Solid State Electronics EC210
Arab Academy for Science and Technology
AAST – Cairo
Fall 2014

Lecture 10:
Semiconductors

Lecture Notes Prepared by:
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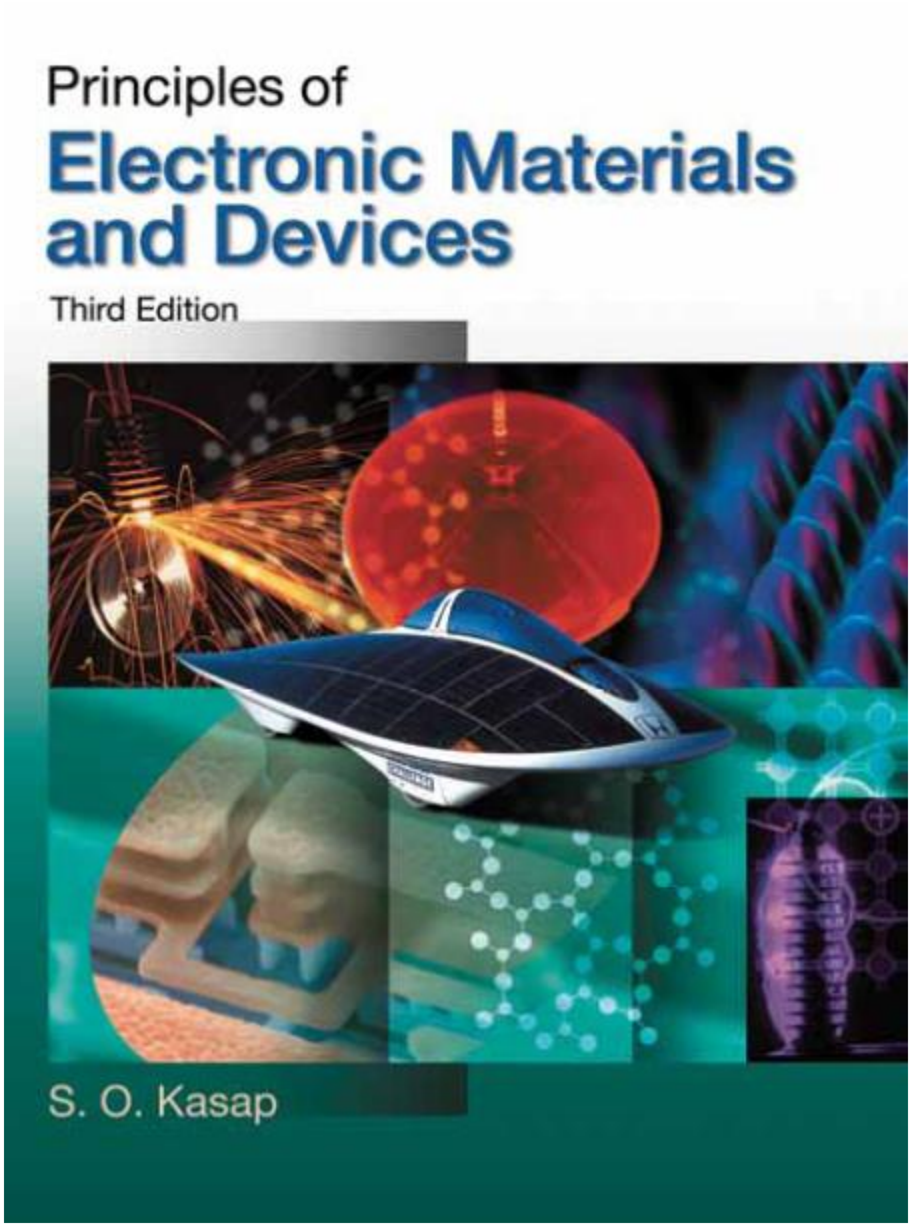

Principles of
Electronic Materials and Devices
Third Edition
S. O. Kasap

- Kasap
  - P. 373-378: Intrinsic Semiconductor
  - P.388-394: Extrinsic Semiconductor

200 mm and 300 mm Si wafers.

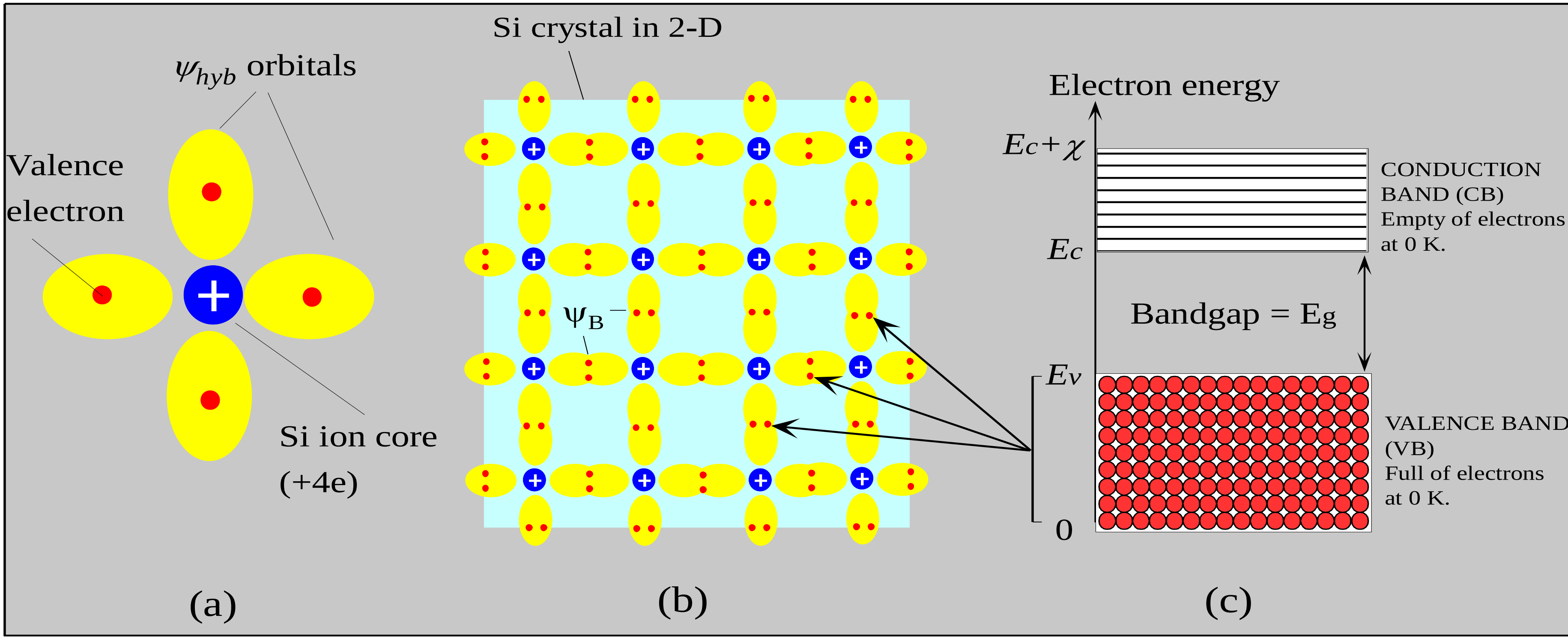
|SOURCE: Courtesy of MEMC, Electronic Materials, Inc.

GaAs ingots and wafers.

GaAs is used in high speed electronic devices, and optoelectronics.

|SOURCE: Courtesy of Sumitomo Electric Industries, Ltd.

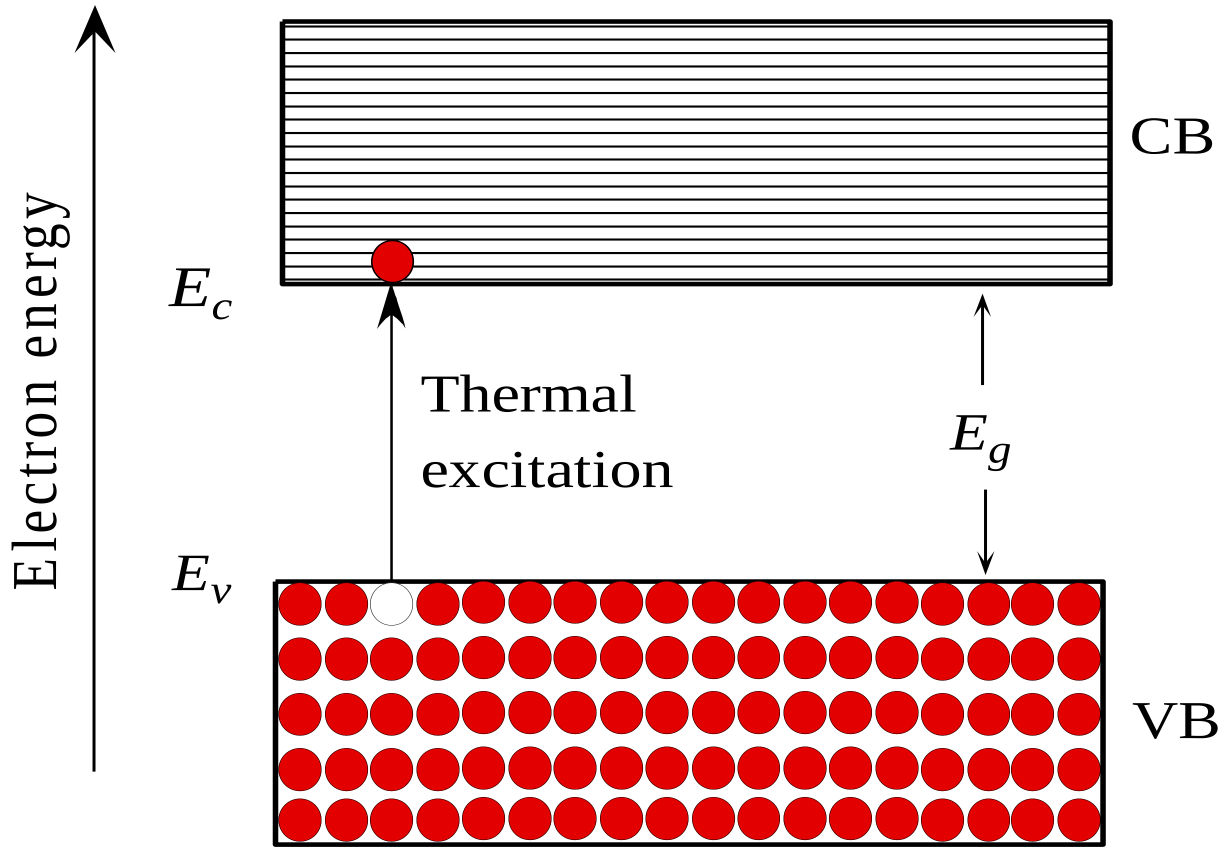
Semiconductors



(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.

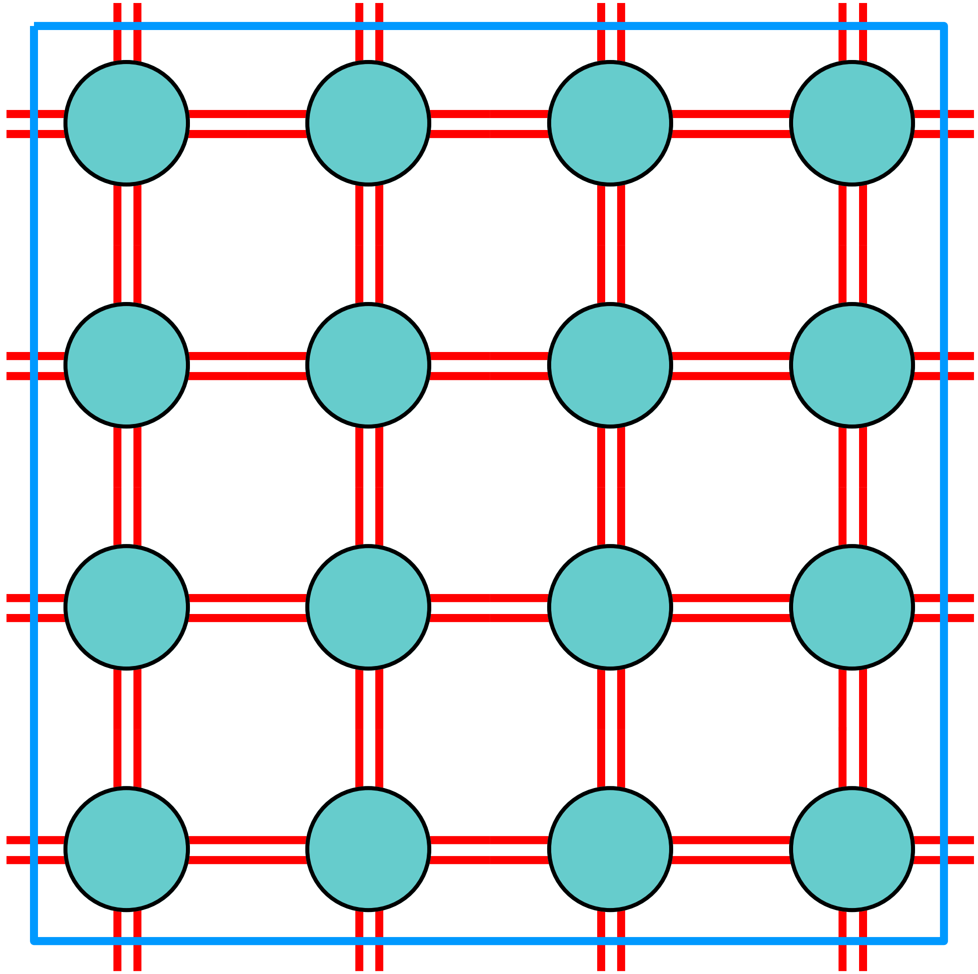
Fig 5.1

Intrinsic Semiconductors



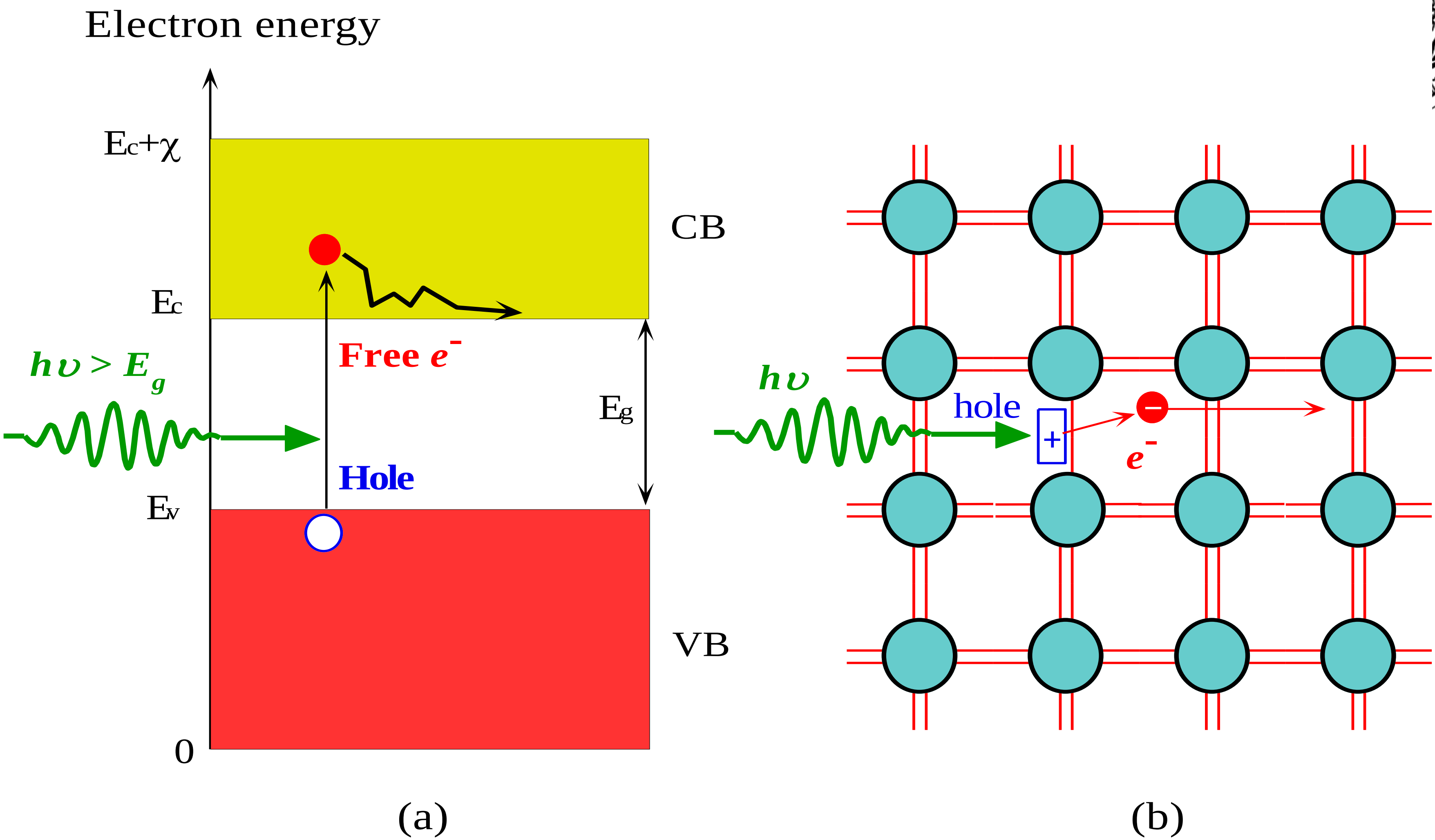
Energy band diagram of a semiconductor. CB is the conduction band and VB is the valence band. At 0 K, the VB is full with all the valence electrons.

Fig 5.2

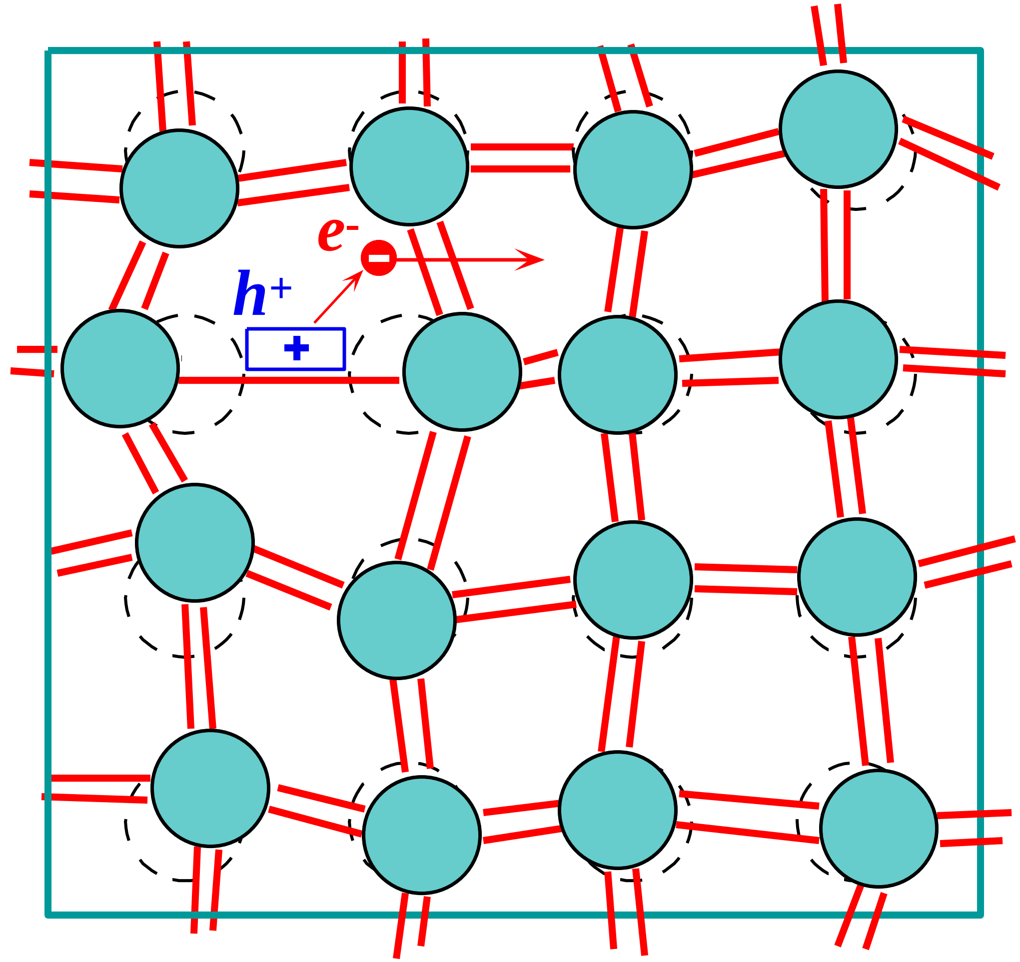


A two dimensional pictorial view of the Si crystal showing covalent bonds as two lines where each line is a valence electron.

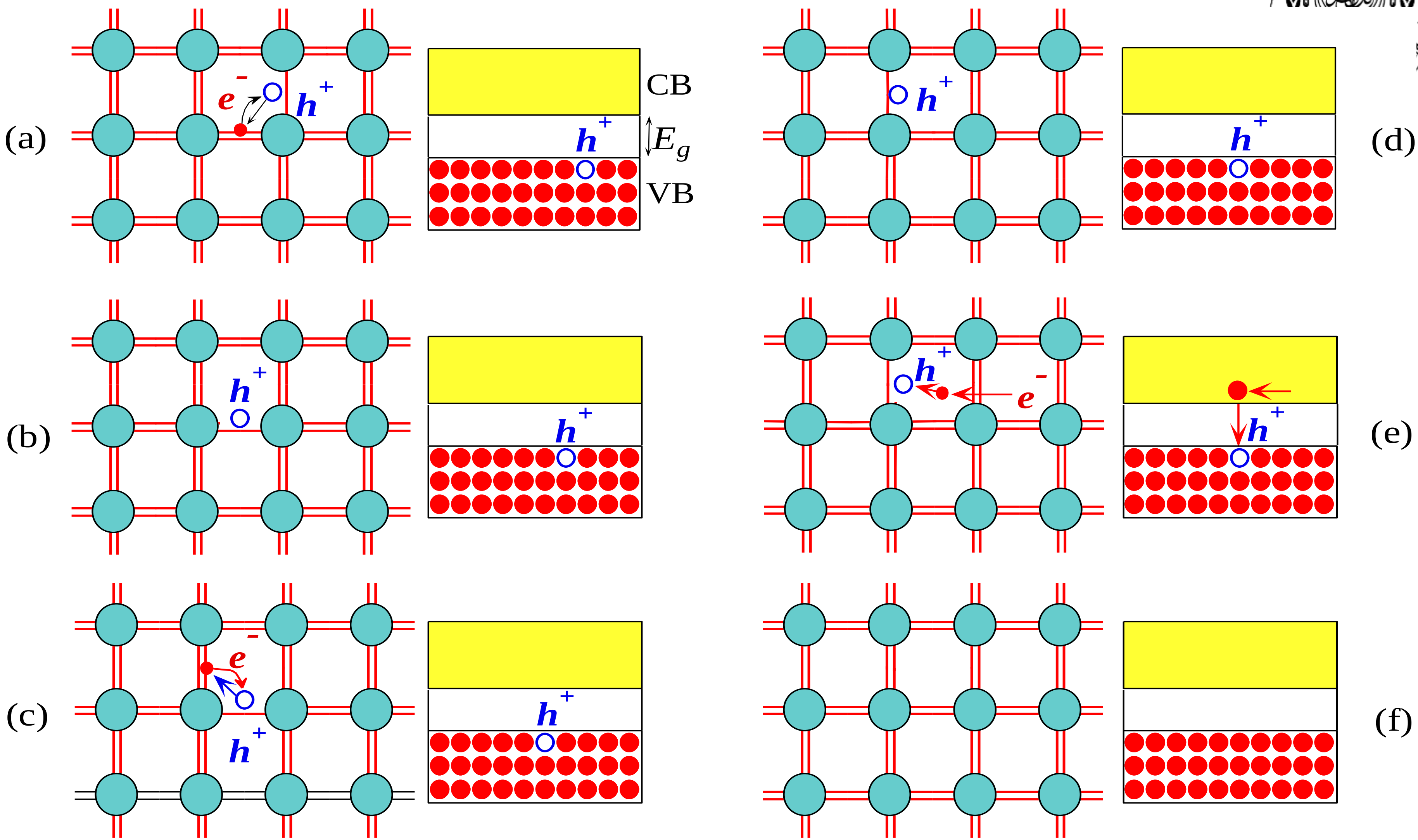
Fig 5.3



(a) A photon with an energy greater than Eg 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.

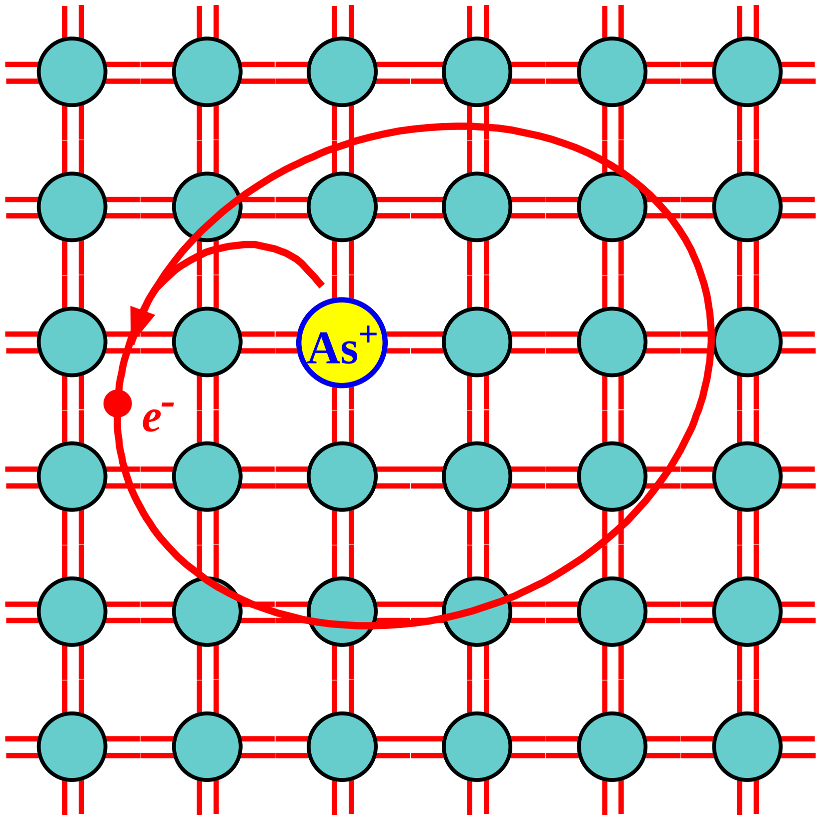


Thermal vibrations of atoms can break bonds and thereby create electron-hole pairs.



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

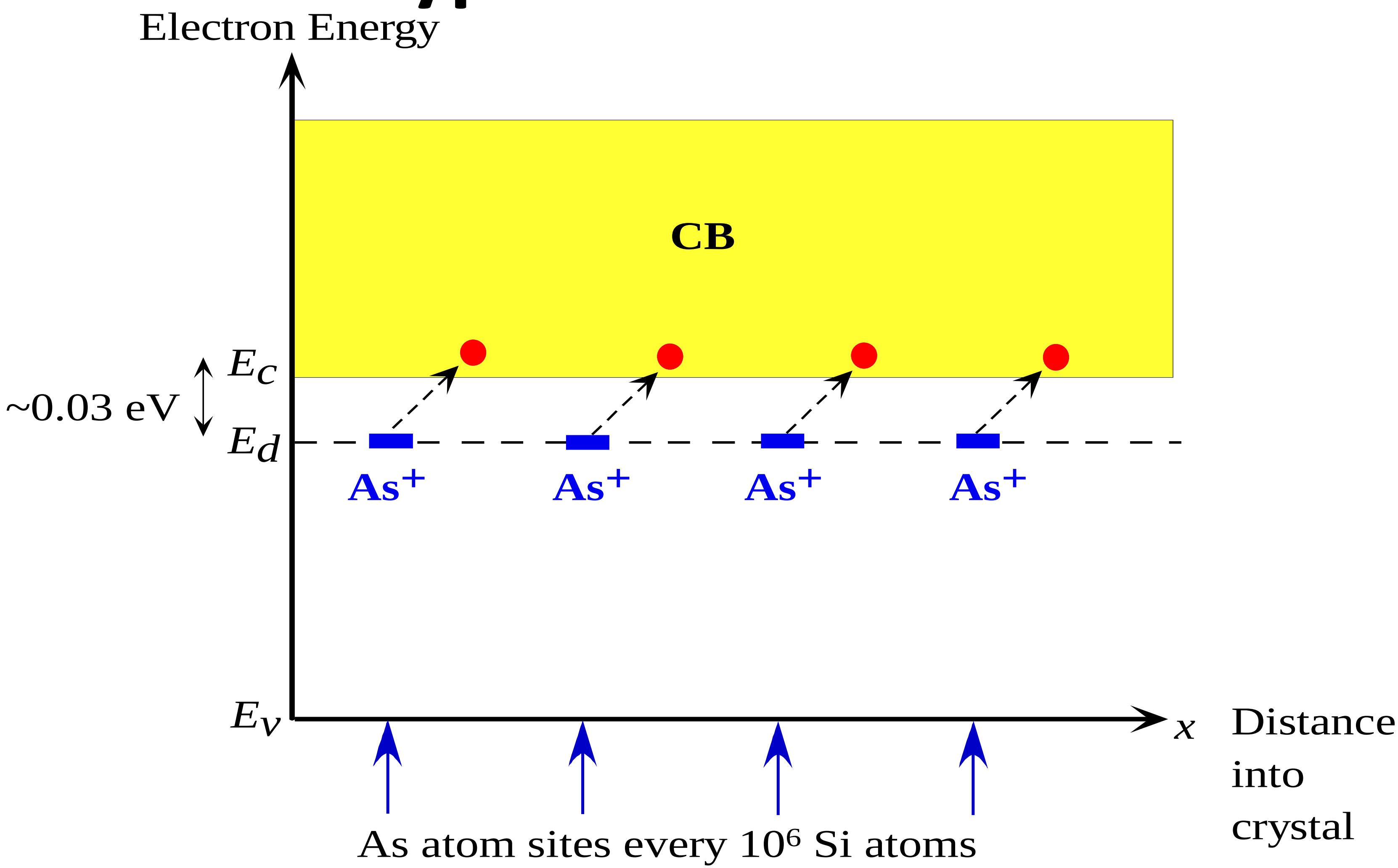
n-type Semiconductors



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

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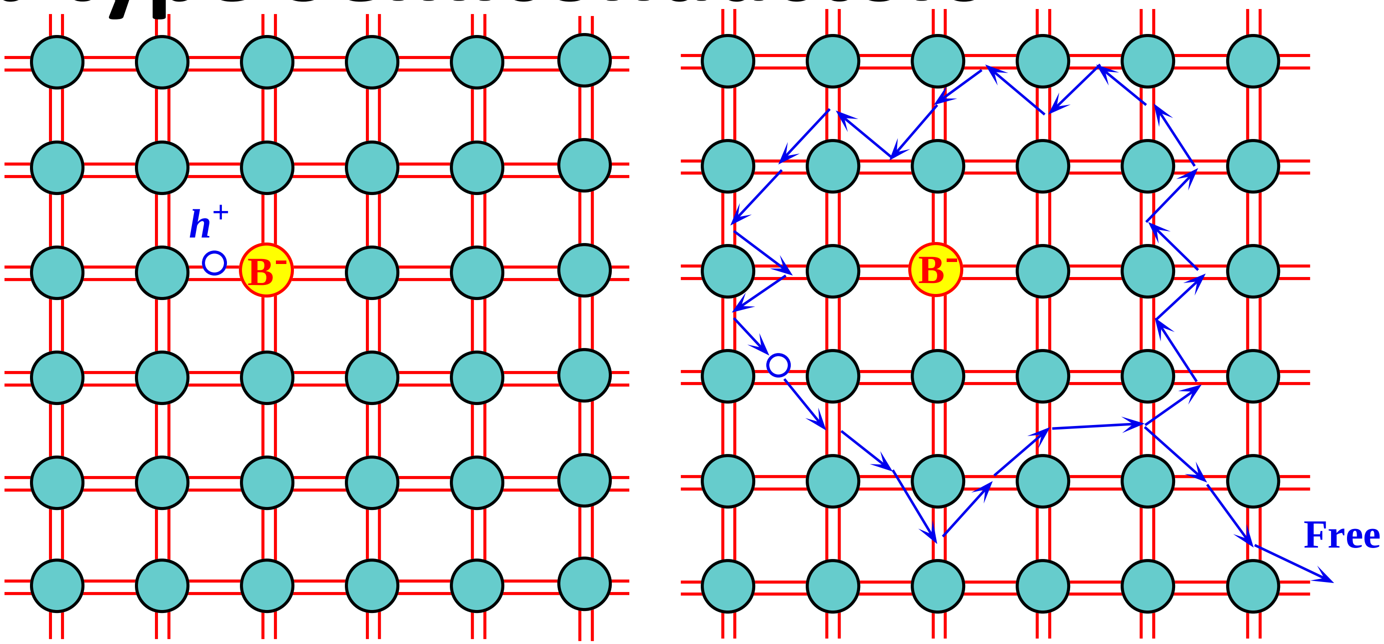
p type Semiconductors

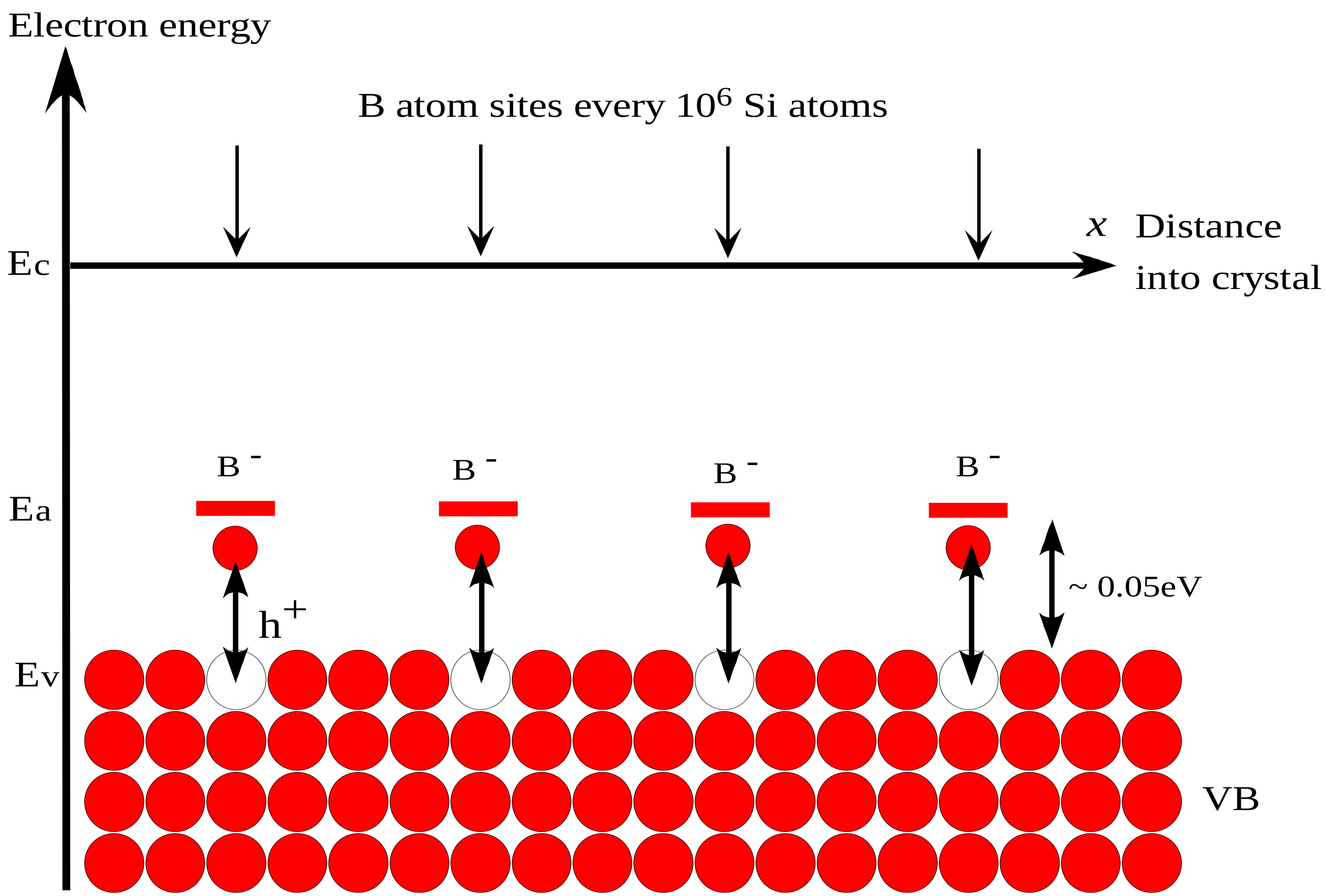


(a) (b)

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

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

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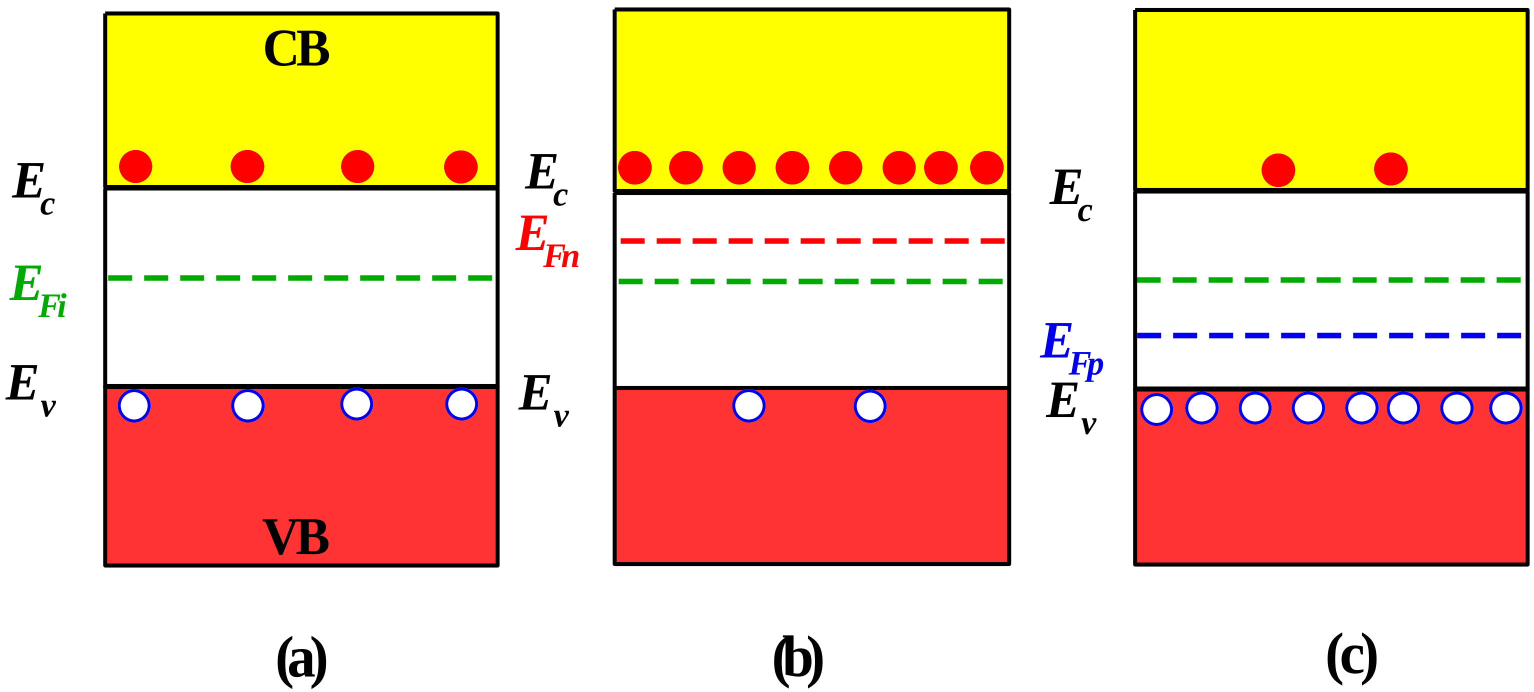

Energy band diagrams for (a) intrinsic (b) *n*-type and (c) p-type semiconductors. In all cases, $np = n_i^2$

Fig 5.8

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