THE CHANNEL LENGTH INFLUENCE ON THE LOW FREQUENCY NOISE IN GC SOI MOSFETs WITH THIN GATE OXIDE LAYER

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1. Abstract

In this work, the channel length influence on the Low Frequency Noise (LFN) of submicron Graded Channel Silicon-On-Insulator MOSFETs (GC SOI) with thin gate oxide layer is studied. This study was performed through experimental measurements in GC SOI with L=240nm, 350nm, 500nm and 1µm working in linear region with V_{DS}=50mV. The results obtained showed that the normalized noise ($S_{ID}/I_{DS}^2.W.L$) increases with channel length increase that goes against the regular theories proposed by Hooge and McWhorter.

2. Introduction

Silicon-On-Insulator technology (SOI) has been show as an alternative in relation to conventional Complementary Metal-Oxide-Semiconductor technology (CMOS), since it can reduces the short channel effects by having a buried oxide layer and thereby allows a major channel length reduction in relation to bulk CMOS technology [1].

Graded Channel SOI MOSFETs (GC SOI) was firstly proposed for reducing the high electric field near to drain existing in uniformly doped SOI transistor [2]. The GC SOI has an asymmetric channel doping concentration with a lightly doping concentration near to drain named L_{LD} and a high concentration near to source named L_{HD} that is responsible for threshold voltage adjust [2]. This characteristic allows GC SOI to present improvements in relation to conventional planar SOI transistor mainly for analog and Radio-Frequency (RF) application [2], such as high voltage gain and high unity gain frequency at high temperatures up to 573 K [3].

Since Aldert van der Ziel [4], Low Frequency Noise has been deeply studied. Two theories about LFN origin have been widely accepted in terms of $1/f^{\gamma}$ in Metal-Oxide-Semiconductor (MOS) and Silicon-On-Insulator transistors (SOI). The carriers' number fluctuation proposed by McWhorter (Δn) [5] equation (1) and the mobility fluctuation proposed by Hooge (Δµ) [6] equation (2).

$$\frac{S_{ID}}{I_{DS}^2}.W.L = \frac{q^2.k.T.N_{itf}}{\alpha_t.f.C_{oxf}^2}.\frac{1}{V_{GF}^2} \qquad (1)$$

where S_{ID} is the Noise spectral current density, I_{DS} is the drain current, q is the elementary electron charge, k is the Boltzmann constant, T is the absolute temperature, V_{GF} is the voltage applied at the gate, N_{itf} is the oxide trap density per unit of area, α_t is a tunnelling parameter usually taken as 10^8cm^{-1} for the Si-SiO_2 interface [7], f is the frequency, W and L are the channel width and length, respectively and C_{oxf} is the front-gate capacitance per unity area.

$$\frac{S_{ID}}{I_{DS}^2} = \frac{\alpha_H}{f.N} \qquad (2)$$

where α_H is the Hooge ranging from 10^{-3} to 10^{-10} [7], N is the number of carries in the cannel where $N=C_{ox}.V_{GF}.W.L/q$ [8]. Replacing N in (2) it has (3).

$$\frac{S_{ID}}{I_{DS}^2}.W.L = \frac{\alpha_H.q}{c_{ox}.f}.\frac{1}{V_{GF}} \qquad (3)$$

It is know that the channel leakage current (I_G) increase with decrease of SiO_2 oxide thickness due to carrier tunneling from gate to silicon layer increasing the body potential [7] and this can lead in an excess noise [9]. Recently, a study performed in MOS transistors showed that with the increase of channel length (L) the normalized noise $S_{ID}/I_{DS}^2.W.L$ also increases, that does not follow the Δn and Δµ theories. It happens by the fact that increasing of I_G increase the traps in the oxide that increases (Nitf) [10] that is demonstrated in equation (4).

$$I_G = q.v.\alpha_t.N_{itf}.W.L \qquad (4)$$

where υ is the velocity of a tunneling front moving through the oxide layer, which should be dependent on the electrical field in the oxide [10].

3. DC Measurements

The measurements were performed in submicron GC SOI devices from a 150 nm commercial technology from OKI Semiconductors with channel length (L) of 240nm, 350nm, 500nm and 1µm channel width (W) of 240 µm, L_{LD}/L=0.5, gate oxide thickness of t_{oxf} = 2.5 nm, silicon film thickness of t_{si} = 40 nm and buried oxide thicknesses of t_{oxb} = 145 nm.

Fig. 1. shows the I_{DS} as a function of the V_{GT} in linear (left y-axis), I_{DS} as a function of the V_{GT} in logarithmic scales at (right y-axis) and I_G current as a function of the V_{GT} in logarithmic scales also (right y-axis). In this picture, it is possible to see the increase of I_{DS} with decrease of cannel length as can see in literature [1]. It is also possible to see the increase of gate current (I_G) with the increase of channel length. It happens due to carries tunneling in thin oxide layer [10].

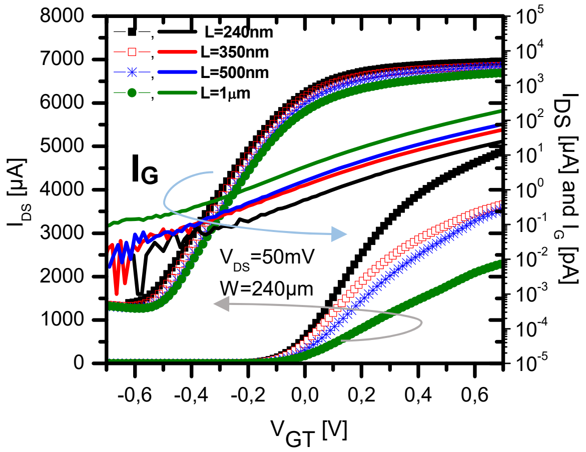

Fig. 1. I_{DS} as a function of V_{GT} in linear scales (left y-axis), I_{DS} as a function of V_{GT} in logarithmic scales at (right y-axis) and I_G current as a function of V_{GT} in logarithmic scales also (right y-axis).

4. Noise Measurements

Fig. 2. shows the Normalized noise spectral current density S_{ID}/I_{DS}^2 as a function of Frequency with V_{GT}, where $V_{GT}=V_{GF}-V_{TH}$ that varies from -100mV to 200mV. It is possible to see that the normalized noise worsens as V_{GT} decrease. The I_{DS} oscillation due to the activation of a single trap is more pronounced closer to V_{TH} due to the smaller concentration of carriers in the channel [11]. For frequencies above 500Hz, the low frequency noise $1/f^{\gamma}$ change the inclination that can indicate the occurrence of Lorentzians that compose the Generation and Recombination noise (GR).

Fig. 3. shows the normalized noise spectral current density S_{ID}/I_{DS}^2.W.L as a function of the V_{GT}. In this picture, it is possible to see that the normalized noise (S_{ID}/I_{DS}^2.W.L) increase with the channel length increase that does not agree with (1) and (2). It happens due to increase of tunneling gate current (I_G) with the increase of cannel length [10]. It is also possible to see that for V_{GT} values < 200mV the S_{ID}/I_{DS}^2.W.L follow the $1/V_{GT}^2$ tendency in according to (1) and for V_{GT}>200mV this tendency starts slightly to change for $1/V_{GT}$ that suggests a mobility interferences in according to (2).

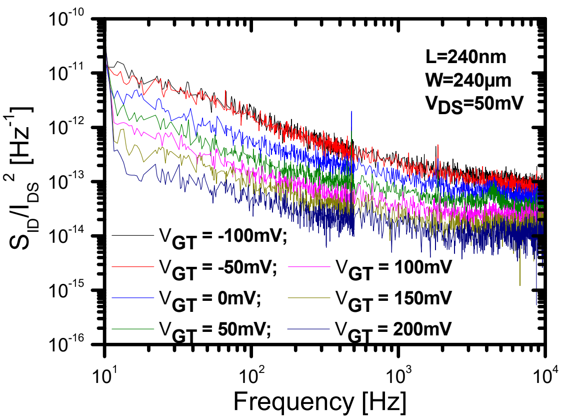

Fig. 2. Normalized noise spectral current density S_{ID}/I_{DS}^2 as a function of Frequency.

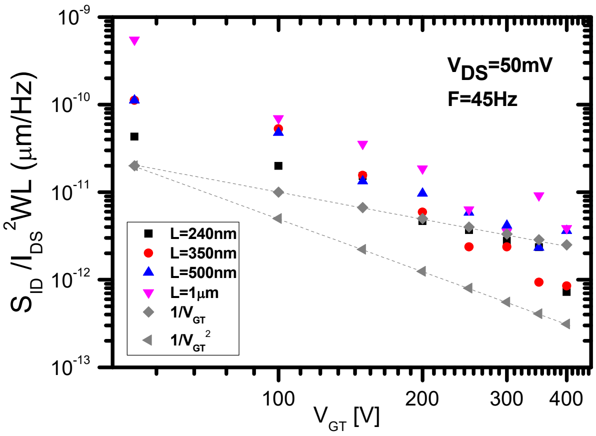

Fig. 3. Normalized noise spectral current density S_{ID}/I_{DS}^2.W.L as a function of the V_{GT}.

5. Conclusions

As a conclusion of this work, it was possible to see in the measurements results performed in GC SOI transistors that the normalized noise (S_{ID}/I_{DS}^2.W.L) increase with channel length increase due to increase of gate leakage current (I_G), in agreement with previous work performed in bulk MOSFETs that goes against the regular theories proposed by Hooge and McWhorter. The leakage current must be considered in noise analyses in devices with thin oxide layers.

Acknowledgments

The authors of this work would like to thank CAPES, CNPq and FAPESP for the financial support.

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