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Semiconductor Device Technology

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Preface

This book is concerned with the *fabrication, operation and performance* of modern semiconductor devices, the term ‘device’ being used here to encompass both discrete devices such as transistors and integrated circuits. The material presented has developed from a series of lectures given to students of electronics in the School of Electronic Engineering and Computer Science at Kingston Polytechnic over the past few years.

To become a competent engineer in hardware electronics, that is, to be able to use electronic devices in practice to produce reliable equipment capable of meeting required performance specifications, it is essential to have an adequate appreciation of the properties and limitations of available devices. Also, to make the circuit design process efficient, it is necessary to be able to analyse circuit performance theoretically so that the effect of modifications can be reliably predicted rather than relying on a haphazard ‘trial and error’ approach. An understanding of the fundamental physical processes responsible for the terminal properties of devices together with knowledge of the construction and method of manufacture provides a foundation for such work.

The objective during the preparation of the book was to provide comprehensive information on the operation and performance of semiconductor devices supported by consideration of the physical processes involved, to provide ways of representing the performance quantitatively in the form of a model enabling analysis of circuits using the devices and to describe the construction and fabrication processes.

Chapter 1 is devoted to the fundamental physical processes involved in semiconducting materials and at junctions between materials. Widespread use is made of the particle atomic *model* of the structure of material and the point is emphasised that in reality the composition of material is not known, discussion of properties in terms of atomic structure, energy and charge being ways of *representing* or *modelling* the situation.

Chapter 2 deals with the wide range of discrete semiconductor devices. Diodes, bipolar transistors and field-effect transistors are considered in

general while specialised devices are grouped according to application as switching devices, devices used in signal generation and optical devices. For each device, the physical construction and mechanism of operation is discussed, typical terminal characteristics are given and, where applicable, the consideration concludes with the formulation of a network model which represents the performance of the device in network form.

The planar fabrication process used to manufacture the vast majority of devices is described in detail in chapter 3.

Circuit integration, both in monolithic and film form, is considered in chapter 4. For monolithic ICs, the fabrication of individual circuit elements is described together with discussion of the design process, that is, the selection of the system to be implemented in integrated form, the choice of the technology to be used, the circuit design and the chip layout design. After this general consideration, the specific technologies are described and compared and their application at the various levels of integration discussed.

General information on network modelling techniques, terminology, preferred component values and device numbering and coding is given in the appendixes. A comprehensive list of symbols and abbreviations used in the text is also included together with manufacturers' device data sheets for some typical devices.

Experience with the courses at Kingston has shown which aspects of the subject present the greatest difficulties to students and during the preparation of the text I have tried to answer the questions that are invariably asked during the course and also to dispel the misconceptions that often occur.

An attempt is made throughout to bring the reader up to date with modern device structures, the corresponding improvements in performance, the use of new materials and trends in development. If the reader requires a deeper academic treatment of a topic, a comprehensive list of appropriate literature is given. Tutorial questions at the end of each chapter provide the opportunity to apply the work to numerical problems.

The material is intended to be covered in the first two years of an undergraduate or diploma course, the subject having a formal timetable allocation of two to three hours per week with students expected to devote an approximately equal period each week to private study. It is considered that treatment in the order presented in the text is the most logical; thus it is intended that the first year is devoted to semiconductor physics and discrete diodes and transistors which leads on from introductory courses at school or at TEC Diploma/Certificate level. The second year of the course can then deal with integrated circuits and specialised discrete devices used in switching, high-frequency signal generation and optical systems. Discussion of the planar fabrication process can be included in the first-year syllabus or left until the second year as time permits. The detail presented is far in excess of what can be included in the corresponding lecture course but the book is intended to act as a reference to help students to clarify points mentioned

only briefly in lectures and to provide the answers to questions left unanswered at the end of lectures.

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I should like to acknowledge the assistance of the staff and students of the School of Electronic Engineering and Computer Science at Kingston Polytechnic during the development of this work, in particular Professor John Coekin and Dr Don Pedder for their helpful comments during the preparation of the manuscript, and the degree and HND students over a number of years who have given their opinions of the devices content of their courses, with particular reference to its practical use in laboratory and industrial work, enabling modifications to be made.

I am grateful to Ferranti Electronics Limited for supplying and giving me permission to publish figures 2.100, 3.4 and 4.40b showing respectively a solar cell element, a processed silicon wafer and an F100-L microprocessor chip. I also appreciate the assistance of Ed Evans of Mullard Limited and John Edwards of Siliconix Limited in giving me permission to include published data sheets of selected devices thus enabling the theoretical work to be related to typical performance characteristics and parameter values.

The electron micrographs of a bipolar transistor chip (figure 2.11a) and a portion of a UV EPROM chip (figure 4.38c) were produced by Bill Edwards of the School of Chemical and Physical Sciences at Kingston Polytechnic using the School's Cambridge Scientific Instruments S600 scanning electron microscope. Other photographs were taken by Jerry Humphreys and David Gore of the Polytechnic's Audio-Visual Services (AVS) unit, while the figure outlines were drawn by Sue Hepworth also of the AVS unit at Kingston.

My special thanks must be to my wife Judith for her patience and encouragement during the preparation of the text and for typing the manuscript — thank you.

MALCOLM GOODGE