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

Gerhard Klimeck

gekco@purdue.edu

PURDUE UNIVERSITY

School of Electrical and Computer Engineering

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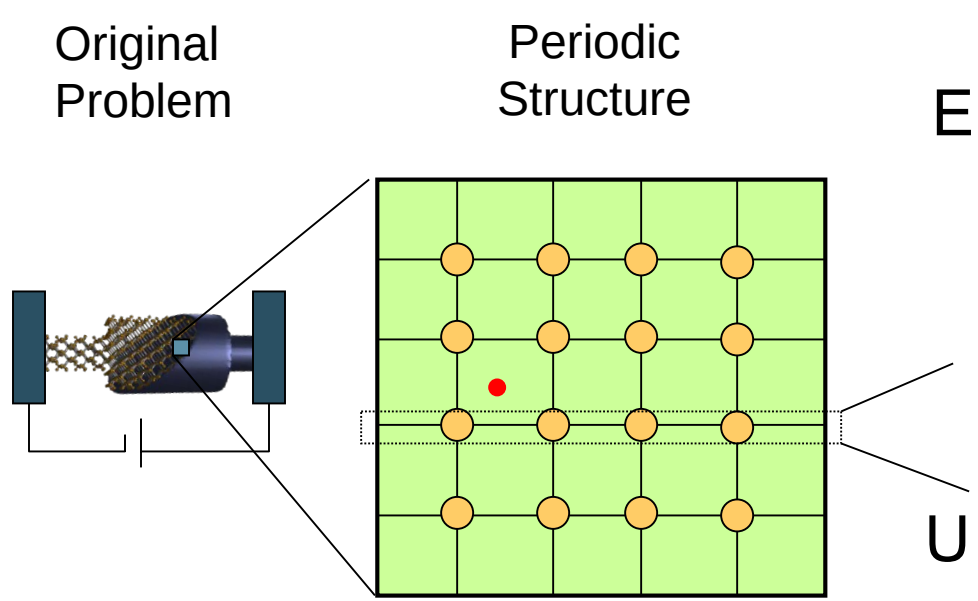
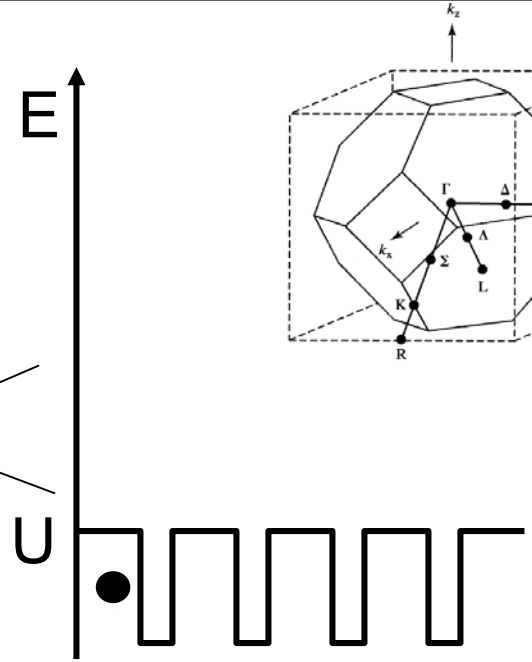
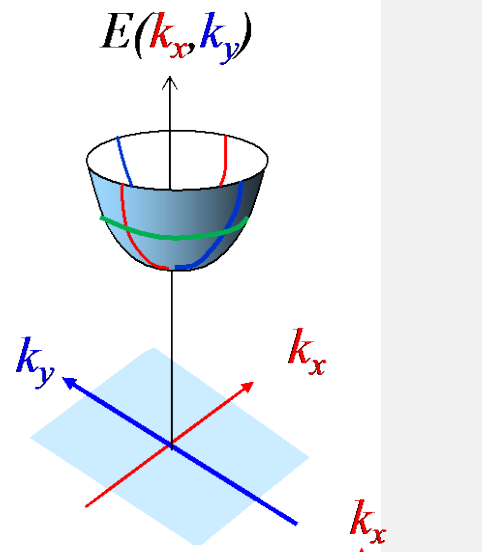
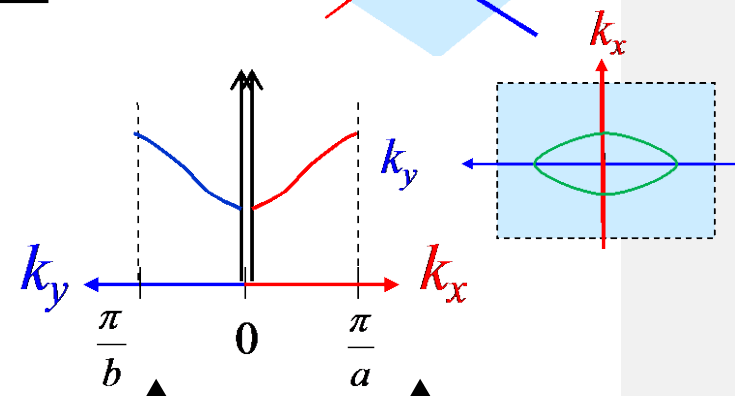
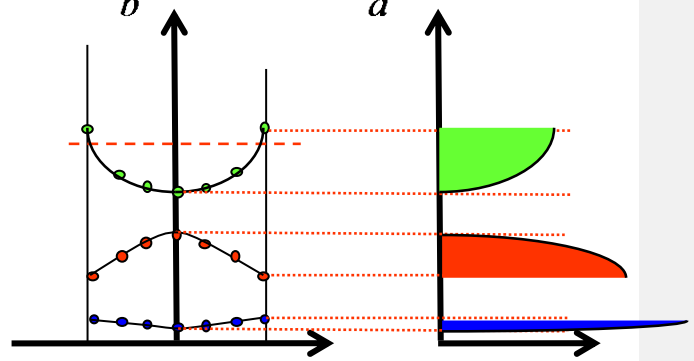










Section 7 – Bandstructure in 1D Periodic Potentials

Section 8 – Brillouin Zone - Reciprocal Lattice

Section 9 – Constant Energy Surfaces & DOS

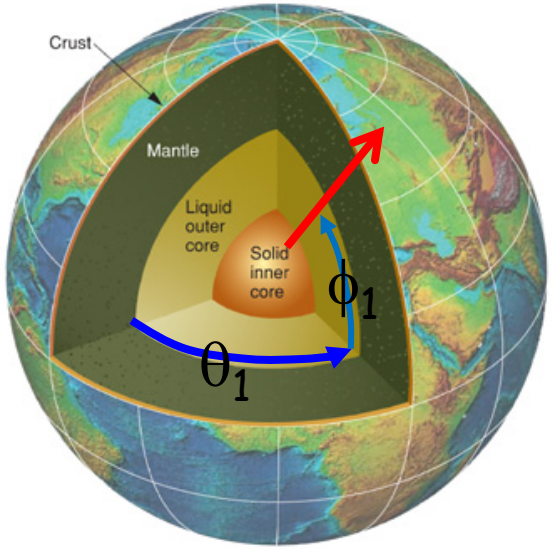
- 10.1 E(k) diagrams in specific crystal directions
- 10.2 Constant Energy Surfaces – Effective Mass Tensor
- 10.3 Density of States Effective Mass

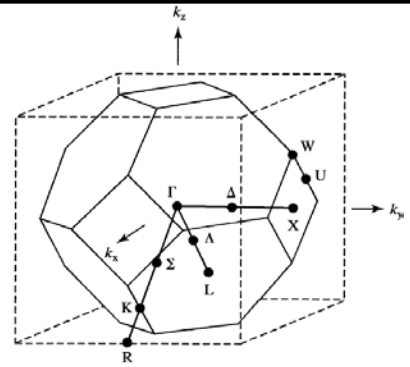
Reference: Vol. 6, Ch. 3

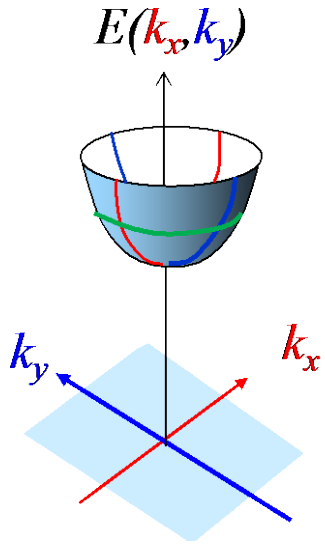
Analogy for E-k Diagram: 4D info through 2D Plots

Density (x,y,z)

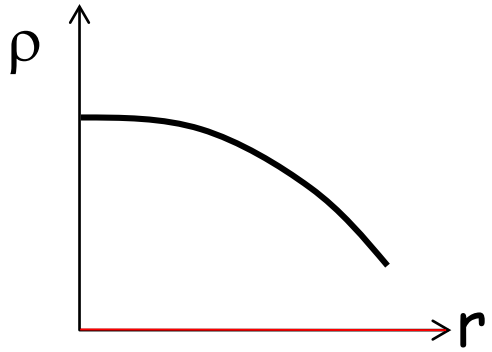
4D information

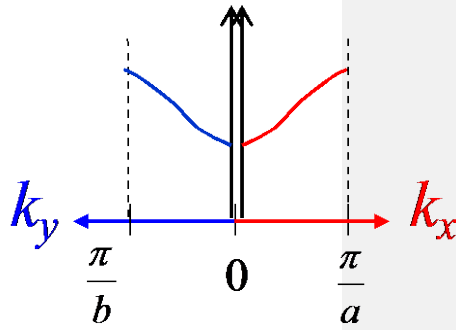






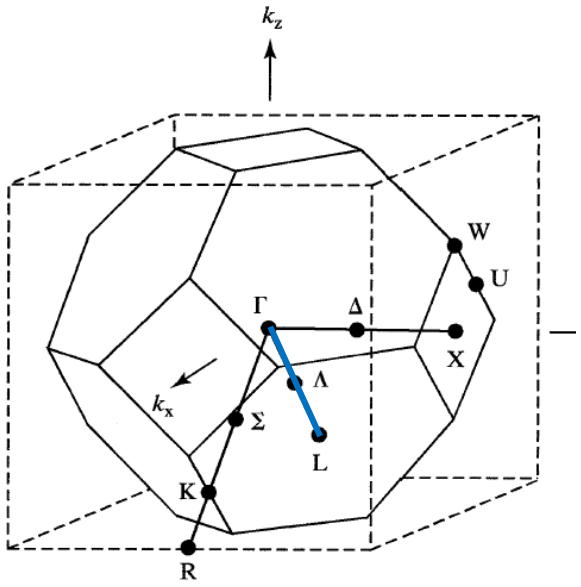
Cut along (θ_1, ϕ_1) …

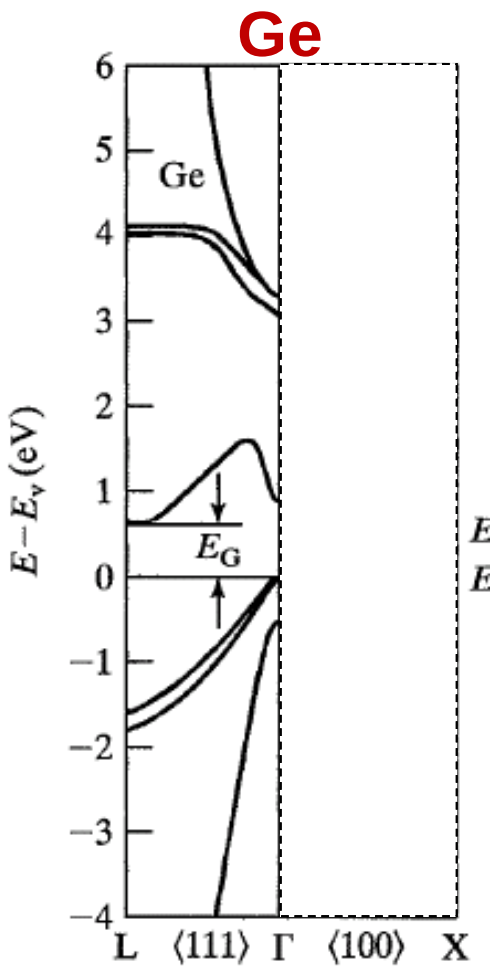


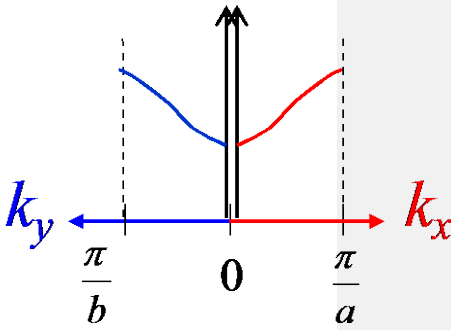


A series of line-sections can
Represent the 4D info in 2D plots

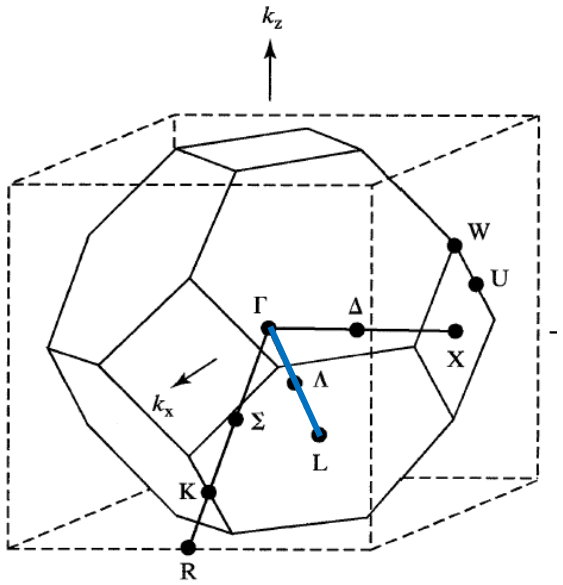
E-k along Γ-X Direction



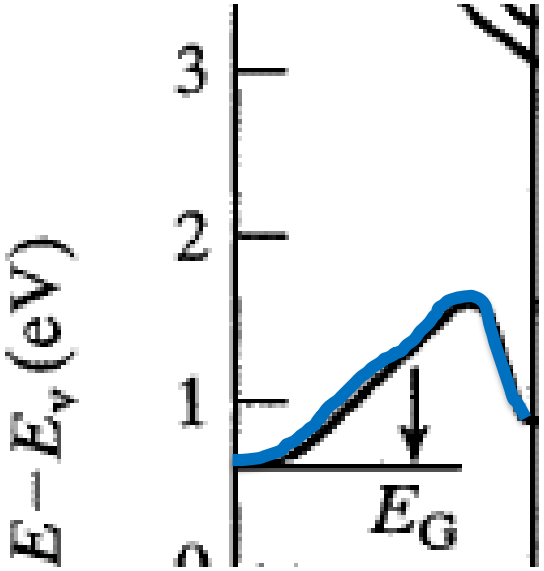


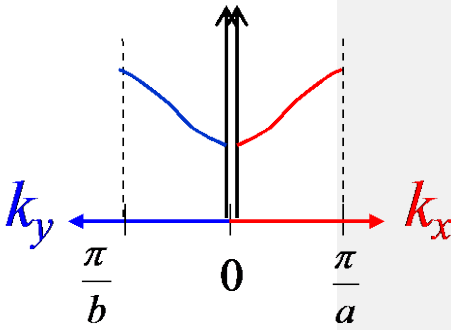


E-k along Γ-X Direction

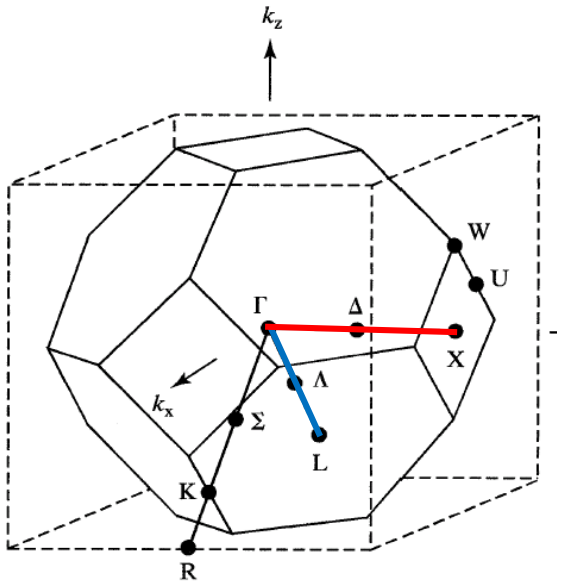


Ge

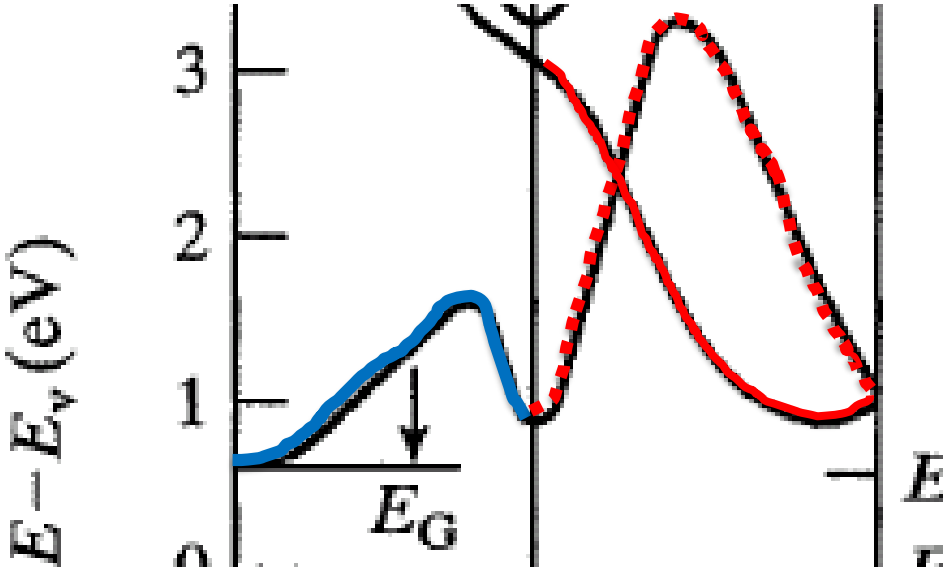


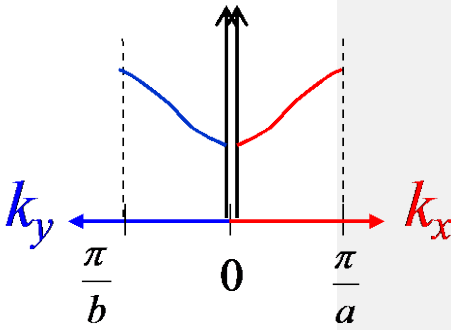


E-k along Γ-X Direction

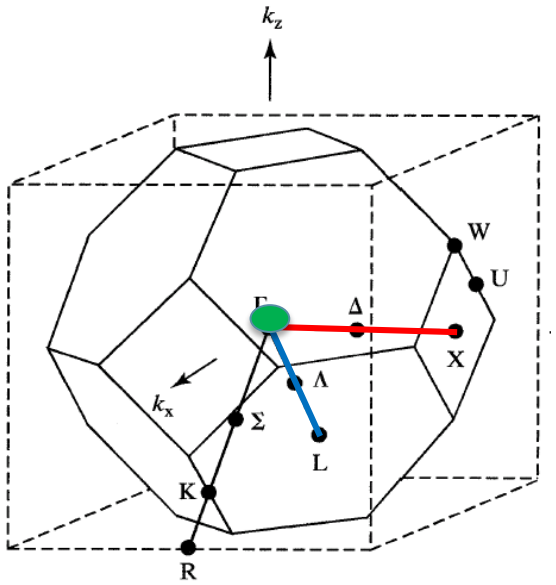


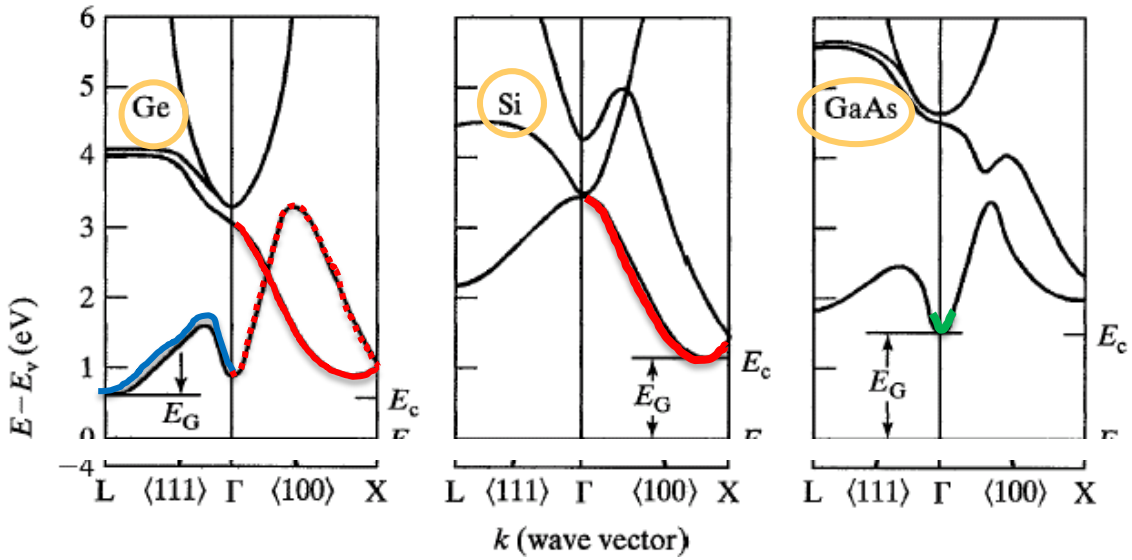
Ge





E-k Diagram – Dispersion for Ge, Si, GaAs





- Minima may not be at zone center
- (Ge: 8 L valleys, Si: 6 X valleys, and GaAs: Γ valleys)

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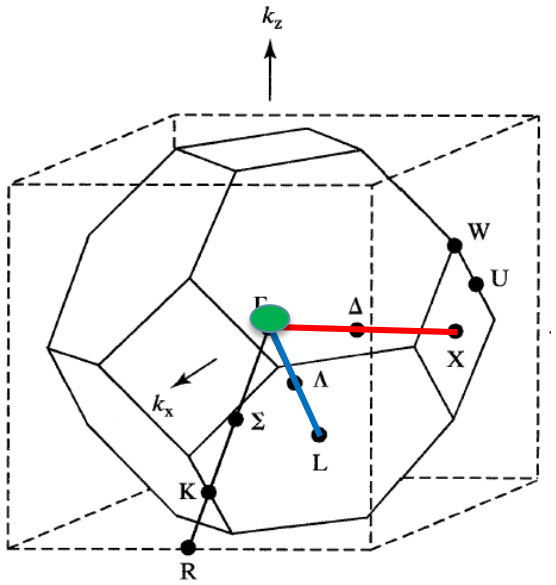
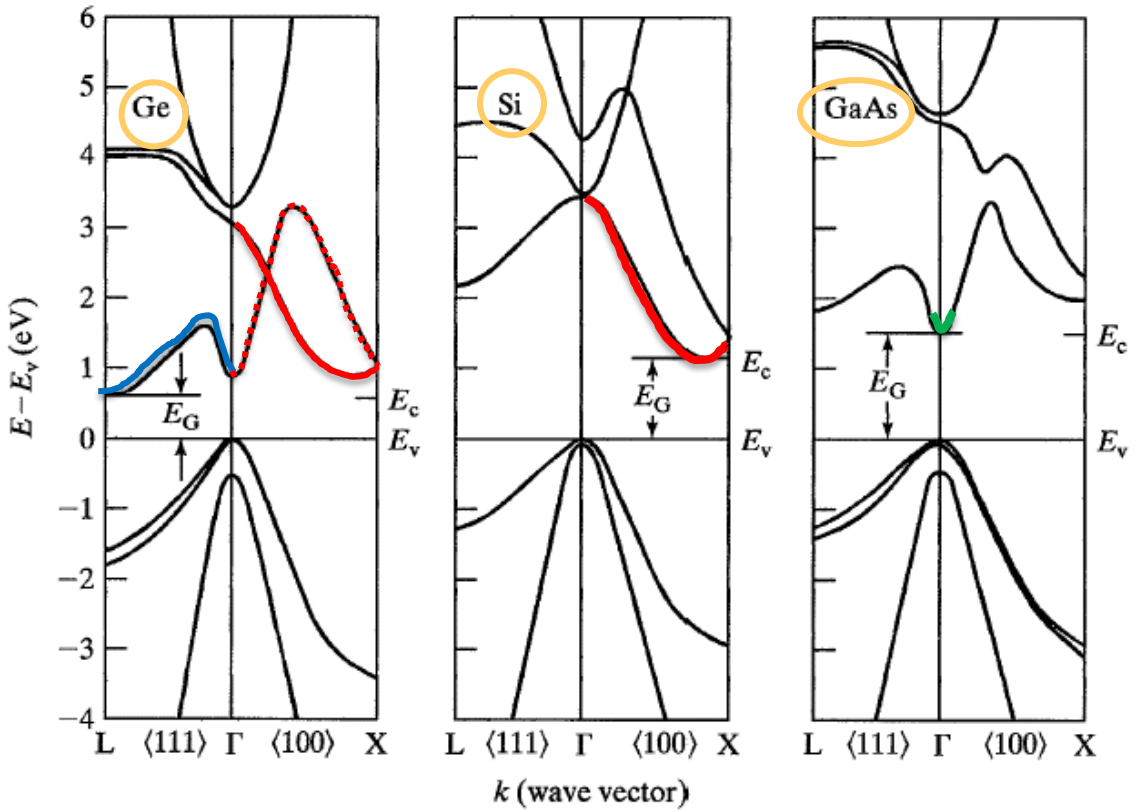
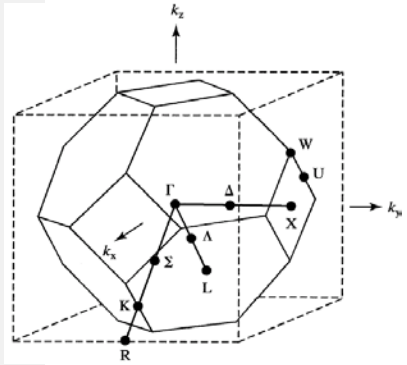


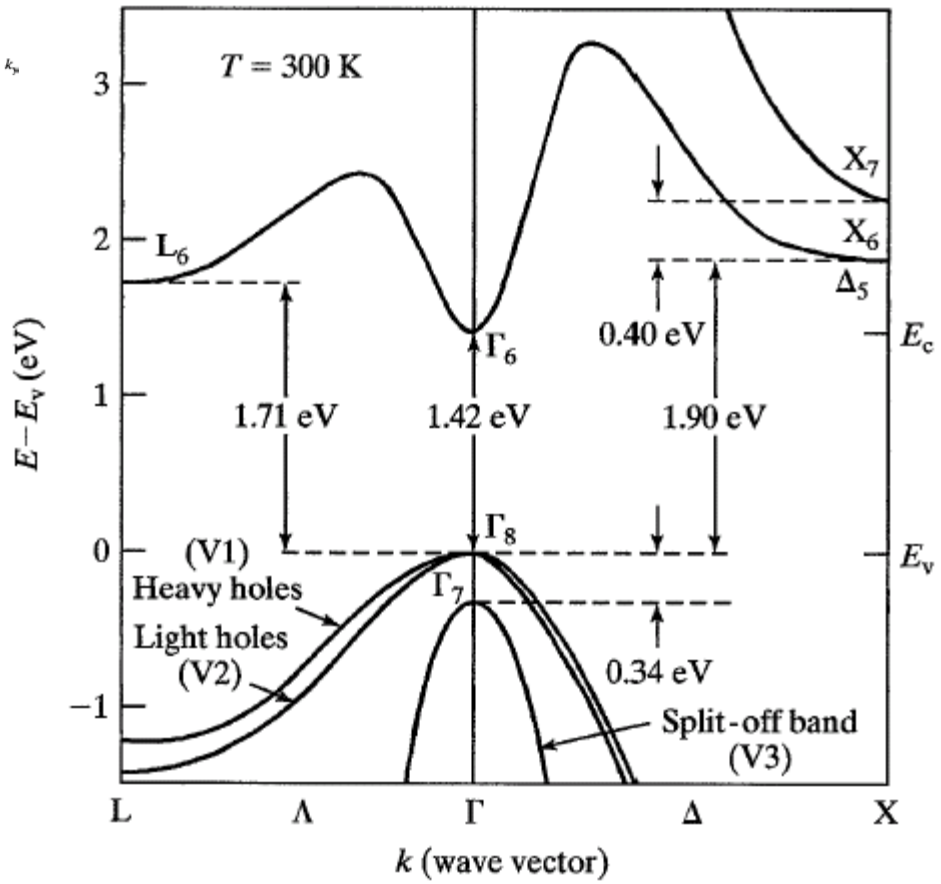


- Minima may not be at zone center
- (Ge: 8 L valleys, Si: 6 X valleys, and GaAs: Γ valleys)

- 3 valence bands (light hole, heavy hole, split-off)
  valence bands near k=0 is essentially $E \sim k^2$

E-k diagram for GaAs



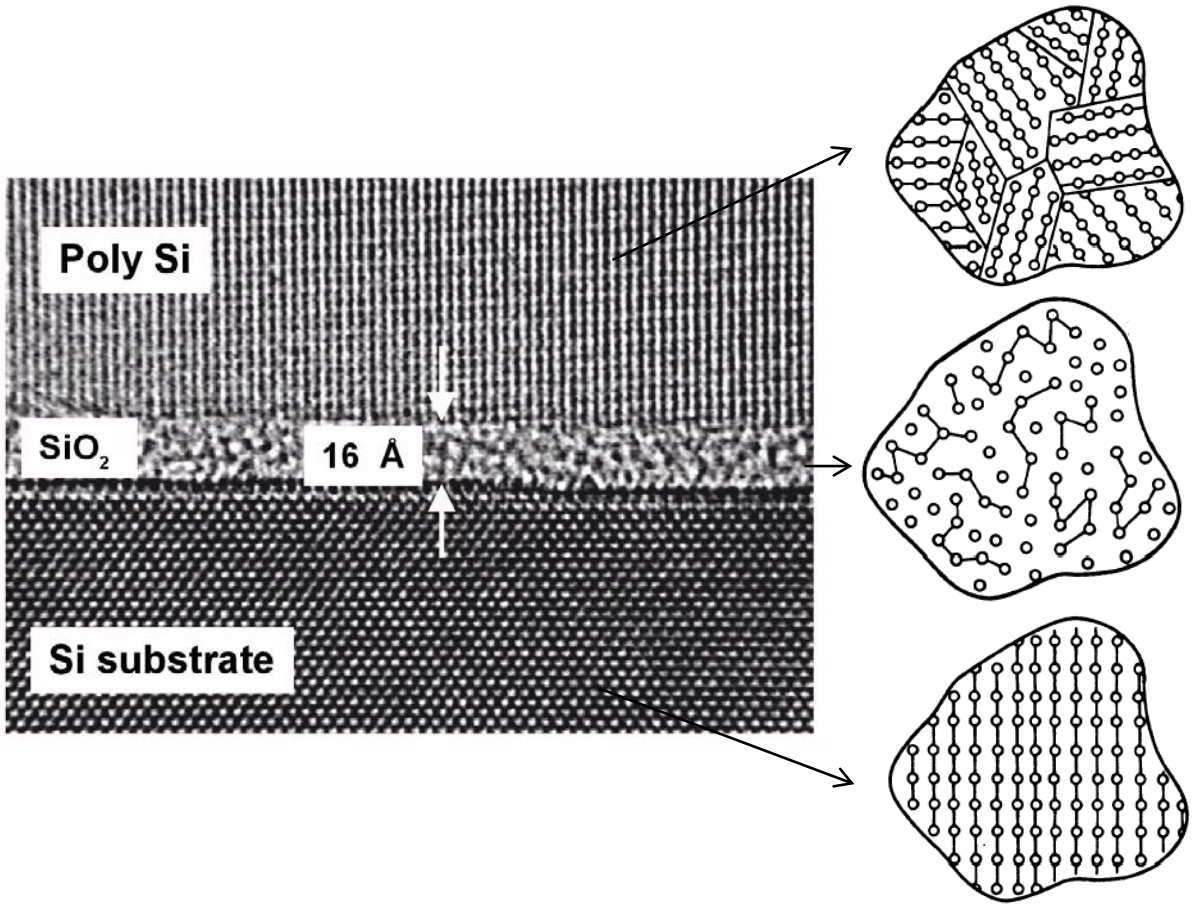


Direct bandgap material

Zone-edge gaps (L_6-Γ_8, X_6-Γ_8) close to direct gap

Has important implications For transport

Arrangement of Atoms

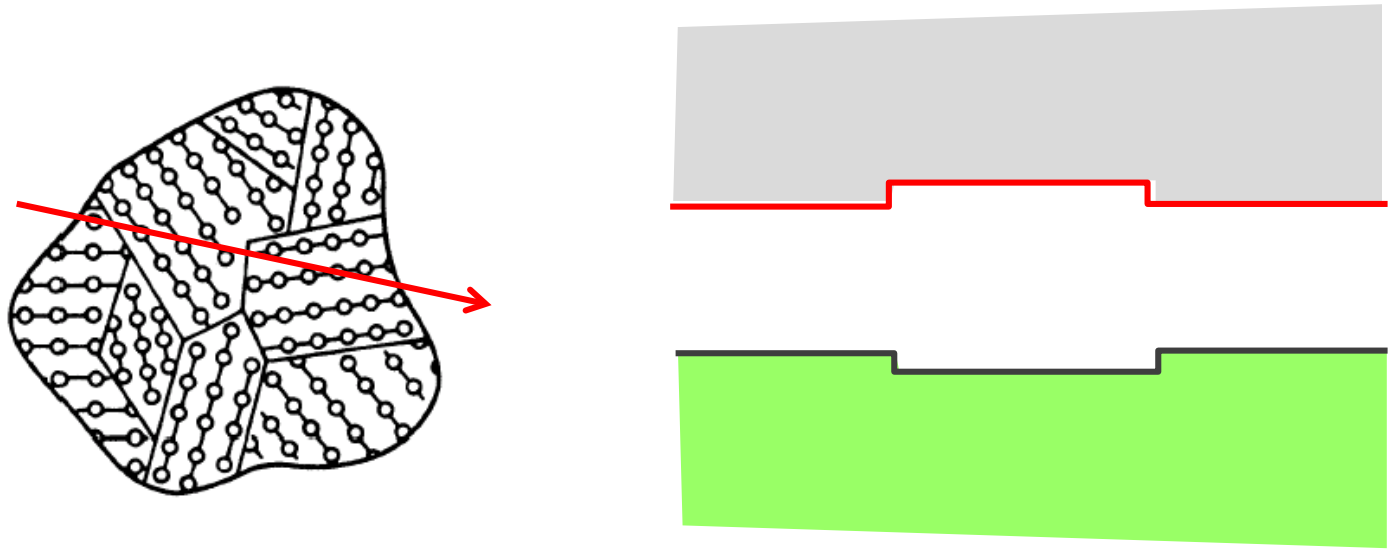


Poly-crystalline
Thin Film
Transistors

Amorphous
Oxides

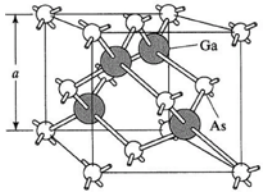
Crystalline

Poly-crystalline material

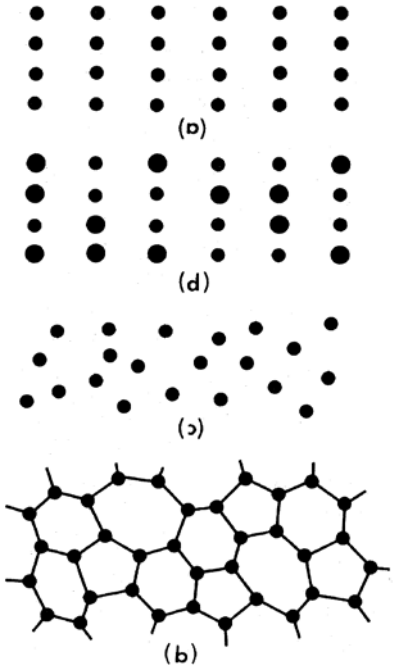


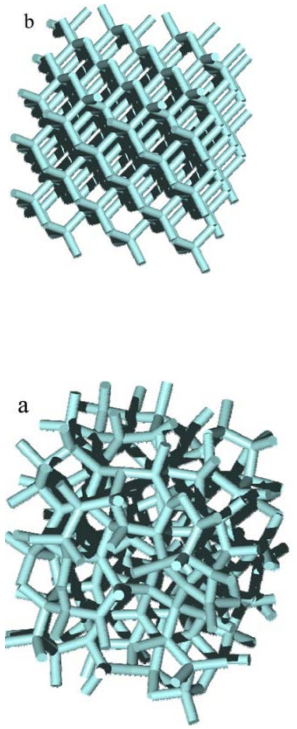
Isotropic bandgap and increase in scattering

Band-structure and Periodicity



PRB, 4, 2508, 1971





Edagawa, PRL, 100,013901, 2008

Periodicity is sufficient, but not necessary for bandgap.
Many amorphous material show full isotropic bandgap

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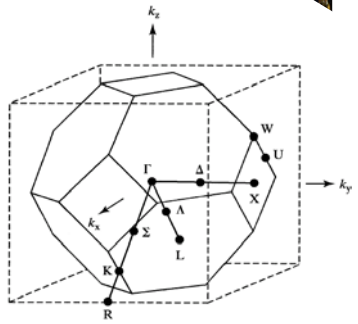
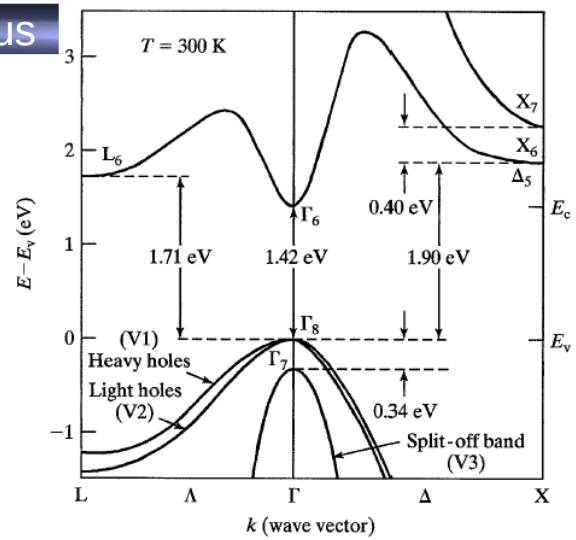
One Video Segment

- 10.1 E(k) diagrams in specific crystal directions

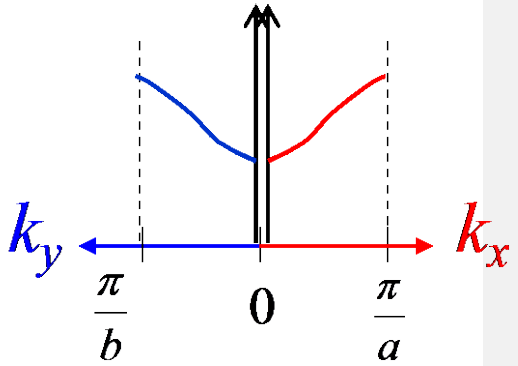
status





One Video Segment

- 10.2 Constant Energy Surfaces – Effective Mass Tensor



One Video Segment

- 10.3 Density of States Effective Mass

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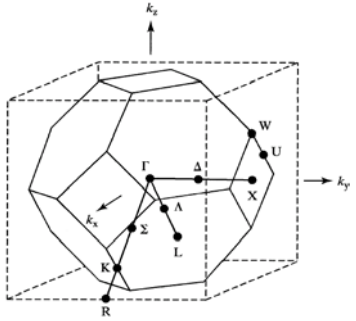

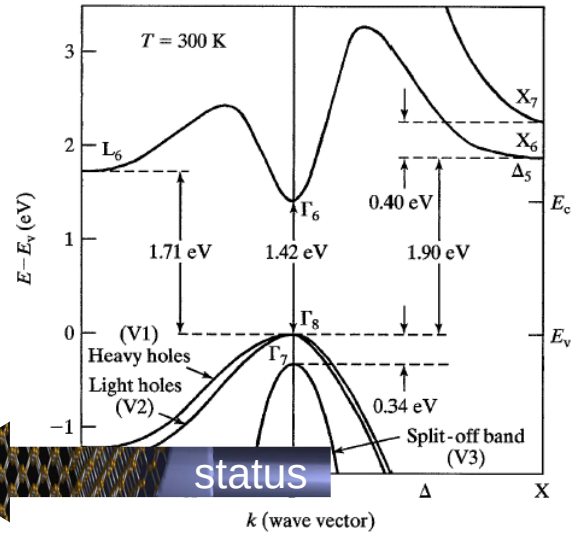

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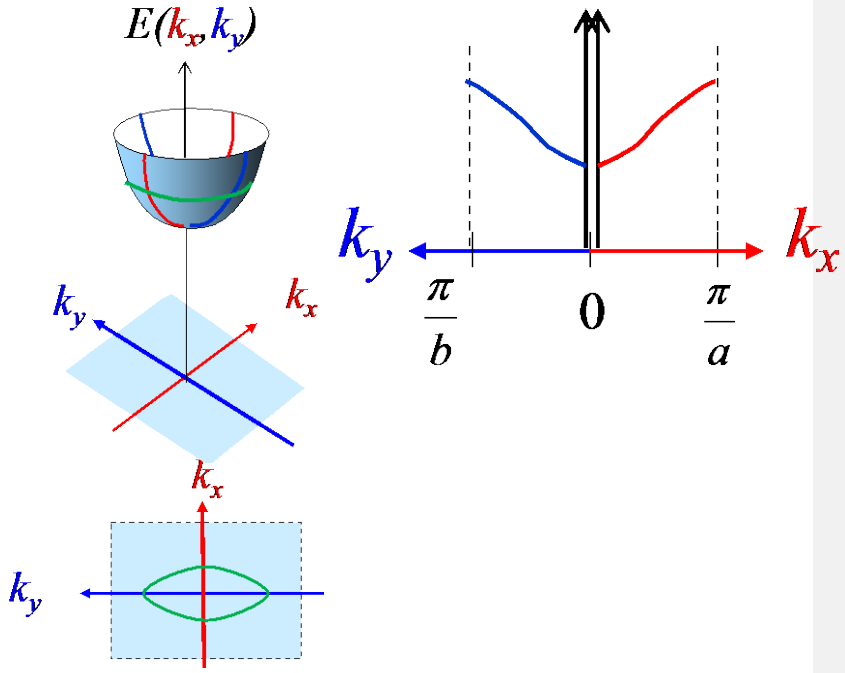

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