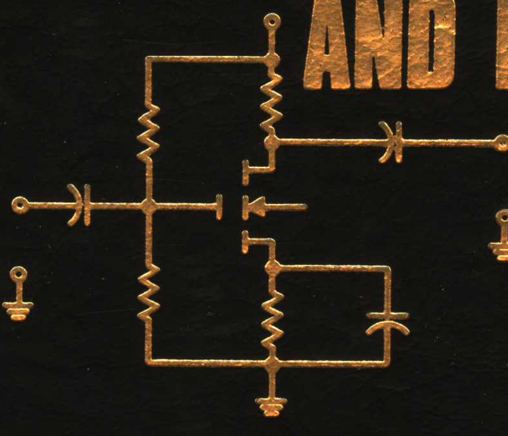
SEMICONDUCTOR MICRODEVICES AND MATERIALS



David H. Navon

SEMICONDUCTOR MICRODEVICES AND MATERIALS

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To
my wife, Bobbe,
my daughter, Beth,
and my son, Marc,
and to the memory
of my mother, Anna,
who made all this possible

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Preface

Goals and Methods

The objective of this book is to provide the reader with a reasonably comprehensive introduction to the wonderland of microchip integrated circuits. To achieve this goal it is necessary to provide some understanding of the semiconductor materials used to fabricate these chips, the physics of the microdevices employed, the integrated circuits utilized, and the technology used in monolithic microcircuit manufacture. The intent is not only to provide an understanding of present-day microchip integrated circuits, but also to present sufficient device and materials physics for the reader to be able to comprehend any future developments in this rapidly moving field.

Audience Addressed

The prerequisites for a good comprehension of the subject matter presented in this text are basic first-year undergraduate courses in college mathematics and physics. A prior study of classical physics and the mathematics of calculus is essential; an introduction to modern physics is useful, as well as some knowledge of differential equations. The practicing engineer new to the field of monolithic integrated circuits should also find this book helpful.

Contents

The treatise begins at the beginning. After a short description of the history of the development of the microchip (Chapter 1), an introduction to the crystallography of the solid state is presented, including the structure of semiconductor crystal materials (Chapter 2). Then the energy band theory of crystals is developed (Chapter 3), followed by an introduction to the quantum theory of semiconductor materials (Chapter 4). Next, the electrical carrier transport mechanisms in uniform semiconductor materials are described (Chapter 5). This is followed by a development of the theory of the electrical properties of the basic *p-n* junction (Chapter 6). Next, some applications of *p-n* junction diodes are described as well as the high frequency and fast switching behavior of these devices (Chapter 7). The physics of the bipolar junction transistor is then developed (Chapter 8), followed by a discussion of the operation of these devices in circuits and at high frequencies (Chapter 9). The physics of operation of unipolar field-effect transistors is next described, including the high frequency and the fast switching performance of these devices (Chapter 10). Junction FETs, MESFETs, MOSFETs, and HEMT devices are also considered.

After completing this introdution to semiconductor materials and the basic devices utilized in the design of integrated circuits, the process physics and methods of fabrication of microchips are described. Modifications of the form of these semiconductor devices needed to adapt them for the monolithic technology are discussed (Chapter 11). Next, the versions of digital and analog circuits that are popular in their integrated form are presented. Limitations on microminiaturization are described, as well as the computer-aided design of microchips. Finally, the physics of other semiconductor electronic devices used primarily in high frequency and/or high power applications is developed (Chapter 12). The physical operation of Gunn-effect devices, IMPATT diodes, the semiconductor laser, the charge-coupled device (CCD), and the family of power thyristors is described.

A summary of the major subjects treated is provided at the end of each chapter. Also there, is a set of problems, each of which is designed to illustrate the major points made in the chapter.

Course Format

The organization of this book provides several possibilities for course presentations. The first ten chapters will provide material for a one-semester undergraduate course on fundamental semiconductor devices and materials. The sections marked with asterisks can be omitted without affecting the continuity of later material. This course should follow the standard two-semester sequence in electronics.

The entire text can be covered in two quarters for those schools operating on the quarter system. For those schools which provide their students with a strong introduction to semiconductor devices as a part of their electronics sequence, Chapters 8 through 12 will provide a detailed introduction to the design of microdevices and microcircuits.

The practicing engineer with a prior knowledge of semiconductor devices will find Chapters 11 and 12 useful in understanding recent developments in integrated-circuit design and the operation of the newer semiconductor devices. The first-year graduate student may want to read the entire text in preparation for advanced study of semiconductor devices or computer engineering.

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The author would like to thank the Motorola Corporation, the Digital Equipment Corporation, the Monsanto Corporation, Texas Instruments, Inc., and Analog Devices Semiconductor, Inc., for supplying some of the photographs and device specification sheets used in this book. He would also like to acknowledge the assistance of the following professors in reviewing the original manuscript and for making many recommendations: Peter Blakey of the University of Michigan, George Prans of Manhattan College, Murray Gersherzon of the Unviersity of Southern California, Richard Williams of the University of Akron, Lester Eastman of Cornell University, Anab Kulkarni of the Michigan Technological Institute, Carlos Araujo of the University of Colorado, Steve Schwarz of the University of California at Berkeley, Archie McCurdy of the Worcester Polytechnic Institute, and M. E. Van Valkenburg of the University of Illinois. In addition, the expert help provided by Mrs. Marge Olanyk in preparing this manuscript is gratefully acknowledged.

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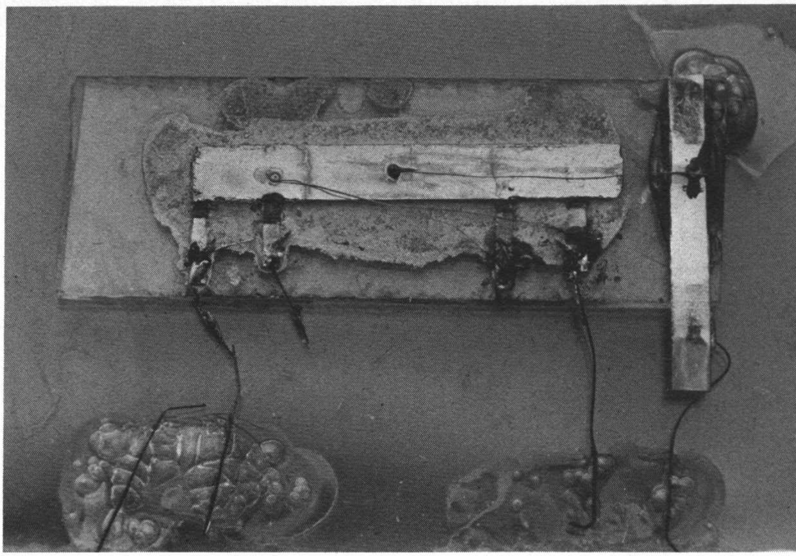
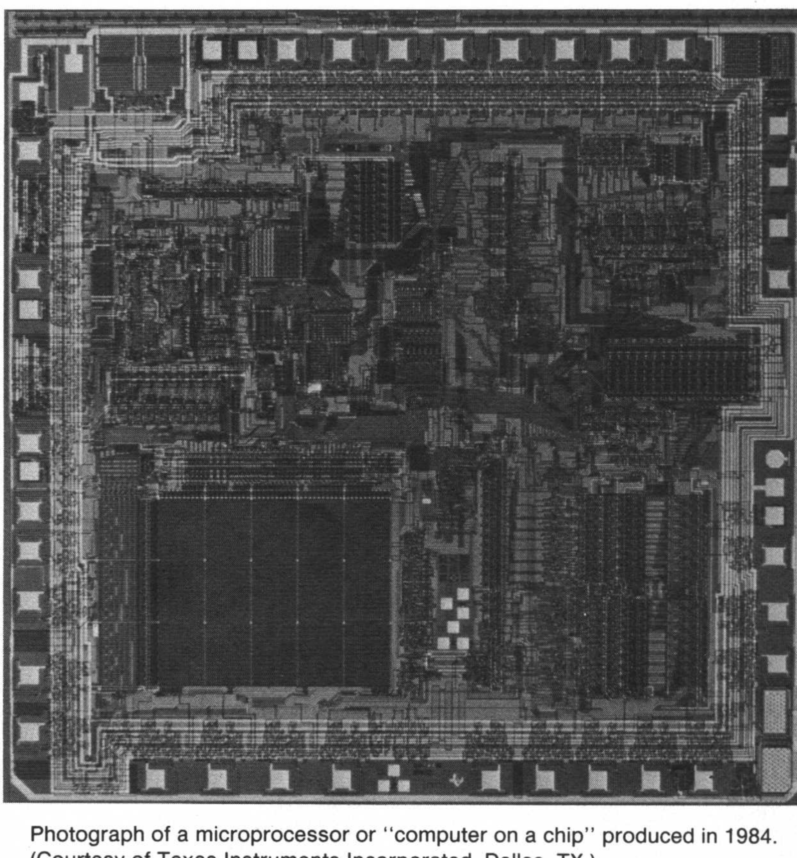


The first elementary integrated circuit fabricated by Jack Kilby of Texas Instruments Incorporated which produced a complete circuit function.



Photograph of a microprocessor or "computer on a chip" produced in 1984. (Courtesy of Texas Instruments Incorporated, Dallas, TX.)

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