VE 320 Fall 2021

Introduction to Semiconductor Devices

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Band gap

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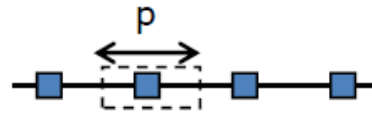
For 1D solid

Brillouin zone

Real-space

p

Replacing
(a+b) by p ...

1st B-Z

$$-\frac{2\pi}{p} \qquad -\frac{\pi}{p} \qquad \frac{\pi}{p} \qquad \frac{2\pi}{p} \qquad k_x$$

E-k diagram

$$-\frac{\pi}{p} \qquad 0 \qquad \frac{\pi}{p} \qquad k_x$$

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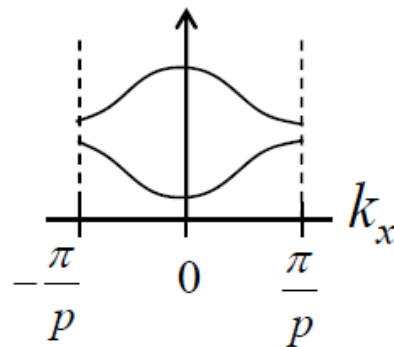
For 2D solid

Real-space

1st B-Z

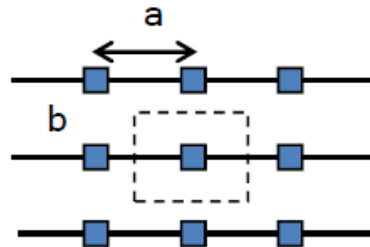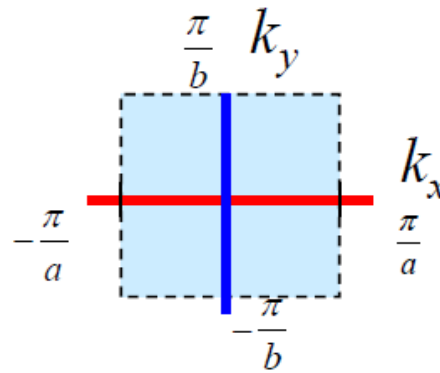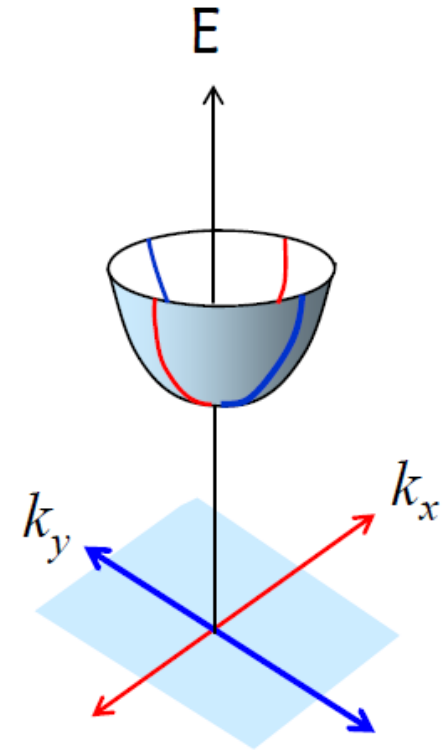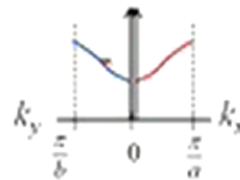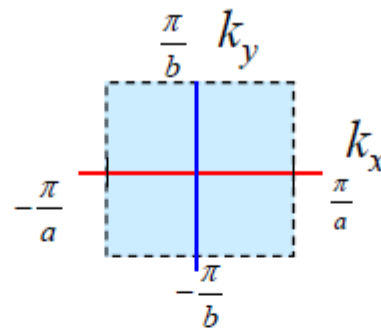E-k diagram
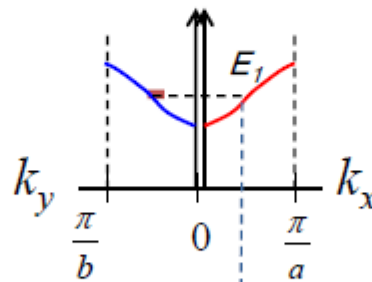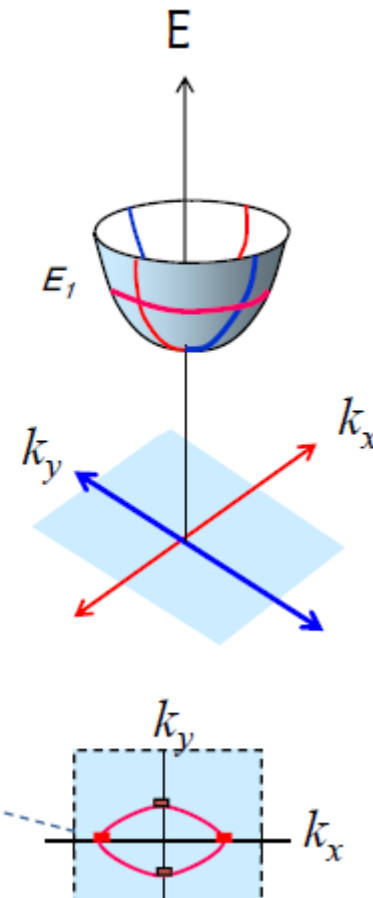
For 2D solid

1st B-Z
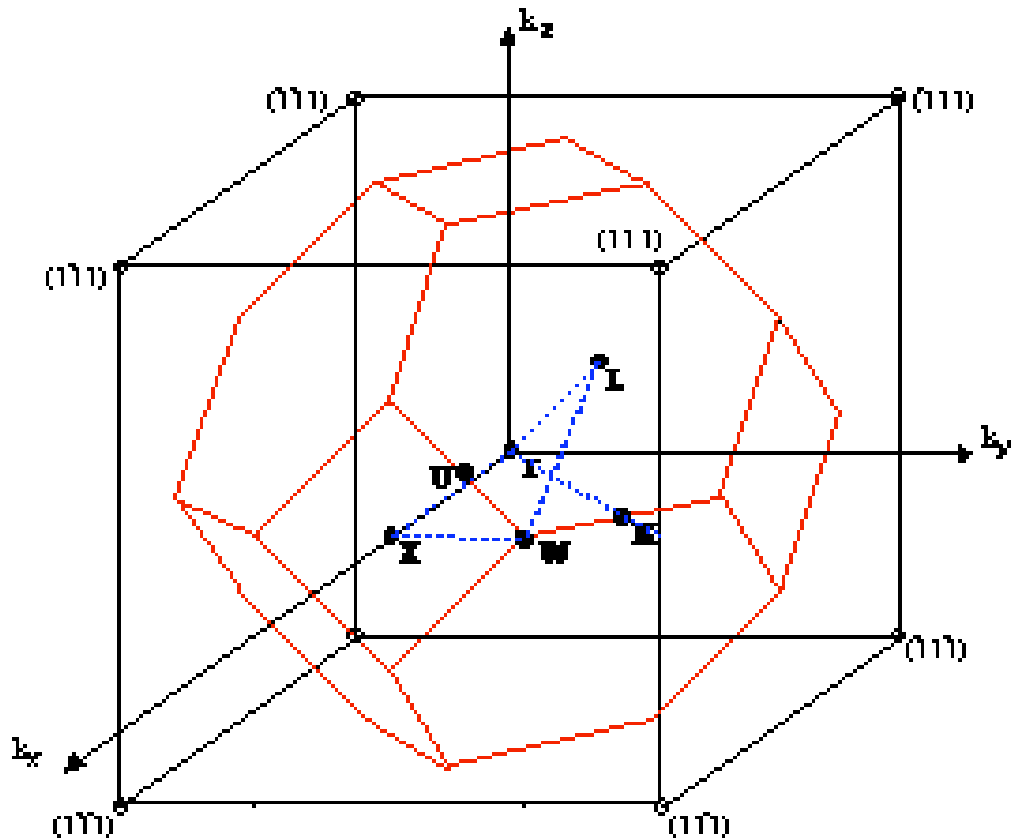
E-k diagram

Const. Energy
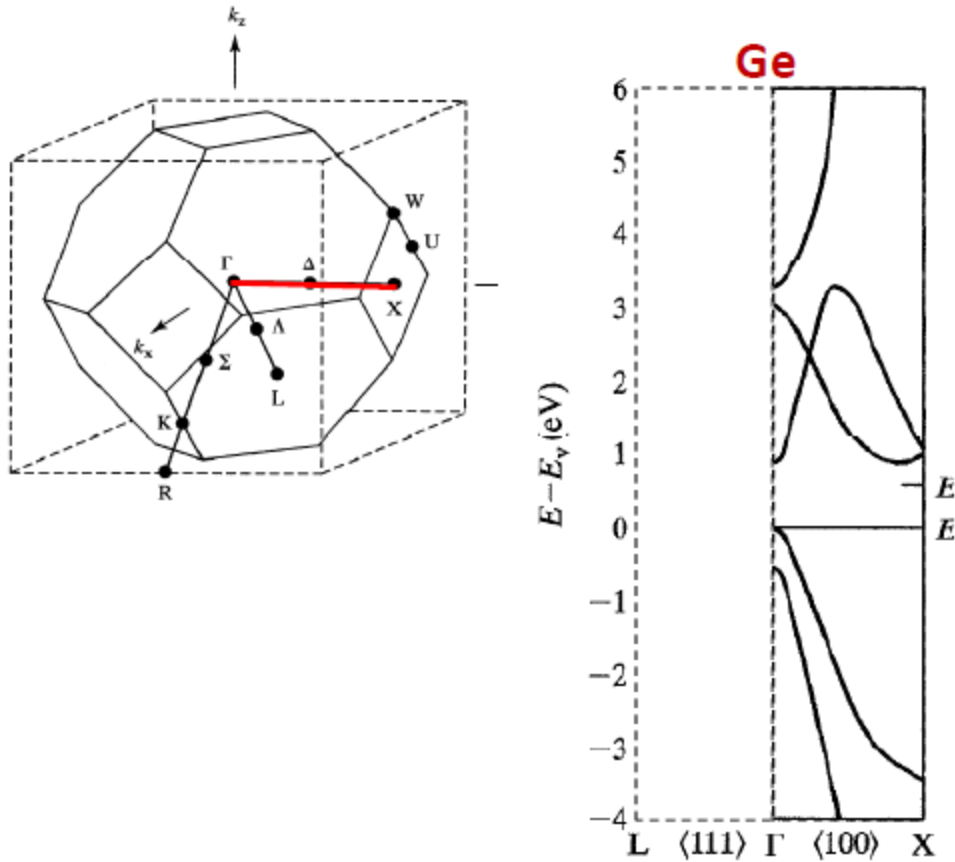Surface

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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

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E-k along Γ-X Direction

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E-k along Γ-L Direction

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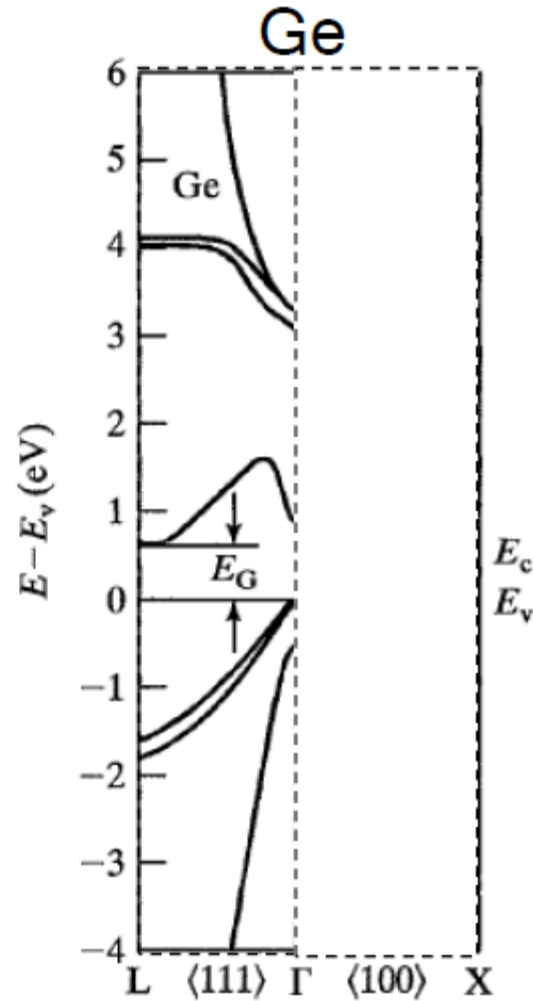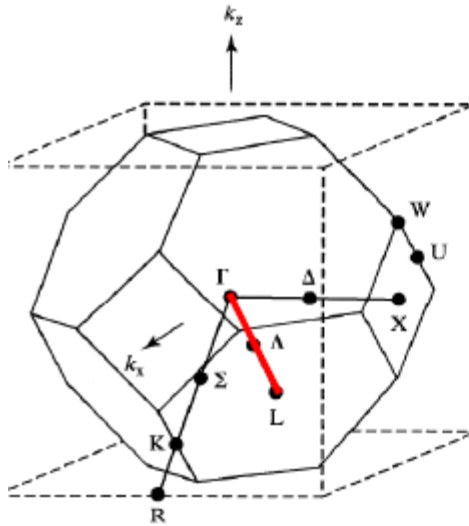
Band structure in 3D k-space
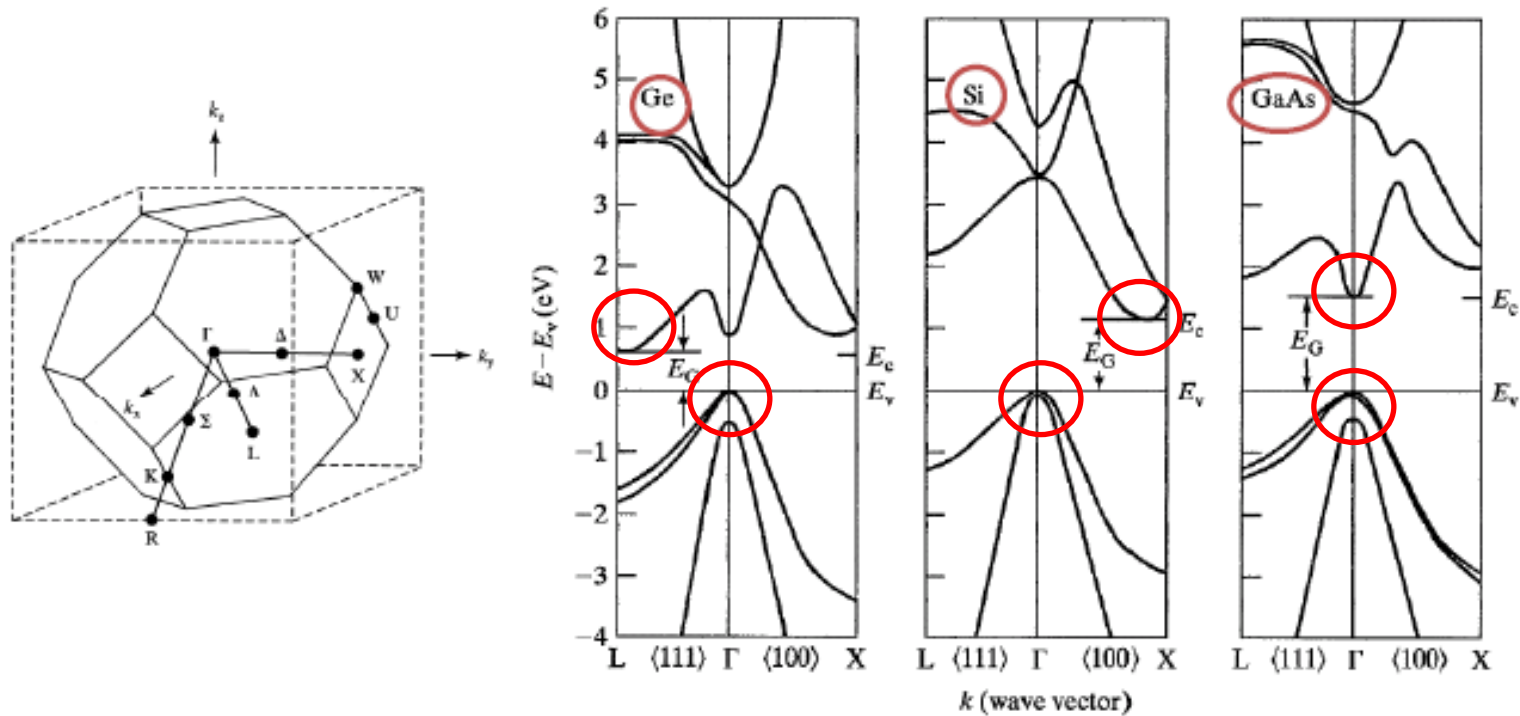
- Direct bandgap

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

- Indirect bandgap

E-k diagram for GaAs

Light holes and heavy holes

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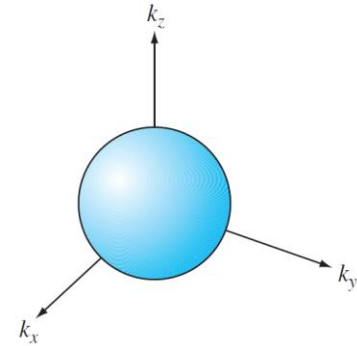
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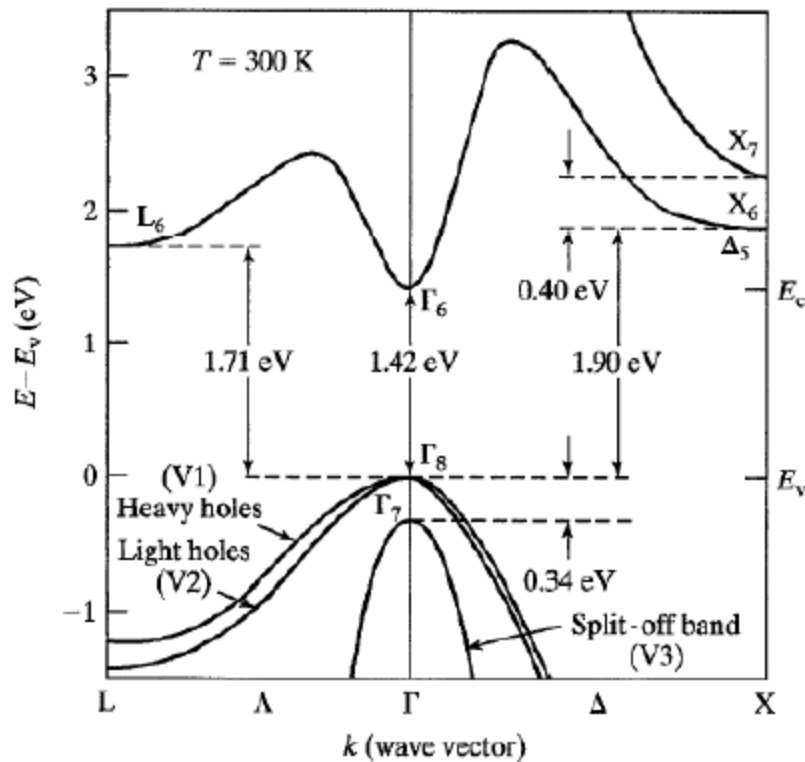
Density of states effective mass

- 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

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

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

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

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

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 $m_{dp}^* = [(m_{hh})^{3/2} + (m_{lh})^{3/2}]^{2/3}$

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