Preface

Integrated circuit (IC) manufacturability has received a great deal of attention in the last few years. As technological processes are advancing toward submicron resolution features—with higher transistor integration on silicon taking place—the need to foresee the ease and feasibility of fabrication of IC designs is becoming a must.

IC manufacturability is no longer a practice that belongs exclusively to industry. Today it is a flourishing area of academic research in which systematic solutions are sought for yield-related problems. This presents a dramatic departure from the previous practice of ad hoc research to address such problems. The result of this interaction is the emergence of methodologies for yield and fault prediction, taking into account existing manufacturing conditions. It is important to emphasize "existing manufacturing conditions" because IC design can no longer be seen as a task using ideal nominal values, but instead as a task where process variations and manufacturing disturbances must be considered. Despite the emphasis on manufacturability, traditional academic curricula do not include special-purpose courses in this field. In all likelihood, this stems from the fact that in common engineering practices, IC design and semiconductor process technology are two distinct and isolated domains. Typically, the design engineer is more accustomed to, say, behavioral and electrical simulations, while the process engineer delves into the physical and chemical components of the technological process. As a result, electrical engineering-related courses are also separate domains. In one domain, for instance, all the courses pertain to IC design (e.g., Digital and Analog IC Design, Very Large-Scale Integration Systems, Logic Synthesis), and in process domain there are courses such as Microelectronic Circuit Fabrication and Microelectronic Device Design.

The traditionally separated areas of IC design and semiconductor manufacturability have been integrated in this new text. This work addresses the study of process and design variables in order to determine the ease and feasibility of fabrication—or manufacturability—of integrated circuits. The book consists of four main sections:

(1) basic processing technology and related disturbances, (2) functional yield prediction, (3) layout defect-sensitivity analysis, and (4) manufacturing fault analysis/debugging. Obviously, given the nature of the topics, some of them could be a book by themselves. Actually, this would correspond to the previously mentioned separation of fields by domains.

The purpose of *Integrated Circuit Manufacturability: The Art of Process and Design Integration* is to link the four sections—for example, to present the impact of process disturbances on the IC performance; to study the feasibility of fabrication through yield prediction and estimation; and to present designs for manufacturability techniques. As process technology and circuit design are still separate domains, a middle strategy is pursued; that is, we seek a compromise between theory and practice, as well as extent of theoretical coverage. The use of computer-aided design tools throughout an academic course is strongly recommended. This is an important aspect of the learning process, for it provides an almost "turnkey" solution to specific application domains. As progress is made during the course, time and resources can be dedicated to understanding and managing more complex and practical problems, rather than putting all efforts into small "classic" examples.

The four core sections of this textbook present the student with practical issues that are normally applied in industry and are usually required by quality, product, and design engineering departments. In fact, the book is a response to the industry's continuous need for qualified engineers in manufacturing positions. Ideally, these engineers have knowledge in defect engineering, circuit design, testing, and failure analysis, and are capable of coordinating and monitoring production activities to ensure that the product meets functional and performance requirements. However, only rarely does the recently graduated engineer possess all this knowledge. Quite often, industry must also incur expensive training programs.

The book consists of nine chapters carefully written by leading authorities in the field. The order of the book is meant to advance progressively from semiconductor processing to electrical design and from electrical design to system architecture. Chapter 1 provides an overview of the book. Chapter 2 deals with the environmental conditions prevailing in the manufacturing line. In particular, it examines methods that characterize defects, and it takes this defect information and translates it into electrical fault models using the inductive fault analysis technique, which is discussed in Chapter 3. Chapter 4 addresses the feasibility of fabrication of the design, taking into account the environmental conditions of the manufacturing line. Chapter 5 discusses the way ICs can be designed to tolerate defects using methods such as critical area analysis, design rule optimization, and process-oriented monitoring. Chapter 6 is aimed at quality control problems of circuit designs; it includes topics such as performance variability minimization and sensitivity reduction w.r.t. process variations. Chapter 7 focuses on tolerance, redundancy, and testability issues at the system level, while Chapter 8 concentrates on design for testability and testing practices at the circuit level. Finally, Chapter 9 presents testing methodologies for multichip modules (MCMs), including topics such as the burn-in of bare dies.

Each chapter is general and is not a review or survey of research topics only. Included are tutorial-like exercises, for the book is intended to serve as a textbook.

Most of the material addressed here is covered in a course on IC Manufacturability taught at Texas A&M. This course is certainly not ultimate; rather, it is meant to serve as an introduction to manufacturing issues from a circuit and production point of view. While the course is functional, our experience has shown that more work is needed to develop a complete curriculum in manufacturing covering formal aspects of yield and testability (e.g., the need of an adequate textbook). Usually, manufacturing courses are related to issues in quality control and originate mostly from an industrial engineering perspective. This course departs from this tradition by giving attention to electrical engineering aspects and by involving students in the use of CAD tools. In fact, use of CAD tools was an important component of this course. These tools give students the ability to work in different areas without having to be experts in any of them. The techniques enable novice students to grasp complex issues such as extraction of manufacturing yield and wafer yield management, or extraction of critical areas and realistic sets of faults. It is hoped that this textbook will complement the needs of a more thorough manufacturability curriculum.

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