Temperature Dependence of AC Floating Body Effects in PD SOI nMOS

Ying-Che Tseng, ‡W. Margaret Huang, Clifford Hwang ‡Pamela Welch, and Jason C. S. Woo
Department of Electrical Engineering, University of California, Los Angeles, CA 90095
‡Embedded Systems Technology Laboratories, Motorola Inc., Mesa, AZ 85202

Introduction: AC floating body effects have significantly impacted SOI analog circuit performance, such as degraded linearity due to the kink on output conductance (G_{DS}) [1] and higher phase noise due to low-frequency (LF) noise overshoot [2]. This is especially true for partially-depleted (PD) SOI MOSFETs. Recently, the high density integration of CMOS on a single chip increases the power dissipation density, resulting in an increased operating temperature. Only a few papers address the influence of high temperature operation for SOI analog applications [3, 4]. In this study, AC floating body effects will be explored in a wide temperature range (from 218K to 423K).

Device description: A 0.45μm PD thin film SOI MOSFET process was used in this study [5]. AC output conductance and low-frequency (LF) noise measurements have been described in [1] and the temperature characterization was performed using Lakeshore Modular Test Dewar Systems.

AC floating body effects: As operation temperature increases, the subthreshold slope (@ $V_{DS} = 0.1$V) degrades. But, the DC subthreshold kink still exists with a weak temperature dependence, as shown in Fig. 1. Fig. 2 shows the AC output conductances and the AC kink effect on G_{DS} have shifted towards lower drain bias as temperature increases [6]. More importantly, the G_{DS} curves converge at the lower frequency range < 1kHz @ T = 398K. This phenomenon is similar to nearly-fully-depleted device measurment at room temperature [1]. This is due to an increase of source/ body (S/B) junction saturation current (I_R) as temperature increases.

The temperature dependence of S/B junction characteristics also affects the well-known LF Lorentzian-like noise overshoot in floating body SOI MOSFETs. Fig. 3 shows the LF noise spectra measured at T = 218K, 298K, and 398K biased at $V_{GT} = 0.2$V, respectively. The noise overshoot at higher drain bias (e.g. $V_{DS} = 1.5$V and 1.75V) remains at similar magnitude. It is important to note that, as the drain biases nears the DC kink onset voltage ($\approx$ 1V), both the corner frequency (f_0) and overshoot magnitude show a strong temperature dependence, as shown in Fig. 3. In addition, f_0 in the pre-kink region (e.g. $V_{DS} = 0.5$V) shifts from 4Hz at T = 298K to 400Hz at T = 398K and the pure $1/f$ noise is observed at lower temperature operation (T = 218K). Therefore, the existence of pre-kink excess noise with a temperature dependence of f_0 in floating body SOI MOSFETs suggests that drain/body (D/B) reverse junction thermal generation current (I_G) is an important body charging source. Therefore, the low-frequency excess noise model [7] has to be revised to include both S/B and D/B junction characteristics as follows,

$$S_{VG,\,excess} = 2q(nV_T)^2\frac{1}{1+(f/f_0)^2}\cdot\frac{I_G+I_{ii}}{(I_R+I_G+I_{ii})^2}\cdot\beta^2 \text{ and } f_0 = (2\pi C_{BB} r_{SB}) \qquad (1)$$

where I_G is proportional to intrinsic concentration ($n_i = 38700\cdot T^{1.5}\cdot\exp(-7000/T)$), r_{SB} is S/B junction resistance, and $f_0 \propto I_R + I_G + I_{ii}$. At higher $V_{DS} - V_{dsat}$, impact ionization current (I_{ii}) overwhelms I_R and I_G resulting in weak temperature dependent noise overshoot magnitude. As temperature increases, I_G and I_R drastically increases, suppressing LF noise overshoot at the drain bias close to DC kink ($I_G + I_R \gg I_{ii}$), as expected in (1). This also contributes to the convergence of high temperature AC kink at lower frequency range, as shown in Fig. 2. In the pre-kink region, reduced n_i (by cooling down the device) suppresses pre-kink excess noise. On the other hand, the increase in I_G, by increasing the operating temperature, charges the body, causing body voltage instability and further shifts f_0 of excess noise towards higher frequencies, as shown in Fig. 4.

Conclusion: In this study, we show that not only S/B junction characteristics influence AC floating body effects, but D/B junction features also affect the device characteristics especially at higher operating temperatures. The increase of I_R by shifting towards fully-depleted (FD) operation can suppress AC floating body effects [1]. But, the reduced depletion width as temperature increases makes it difficult to realize the FD mode operating at high temperatures. Therefore, body contacts can be an option for high temperature low noise analog applications.

Acknowledgments: This work is supported by the Semiconductor Research Corporation under the project SJ-407.

0-7803-5456-7/99/$10.00 ©1999 IEEE

References

[1] Y.-C. Tseng, et al., *VLSI Technology*, pp. 122-123, 1998.
[2] Y.-C. Tseng, et al., *IEDM*, pp. 949-952, 1998.
[3] V. Dessard, et al., *HTEMDSC*, pp. 94-99, 1998.
[4] J.-P. Eggermont, et al., JSSC, pp. 179-186, 1996.
[5] W. M. Huang, et al., *CICC*, pp. 421-426, 1997.
[6] Y.-C. Tseng, et al., *VLSI Technology*, 1999.
[7] W. Jin, et al., *SOI Conf.*, pp. 23-24, 1998.

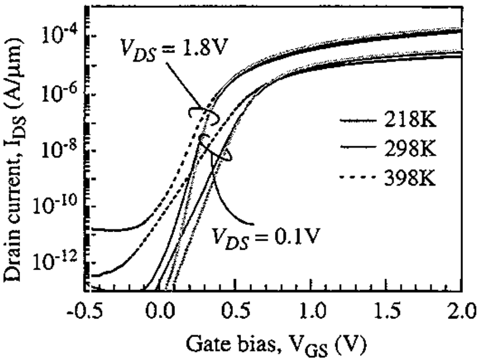

Fig. 1 Subthreshold characteristics in a 0.45μm PD floating body SOI nMOS as a function of temperature.

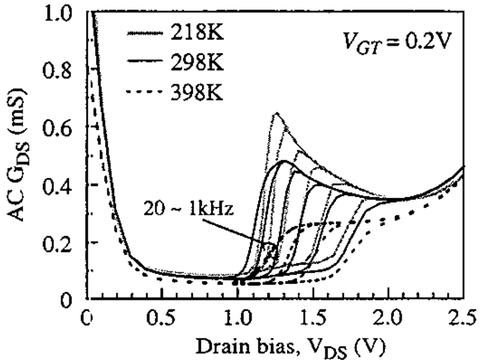

Fig. 2 AC output conductance as a function of temperature (from left to right, the measured frequencies are 20, 100, 1k, 10k, 100k, and 1MHz). Arc indicates the convergence of G_{DS} (T = 398K) at low frequency range.

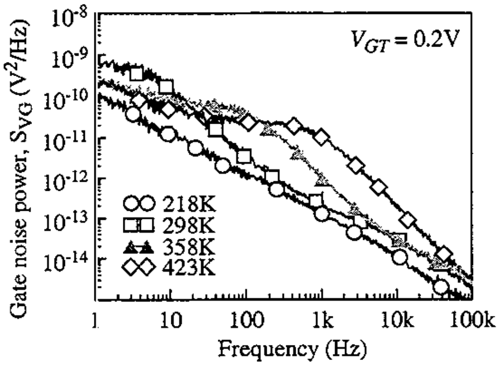

Fig. 4 Pre-kink excess noise of a 0.45μm PD floating body SOI nMOS biased at V_{DS} = 0.75V as a function of temperature.

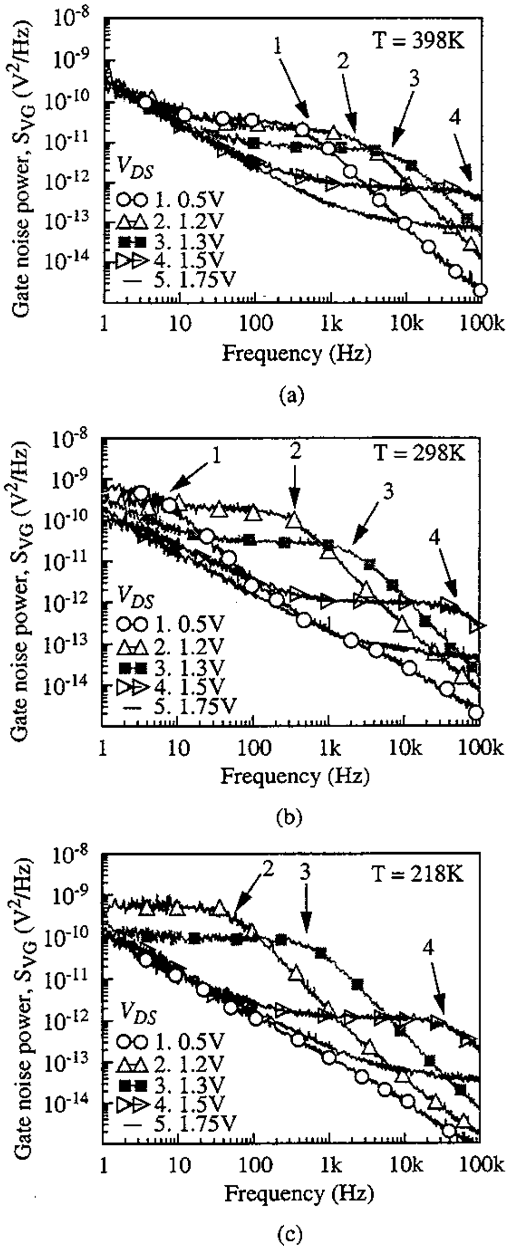

Fig. 3 Low-frequency noise characteristics of a 0.45μm PD floating body SOI nMOS biased at V_{GT} = 0.2V as a function of drain bias for (a) T = 398K, (b) T = 298K, and (c) T = 218K. Arrows indicate the corner frequency f_0 at different drain biases.