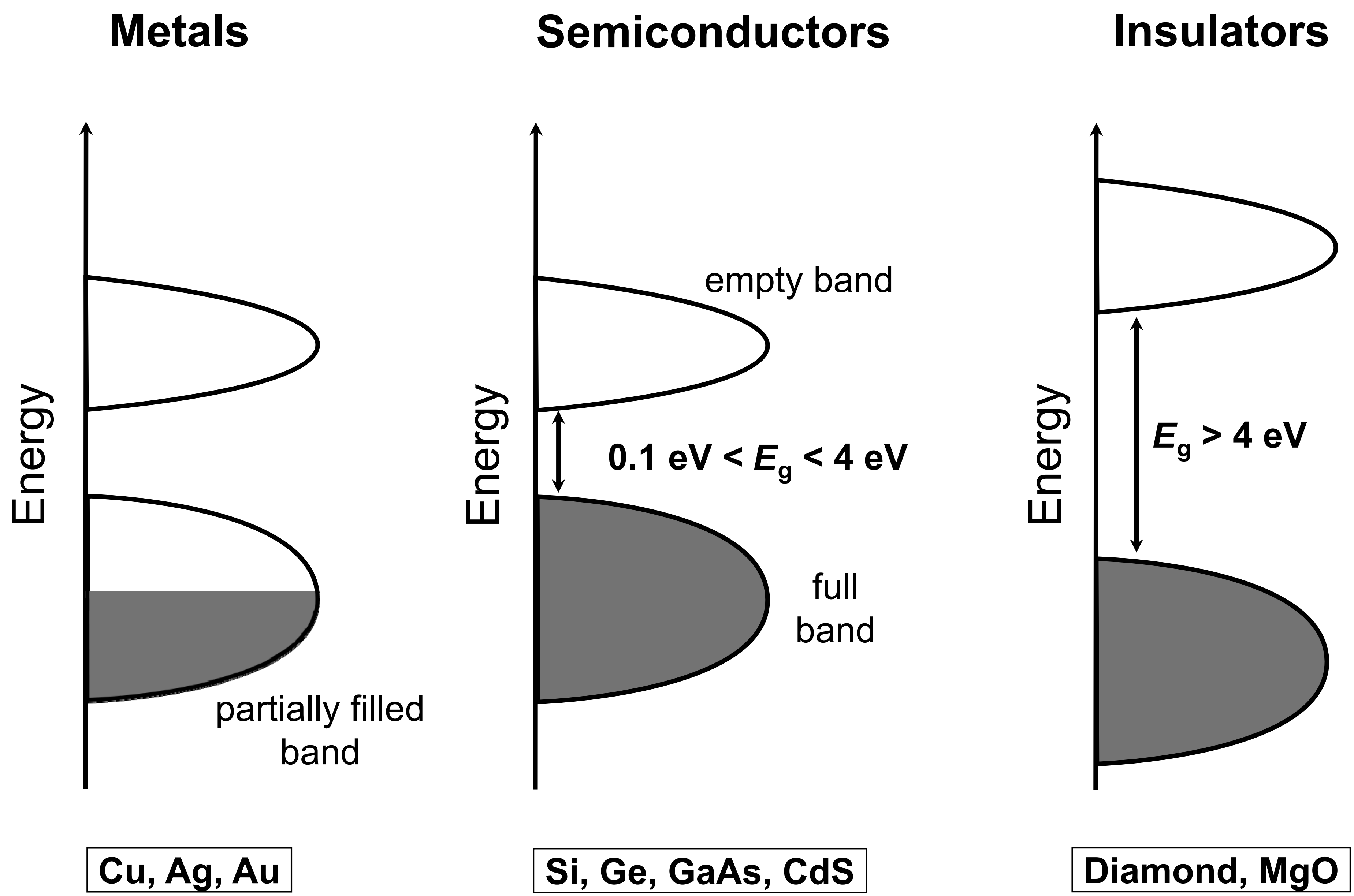
Semiconductors and Devices based on *p-n* Junctions

Chapter 7

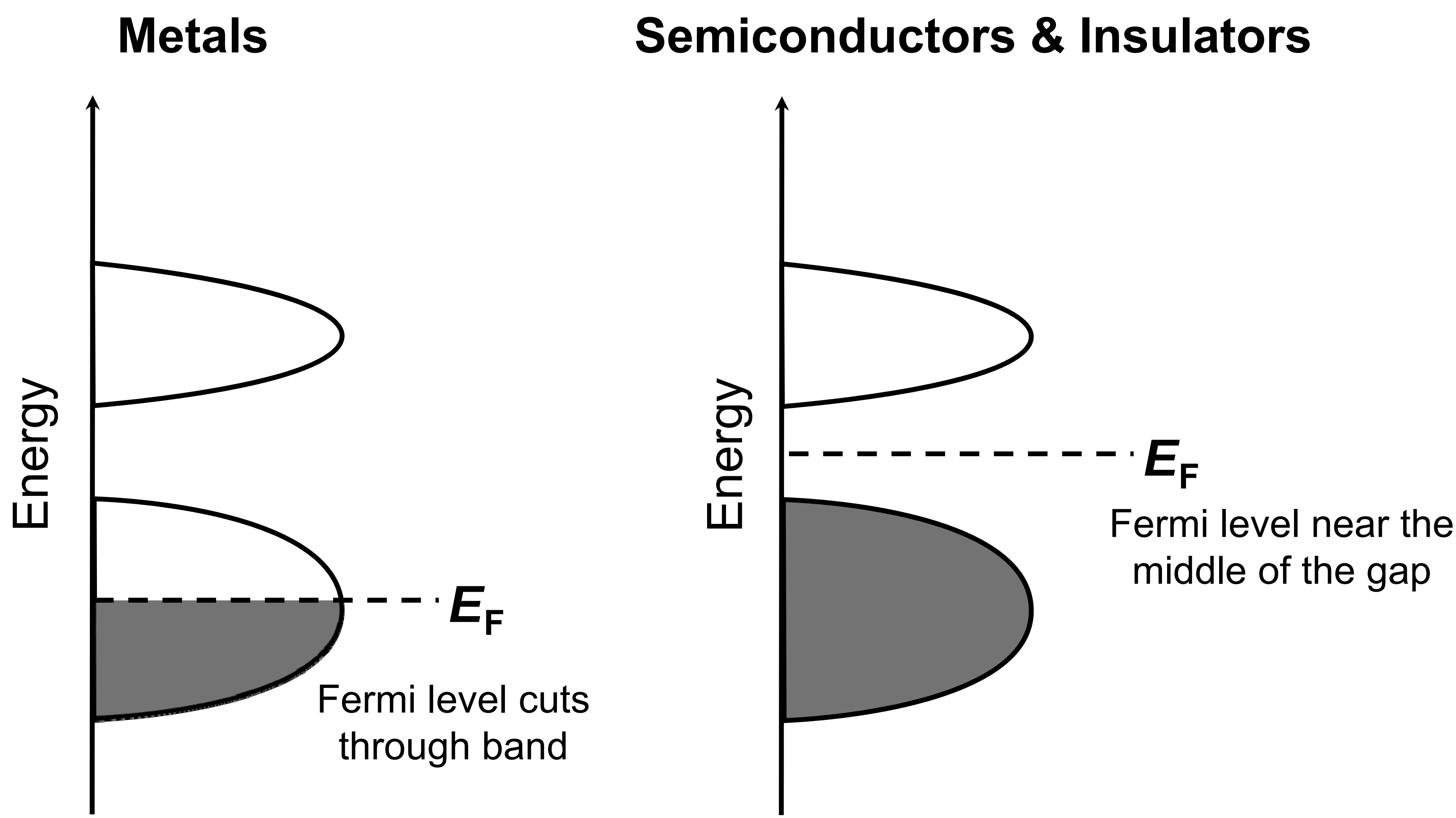
Wednesday, October 28, 2015

Metals, Semiconductors, and Insulators



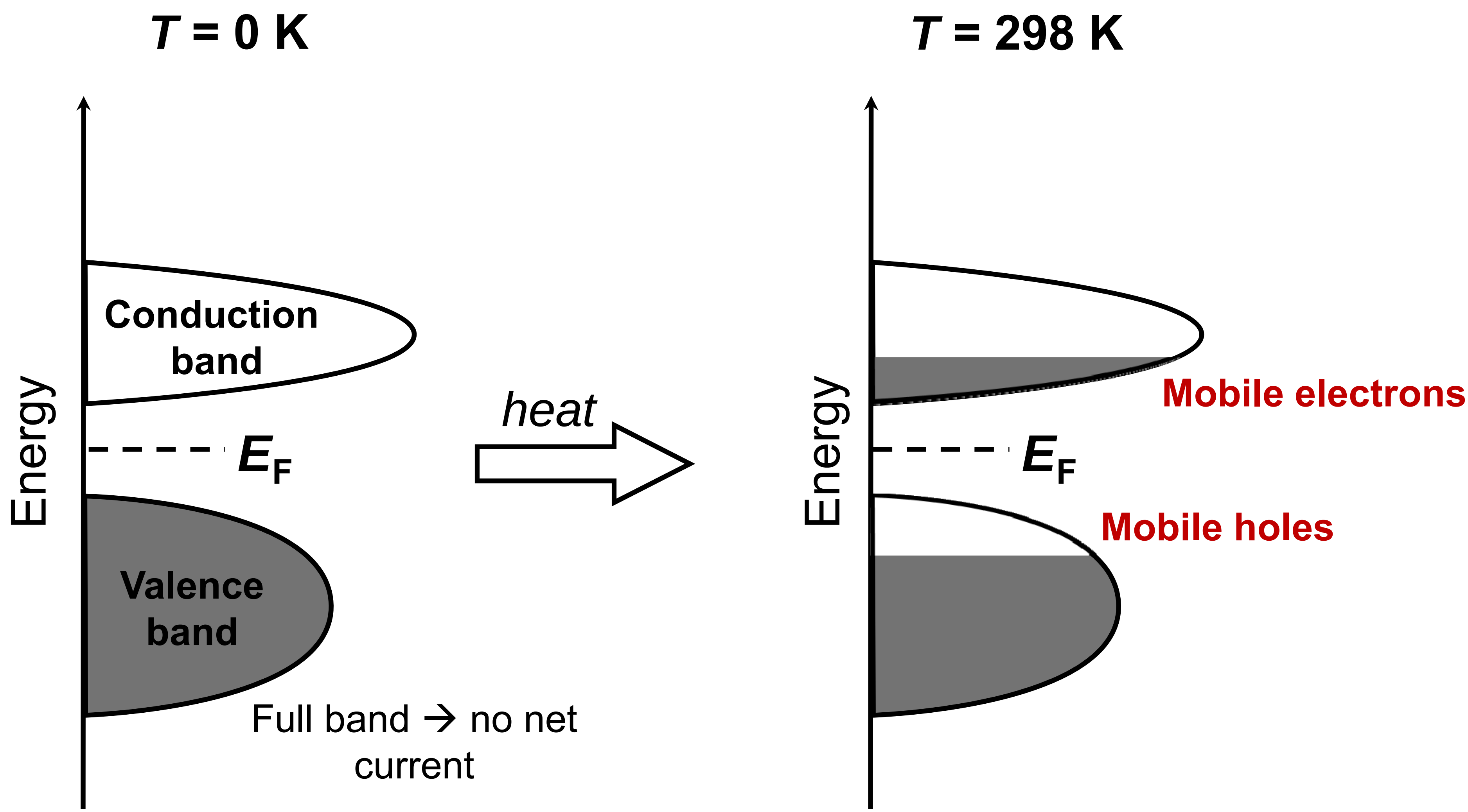
The Fermi Level

The Fermi level (E_F) is the chemical potential for electrons. It is the (possibly hypothetical) energy level at which the probability of electron occupancy is 50%.



Mobile Charges in Pure Semiconductors

Heat, light, and other stimuli can excite electrons across the band gap, resulting in mobile electrons (negative charges) and holes (electron vacancies, positive charges) and electrical conductivity.

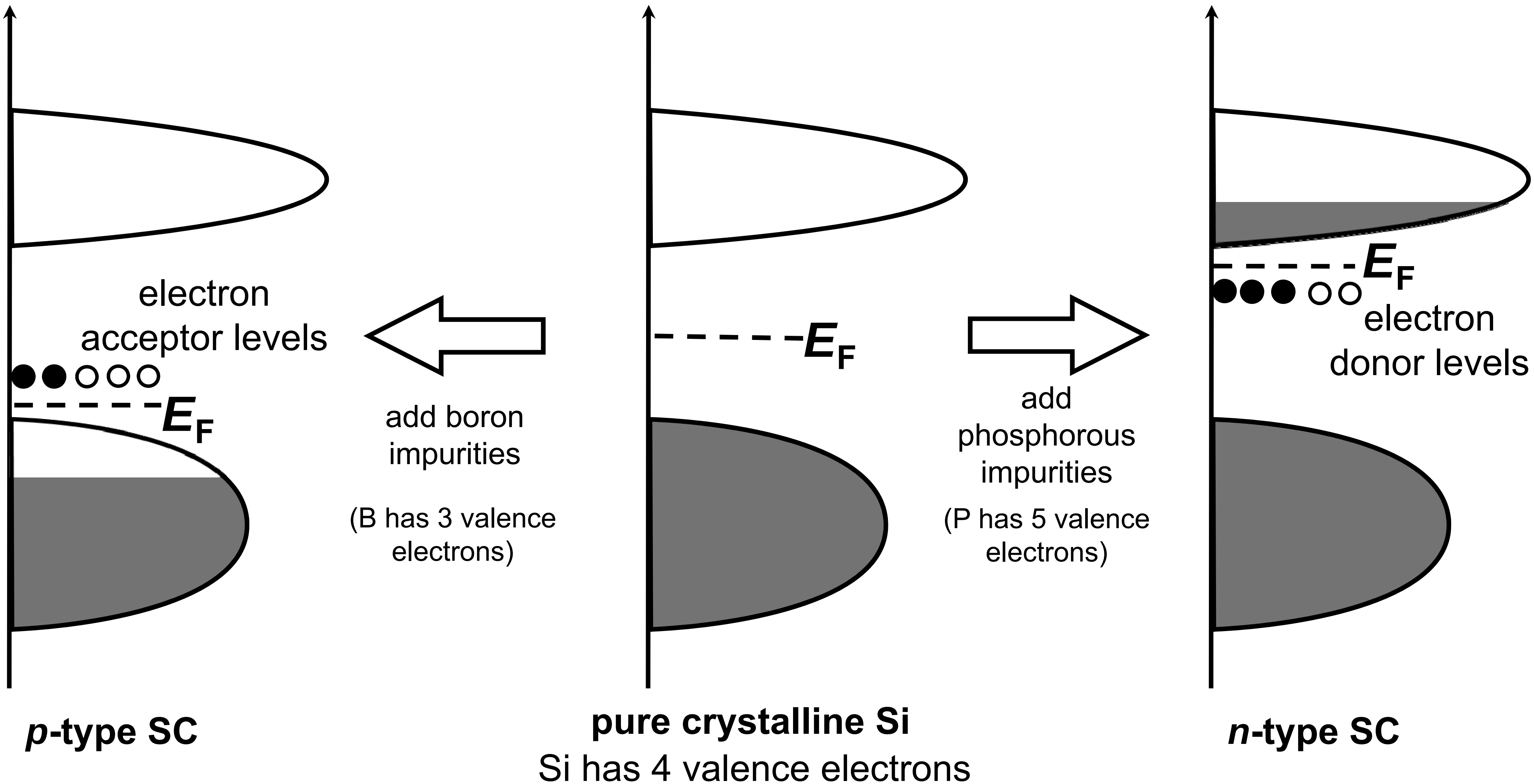


Common Semiconductors

Semi-Conductor	Band Gap / eV	color
TiO_2	3.0-3.2	colorless
CdS	2.4	yellow
HgS	2.1	red
CdTe	1.5	black
Si	1.12	dark gray
Ge	0.67	light gray

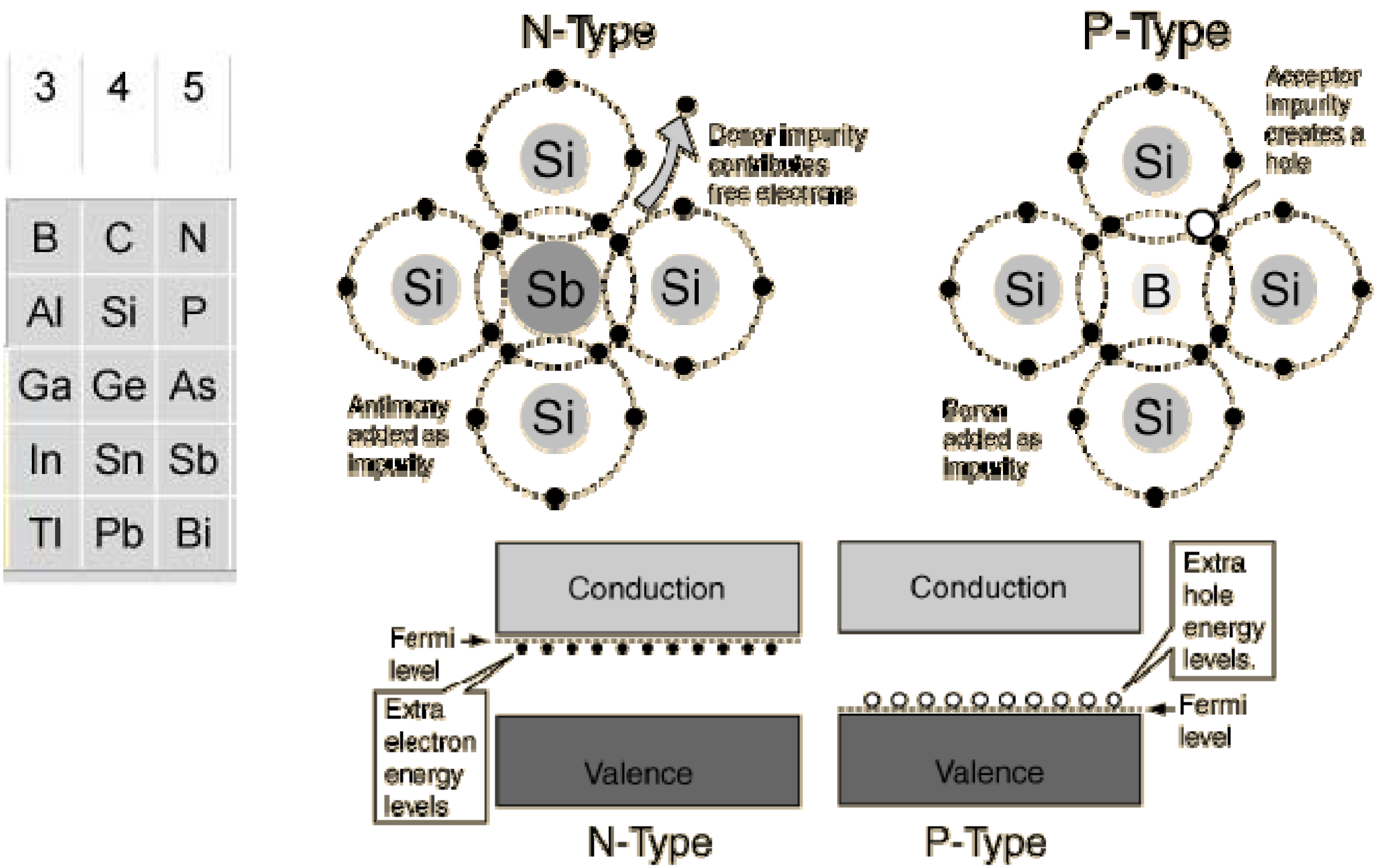
Doping of Semiconductors

Doping means adding impurity atoms to a semiconductor to change its electrical properties. Consider silicon:



Doping

Adding foreign atoms (dopants) of Group V or Group III to a Group IV semiconductor produces *n*-type or *p*-type semiconductors.

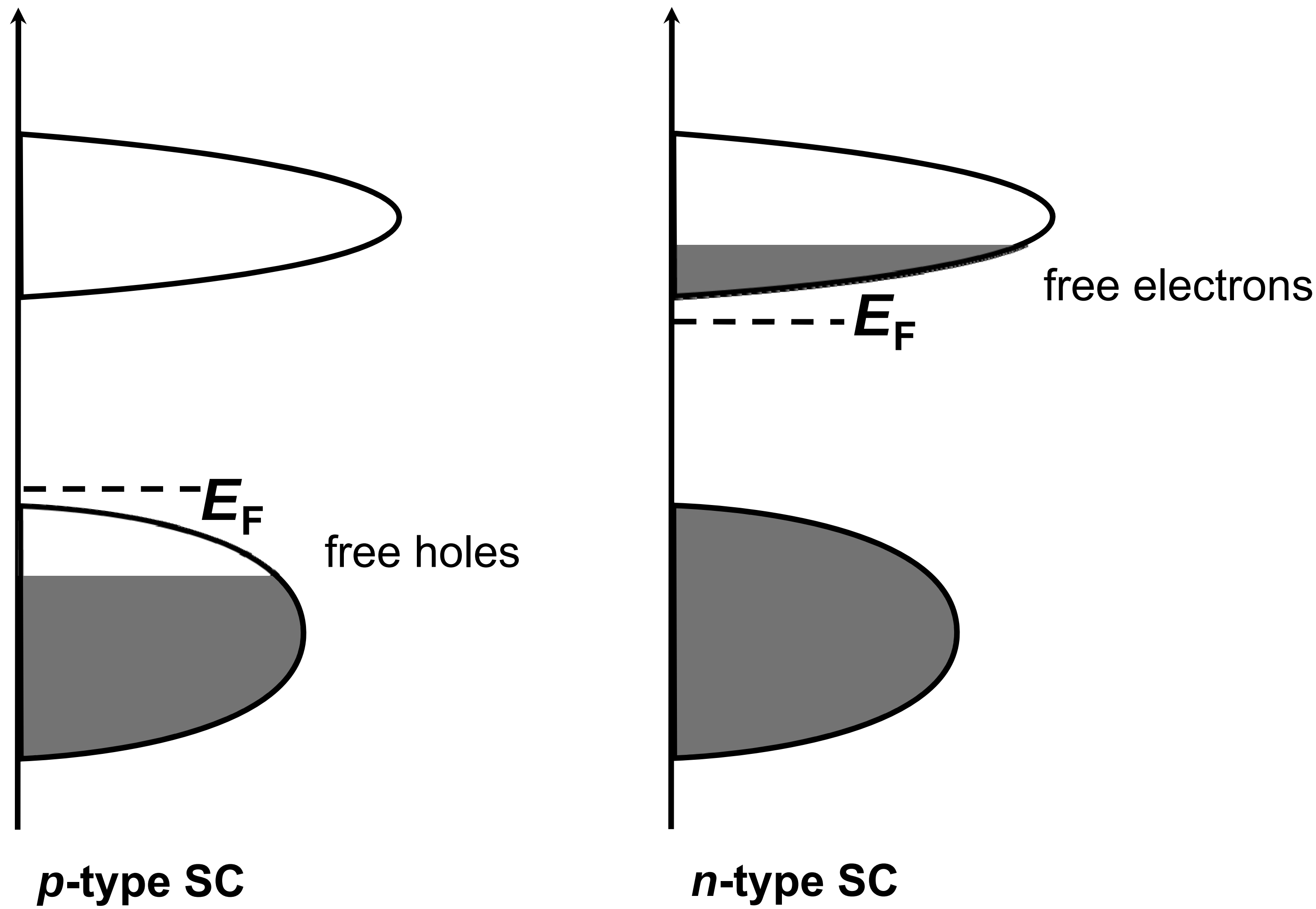


	N-Type	P-Type
dopant type:	donor	acceptor
majority carrier:	electrons	holes

p–n Junctions

Advanced optoelectronic devices can be made by layering *p*-type and *n*-type semiconductors:

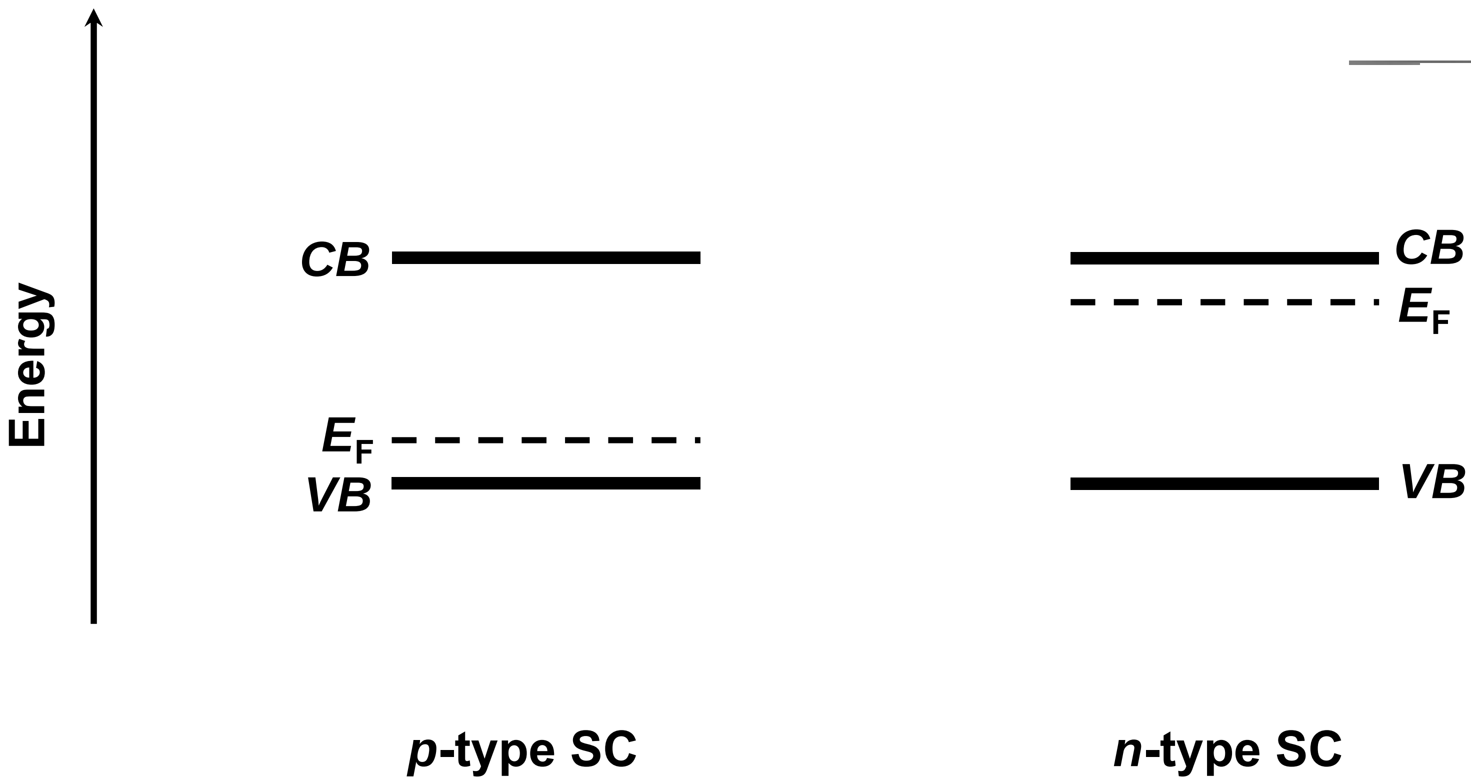
- transistors
- solar cells
- photodetectors
- LEDs and lasers



p–*n* Junctions

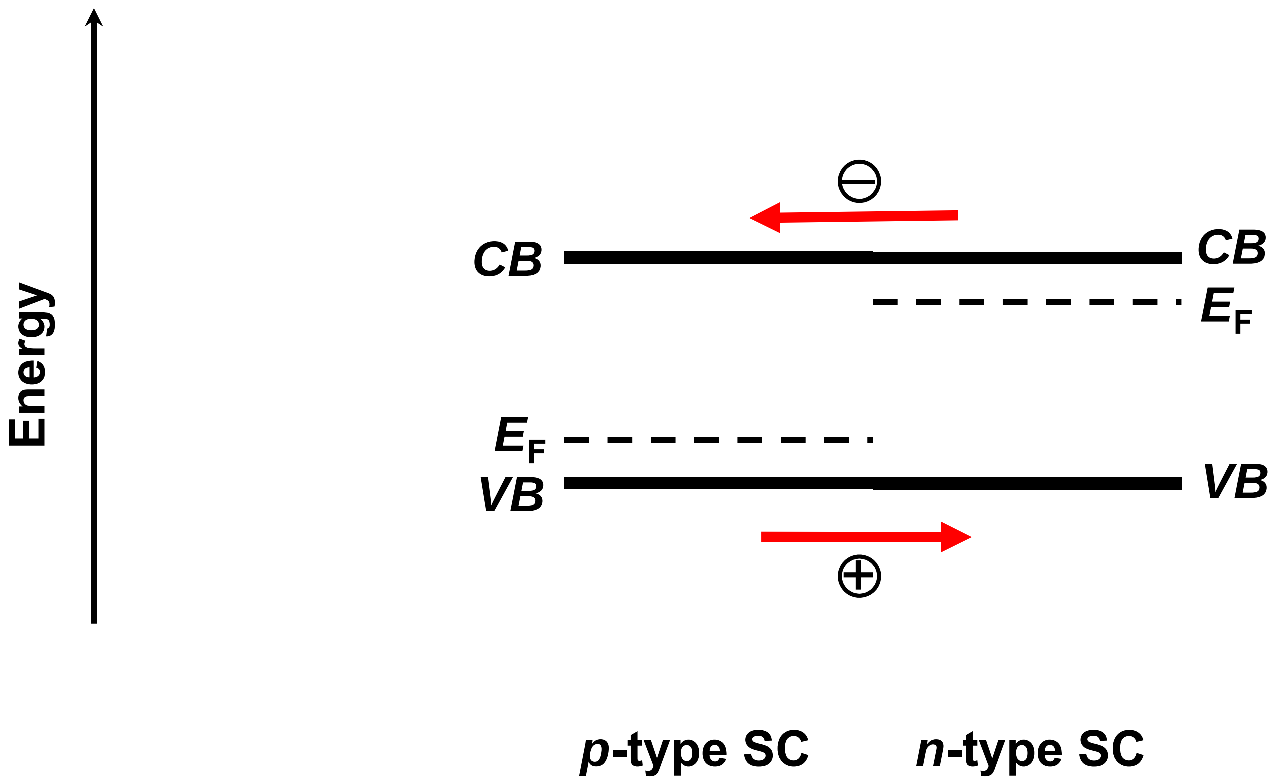
Consider what happens when a junction between *p*-type and *n*-type semiconductors is made:

Before contact, the Fermi level of the *n*-type SC is higher than that of the *p*-type SC.



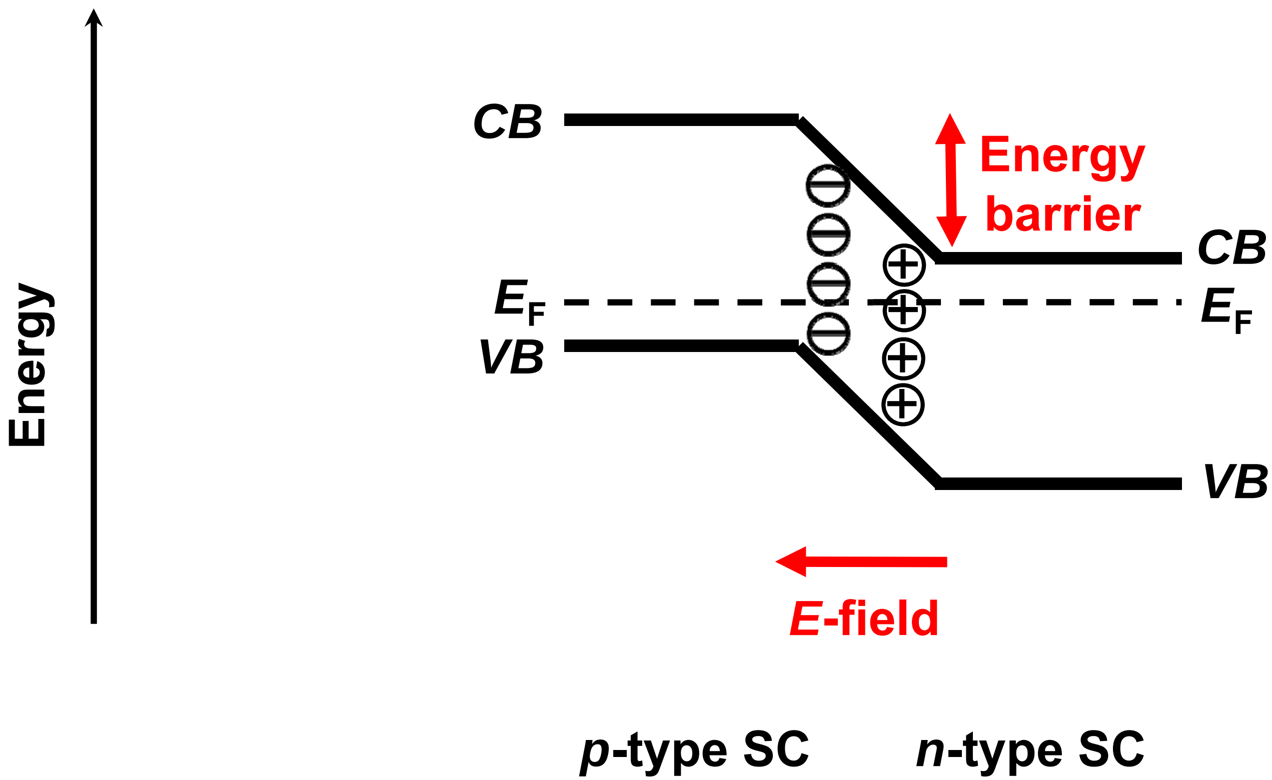
p–n Junctions

Upon contact, electrons diffuse from *n* side to *p* side. Holes diffuse in the opposite direction (*p* to *n*).



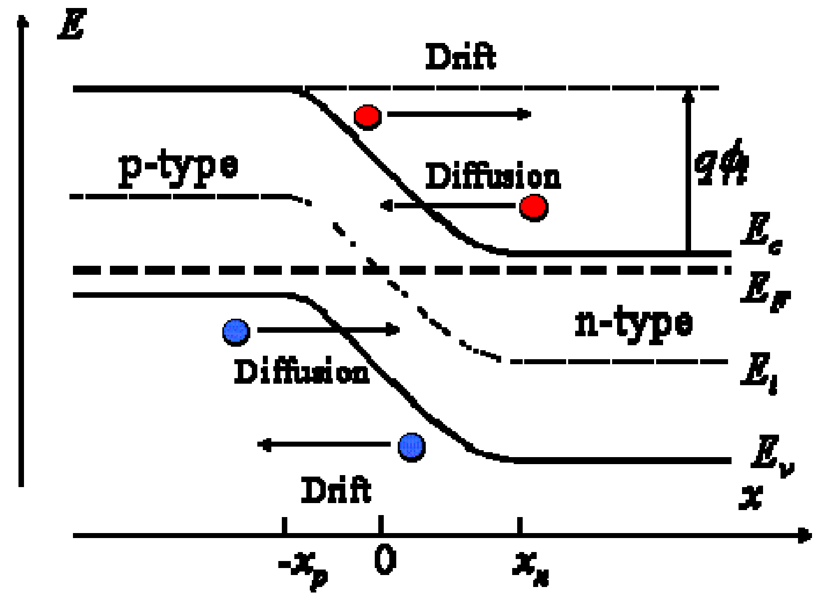
p–n Junctions

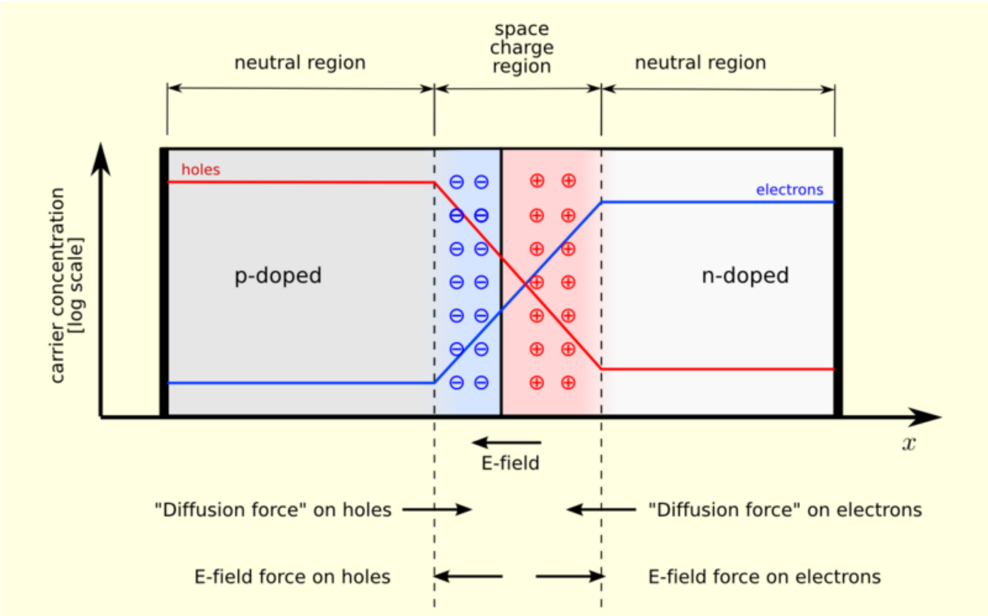
Net diffusion occurs until balanced by an electric field at the junction. At this point, equilibrium is established (Fermi levels equal).



p–n Junctions

at equilibrium:

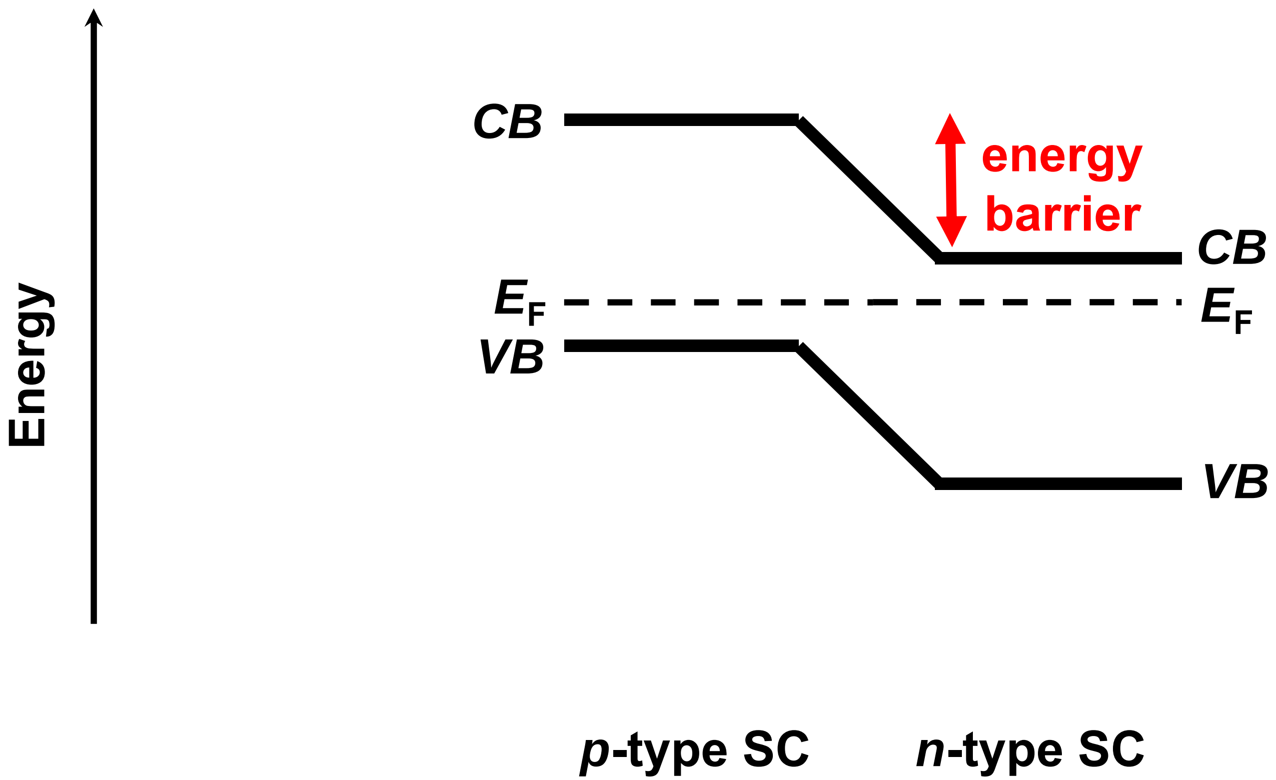


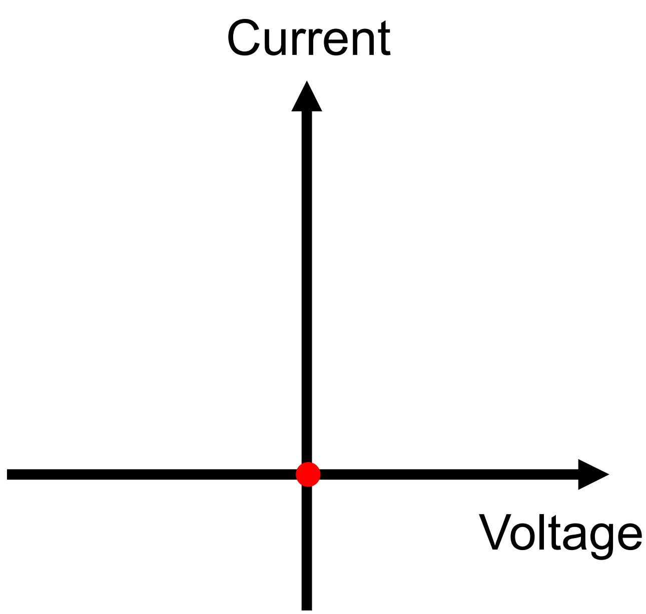


p–n Junctions

The *p-n* junction is an electrical <u>*diode*</u>, a device through which current flows in only one direction.

At equilibrium (zero applied voltage), the net current is zero.

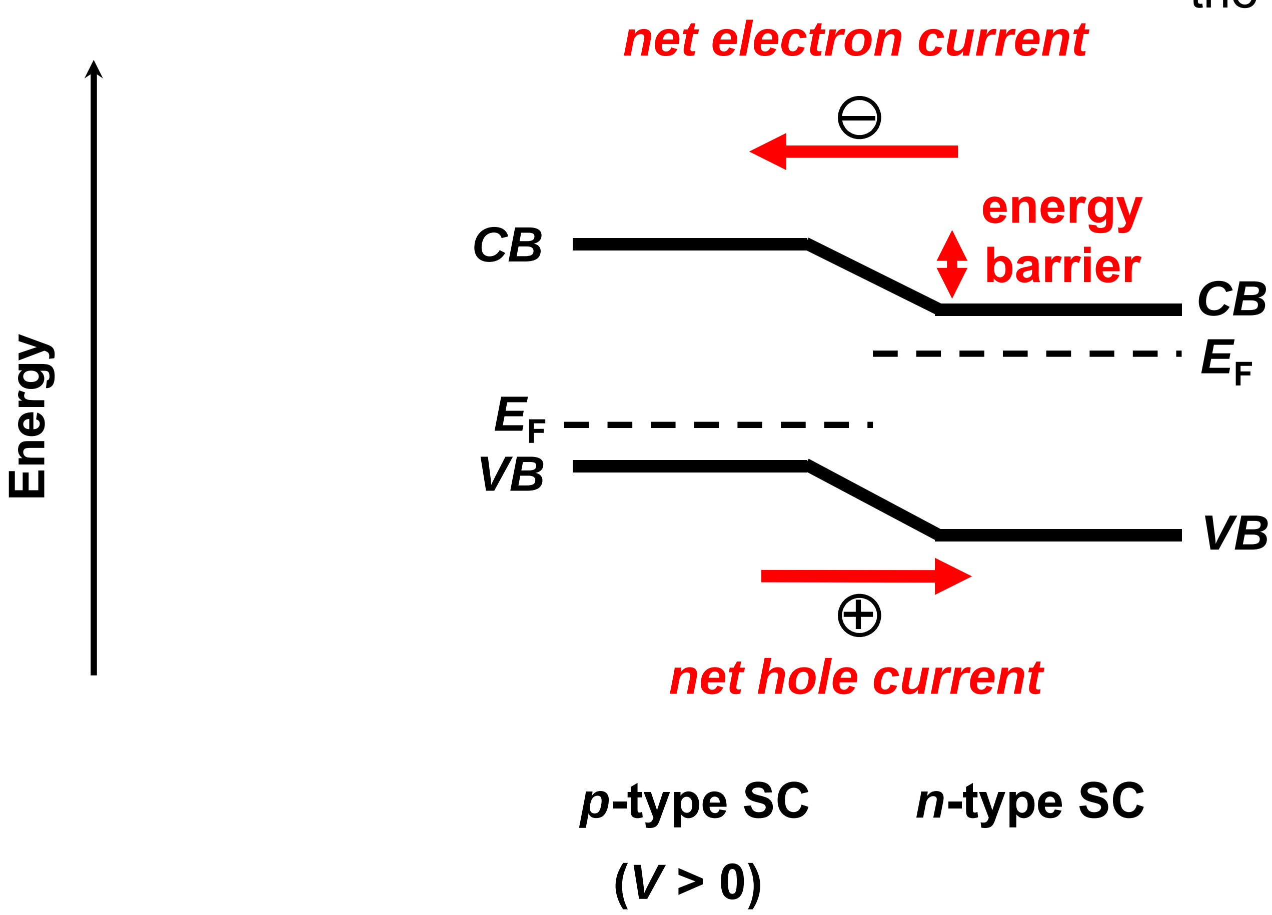


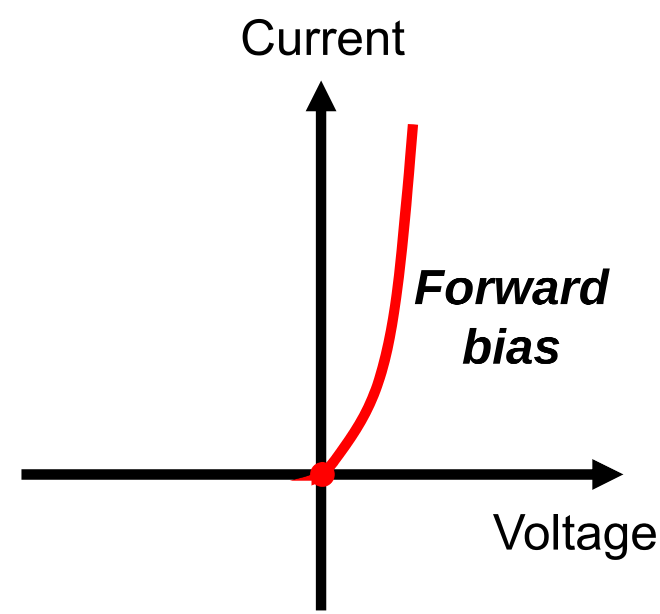


p–n Junctions

The *p-n* junction is an electrical *diode*, a device through which current flows in only one direction.

Under forward bias, large positive current flows because the energy barrier for diffusion is reduced.

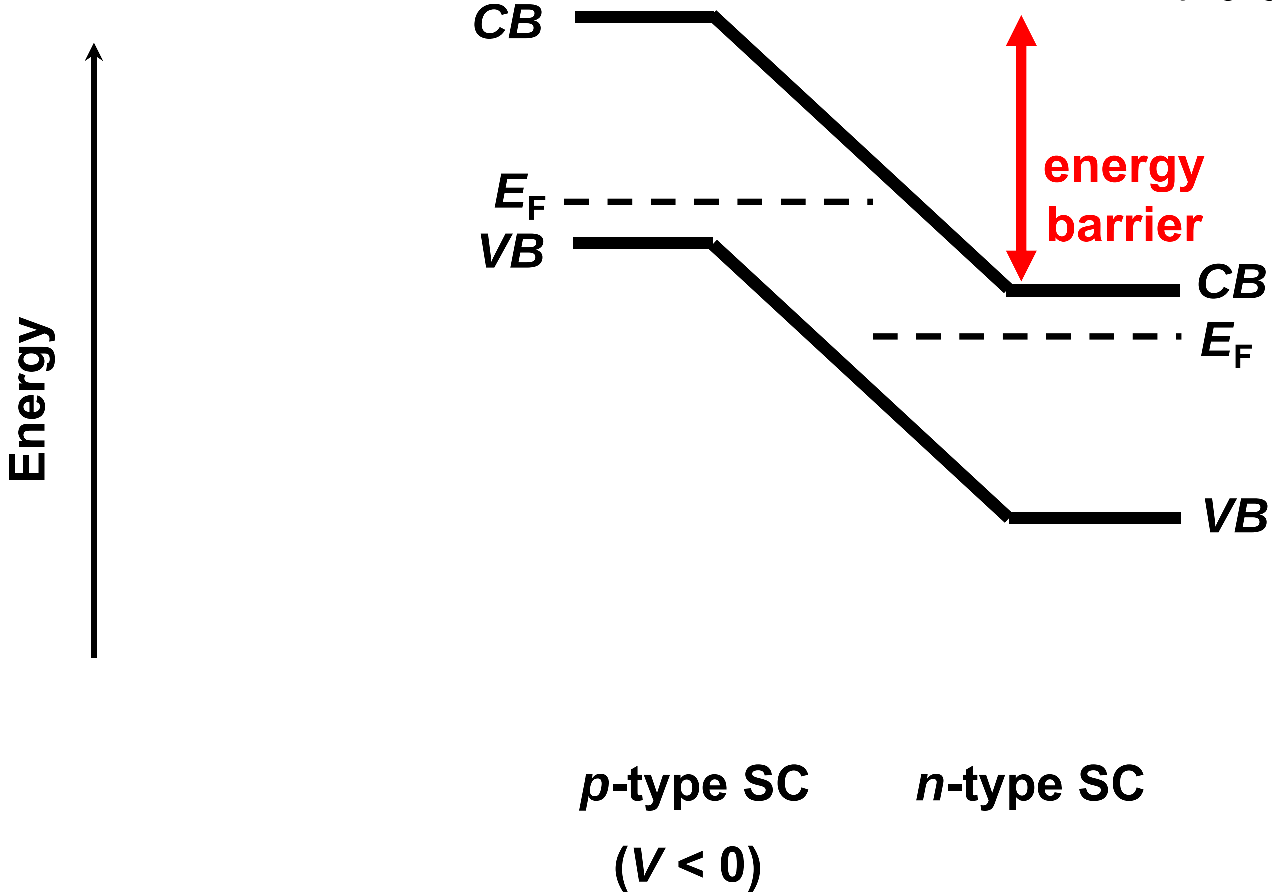


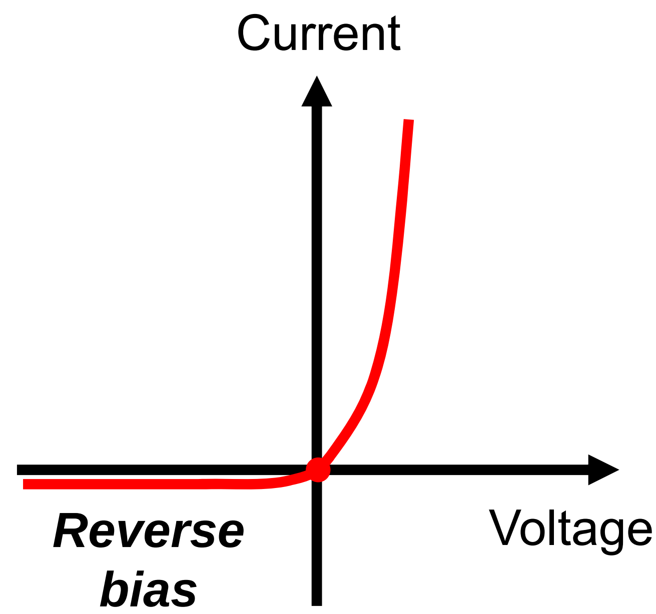


p–n Junctions

The *p-n* junction is an electrical *diode*, a device through which current flows in only one direction.

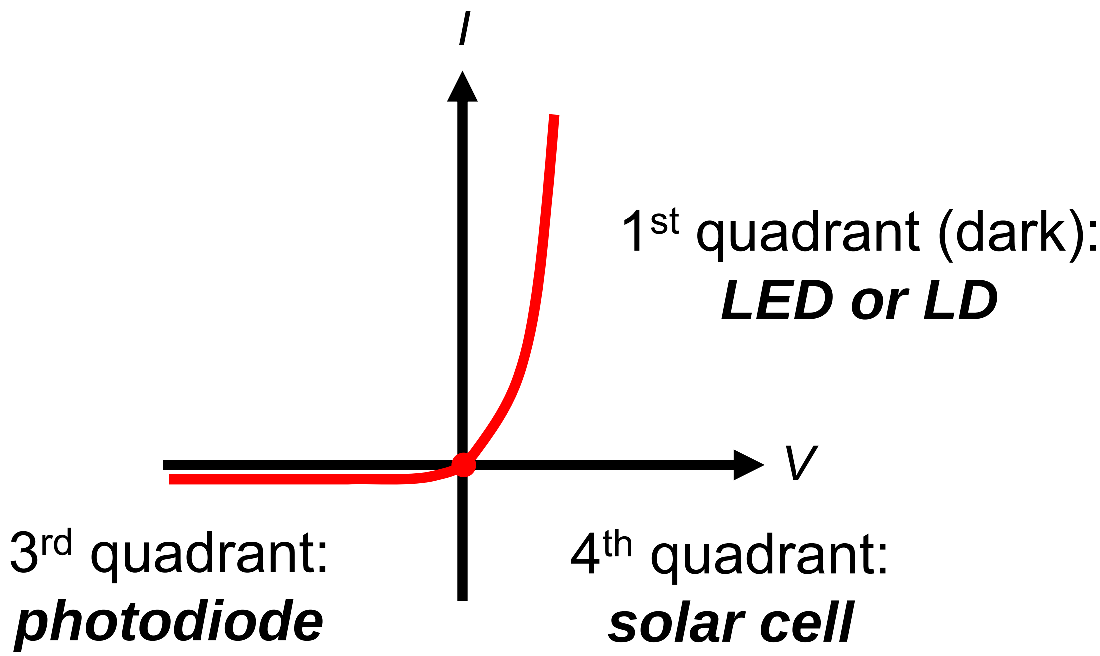
Under reverse bias, only tiny negative current flows because the energy barrier to diffusion is increased.





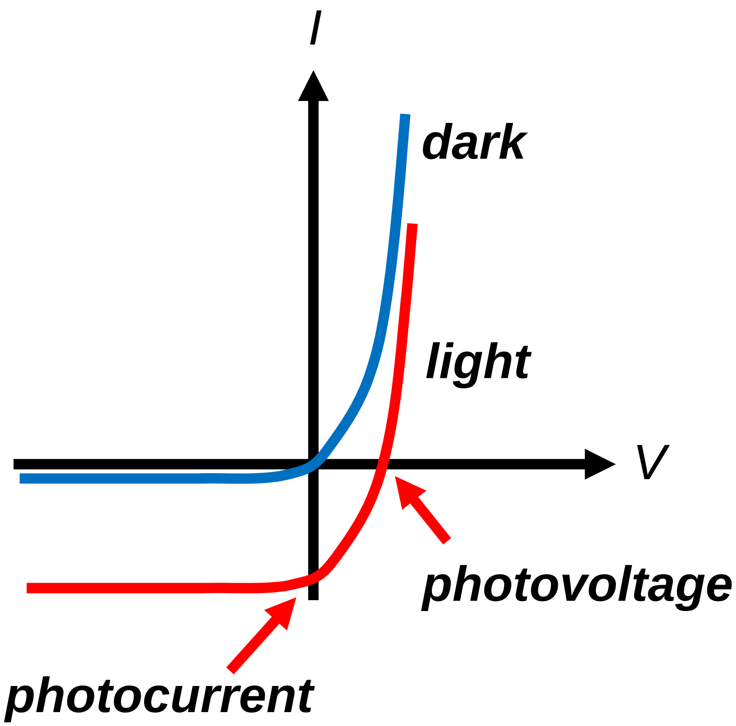
p–n Junctions

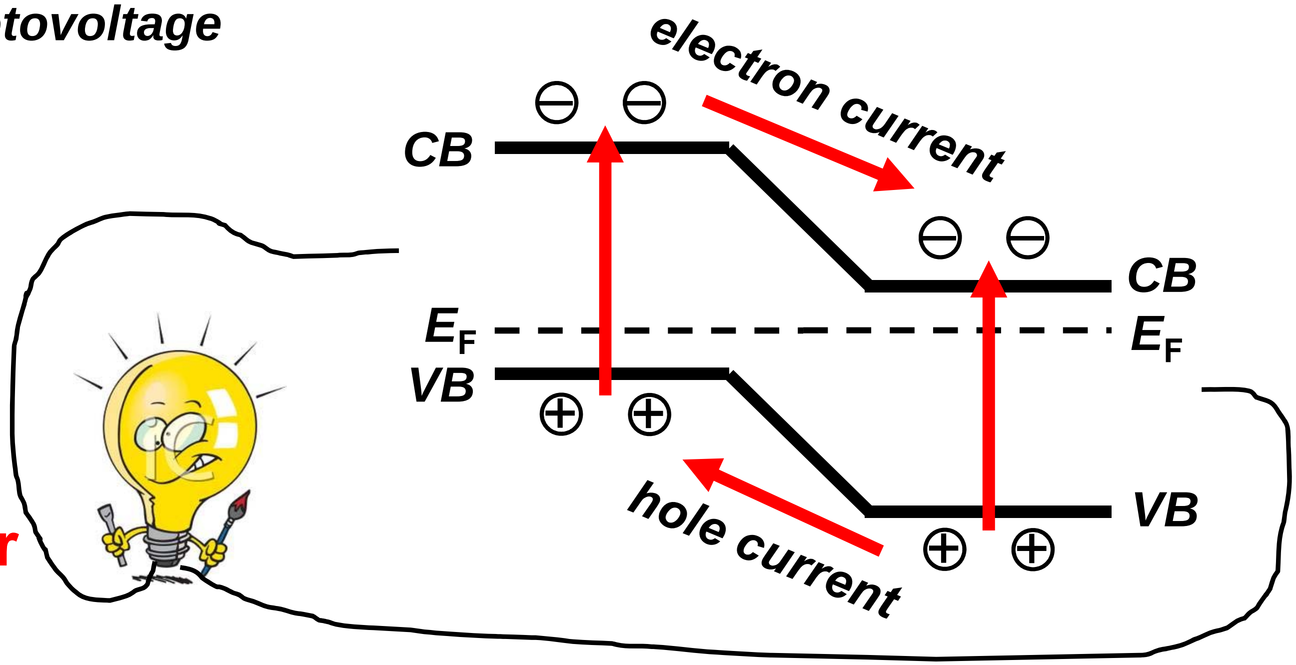
p-n **diodes are the basis for solar cells, photodiodes, light-emitting diodes (LEDs), and laser diodes.**



Solar Cells

Solar cells are illuminated *p-n* junctions. They convert sunlight into electricity.

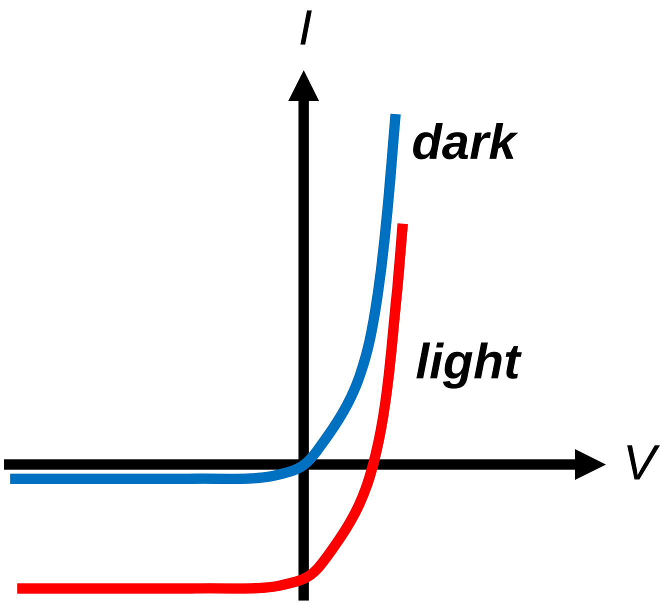


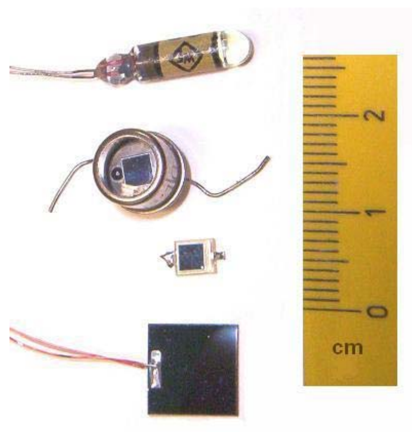


current × voltage = power

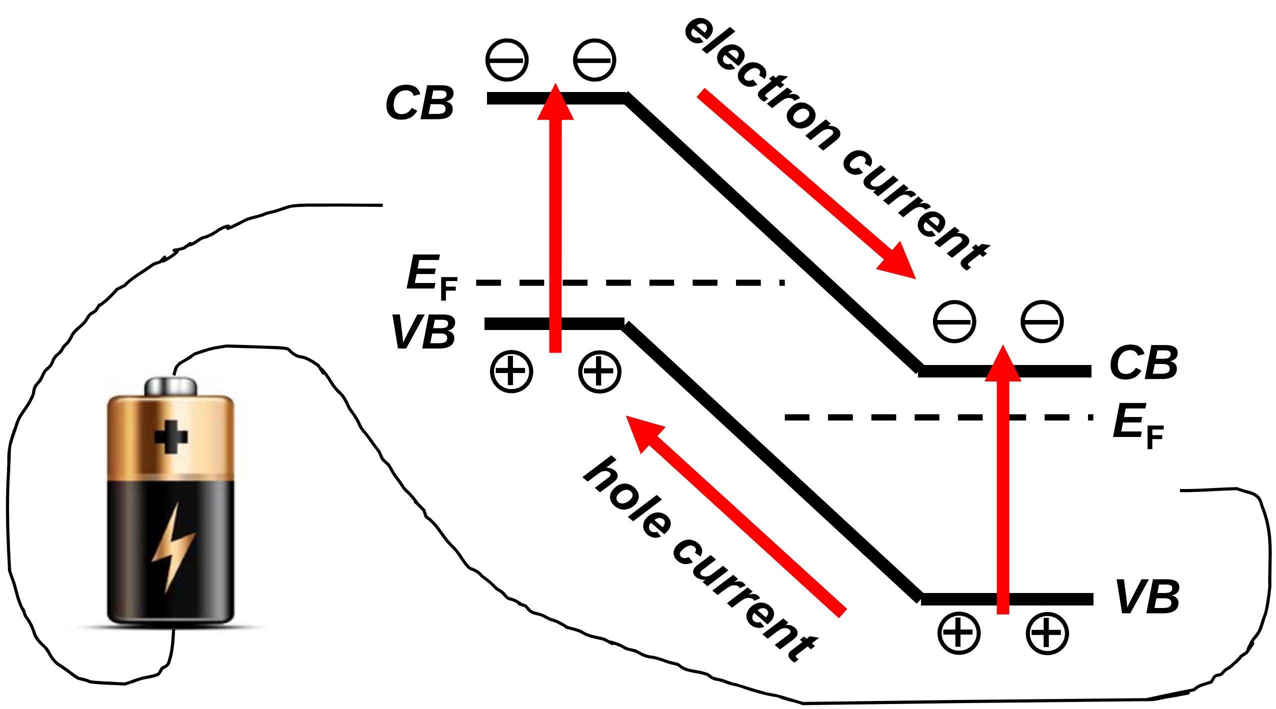
Photodiodes

Photodiodes are *p-n* junctions held in reverse bias used to detect light.



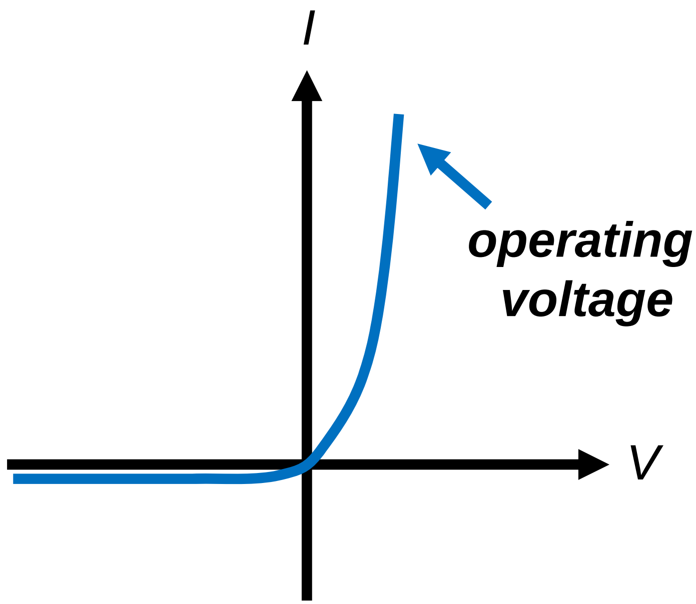


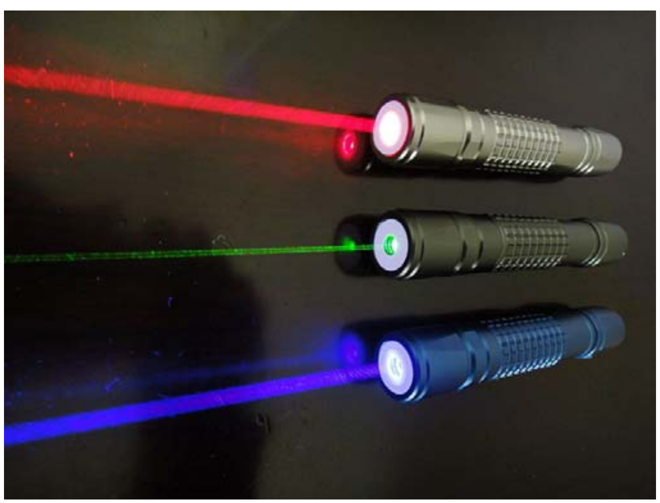
photodiode operated here to increase E-field & collect as much current as possible; also improves speed

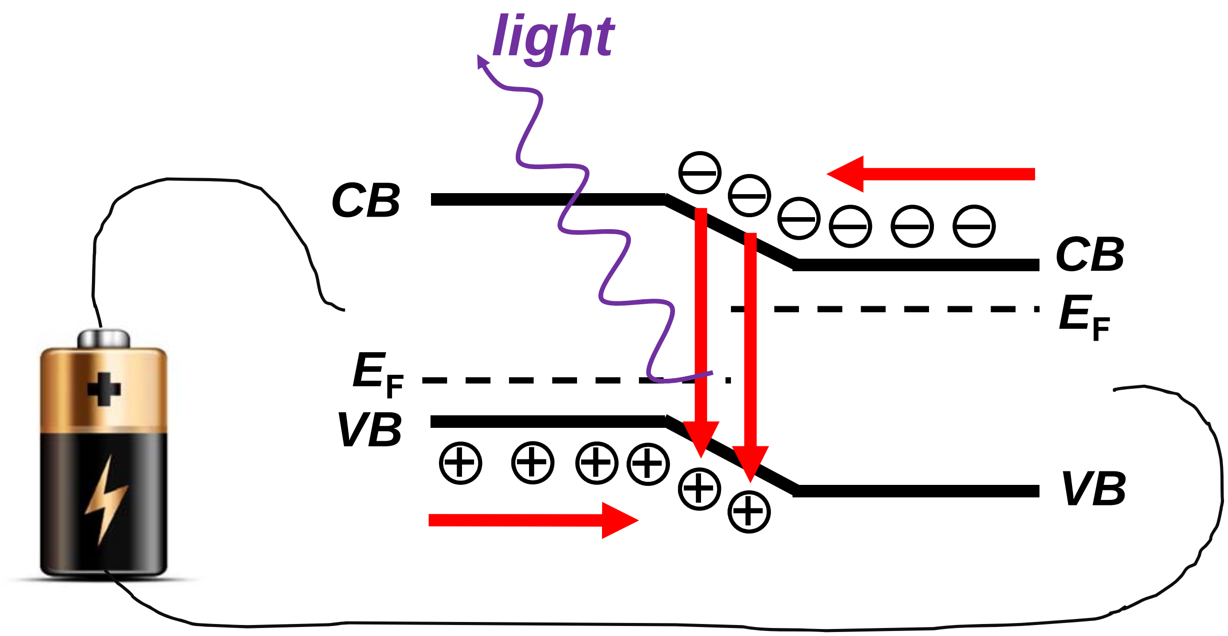


LEDs and Laser Diodes

Light-emitting diodes and laser diodes are *p-n* junctions held at large forward bias that convert electricity to light.







Chapter 7 Summary

Crystalline solids possess long-rang periodicity with a repeating unit called the unit cell.

All crystals belong to one of 14 Bravais lattices. Many crystals can be described in terms of close-packed arrays with some specific filling of tetrahedral sites (2 per ion) and octahedral sites (1 per ion).

The structures of ionic crystals depend on the ratio of ion radii, stoichiometry, and electronic factors. The lattice energy can be determined from Born-Haber cycles and calculated using the Born-Landé equation.

The frontier electronic structure of solids is characterized by valence and conduction bands, which are analogous to the HOMO and LUMO of molecules built from MO theory.

Junctions between *p*-type and *n*-type semiconductors are used to make solar cells, photodiodes, light-emitting diodes, and laser diodes.