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Comparison Between High-Dose and Low-Dose SIMOX MOSFET's for Low-Power Radio-Frequency Applications

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1. Introduction

Although different types of SOI materials have been developed during the last decades, SIMOX technologies remain the most widely used. A high- and low-dose SIMOX processes are available. In addition, several recent works have confirmed the suitability of SOI technologies for analog-digital integration applications. The use of high resistivity SOI substrates allows the elaboration of passive components, such as CPW, inductances, etc. presenting very good performances at frequencies as high as 10 GHz [1-2]. In this work, the high frequency behavior is investigated for both high- and low-dose SIMOX NMOSFET's.

2. Results and discussion.

Fully-depleted SOI MOSFET's are fabricated on p-type silicon wafer. The SOI substrates are elaborated using low-dose (LD) and high-dose (HD) SIMOX processes and consequently, the buried oxide thicknesses are 100nm and 380nm respectively. A silicon film thickness of 100nm and a front gate oxide thickness of 7nm are used in this study. N-channel SOI MOSFET's with a 0.4μm gate length and 70 fingers of 5μm gate width, have been especially designed for RF applications. The high frequency characteristics are obtained from S-parameters measurements with an HP8510B network analyser and a Cascade Microtech Probe Station with frequency ranging between 100MHz and 18GHz. For each RF measurement, a de-embedding procedure is applied to eliminate the parasitic contribution of pads.

The parameters of small signal equivalent circuit (Fig. 1) for LD and HD SIMOX MOSFET's have been extracted with an analytical calculation method. Table 1 shows the access parasitic source, drain and gate resistances. Note that the gate resistance is very low, despite the non-salicided process, thanks to the multifingers architecture. From another part, the gate-source, gate-drain and drain-source capacitances (C_{gs}, C_{gd} and C_{ds} respectively) and the drain conductance (g_{ds}) are extracted (Table 2). At $V_{ds}=V_{gs}=0V$, the capacitance values, corresponding to the extrinsic capacitances (overlaps capacitances, fringing capacitances, etc.), are lower for high-dose SIMOX devices than low-dose SIMOX ones and these differences remain when a bias is applied. This could be attributed to a further extension for the drain and source regions beneath the channel in the case of LD SIMOX MOSFETs. Moreover, the drain conductance is higher for high-dose SIMOX devices because the short channel effects are more pronounced in this case. The output transcondutance g_m has also been plotted versus drain voltage V_{ds} at $V_{gs}=0.5V$ (Fig. 2) and $V_{gs}=1V$ (Fig. 3). At $V_{gs}=0.5V$, we can notice higher tranconductance values for high-dose SIMOX devices contrary to $V_{gs}=1V$ case, where g_m becomes lower than low-dose SIMOX one. This behavior is typically due to the self-heating effect [3]. Indeed, the low thermal conductivity of the buried oxide inhibits cooling of SOI devices and causes severe self-heating effects. The device mobility is reduced as a result of the higher channel temperature reducing the transconductance. Note that the temperature rise is reduced as buried oxide thickness is reduced.

The cut-off frequencies f_T (transition frequency) and f_{max} (maximal frequency oscillation) have also been respectively extracted from the current gain h_{21} and the unilateral power gain U variations with frequency. Figures 4-5 show f_T and f_{max} variations versus drain voltage at $V_{gs}=0.5V$ (Fig. 4) and $V_{gs}=1V$ (Fig. 5). Very good values of f_T and f_{max} are obtained at low voltage range. At $V_{gs}=0.5V$ and whatever the V_{ds} value is, the transition frequency for HD SIMOX MOSFETs is higher than that LD ones due to a lower C_{gs}, and C_{gd} values. However, at higher V_{gs}, no significant difference is obtained, especially at high V_{ds}. This is can also be attributed to the SH effect because in this case, f_T for HD SIMOX MOSFETs decreases due to a g_m decrease and the difference between the two f_T (corresponding to HD and LD SIMOX devices) becomes neglected. Finally, it is worth noticing that f_{max} is higher than f_t whatever the substrate type or the bias range are, due to a very low access gate resistance.

3. Summary

High-frequency characterization of LD and HD SIMOX NMOSFETs is achieved. Good RF performances are obtained even at very low voltage, which is suitable for low power consumption. Excepted the self-heating effect, no significant difference is noticed to be inherent to the substrate type. For the purpose of further improvements, series resistance and capacitances have to be optimised.

References

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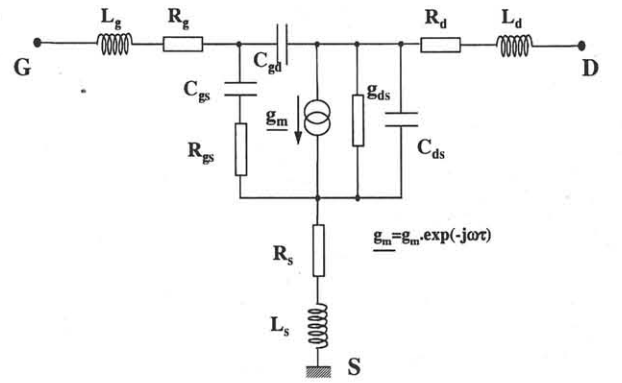

Figure 1: Small signal equivalent circuit of SOI MOSFET.

Table 1: Extracted values of access resistances for Low-Dose and High-Dose SIMOX MOSFET's.

	Low-Dose SIMOX	High-Dose SIMOX
R_g (Ω)	8.9	5.8
R_d (Ω)	1.8	1.9
R_s (Ω)	1.0	1.5

Table 2: Extracted values of capacitances and drain conductance for Low-Dose and High-Dose SIMOX MOSFET's.

	V_{gs} (V)	V_{ds} (V)	C_{gs} (fF)	C_{gd} (fF)	C_{ds} (fF)	g_{ds} (mS)
Low-Dose SIMOX	0.0	0.0	180	104	146	
	0.5	2.0	267	96	145	5.2
	1.0	2.0	286	98	142	7.5
High-Dose SIMOX	0.0	0.0	134	84	80	
	0.5	2.0	216	70	94	7.6
	1.0	2.0	234	70	93	9.4

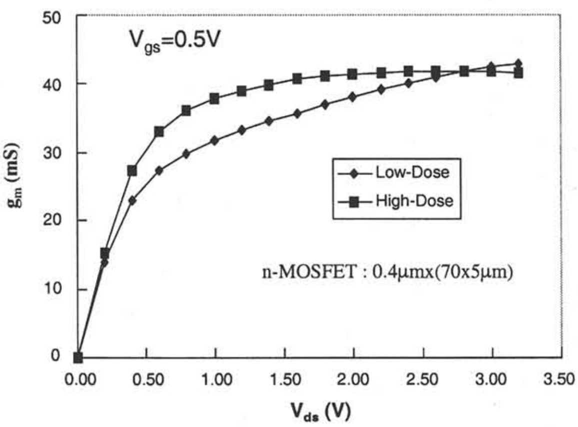

Figure 2: Transconductance g_m versus drain voltage V_{ds} for Low-Dose and High-Dose SIMOX MOSFET's at V_{gs}=0.5V.

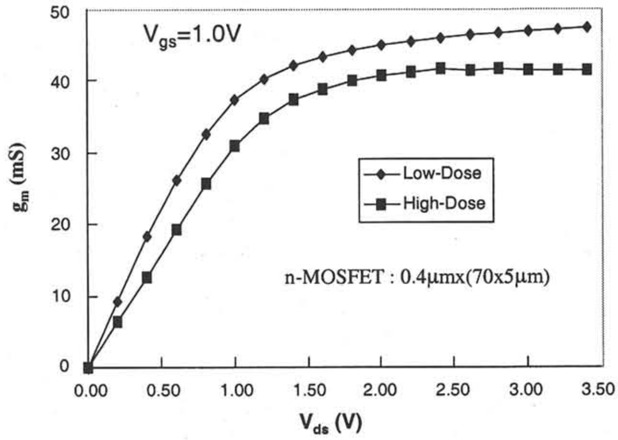

Figure 3: Transconductance g_m versus drain voltage V_{ds} for Low-Dose and High-Dose SIMOX MOSFET's at V_{gs}=1.0V.

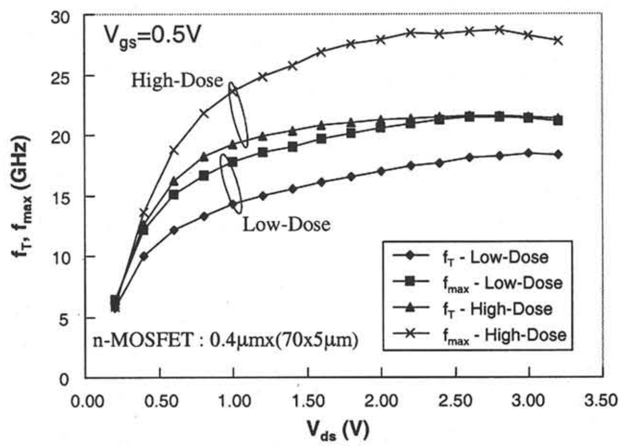

Figure 4: Cut-off frequencies f_T and f_{max} versus drain voltage V_{ds} for Low-Dose and High-Dose SIMOX MOSFET's at V_{gs}=0.5V.

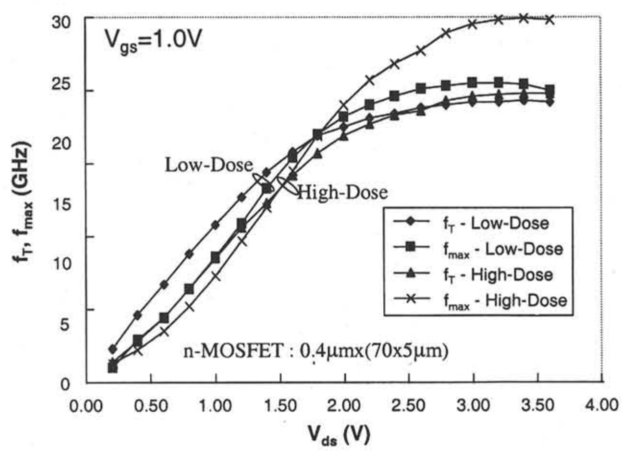

Figure 5: Cut-off frequencies f_T and f_{max} versus drain voltage V_{ds} for Low-Dose and High-Dose SIMOX MOSFET's at V_{gs}=1.0V