AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics Engineering and Electrical Communications

Electrical Modeling of Interconnects in Three Dimensional Integrated Circuits

A Thesis submitted in partial fulfillment of the requirements of
Master of Science in Electrical Engineering
(Electronics Engineering and Electrical Communications)

by

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Bachelor of Science in Electrical Engineering
(Electronics Engineering and Electrical Communications)
Faculty of Engineering, Ain Shams University, 2010

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Cairo, 2016

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University. The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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May 2016

Abstract

Faculty of Engineering – Ain Shams University
Electronics and Communication Engineering Department

Thesis title: **"Electrical Modeling of Interconnects in Three Dimensional Integrated Circuits"**
Submitted by: **Tarek Ramadan Hamed Omar**
Degree: **Master of Science in Electrical Engineering**

Abstract

In this thesis, we show that using the relation between the inductance matrix and the capacitance matrix in a homogeneous medium (the inverse inductance model) to extract the coupling capacitance in a through silicon via (TSV) array is inaccurate. This is because this relation assumes a lossless, homogeneous surrounding medium. We show that this model can cause an error up to 70% in the coupling capacitance compared to ANSYS Q3D extractor simulations.

Instead of using high accuracy, time consuming numerical electromagnetic techniques, we suggest a correction methodology for the inverse inductance model so that it can account for the non-homogeneous nature of the TSVs surrounding medium and the lossy nature of the silicon substrate.

Dimensional analysis is used to understand the correction function dependencies on TSV dimensions and to reduce the number of independent physical variables needed for regression analysis. Once the independent physical variables are reduced to dimensionless variables, multiple regression techniques are used to estimate the correction function for TSV arrays. Q3D extractor simulations are used to show that the corrected model reduces the coupling capacitance error significantly. The correction function behavior vs. frequency is discussed as well.

Keywords: More than Moore, 3D-IC, 2.5D-IC, TSV

Thesis Summary

Faculty of Engineering – Ain Shams University
Electronics and Communication Engineering Department

Thesis title: **"Electrical Modeling of Interconnects in Three Dimensional Integrated Circuits"**
Submitted by: **Tarek Ramadan Hamed Omar**
Degree: **Master of Science in Electrical Engineering**

Summary

The thesis is divided into five chapters:

Chapter 1

This chapter is an introduction to the thesis that clarifies the motivation and the objective behind this work. It also highlights the organization of the thesis.

Chapter 2

This chapter contains all the required background information about three dimensional integrated circuits (3D-ICs) and through-silicon vias (TSVs). A literature survey about the available coupling capacitance models for TSV arrays is presented.

Chapter 3

In this chapter, the inverse inductance model accuracy limitations for coupling capacitance extraction for TSVs are discussed. The theoretical explanation of this inaccuracy is presented based on multiconductor transmission lines theory (MTLs). Then, the theory is validated using electromagnetic field solver extractor (ANSYS Q3D). The coupling capacitance error between the inverse inductance model results and Q3D results is characterized across different TSVs dimensions, operating frequency and different TSVs configurations.

Chapter 4

In this chapter, a correction methodology for the inverse inductance model is presented. The correction is done using dimensional analysis technique to reduce the number of physical independent variables, then regression analysis is used to estimate the correction function. ANSYS Q3D is used to generate the observational data. Then, non-linear, multiple regression functions in MATLAB are used. Also the correction function dependency on the operating frequency is discussed.

Chapter 5

This chapter concludes the modeling and simulation results. It also summarizes all the future work that should be considered.

Key words: More than Moore, 3D-IC, 2.5D-IC, TSV

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