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Impact of Hot Carrier Stress on Low-Frequency Noise Characteristics in Floating-Body SOI MOSFETs

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1. Introduction

Much attention has been devoted to SOI CMOS technology for high performance digital, RF and analog circuit applications, and their integration into VLSIs. Low-frequency (LF) noise is an important parameter in analog applications. Common LF noise in MOSFETs is flicker (1/f) noise and much effort has been spent in understanding and reducing this for better performance in VLSI circuits.

1/f noise is sensitive to the gate oxide interface, and it increases due to generated oxide-charge and interface-traps after hot carrier stress, which has been reported in conventional bulk-Si MOSFETs [1]-[3]. On the other hand, for floating-body partially-depleted (PD) SOI MOSFETs, additional LF noise with a Lorentzian-like spectrum has recently been observed [4], and the origin of this excess noise has been investigated [5][6] (this is explained in more detail in the next section). However, the influence of hot-carrier stress on LF noise in floating-body SOI MOSFETs has not yet, to our knowledge, been reported.

In this paper, for the first time, we report on the impact of hot-carrier stress on the LF noise characteristics peculiar to floating-body SOI MOSFETs, including fully-depleted (FD) and PD SOI MOSFETs.

2. Excess Low-Frequency Noise in SOI MOSFETs

Floating-body PD SOI MOSFETs exhibit excess LF noise with a Lorentzian-like spectrum, when the drain bias exceeds the kink onset voltage, as shown in Fig.1. The noise spectrum exhibits a plateau up to a characteristic frequency. The origin of the excess noise is considered to be shot noise due to the impact ionization current, which flows through the floating-body to the source, and the body-source diode current [5]. The shot noise causes fluctuations in the body potential and the threshold voltage, and consequently leads to excess noise in drain current. Although the excess noise is clearly present in PD SOI MOSFETs, it is also present even in FD SOI MOSFETs depending on the gate and drain voltages, as shown in Fig. 2.

When such a Lorentzian-like excess noise appears in the spectrum, the frequency region that contributes the dominant noise power is around the characteristic frequency according to the 1/f noise tangent principle [7]. Therefore, this bias-dependent unstable excess noise is an undesirable phenomenon.

3. Experimental

FD and PD SOI nMOSFETs were used in this study. They have single drain structures, and no body contacts. The gate oxide is 5 nm thick, the top silicon layer is 50 nm thick, and the gate length and width are 0.24 μ m and 8 μ m, respectively. These devices were fabricated on a SIMOX wafer with a buried oxide of 100 nm thick. LF noise was measured with an Agilent Technologies set-up consisting of a HP 89410A vector signal analyzer, an EG&G 5184 ultra-low noise preamplifier, and a ShibaSoku PA14A1 ultra-low noise DC source.

4. Hot-Carrier-Induced Instability in LF Noise

Fully-Depleted MOSFETs

Hot-carrier stress was performed at V_D=2.9 V and V_G=0.2 V for 3 min, and the LF noise was measured in normal and reverse (source and drain interchanged) modes. Input referred noise spectra measured in both modes before and after stress are shown in Figs. 3(a) and (b), respectively. It is found from these figures that, after stress, (i) 1/f noise power increases as in conventional bulk Si MOSFETs, and (ii) the Lorentzian-like excess noise is surprisingly suppressed. Considering the following experimental results, it can be concluded that the suppression of the excess noise is caused by the restraint of the floating body effect due to interface traps generated by hot-carrier-stress.

The dependency of the threshold voltage V_T upon V_D in both modes before and after stress are shown in Fig. 4. V_T lowering in the region V_D>1 V due to parasitic bipolar action, i.e., the floating body effect, is suppressed in the reverse mode after stress. Figures 5(a) and (b) show subthreshold characteristics at V_D=0.1 V and 2.1 V in each mode before and after stress. An abnormal increase in the drain current due to parasitic bipolar action observed in the initial stages at V_D=2.1 V is suppressed in the reverse mode after stress. These phenomena are caused by the suppression of the floating body effect due to hot-carrier-generated interface traps [8], i.e., excess holes in the body produced by impact ionization effectively recombine with electrons via the generated interface traps.

Partially-Depleted MOSFETs

Hot-carrier stress was performed at V_D=2.9 V and V_G=0.7 V for 4 min. Input referred noise spectra in both modes before and after stress are shown in Figs. 6(a) and (b), respectively, and, the V_T dependency upon V_D in both modes before and after stress are shown in Fig. 7. For PD SOI MOSFETs, the impact of hot-carrier-induced interface traps on LF noise is not so significant, compared with FD SOI MOSFETs. However, it can be seen that the characteristic frequency becomes lower in the reverse mode after stress.

5. Conclusions

Hot-carrier-induced instability in Lorentzian-like excess LF noise in floating-body SOI MOSFETs is reported for the first time. The excess noise is suppressed by hot-carrier stress in FD SOI MOSFETs. Such an effect is not so significant in PD SOI MOSFETs, but the characteristic frequency in the excess noise spectrum shifts after stress. These phenomena are caused by suppression of the floating body effect due to hot-carrier-generated interface traps.

Acknowledgments

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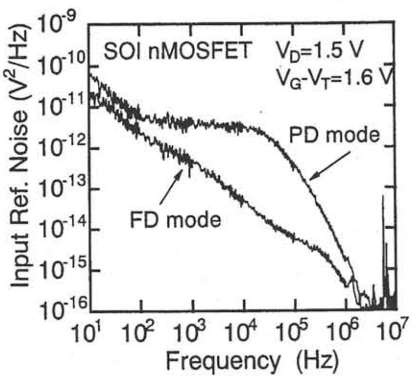


Fig. 1. Input referred noise spectra in FD- and PD-mode SOI MOSFETs.

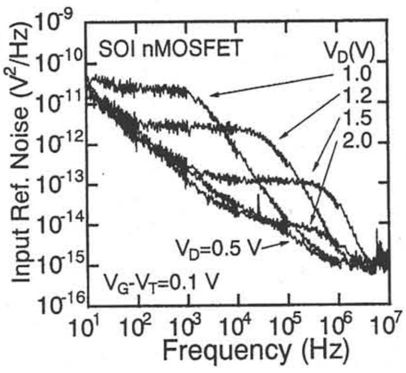


Fig. 2. Lorentzian-like excess noise in FD SOI MOSFETs.

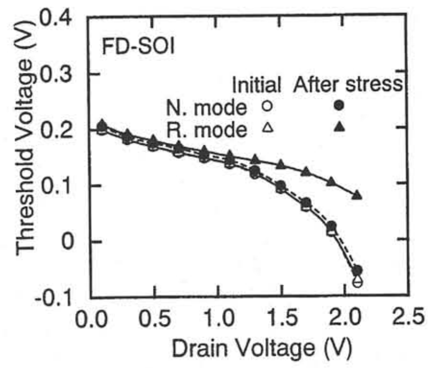
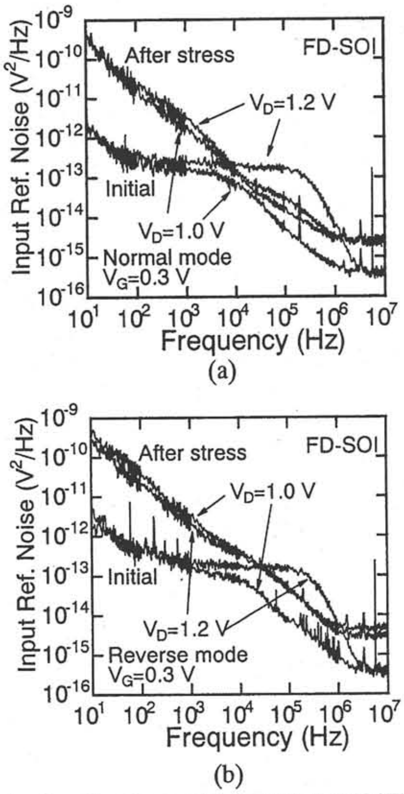
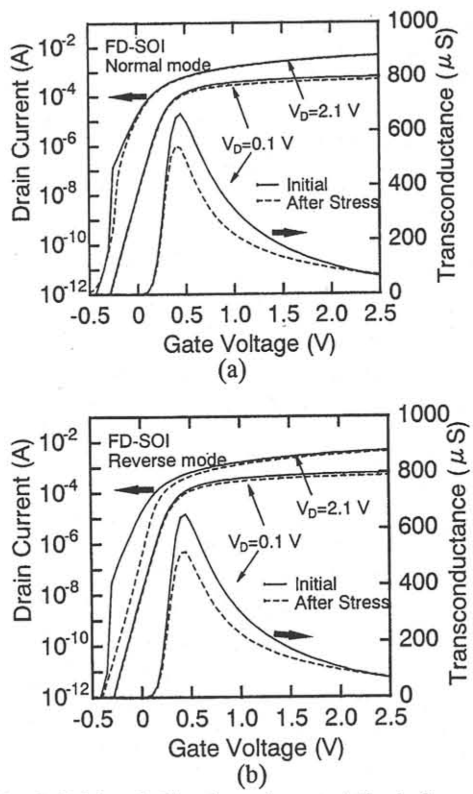


Fig. 4. Threshold voltage dependency upon drain voltage in normal and reverse modes before and after stress for FD SOI MOSFETs.



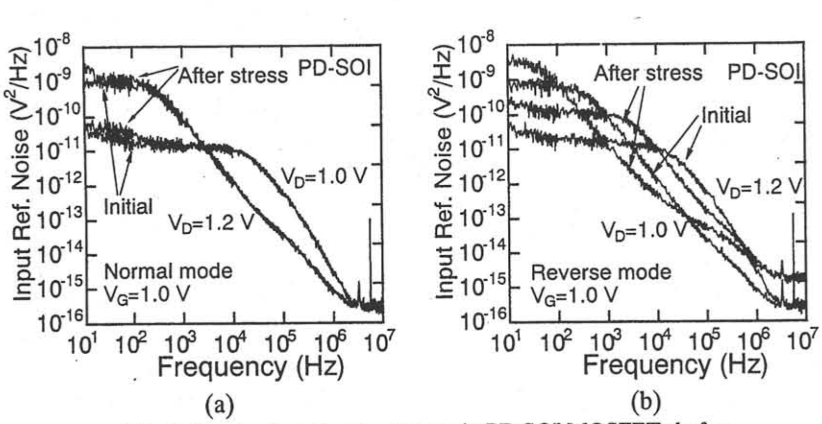
(b)

Fig. 3. Input referred noise spectra in FD SOI MOSFETs before and after hot-carrier stress. (a) Normal mode, (b) Reverse mode.



(b)

Fig. 5. Subthreshold and g_m characteristics before and after stress in FD SOI MOSFETs. (a) Normal mode, (b) Reverse mode.



(b)

Fig. 6. Input referred noise spectra in PD SOI MOSFETs before and after hot-carrier stress. (a) Normal mode, (b) Reverse mode.

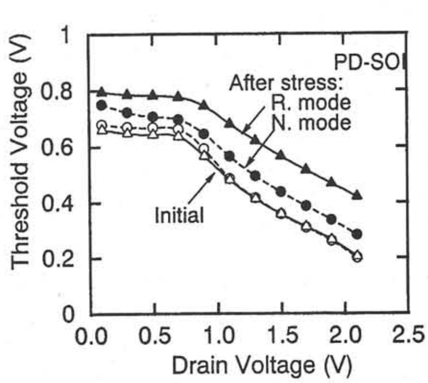


Fig. 7. Threshold voltage dependency upon drain voltage in normal and reverse modes before and after stress for PD SOI MOSFETs.