

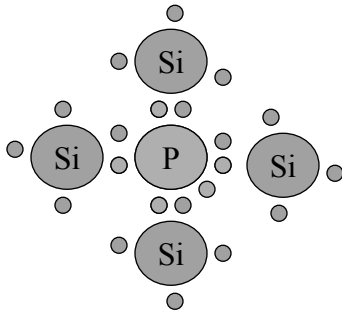
# Week 11: Extrinsic Semiconductor Announcements

## 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

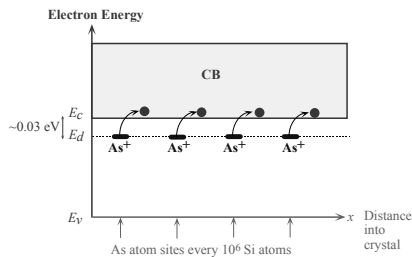
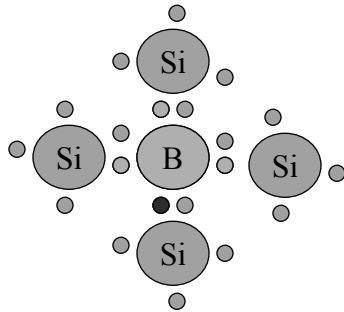


Fig. 5.10: Energy band diagram for an n-type Si doped with 1 ppm As. There are donor energy levels just below  $E_c$  around  $As^+$  sites.

\*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

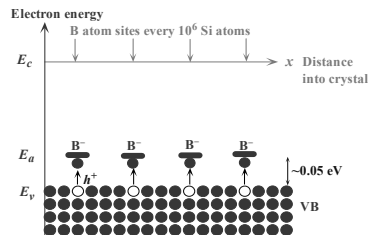


Fig. 5.12: Energy band diagram for a *p*-type Si doped with 1 ppm B. There are acceptor energy levels just above  $E_v$  around B<sup>-</sup> sites. These acceptor levels accept electrons from the VB and therefore create holes in the VB.

## 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

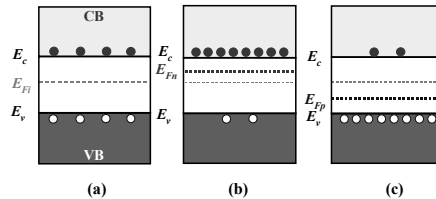


Fig. 5.8: Energy band diagrams for (a) intrinsic (b) *n*-type and (c) *p*-type semiconductors. In all cases,  $np = n_i^2$

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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

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

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