ANALYTIC MODEL CORRECTION FOR LOW TEMPERATURE TWO-DIMENTIONAL SIMULATION

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ABSTRACT

The Analytic mobility model of Numeric two-dimensional simulator MEDICI has presented inefficient when it was applied in low temperatures. Therefore it cause a mobility decrease with the temperature increase which do not corresponds to the reality.

This paper proposes a correction in this model constant when it is used in low temperatures.

1. INTRODUCTION

The transistor operation in low temperatures is a great center of interest, due to the improved device performance such as decreased of subthreshold slope and increased of carrier mobility. It results in an increasing of switching rate in digital systems and larger bandwidth in analog systems.

The theoretical models accounting for the carrier mobility considering the lattice scattering and ionized impurities scattering are presented in equations 1[5] and 2[6], respectively.

$$\mu_{nls} = \left[\frac{1}{\dfrac{1}{\mu_{ona}\left(\dfrac{T}{300}\right)^{-\alpha n}} + \dfrac{1}{\mu_{onb}\left(\dfrac{T}{300}\right)^{-\beta n}}} \right] \quad \textbf{(1)}$$

where μ_{nls} is the scattering of carriers in the crystalline lattice; T is the absolute temperature; μ_{ona}, αn and β n are model coefficients.

$$\mu_{I_n} = \left[\mu \min{}_n + \frac{\mu_{nls} - \mu_{\min_n}}{1 + \left(\dfrac{N_a}{N_{ref_n}}\right)} \right] \quad \textbf{(2)}$$

where μIn is the mobility; Na is the carriers concentrations and μ_{minn} and N_{ref} is the model coefficients.

These models have been implemented using the Matlab tool and solved in the temperature range of 300K down to 100K. In ref.[5] there are five combinations of coefficients to be used in equations (1) and (2), which are presented in table 1. After solving the set of equations the obtained results for the carrier mobility as a function of the temperature are plotted in figure1. It is clear form figure 1 that the mobility increases as the temperature reduces, independently off the set of constants adopted.

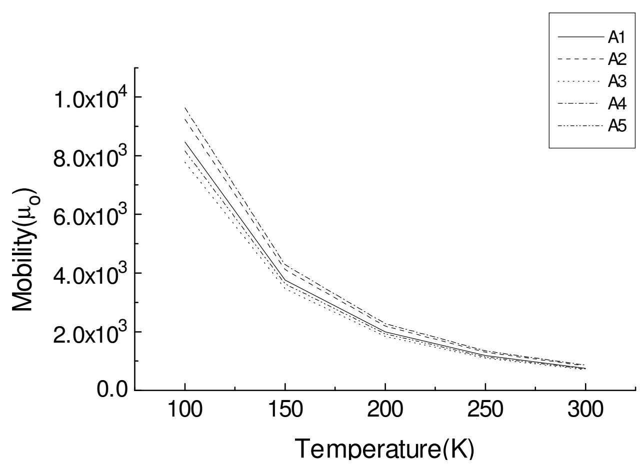

Figure1- μ x T curve from scattering of ionization impurity equation using the table 1 values.

Table I- Constants values to carriers ionization scattering equation

Row	μ_{minn} cm^2/Vs	α_n	N_{refn} [cm^{-3}]
A1	55.24	0.733	$1.072x10^{17}$
A2	92.00	0.910	$1.300x10^{17}$
A3	65.00	0.720	$8.500x10^{16}$
A4	71.12	0.729	$1.059x10^{17}$
A5	52.20	0.680	$9.680x10^{16}$

Equation (3) describes the temperature dependent mobility model available in ref [7]. Table 2 shows the set of parameters used by the simulator.

$$\mu_{on} = MUN.MIN + \frac{MUN.MAX\left(\dfrac{T}{300}\right)^{NUN} - MUN.MIN}{1 + \left(\dfrac{T}{300}\right)^{XIN}\left(\dfrac{N_{TOTAL(X,Y)}}{N_{REFN}}\right)^{ALPHAN}} \quad \textbf{(3)}$$

Table II- Default Constants values to using in Analytic Mode l

Parameters	Value for Silicon
MUN.MIN	55.24
MUN.MIN	1429.23
NREFN	$1.072x10^{17}$
NUN	-2.3
XIN	-3.8
ALPHAN	0.73

Solving equation (3) in the same temperature range then in figure 1 it is possible to observe an unrealistic behavior for the mobility for the temperature smaller than 250K.

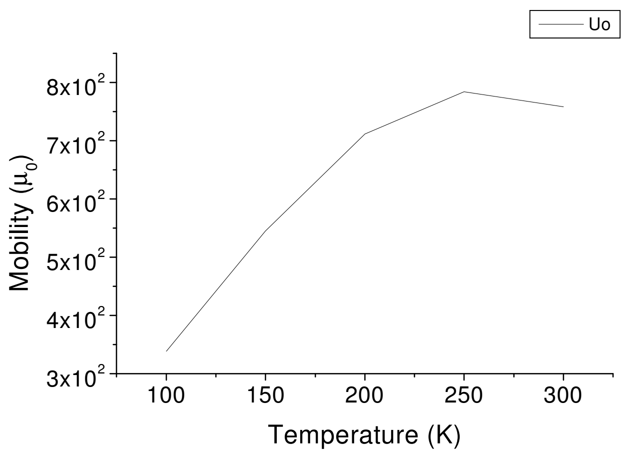

Fig.2 μ x T curve with the Analytic Model using the default values in table 2.

2. PROPOSAL OF MODEL CORRECTION

The strategy adopted for the MEDICI simulator model correction was to adjust the XIN parameter in order to obtain similar results than presented in figure1. To do so, we calculated XIN for each temperature by equating equations (2) and (3). The resulting values are plotted in figure3, indicating that XIN is temperature dependent.

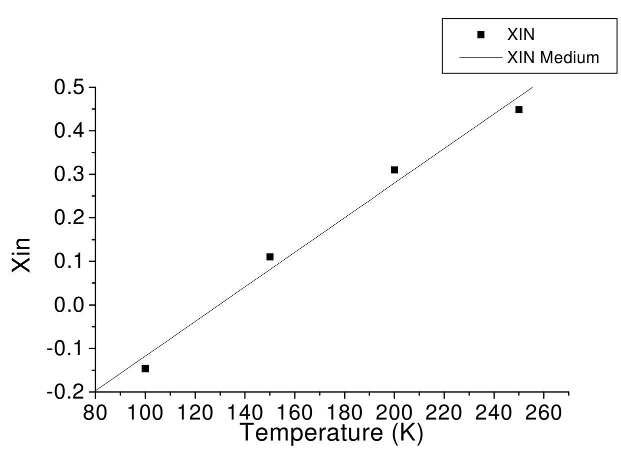

Fig.3 XIN x T curve of Analytic Model using the theoretical mobility values of equation 2 with the row A1 table1.

In order to obtain a closed formula for XIN we performed a linear regression in the points of figure 3 (noted XIN medium). The resulting expression was:

$$XIN= -0.51437 + 3.71768x10^{-4}\,T \quad \textbf{(4)}$$

Table III- Relation of theoretical and medium values of mobility and percentage of error.

Temperature	**Mobility(XIN)**	**Mobility(XIN medium)**	**Error(%)**
100	8.60358E+03	8.46162E+03	1.65
150	3.72562E+03	3.76039E+03	0.93
200	1.98578E+03	1.99663E+03	0.54
250	1.18502E+03	1.18216E+03	0.24

I. CONCLUSION

This paper offers a possible model correction to allow low temperature two-dimensional simulations. The correction is based in a linear approximation of the coefficient XIN. Comparisons between the proposed model correction and literature models show that a good agreement can be found down to 150 K.

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