LFN and RTN in Nanoscale Devices: Modeling and Impact on Circuit Operation

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Abstract—In this work, we present the latest modeling approaches regarding LFN and RTN in advanced MOSFETs, with a special focus on the FDSOI technology. Furthermore, various methods of model implementation are shown, allowing for accurate defect-aware circuit noise and reliability studies.

Keywords—Low frequency noise, Random Telegraph Noise, Modeling, Verilog-A, FDSOI, MOSFET

I. INTRODUCTION

As the intensity of Low frequency noise (LFN) and Random Telegraph Noise (RTN) fluctuations increases with the reciprocal device area, they can therefore jeopardize the functionality of both analog and digital circuits. In Ultra-Thin Body and Box (UTBB) Fully Depleted Silicon-On-Insulator (FDSOI) MOSFETs in particular, LFN and RTN can be further influenced by coupling effects. In this work, we present some important aspects concerning the LFN/RTN modeling in advanced devices, as well as the development of circuit noise simulation methods.

II. NOISE MODEL APPROACHES

A. Dependence of Hooge parameter on inversion charge

As the Hooge mobility fluctuations depend only on the phonon scattering rate [1], the Hooge parameter, $\alpha_H$, should be modulated by its contribution among other scattering mechanisms limiting the carrier mobility:

$$\alpha_H = \alpha_{Ho} \left[ \frac{1}{\mu_{ph}} \left( \frac{1}{\mu_{ph}} + \frac{1}{\mu_{CS}} + \frac{1}{\mu_{SR}} \right) \right]^2$$ (1)

where $\alpha_{Ho}$ refers to the intrinsic Hooge parameter and $\mu_{ph}$, $\mu_{CS}$ and $\mu_{SR}$ are respectively the phonon, Coulomb and surface roughness scattering limited mobility in the inversion layer [2]. The dependence of $\alpha_H$ is evaluated theoretically versus the inversion charge from weak to strong inversion, revealing that $\alpha_H$ is far from being independent of inversion charge, and is maximized when the PH contribution prevails with respect to CS and SR rates.

B. Impact of QMEs on Random Telegraph Noise

When the trap is not located right at the oxide-channel interface, but at a depth $x_i$ in the oxide, the apparent trap energy $E_t$ depends on the band bending in the gate dielectric [3], [4]. Moreover, the capture ($\tau_c$) and emission ($\tau_e$) times should be updated when quantum mechanical effects (QMEs) become important. So, finally, $\tau_c$ and $\tau_e$ can be expressed in a way that accounts for both $x_i$ and QMEs:

$$\tau_c = \frac{q}{\sigma \cdot freq \cdot Q_i (a)}$$
$$\tau_e = \frac{q \cdot e^{-kF \cdot x_i}}{\sigma \cdot freq \cdot Q_i (b)}$$ (2)

where $freq$ is the escape frequency ($\approx 2 \times 10^{13}$ Hz) of the electrons in the quantized sub-band, $Q_i$ the inversion charge when $E_t$ crosses $E_F$ and $Q_d$ the depletion charge.

REFERENCES