Temperature Influence on the Generation Lifetime Determination Based on Drain Current Transients in Partially Depleted SOI nMOSFETs

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Carrier lifetime in SOI MOSFETs is an important parameter for technology characterization and device performance. Several authors have reported generation lifetime measurement methods using SOI MOSFETs [1-4], but most of them require complicated data analysis. Floating body Partially Depleted (PD) SOI MOSFETs exhibit drain current transients [5-8] and these can be used to determine the generation lifetime, τ_g, without numerical analysis [9]. The use of the above methods to obtain τ_g for different temperatures can take a long time, while for many applications one only needs at dedicated operation temperatures an estimation of τ_g to evaluate the impact of the wafer quality and/or some process steps.

This paper presents an analysis of the temperature influence on the τ_g determination using drain current transients in floating body PD nMOSFETs[9] fabricated in a 0.13µm SOI CMOS technology.

Figure 1 shows the measured drain current transients $I_d(t)$ normalized to the steady-state current level $I_{d\infty}$ for a PD SOI nMOSFET after switching its gate from V_{Ghigh}=0.7V to V_{Glow}=0.1V at different temperatures in the 20ºC to 80^0C range. As can be easily seen, the I_d is significantly suppressed immediately after the negative voltage step and it gradually increases towards the steady-state value due to the generation of holes. The magnitude of the transient time T_o decreases with increasing temperature. Applying the τ_g calculation method [9] for a nMOSFET with L=W=10 µm, a gate oxide thickness t_{ox}=2.5nm and a film doping concentration N_a=5.5x10^{17}cm^{-3} as used in this work, a τ_g of 0.09 μs is obtained at 20^0C.

The expression used to calculate τ_g has 3 terms [9]: a factor F, n_i (intrinsic carrier concentration) and T_o. The F factor is a function of both t_{ox} and N_a. Figure 2 shows the temperature dependence of the F factor, n_i and T_o for the same device operating between 20^0C to 80^0C. In spite of the fact that n_i strongly increases with temperature, T_0 decreases almost with the same rate and the F factor only slightly increases from 6.82x10^{-19} (at 20^{o}C) to 7.71x10^{-19} cm^3 (at 80^{o}C). Taking as a reference the F factor at 20^0C (F_1) the change to 80^0C (F_2) is about 13%. The sensitivity of F to t_{ox} and N_a is also studied and the maximum change in F is about 17%, obtained at 80^0C and with ±10% error on N_a.

As for many applications the F factor changes can be neglected, a simple method to estimate τ_g at different temperatures is proposed using the equation bellow.

$$\tau_{g3} = \left[\tau_{g1} . \left(\frac{T_3}{T_1} \right)^{3/2} . e^{-\frac{1}{2.K}\left(\frac{E_{g3}}{T_3} - \frac{E_{g1}}{T_1} \right)} \right] . \left(\frac{T_{0,2}}{T_{0,1}} \right)^{\left(\frac{T_3 - T_1}{T_3 . T_1} \right) . \left(\frac{T_2 . T_1}{T_2 - T_1} \right)}$$

It is only required to measure T_o at 2 different temperatures T_1 and T_2 and to calculate τ_{g1} at T_1 in order to determine τ_{g3} at any arbitrary temperature T_3. Figure 3 shows the experimental τ_g values for different operation temperatures using [9] and the proposed method. A good agreement is observed and the maximum error, including both, the F factor and the apparent linear approximation errors, is estimated to be around 6%.

References

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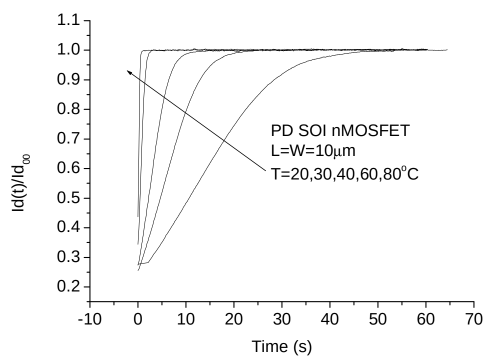

Figure 1 – Temperature dependence of the drain current transients drain current measured after applying a switch-off gate voltage step.

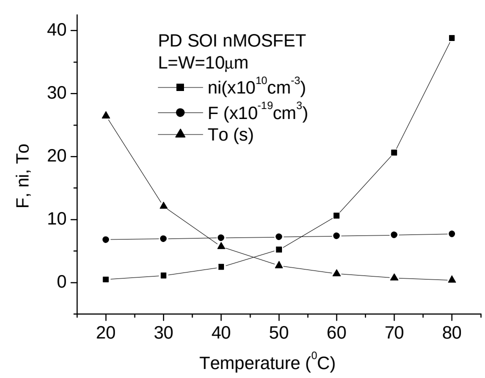

Figure 2 – Theoretically calculated F factor and n_i values and experimentally obtained T_0 as a function of temperature.

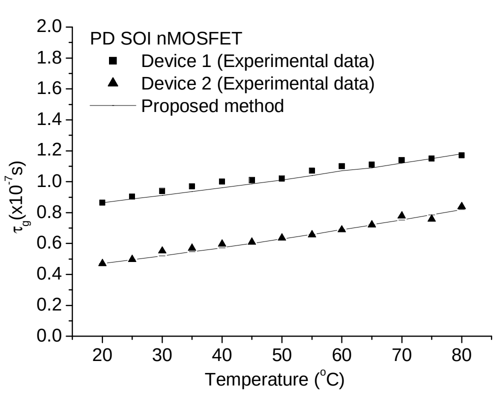

Figure 3 – Generation lifetime values obtained experimentally and by using the proposed method.