VE 320 Summer 2019

Introduction to Semiconductor Devices

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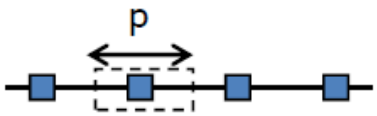
Band gap

For 1D solid

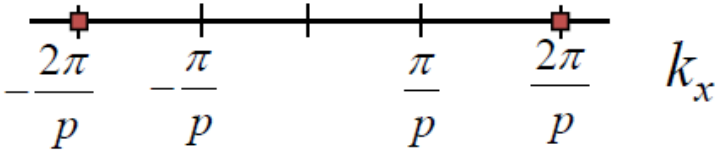
Brillouin zone

Real-space

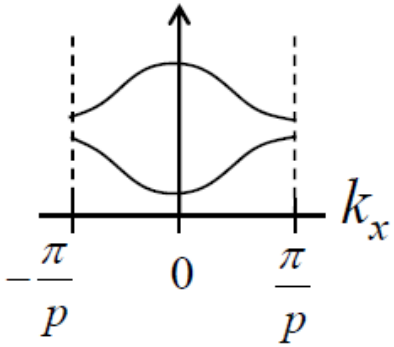


Replacing (a+b) by p …

1st B-Z

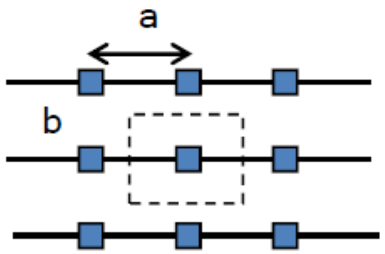


E-k diagram

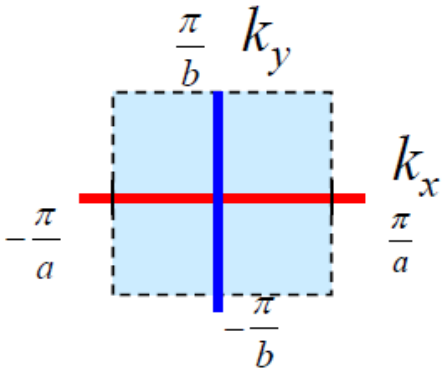


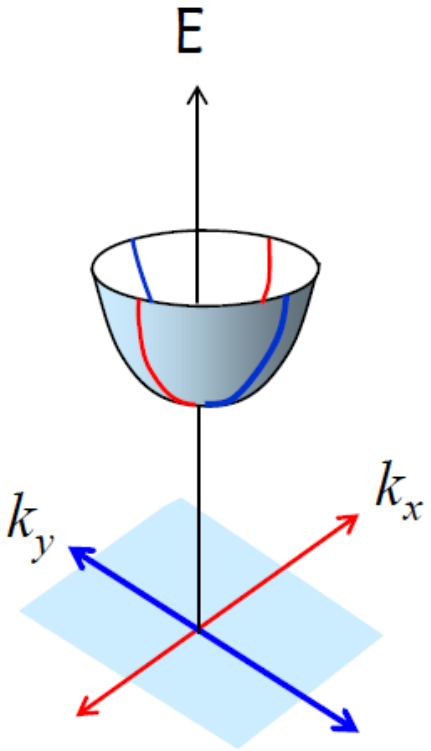
For 2D solid

Real-space

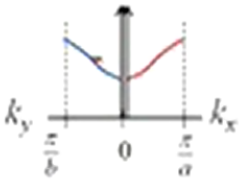


1st B-Z





E-k diagram

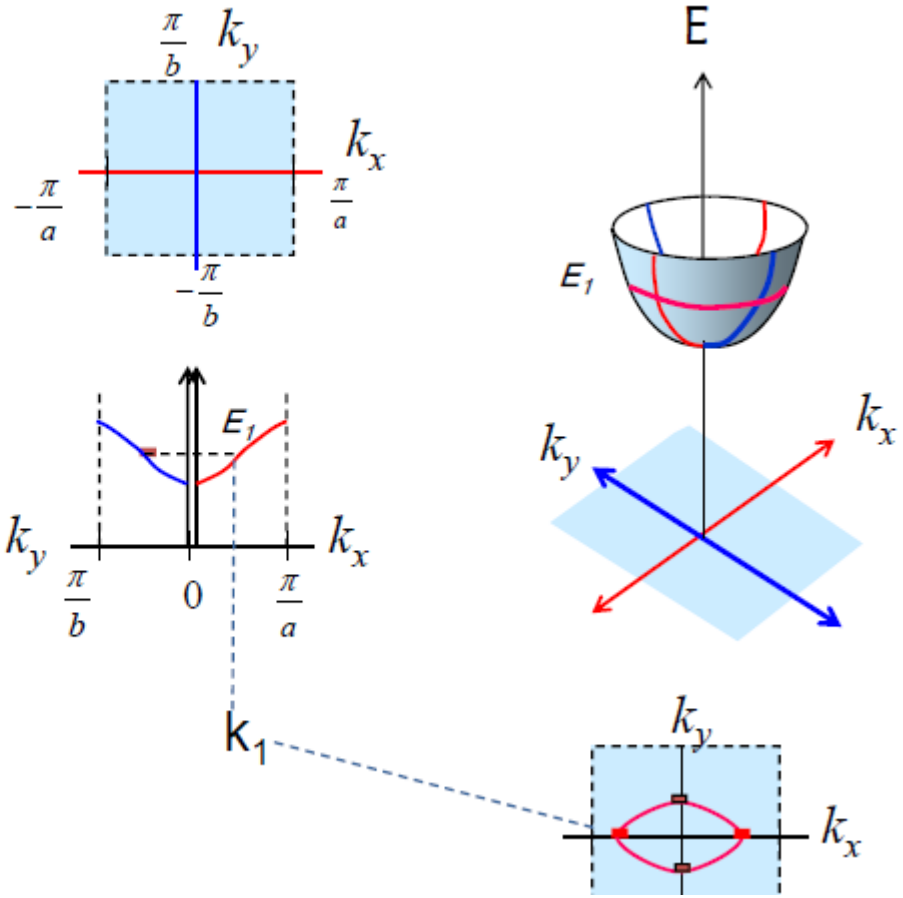


For 2D solid

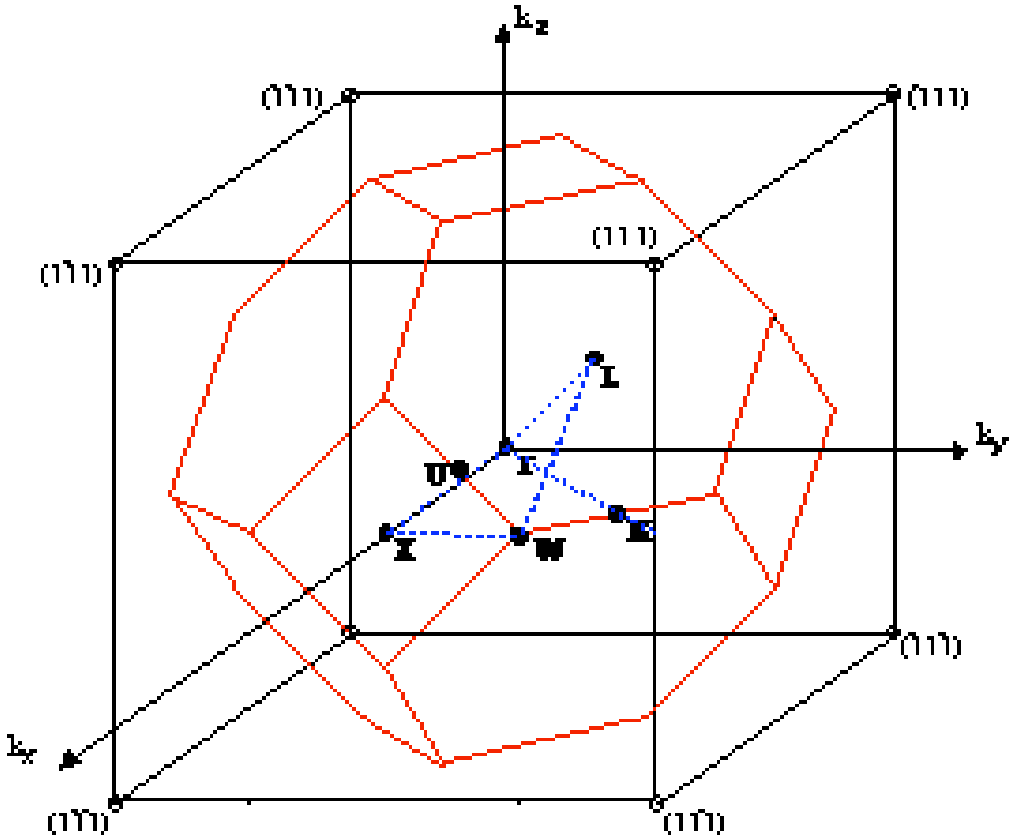
1st B-Z

E-k diagram

Const. Energy Surface

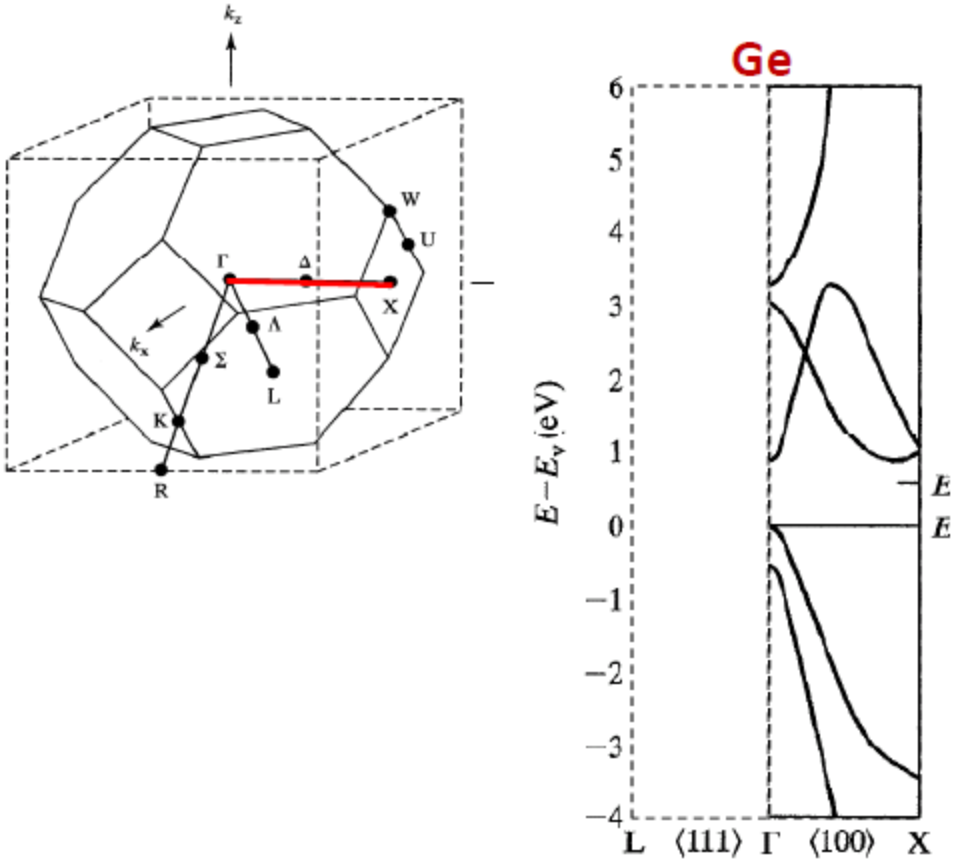


Band structure in 3D k-space

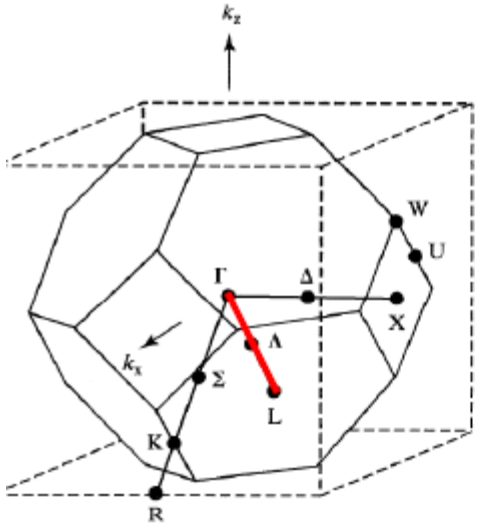


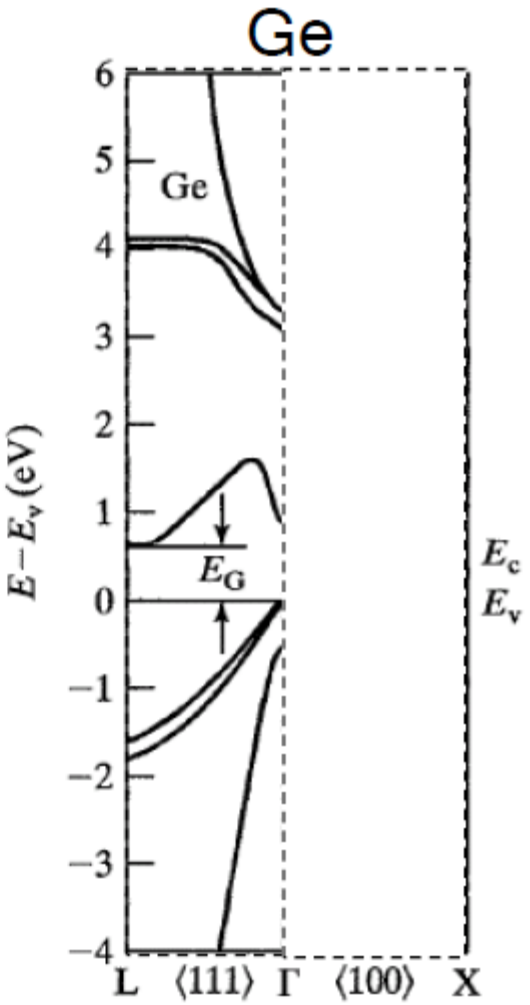
Γ - center of the BZ
X - [100] intercept; Γ – X path Δ
K - [110] intercept; Γ – K path ∑
L - [111] intercept; Γ – L path Λ

E-k along Γ-X Direction

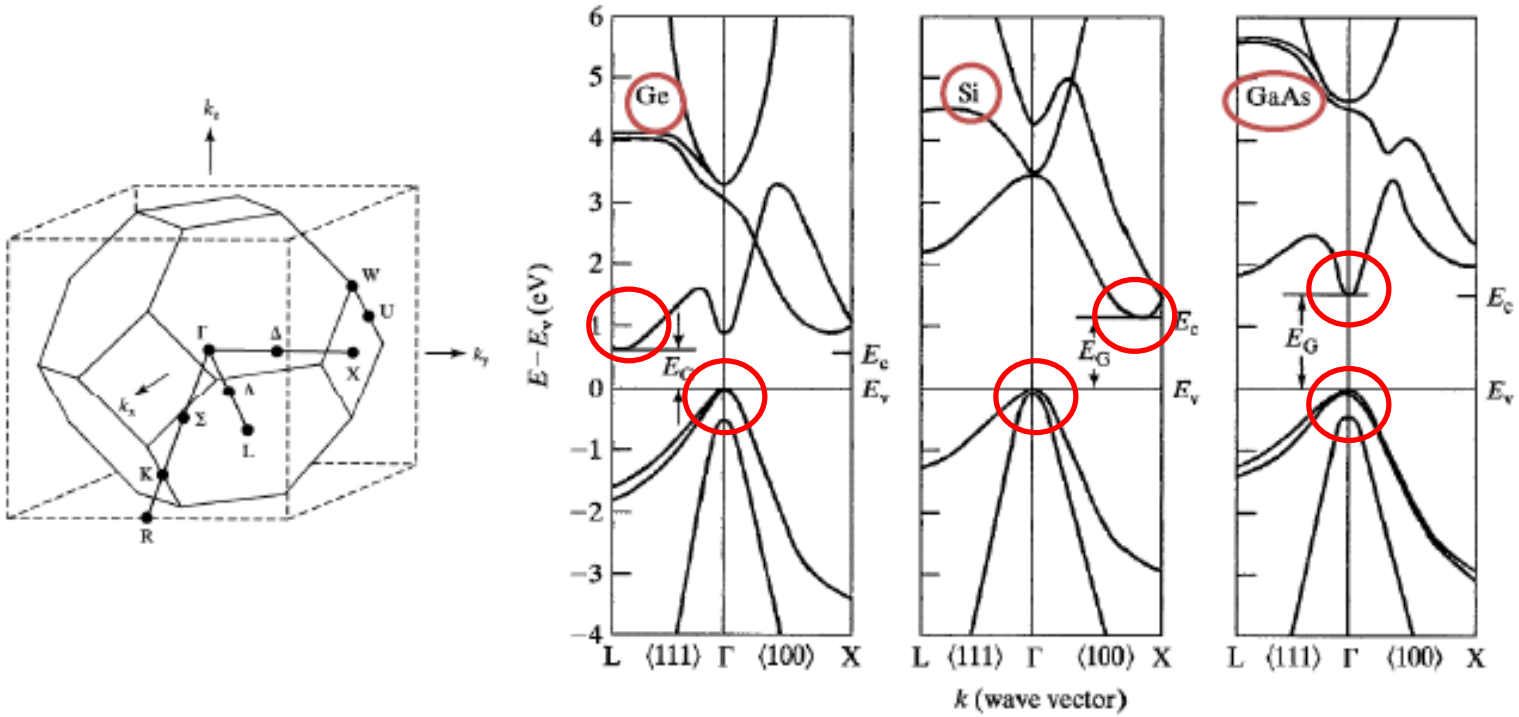


E-k along Γ-L Direction





Band structure in 3D k-space



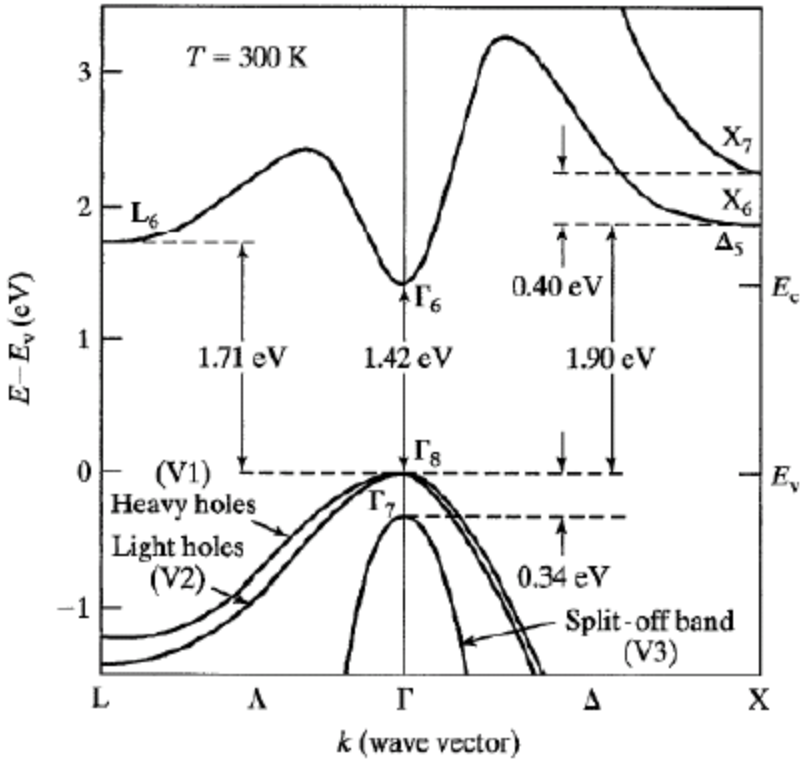
- Direct bandgap

  (electron excited, k constant, E↑ → f ↑, v = f λ ↑)

- Indirect bandgap

E-k diagram for GaAs

Light holes and heavy holes

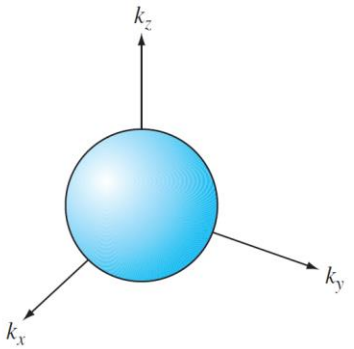


Density of states effective mass

- Holes: In the 3D k_x-k_y-k_z coordinate system, the constant energy is essentially spherical for both the heavy and light holes.
- "Average" effective mass
- The volume of a sphere in momentum space is

$$\text{Volume} \propto p^3$$

$$p_{hh}^2 = 2m_{hh}E \quad \text{and} \quad p_{lh}^2 = 2m_{lh}E$$



m_{hh}: effective mass of heavy hole
m_{lh}: effective mass of light hole

2 spheres for hh and lh $\quad \text{Total volume} \propto (m_{hh})^{3/2} + (m_{lh})^{3/2}$

Density of states function for holes

$$g_v(E) \propto \text{Volume} \propto (m_{dp}^*)^{3/2} = (m_{hh})^{3/2} + (m_{lh})^{3/2}$$

Density of states effective hole mass $\quad m_{dp}^* = [(m_{hh})^{3/2} + (m_{lh})^{3/2}]^{2/3}$