Evidence for a "linear kink effect" in ultra-thin gate oxide SOI n-MOSFETs

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Introduction

An excess of the drain current I_D, related to the floating body effect and hole generation by impact ionization, can appear in the saturation region of SOI MOSFETs [1]. This mechanism has been reported for drain voltages below the band-gap voltage (V_D=0.7 V) by including additional energy gain mechanisms to overcome the thresholds of impact ionization processes [2,3]. In this paper we examine a new type of "kink effect" appearing in the linear regime ($V_D \leq 25$ mV) of ultra-thin gate SOI n-MOSFETs: the Linear Kink Effect (LKE). As will be shown, the LKE gives rise to a second peak in the linear transconductance G_m and an overshoot in the low-frequency noise spectral density S_I for front gate voltages exceeding 1 V. The effect occurs both in Partially (PD) and Fully Depleted (FD) devices. For the latter case, the back gate should preferably be biased in accumulation. Moreover, the LKE affects drastically the switch off behavior of the transistors, which has consequences both for circuit operation and lifetime extraction. Finally, a possible model will be proposed, explaining the observations in terms of electron valence band tunneling through the ultra-thin oxide.

The Linear Kink Effect (LKE): Experiments and Analysis

The Linear Kink Effect is experimentally investigated at low drain bias for SOI n-MOSFETs fabricated in a 0.13 µm SOI process using a PELOX isolation scheme, a 2.5 nm Nitrided gate Oxide (NO), 150 nm polysilicon gate and 80 nm nitride spacers. The test structures have both common gate/common source configuration with separate drain pads and there is no film contact. The LKE is clearly identified by an excess of the drain current and a "second peak" in the transconductance for the usual experimental conditions at room temperature in Partially Depleted (PD) or Fully Depleted (FD) SOI MOSFETs with the appropriate back gate bias (V_{GB}) (Fig. 1). For the devices studied, the second peak typically occurs for a V_G above 1.1 V.

Impact of LKE on Low Frequency Noise and Device Switching

In addition to this LKE related second G_m peak, an overshoot can also be measured in the normalized low frequency noise spectral density (Fig. 1). As will be shown, the corresponding spectrum is Lorentzian, while a 1/f spectrum is normally found outside the overshoot region. This resembles closely the well-known behavior of the kink-related noise overshoot, which is believed to originate from RC filtered shot noise of the source/drain-body junctions.

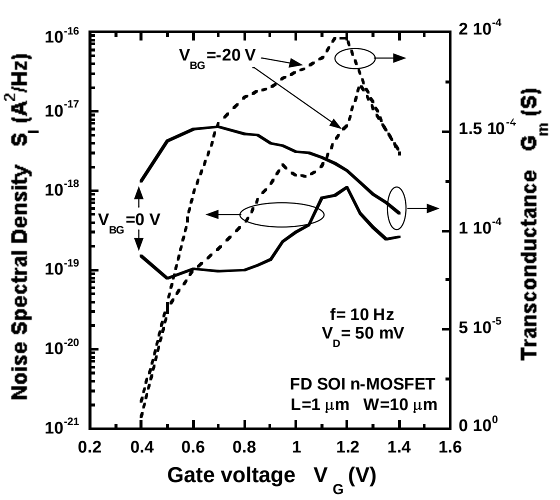

Figure 1: Linear Kink Effect related noise contribution to the drain current noise power spectral density in a FD (at V_{BG}=0 V and –20 V) SOI n-MOSFET with L=1 µm and W=10 µm.

The impact of the LKE and the source/substrate junction turning on, on both the noise overshoot and the switch off behavior will be addressed. The latter is studied via the drain current transients corresponding to the switch off at low drain bias (V_D= 25 mV) when the gate is driven by a voltage step from ON gate biases ($V_{G\ high}$) to 0.1 V. For gate biases lower than 1.1 V, corresponding to the regime without LKE, an I_D undershoot first arises and then the steady state is recovered by hole thermal generation. Analyzing this transient enables to extract the generation lifetime in the film. On the other hand, for $V_{G\ high}$ higher than 1.1 V, it is believed that holes are accumulated in the body due to LKE. Consequently, at the turn off the body potential V_{SUB} decays due to the discharge of the holes. Therefore, no current undershoot is observed for $V_{G\ high}$. The peak current depends on $V_{G\ high}$, but the time scale of the decay remains the same because it is related to the same capacitance discharge through the source/body junction.

Discussion and Conclusion

The Linear Kink Effect shows up many similarities with the well-known impact-ionization-induced kink effect affecting SOI MOSFETs at high drain bias. By analogy, the main mechanisms observed in the LKE case can be simply interpreted by considering that the pertinent electrical field is the vertical one and that the hole generation mechanism is related to valence band electron tunneling [4]. LKE can be a major limitation for common gate circuits like amplifiers or memories that are sensitive to the device history.

References

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