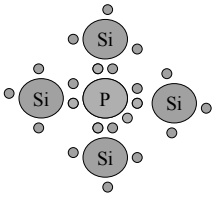
Week 11: Extrinsic Semiconductor Announcements

How is conduction controlled in a semiconductor?

- Heating up a semiconductor will increase its conductivity. However, microelectronics need localized areas where the conductivity changes.
- This is accomplished by doping, replacing some Si atoms with atoms that have a different number of electrons.

N-type Silicon

III	IV	V
5 B	6 C	7 N
13 Al	14 Si	15 P
31 Ga	32 Ge	33 As



- Replace Si with an atom from _____
- Now there is one extra electron.
- The dopant is called a _____
- Si doped with donors is known as _____

N-type Band Diagram

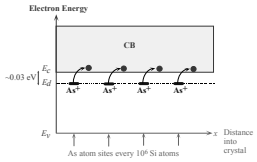
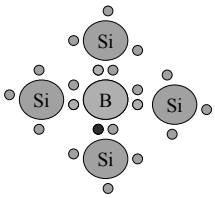


Fig. 5.10: Energy band diagram for an n-type Si doped with 1 ppm As. There are donor energy levels just below E_c around As+ sites.

*Used with permission from Kasap

P-type Silicon

III	IV	V
5 B	6 C	7 N
13 Al	14 Si	15 P
31 Ga	32 Ge	33 As



- Replace Si with an atom from _____
- Now there is a missing electron called a _____
- The dopant is called a _____
- Si doped with acceptors is known as _____

P-type Band Diagram

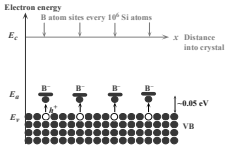


Fig. 5.12: Energy band diagram for a *p*-type Si doped with 1 ppm B. There are acceptor energy levels just above E_v around B– sites. These acceptor levels accept electrons from the VB and therefore create holes in the VB.

*Used with permission from Kasap

Majority & Minority Carriers

- *Assume all the dopants are ionized* (meaning they have given off (n- type) or accepted (p type) electrons
- n type ($N_D > n_i$):
  - majority carrier
  - minority carrier
- p type ($N_A > n_i$):
  - majority carrier
  - minority carrier

Extrinsic Fermi Energy

- Fermi level in doped semiconductors moves to adjust probability of having a free electron or hole
- n-type: E_F moves up towards conduction band, more dopants the higher it moves up
- p-type: E_F moves down towards valence band, more dopants the lower it moves

Intrinsic & Extrinsic Fermi Energies

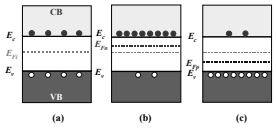


Fig. 5.8: Energy band diagrams for (a) intrinsic (b) *n*-type and (c) p-type semiconductors. In all cases, $np = n_i^2$

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Calculating the Fermi Level

- N-type: some amount above the intrinsic Fermi energy

$$E_{Fn} - E_{Fi} = kT \ln\left(\frac{N_D}{n_i}\right)$$

- P-type: some amount below the intrinsic Fermi energy

$$E_{Fp} - E_{Fi} = -kT \ln\left(\frac{N_A}{n_i}\right)$$