SCREENING DESIGN AND DEVICE/TECHNOLOGY DEEP-SUBMICRON MOSFET SIMULATION

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Abstract – The problem concerned to the verification of the significant parameters of the compact deep-submicron MOS-FET model was investigated in the presented work. The screening experiments methodology is used for the extraction of the significant parameters from the entire set of the model parameters.

I. INTRODUCTION

Compact models intended for the simulation of the microelectronic devices features are the most popular now. Correspondence to the real structural and technological parameters is the main their peculiarity. Compact models with their corresponding Spice parameters are well developed today and provide adequate results for the experimental submicron (>0.13 µm) devices. However, for the deep submicron (< 0.13 µm) MOSFETs ordinary compact model based on the drift-diffusion approximation is not suitable because they do not take into account quantum confinement, ballistic or quasi-ballistic transport, gate tunneling current, etc. Thus it has become necessary to develop a new compact model for deep submicron devices and related devices with such adjustable parameters. The verification process is based on the methods of optimization of physical parameters of the device models derived from experimental data. Thus, the first stage of solving this problem is identification of the most significant parameters of the model. Presented work is devoted to the solution of this problem using screening computer experiment methodology.

II. METHODOLOGIES AND RESULTS

Among main modern simulation means, Silvaco software package is the modern and convenient tool for the physically adequate technology and device design in microelectronics. The presented results were obtained with use modules ATHENA, technology simulation, ATLAS [1], device simulation on the base of diffusion-drift approximations intended for submicron MOSFET, and QUANTUM, device simulation using various models and taking into account quantum effects during charge carriers transfer through the deep submicron device structure.

The problem of identify the most significant parameters of the transport model we solved using screening designs methodology. Screening designs are economical experimental plans that focus on determining the relative significance of many main effects. If design has more than 5 factors, fractional factorial or Plackett-Burman designs are used in order to reduce the number of experiments. As compared with fractional factor design, Placket-Burman (PB) design is more economical with the run number a multiple of four. PB designs are very efficient screening designs when only main effects are of interest [2]. The PB design in 36 runs, for example, may be used for an experiment containing up to 35 factors.

For screening experiments, all factors are varied between up and low level [3]. Those levels are chosen from desired consideration with concrete values. Design of experiments describes the combination of levels in experiments. Planning conditions of PB design are numbers of up and low levels in the each column must be equal, and sum of products of the elements belonging to the same experiment is equal to zero for any two columns.

After computer experiments were performed, results are handled to measure effect of the factors in responses. Main effect of a factor is the difference in the response when this factor is at its up level as opposed to its low level.

The parameters of Darwish model was investigated in this work. Darwish model is physically-based, semi-empirical, local model for transverse-field dependent electron and hole mobility. The model accounts for the functional dependence of surface roughness limited mobility on the inversion charge density, in addition to coulomb screening effects of impurities by charge carriers [4]. Darwish Model Number factors available for variation in Silvaco, equal 33.

TABLE 1 – The results of screening experiments

Channel length	The most significant parameters to influence the threshold voltage	The most significant parameters to influence the drain current
20 nm	AN.CVT, S1.KLA, MUMINN.KLA, ALPHA1N.KLA	AN.CVT, DN.CVT, ALPHA1N.KLA, MUMINN.KLA
40 nm	AN.CVT, S1.KLA, ALPHA1N.KLA, MUMINN.KLA	AN.CVT, DN.CVT, ALPHA1N.KLA, MUMINN.KLA
60 nm	AN.CVT, ALPHA1N.KLA, MUMINN.KLA, S1.KLA	AN.CVT, DN.CVT, ALPHA1N.KLA, EN.CVT
100 nm	AN.CVT, ALPHA1N.KLA, MUMINN.KLA, S1.KLA	AN.CVT, DN.CVT, EN.CVT, ALPHA1N.KLA
130 nm	AN.CVT, ALPHA1N.KLA, MUMINN.KLA, S1.KLA	AN.CVT, DN.CVT, EN.CVT, ALPHA1N.KLA

The purpose of the computer experiments is finding out parameters, which significantly affect to threshold voltage and drain current of the MOSFETs. Range of values from the nominal value is 20%. Studies on the significance carried out for MOSFETs with a channel length of 20 nm, 40 nm, 60 nm, 100 nm, 130 nm. I_D/V_G dependencies of this MOSFETs are shown in Fig. 1. The results of screening experiments are given in Table 1. Notations correspond to the factors used in the Silvaco.

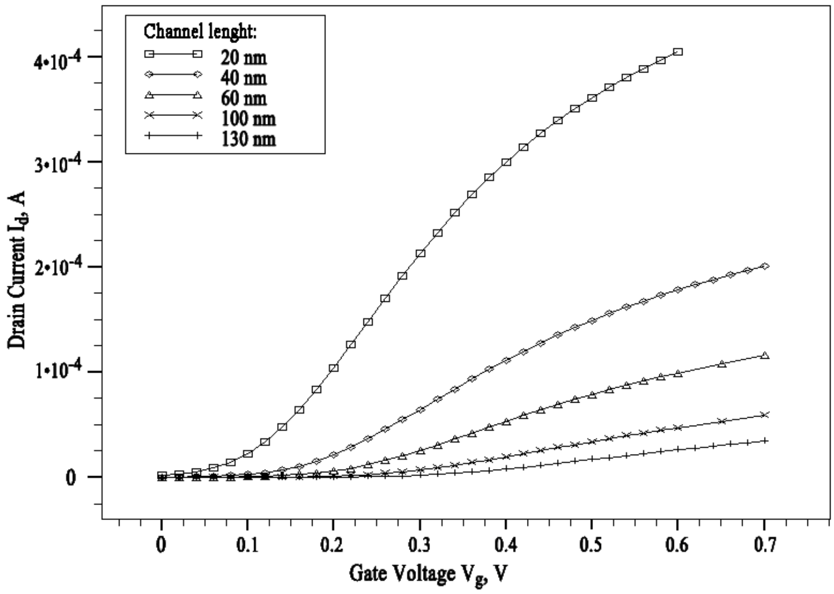
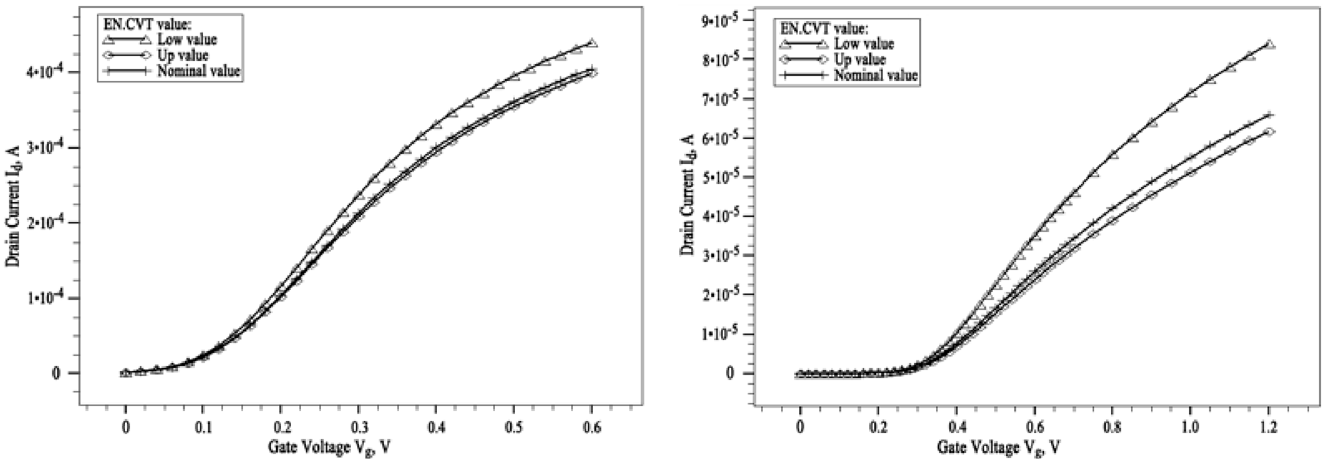


Figure 1 – I_D/V_G dependencies for MOSFETs with different channel length

Experiments show that AN.CVT, DN.CVT, S1.KLA, ALPHA1N.KLA, MUMINN.KLA, EN.CVT, especially AN.CVT, significantly affect on the transistor threshold voltage V_{TH} and drain current I_D. However, the extent of their influence depends on the size of devices. As an example, Fig. 2 shows the I_D/V_G dependencies that demonstrate differences in the degree of influence of the parameter EN.CVT when changing channel length.

III. CONCLUSION

The results of identification of the most significant Darwish model parameters for different channel length are presented. This problem was solved in the frame of the screening experiments methodology. The dependence of the degree of influence of parameters on the length of the channel is shown. These results will be used in the procedure of the parameters extraction of the deep submicron compact model of microelectronics devices.



a) b)

Figure 2 – I_D/V_G dependencies for MOSFETs with channel length of 20 nm (a) and 130 nm (b) for different value of EN.CVT

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