Semiconductor Fundamentals

Presented to

EE2187 class in Semester 1 2019/20

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Lecture 9

Course information

- Semiconductors Materials - Types of Solids, Space lattice, Atomic Bonding,
- Introduction to quantum theory, Schrodinger wave equation, Electron in free space, Infinite well, and step potentials, Allowed and forbidden bands
- Electrical conduction in solids, Density of states functions, Fermi-Dirac distribution in Equilibrium,
- Valence band and Energy band models of intrinsic and extrinsic Semiconductors. Degenerate and non degenerate doping
- Thermal equilibrium carrier concentration, charge neutrality
- Carrier transport – Mobility, drift, diffusion, Continuity equation.

Reference

Text Book:

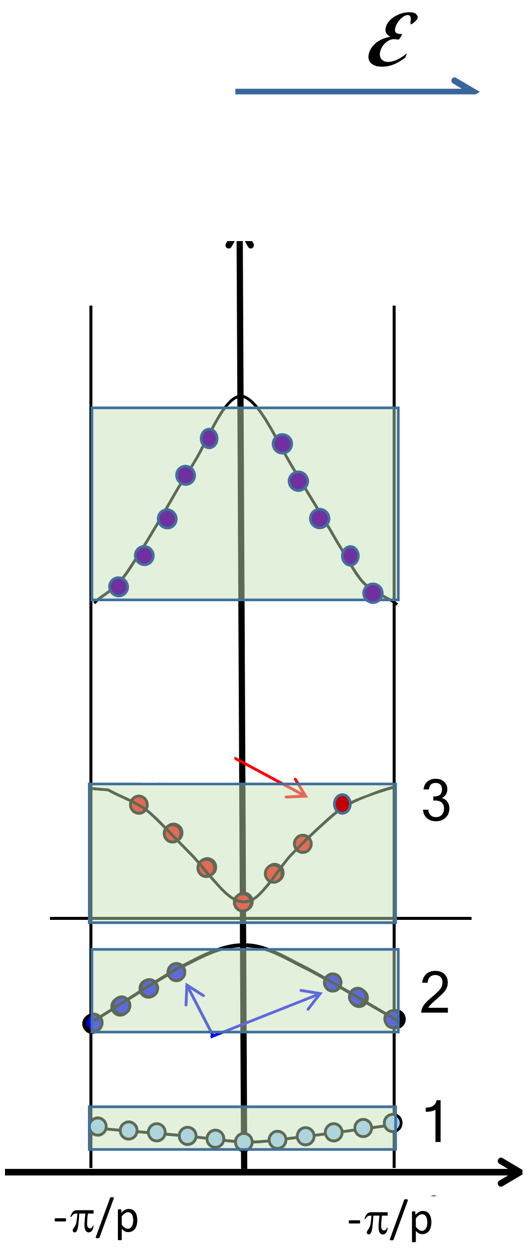
1. Physics of Semiconductor Devices, *S. M. Sze*, John Wiley & Sons (1981).
2. Solid State Electronics by *Ben G. Streetman and Sanjay Banerjee,* Prentice Hall International , Inc.
3. Semiconductor Physics and Devices, Donald A. Neamen, Tata Mcgraw-Hill Publishing company Limited.
4. Advanced Semiconductor Fundamentals by Pirret

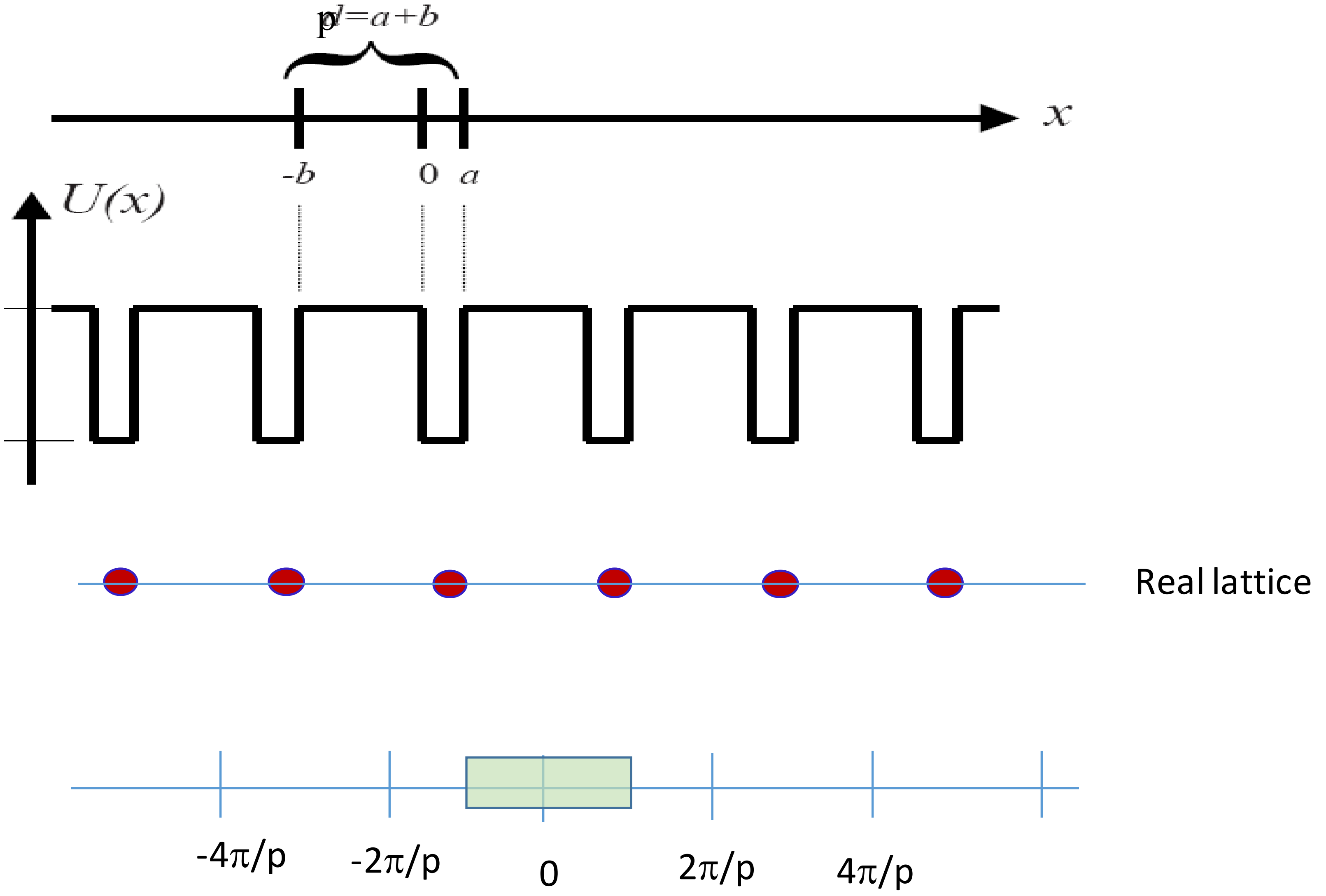
Reference Book:

1. Fundamentals of Solid-State Electronic Devices, *C. T. Sah*, Allied Publisher and World Scientific, 1991.
2. Complete Guide to Semiconductor Devices, *K. K. Ng*, McGraw Hill, 1995.
3. Solid state physics, Ashcroft & Mermins.
4. Introduction to Solid State Electronics, *E. F. Y. Waug*, North Holland, 1980.

Recap

Brillouin Zone





How to get Reciprocal Space Lattice and BZ?

Reciprocal space lattice from real space vector

$$K_x = 2\pi\ b\times c/|a.b\times c| = 2\pi\ b\times c/V$$

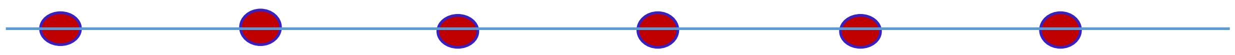
$$K_y = 2\pi\ c\times a/|a.b\times c| = 2\pi\ c\times a/V$$

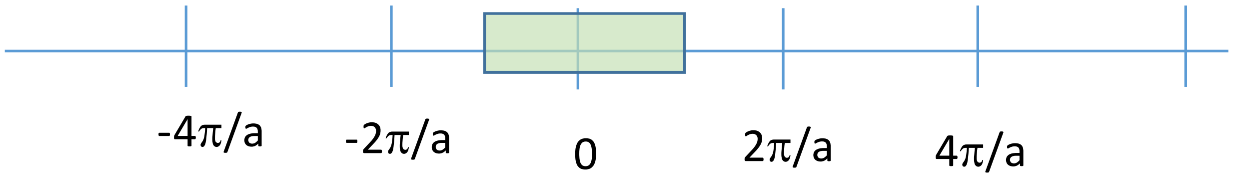
$$Kz = 2\pi\ a\times b/|a.b\times c| = 2\pi\ a\times b/V$$

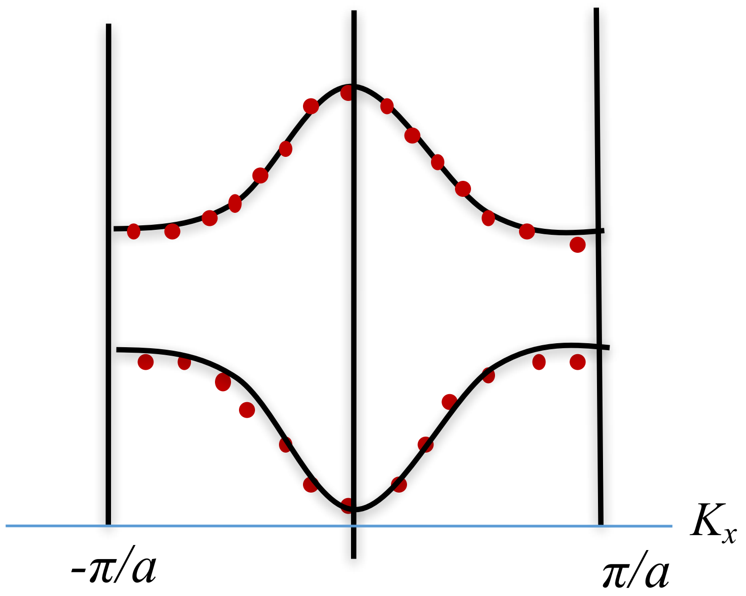
For BZ

Wigner Size cell in Reciprocal lattice

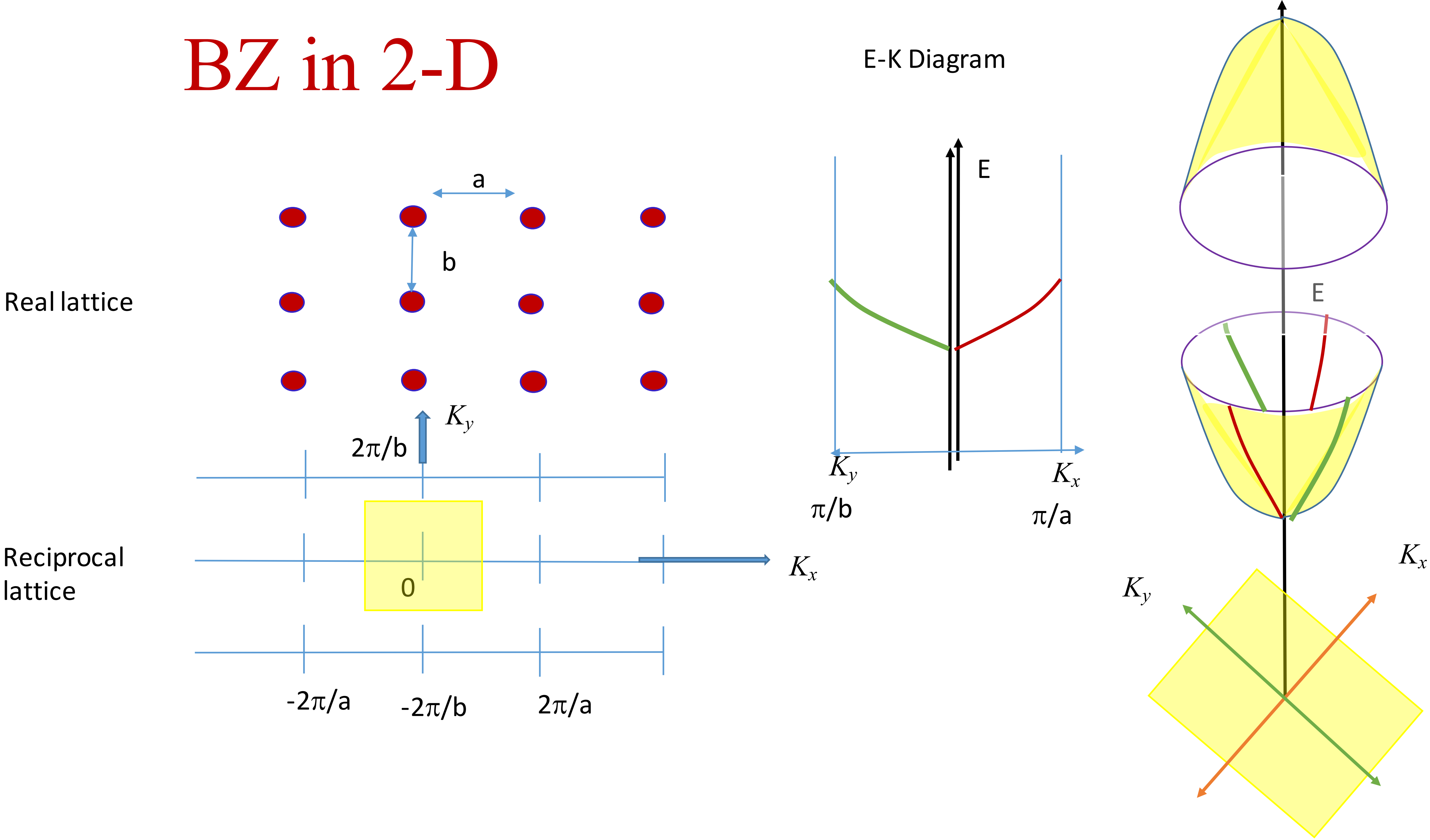
BZ in 1-D





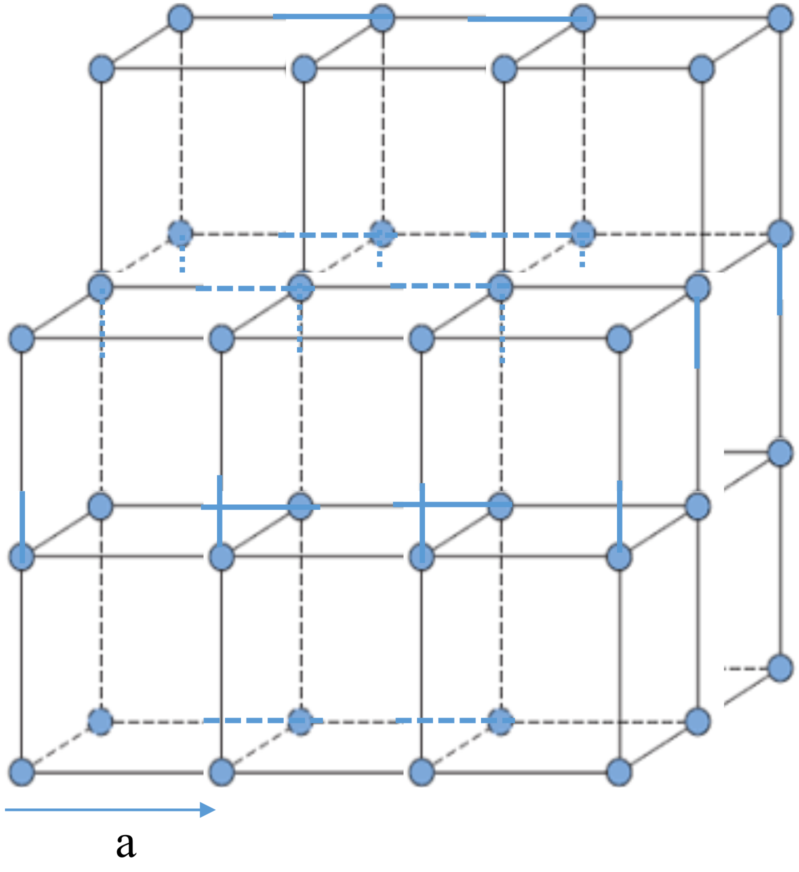


BZ in 2-D

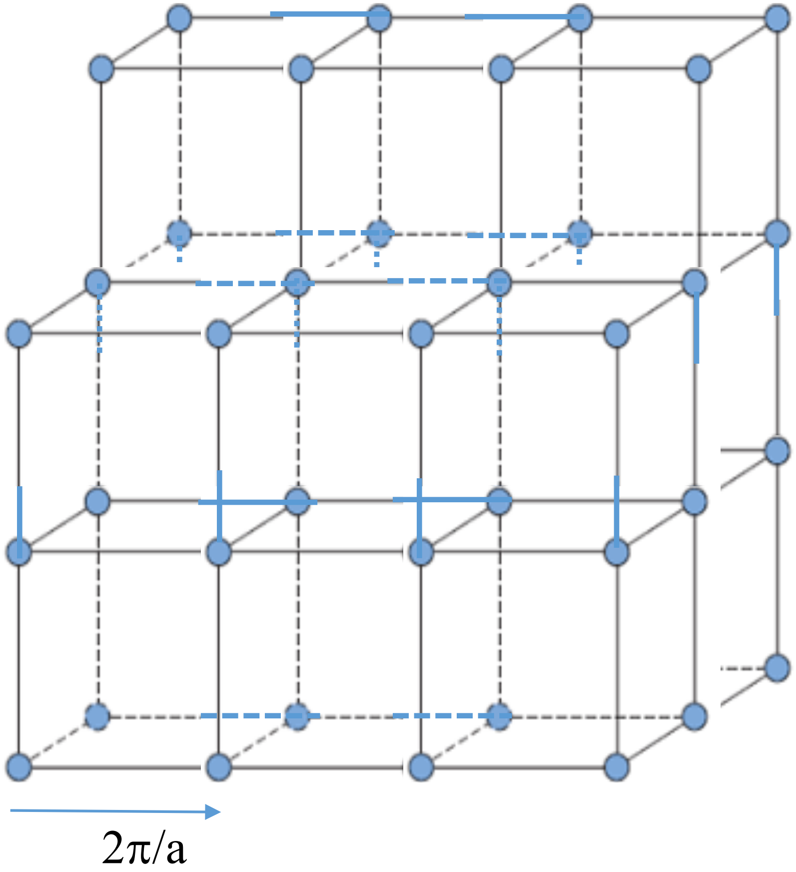


Real lattice
a
b
Reciprocal lattice
K_y
$2\pi/b$
0
K_x
$-2\pi/a$
$-2\pi/b$
$2\pi/a$
E-K Diagram
E
K_y
π/b
K_x
π/a
E
K_x
K_y

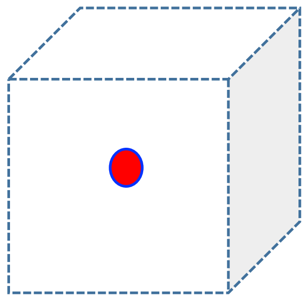
BZ in 3-D



Real Space



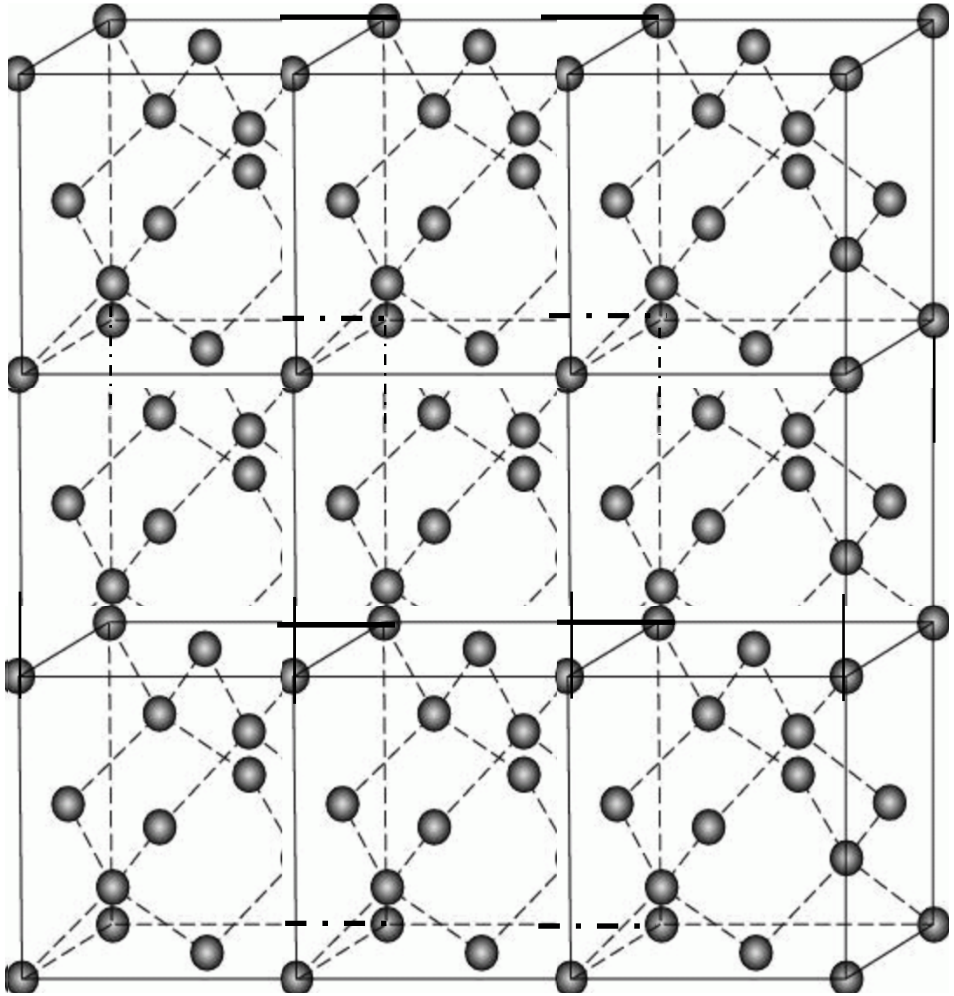
Reciprocal Space

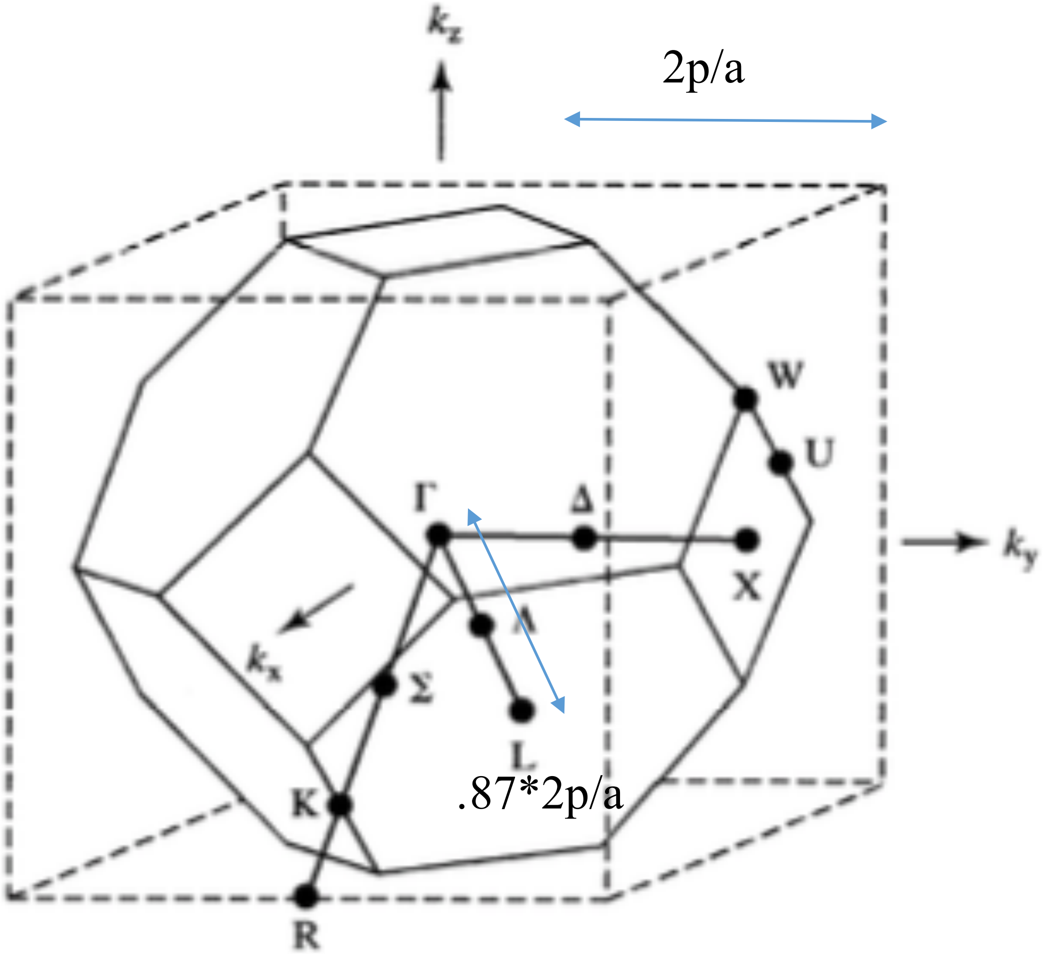


BZ

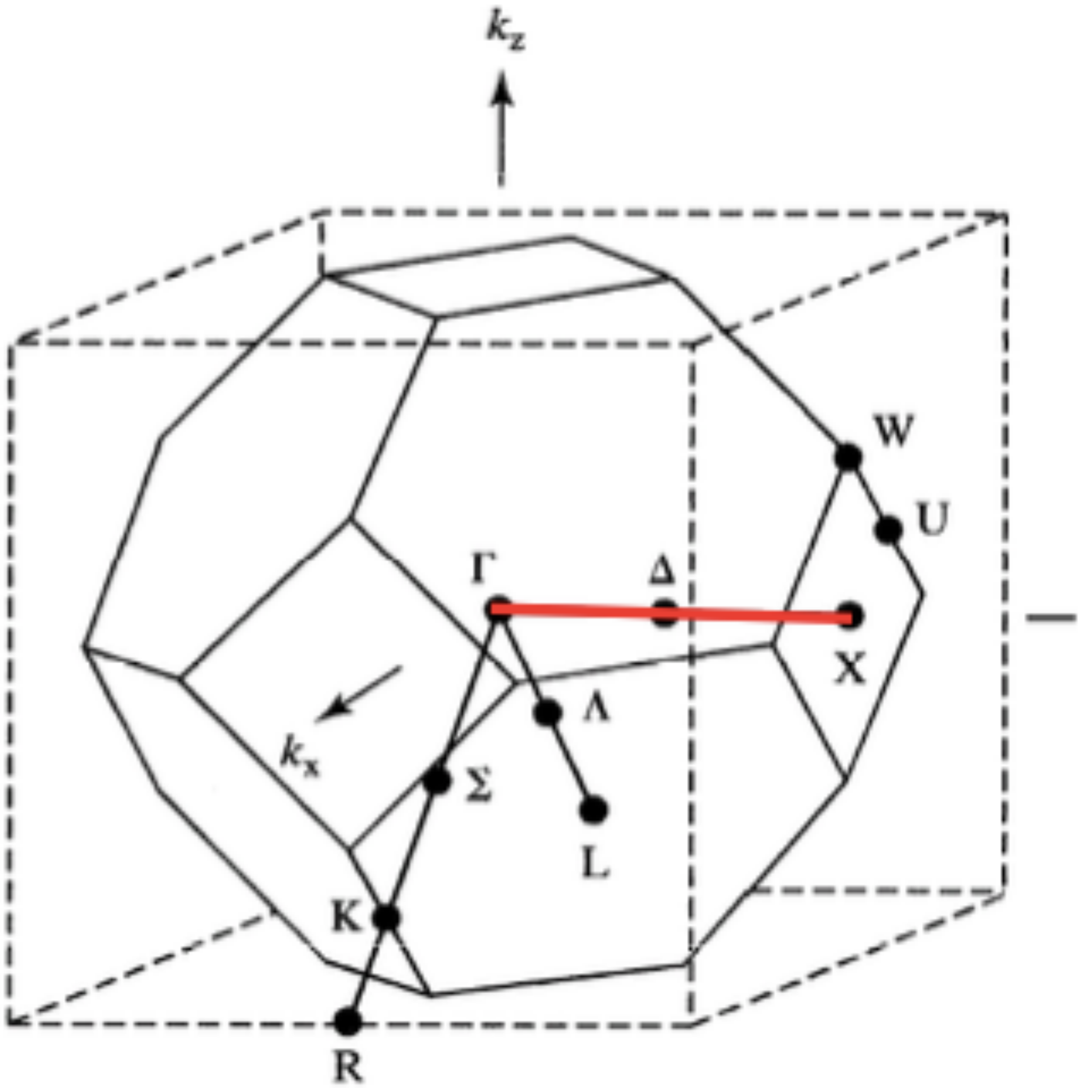
Now; BZ Ge, Si, GaAs

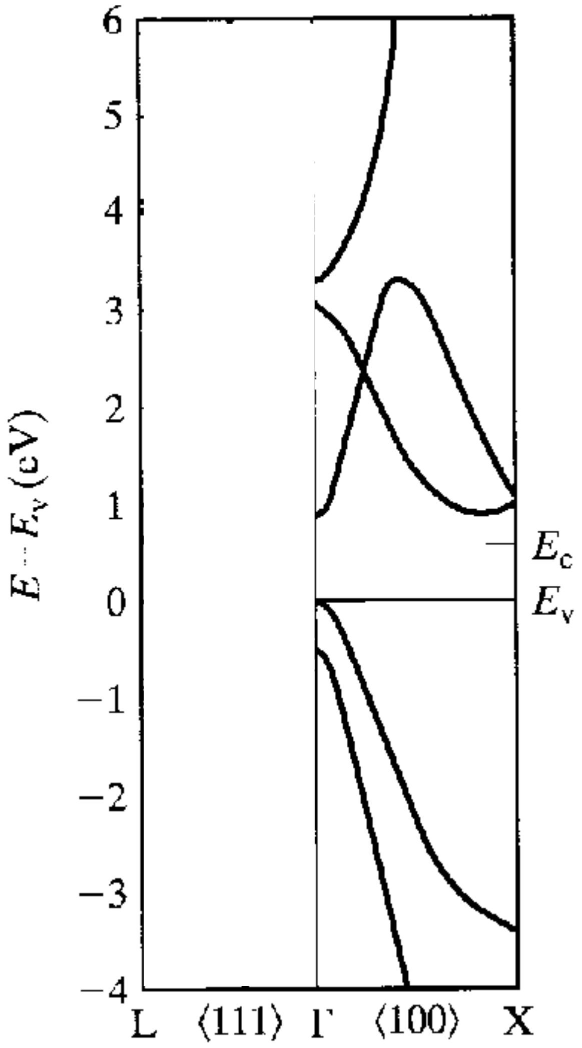
Real Space





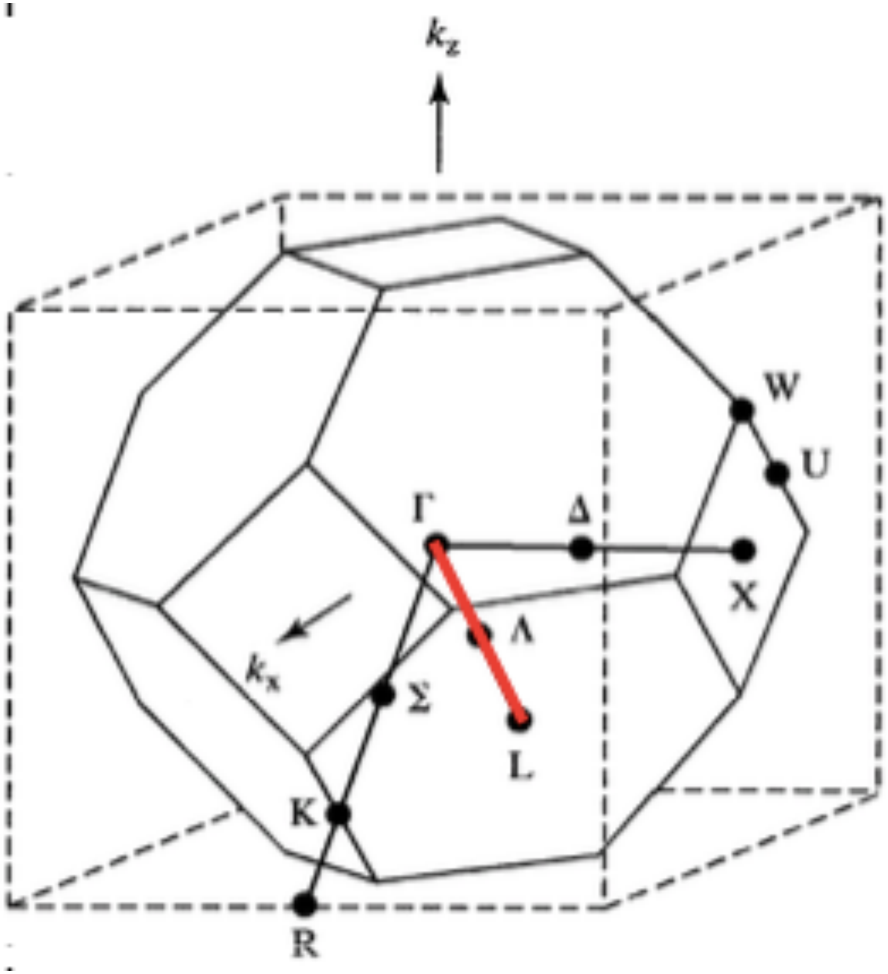
E-K Along X point

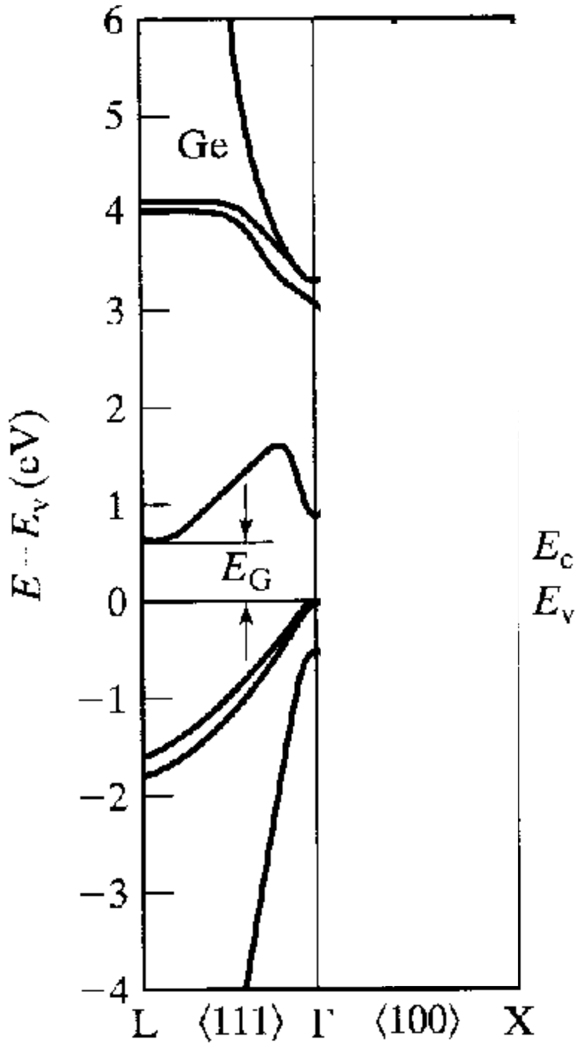




- <100> direction
- 2π/a(1,0,0) 6 symmetrical point
- (100), (-100), (010), (0-10), (001), (00-1)
-

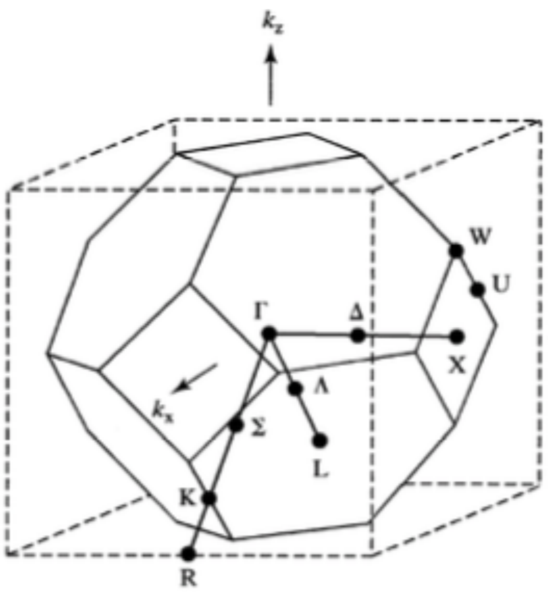
E-K Along L point

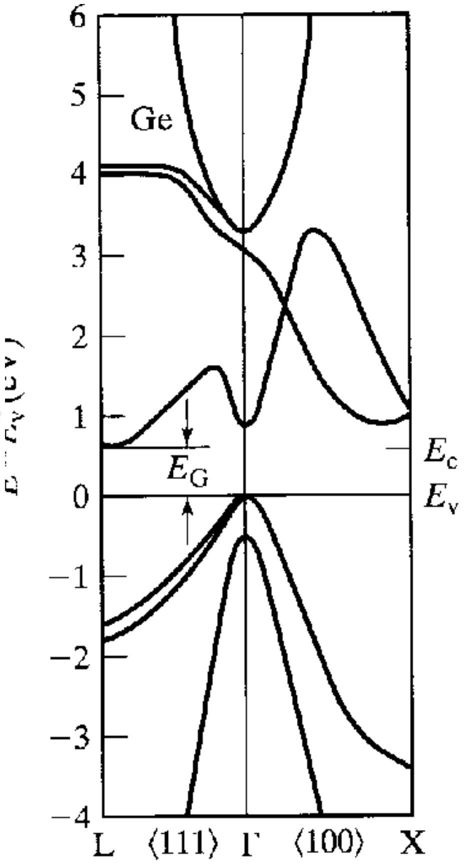


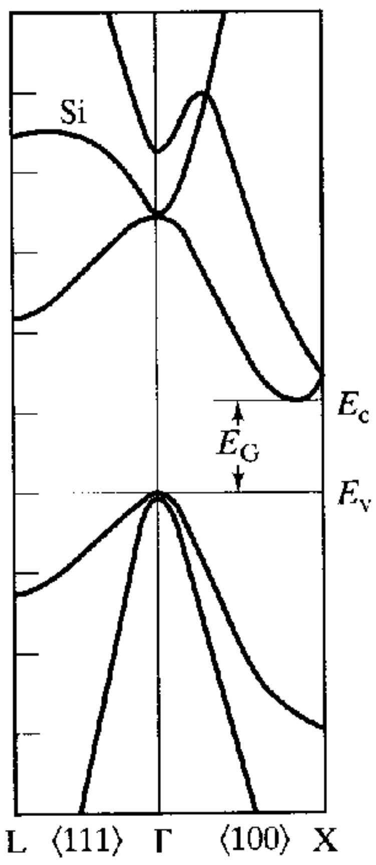


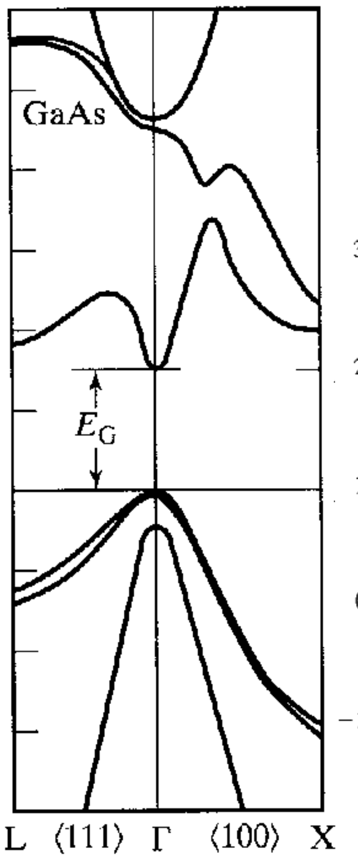
- <111> direction
- 2π/a(1/2,1/2,1/2) 8 symmetrical point

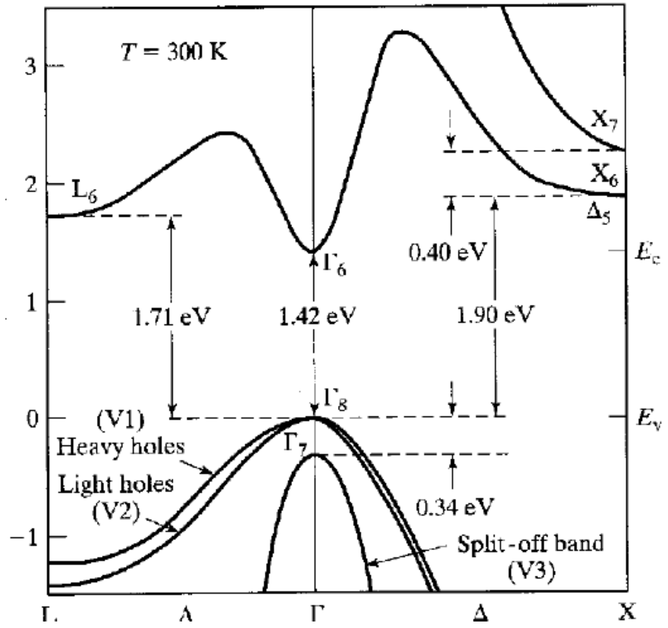
3-D E-k Diagram









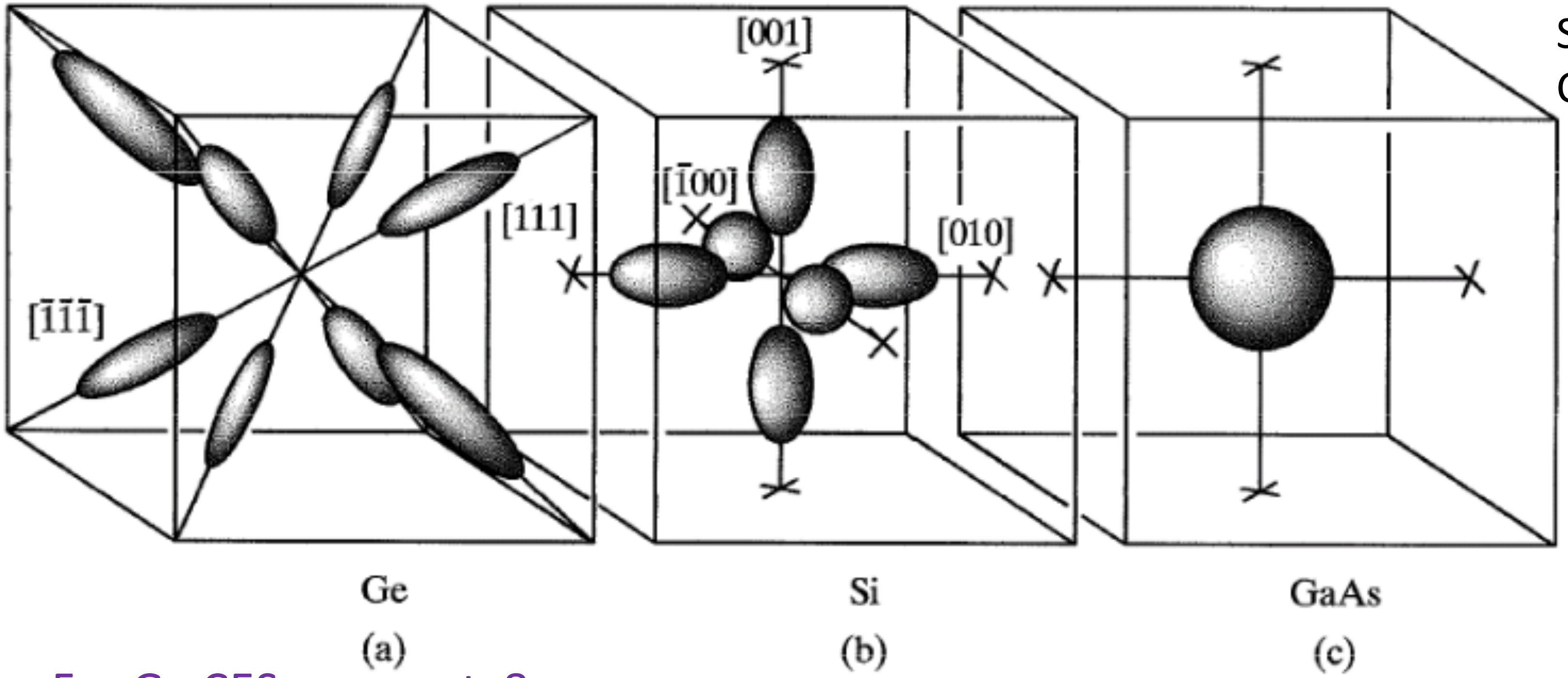


Ge Si GaAs GaAs

X,L points are highly symmetrical, energy stable states

Constant-Energy Surfaces: Conduction Band

Geometrical shapes for given Energy are called CES



For Ge CES occurs at 8 equivalent <111> direction

For Si CES occurs at 6 equivalent <100> direction

For GaAs CES occurs at Zone center

So Energy E in Conduction band

$$E = Ec + Ak_1^2 + Bk_2^2 + Ck_3^2$$

k,, k2, k3 are k space coordinate measured from center of band minimum along the principle axis for example Ge it will be center on L point and one of the axis say k_1 would directed along kx, ky, kz in [111} direction

For GaAs A=B=C
And for Si, and Ge, B=C