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FACULTY OF ENGINEERING

CHARACTERIZATION AND MODELING OF THE LARGE SIGNAL RESPONSE OF MOS TRANSISTORS

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*This work is dedicated to **ALLAH** who made the seek for knowledge a duty for every Muslim and who said through his prophet **Mohammed** (peace on him): "Who ever seeks a road to knowledge, ALLAH opens to him a road to paradise."*

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STATEMENT

This dissertation is submitted to **Ain Shams University** for the degree of M.Sc. in Electrical Engineering.

The work included in this thesis was carried out by the author in the department of Electronics and Communications Engineering, Ain Shams University from December 1992 to September 1994.

No part of this thesis has been submitted for a degree or qualification at any other university or institution.

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ABSTRACT

The object of this work is to develop a model that describes the large signal behavior of the MOS transistor. The effect of the interface traps on the transient response of the MOS transistor will be studied. The model to be introduced is a one-dimensional model based on the charge sheet model. The interface traps charging/discharging behavior will be base on the Shokley-Read-Hall statistics. The model will be valid for all regions of operation of the MOS transistor (weak inversion, moderate inversion, and strong inversion). Also, the model can be used for any arbitrary input voltage waveforms; large signal or small signal. The results of the model will be compared to the available experimental measurements.

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SUMMARY

The large signal behavior of small area MOSFETs depends to a great extent on the gate oxide quality and the amount of defects present at the Si-SiO_2 interface. In fact, the switching speed of the transistor depends on the carrier mobility and the input capacitance of the device; both of which are strong functions of the defect density at the interface. The aim of this study is to model and characterize the large signal response of MOSFETs fabricated on bulk Si.

It is necessary to clarify the frequently used terms *analysis*, *simulation* and *modeling*. The interpretation of each term may be as follows

Analysis

- Separation of a whole into its component parts, possibly with comment and judgment.
- Examination of a complex, its elements, and their relations in order to learn about.

Simulation

- Imitative representation of the functioning of one system or process by means of the functioning of another.
- Examination of a problem not subject to experimentation

Modeling

- To produce a representation or simulation of a problem or process.
- To make a description or analogy used to help visualize something that cannot be directly observed.

From the above dictionary-meanings, modeling is obviously a necessity for analysis and simulation. With a model one can analyze some phenomena, provided that the effects one wants to extract are built in the model, possibly in a very complex manner. A model for the purpose of pure simulation (like a curve fitting model) is usually much more simple than a model for analysis. Many effects can be treated in a very heuristic manner for the purpose of simulation, just reflecting the underlying physics in a quantitative way.

The research work described in this thesis is devoted to model the large signal behavior of MOSFET's. The interest of this work is twofold: first, the effect of interface traps on the large signal response of the transistor is taken into account and second, the model is valid for gate pulse top levels situated in weak or strong inversion. The exploration of the weak inversion regime is very important due to the emerging multitude of low voltage-low power applications where the transistor is operated below threshold.

The thesis contains four chapters. The first chapter gives a brief review about the MOS transistor. The basic equations that describe the operation of the MOS transistor will be presented. Then, the charge sheet model describing the dc steady-state characteristics of the MOS transistor will be discussed. The main features of the weak inversion regime, as described by the charge sheet model, will be pointed out.

The second chapter will review the interface states located at the Si-SiO_2 interface. The nature of interface states and the parameters used to describe them will be presented. The dynamic behavior including the mechanisms with which the interface states communicate with the silicon bands will be discussed. A mathematical model describing the occupancy function of interface traps based on the Shokley-Read-Hall statistics will be developed.

The third chapter is dedicated to discuss the modeling of the large signal behavior of the MOS transistor. A model that describes the large signal response of the MOS transistor without including interface states will be developed. A new model describing the large signal behavior of the MOS transistor including the effect of interface states will be presented here.

The fourth chapter is devoted to discuss the results of the numerical solution of the model developed in chapter (3) that describes the transient response of the MOS transistor with and without considering the effect of interface states.