Andrew Snydgrass

Metal Mania

Simple Models of the Material World

Questions

Why are some materials insulators and some conductors?

Why do thermal and electrical conductivity go hand-in-hand?

Bonding

Gas → Liq → Solid (↑ import of interact)

- generalizes to intermolecular bonding
- directional bonding ⟺ e^- pairing ⟺ band filling ⟺ insulator/semiconduct

However, all bonding types play a role

Quantum

B.C. (Box, Lattice) → Discrete E Lvls "Quantization"

- Quantize dynamical variable (property of system)

  Ex: $\vec{L}$, $\vec{p}$, $\vec{k}$ (periodic), $\vec{S}$ (intrinsic) [$s = \frac{1}{2}$]

N Inputs → N States $N \to \infty$ → Continuum

★ Counterintuitive continuous states from quantum theory

Scope: Macroscopic Object | Restrict to Crystals

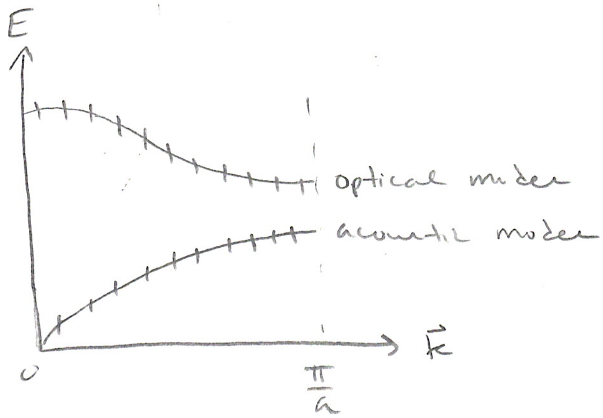
Molecular | ↓

Atomic |

e^- | Periodicity

Nucleonic |

Atoms

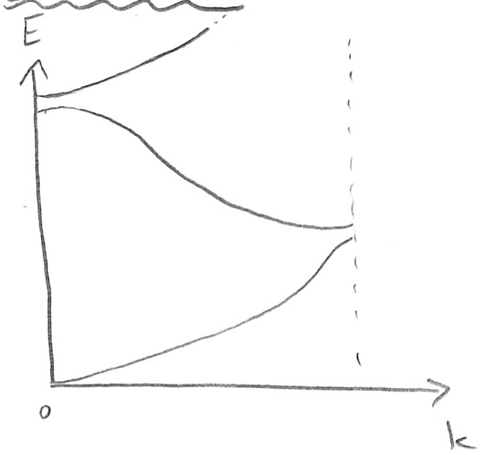


Coupled SHO

"Hooke's Law"

$V = \frac{1}{2} G x^2$

Electrons



2N b/c Spin $S = \frac{1}{2}$

"Free e^- Model"
"Drude Model"

$KE = \frac{p^2}{2m} \rightarrow \frac{\hbar^2 k^2}{2m}$

Symmetry Allows Rerepresent

Electrical Conduction

Charges accelerate in an E field

$\Rightarrow$

$j = \sigma \left(\frac{dV}{dx} \right) = \sigma E$

$j = \frac{dq}{dt} = -ne\langle v \rangle$

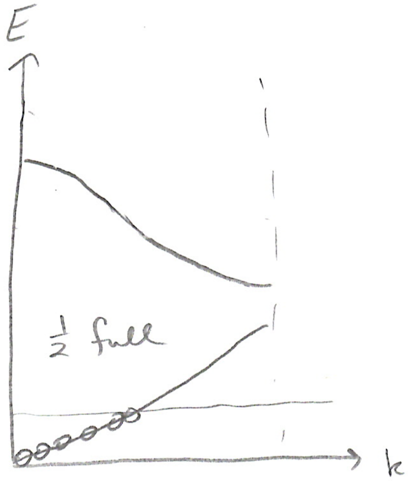
$\langle v \rangle = -\frac{e\tau}{m} E$

$\sigma = \frac{ne^2\tau}{m}$

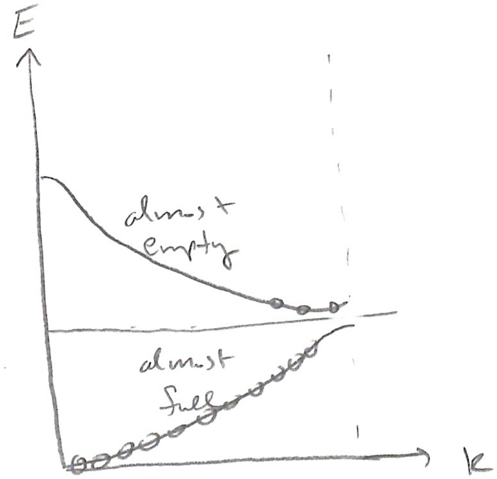
key is n

$\Rightarrow$

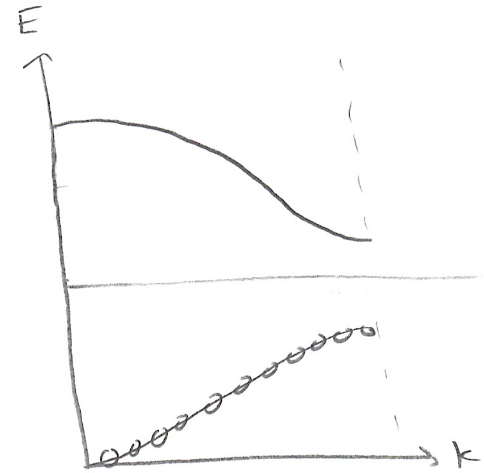
$\sigma = \frac{1}{\rho}$ $\rho = \frac{RA}{l}$



Conductor



Semiconductor
- Intrinsic T
- Extrinsic (Dope)



Insulator

Key Point: Symmetry of $\vec{k}$

- not full → destabilize
- full → net zero motion

⇒ $n = \#\ e^-$ in not filled band

Thermal Conduction

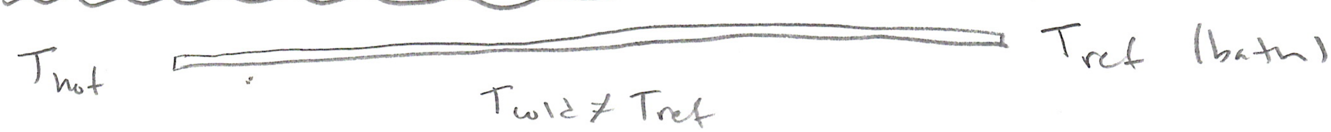
$$j = \frac{dQ}{dt} = -k\frac{dT}{dx}$$

- e^- + phonon can carry E ⟨v⟩
- e^- more free ⇒ carry more E

} ⇒ e^- + thermal conduct similar

b/c e^- dominate!!!

Thermal ∩ Electrical "Thermocouple"



Difference in ⟨v⟩ → e^- build up

$$V = \frac{e \cdot e}{r}$$ repulsive Coulomb Potential

⇒ opposing E field ⇒ ΔV measure

Summary:

- Bonding intuition → detailed quantum bands
  - nonmetallic bonds play role in Semiconductors
- Quantum Atomic v Electronic Roles
- Springs or Free e^- qualitatively describe material