04. DIODES

- Physics of semiconductor
- p-n junction diode
- Diode rectifier circuits
- Other diode circuits

PHYSICS OF SEMICONDUCTOR

Semiconductor

- Resistivity: conductor: $\rho < 10^{-8}\ \Omega.m$

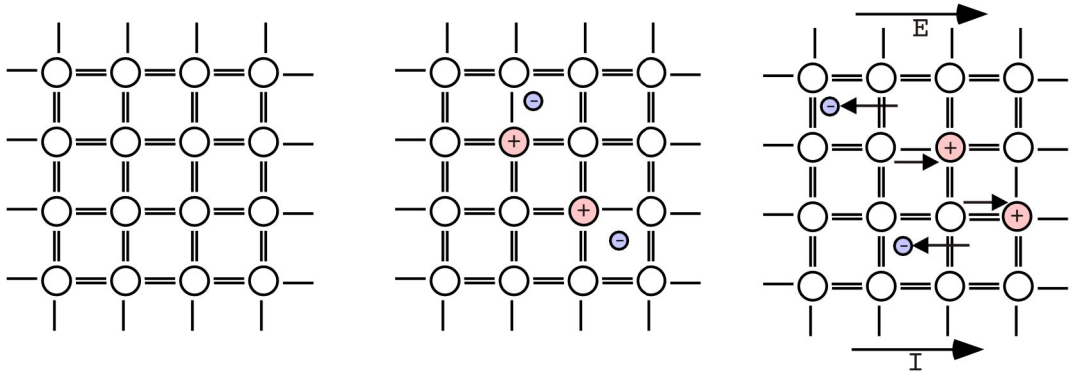
  insulator: $\rho > 10^{11}\ \Omega.m$

- resistivity of semiconductors: $\rho = 10^{-6} \sim 10^{4}\ \Omega.m$
- ρ varies over large range with temperature, voltage, impurity concentration, geometry, etc.

Intrinsic Semiconductor

- Si, Ge, GaAs, etc.
- Four valence electrons per atom
- Creation of electron-hole pairs by thermal excitation: $\propto e^{kT/E}$
- Conduction of free electrons and holes.

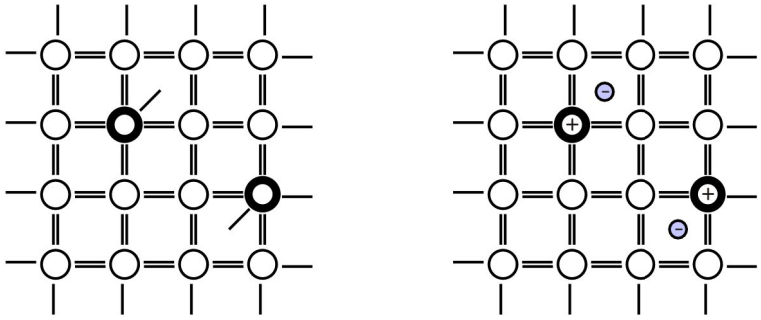
III	IV	V
^{5}B	^{6}C	^{7}N
^{13}Al	^{14}Si	^{15}P
^{31}Ga	^{32}Ge	^{33}As
^{49}In	^{50}Sn	^{51}Sb
^{81}Tl	^{82}Pb	^{83}Bi



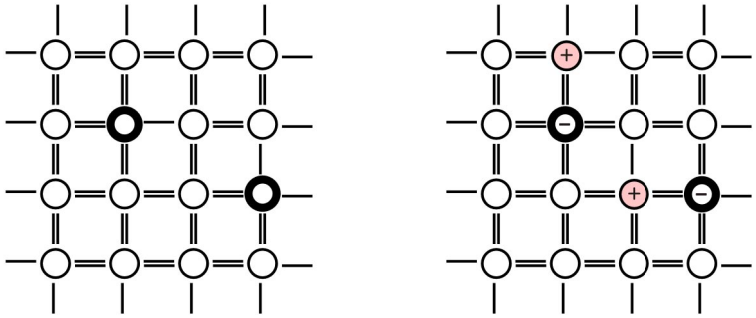
Extrinsic Semiconductor

- n-type semiconductor: doped by donor (e.g. group V elements) atoms.
- p-type semiconductor: doped by accepter (e.g. group III elements) atoms.
- Donor atoms easily give up electrons, generating free electrons.
- Accepter atoms easily take up electrons from neighbor, generating holes.

n-type semicondutor w. donor atoms generate free electrons.



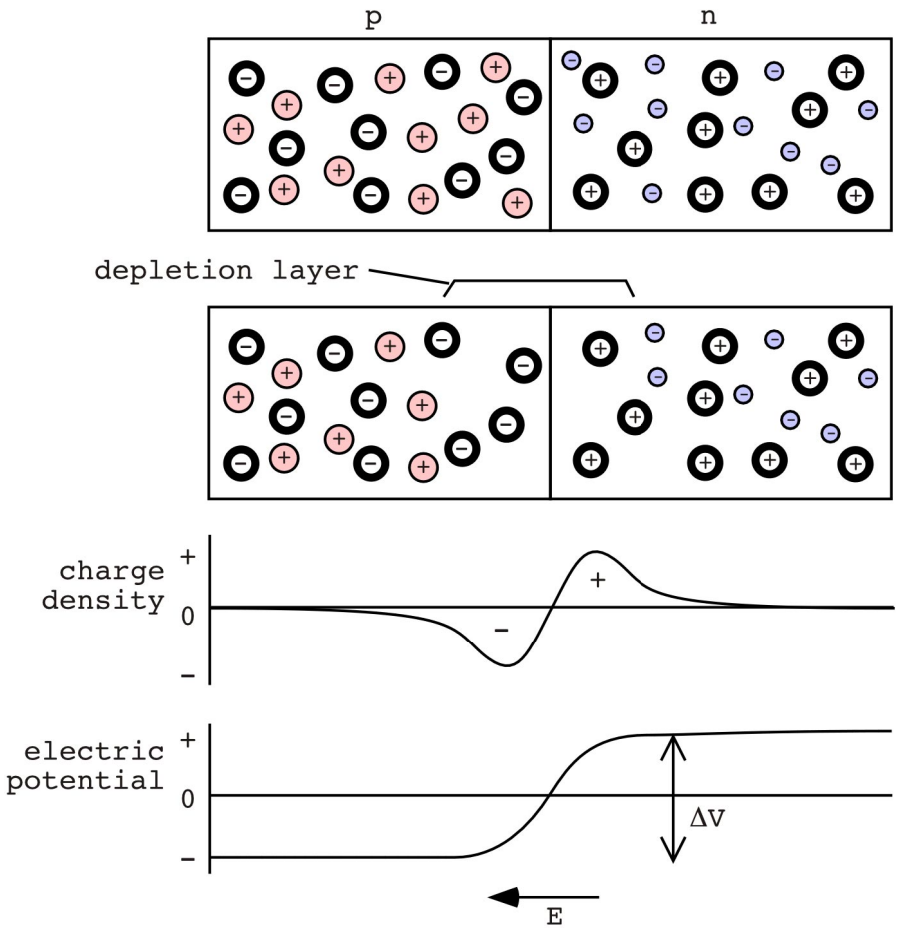
p-type semicondutor w. acceptor atoms generate holes.



p-n Junction Diode

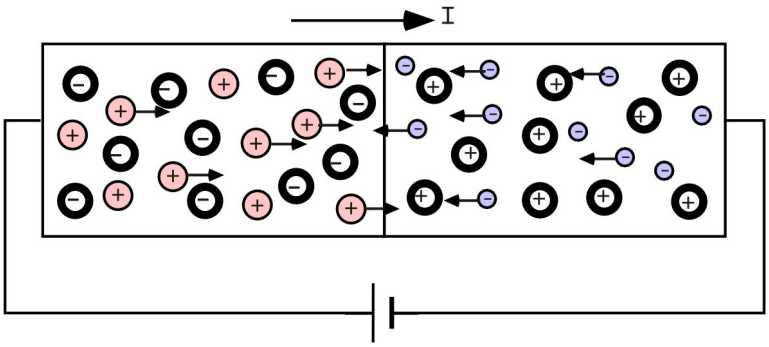
- p-type and n-type semiconductors in contact
- Recombination of holes and electrons create depletion layer.
- Net charge density of depletion layer (dipolar layer) gives rise to electric field and potential gradiant in the region.

  ΔV ~ 0.6 V for Si; ~ 0.3 V for Ge



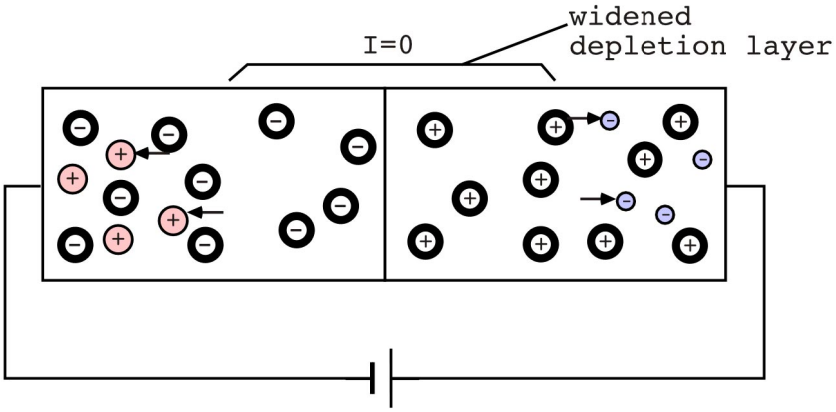
Forward-biased p-n junction:

- Raise the potential of the p-type side by more than ΔV.
- Holes and electrons flow through the junction.



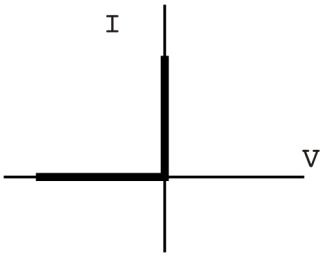
Reverse-biased p-n junction:

- Raise the potential of the n-type side.
- Holes and electrons are pushed away from the junction.
- Depletion layer widens.
- No current flows through the junction.



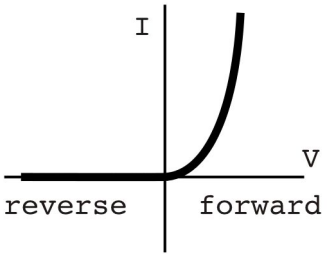
DIODE

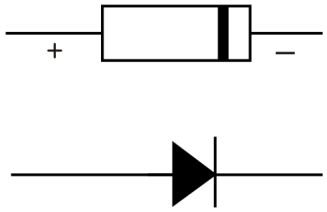
Ideal Diode

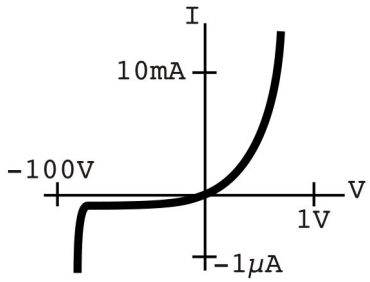


- infinite resistance for reverse bias
- zero resistance for forward bias

p-n Junction Diode







Detail of diode I-V curve:
Note the scales are very different for the forward and reverse directions.

$$I = I_s\left[\exp\left(\frac{eV}{kT}\right) - 1\right]$$

I_s: reverse saturation current (~ 0.1 μA)

e: electron charge

k: Boltzmann constant

T: temperature

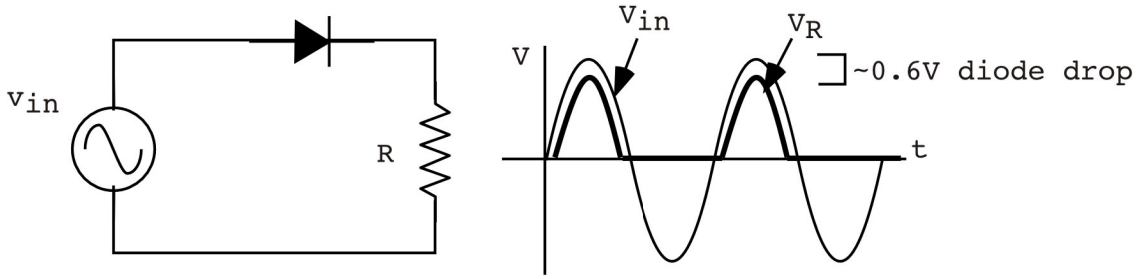
- Diode drop (ΔV_{diode}): ~0.6 V for silicon; 0.3 V for Ge

Diode Types

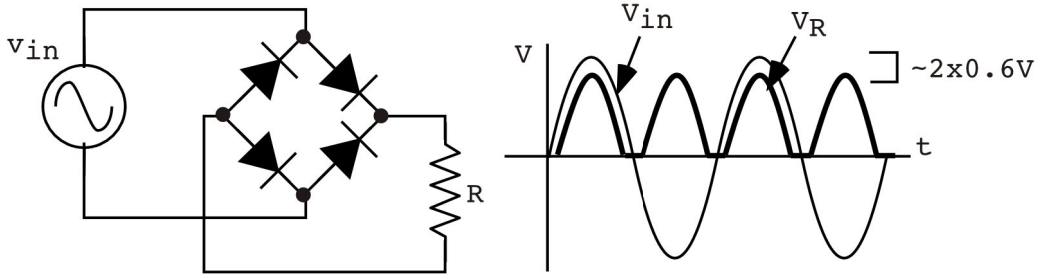
- switching diode: low power, high frequency
- rectifier: high current, high power
- LED (light emitting diode): electron-hole recombination > photon emission
  forward voltage drop: 1.5~2.5 V; 5~20 mA
- photodiode: electron-hole pair generation by absorption of photon in reverse-biased depletion layer
- Zener diode: non-destructive breakdown at specified reverse voltage; used in voltage regulation
- tunnel diode: high speed switching

DIODE RECTIFIER CIRCUITS

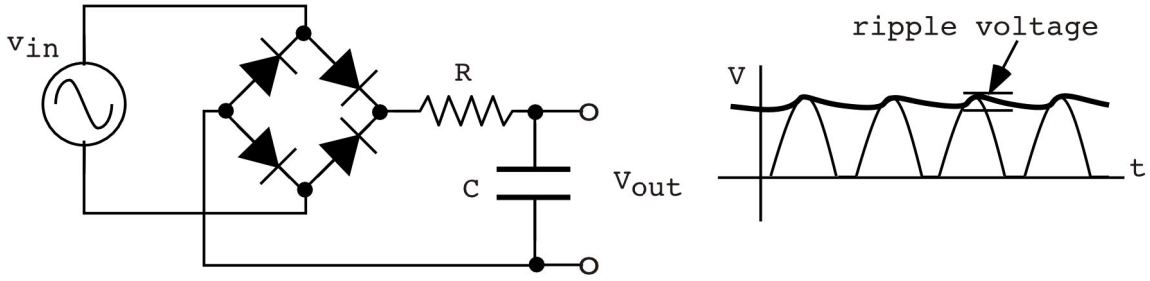
Half-Wave Rectifier



Full-Wave Bridge Rectifier



Full-Wave Rectifier with Filtering



OTHER DIODE CIRCUITS

Diode Clamp