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 VDS=50mV. The results obtained showed that the normalized noise (SID/IDS².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 LLD and a high concentration near to source named LH 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 γ in Metal-Oxide-Semiconductor (MOS) and Silicon-On-Insulator transistors (SOI). The carriers’ number fluctuation proposed by McWhorter (Δn) equation (1) and the mobility fluctuation proposed by Hooge (Δµ) equation (2).

\[ \frac{S_{ID}}{I_{DS}^2} W L = \frac{q^2 k T N_{itf}}{\alpha_1 f C_{oxf}^2} \frac{1}{V_{GF}^2} \] (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, \( \alpha_1 \) is a tunnelling parameter usually taken as 10⁶cm⁻¹ for the Si-SiO₂ 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.

\[ \frac{S_{ID}}{I_{DS}^2} W L = \alpha_1 \frac{q^2 k T N_{itf}}{C_{oxf}^2} \frac{1}{V_{GF}^2} \] (2)

where \( \alpha_1 \) is the Hooge ranging from 10⁻³ to 10⁻¹0 [7], \( N \) is the number of carries in the channel where \( N=C_{oxf} V_{GF} W L/q \) [8]. Replacing \( N \) in (2) it has (3).

\[ \frac{S_{ID}}{I_{DS}^2} W L = \frac{1}{c_{ox} f^2 V_{GF}^2} \] (3)

It is know that the channel leakage current (I_G) increase with decrease of SiO₂ 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 \( S_{ID}/I_{DS}^2W.L \) also increases, that does not follow the \( \Delta n \) and \( \Delta \mu \) 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).

\[ I_G = q v \alpha_1 N_{itf} W L \] (4)

where \( v \) 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_{ox} = 2.5 nm, silicon film thickness of t_{d} = 40 nm and buried oxide thicknesses of t_{amb} = 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 channel 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].
4. Noise Measurements

Fig. 2. shows the Normalized noise spectral current density $S_{ID/IDS^2}$ as a function of Frequency with $V_{GT}$. In this picture, 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 $1/f$ 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 $S_{ID/IDS^2}.W.L$ as a function of $V_{GT}$. In this measurement results performed in GC SOI transistors that the normalized noise ($S_{ID/IDS^2}.W.L$) 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.

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References