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

EECS 230
3 Units
Sp 2007

SOLID STATE PRINCIPLES FOR APPLIED SCIENCE AND TECHNOLOGY

The aim of this course is to develop an understanding of solid state principles with emphasis on those of relevance to recent developments in applied science and technology.

The course begins with symmetry principles of solid state structures and the limitations it imposes on macroscopic physical properties such as mechanical, acoustical, electrical, magnetic and electromagnetic.

Symmetry constraints on electron propagation in idealized (non-interacting) microscopic solid state structure are then considered beginning with the Block Theorem. Symmetry based approximate methods for describing electronic and vibrational energy level structure near high symmetry points are given. While phonons and electrons are of particular interest the goal is to develop a general viewpoint. We consider the basic consequences of quantum structuring in one, two, and three dimensions.

A general coupled mode (pseudo-potential) interpretation of band structure for electron and phonon band gaps is considered with the goal of understanding and designing macroscopic properties by using microscopic structure.

Various interactions and their consequences are considered. These include electron-phonon electron- photons, electron-hole and spin-spin.

The relation of such interactions to transport properties of bulk and structured materials and devices is discussed.

As time permits electronic tunneling including quantum tunnelling 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.

COURSE OUTLINE

Topic and Text References [1]	**Additional References**
Symmetry and Crystal Structure (Chs. 1,2,3 and 6-1 (Summary of Chs. 1,2,3))	Nye [2] Cotton [3], Falicov [4], Sands [5]
Constituitive relations and transport Parameters (Ch. 5)	Nye [2]
Review of quantum mechanics and statistics as necessary, (For Intro to q.m (Eisberg Fund. of Mod. Phys.(Wiley))	Sakurai [6]
Density of states, elementary quantum structures, (Ch. 9, pgs 203-212 Ch. 18, pgs 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, (Ch. 4, Secs. 10-6, 10-7)	
Block and Floquets theorems. (Ch. 10 Pgs. 252-253)	
Bonding in solids (basic overview only); Repulsion (Sec. 6-4), Van-der-Walls bonding (Sec. 6-5)	
Hydrogen (Sec. 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 (Secs. 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 Secs. 10-1 to 10-15 with emphasis on 10-13 to 10-15). Additional material taken from	Yu and Cardona [7], Also Chapters 5 and 6 of
The k.p method for band calculations. (Sec. 10-4d)	Chuang Ch. 4 [9], Datta [10]
(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)	Ch. 13 of Chuang [9]
Coupled Oscillators and Lattice vibrations,	Ludwig and Falter (235-244) [11]
Phonon scattering (Ch. 12)	Ferry [12] , Chs. 4, 7
Optical properties, direct and indirect transitions (Ch. 13)	Fox [13], Wooten [14]
Gain and loss, scattering (Raman and the Stimulated Raman)	
Surface science (Ch. 17)(Ferry Sec. 5.10)	Prutton [15]
Overview of phase transitions leading to ferroelectricity magnetic phenomena, and superconductuctivity (Chs. 14, 15, 16)	Tinkem-Ch. 1 [16]
Quantum Hall effect	
Calculation of transport parameters based upon Boltzmann's equation. Datta [17]	Ferry Ch. 8 (neglect 8.3) [12]
Diffusion and excess carriers Datta,	Ferry Secs. 9.1,9.2
electron-electron scattering (Datta)	Ferry Ch. 12

Recombination and photo-conductivity, Shockley-Read-Hall theory	Ferry Secs. 9.4,9.5
High field transport, simulation techniques	(Ferry Chs. 10 and 11)
Quantum transport, the Landauer equation highlights of Chs. 15 and 16)	(Ferry Secs. 14.3,14.4 and Ferry and Goodnick (Ch. 3) [18]

Other general references are included as [19] through [36]

REFERENCES

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

[2] J. Nye, *Physical Properties of Crystals* (Clarendon Press, Oxford, 1985).

[3] F. A. 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 Pressa, 1966).

[5] D. E. Sands, *Introduction to Crystallography* (Dover Publications, 1969), (Symmetry, Space Groups, X-Ray diffraction, The 230 space groups in appendix).

[6] J. Sakurai, *Modern Quantum Mechanics* (Addison Wesley, 1985).

[7] P. Y. Yu and M. Cardona, *Fundamentals of Semiconductors* (Springer, 2001), 3rd ed.

[8] S. Datta, *Quantum Transport, Atom to Transistor* (Cambridge University Press, New York, 2005), [ISBN 10-521-63145-9].

[9] S. L. 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.

[10] S. 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 Band Structure, quantum transport in nanostructures and electron- phonon interactions).

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[35] J. Pankove, *Optical Processes in Semiconductors* (Dover Publications, 1971).

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