Solid State Electronics EC210
Arab Academy for Science and Technology
AAST – Cairo
Spring 2016

Lecture 4:

Conductivity

Lecture Notes Prepared by:
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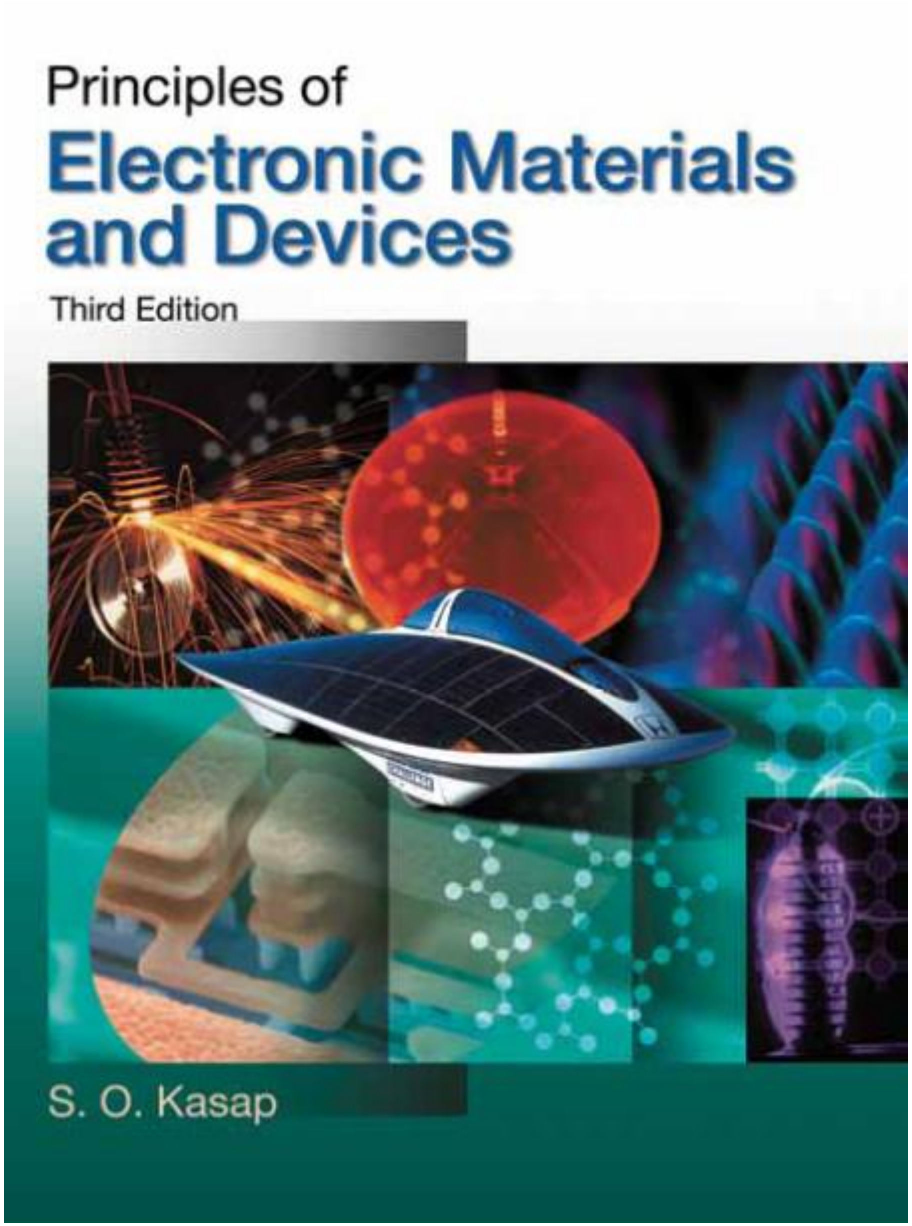

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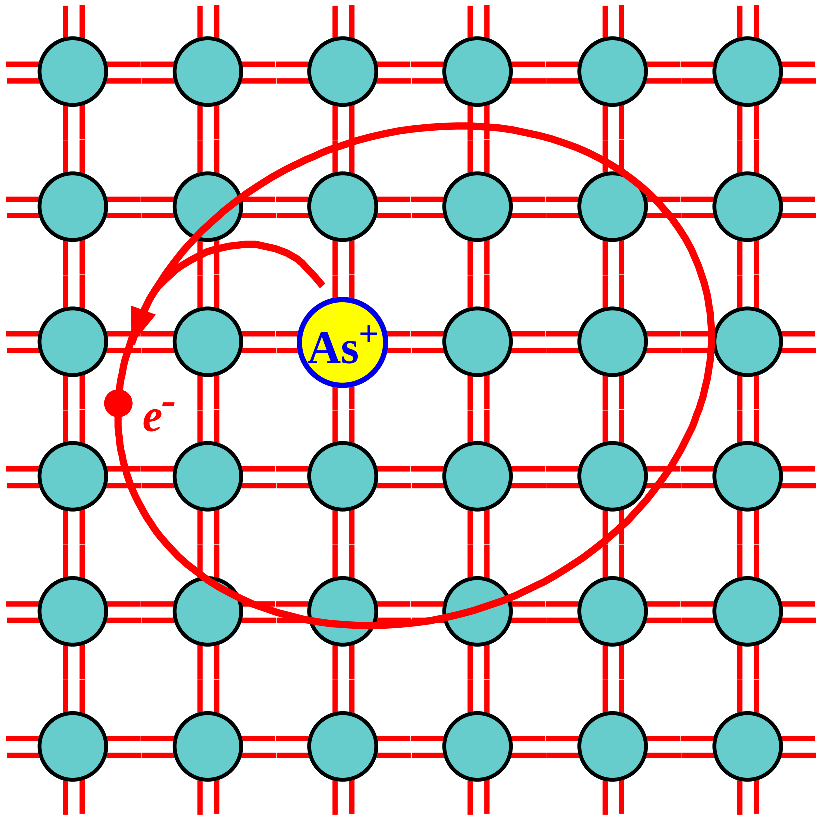
Pages

- Kasap
  - Drift: P. 378-380

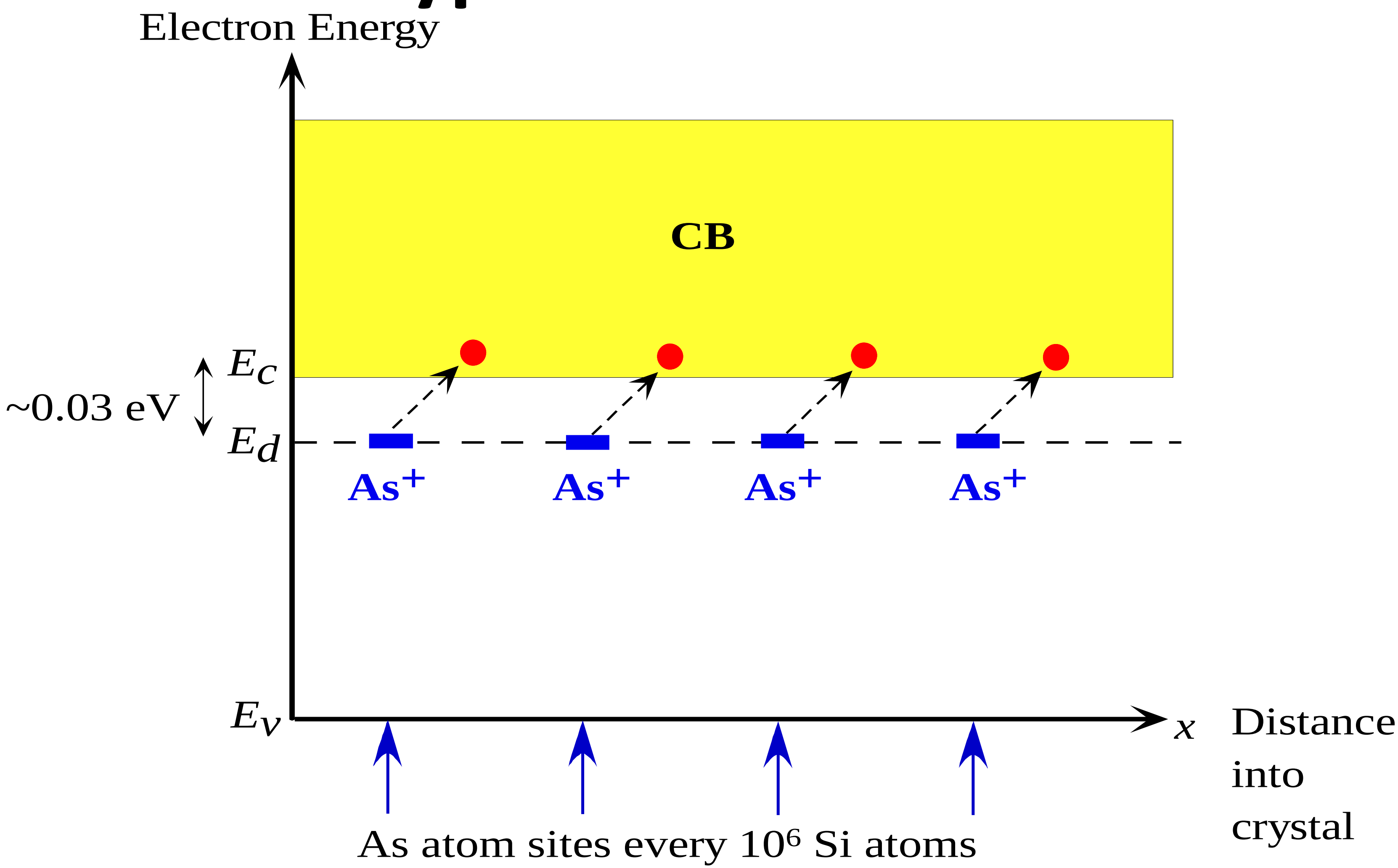
n-type Semiconductors



Arsenic doped Si crystal. The four valence electrons of As allow it to bond just like Si but the fifth electron is left orbiting the As site. The energy required to release to free fifth-electron into the CB is very small.

Fig 5.9

n type Semiconductors

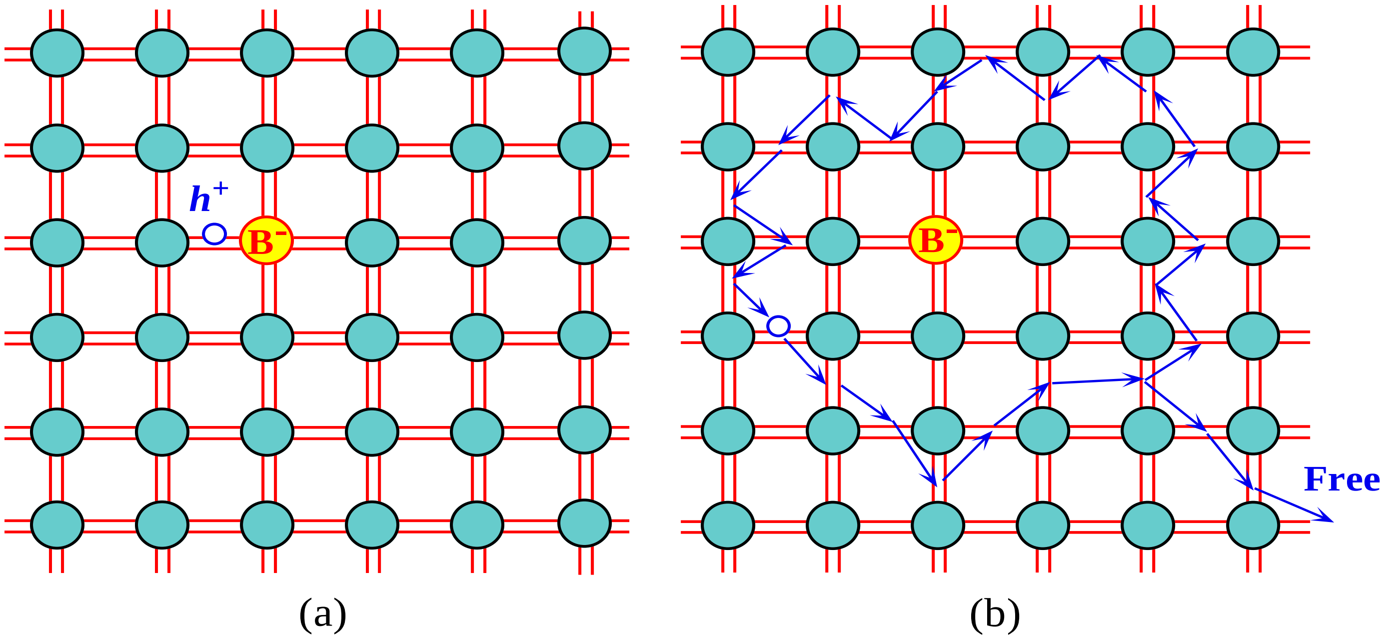


Energy band diagram for an n-type Si doped with As. There are donor energy levels just below E_c around As^+ sites.

Fig 5.10

From *Principles of Electronic Materials and Devices, Third Edition*, S.O. Kasap (© McGraw-Hill, 2005)

p type Semiconductors

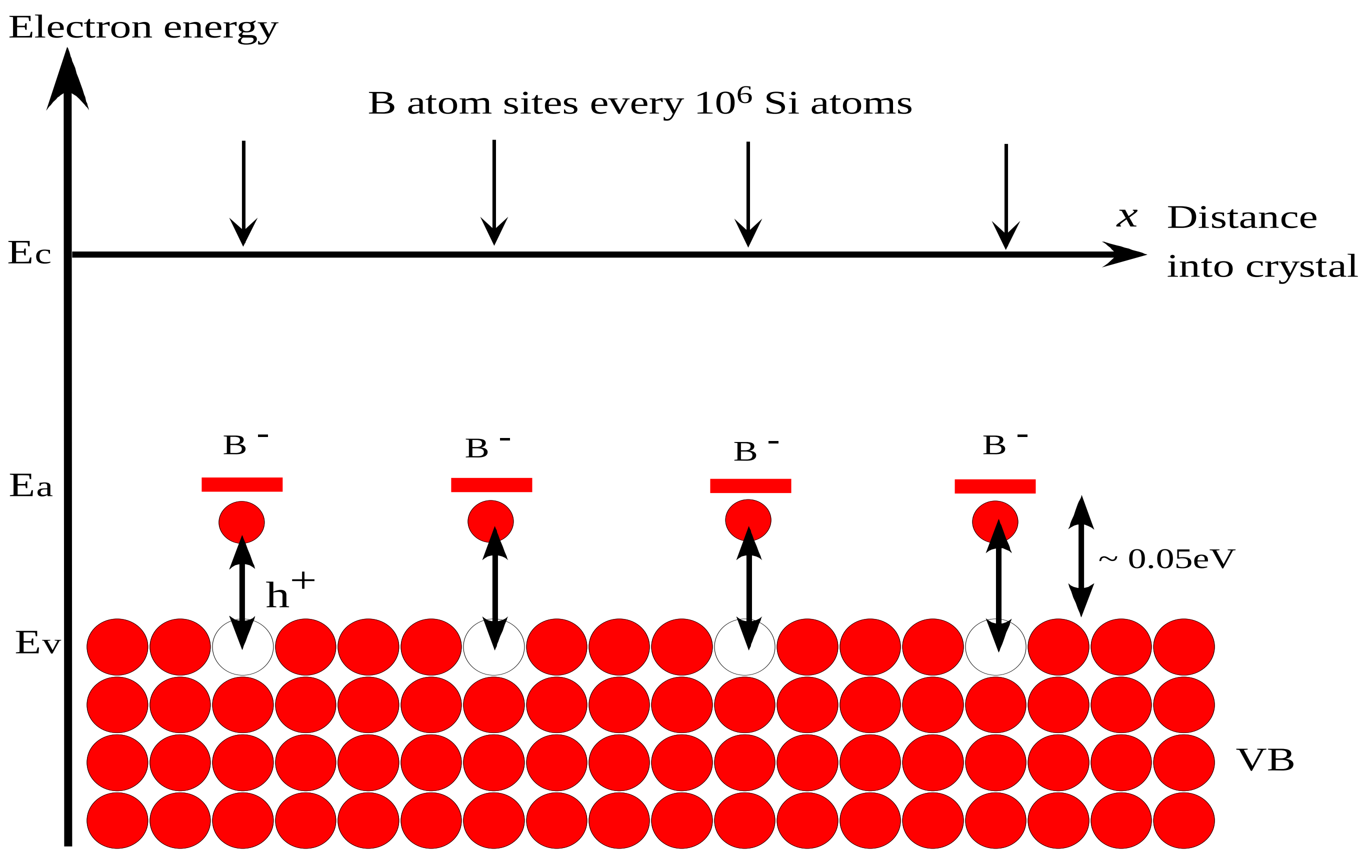


Boron doped Si crystal. B has only three valence electrons. When it substitutes for a Si atom one of its bonds has an electron missing and therefore a hole as shown in (a). The hole orbits around the B^- site by the tunneling of electrons from neighboring bonds as shown in (b). Eventually, thermally vibrating Si atoms provides enough energy to free the hole from the B^- site into the VB as shown.

Fig 5.11

From *Principles of Electronic Materials and Devices, Third Edition*, S.O. Kasap (© McGraw-Hill, 2005)

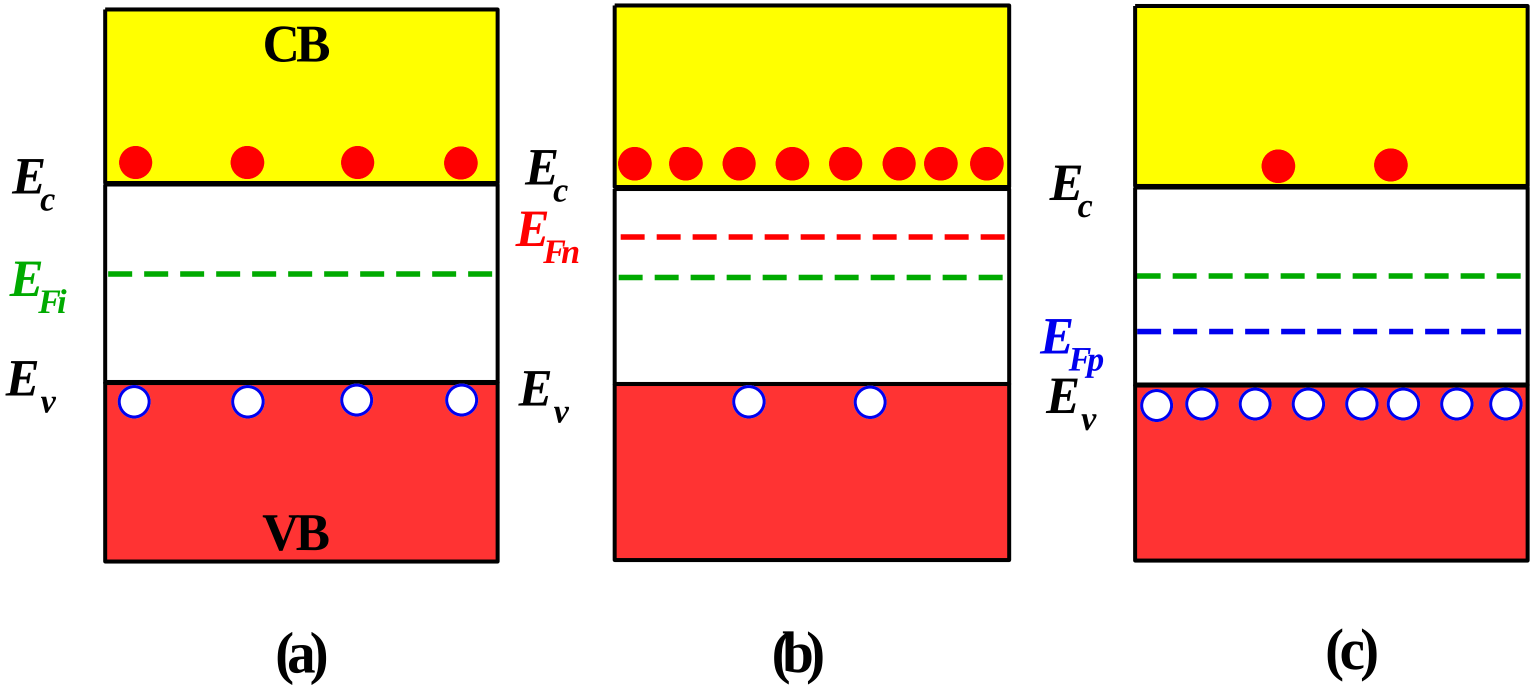
p type Semiconductors



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.

Fig 5.12

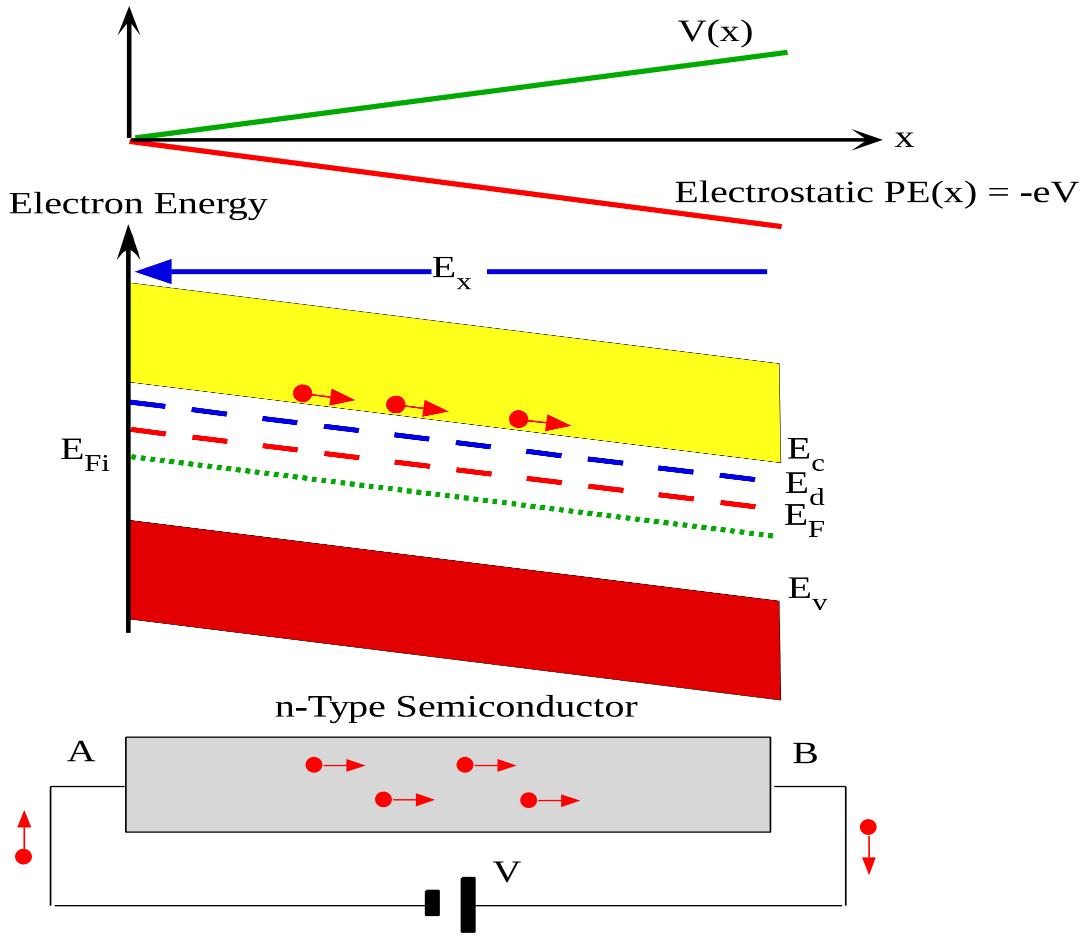
From *Principles of Electronic Materials and Devices, Third Edition*, S.O. Kasap (© McGraw-Hill, 2005)



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

Fig 5.8

Conduction in Semiconductors



P.E.=-q V_{app}

Energy band diagram of an *n*-type semiconductor connected to a voltage supply of *V* volts. The whole energy diagram tilts because the electron now has an electrostatic potential energy as well

Fig 5.13

Drift Current (Ohm's Law)

$$J = e\,n\,v_{de} + e\,p\,v_{dh}$$

- ***J*** : current density A/m^2
- *n: concentration of electrons in Conduction Band cm^{-3}*
- *p: concentration of holes in Valence Band cm^{-3}*
- *v_{de} and v_{dh} :drift velocities "m/s"*

$$v_{de} = \mu_e E_x \qquad v_{dh} = \mu_h E_x$$

E_x : Applied electric field = -dV/dx

μ_e and μ_h : electron and hole drift mobilities

Mobility

- Mobility is a material property
- A measure of how easily can the electron or hole move in the material
- Units: $m^2 sec^{-1} V^{-1}$

μ_e and μ_h : electron and hole drift mobilities

$$\mu_e = \frac{e\tau_e}{m_e^*} \qquad \mu_h = \frac{e\tau_h}{m_h^*}$$

τ_e and τ_h : *electron* ***and hole mean free time***

(time between scattering events)

Conductivity

$$J = en\mu_e E_x + ep\mu_h E_x$$

$$J = \sigma\, E_x$$

$$\sigma = en\mu_e + ep\mu_h$$

$\sigma = conductivity$ ($Ohm^{-1}.m^{-1}$)

$\rho = resistivity = 1/\sigma$ (Ohm.m)

$Resistance = \frac{\rho L}{A}$ (Ohm)