MESH GENERATION AND INFORMATION MODEL FOR DEVICE SIMULATION

A DISSERTATION

SUBMITTED TO

THE SCIENTIFIC COMPUTING AND COMPUTATIONAL MATHEMATICS PROGRAM

AND THE COMMITTEE ON GRADUATE STUDIES

OF STANFORD UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

By

Dan Dian-Xiong Yang

June 1994

I certify that I have read this dissertation and that in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert W. Dutton (Principal Advisor)

I certify that I have read this dissertation and that in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Kincho H. Law (Co-Advisor)

I certify that I have read this dissertation and that in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gene H. Golub

Approved for the University Committee on Graduate Studies:

Abstract

Automated mesh generation is a major challenge for semiconductor device and process simulation. In the past, various mesh generation schemes have been proposed and implemented to solve systems of linear and non-linear partial differential equations. However, few of them can be directly adopted by technology CAD (TCAD) tools due to special requirements imposed by TCAD applications. In this study, an automatic mesh generation scheme suited for device simulators, such as PISCES and STRIDE, is presented and the mesh generator is integrated with a device simulation environment using an information model based framework.

In the first part of the study, the implementation of a tree based semi-structured mesh generation scheme is discussed. Two major enhancements, the level control function and the δ-zone triangulation and tetrahedralization, distinguish the new scheme from traditional tree based mesh generation schemes. With the enhancements, a balanced optimal quadtree/octree is guaranteed and a quality mesh is generated for both the interior region and the region near the boundary.

In the second part of the study, an information model based framework is proposed for TCAD applications. A prototype framework based on the Semiconductor Wafer Representation (SWR) is implemented. The framework provides (i) a complete 3D information model for the wafer state and (ii) services to facilitate TCAD tool development. By sharing a common information model, different TCAD simulators are

able to produce a set of consistent and cohesive simulation data. The prototype incorporates both PISCES and FASTCAP to extract, respectively, the device and interconnect behavior using the same information model. An SRAM example is used to demonstrate how a 3D information model based device simulation system can be utilized in a device design process.

Acknowledgments

Throughout the research life at Stanford, for most, I would like to thank my principal advisor Professor Robert Dutton. His guidance and encouragement is essential for completing my thesis research work. He cultivates such a multidiciplinary environment which enables me to explore scientific computing applications in the semiconductor research field. Among many memorable things, his around-campus ‘safari’ trips are specially worth mentioning. These are wonderful occasions where informal and fruitful communications take place.

I also would like to thank my co-advisor Professor Kincho Law for helping me in many aspects of the research work, including the research topic selection, algorithm development, mathematical proof and critical reading of the final thesis.

I am grateful to Professor Gene Golub for introducing me to the SCCM program and serves as the third reader of my thesis. I would like to thank Professor Greg Kovacs to serve on my oral defense committee and Professor Tai-Ping Liu as the chairman.

The research work such as this covers a wide range of disciplines. It would be impossible to complete without contributions from others. I specially thank Dr. William Wong for helping me to broaden the knowledge of the semiconductor science and manufacturing. His comments and suggestions greatly helped the usability of the mesh generator. He is instrumental for initiating and prototyping the SWR3D project. I also would like to thank Dr. Zhi-ping Yu, Dr. Ronald Goossens, Dr. Ke-Zhe Wu and my officemate Narayan Aluru for helping me during my research work. For the TCAD framework effort, I thank Eric Tse, Tao Chen, Melissa Cheok, Kenneth Wang, and Anyu Lee. Thanks also go to Martin Gander for his careful reading of my thesis and very useful comments and suggestions. I thank Fely Barera and Maria Perea for their administrative assistance and Chris Quinn and Steve Hensen for providing a reliable computing environment. To each member of Prof. Dutton's group, I am thankful.

In the initial phase of the study, many of the meshing schemes have been borrowed from other researchers and colleaques. I am grateful to Professor Wolfgang of ETH for letting me to have access to their research work and their mesh generation software, including both MESHBUILD and OMEGA.

My research work was partially motivated by the previous industrial experience. I would like to thank my former management team at LSI Logic, Dr. James Koford, Dr. Edwin Jones and Dennis Yamamoto, for their encouragement and financial support.

An endeavor like this cannot be accomplished without the full support from my family. I am grateful to my wife Christiana for her faith, encouragement and sacrifice. During the past four years, she took care of almost every domestic issues and spent many nights and weekends alone by herself. I also would like to thank my parents Shan-Chin and Yu-Fen for encouraging me to finish my Ph.D study.

To Christiana