contact electrode is extended to the drain region to increase the breakdown voltage.

The device structure parameters for the power MOSFET and the nMOSFET for both types of substrate are as follows: 160-nm-thick top silicon layer, 400-nm-thick buried SiO_2 layer, and 40-nm-thick gate oxide layer.

3. Results and Discussions

Dependence of the threshold voltage (V_{th}) on the substrate bias (V_{sub}) of both types of SOI power MOSFET is shown in Fig. 2. The threshold voltage of the SOI power MOSFET fabricated by RSDB is independent of the substrate bias. The threshold voltage of the power MOSFET/SIMOX decreases with increasing

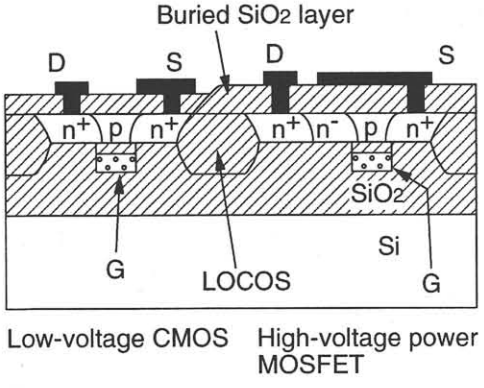

Fig. 1 Schematic cross-section of SOI power IC.

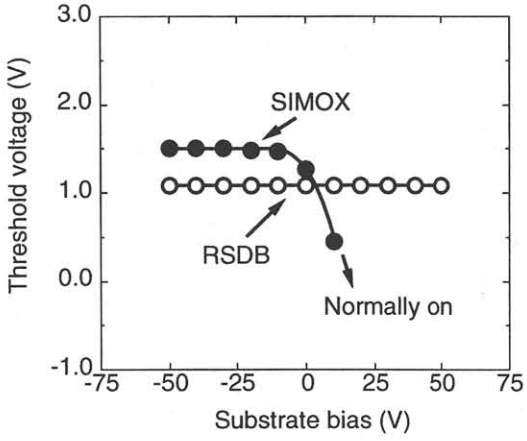

Fig. 2 Dependence of the threshold voltage on substrate bias.

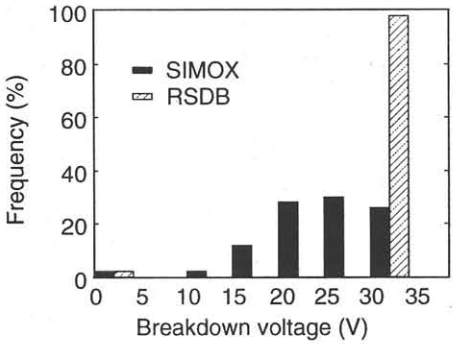

Fig. 3 Distribution of breakdown voltage for both types of SOI power MOSFET.

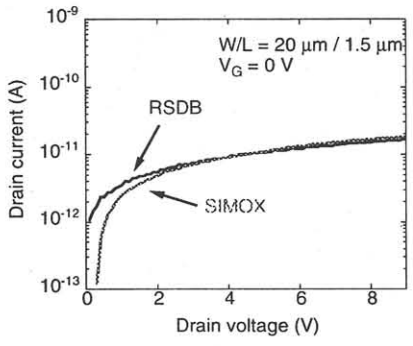

Fig. 4 Off-state current characteristics for both types of SOI nMOSFETs.

substrate bias when substrate bias is positive, and adopts normal-on characteristics at V_{sub} = 25 V. The increase in V_{sub} forms a back-channel, so the threshold voltage changes to negative. In contrast, the gate electrode is shielded using RSDB, so the substrate bias does not affect the channel region. This means that RSDB is suitable for high-side switches.

The distribution of breakdown voltage of both types of SOI power MOSFET is charted in Fig. 3. RSDB gives a high yield. In contrast, the SOI power MOSFET using SIMOX substrate have the breakdown where the voltage is less than 30 V. The production yield of this MOSFET fabricated by RSDB is higher than that of the SOI power MOSFET fabricated using SIMOX substrate because the buried oxide quality is better.

Source-to-drain leakage current characteristics of nMOSFETs fabricated by RSDB and using SIMOX substrate are shown in Fig. 4. The breakdown voltage is more than 10 V. The source-to-drain leakage current characteristics for the nMOSFET fabricated by RSDB are almost the same as those for the nMOSFET fabricated using the SIMOX substrate.

Subthreshold characteristics in both types of nMOSFETs are shown in Fig. 5. The drain current characteristics are almost the same for the different nMOSFETs. This means that RSDB can be applied to nMOSFETs as well as power MOSFETs.

The two fabrication technologies are compared in Table 1. In the SOI power MOSFETs fabricated by RSDB, the parasitic

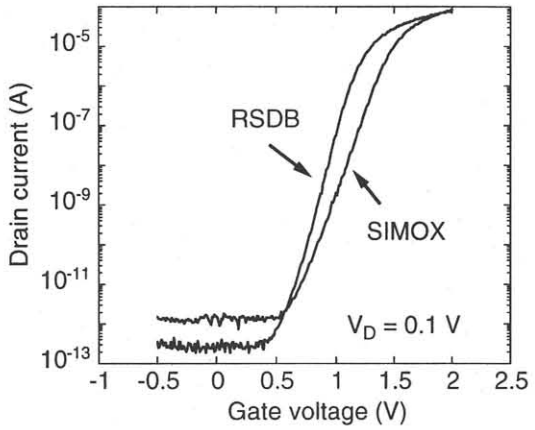

Fig. 5 I_D-V_G characteristics of nMOSFETs fabricated by RSDB and using SIMOX substrate.

Table 1 Comparison of RSDB-based and conventional-SOI-based power IC technologies.

	RSDB	conv. SOI (SIMOX)
parasitic bipolar effect*	Suppress	Fair
Breakdown voltage*	33 V	32 V
High-side switch application*	Excellent	Poor
Leak current**	Fair	Fair
I_D-V_G characteristics**	Good	Good

*:Characteristics as the power device. **:Characteristics as the nMOSFET.

bipolar effect is suppressed because the MOSFETs can easily employ the quasi-SOI structure [6]. These mean that RSDB is applicable to the SOI power ICs, and the SOI power ICs fabricated by RSDB are superior to those fabricated using conventional SOI substrates.

4. Conclusion

The significant features of SOI power ICs fabricated by RSDB have been discussed. We have demonstrated the superiority of power MOSFETs fabricated by RSDB. The nMOSFETs fabricated by RSDB have nearly the same electrical characteristics as conventional SOI devices. We have also demonstrated that RSDB is applicable to high-side switches.

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