Week 10: Intrinsic Semiconductors
Announcements

Semiconductor Definitions

- Bandgap
- Electron Affinity
- E_V
- E_C
- E_G

Intrinsic Semiconductors

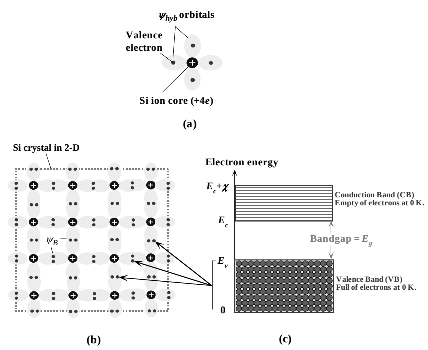

Fig. 5.1: (a) A simplified two dimensional illustration of a Si atom with four hybrid orbitals, ψ_{hyb}. Each orbital has one electron. (b) A simplified two dimensional view of a region of the Si crystal showing covalent bonds. (c) The energy band diagram at absolute zero of temperature.

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Using Light to Create Holes

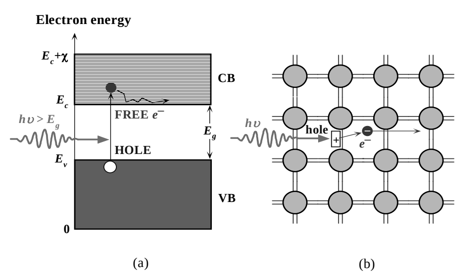

Fig. 5.3: (a) A photon with an energy greater than E_g can excite an electron from the VB to the CB. (b) When a photon breaks a Si-Si bond, a free electron and a hole in the Si-Si bond is created.

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Holes in a Semiconductor

- Hole is a vacancy (missing electron) in the valence band
- Thermal vibrations or energy can be used to create a hole by exciting an electron from the valence band to the conduction band
- In an intrinsic (undoped) semiconductor, the number of holes in the valence band equals the electrons in the conduction band
- Holes can move about the valence band and recombine with electrons in the conduction band (to disappear)

Hole Movement & Recombination

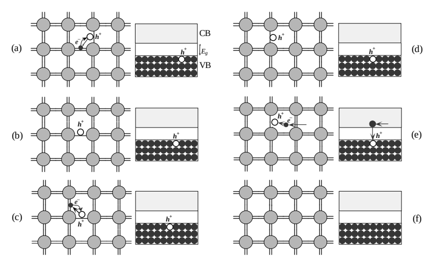

Fig. 5.5: A pictorial illustration of a hole in the valence band wandering around the crystal due to the tunneling of electrons from neighboring bonds.

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n and p Concentrations

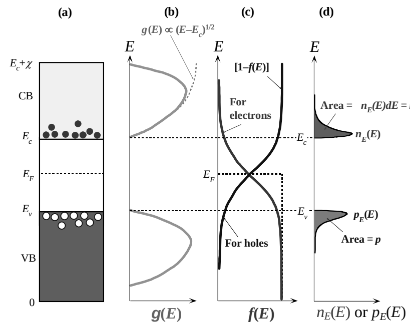

Fig. 5.7: (a) Energy band diagram. (b) Density of states (number of states per unit energy per unit volume). (c) Fermi-Dirac probability function (probability of occupancy of a state). (d) The product of $g(E)$ and $f(E)$ is the energy density of electrons in the CB (number of electrons per unit energy per unit volume). The area under $n_E(E)$ vs. E is the electron concentration in the conduction band.

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Definition of n and p

- n: free electron concentration in the conduction band
- p: hole concentration in the valence band
- In intrinsic semiconductors: $n=p=n_i$ (intrinsic carrier concentration
- Both electrons and holes contribute to conductivity

Intrinsic Carrier Concentrations

$$n = \int_{E_C}^{E_C+\chi} n_E(E)dE = \int_{E_C}^{E_C+\chi} g_{CB}(E)f(E)dE =$$

$$2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \exp\left[\frac{-(E_c - E_F)}{kT}\right]$$

$$N_C = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}$$

$$p = \int_0^{E_V} p_E(E)dE = \int_0^{E_V} g_{CB}(E)[1 - f(E)]dE =$$

$$2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \exp\left[\frac{-(E_F - E_V)}{kT}\right]$$

$$N_V = 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}$$

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Intrinsic Fermi Energy

- Full equation for Fermi Energy in an intrinsic semiconductor

$$E_{Fi} = E_V + \frac{1}{2}E_G - \frac{1}{2}kT\ln\left(\frac{N_C}{N_V}\right)$$

- If $m_e^*=m_h^*$, it simplifies to

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