SIMULATION OF SEMICONDUCTOR DEVICES AND PROCESSES Vol. 5
Edited by S. Selberherr, H. Stippel, E. Strasser – September 1993

Analysis of Charge Storage in Polysilicon Contacts

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Abstract

We present the use of a commercial 2D device simulator, MEDICI [1], to analyze a polysilicon emitter contact. By using a 2-box model we adjust simultaneously the effective recombination velocity and the stored charge in the polysilicon layer.

1. Introduction

Polysilicon emitter transistors have been a main topic in device research during the last years [2], [3]. The progressive scaling-down of both horizontal and vertical dimensions enhances the interest of an accurate simulation of the static and dynamic characteristics of this kind of contacts.

Simulation of these contacts is usually done [4] by using an effective recombination velocity as a boundary condition. The stored charge can be then considered through a correction in the emitter transit time τ_e [5].

$$\tau_e = \tau_{es} \cdot (1 + \frac{Q_{ep}}{Q_{es}}) \tag{1}$$

In most 2D simulators as MEDICI, polysilicon contacts are simulated through the use of virtual semiconductor parameters in the polysilicon layer. This allows to fit the DC characteristics of the whole bipolar transistor [4].

In this work we propose a two layer model that can be easily implemented through MEDICI allowing to adjust the DC characteristics and at the same time to evaluate the stored charge in the polysilicon layer.

2. Simulation method

Classically, the simulation of polysilicon emitter contacts trough MEDICI is done providing an equivalent boundary condition [6] to the device, that considers an effective surface recombination velocity:

$$J = q \cdot S_{eff} \cdot p \tag{2}$$

S_{eff} is obtained by modifying the minority carrier mobility and lifetime in the region corresponding to the polysilicon. Solving the diffusion equation in this zone with these modified parameters leads to the desired effective recombination velocity.

$$S_{eff} = \frac{D_p}{L_p} \coth \frac{W_{Poly}}{L_p} \tag{3}$$

Where D_p is the modified diffusion coefficient for holes, L_p the modified diffusion length and W_{Poly} is the polysilicon layer width. Although this procedure can be useful for DC conditions, we have no mean to control the stored charge in the poly. As this charge may significantly modify the forward transit time in scaled down structures [5], it is worthy to have a realistic estimation for the stored charge in the poly, and, as a consequence, for τ_{poly}.

Our proposal, based on the box model [6], is to consider two regions to simulate the contact. One corresponding to the thin oxide layer (or a grain boundary, if there is no oxide present), and another to the rest of the contact. The properties of this oxide layer mostly determine the stored charge in the poly.

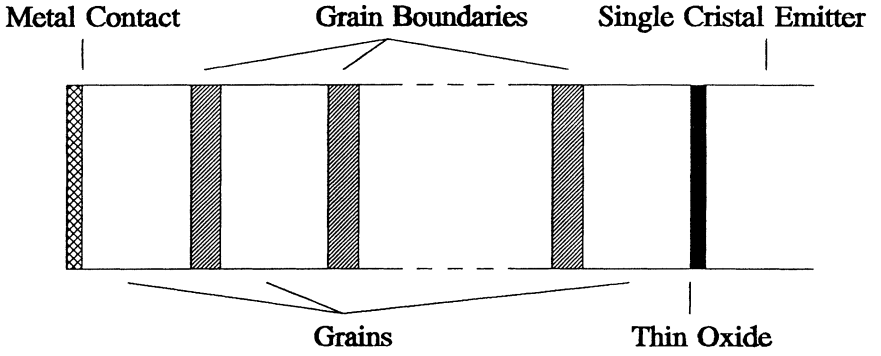

Figure 1: Scheme of a polysilicon emitter, box model.

The parameters describing this two regions, i.e. the minority carrier lifetimes and mobilities, are found from the equations and parameters given in [6] for the hole transport.

For the oxide layer, the effective diffusion coefficient, D_{eff}, and the effective diffusion length, L_{eff} are calculated through.

$$L_{eff} = \frac{d_{ox}}{\arg\cosh \frac{S_{ox}+T_{ox}}{T_{ox}}} \tag{4}$$

$$D_{eff} = T_{ox} \cdot L_{eff} \cdot \sinh \frac{d_{ox}}{L_{eff}} \tag{5}$$

T_{ox} is a coefficient related to the tunneling trough the oxide, and depends [6] on the hole potential barrier, χ_h and the hole effective mass in the oxide, m_h^* , S_{ox} a surface recombination velocity located at the two edges of the thin oxide layer, and d_{ox} is the oxide layer width.

The second region, which models the polysilicon, can be described classically through the modified mobility method mentioned above.

In this way good estimations for the charge in the poly can be obtained. If more accuracy is desired, it is easy to extend the method to consider the polysilicon grains and grain boundaries in different regions instead of joining them in a single region. The grain boundary zones are described in [6] through expressions (4) and (5) using a T_{gb} (a transport coefficient in the grain boundary), and S_{gb}, for recombination, instead of T_{ox} and S_{ox}.

3. Results

We have used the parameters shown in table I in equations (3) to (5) to simulate a polysilicon emitter with MEDICI, and to perform the analytical calculations. In Figures 2 and 3 we compare the obtained results with those found through analytical expressions.

Polysilicon layer thickness	W_{Poly}	0.4 μm
Hole transport parameters in grain boundaries	T_{gb}	$2.5\ 10^5$ cm/s
	S_{gb}	$7.5\ 10^4$ cm/s
Grain boundaries thickness	d_{gb}	20 Å
Recombination velocity at the oxide edges	S_{ox}	$1.5\ 10^3$ cm/s
Hole effective mass in the oxide	m_h^*	0.42 m_o
Hole potential barrier in the oxide	χ_h	1 eV
Hole diffusion coefficient in the grains	D_p	3.28 cm^2/s
Hole diffusion length in the grains	L_p	0.812 μm
Donor concentration in the polysilicon	N_{dpoly}	$7\ 10^{19}$ cm^{-3}

Table 1: Values used for the calculations

We can see in Figure 2 the stored charge in the poly as a function of the oxide layer thickness. Results obtained with the classical method and through the analytical expressions are shown for comparison.

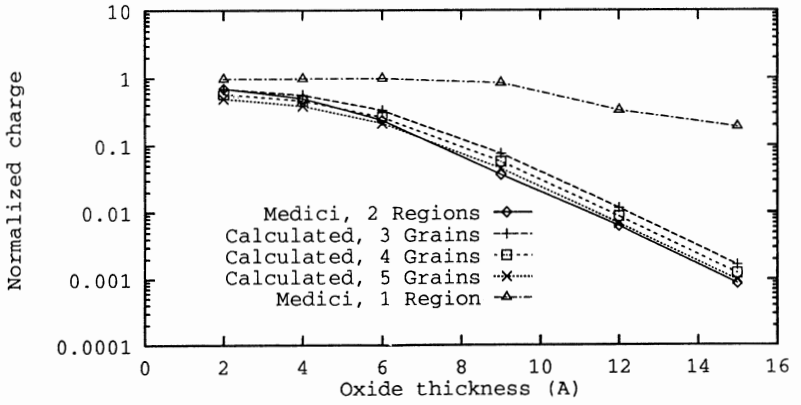

Figure 2: Integrated charge density as a function of oxide thickness.

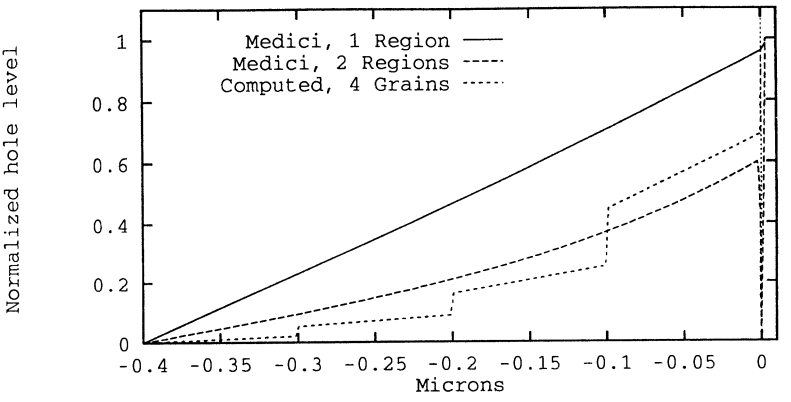

Figure 3: Hole concentration profile versus depth in polysilicon and oxide layers.

In Figure 3 the hole profile in the polysilicon layer is shown. Three cases are compared for an oxide thickness of 4 Å: the obtained analitically in the case of 4 grains [5], and those found with MEDICI, through the proposed method and by using the classical one.

4. Conclusions

This work uses a numerical simulator, MEDICI, to evaluate the charge storage in the polysilicon layer of a polysilicon emitter bipolar transistor. The used method provides an estimation for the stored charge that agrees with previous results. If more accuracy is needed, a straightforward extension of the method has been proposed.

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