University of California
College of Engineering
Department of Electrical Engineering
and Computer Sciences

EECS 230
3 units
Spring 2005

T. K. Gustafson
459 Cory Hall

Solid State Electronics (3)
General Outline

The aim of this course is to develop an understanding of solid state principles with emphasis on those of relevance to applied science and technology. The course begins with symmetry principles of crystal structures and the limitations imposed by symmetry on macroscopic physical properties such as mechanical, acoustical, electrical, magnetic and electromagnetic.

Symmetry imposed limitations on idealized (non-interacting) microscopic state structure are then considered beginning with the Block Theorem and ending with approximate methods for the description near high symmetry points. Phonons and electrons are of particular interest, however, the goal is to develop a general viewpoint. We consider the basic consequences of quantum structuring in one, two, and three dimensions.

We then wish to develop classical and quantum models to treat the coupling of microscopic states, mutual and otherwise, with the goal of understanding and designing macroscopic properties. Interactions to be considered include electrons with phonons and photons, spin, and holes.

The consequences of such interactions on transport properties of bulk and structured materials and devices are discussed.

As time permits electronic tunneling including quantum tunneling in single junctions, resonant tunnelling, and quantized conductivity due to transverse modes in junctions (Landauer Formula) are included.

Superconducting principles and applications are also considered as time permits.

Note that the book (Burns) suggests the alternative of beginning at Chapt. six with less emphasis on crystal structures. It is recommended that sec. 6.1 be read first to grasp the content of the first couple of weeks of the course.

Topic and Main Reference	**Additional References**
Symmetry and Crystal Structure (Chapts. 1,2,3,; and 6-1 (summary of Chpts 1,2,3))	Nye Cotton, Falicov
Constituitive relations and transport Parameters (Chpt 5)	Nye
Review of quantum mechanics and statistics as necessary, (For Intro to q.m (Eisberg Fund. of Mod. Phys.(Wiley))	Sakurai
Density of states, elementary quantum structures, (Ch 9 pgs 203-212 Ch 18 715-724 (artificial structures))	
Free-electron Metals and heavily doped semiconductors. (Ch 9 Note that this is an alternative start point in the book)	
Diffraction in periodic structures, the reciprocal lattice, (Chapt. 4, 10-6, 10-7) Block and Floquets theorems. (Ch 10 Pages 252-253)	

Topic and Main Reference	Additional References
Bonding in solids (basic overview only); Repulsion (6-4), Van-der-Walls (6-5), Hydrogen (6-6) , ionic (Ch. 7) , and co-valent bonding and anti-bonding (Ch 8) Tetrahedral bonding in III-V and II-VI semiconductors based upon "mode-coupling" and symmetry approaches to treat the basic crystal lattices (8-4, 8-5, 8-6).	
Band structure, band-gaps, symmetry description of three dimensional band structure. A consideration of GaAs and Si and three-dimensional electro-magnetic filters. (Based upon 10.1 to 10.15 with emphasis on 10.13 to 10.15 , additional material taken from Yu and Cardona) The k.p method for band calculations. (10-4d)	(Chuang Chapt 4) (Also see Datta)
(Read Secs. 10.16 to end as a review of p-n junctions and Schottky barriers)	
Band structure modification- quantum wells, superlattices, modulation doped heterojunctions and applications. Electro-absorption and refraction (Based upon Secs. 18.1-18.5, 18.9-10)	Chapt 13 of Chuang
Coupled Oscillators and Lattice vibrations, Phonon scattering (Chapt. 12)	Ludwig, Falter (235-244) Ferry, Chapt. 4, 7
Optical properties, direct and indirect transitions (Chapt. 13) gain and loss, scattering (Raman and the Stimulated Raman)	Fox, Wooten
Surface science (Chapt 17)(Ferry 5.10),	Prutton
Overview of phase transitions leading to ferroelectricity (Chapt 14) magnetic phenomena, and superconductuctivity (Chapts. 14, 15, 16) quantum Hall effect	Tinkem-Chp 1
Calculation of transport parameters based upon Boltzmann's equation.(Datta)	Ferry Chapt 8 (neglect 8.3)
Diffusion and excess carriers (Datta), electron-electron scattering (Datta)	Ferry 9.1,9.2 Ferry Chp 12 McKelvey
Recombination and photo-conductivity, Shockley-Read-Hall Ferry 9.4,9.5	
High field transport, simulation techniques (Ferry Chapt. 10 & Chapt. 11)	
Quantum transport, the Landauer equation (Ferry Secs. 14.3,14.4 and highlights of Chapts. 15 and 16)	Ferry & Goodnick (Chpt 3)

Texts

Basic General Text For The Course

1) Gerald Burns, **Solid State Physics**, Academic Press, N.Y.(1985)[ISBN-0-12-146070-3])

Additional Material Taken From

1) Donald E. Sands, **Introduction to Crystallography Dover Publication (1969) (Symmetry, Space Groups, X-Ray diffraction, The 230 space groups in appendix)**

2) J.F. Nye, Physical Properties of Crystals, Clarendon Press, Oxford (1985).

3) F. Albert Cotton, **Chemical Applications of Group Theory**, Interscience Publishers (1963). (Understandable treatment of symmetry principles and applications)

4) L. M. Falicov, **Group Theory and its Physical Applications**, The University of Chicago Press (1966).

5) Peter Y. Yu and Manuel Cardona **Fundamentals of Semiconductors**, Springer (3'rd ed.) (2001).

6) Shun Lien Chuang, **Physics of Optoelectronic Devices**, John Wiley and Sons (1995), [ISBN 0-471-10939-8] (k.p perturbation, electro-absorption and -refraction, electro-optic effects)

7) Supriyo Datta, **Quantum Phenomena**, Modular Series on Solid State Devices Vo. III, (Addison-Wesley, Reading, Mass. (1989))[ISBN 0-201-07956-9] TK7871.85.D375 (for k.p perturbation (last chapter, the BTE, and excitons).

8) David K. Ferry, **Semiconductors**, MacMillan, N.Y. (1991)[ISBN 0-02-337130-7], QC611.F43 (Advanced treatment, density matrix treatment of transport)

9) David K. Ferry, Stephen M. Goodnick, **Transport in Nanostructures**, Cambridge University Press (1999) [ISBN 0-521-66365-2]

10) Michael Tinkham, **Introduction to Superconductivity**, Robert E. Krieger, 1980.

11) J.J. Sakurai, **Modern Quantum Mechanics**, Addison Wesley (1985).

References

1) Charles Kittel, **Introduction to Solid State Physics**, Wiley, 4'th edition (1971).

2) Robert H. Silsbee, Jorg Drager, **Simulations for Solid State Physics**, Cambridge University Press, ISBN 0 521 59911 3

3) J.S. Blakemore, **Solid State Physics** W.B. Saunders (1974).

4) Frederick Seitz, **The Theory of Solids**, Dover Publications(1987)[ISBN 0-486-65482-5]

5) William Jones, Normal H. March, **Theoretical Solid State Physics**, Dover Publications (1973)[ISBN-0-486-65015-4(&65016-2)](two volumes){for magnetism}

6) Walter A. Harrison, **Solid State Theory**, Dover Publications (1979)

7) W. Ludwig, C. Faller, **Symmetries in Physics**, Sringer-Verlag(1996)[ISBN-3-540-60284-4] {for advanced group theory and applications}

8) Tom Wenckebach, **Essentials of Semiconductor Physics** , Wiley (1999)[ISBN-0-471-96539-1]

9) Mark Fox, **Optical Properties of Solids**, The Oxford University Press Inc., New York (2001)[ISBN-0-19-850612]

10) Roy A. Colclaser and Sherra Diehl-Nagle, **Materials and Devices for Electrical Engineers and Physicists**, McGraw-Hill (1985).

11) L. Solymar, D. Walsh, **lectures on The Electrical Properties of Materials**, Oxford University Press, 4'th ed. (1988) [ISBN-0-19-856192-X].

12) Alan Holden, **The Nature of Solids**, Dover Publication (1963). (Qualitative and Descriptive including Magnetic Effects)

13) J. P. McKelvey, **Solid-State and Semiconductor Physics**, Robert E. Krieger, 1982. (**Text**) (Boltzmann Equation and Transport)

14) Ben G. Streetman, **Solid State Electronic Devices**, (Prentice Hall series in solid state physical electronics, Nick Holonyak, Jr. Editor, second edition (1980) [ISBN 0-13-822171-5] or fifth edition by Streetmen and Banerjee (2000) [ISBN 0-13-025538-6]. (inside covers have excellent overview of relevent device transport equations)

15) David W. Greve, Field Effect Devices and Applications, Prentice-Hall ((1998) [ISBN 0-13-754854-0] (Includes such topics as CCD's and Flash Memories) 16) S. M. Sze, **The Physics of Semiconductor Devices**, John Wiley and Sons (1981) [ISBN 0-471-05661-8]

17) Lindsay, **Introduction to Quantum Mechanics for Electrical Engineers**, McGraw Hill (1967).

18) M. Prutton, **Surface Science**, Oxford Physics Series, Clarandon Press, Oxford(1983).

19) A. Yariv, **Introduction to Optical Electronics**, Holt Reinhardt and Winsten

20) Jacques Pankove, **Optical Processes in Semiconductors**, Dover Publications (1971)

21) Richard S. Muller and Theodore I. Kamins, with Mansun Chan,
Device Electronics for Integrated Circuits , John Wiley and Sons (3'rd Ed. (2003)), [ISBN 0-471-59398-2] (Recombination processes, Chapter 5)