Lect. 5: Semicondutors (Razavi 2.1)

What is a semiconductor?

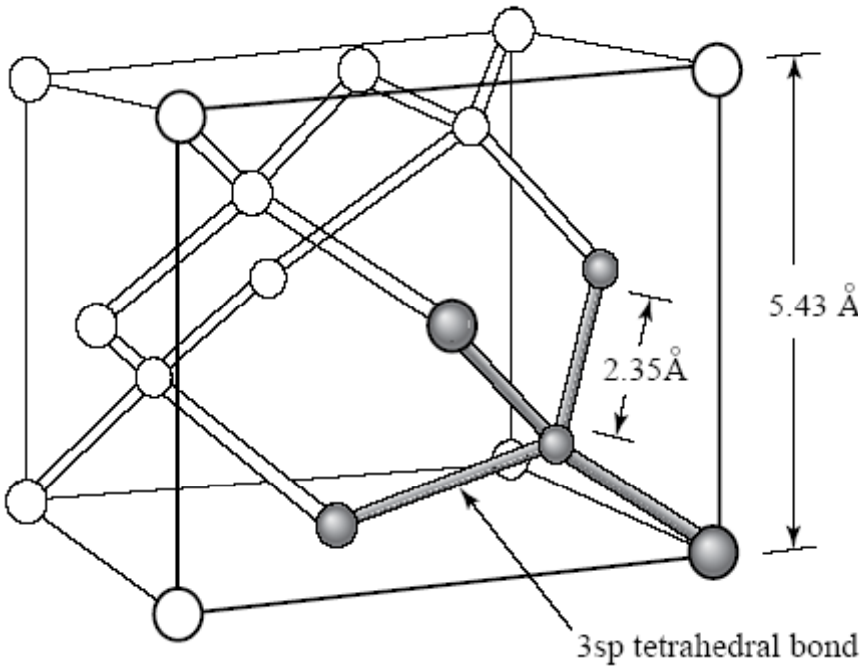
	IIIA	IVA	VA	VIA
	5 B	6 C	7 N	8 O
IIB	13 Al	14 Si	15 P	16 S
30 Zn	31 Ga	32 Ge	33 As	34 Se
48 Cd	49 In	50 Sn	51 Sb	52 Te

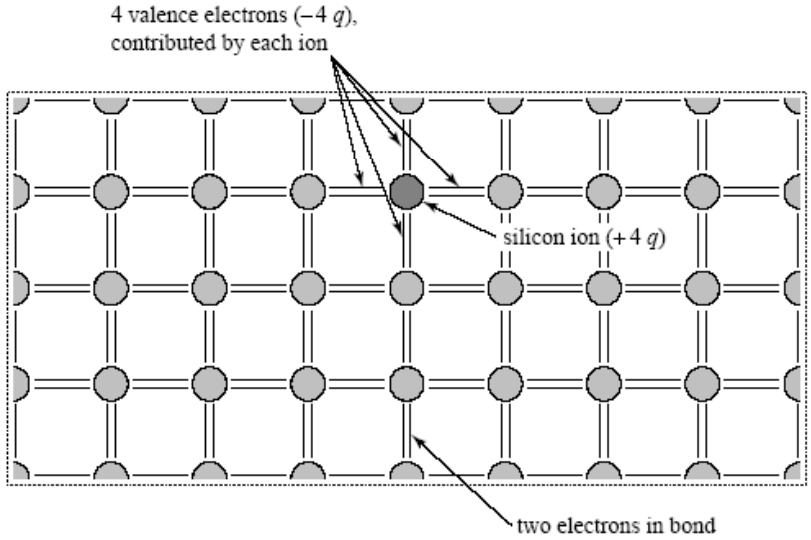
Group IV elements (for example, Si) has four valence electrons

(Also for combination of Group III and Group V elements: for example GaAs)

Lect. 5: Semicondutors

How does it look? Diamond-like crystal structure





2-dimensional model

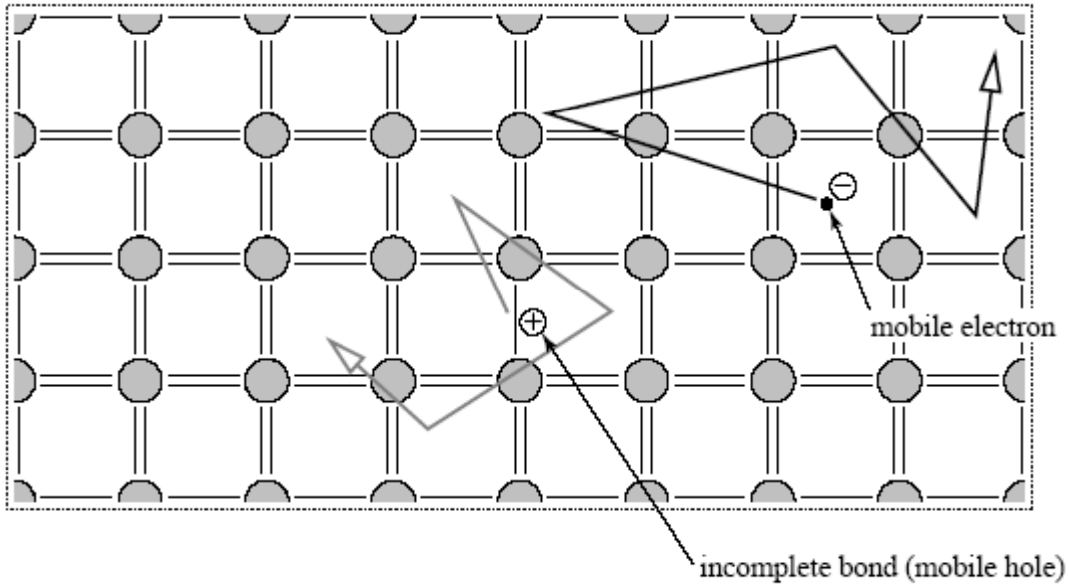
Can currents flow?

Si atoms share electrons with neighboring atoms

➔ each atom can have 8 electrons

Lect. 5: Semicondutors

At finite temperature, some electrons escape from bonds creating mobile electrons and holes



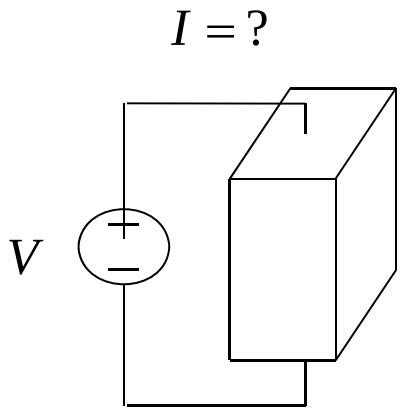
n (density of electrons) = p (density of holes) = $n_i(T)$:

➔ Current conduction due to electrons and holes.

Intrinsic semicondutor

Lect. 5: Semicondutors

How much currents flow?



$$I = \frac{V}{R}$$

$$R = \frac{L}{A\sigma} \quad (\sigma: \text{ conductivity})$$

$\sigma = \mu \bullet$ charge density (μ: mobility)

charge density = $qn + qp$

$$\sigma = \mu_n qn + \mu_p qp$$

$$R = \frac{L}{Aq(\mu_n n + \mu_p p)}$$

$$I = \frac{V}{L} Aq(\mu_n n + \mu_p p)$$

Semiconductor as a resistor!

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What happens when Group V (donor) atoms are added (doping)?

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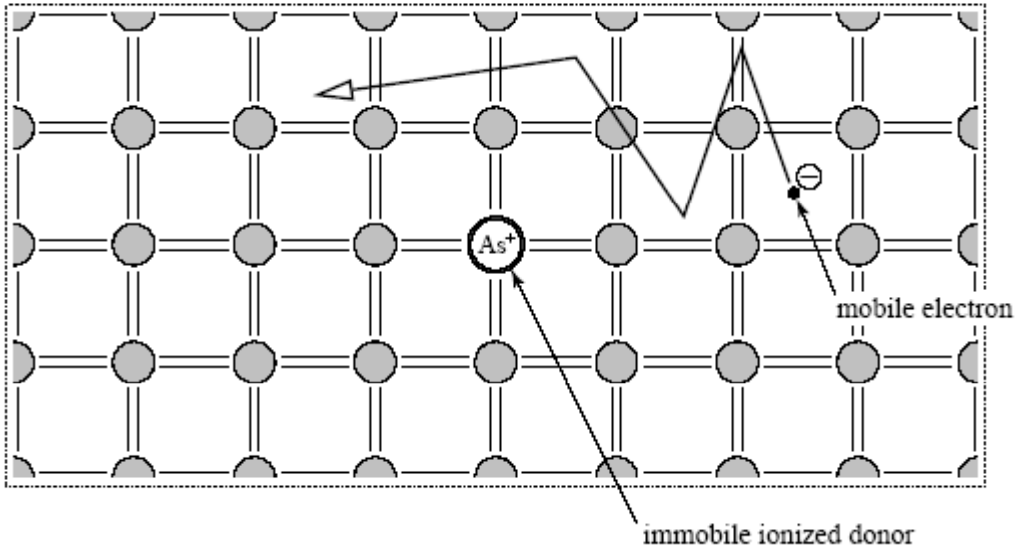


Extra electrons!

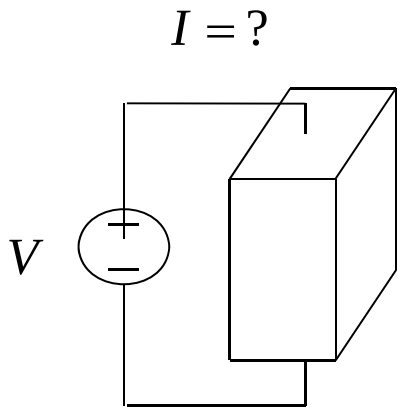
$n = N_D >> p$

Current conduction

Extrinsic semiconductor: N-type

Lect. 5: Semicondutors

How much currents flow in N-type semiconductor?



$$I = \frac{V}{R}$$

$$R = \frac{L}{A\sigma} \quad (\sigma: \text{ conductivity})$$

$\sigma = \mu \bullet$ charge density (μ: mobility)

charge density = $qn + qp$

$$\sigma = \mu_n qn + \mu_p qp$$

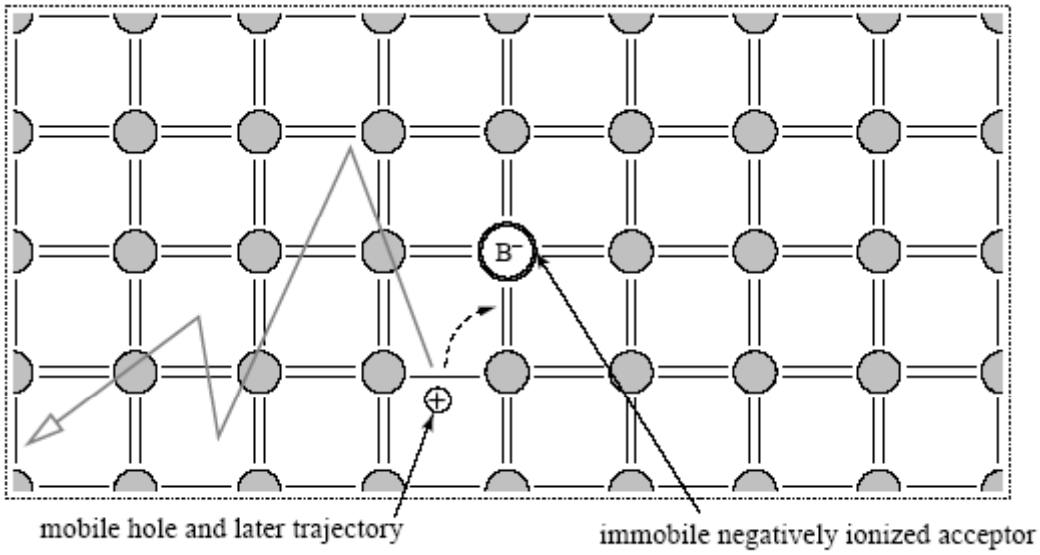
$$R = \frac{L}{Aq(\mu_n n + \mu_p p)}$$

$$R \simeq \frac{L}{Aq\mu_n n}$$

Lect. 5: Semicondutors

What happens when Group III (acceptor) atoms are added (doping)?

	IIIA	IVA	VA	VIA
	5 B	6 C	7 N	8 O
IIB	13 Al	14 Si	15 P	16 S
30 Zn	31 Ga	32 Ge	33 As	34 Se
48 Cd	49 In	50 Sn	51 Sb	52 Te



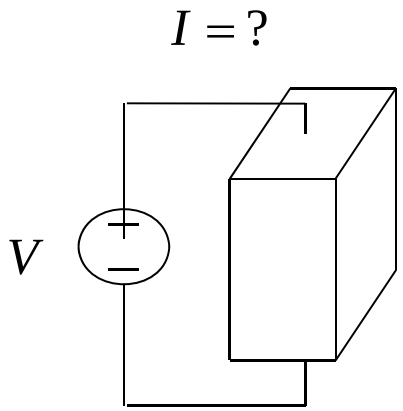
Extra holes

$p = N_A >> n$ Extrinsic semiconductor: P-type

Current conduction

Lect. 5: Semicondutors

How much currents flow in P-type semiconductor?



$$I = \frac{V}{R}$$

$$R = \frac{L}{A\sigma} \quad (\sigma: \text{ conductivity})$$

$\sigma = \mu \bullet$ charge density (μ: mobility)

charge density = $qn + qp$

$$\sigma = \mu_n qn + \mu_p qp$$

$$R = \frac{L}{Aq(\mu_n n + \mu_p p)}$$

$$R \simeq \frac{L}{Aq\mu_p p}$$

Lect. 5: Semicondutors

Homework Problems (Due Next Monday before Tutorial)

1. Determine the conductivity σ of intrinsic Si in $(\Omega cm)^{-1}$.
   Use $q=1.6 \times 10^{-19}$ C, $n_i=10^{10}/cm^3$, $\mu_n=1000\ cm^2/Vs$, $\mu_p=400\ cm^2/Vs$

2. Determine the conductivity σ of extrinsic Si with $N_D = 10^{18}/cm^3$.

3. Determine L required for 1K Ohm resistor using the above extrinsic Si.
   Use $A = 100\ \mu m^2$.