

Spherical Harmonics

<http://www.lifsmith.com/spharm01.html>



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$$\rho = \sin(a * \phi)^b + \cos(c * \phi)^d + \sin(e * \theta)^f + \cos(g * \theta)^h$$

Solid State Electronics

- Use semiconductors—silicon or germanium
- Are tetravalent; have covalent bonds
- Add small amounts of impurities
- Arsenic has valence 3: p-type semiconductor
- Phosphorus has valence 5: n-type semiconductor

Semiconductor Diode

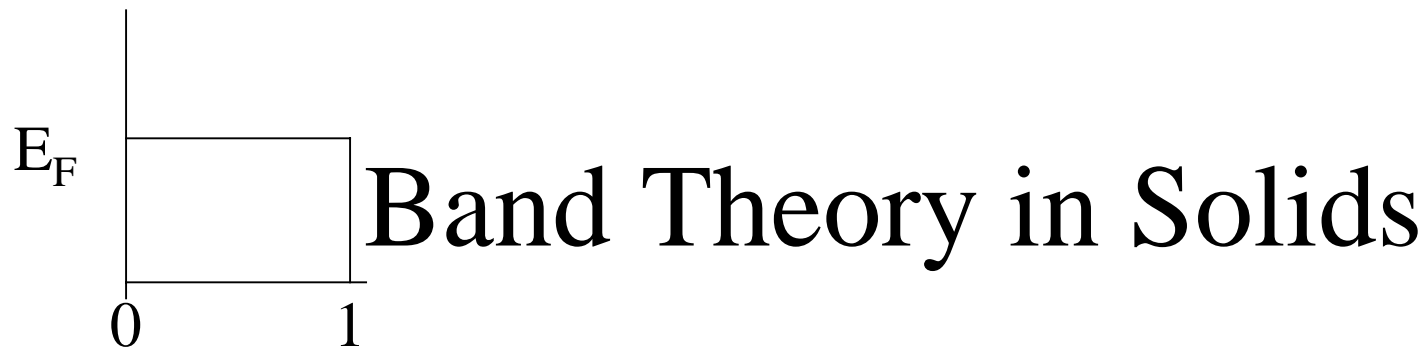


Band Theory in Solids

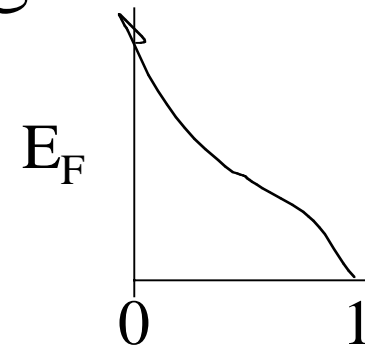
- When atoms are distinct, as in vapor phase, energy levels are well-defined
- Atoms come together in a solid, atoms affect each other and energy levels become a “band”
- Ex: 10^{22} atoms of sodium—1s,2s,2p bands are full; 3s band is 1/2 full; 3p band is empty

Band Theory

- Band theory results from solving the SE with a periodic potential on a 3d lattice
- Band gaps result because certain energies have deBroglie wavelengths that match the lattice spacing and these wavefunctions are not allowed



- Fermi energy (E_F) is in the middle of the 3s band
- At 0° K, all energy levels up to E_F are filled and all levels above E_F are empty
- At finite temperature, some levels below E_F become empty and some higher levels fill



Band Theory in Solids

- Sodium is a good conductor because many energy levels are open and easily accessible
- Characteristics of insulators are: large gap between highest filled (valence) and lowest unfilled (conduction) band; E_F in the band gap
- Insulators with small band gaps (≤ 1 eV) and E_F in the band gap are called “semiconductors”

Applications of Band Theory

- Magnesium has a filled 3s shell. Atomic theory would suggest a bad conductor. Band theory calculations however show that 3s and 3p in magnesium overlap, creating a band that is only 1/4 filled; therefore, Mg is a good conductor

Application of Band Theory

- 2p shell of carbon is only $1/3$ filled, so atomic theory suggests carbon is a good conductor. However, band theory calculations for carbon show that the 2s and 2p bands overlap but split into bands that contain 4 electrons per atom. The lower energy band is filled and carbon is a poor conductor

Applications of Band Theory

- Germanium and silicon are similar to carbon but equilibrium atomic spacings are larger and band gap is smaller (<1 eV)
- Band gap is smaller in germanium than silicon; germanium is more susceptible to “thermal runaway”