

Process Technology for the 21st Century

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Preface

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Preface

Introduction

The integrated circuit celebrated its 40th anniversary in 1998. In 40 years the integrated circuit has undergone an almost unbelievable amount of technological change. From the ICs of the early 1960s, which contained 10 or less components, the industry has progressed to early 256 Megabit DRAM production, with over 500 million components per IC (1 transistor and 1 capacitor per bit, plus additional peripheral circuitry). For 40 years there have been new process advances and new technology generations every three years or so. New materials have been formulated and linewidths have been reduced, so that now 250nanometer (nm) manufacturing is a mainstream process. The fact that a human hair is approximately 75microns (75,000nm) in diameter helps to put these dimensions in perspective.

The incredible technological change in IC's has resulted in memory prices falling from 1¢ per bit of memory in 1970 to less than 0.0001¢ per memory bit today. Microprocessors once costing \$1,000 per million-instructions-per-second (MIPS), now cost around 10¢ per MIPS.

As the power of ICs has increased and the cost of ICs has decreased, entirely new products have become possible. Portable cellular phones, desktop personnel computers, compact disc players and many other products taken for granted in our everyday lives, were unimaginable only a few short years ago.

The growth in applications for ICs has fueled the growth of the IC industry. In 1960 the worldwide semiconductor market (primarily discrete products) was approximately \$800

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million dollars. Today the semiconductor market is primarily ICs and is over \$130 billion dollars¹.

With the incredible rate of technological change that the semiconductor industry has experienced in the past, one might expect that the rate of technological change would be slowing down. Quite to the contrary, the rate of change in the semiconductor industry is actually increasing. With semiconductor fabs around the world preparing for 180nm processes in 1999, the transition from 250nm to 180nm manufacturing will have taken place in just 2 years. Many of the more aggressive semiconductor companies are now planning to stay on a 2 year or less per generation technology cycle. As the industry moves to sub 250nm processing, new process technologies and new materials have been introduced into production at the fastest rate in the history of the industry.

Keeping abreast of the changes in the industry is a major challenge, whether the professional is responsible for management of materials, technologies or equipment used in the semiconductor industry. Marketing personnel, design engineers and outside observers have the same challenge

The objective of this book is to provide clear, easily understandable explanations, of the changes taking place in semiconductor processing. The device and product requirements that are driving the process technologies forward will also be discussed. The challenges of the current 250nm process technologies, and how the processes will evolve as the industry transitions to 180nm, 150nm, 130 nm and smaller manufacturing, are also presented. Throughout the book terminology will be defined and the use of formulas will be restricted to those absolutely necessary to make a point. In the first section of the book we will provide background material to help the reader better understand the material presented in the later sections.

This book is organized into 5 major sections.

1. The first section provides introductory material and includes Chapters 1 and 2. Chapter 1 will discuss the basics of MOSFET operation and how scaling of MOSFET transistors, interconnects and DRAM capacitors is driving the requirements for new process technologies and materials. The focus of Chapter 1 is on MOSFETs because MOSFET based technology is by far the dominant technology in the world today. Throughout this book microprocessor and DRAM requirements will be used in illustrations, since microprocessors and DRAMs are the two largest technology drivers today. Chapter 2 will present a brief high level overview of semiconductor processing. The purpose of Chapter 2 is to provide the reader with a brief overview before beginning to discuss processing in more detail. It is useful to have a high level framework in mind while reading the process detail section, as it helps describe how the overall process flow fits together can be understood.
2. The second major section of the book provides a process step by process step discussion of the latest process technologies. Section 2 is made up of Chapter 3 through Chapter 9. Each chapter is dedicated to individual process steps such as photolithography, ion implantation, rapid thermal processing, etc. In each chapter an easy to understand discussion of the latest technologies and technical challenges will be presented. This section is the heart of the book.
3. The third major section of the book provides a process-block by process-block analysis of the new processes and materials required for sub 250nm processing. The third section is comprised of Chapter 10 and Chapter 11. The discussion of each major process block will include the evolution of the process steps involved and how the individual process steps fit together to achieve the desired product result. Chapters

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10 and 11 will bring into clearer focus the unique process and material requirements for sub 250nm manufacturing.

4. The fourth section of the book will present process flows for 180nm microprocessors, 180nm DRAM memory and 180nm embedded DRAM into a general logic process for System on a Chip (SOC) applications. Section 4 is made up of Chapters 12, 13 and 14. Chapter 12 will present a step by step description of a 180nm microprocessor manufacturing flow. Chapter 13 will present a 180nm DRAM memory manufacturing flow. Chapter 14 will present a step by step description of a 180nm embedded DRAM process flow for SOC.
5. The fifth and final section of the book will present a summary of the major process and material trends in the industry. The fifth section is comprised of Chapter 15, the summary chapter, and appendix A. Chapter 15 should be particularly useful for one trying to understand how changes in the industry may effect process technologies, materials and equipment in the future. Understanding process technology, material and equipment trends should allow the user to make informed decisions about technology for internal use, or the future prospects for suppliers, customers or competitor's technology positions. Appendix A presents trend summary charts.

References

- ¹ World Semiconductor Trade Statistics