# Design Space Exploration Of Emerging Technologies For Energy Efficiency

Aida Todri-Sanial

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UNIVERSITY OF MONTPELLIER II

# DESIGN SPACE EXPLORATION OF EMERGING TECHNOLOGIES FOR ENERGY EFFICIENCY

by

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A manuscript submitted in partial fulfillment for the degree of Habilitation a Diriger des Recherches

in the
Faculty of Science, University of Montpellier 2
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December 17, 2014

# Declaration of Authorship

I, AIDA TODRI-SANIAL, declare that this HDR titled, 'Design Space Exploration of Emerging Technologies for Energy Efficiency' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: _____

Date: _____

*"Most people say that it is intellect which makes a great scientist. They are wrong: it is character."*

Albert Einstein

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*Dedicated to my family...*

# Chapter 1

# Introduction

My research interest are primarily focused on the physical effects of nanoscale devices and interconnects on integrated circuits and systems.

I have worked on many projects, but there are several things that they all have in common. First, nearly all my research projects involved investigating the physical characteristics and behaviour that governed the electrical and thermal properties of the devices and circuits. A second common denominator is that even though my work has performed design and optimization of circuits in an "academic context", the goals were targeted toward industrial needs. Lastly, the design methods and techniques developed, they were all based on mathematical description of the circuits that enabled to formulate close-form analytical problems that can be solved efficiently and accurately.

Hence, in my research, modeling (i.e. multi-scale, multi-physics) was very useful and beneficial for these projects. The models developed (mainly numerical and sometimes analytical) were initially derived from experimental evidence and then validated and improved with further experimentation. The developed models provided an efficient means of: (i) representing complex circuit structures i.e three-dimensional circuits or carbon nanotube interconnect material, (ii) better understanding of the electrical and thermal interdependencies based on circuit switching activity, (iii) optimizing the interconnect topology to alleviate any critical electro-thermal issues and thereby optimizing the physical design methods.

The study of the physical behaviour between circuit structure and properties was performed on a wide variety of physical properties and materials such as 2D, 3D and carbon nanotube based integrated circuits. The drive for studying such in-depth physical and structural properties is to find effective means for designing energy efficient circuits and systems while exploring the advantages and potentials of the technology. The main

thrust of these researches has been to develop dedicated physical design techniques that leverages the advantages of the technology for reducing power consumption while meeting performance constraints.

This manuscript containts four main chapters which are arranged as follows:

**Chapter 2.** In this first part, an overview of my research and teaching activities is provided. A detailed description of my scientific research and related activities are provided.

**Chapter 3.** In this chapter, the physical, electrical and thermal issues are discussed for three-dimensional (3D) technology and some design methods are described for further enhancing their energy efficiency.

**Chapter 4.** This chapter is devoted to energy efficiency exploration on circuits that are built using carbon nanotube (CNT) interconnects. Also, several issues introduced by CNTs are discussed accompanied with potential solutions for overcoming them.

**Chapter 5.** This chapter present the future research directions that I am pursuing while exploring emerging technologies and novel materials for devices and interconnects which can serve as the basis for future energy-efficient circuits.

**Appendix A.** This part includes my detailed curriculum vitae (CV).

**Appendix B.** This part includes my list of publications.