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# 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

**Aida Todri-Sanial**

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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  
Microelectronics Department, CNRS-LIRMM

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:

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Date:

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

Albert Einstein

UNIVERSITY OF MONTPELLIER II

*Jury Members*

Faculty of Science, University of Montpellier 2  
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# Contents

<b>Declaration of Authorship</b>	<b>i</b>
<b>Jury Members</b>	<b>iii</b>
<b>Acknowledgements</b>	<b>iv</b>
<b>List of Figures</b>	<b>vii</b>
<b>List of Tables</b>	<b>ix</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Overview of Scientific Research and Teaching Activities</b>	<b>3</b>
2.1 Overview of Research Activities . . . . .	3
2.2 Research Activities at University of California Santa Barbara . . . . .	5
2.2.1 Contribution of the work . . . . .	9
2.2.2 Results . . . . .	10
2.2.3 Impact . . . . .	10
2.3 Research Activities at Fermilab . . . . .	10
2.3.1 Results . . . . .	12
2.3.2 Broader Impact . . . . .	12
2.4 Research Activities at CNRS-LIRMM . . . . .	13
2.4.1 Overview . . . . .	13
2.4.2 Results . . . . .	17
2.4.3 Impact . . . . .	18
2.5 Scientific Collaborations . . . . .	18
2.6 Scientific Distinctions . . . . .	19
2.7 Publications . . . . .	19
2.8 Supervision of Students . . . . .	20
2.9 Teaching Activities . . . . .	22
2.10 Participation on Organization of Conferences and Workshops . . . . .	22
2.11 Participation on Journals . . . . .	24
2.12 Participation as Thesis Jury Member . . . . .	25
2.13 Participation as Expert . . . . .	25

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2.14	Research Management . . . . .	25
2.14.1	Responsibilities on Research Project . . . . .	25
2.14.2	Responsibilities in Group/Lab Management . . . . .	26
<b>3</b>	<b>Investigating Power Delivery Networks for Energy-Efficient 3D ICs</b>	<b>28</b>
3.1	Introduction . . . . .	28
3.2	Preliminaries . . . . .	30
3.3	Power and Thermal Effects . . . . .	31
3.4	3D Power Delivery Network Analysis and Optimization . . . . .	34
3.4.1	3D Power Network Analysis . . . . .	34
3.4.2	Voltage Droop and Thermal Constraints Driven 3D PDN Optimization . . . . .	36
3.5	Experiments . . . . .	40
3.5.1	Impact of Optimization Parameter, $\alpha$ . . . . .	40
3.5.2	Impact of Power Density Distribution . . . . .	42
3.6	Conclusion . . . . .	43
<b>4</b>	<b>Energy Exploration with Carbon Nanotube Interconnects</b>	<b>44</b>
4.1	Introduction . . . . .	44
4.2	Modeling of Carbon Nanotubes . . . . .	45
4.3	CNTs for 3D Power Delivery Network . . . . .	48
4.3.1	Power Delivery Network . . . . .	49
4.3.2	Branch Analysis with CNTs . . . . .	50
4.4	Conclusion . . . . .	54
<b>5</b>	<b>Future Research Directions</b>	<b>55</b>
5.1	Prospect of Future Research Project . . . . .	55
5.2	Objectives of Future Research . . . . .	55
5.3	Objectives for Research Management and Teaching . . . . .	62
<b>A</b>	<b>CV</b>	<b>65</b>
<b>B</b>	<b>Publication List</b>	<b>75</b>
	<b>Bibliography</b>	<b>87</b>



# List of Figures

2.1	Chart describing my research activities. . . . .	4
2.2	Illustration of on-chip power delivery network distribution. . . . .	7
2.3	Power delivery networks with power gated blocks. . . . .	8
2.4	Cross section of mask layers for devices and interconnects where CNTs can replace Copper interconnect layers. . . . .	15
2.5	Inverter gate based on aggressively scaled CMOS devices connected through CNT interconnects. . . . .	15
2.6	Illustration of 3D system-on-chip stacking and electro-thermal modeling of 3D power delivery networks. . . . .	16
2.7	3D MPSoC and various workload distributions that can generate different amount of power supply noise and hot spots. . . . .	16
2.8	Illustration of flow for computing power (dynamic, static and leakage) consumption of circuits. . . . .	16
2.9	3D integration and characterization of TSVs for defects and performance. . . . .	17
2.10	Path delay characterization based on the layout information to consider both power and ground supply noise on a critical path. . . . .	17
3.1	Three-tier network using face-to-back TSVs. . . . .	29
3.2	Illustration of each tier's voltage droop constraints. . . . .	37
3.3	The steps of the proposed optimization flow. . . . .	39
3.4	Optimization objectives for (a) $\alpha = 0$ , (b) $\alpha = 1$ , and (c) $\alpha = 0.5$ and (d) optimized power grid area with varying $\alpha$ . . . . .	41
4.1	(a) Circuit model of an individual MWCNT and (b) multiple MWCNTs. This is general enough to be applicable to MWCNTs of different diameters and shell numbers. It can also be applicable to SWCNTs where the model of a single shell can be utilized. . . . .	46
4.2	(a) Illustration of global power delivery network for a single tier, and (b) description of uniform and non-uniform power delivery networks. The meshes have the same area and regular structure but some tracks have different widths, thus varying the branches lengths. (c) Illustration of 3D power delivery network for two tiers connected via TSVs. . . . .	50
4.3	Branch resistivity of MWCNT bundle for various diameters and lengths . . . . .	51
4.4	Branch capacitance (quantum and electrostatic capacitance) of MWCNT bundle for various diameters and lengths . . . . .	51
4.5	Branch inductance (kinetic and magnetic inductance) of MWCNT bundle for various diameters and lengths . . . . .	52
4.6	Individual impact of parasitic resistance, inductance and capacitance to voltage drop on a power grid branch. . . . .	52

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4.7	Contour plot of voltage drop on a power grid <i>branch</i> as a function of MWCNT bundle length ( $1\mu\text{m}$ to $100\mu\text{m}$ ) and diameter (1nm to 100nm). . .	53
5.1	Illustration of interconnects for 2D integrated circuits. . . . .	56
5.2	Interdisciplinary vision of research project. . . . .	58
5.3	Via-last and via-middle approach for through-silicon-vias (TSVs) for 3D integration that could be potentially replaced by carbon nanotubes. . . .	59
5.4	Different interconnect segments to be explored with carbon nanotubes (a) on-chip interconnects i.e. local, intermediate, global interconnects. . . . .	59
5.5	(b) micro-bumps for 3D integration . . . . .	60
5.6	(c) TSVs and micro-bumps using carbon nanotubes. . . . .	60

# List of Tables

2.1	A detailed summary of publication types throughout the years. Note: TBP = to be published. . . . .	20
2.2	A detailed summary of students that I have advised throughout the years.	20
3.1	A detailed summary of the parameter values used in this work. . . . .	31
3.2	Voltage droop and temperature measurements. . . . .	32
3.3	Voltage droop and temperature measurements. . . . .	33
3.4	Area savings for different power density distribution. . . . .	42

*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 contains 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.