Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.258-259

B-3-1

Impact of The Improved High Performance Si(110) Oriented MOSFETs by Using Accumulation-Mode Fully Depleted SOI Devices

Cheng Weitao, Akinobu Teramoto[1], Masaki Hirayama[1],
Shigetoshi Sugawa, and Tadahiro Ohmi[1]
Graduate School of Engineering, Tohoku University,
[1]New Industry Creation Hatchery Center, Tohoku University.
Aza-Aoba 6-6-10, Aramaki, Aoba-Ku, Sendai 980-8579, Japan, (Phone: +81-22-795-3977/ FAX: +81-22-795-3986).
E-mail: cheng@fff.niche.tohoku.ac.jp

Abstract

This paper focuses attention on the improved device characteristics of Fully Depleted silicon on insulator (FD-SOI) MOSFETs on Si(110) surface using normally-off Accumulation-mode device structure. We demonstrated that the current drivability of Accumulation-mode FD-SOI n-MOSFET on Si(110) is about 1.5 times larger than that of conventional Inversion-mode FD-SOI n-MOSFET on (110) orientated. Furthermore, We confirmed the current drivability of Accumulation-mode FD-SOI p-MOSFET fabricated on Si(110) is 3 times larger than that of conventional FD-SOI pMOS formed on Si(100) surface[1].

Introduction

Aggressive scaling-down has made the trade-off between high-speed, low power consume and low noise very difficult. It has been reported that the p-MOSFET fabricated on Si(110) surface has performed higher mobility comparison with that on Si(100) surface[1]. However, the current drivability of n-MOSFET is lower than that on Si(100) surface. We demonstrated both the n-type and p-type FD-SOI MOSFETs have higher current drivability by using normally-off Accumulation-mode FD-SOI device structure.

In this paper, we demonstrate the higher current drivability of both the nMOS and pMOS fabricated on orientated Si(110) surface by using the Accumulation-mode FD-SOI MOSFETs.

Experimental

Fig.1 shows the schematic of the Inversion-mode and Accumulation-mode FD-SOI n-MOSFETs. Both the Accumulation-mode and Inversion-mode FD-SOI MOSFETs including n and p-type on Si(100) and (110) surface are employed for this experiment. UNIBOND p-type (100) and (110) orientated SOI wafers (SOI/BOX=65/100nm) with resistivity 9~18 Ohm·cm were used and adjusted the SOI layer doping concentration by ion implantation before isolation. After the Mesa isolation, 7.5nm-gate oxides are formed by the microwave excited high density plasma oxidation (radical oxidation) at 400°C after 5 steps room temperature wet cleaning to realize the high quality oxidation and avoid the micro-roughness of Si(110) surface caused by RCA conventional wafer cleaning[1,2,3]. As^+ and BF_2^+ ($1.5x10^{15}cm^{-2}$) ions are implanted to the gate poly-Si (300nm) and source/drain regions after gate formation for n-MOSFET and p-MOSFET, respectively. Post metal annealing was carried out at 400°C in N_2/H_2=90/10 forming gas for 30min.

Results and Discussions

Fig.2 shows the current drivability of Accumulation-mode FD-SOI p-MOSFET on Si(110) surface is also 3 times larger than that of Inversion-mode FD-SOI p-MOSFET fabricated on Si(100) surface what had been reported at bulk p-MOSFET[1].

Fig.3 shows the subthreshold characteristics of Accumulation-mode and Inversion-mode (110) FD-SOI n-MOSFETs. Normally-off Accumulation-mode FD-SOI nMOS is realized and shows excellent off-state leakage current level. Comparison with the Inversion-mode FD-SOI n-MOSFET, the Accumulation-mode FD-SOI n-MOSFET has a better S-factor of 66.4mV/dec.

Fig.4 shows the Si(110) orientated FD-SOI n-MOSFET transconductance characteristics. The Accumulation-mode FD-SOI n-MOSFET shows the peak value of 17.2μS about 30% larger than that of Inversion-mode. The Accumulation-mode Si(110) FD-SOI n-MOSFET keeps larger g_m even at high field.

Fig.5 shows the I_D-V_D characteristics. The saturated current of Si(110) orientated Accumulation-mode FD-SOI n-MOSFET at V_G-V_{th}=2.5V is 0.841mA, about 1.5 times larger than that of Inversion-mode. The current drivability is improved by using the Accumulation-mode FD-SOI n-MOSFET at any bias condition.

Fig.6 shows the I_D-V_D characteristics dependence of SOI layer doping concentration. The current drivability of Si(110) orientated Accumulation-mode FD-SOI n-MOSFET is improved when increase the SOI layer doping concentration and is opposite to the characteristics of Inversion-mode FD-SOI n-MOSFET. It indicates that there is different current conduction mechanism existed in the two modes FD-SOI MOSFETs.

Fig.7 shows that the current drivability of conventional Inversion-mode FD-SOI n-MOSFET fabricated on Si(110) surface is about 61% comparison to that formed on Si(100) surface[4]. In this work, the current drivability of Si(110) oriented Accumulation-mode FD-SOI n-MOSFET is improved 1.5 times larger than that of Inversion-mode and almost the same as the current drivability of the Inversion-mode FD-SOI n-MOSFET on Si(100) surface. It indicates that the high-speed balanced CMOS[1] can be realized using FD-SOI MOSFETs of accumulation-mode nMOS and inversion-mode pMOS.

Conclusion

We have successfully fabricated the normally-off Accumulation-mode n and p-type FD-SOI MOSFETs on Si(110) surface. We confirmed the high mobility of FD-SOI p-MOSFET on Si(110) surface and demonstrated the excellent subthreshold and transconductance characteristics of the Accumulation-mode FD-SOI n-MOSFET on Si(110) surface. By using the Accumulation-mode FD-SOI MOSFETs, the current drivability of n-MOSFET formed on Si(110) surface is improved about 50% comparison with the conventional Inversion-mode n-MOSFET. These are

promising to realize high-speed and low power consume [1] balanced CMOS integrated circuits.

References

[1] A. Teramoto et al, IEDM Technical Dig. P.801 (2003)
[2] S. Sugawa et al., IEDM Technical Dig. P.817 (2001)
[3] K. Tanaka et al., Jpn. J. Appl. Phys., vol. 42, p. 2106 (2003)
[4] T. Mizuno et al., VLSI Tech. Dig., p.97 (2003)

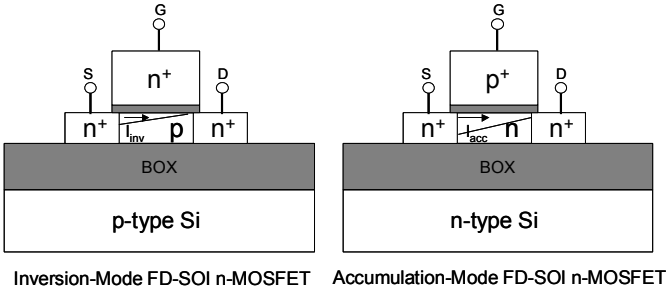

Fig.1 Schematic of Inversion-mode and Accumulation-Mode FD-SOI n-MOSFET Structures.

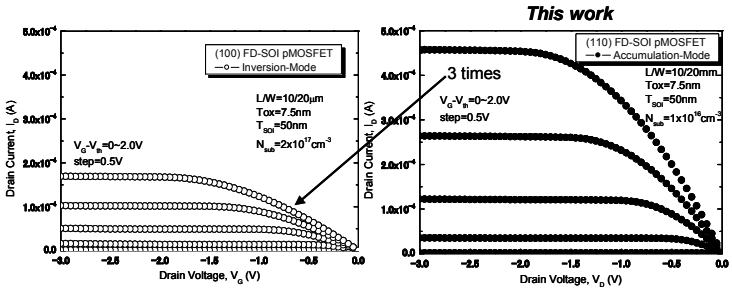

Fig.2 I_D-V_D characteristics of FD-SOI p-MOSFET on Si(110) and (100) surface. It is confirmed that comparison with the conventional FD-SOI p-MOSFET fabricated on Si(100) surface, the current drivability of Accumulation-mode on Si(110) surface is 3 times larger than that on Si(100) surface else.

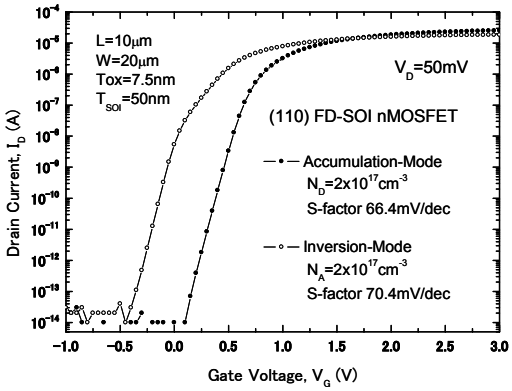

Fig.3 Subthreshold characteristics of normally-off Inversion-mode and Accumulation-mode FD-SOI devices fabricated on Si (110) surface. Accumulation-mode n-MOSFET shows good off-current and excellent S-factor of 66.4mV/dec.

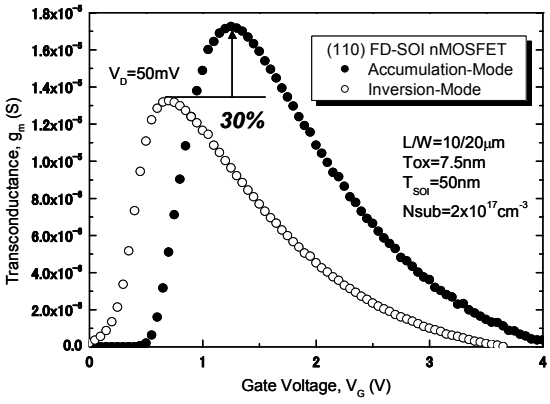

Fig.4 Transconductance characteristics of Si(110) orientated Accumulation and Inversion-mode FD-SOI nMOSFETs. Both the peak value and the high field characteristics have been improved by Accumulation-mode.

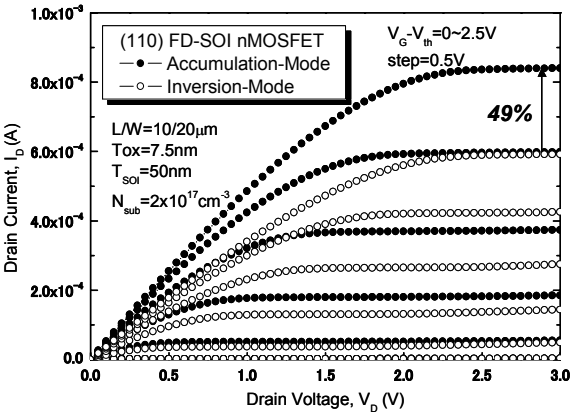

Fig.5 I_D-V_D characteristics of Accumulation and Inversion-mode FD-SOI nMOS on Si(110) surface. The current drivability of Accumulation-mode is about 1.5 times larger than that of Inversion-mode.

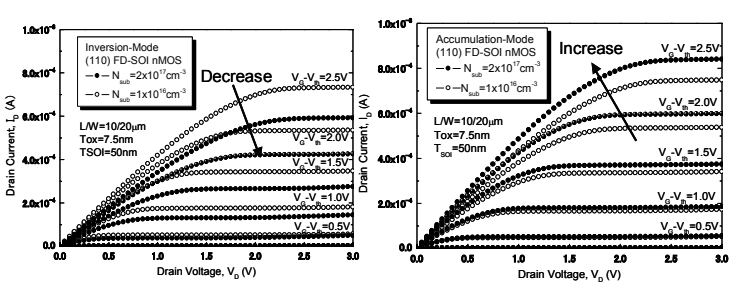

Fig.6 I_D-V_D characteristics SOI layer doing concentration dependence of Accumulation and Inversion-mode FD-SOI n-MOSFETs on Si(110) surface. At Accumulation-mode, the current drivability is improved when the doping concentration is increased. This indicates the different current conduction mechanism in these two modes.

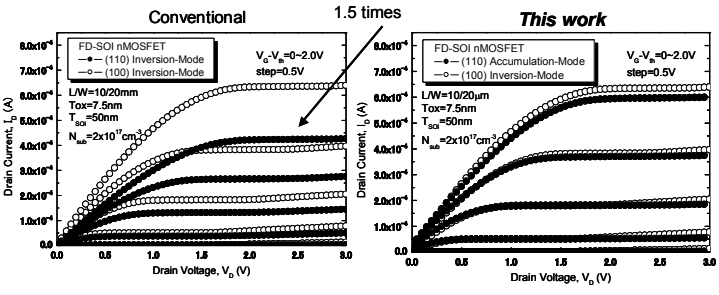

Fig.7 Improved I_D-V_D characteristics of Si(110) Accumulation-mode FD-SOI n-MOSFET. In this work, the current drivability of Accumulation-mode FD-SOI n-MOSFET shows 1.5 times larger than that of Inversion-mode on Si(110) surface and almost as the same as the current drivability of that on Si(100) surface.