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The Impact of Body-Potential on Hot-Carrier-Induced Device Degradation for 90nm Partially-Depleted SOI nMOSFETs

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1. Introduction

Partially Depleted SOI MOSFETs (PD-SOI) was an attractive device due to the advantages such as full dielectric isolation and reduced junction capacitance which over bulk-Si device [1-2]. Especially for low-power digital and analog system, it is very attractive to apply narrow device fabricated on SOI substrate. However for narrow SOI devices, there is no study of body potential impact on hot carrier effect. This work investigates the body-potential impact on hot-carrier-induced device degradation for various channel-width 90nm PD-SOI nMOSFETs. In comparison with BC-SOI device, it was found that lower hot-carrier induced device degradation was happened on FB-SOI due to higher body-potential especially for wider device.

2. Experiments

PD-SOI nMOSFETs on IMplanted Oxygen (SIMOX) SOI substrates were fabricated with 90nm thick Si active layers, 200nm thick buried oxide (BOX), using the 90nm process with STI isolation technology. SOI nMOSFETs with H-gate body-contact (BC-SOI) and without body-contact (FB-SOI) was compared for device performance inspection. Device HCE stressing and measurements were performed on probe station using various drain voltages (V_D=0~1.5V), and various gate voltages (V_G=0V~1.5V) with 300 minutes stress time.

3. Results

The leakage path impact on body-potential (V_B) for FB-SOI nMOSFETs was shown in Fig. 1, it is apparent that the V_B can be affected by gate (I_G), junction (I_J), impact-ionization (I_{II}) and STI edge (I_{EL}) currents. For BC-SOI, the narrower channel-width device shows more severe V_t roll-off, as shown in Fig. 2. Figure 3 shows the width effect on I_D-V_D characteristic of 90nm BC-SOI nMOSFETs. The drain current density (I_D/W) increases apparent as the channel width decreases due to the increase of channel edge current [3]. Figure 4 shows large channel edge current in narrow channel-width devices will cause the larger off-state drain current in subthreshold region, degrading device's subthreshold slope and lowering the threshold voltage. Thus for SOI nMOSFETs with width=1.2um, apparent I_D degradation was happened especially with stressed V_G=V_D=1.5V. It is due to the large vertical electrical field will increase inversion channel charge and enhance hot carrier effect. Therefore more serious valence-band electron tunneling was happened, increasing the interface state generation rate [4], resulting in serious I_{Dsat} degradation (Fig. 5) and gate leakage variation ($\Delta I_G(\%)$) (Fig. 6). We believed that the hot-carrier-induced defects at Si-SiO_2 interface will cause device's threshold voltage shift, and provide a gate leakage path for carrier tunneling. Figure 7 shows the V_{th} shift versus hot carrier stress time. It is obvious that the V_{th} had a positive shift at first, and then the gate oxide breakdown occurred, resulting in serious device I_D degradation.

In this work, a method which setting BC-SOI device with I_B=0 was used to monitor the V_B of FB-SOI device, as shown in inset of Fig. 8. Figure 8 shows that a kink effect will happen on BC-SOI nMOSFETs with I_B=0; thus, we believed it is a reasonable way to monitor the characteristic of FB-SOI devices. Figure 9 shows the mobility will increase with channel width decrease for both SOI nMOSFETs. Figure 10 shows lower V_B was found at narrower channel-width device especially at large V_D, and is more sensitive with gate voltage because of gate-induced drain leakage and gate tunneling (Fig. 11). In order to investigate channel edge leakage, we inspect the I_D-V_G plot with V_B=V_D without the impact of I_J and I_G. Owing to I_{EL}, it is apparent that larger I_D happens especially on narrower channel-width device, as shown in Fig. 12. Compared with BC-SOI nMOSFETs, FB-SOI device possesses a larger I_D due to serious kink effect. Besides, we found that the body potential was also affected by channel width. In this work, lower V_B was found at narrower channel-width device; it is due presumably to fewer hole accumulated at neutral region of substrate. For FB-SOI nMOSFETs, narrower channel-width device possesses lower body potential; thus, higher electric field between body and drain happen, causing larger hot-carrier-induced device degradation. Figure 13 shows the width effect on V_t roll-off for BC-SOI nMOSFETs with V_B=1V or not. As V_B=1V, it is apparent that threshold voltage decreases rapidly with channel-width shrinks; it is due to the barrier height lowering between body and source. Thus for narrow width devices, we believed that the device characteristic of FB-SOI was very sensitive to body potential. Figure 14 shows the I_{Dsat} degradation and V_{th} shift of FB-SOI devices with various stress gate voltages. Compared with BC-SOI nMOSFETs, FB-SOI device possesses similar trend but with small extent because body potential happen. For 90nm SOI nMOSFETs with ultra thin gate oxide (T_{ox}=1.6nm), the hot carrier was more easy to induce defects at Si-SiO_2 interface for narrow width device; which will cause a positive shift of threshold voltage and aggravates the I_{Dsat} degradation especially at high stress gate voltage. Thus for narrow channel-width devices, the hot-carrier-induced degradation will increase with width decrease and aggravate with stress gate voltage increase. Figure 15 shows the lifetime of 90nm BC-SOI nMOSFETs versus various stressed gate voltages with constant stressed drain voltage (V_D=1.5V). 5% I_D degradation was chosen to identify the device's lifetime. It can be found that the lifetime decreased dramatically as the channel width decreased. In this work, same trend of device degradation was found on FB-SOI nMOSFETs, but with larger lifetime (Fig 16). For FB-SOI device, we believe that the body potential will suppress the field between drain to body, thus alleviate the hot-carrier-induced device degradation.

4. Summary

For 90nm BC-SOI nMOSFETs, the narrower channel width device will induce edge current, thus enhancing hot-carrier-induced device's degradation. But for FB-SOI nMOSFETs, the body potential caused by narrow width is the major factor for hot-carrier device degradation. In this work, we design a method using BC-SOI device with I_B=0 to monitor V_B for different narrow width device. For FB-SOI nMOSFET, narrower width device possesses lower body potential, causing higher electric field between body and drain, thus enhancing device's driving capability and hot-carrier-induced device degradation.

Acknowledgement

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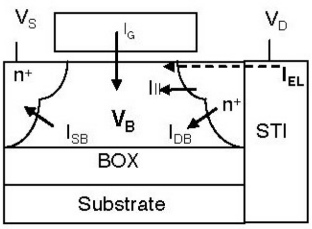

Fig. 1. Leakage path impact on V_B of nMOSFETs on PD-SOI Substrate.

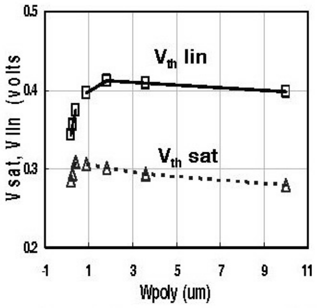

Fig. 2. Linear and saturated V_t roll-off versus gate width of 90nm BC-SOI nMOSFETs.

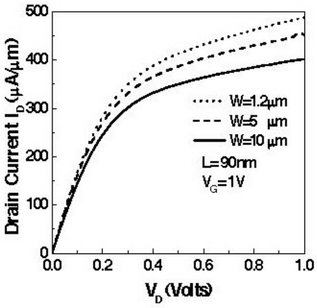

Fig. 3. I_D-V_D characteristics of 90nm BC-SOI nMOSFETs with different gate width.

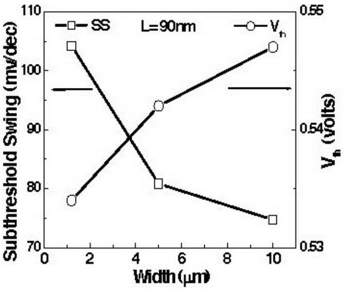

Fig. 4. V_{th} and Subthreshold swing of 90nm BC-SOI nMOSFETs with different gate width.

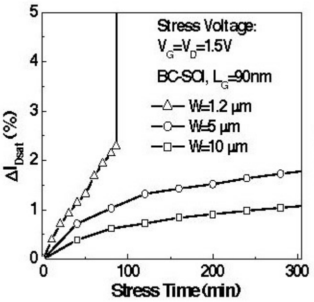

Fig. 5. I_{Dsat} degradation *vs.* stress time at stressed V_G= 1.5V for 90nm BC-SOI nMOSFETs with different gate width.

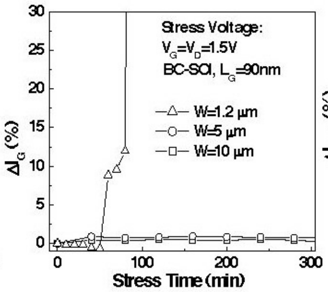

Fig. 6. I_G shift *vs.* stress time at stressed V_G=1.5V for 90nm BC-SOI nMOSFETs with different gate width.

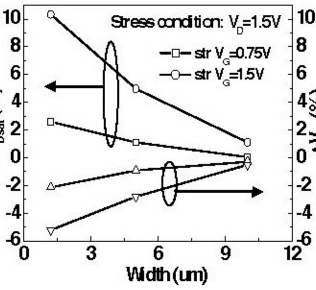

Fig. 7. I_{Dsat} degradation and V_{th} shift of 90nm BC-SOI nMOSFETs with different stress gate voltage.

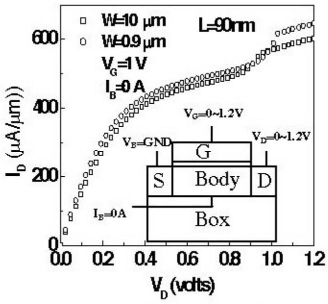

Fig. 8. I_D-V_D characteristics of 90nm BC-SOI nMOSFETs with different gate width and I_B=0 A. The insert shows the measurement setup.

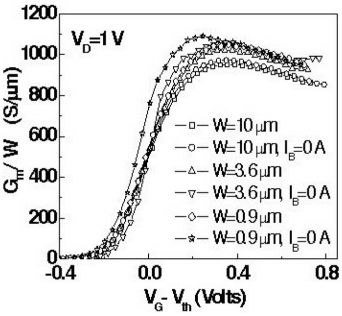

Fig. 9. Width Effect on G_m of 90nm BC-SOI nMOSFETs with I_B=0 or not.

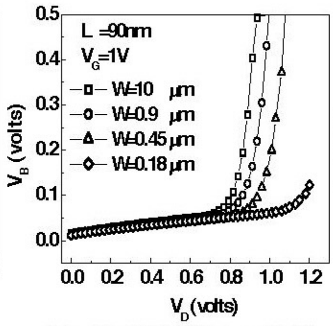

Fig. 10. Width Effect on V_B-V_D characteristics of 90nm BC-SOI nMOSFETs with I_B=0.

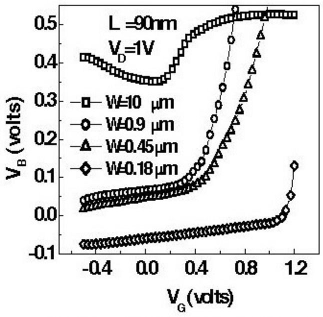

Fig. 11. Width Effect on V_B-V_G characteristics of 90nm BC-SOI nMOSFETs with I_B=0.

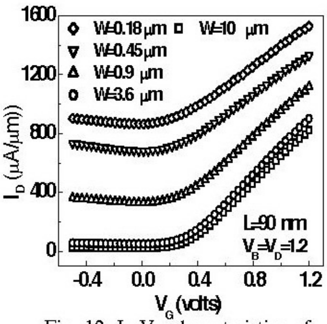

Fig. 12. I_D-V_G characteristics of 90nm BC-SOI nMOSFETs with V_D=V_B=1.2 V.

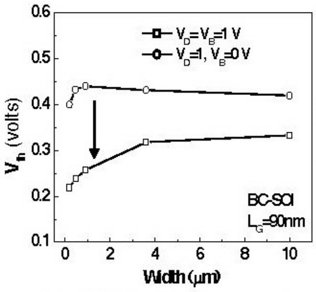

Fig. 13. V_t roll-off versus gate width of 90nm BC-SOI nMOSFETs with V_B or not.

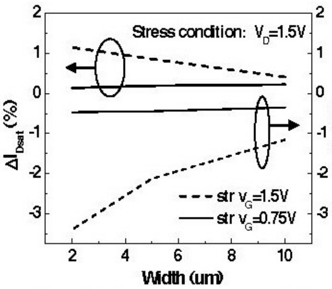

Fig. 14. I_{Dsat} degradation and V_{th} shift of 90nm FB-SOI nMOSFETs with different stress gate voltage.

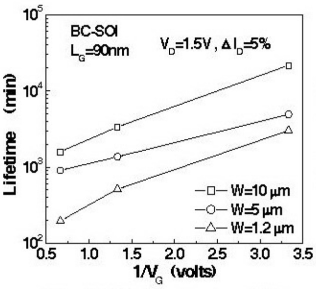

Fig. 15. Width effect on lifetime of 90nm BC-SOI nMOSFETs at various stressed gate voltage.

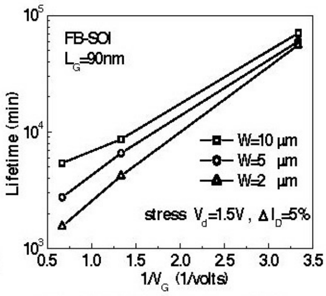

Fig. 16. Width effect on lifetime of 90nm FB-SOI nMOSFETs at various stressed gate voltage.