**Ain Shams University**

**Faculty of Engineering**

Engineering Physics and Mathematics Department

# Simulation and Modeling of Nanowire transistors

**A THESIS**

Submitted in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Engineering Physics

By

**Dalia Selim Louis**

M.Sc. in Engineering Physics
(Engineering Physics and Mathematics)
Ain Shams University - 2007

Supervised by:

**Prof. Dr. Omar Abd-El Halim Omar**
Ain Shams University

**Prof. Dr. Wael Fikry Farouk**
Ain Shams University

**Prof. Dr. Salah El-Din Hassan Gamal**
Ain Shams University

**Cairo, 2012**

**Ain Shams University**
**Faculty of Engineering**
Engineering Physics and Mathematics Department
Cairo, Egypt

# EXAMINERS' COMMITTEE

Name : Dalia Selim Louis Armanious

Thesis : Simulation and Modeling of Nanowire Transistors

Degree: Doctor of Philosophy in Engineering Physics.

| Title, Name and Affiliation | **Signature** |
|---|---|
| **Prof. Dr. Gusteau Duclos**<br>Electronics Engineering Technology (Chair)<br>DeVry College of New York - USA | …… |
| **Prof. Dr. Abd-El Halim Mahmoud Shousha**<br>Electronics and Communication Eng. Department<br>Faculty of Engineering-Cairo University | …… |
| **Prof. Dr. Omar Abd-El Halim Omar**<br>Engineering Physics and Mathematics Department<br>Faculty of Engineering -Ain Shams University | …… |
| **Prof. Dr. Salah El-Din Hassan Gamal**<br>Engineering Physics and Mathematics Department<br>Faculty of Engineering -Ain Shams University | …… |

Date: …/…/2012

# STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Engineering Physics.

The work included in the thesis was carried out by the author at the Engineering Physics and Mathematics Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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

**Name: Dalia Selim Louis**

**Signature:**

**Date:**

# CURRICULUM VITAE

| | |
|---|---|
| **Name of Researcher** | Dalia Selim Louis Armanious |
| **Date of Birth** | 12/12/1979 |
| **Place of Birth** | Kuwait |
| **First University Degree** | B.Sc. in Electrical Engineering |
| **Name of University** | Ain Shams University |
| **Date of Degree** | 2001 |
| **Last Degree** | M.Sc. in Engineering Physics |
| **Name of University** | Ain Shams University |
| **Date of Degree** | 2007 |

# ABSTRACT

***Dalia Selim Louis, "Simulation and modeling of nanowire Transistors," Doctor of Philosophy dissertation, Ain Shams University, 2012.***

Scaling challenges and performance are directing the research into new device structures in the nanoscale regime. Among these devices are the silicon nanowire transistors that had attracted broad attention from both the semiconductor industry and the academic researchers. This is attributable to its improved electrostatic control of the channel and consequent suppression for the short-channel effects. For the design and optimization of nanowire transistors numerical quantum-based device simulator is needed that helps to understand its physics and further enhance its behavior. It is worth mentioning that both computational efficiency and high accuracy, taking physical effects into consideration, are crucial in building a simulator.

The main objective of this work is to build a full numerical simulator for cylindrical nanowire transistors under MATLAB environment that can be used in the investigation of the device's properties and output characteristics with efficient simulation time. This simulator is based on the effective mass approximation and utilizes the cylindrical coordinate system in order to take the advantage of the symmetry in the $\varphi -$ direction, thus, an isotropic effective mass has been introduced in the simulator. The objectives of this thesis are: 1) Investigating the quantization effects in nanowire transistors using a 1D self-consistent Poisson – Schrödinger solver in conjunction with a semi-classical current model; 2) Examining the upper performance limit of the transistor (ballistic case) through proposing a 2D numerical simulator that uses the mode space approach where the Non-Equilibrium Green's Function (NEGF) is used to solve the transport equation; 3) Studying the non-coherent transport via including a phenomenological model to the simulator. Accordingly, a complete simulator is achieved that has the great advantage of simulation time reduction while keeping high level of precision

**Key Words**: SNWTs, NEGF, Mode space, Isotropic effective mass.

# ACKNOWLEDGMENT

*No one who achieves success does so without the help of others.*
*The wise and confident acknowledge this help with gratitude.*
***Alfred North Whitehead***

First and foremost, I would like to thank my greatest teacher of all: God. I know that I am here and that I am able to write all of this for a reason. I will do my best in never forgetting what a great fortune I have had in just being here, and that it comes with a lesson and a responsibility. I hope I am doing the work You have planned me to do.

I am specifically grateful to my Prof. Dr. Omar Abd-El Halim for his kind support and guidance that has been of great value in my academic life. Also, I wish to express my warm and sincere gratitude to Prof. Dr. Wael Fikry Farouk for always making himself available with useful tips despite his super busy schedules. Their ideas and concepts have had a remarkable influence on my entire career and I am sure will be of great help to me in my future professional life.

I am deeply indebted to my thesis supervisor, Prof. Dr. Salah El-Din Hassan Gamal for his help and advice through the course of my PhD study. His wide knowledge and his logical way of thinking have been of great value for me. His understanding, encouraging and personal guidance have provided a good foundation for the present thesis.

I warmly extend my thanks to Dr. Mahmoud Ibrahim, Dr. Mohamed El-Banna and Dr. Mona El-Sabbagh for the fruitful discussions we had together around my work area. And my old friend Dr. Michael Bebars, who have generously provided me with material and papers that were much needed for my research. During this work I have collaborated with many colleagues in our department for whom I have great regard, and I wish to extend my warmest thanks to all of them

Last but not least, I can't thank my husband Rafik, son Fady and my loving parents enough, without their support, encouragement and understanding it would have been impossible for me to finish this work.

# CONTENTS

# LIST OF FIGURES