Section 10
Bandstructure in Real Materials (Si, Ge, GaAs)
10.2 Constant Energy Surfaces - Effective Mass Tensor

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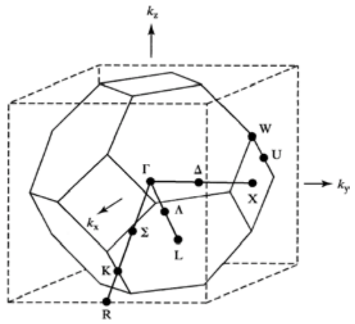
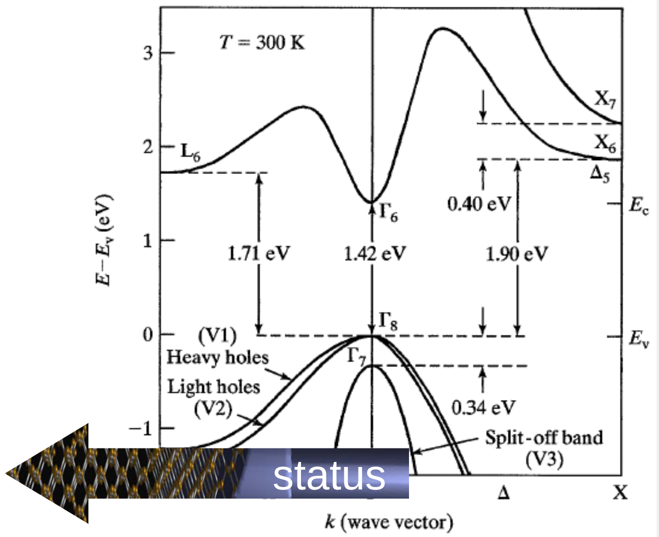
Section 10
Bandstructure in Real Materials (Si, Ge, GaAs)

One Video Segment

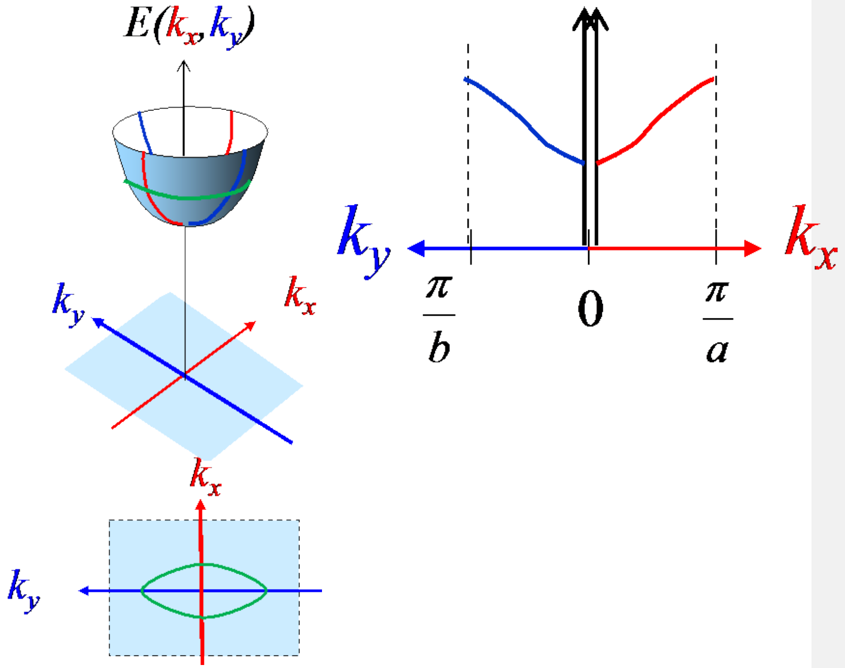
- 10.1 E(k) diagrams in specific crystal directions





One Video Segment

- 10.2 Constant Energy Surfaces – Effective Mass Tensor



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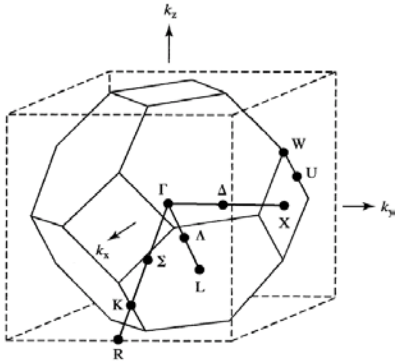
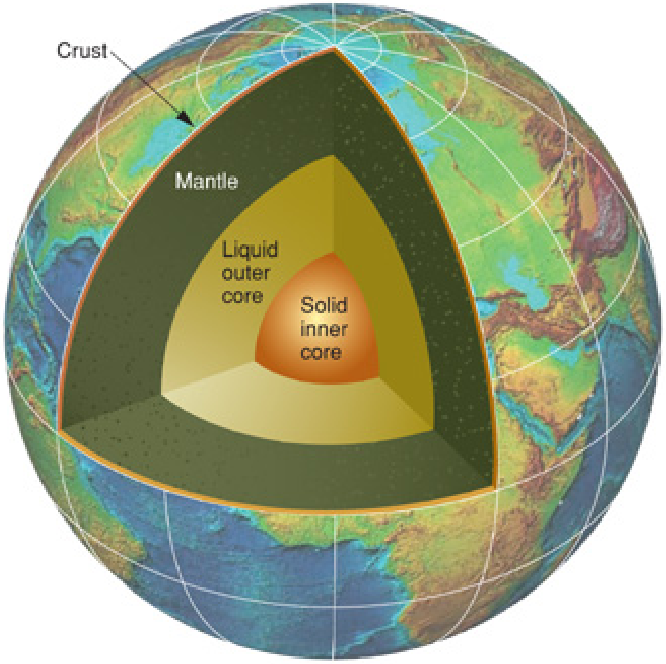
- 10.3 Density of States Effective Mass

Reference: Vol. 6, Ch. 3

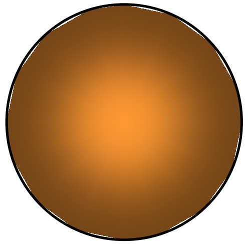
Analogy for E-k Diagram

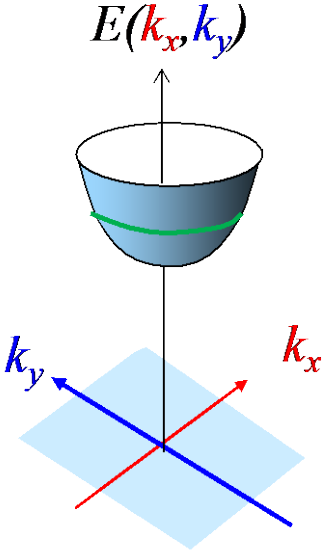


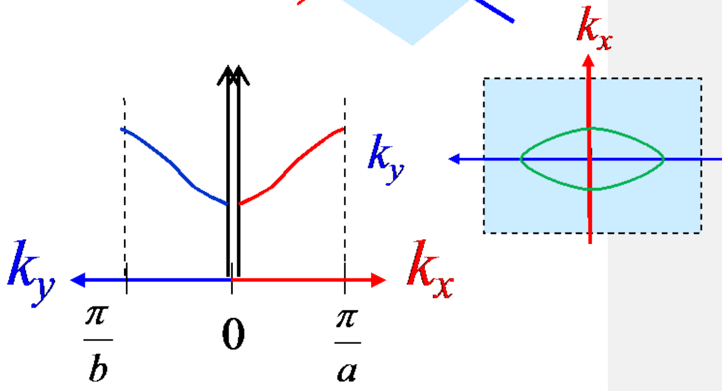


Density (x,y,z)

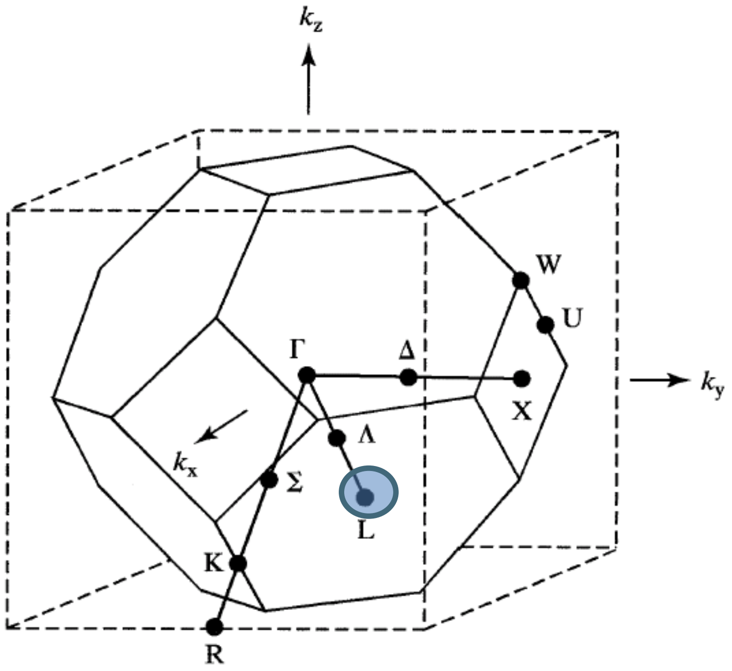
Contours of density ….

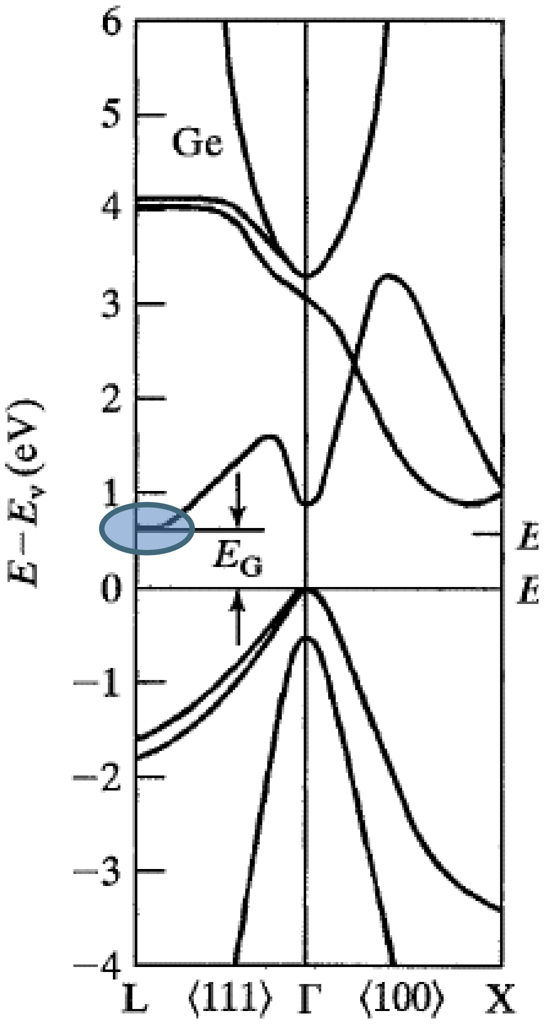


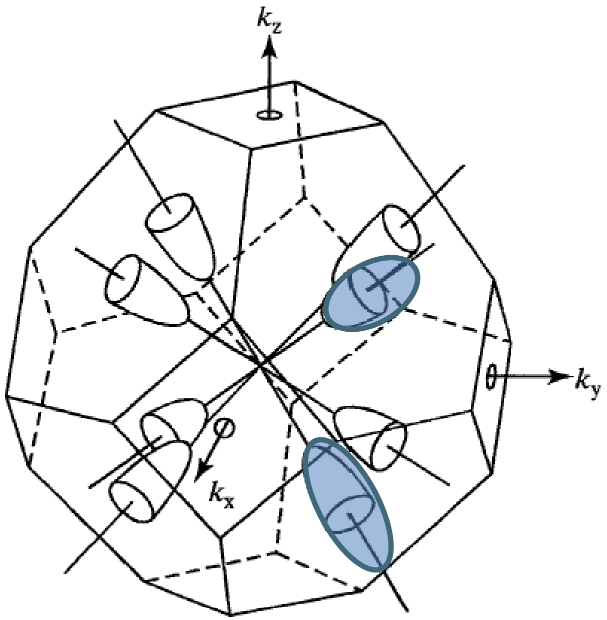




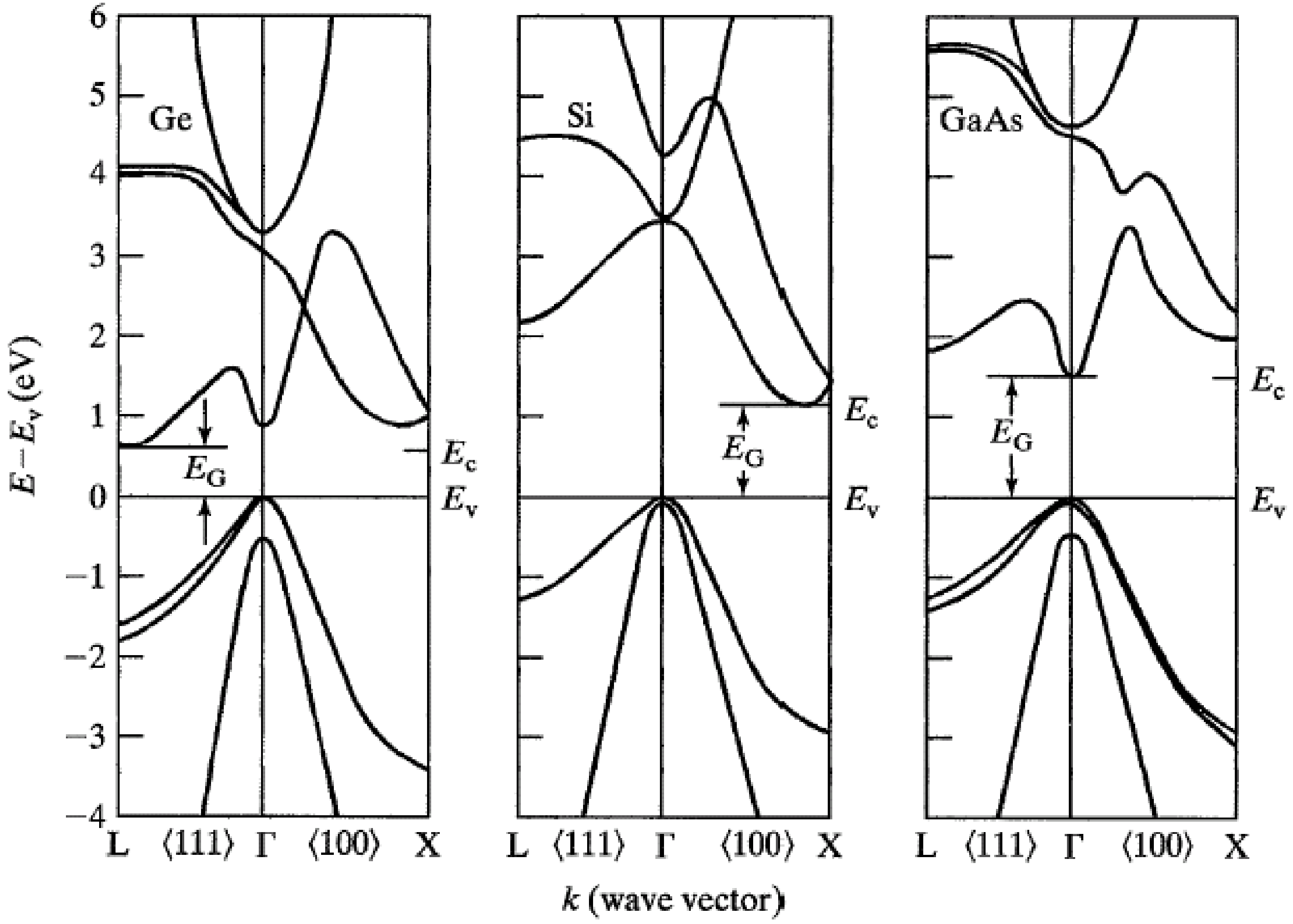
Four valleys (8 halves) inside BZ for Germanium



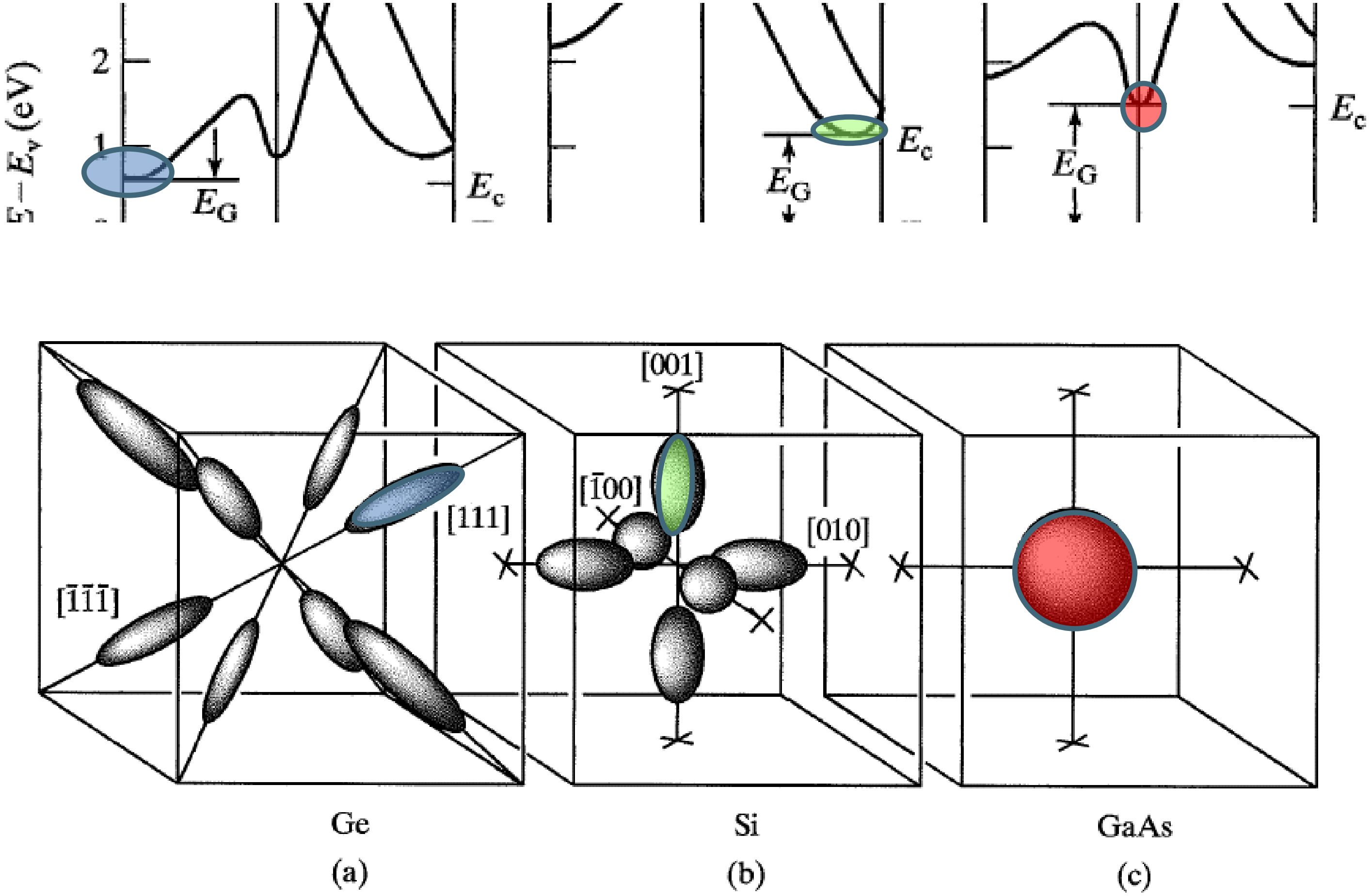




Constant-E surface for Conduction Band

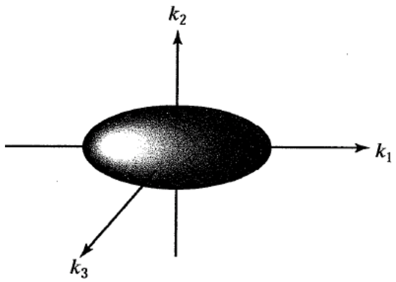


Constant-E surface for Conduction Band

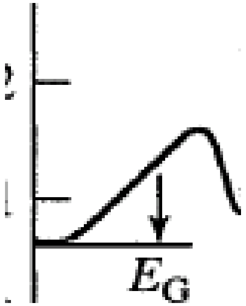


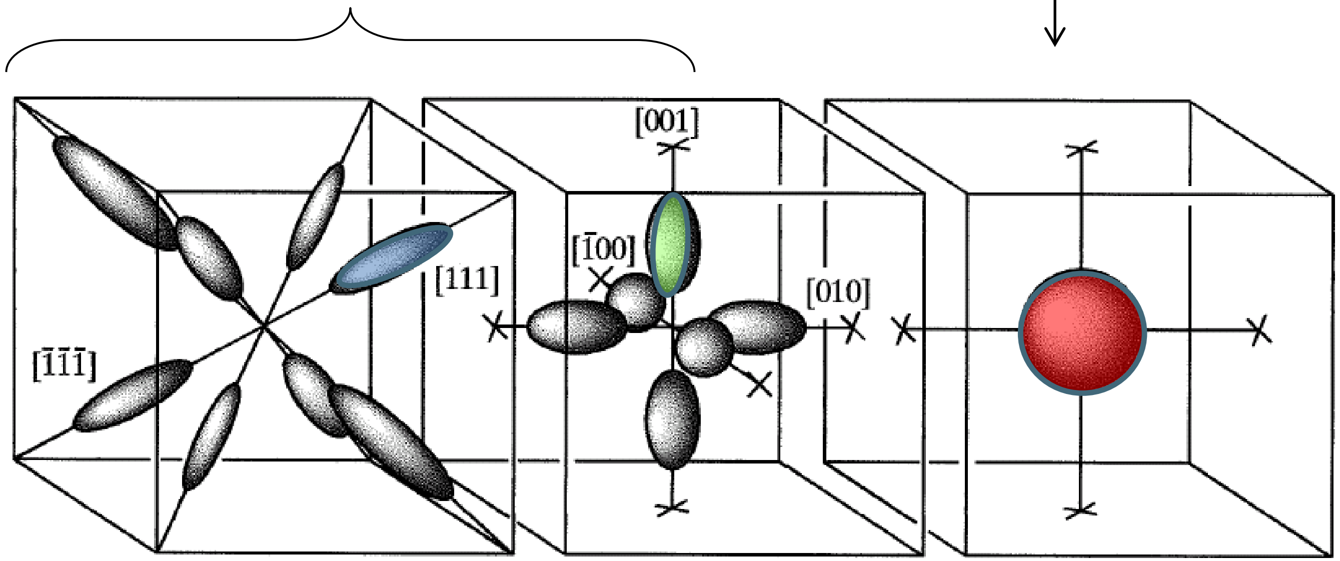
Constant-E surface for Conduction Band

$$E = E_c + Ak_1^2 + B(k_2^2 + k_3^2)$$



$$E = E_c + A(k_1^2 + k_2^2 + k_3^2)$$

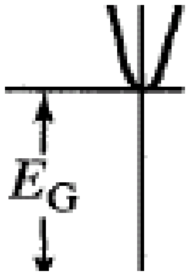




Ge
(a)

Si
(b)

GaAs
(c)

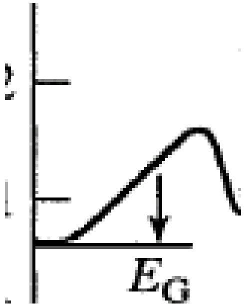


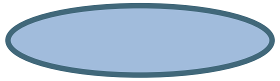
Constant E-surface and Effective Mass Tensor

$$E = E_c + Ak_1^2 + B(k_2^2 + k_3^2)$$

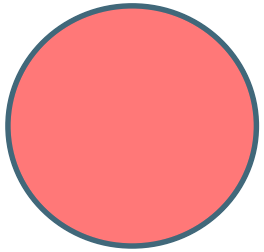
$$E = E_c + A(k_1^2 + k_2^2 + k_3^2)$$

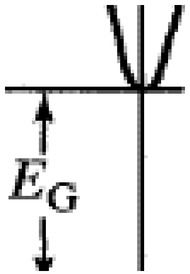
$$\frac{1}{m_{ij}} = \frac{1}{\hbar^2}\frac{\partial^2 E}{\partial k_i \partial k_j}$$





Ge: 8 valleys
Si: 6 valleys





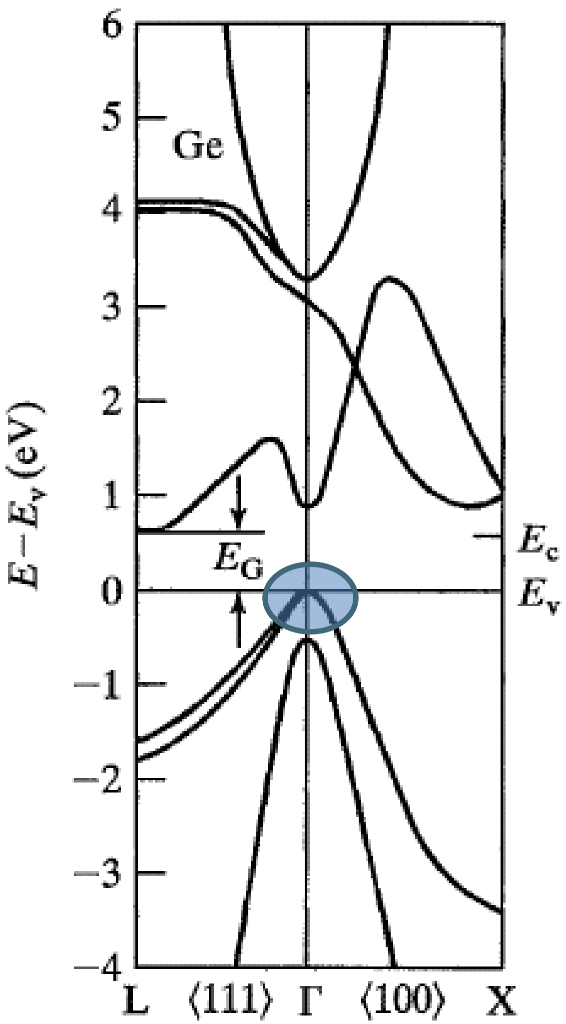
$$\frac{1}{m_{11}} = \frac{2A}{\hbar^2}; \quad \frac{1}{m_{22}} = \frac{1}{m_{33}} = \frac{2B}{\hbar^2}; \quad \frac{1}{m_{ij}(i \neq j)} = 0$$

1 heavy mass
2 light masses

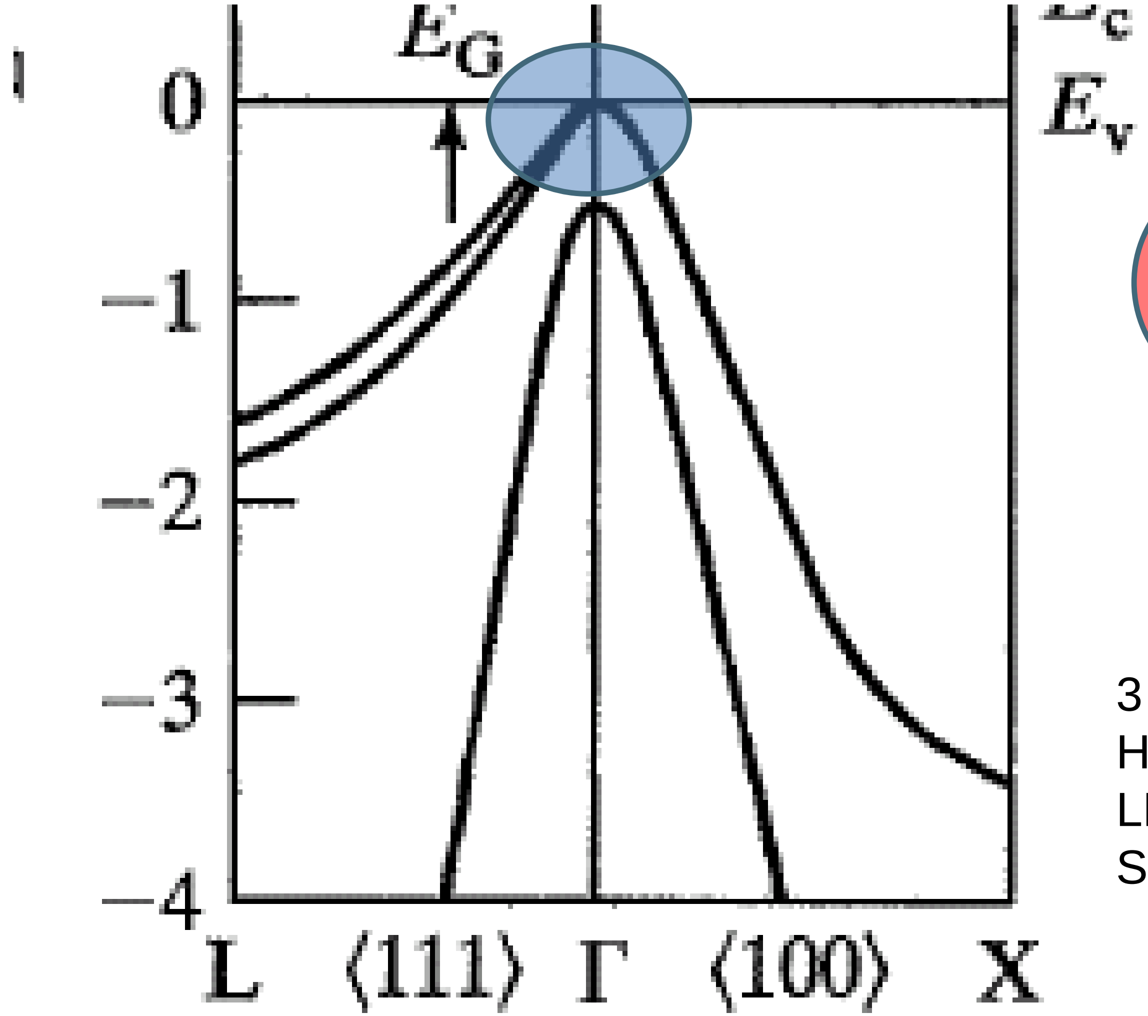
$$\frac{1}{m_{11}} = \frac{1}{m_{22}} = \frac{1}{m_{33}} = 2A; \quad \frac{1}{m_{ij}(i \neq j)} = 0$$

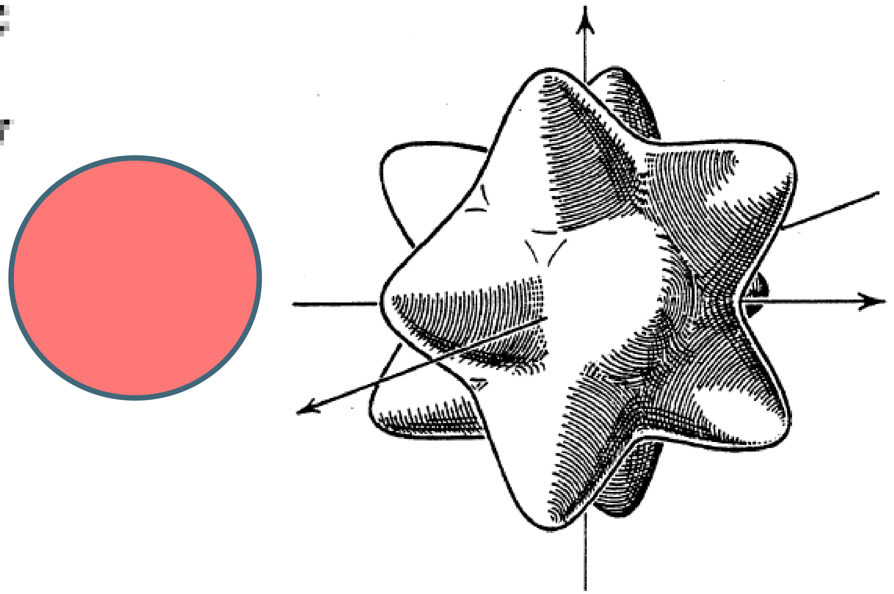
Offdiagonal Elements=0
=> Force and movement aligned

Constant E-surface for Valence Band



Constant E-surface for Valence Band





3 bands:
HH – Heavy Hole
LH – Light Hole
SO – Split-off band

HH and LH are NOT Isotropic
=> NOT spheres
=> strong spatial variations

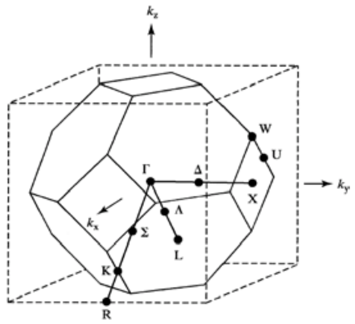
Rotated substrate technology at TI
Robert C. Bowen
Enhanced PMOS

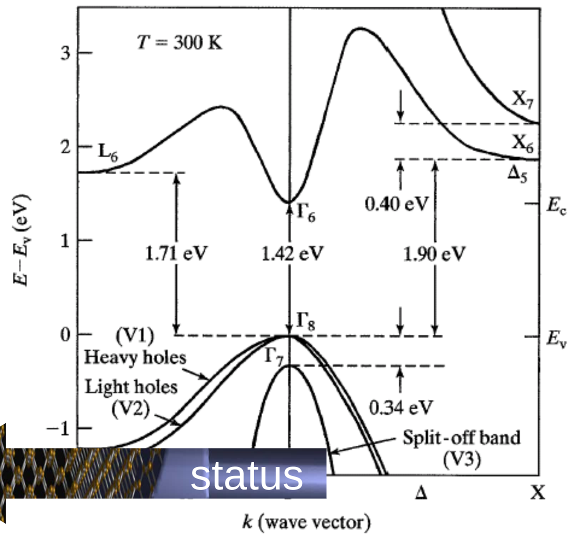
$$E = E_v - Ak^2 \mp \sqrt{\ [B^2k^4 + C^2(k_x^2k_y^2 + k_y^2k_z^2 + k_z^2k_x^2)]}$$

Si: A=4.29, B=0.68, C=4.87; Ge: A=13.38, B=8.48, C=13.15

One Video Segment

- 10.1 E(k) diagrams in specific crystal directions

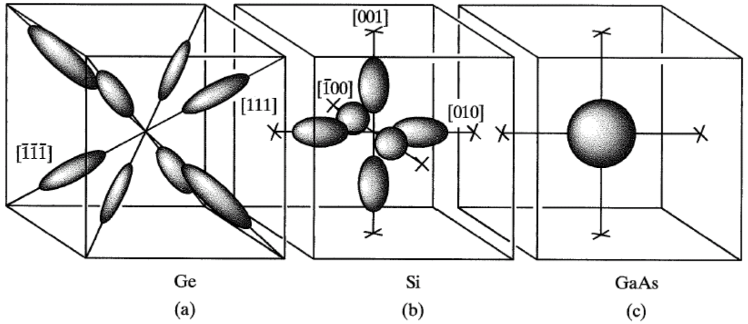




One Video Segment

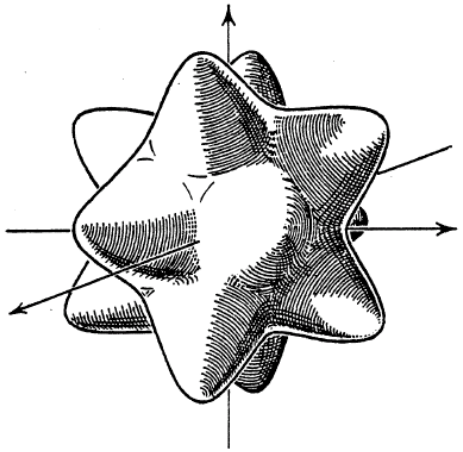
- 10.2 Constant Energy Surfaces – Effective Mass Tensor

$$\frac{1}{m_{ij}} = \frac{1}{\hbar^2}\frac{\partial^2 E}{\partial k_i \partial k_j}$$



One Video Segment

- 10.3 Density of States Effective Mass



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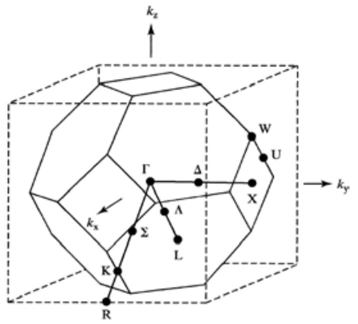

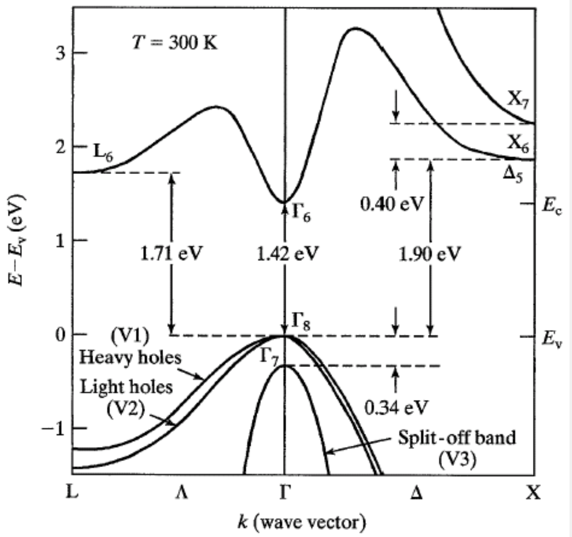

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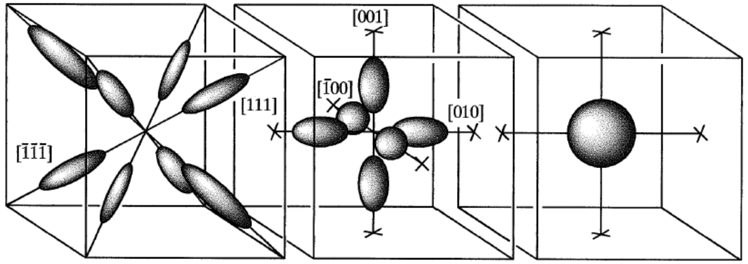
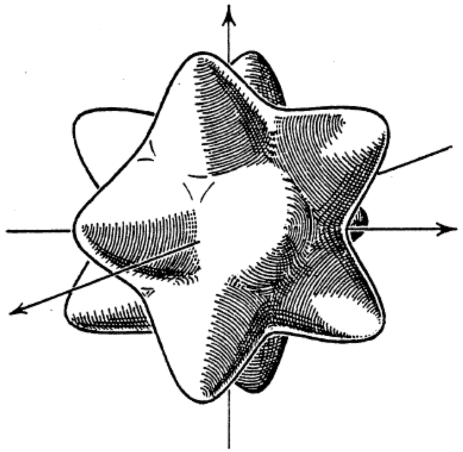


Ge (a) Si (b) GaAs (c)



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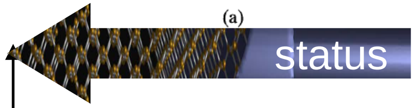

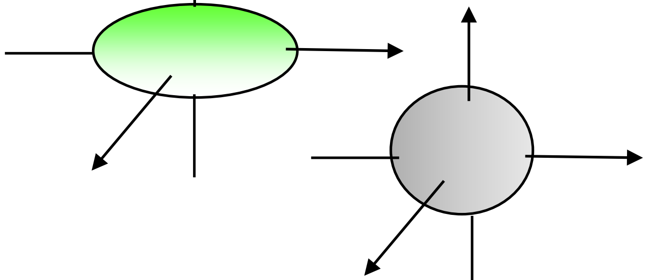

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Bandstructure in Real Materials (Si, Ge, GaAs)

Video

Video

Video

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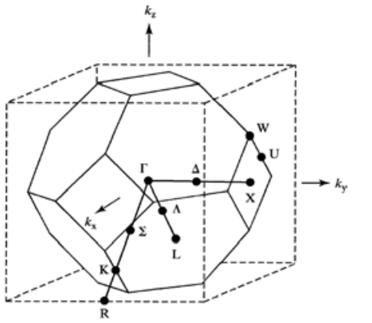
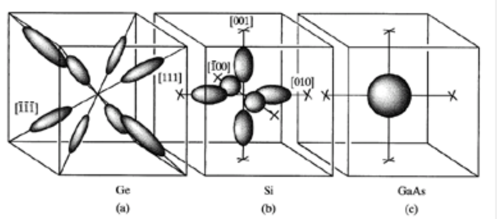


$$\frac{1}{m_{ij}} = \frac{1}{\hbar^2}\frac{\partial^2 E}{\partial k_i \partial k_j}$$

$$m_{eff}^* = 6^{2/3}\left(m_l^* m_t^{*2}\right)^{1/3}$$



1) E-k diagrams emerge from the solution of Schrödinger’s Eq.
2) E-k diagrams at which energy an electron with a specific crystal momentum ***can*** reside.
3) E-k diagrams depend on the underlying crystal symmetry
4) Only a fraction of the available states are occupied. The number of available states change with energy.
5) DOS of g(E) describes the number of available states in a small energy window around energy E
6) DOS is an important and useful characteristic of a material