Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 508-509

P4-9L

Degradation of Low-Frequency Noise in PD SOI MOSFETs after Hot-Carrier Stress

Kun-Ming Chen[1], Hsin-Hui Hu[2], Guo-Wei Huang[1], and Chun-Yen Chang[2]

[1]National Nano Device Laboratories
1001-1 Ta Hsueh Road, Hsinchu 300, Taiwan
Phone: +886-3-5726100 E-mail: kmchen@ndl.gov.tw
[2] Department of Electronics Engineering, National Chiao Tung University
1001 Ta Hsueh Road, Hsinchu 300, Taiwan

1. Introduction

The low-frequency (LF) noise in partially depleted (PD) silicon-on-insulator (SOI) MOSFETs includes $1/f$ noise and kink-related excess noise. Several mechanisms have been proposed to explain this excess noise, such as trap-assisted generation- recombination noise [1] or shot noise amplified by the floating body effect [2]. Because the $1/f$ noise is sensitive to oxide charge and interface traps, it is good to monitor the device reliability by measuring the $1/f$ noise. In this paper, we investigate the impact of hot carrier stress on the LF noise of PD SOI MOSFETs. The noise characteristics of the devices with floating-body and body-contact structures have been discussed.

2. Experiments

The n-channel MOSFETs were fabricated on SIMOX SOI substrates with 200nm thick Si active layers, 400nm thick buried oxide, and 4nm gate oxides. The gate length and gate width were 0.4μm and 20μm, respectively. The hot-carrier stress was applied at a drain voltage of V_{DS} = 4V and a gate voltage of V_{GS} = 2V with a stressing time ranging from 0 to 3000 sec.

3. Results and Discussion

The LF noise characteristics of a floating-body PD SOI MOSFET are shown in Fig. 1. When operating in the pre-kink region (V_{DS}=1.2 V), the device exhibits excess noise with a Lorentzian-like noise spectrum which has a plateau followed by a $1/f^2$ roll-off at the corner frequency f_0. A model proposed by Tseng [2] has related the origin of excess noise to the interaction between the shot noise of the drain-body junction leakage I_L and the source-body impedance. They concluded that the plateau is proportional to $1/I_L$, and f_0 is proportional to I_L. When operating in the post-kink region (V_{DS}=2 V), the I_L is dominated by impact ionization current. Because the large impact ionization current should increase the f_0 and reduce the plateau, the excess noise will be overwhelmed by the $1/f$ noise.

Fig. 2 shows the LF noise measured in a floating-body SOI device before and after stresses. The $1/f$ noise at V_{DS}=2 V increases after stress due to hot-carrier-generated oxide charge and interface traps, as observed in bulk Si MOSFETs. The hot carrier stress also impacts the kink-related excess noise. As shown in Fig. 2, the magnitude of excess noise has reduced after stress. This observation is different from the measured results in [3] where the excess noise was almost unchanged under stress. Because, in [3], the excess noise was observed in post-kink region, the I_L is dominated with impact ionization current. In our experiment, the excess noise was observed in pre-kink region, and the I_L is dominated with junction generation current. After stressing the device, the increased interface-trap density near the drain junction causes the increase of gate-induced-drain-leakage (GIDL) current as shown in Fig. 3, and provides an additional drain-to-substrate leakage [4]. With the increase of I_L, the f_0 increases and the plateau decreases.

When the LF noise was measured in reverse mode (i.e. source and drain interchanged), the excess noise will disappear, as shown in Fig. 4. In reverse mode, because the interface traps are located on the source side, the GIDL current would not be changed as shown in Fig. 5. However, the excess holes, which exist in body region due to the floating-body effect, can effectively recombine through the interface traps with electrons from source. As a result, the floating-body effect is suppressed, and thus the kink-related excess noise is suppressed. From Fig. 4, we only observe the $1/f$ noise after stress with reverse mode.

Figs. 6 and 7 show the LF noise characteristics of a body-contact PD device operating in the linear and saturation region respectively. Because the body contact structure can reduce the floating body effect, the input noise spectrum is dominated with $1/f$ noise component. As the same with the floating–body devices, the $1/f$ noise would increase after hot-carrier stress. Based on the McWhorter's model [5], we can evaluate the oxide trap density N_{it} from $1/f$ noise data (see Fig. 6), and it was found that the ratio of N_{it} after stress ($N_{it,stress}$) and N_{it} before stress ($N_{it,fresh}$) is 3.92. In the same way, we can calculate the $N_{it,stress}/N_{it,fresh}$ of floating-body devices as 3.33. The higher $N_{it,stress}/N_{it,fresh}$ in body-contact devices has corresponded to the larger dc degradation under stress as compared to body-contact devices (not shown here).

4. Conclusions

The effect of hot-carrier stress on the LF noise of PD SOI MOSFETs has been studied. After stress, the increase of GIDL current in floating-body devices would result in a lower plateau and higher corner frequency for kink-related excess noise measured in normal mode. However, in reverse mode, the floating-body effect and the kink-related excess noise will be suppressed after stress. In addition, the 1/*f* noise degradation of body-contact devices after hot-carrier stress was more serious than that of floating-body devices.

References

[1] E. Simoen et al., IEEE Trans. Electron Devices **41** (1994) 330.

[2] Y.-C. Tseng et al., IEEE Trans. Electron Devices **48** (2001) 1428.

[3] T. Tsuchiya et al., Jpn. J. Appl. Phys. **41** (2002) 4427.

[4] B. Zhang et al., IEEE Electron Device Lett. **15** (1994) 169.

[5] P. Morfouli et al., IEEE Electron Device Lett. **17** (1996) 395.

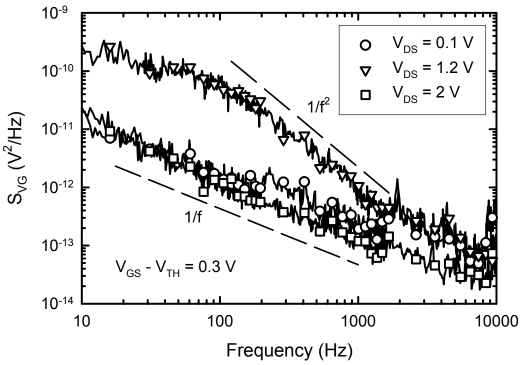

Fig. 1 Input referred noise spectra of a PD floating body SOI MOSFET with different drain biases.

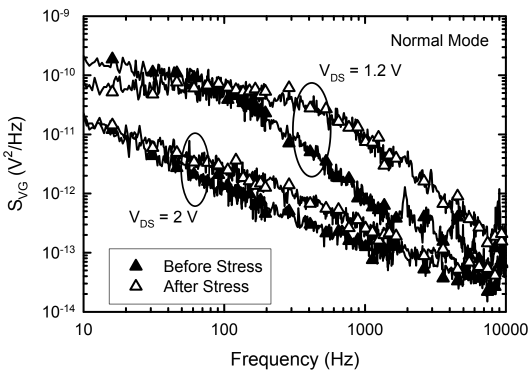

Fig. 2 Input-referred noise spectra of a PD floating-body SOI MOSFET at V_{GS} = 1.56 V in normal mode before and after stress.

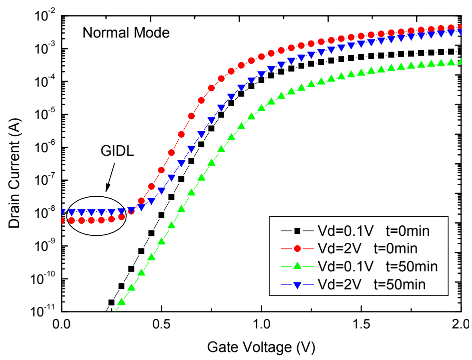

Fig. 3 I_D-V_G characteristics of a PD floating-body SOI MOSFET in normal mode before and after stress.

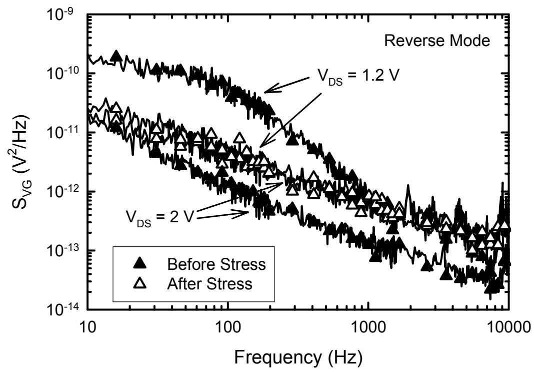

Fig. 4 Input-referred noise spectra of a PD floating-body SOI MOSFET at V_{GS} = 1.56V in reverse mode before and after stress.

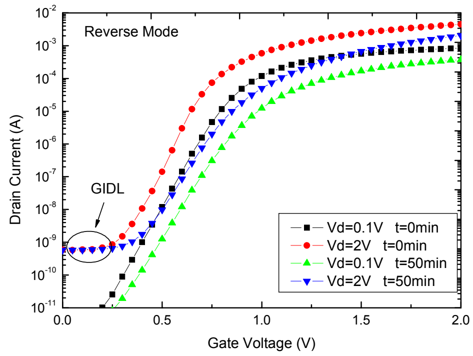

Fig. 5 I_D-V_G characteristics of a PD floating-body SOI MOSFET in reverse mode before and after stress.

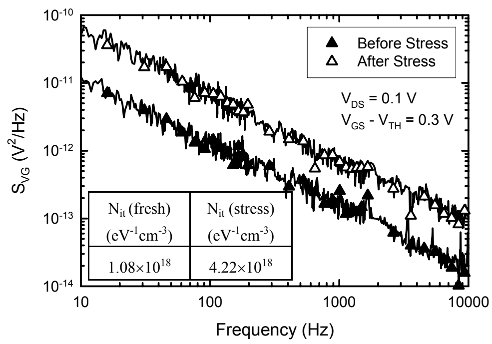

Fig. 6 Input-referred noise spectra of a PD body-contact SOI MOSFET at V_{DS} = 0.1 V.

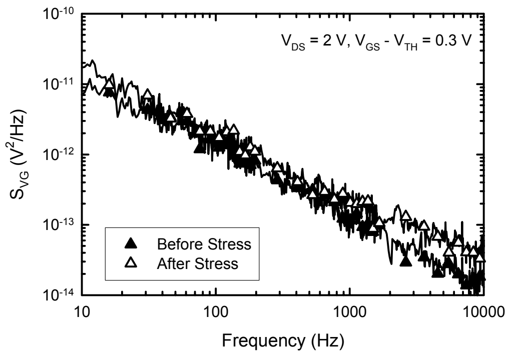

Fig. 7 Input-referred noise spectra of a PD body-contact SOI MOSFET at V_{DS} = 2 V.