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A NON LINEAR FIT BASED METHOD TO SEPARATE EXTRACTION OF SERIES RESISTANCE AND MOBILITY ATTENUATION PARAMETER IN ULTRA-THIN OXIDE MOSFET

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ABSTRACT

We present in this work a new procedure to separate extraction of the series resistance and the mobility degradation factor in ultra thin MOSFETs. The method is based on the manipulation of the exponential model of effective mobility and extraction different parameters using a non linear fit of the experimental characteristic I_d (V_g) measured in strong inversion at small drain bias. The results obtained have shown better agreement with measurements data

Key words: MOSFET, Series Resistance, Surface Roughness, Mobility, Mobility degradation.

I. INTRODUCTION

Accurate model parameter extraction is crucial for modeling modern MOSFET devices. Extensive work abounds in the literature dedicated to this subject. Free-carrier mobility degradation and source-drain series resistance are two parameters of special importance for MOSFET characterization that are particularly cumbersome to extract independently from each other. Both of these parameters produce similar effects on the device's transfer characteristics, I_d (V_g), a fact that complicates their accurate extraction.

Several procedures have been proposed to get around this difficulty [1–5]. Another method was proposed to extract these parameters from the drain current versus gate voltage characteristics in the saturation region using several devices of different mask channel lengths [6]. An alternative procedure was recently proposed to extract the source-and-drain series resistance independently of mobility degradation by using bias conditions under which the channel carrier mobility is kept constant [7]. Juan Muci and al [8-9] was presented a procedure to separate and extract source and series resistance and mobility degradation, this method is based on directly calculating the three parameters by solving a system of three simultaneous equations and using a classical model of mobility with mobility degradation exponent n (equation 1), if n equal to unity, the effect of series resistance and mobility attenuation parameter would be inseparable.

$$\mu_{eff} = \frac{\mu_0}{1+\theta.(V_G - V_t)^n} \quad (1)$$

where θ is the mobility degradation factor due to the gate field, μ_0 is the low-field mobility, V_G is the intrinsic gate voltage and V_t is the threshold voltage. The fact that n is different to unity is what allows the separation of these two parameters effect at small drain voltage. However, this procedure is immune to such inconveniences since it based on extracting parameter n by fitting the experimental data of long channel device to the drain current equation neglecting the parasitic resistance.

In what follows we present a new procedure to be applied in strong inversion to the drain current vs. gate voltage characteristics of a single transistor, measured at a small drain bias. It is based on the exploiting of exponential model of effective mobility and a non linear fit. The procedure has been validated using data from a single experimental short channel device.

The drain current I_d in the linear region can be expressed as:

$$I_d = \frac{W}{L}.\mu_{eff}.C_{ox}.(V_G - V_t).V_D \quad (2)$$

where W is the channel width, L is the channel length, C_{ox} is the oxide capacitance, μ_{eff} is the effective free-carrier mobility, V_G is the intrinsic gate voltage, V_D the intrinsic drain voltage and V_t is the threshold voltage.

The model of variation mobility with effective field considers that the attenuation of effective mobility is particularly due to Surface Roughness Scattering [10]. When the transversal field increases, inversion charges are flattened on the weak mobility edge, on a length A of some Angstr6ms near the interface Si/SiO2. This work generalized all the classical models [9, 11], and give a physical meaning to the different used parameters.

The effective mobility exempt series resistance is given by the exponential model in strong inversion:

$$\mu_{eff} = \mu_0.\exp\left(-\theta.(V_G - V_t)\right) \quad (3)$$

where

$$\theta = \frac{\eta.\beta.\Delta.C_{ox}}{\varepsilon_{si}} \quad (4)$$

θ is the attenuation coefficient of mobility, η is constant parameter equal to 0.5for electrons and 0.33 for holes, $\beta = q/kT$ is the inverse of the thermal potential, ε_{si} silicon permittivity, Δ is the surface roughness amplitude , μ_0 represents the low-field mobility.

If the source-drain series resistance is significant, the device's intrinsic gate and drain voltages are:

$$V_G = V_g - I_d.\frac{R_{sd}}{2} \quad (5)$$

$$V_D = V_d - I_d.R_{sd} \quad (6)$$

where V_g and V_d are the externally applied gate and drain voltages, respectively, R_{sd} is the total source-drain series resistance.

Assuming that $V_g - V_t >> I_d.R_{sd}/2$, relation (2) becomes:

$$I_d = K.\frac{(V_g - V_t)}{\exp(\theta.(V_g - V_t)) + \frac{K.R_{sd}}{V_d}.(V_g - V_t)} \quad (7)$$

where

$$K = \frac{W}{L}.\mu_0.C_{ox}.V_d \quad . \quad (8)$$

II. PROCEDURE EXTRACTION

The procedure is based on calculating the function $R(V_g) = (V_g-V_t) / I_d = V_{gt} / I_d$

$$R\left(V_g\right) = \frac{V_{gt}}{I_d} = C_1 \exp(C_2.V_{gt}) + C_3.V_{gt} \quad (9)$$

with $C_1 = \frac{1}{k}, C_2 = \theta, C_3 = \frac{R_{sd}}{V_d}$.

We find the extraction of these three parameters by direct nonlinear fit of equation (9) to the experimental data.

III. RESULTS AND DISCUSSION

In order to illustrate the proposed procedure, we use 0.1µm short channel length device, the channel width W = 4µm, gate oxide thickness t_{ox} = 5nm, and channel doping Na = 10^{16} cm^{-3}. To start this procedure we need to find the threshold voltage V_t, value using any of the known conventional threshold voltage extraction methods. Here we have used a method based on function Y(Vg) = $\frac{I_d}{\sqrt{g_m}}$, where g_m is the transconductance that is given by dI_d / dV_g. V_t can be extracted from the V_g axis intercept of the observed straight lines of Y versus V_g characteristic. The V_t value for this device turns out to be 0.2 V.

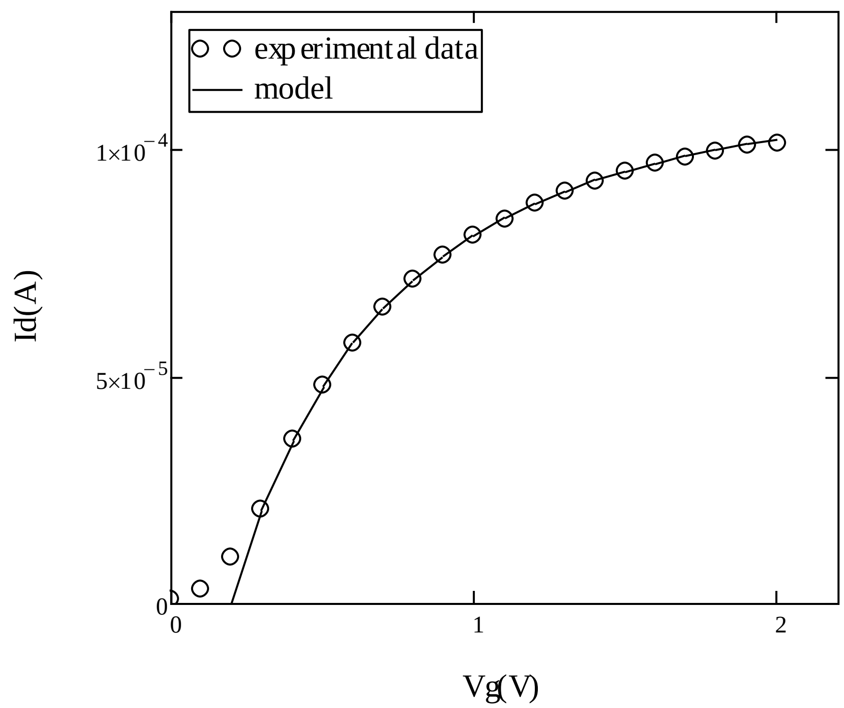

Figure 1: Experimental and simulated characteristic I_d vs. V_g

Figure 1 presents the experimental characteristics measured at a small drain voltage of 20 mV and the theoretical characteristics using different calculated parameters. The application of our method shows a best agreement with experimental data.

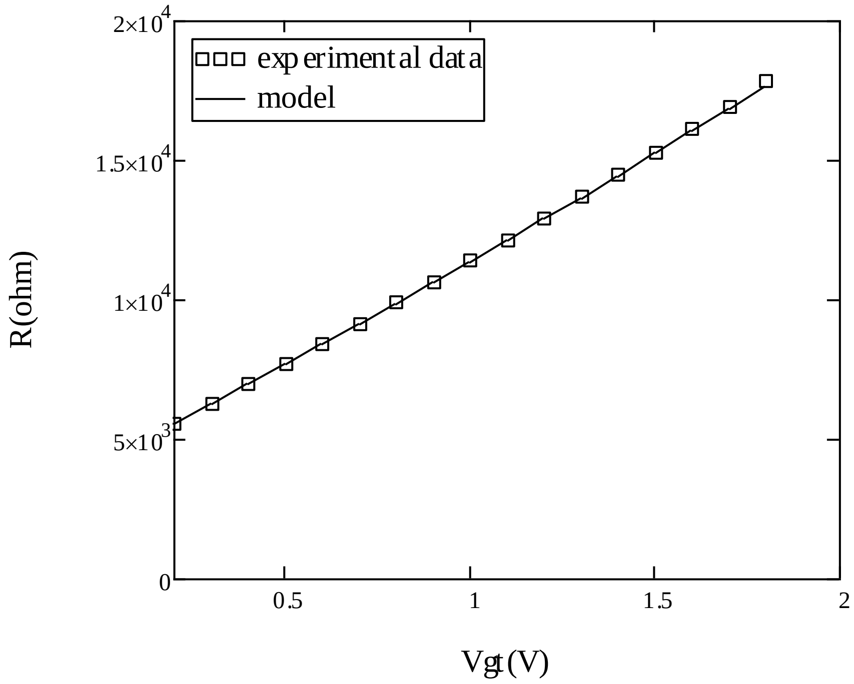

Figure 2: Experimental and simulated characteristic R vs. V_{gt}

Figure 2 shows the experimental variation of the corresponding function R, vs. the gate voltage overdrive V_{gt}. It is clearly that the application of model given in equation (9) shows a good fit.

The resulting parameter values for this device are presented in Table 1.Also presented are the parameters extracted by two other methods also based on exponential model of mobility:

Table 1: Values of the different extracted parameters

Parameter	θ (1/V)	R_{sd} (Ω)	Δ (nm)
Method [10]	0.363	107.53	0.31
Method [12]	0.36	108.8	0.28
Our method	0.36	108	0.28

IV. CONCLUSION

We have presented a procedure that permits us to separately extract the series resistance and the mobility degradation parameter in MOSFETs has been presented using exponential model of mobility. It based on non linear fit of the experimental characteristic I_d (V_g) in strong inversion at a small drain bias from the characteristic. The proposed method has been illustrated by applying it to an experimental short channel MOSFET. The results obtained by this technique have a best agreement with experimental data. The exponential model of mobility is advantageous because it allowed us to easily access to the surface roughness.

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