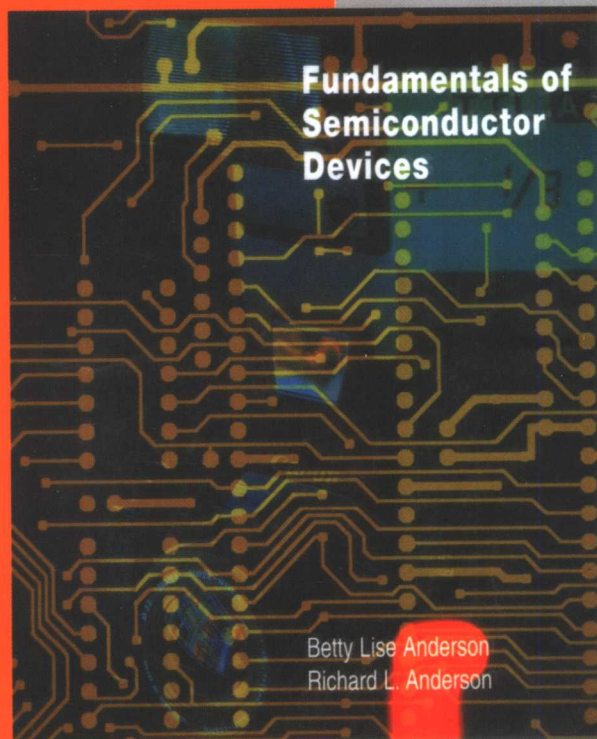


国外大学优秀教材 —— 微电子类系列 (影印版)

Betty Lise Anderson Richard L. Anderson

半导体器件基础



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Fundamentals of Semiconductor Devices

Betty Lise Anderson

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出版前言

微电子技术是信息科学技术的核心技术之一，微电子产业是当代高新技术产业群的核心和维护国家主权、保障国家安全的战略性新兴产业。我国在《信息产业“十五”计划纲要》中明确提出：坚持自主发展，增强创新能力和核心竞争力，掌握以集成电路和软件技术为重点的信息产业的核心技术，提高具有自主知识产权产品的比重。发展集成电路技术的关键之一是培养具有国际竞争力的专业人才。

微电子技术发展迅速，内容更新快，而我国微电子专业图书数量少，且内容和体系不能反映科技发展的水平，不能满足培养人才的需求，为此，我们系统挑选了一批国外经典教材和前沿著作，组织分批出版。图书选择的几个基本原则是：在本领域内广泛采用，有很大影响力；内容反映科技的最新发展，所述内容是本领域的研究热点；编写和体系与国内现有图书差别较大，能对我国微电子教育改革有所启示。本套丛书还侧重于微电子技术的实用性，选取了一批集成电路设计方面的工程技术用书，使读者能方便地应用于实践。本套丛书不仅能作为相关课程的教科书和教学参考书，也可作为工程技术人员的自学读物。

我们真诚地希望，这套丛书能对国内高校师生、工程技术人员以及科研人员的学习和工作有所帮助，对推动我国集成电路的发展有所促进。也衷心期望着广大读者对我们一如既往的关怀和支持，鼓励我们出版更多、更好的图书。

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Fundamentals of Semiconductor Devices

影印版序

Anderson 的这本《半导体器件基础》(Fundamentals of Semiconductor Devices)是一本适合微电子专业、电气和电子工程专业本科高年级学生和研究生使用的教材。与国内外关于半导体器件的其他教科书相比,这本书和半导体物理衔接更紧密,介绍了最新的半导体器件方面的进展,从器件物理和工程应用的角度对现代半导体器件进行了全面而注重实际的讲述。本书特别强调对决定半导体材料和器件电学性质的物理过程的理解,以及器件的实际应用。读者阅读此书,不仅可以知道公式的推导过程,更能够理解公式的物理意义,了解公式的应用范围。此外,作者清晰和有条理的写作风格、核心内容的全面覆盖以及对当前研究热点问题的关注也是这本书的特点。

全书分为 5 部分共 11 章,全面介绍了半导体材料的基本性质和半导体器件的基本工作原理。在内容的选取方面,本书不仅包括了量子力学、半导体物理和半导体器件(包括二极管、场效应晶体管、双极晶体管和光电器件)的基本工作原理等内容,还写进了现代半导体器件的最新进展以及器件的实际应用。例如:对于显著影响现代小尺寸器件电学特性的二级效应进行了分析和公式推导,给出了描述小尺寸器件特性的最新的数学表达式;考虑到异质结在场效应器件、双极器件和光电器件中的应用日益增加,书中对半导体异质结作了着重介绍;由于半导体制造设备和工艺技术的提高,“能带工程”得以实现,随之带来了器件性能的提高,所以本书在重点介绍硅材料和硅器件的基础上,还介绍了化合物半导体器件、合金器件(如 SiGe, AlGaAs)和异质结器件;本书还利用电路分析程序 SPICE 对器件的 I-V 特性进行了模拟,对简单电路进行了稳态和瞬态分析。书中列出的参考文献大多选自最近几年业内最具影响力的刊物(如 IEEE Transaction on Electron Devices, Journal of Applied Physics)和会议(如 IEDM)。

在内容的组织方面,除了正文,书中每一章的后面都有总结、复习提纲和习题,还有参考书和参考文献。为了使全书的结构更加紧凑,作者把那些对于理解器件的基本工作原理不是必需的,但有助于加强这门课程的内容放在各部分后面的补充材料(Supplement)里,供读者根据需要选择阅读。书的最后还有若干附录,以方便读者查阅。

本书采用了有特色的插图、例题、习题等多种形式帮助读者加深对问题的理解。例如:用含有载流子浓度分布的能带图来定性解释器件的工作原理,通过大量的例题告诉读者如何解决一个实际问题。这些例题的结果也使读者对所

求的参数有了定量的概念。

本教材内容可以按照 2 学期 96 学时或 1 学期 64 学时的进度教授。附录中的内容可以结合教学情况安排学生课后阅读。

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本书不仅是一本很好的教科书, 同时也适合用作微电子和相关领域的工程技术人员参考书。

田立林, 邓宁

2005 年 12 月于清华园

This is a textbook on the operating principles of semiconductor devices. It is appropriate for undergraduate (junior or senior) or beginning graduate students in electrical engineering as well as students of computer engineering, physics, and materials science. It is also useful as a reference for practicing engineers and scientists who are involved with modern semiconductor devices.

Prerequisites are courses in chemistry and physics and in basic electric circuits, which are normally taken in the freshman and sophomore years.

This text is appropriate for a two-semester course on semiconductor devices. However, it can be used for a one-semester course by eliminating some of the more advanced material and assigning some of the sections as "read only." The authors have attempted to organize the material so that some of the detailed derivation sections can be skipped without affecting the comprehension of other sections. Some of these sections are marked with an asterisk.

This book is divided into five parts:

1. Materials
2. Diodes
3. Field-Effect Transistors
4. Bipolar Transistors
5. Optoelectronic Devices

The first four parts are followed by "Supplements" that, while not required for an understanding of the basic principles of device operation, contain related material that may be assigned at the discretion of the instructor. For example, the use of SPICE for device and circuit analysis is briefly discussed for diodes, field-effect transistors, and bipolar transistors. While SPICE is normally taught in courses on electric circuits, it is useful to know the origin of the various parameters used to characterize devices. This material on SPICE is relegated to supplements, since not all schools cover SPICE in courses on electron circuit analysis and such courses may be taught before, concurrently with, or after the course on semiconductor devices.

Part 1, "Materials," contains four chapters and two supplements. The first two chapters contain considerable review material from the prerequisite courses. This material is included since it is used extensively in later chapters to explain the principles of device operations. Depending on the detailed content of the prerequisite courses, much of these chapters can be relegated to reading assignments.

The level of quantum mechanics to be covered in a course like this varies widely. In this book some basic concepts are included in the main chapters of Part I; those wishing to cover quantum mechanics in more detail will find more extensive material in Supplement A to Part I.

The basic operating principles of large and small devices of a particular type (e.g., diodes, field-effect transistors, bipolar junction transistors, photodetectors) are the same. However, the relative importance of many of the parameters involved in device operation depends on the device dimensions. In this book the general behavior of devices of large dimensions is treated first. We treat, in each case, “prototype” devices (such as step junctions and long-channel field-effect transistors), from which the fundamental physics can be learned, and then develop more realistic models considering “second-order effects.” These second-order effects can have significant influence on the electrical characteristics of modern, small-geometry devices. The instructor can go into as much depth as desired or as time permits.

Topics treated that are typically omitted in undergraduate texts are:

- The differences between the electron and hole effective masses as used in density-of-state calculations and conductivity calculations.
- The differences in electron and hole mobilities (and thus diffusion coefficients) if they are majority carriers or minority carriers.
- The effects of doping gradients in the base of bipolar junction transistors (and/or the composition in heterojunction BJTs) on the current gain and switching speed.
- Band-gap reduction in degenerate semiconductors. While this has little effect on the electrical characteristics of diodes or field-effect transistors, its effect in the emitter of bipolar junction transistors reduces the current gain by an order of magnitude.
- The velocity saturation effects due to the longitudinal field in the channel of modern field-effect transistors with submicrometer channel lengths reduces the current by an order of magnitude compared with that calculated if this effect is neglected.

While the major emphasis is on silicon and silicon devices, the operation of compound semiconductor devices, alloyed devices (e.g., SiGe, AlGaAs) and heterojunction devices (junctions between semiconductors of different composition) are also considered because of the increased performance that is possible with such *band-gap engineering*.

Many of the seminal publications on semiconductor devices cited in the references at the end of each chapter through 1990 are reprinted in *Semiconductor Devices: Pioneering Papers*, edited by S. M. Sze, World Scientific Publishing Co., Singapore, 1991.

Fabrication, while an important part of semiconductor engineering, is often skipped in the interest of time. This material is introduced in Appendix C, and can be assigned as read-only material if desired.

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Anderson & Anderson

PART 1 Materials 1

Chapter 1

Electron Energy and States in Semiconductors 3

- 1.1 Introduction and Preview 3
- 1.2 A Brief History 4
- 1.3 Application to the Hydrogen Atom 5
 - 1.3.1 *The Bohr Model for the Hydrogen Atom* 5
 - 1.3.2 *Application to Molecules: Covalent Bonding* 11
 - 1.3.3 *Quantum Numbers and the Pauli Exclusion Principle* 13
 - 1.3.4 *Covalent Bonding in Crystalline Solids* 14
- 1.4 Wave-Particle Duality 20
- 1.5 The Wave Function 22
 - 1.5.1 *Probability and the Wave Function* 22
- 1.6 The Electron Wave Function 23
 - 1.6.1 *The Free Electron in One Dimension* 23
 - 1.6.2 *The de Broglie Relationship* 25
 - *1.6.3 *The Free Electron in Three Dimensions* 26
 - 1.6.4 *The Quasi-Free Electron Model* 27
 - 1.6.5 *Reflection and Tunneling* 32
- 1.7 A First Look at Optical Emission and Absorption 33

- 1.8 Crystal Structures, Planes, and Directions 39
- 1.9 Summary 41
- 1.10 Reading List 42
- 1.11 References 42
- 1.12 Review Questions 42
- 1.13 Problems 43

Chapter 2

Homogeneous Semiconductors 48

- 2.1 Introduction and Preview 48
- 2.2 Pseudo-Classical Mechanics for Electrons in Crystals 49
 - 2.2.1 *One-Dimensional Crystals* 49
 - *2.2.2 *Three-Dimensional Crystals* 55
- 2.3 Conduction Band Structure 56
- 2.4 Valence Band Structure 58
- 2.5 Intrinsic Semiconductors 59
- 2.6 Extrinsic Semiconductors 62
 - 2.6.1 *Donors* 62
 - 2.6.2 *Acceptors* 66
- 2.7 The Concept of Holes 67
 - 2.7.1 *Hole Charge* 67
 - *2.7.2 *Effective Mass of Holes* 69
- 2.8 Density-of-States Functions for Electrons in Bands 71
 - 2.8.1 *Density of States and Density-of-States Effective Mass* 71
- 2.9 Fermi-Dirac Statistics 73
 - 2.9.1 *Fermi-Dirac Statistics for Electrons and Holes in Bands* 73
- 2.10 Electron and Hole Distributions with Energy 76

- *2.11 Temperature Dependence of Carrier Concentrations in Nondegenerate Semiconductors** 89
 - *2.11.1 Carrier Concentrations at High Temperatures* 89
 - *2.11.2 Carrier Concentrations at Low Temperatures (Carrier Freeze-out)* 93
- 2.12 Degenerate Semiconductors** 94
 - 2.12.1 Impurity-Induced Band-Gap Narrowing* 94
 - 2.12.2 Apparent Band-Gap Narrowing* 97
 - 2.12.3 Carrier Concentrations in Degenerate Semiconductors* 99
- 2.13 Summary** 100
 - 2.13.1 Nondegenerate Semiconductors* 101
 - 2.13.2 Degenerate Semiconductors* 102
- 2.14 Reading List** 103
- 2.15 References** 103
- 2.16 Review Questions** 103
- 2.17 Problems** 104

Chapter 3

Current Flow in Homogeneous Semiconductors 111

- 3.1 Introduction** 111
- 3.2 Drift Current** 111
- 3.3 Carrier Mobility** 115
 - 3.3.1 Carrier Scattering* 119
 - 3.3.2 Scattering Mobility* 121
 - 3.3.3 Impurity Band Mobility* 122
 - 3.3.4 Temperature Dependence of Mobility* 124
 - 3.3.5 High-Field Effects* 124
- 3.4 Diffusion Current** 128
- 3.5 Carrier Generation and Recombination** 131
 - 3.5.1 Band-to-Band Generation and Recombination* 133
 - 3.5.2 Two-Step Processes* 133
- 3.6 Optical Processes in Semiconductors** 133
 - *3.6.1 Absorption* 133
 - *3.6.2 Emission* 137

- 3.7 Continuity Equations** 139
- 3.8 Minority Carrier Lifetime** 142
 - 3.8.1 Rise Time* 144
 - 3.8.2 Fall Time* 144
- 3.9 Minority Carrier Diffusion Lengths** 147
- 3.10 Quasi Fermi Levels** 149
- 3.11 Summary** 152
- 3.12 Reading List** 154
- 3.13 References** 154
- 3.14 Review Questions** 154
- 3.15 Problems** 155

Chapter 4

Nonhomogeneous Semiconductors 159

- 4.1 Constancy of the Fermi Level at Equilibrium** 159
- 4.2 Graded Doping** 161
 - 4.2.1 The Einstein Relation* 165
 - 4.2.2 A Graded-Base Transistor* 166
- *4.3 Nonuniform Composition** 170
- *4.4 Graded Doping and Graded Composition Combined** 173
- 4.5 Summary** 175
- 4.6 Reading List** 175
- 4.7 References** 175
- 4.8 Review Questions** 176
- 4.9 Problems** 176

Supplement to Part 1

Materials 179

Supplement 1A

Introduction to Quantum Mechanics 180

- S1A.1 Introduction** 180
- S1A.2 The Wave Function** 180
- S1A.3 Probability and the Wave Function** 182
 - *S1A.3.1 Particle in a One-Dimensional Potential Well* 182

- S1A.4** Schrodinger's Equation 184
- S1A.5** Applying Schrodinger's Equation to Electrons 185
- S1A.6** Some Results from Quantum Mechanics 187
- S1A.6.1 The Free Electron* 187
- S1A.6.2 The Quasi-Free Electron* 188
- S1A.6.3 The Potential Energy Well* 189
- S1A.6.4 The Infinite Potential Well in One Dimension* 191
- S1A.6.5 Reflection and Transmission at a Finite Potential Barrier* 194
- S1A.6.6 Tunneling* 196
- S1A.6.7 The Finite Potential Well* 203
- S1A.6.8 The Hydrogen Atom Revisited* 205
- S1A.6.9 The Uncertainty Principle* 206
- S1A.7** Summary 210
- S1A.8** Review Questions 211
- S1A.9** Problems 211

Supplement 1B

Additional Topics on Materials 215

- S1B.1** Measurement of Carrier Concentration and Mobility 215
- S1B.1.1 Resistivity Measurement* 215
- S1B.1.2 Hall Effect* 216
- S1B.2** Fermi-Dirac Statistics for Electrons in Bound States 219
- S1B.3** Carrier Freeze-out in Semiconductors 222
- S1B.4** Phonons 223
- *S1B.4.1 Carrier Scattering by Phonons* 228
- S1B.4.2 Indirect Electron Transitions* 230
- S1B.5** Summary 232
- S1B.6** Reading List 232
- S1B.7** References 232
- S1B.8** Review Questions 232
- S1B.9** Problems 233

PART 2

Diodes 235

Chapter 5

Prototype pn Homojunctions 239

- 5.1** Introduction 239
- 5.2** Prototype pn Junctions (Qualitative) 241
- 5.2.1 *Energy Band Diagrams of Prototype Junctions* 241
- 5.2.2 *Description of Current Flow in a pn Homojunction* 248
- 5.3** Prototype pn Homojunctions (Quantitative) 253
- 5.3.1 *Energy Band Diagram at Equilibrium (Step Junction)* 253
- 5.3.2 *Energy Band Diagram with Applied Voltage* 256
- 5.3.3 *Current-Voltage Characteristics of pn Homojunctions* 263
- 5.3.4 *Reverse-Bias Breakdown* 284
- 5.4** Small-Signal Impedance of Prototype Homojunctions 286
- 5.4.1 *Junction Resistance* 286
- 5.4.2 *Junction Capacitance* 288
- 5.4.3 *Stored-Charge Capacitance* 290
- 5.5** Transient Effects 294
- 5.5.1 *Turn-off Transient* 294
- 5.5.2 *Turn-on Transient* 297
- 5.6** Effects of Temperature 301
- 5.7** Summary 301
- 5.7.1 *Built-in Voltage* 302
- 5.7.2 *Junction Width* 302
- 5.7.3 *Junction Current* 303
- 5.7.4 *Junction Breakdown* 304
- 5.7.5 *Capacitance* 305
- 5.7.6 *Transient Effects* 305
- 5.8** Reading List 305
- 5.9** Review Questions 306
- 5.10** Problems 306

Chapter 6**Additional Considerations
for Diodes** 311

- 6.1 Introduction 311
- 6.2 Nonstep Homojunctions 311
 - *6.2.1 Linearly Graded Junctions 314
 - 6.2.2 Hyperabrupt Junctions 317
- 6.3 Semiconductor Heterojunctions 317
 - 6.3.1 The Energy Band Diagrams of Semiconductor-Semiconductor Heterojunctions 317
 - 6.3.2 Effects of Interface States 327
 - *6.3.3 Effects of Lattice Mismatch on Heterojunctions 329
- 6.4 Metal-Semiconductor Junctions 331
 - 6.4.1 Ideal Metal-Semiconductor Junctions (Electron Affinity Model) 331
 - 6.4.2 Influence of Interface-Induced Dipoles 331
 - 6.4.3 The Current-Voltage Characteristics of Metal-Semiconductor Junctions 334
 - 6.4.4 Ohmic (Low-Resistance) Contacts 337
 - 6.4.5 I - V_a Characteristics of Heterojunction Diodes 339
- *6.5 Capacitance in Nonideal Junctions and Heterojunctions 339
- 6.6 Summary 340
- 6.7 Reading List 340
- 6.8 References 340
- 6.9 Review Questions 341
- 6.10 Problems 341

Supplement to Part 2**Diodes** 346

- S2.1 Introduction 346
- S2.2 Dielectric Relaxation Time 346
 - S2.2.1 Case 1: Dielectric Relaxation Time for Injection of Majority Carriers 347
 - S2.2.2 Case 2: Injection of Minority Carriers 349

S2.3 Junction Capacitance 350

- S2.3.1 Junction Capacitance in a Prototype (Step) Junction 350
- S2.3.2 Junction Capacitance in a Nonuniformly Doped Junction 352
- S2.3.3 Varactors 353
- S2.3.4 Stored-Charge Capacitance of Short-Base Diodes 354

S2.4 Second-Order Effects in Schottky Diodes 356

- S2.4.1 Tunneling Through Schottky Barriers 357
- S2.4.2 Barrier Lowering in Schottky Diodes Due to the Image Effect 359

S2.5 SPICE Model for Diodes 361

- S2.5.1 The Use of SPICE as a Curve Tracer 362
- S2.5.2 Transient Analysis 365

S2.6 Summary 368**S2.7 Reading List** 368**S2.8 References** 369**S2.9 Problems** 369**PART 3****Field-Effect Transistors** 373Chapter 7**The MOSFET** 385

- 7.1 Introduction 385
- 7.2 MOSFETs (Qualitative) 385
 - 7.2.1 Introduction to MOS Capacitors 386
 - 7.2.2 MOSFETs at Equilibrium (Qualitative) 390
 - 7.2.3 MOSFETs Not at Equilibrium (Qualitative) 392
- 7.3 MOSFETs (Quantitative) 403
 - 7.3.1 Long-Channel MOSFET Model with Constant Mobility 404
 - 7.3.2 More Realistic Long-Channel Models: Effect of Fields on the Mobility 417
 - *7.3.3 Series Resistance 432

- 7.4 Comparison of Models with Experiment 434
- 7.5 Summary 435
- 7.6 Reading List 438
- 7.7 References 438
- 7.8 Review Questions 438
- 7.9 Problems 439

Chapter 8

Additional Considerations for FETs 442

- 8.1 Introduction 442
- 8.2 Measurement of Threshold Voltage and Low-Field Mobility 443
- 8.3 Subthreshold Leakage Current 445
- 8.4 Complementary MOSFETs (CMOS) 448
 - 8.4.1 Operation of the Inverter 449
 - *8.4.2 Matching of CMOS devices 450
- 8.5 Switching in CMOS Inverter Circuits 452
 - 8.5.1 Effect of Load Capacitance 452
 - 8.5.2 Propagation (Gate) Delay in Switching Circuits 454
 - 8.5.3 Pass-through Current in CMOS Switching 457
- 8.6 MOSFET Equivalent Circuit 457
 - 8.6.1 Small-Signal Equivalent Circuit 458
 - 8.6.2 CMOS Amplifiers 463
- 8.7 Unity Current Gain Cutoff Frequency f_T 463
- *8.8 Short-Channel Effects 464
 - 8.8.1 Dependence of Effective Channel Length on V_{DS} 464
 - 8.8.2 Dependence of Threshold Voltage on the Drain Voltage 466
- 8.9 MOSFET Scaling 467
- 8.10 Silicon on Insulator (SOI) 469
- 8.11 Other FETs 473
 - 8.11.1 Heterojunction Field-Effect Transistors (HFETs) 473

8.11.2 MESFETs 476

8.11.3 Junction Field-Effect Transistors (JFETs) 481

8.11.4 Bulk Channel FETs: Quantitative 482

- 8.12 Summary 485
- 8.13 Reading List 486
- 8.14 References 486
- 8.15 Review Questions 487
- 8.16 Problems 487

Supplement to Part 3

Field-Effect Transistors 491

- S3.1 Introduction 491
- S3.2 Comments on the Formulation for the Channel Charge Q_{ch} 491
 - S3.2.1 Effect of Varying Depletion Width on the Channel Charge 491
 - S3.2.2 Dependence of the Channel Charge Q_{ch} on the Longitudinal Field \mathcal{E}_L 493
- S3.3 Threshold Voltage for MOSFETs 495
 - S3.3.1 Fixed Charge 497
 - S3.3.2 Interface Trapped Charge 497
 - S3.3.3 Bulk Charge 498
 - S3.3.4 Effect of Charges on the Threshold Voltage 498
 - S3.3.5 Flat Band Voltage 499
 - S3.3.6 Threshold Voltage Control 502
 - *S3.3.7 Channel Quantum Effects 504
- S3.4 Universal Relations for Low-Field Mobility 507
- S3.5 Measurement of V_T 509
- *S3.6 Alternative Method to Determine V_T and μ_{lf} Applicable to Long-Channel MOSFETs 513
- S3.7 MOS Capacitors 514
 - S3.7.1 Ideal MOS Capacitance 515
 - S3.7.2 The $C-V_G$ Characteristics of Real MOS Capacitors 520
 - S3.7.3 Parameter Analyses from $C-V_G$ Measurements 521

- *S3.8 MOS Capacitor Hybrid Diagrams 521
 - *S3.8.1 *Dynamic Random-Access Memories (DRAMs)* 525
 - *S3.8.2 *Charge-Coupled Devices (CCDs)* 527
- *S3.9 Device Degradation 530
 - *S3.9.1 *Lightly Doped Drain (LDD) MOSFETs* 534
- *S3.10 Low-Temperature Operation of MOSFETs 535
- *S3.11 Applications of SPICE to MOSFETs 538
 - S3.11.1 *Examples of the Use of SPICE with MOSFETs* 539
 - S3.11.2 *Determining the Transient Characteristics of a CMOS Digital Inverter* 543
- S3.12 Summary 545
- S3.13 Reading List 546
- S3.14 References 546
- S3.15 Review Questions 547
- S3.16 Problems 547

PART 4

Bipolar Junction Transistors 551

Chapter 9

Bipolar Junction Devices: Statics 557

- 9.1 Introduction 557
- 9.2 Output Characteristics (Qualitative) 561
- 9.3 Current Gain 563
- 9.4 Model of a Prototype BJT 564
 - 9.4.1 *Collection Efficiency M* 567
 - 9.4.2 *Injection Efficiency γ* 568
 - 9.4.3 *Base Transport Efficiency α_T* 570

- 9.5 Doping Gradients in BJTs 575
 - 9.5.1 *The Graded-Base Transistor* 578
 - 9.5.2 *Effect of Base Field on β* 582
- 9.6 The Basic Ebers-Moll DC Model 583
- 9.7 Current Crowding and Base Resistance in BJTs 586
- 9.8 Base Width Modulation (Early Effect) 590
- 9.9 Avalanche Breakdown 594
- 9.10 High Injection 594
- 9.11 Base Push-out (Kirk) Effect 595
- 9.12 Recombination in the Emitter-Base Junction 597
- 9.13 Summary 598
- 9.14 Reading List 599
- 9.15 References 599
- 9.16 Review Questions 600
- 9.17 Problems 601

Chapter 10

Time-Dependent Analysis of BJTs 607

- 10.1 Introduction 607
- 10.2 Ebers-Moll AC Model 607
- 10.3 Small-Signal Equivalent Circuits 609
 - 10.3.1 *Hybrid- π Models* 611
- 10.4 Stored-Charge Capacitance in BJTs 615
- 10.5 Frequency Response 620
 - 10.5.1 *Unity Current Gain Frequency f_T* 621
 - 10.5.2 *Base Transit Time* 623
 - 10.5.3 *Base-Collector Transit Time, t_{BC}* 624
 - 10.5.4 *Maximum Oscillation Frequency f_{max}* 625
- 10.6 High-Frequency Transistors 625
 - 10.6.1 *Double Poly Si Self-Aligned Transistor* 625
- 10.7 BJT Switching Transistor 628
 - 10.7.1 *Output Low-to-High Transition Time* 629

10.7.2 *Schottky-Clamped Transistor* 631

10.7.3 *Emitter-Coupled Logic* 632

10.8 BJT, MOSFET, and BiMOS 635

10.8.1 *Comparison of BJTs and MOSFETs* 635

10.8.2 *BiMOS* 636

10.9 Summary 638

10.10 Reading List 639

10.11 References 639

10.12 Review Questions 639

10.13 Problems 639

Supplement to Part 4

Bipolar Devices 642

S4.1 Introduction 642

S4.2 Heterojunction Bipolar Transistors (HBTs) 642

S4.2.1 *Uniformly Doped HBT* 644

S4.2.2 *Graded-Composition HBT* 646

S4.3 Comparison of Si-Base, SiGe-Base, and GaAs-Base HBTs 649

S4.4 Thyristors (npnp Switching Devices) 650

S4.4.1 *Four-Layer Diode Switch* 650

S4.4.2 *Two-Transistor Model of an npnp Switch* 652

S4.5 Silicon Controlled Rectifiers (SCRs) 654

S4.6 Parasitic npnp Switching in CMOS Circuits 658

S4.7 Applications of SPICE to BJTs 658

S4.7.1 *Parasitic Effects* 661

S4.7.2 *Low to Medium Currents* 661

S4.7.3 *High Currents* 663

S4.8 Examples of the Application of SPICE to BJTs 664

S4.9 Summary 669

S4.10 References 670

S4.11 Review Questions 670

S4.12 Problems 671

PART 5

Optoelectronic Devices 673

Chapter 11

Optoelectronic Devices 675

11.1 Introduction and Preview 675

11.2 Photodetectors 675

11.2.1 *Generic Photodetector* 675

*11.2.2 *Solar Cells* 683

11.2.3 *The p-i-n (PIN) Photodetector* 689

11.2.4 *Avalanche Photodiodes* 691

11.3 Light-Emitting Diodes 692

11.3.1 *Spontaneous Emission in a Forward-Biased Junction* 692

*11.3.2 *Isoelectronic Traps* 694

11.3.3 *Blue LEDs and White LEDs* 696

11.3.4 *Infrared LEDs* 696

11.4 Laser Diodes 702

11.4.1 *Optical Gain* 703

11.4.2 *Feedback* 706

11.4.3 *Gain + Feedback = Laser* 709

11.4.4 *Laser Structures* 710

11.4.5 *Other Semiconductor Laser Materials* 714

11.5 Image Sensors 715

11.5.1 *Charge-Coupled Image Sensors* 715

11.5.2 *MOS Image Sensors* 717

11.6 Summary 718

11.7 Reading List 719

11.8 References 719

11.9 Review Questions 719

11.10 Problems 720

Appendices

Appendix A Constants 724

Appendix B List of Symbols 725

Appendix C Density-of-States Function, Density-of-States Effective Mass, Conductivity Effective Mass 738

- C.1 Introduction 738
- C.2 Free Electrons in One Dimension 738
- C.3 Free Electrons in Two Dimensions 740
- C.4 Free Electrons in Three Dimensions 741
- C.5 Quasi-Free Electrons in a Periodic Crystal 743
- C.6 Density-of-States Effective Mass 743
 - C.6.1 Case 1: Conduction Band with a Single Minimum at $K = 0$ 744
 - C.6.2 Case 2: Valence Band with Two Bands Having Maxima at E_V and at $K = 0$ 744
 - C.6.3 Case 3: Conduction Band has Multiple Equivalent Minima at $K = 0$ (e.g., Si, Ge, GaP) 745

C.7 Conductivity Effective Mass 747

- C.7.1 Case 1: Single Minimum in the Conduction Band at $K = 0$ 747
- C.7.2 Case 2: Holes in the Valence Band 747
- C.7.3 Case 3: Electrons in Conduction Band with Multiple Equivalent Minima 748
- C.7.4 Case 4: Strained Silicon 748

C.8 Summary of Common Results for Effective Mass 750

Appendix D Some Useful Integrals 752

Appendix E Useful Equations 753

Appendix F List of Suggested Readings 763

Index 766