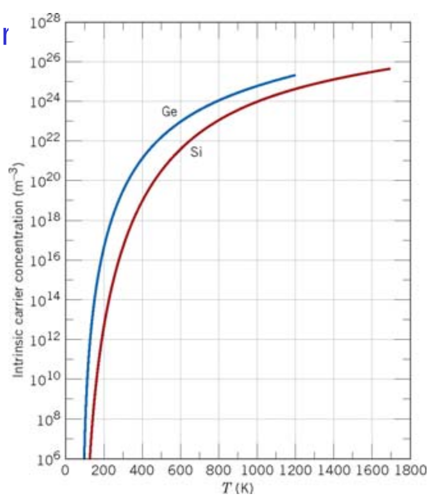
Chapter 18 Electrical properties

- ☐ Electrical conduction of semiconductor
- ☐ Factors influence carrier mobility
- ☐ Semiconductor devices
- ☐ Electrical conduction of ironic crystals and polymers

Temperature dependence of electric conductivity

☐ Carrier concentration vs T for intrinsic semiconductor



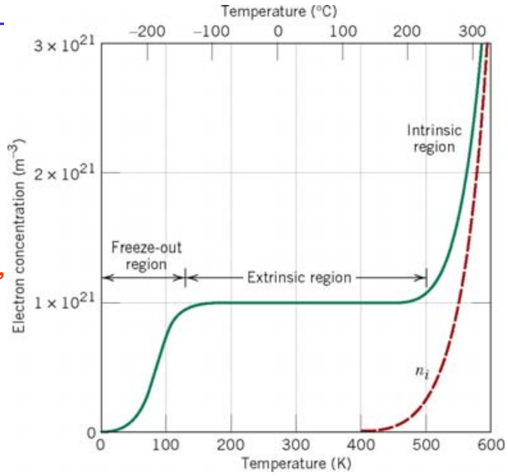
Temperature dependence of electric conductivity

☐ Carrier concentration vs T for extrinsic semiconductor

--for T < 100K: "freeze-out" thermal energy insufficient to excite electrons.

--for 150K < T < 450K: "extrinsic"

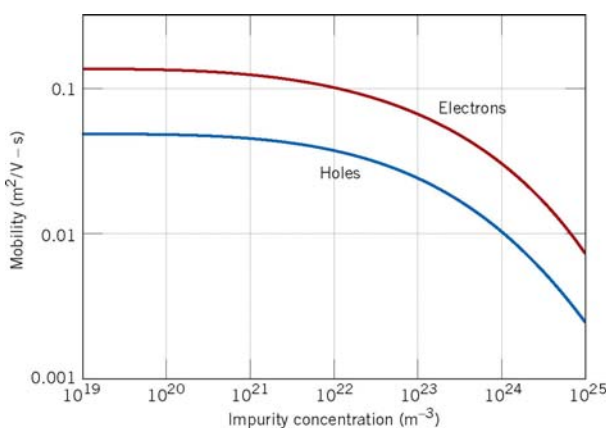
--for T >> 450K: "intrinsic"



Boron-doped silicon (green)

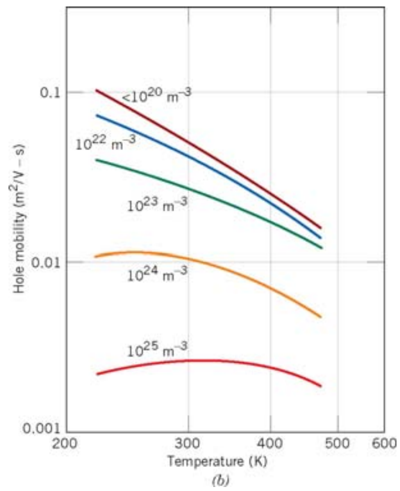
Factors that affect carrier mobility

☐ Influence of dopant content



Factors that affect carrier mobility

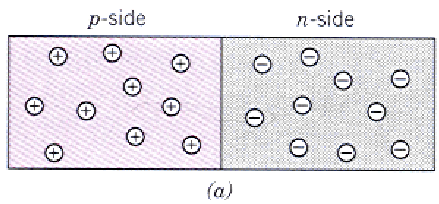
- Influence of temperature



Hole mobilities for silicon with acceptor concentrations

Semiconductor devices

- Advantages of SC devices
  - small size
  - low power consumption
  - no warm up time



- A rectifier(diode): an electronic device that allows the current to flow in one direction

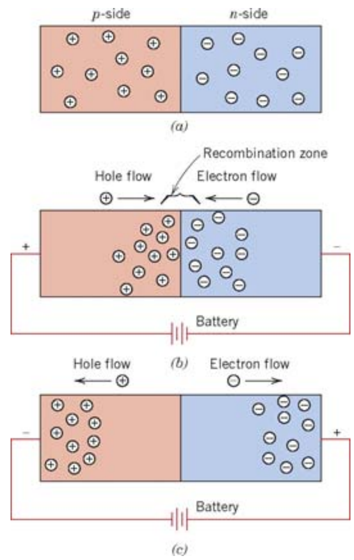
Semiconductor devices

- Allows flow of electrons in one direction only

  No applied potential: no net current flow
- Forward bias: positive terminal is connected to the positive side

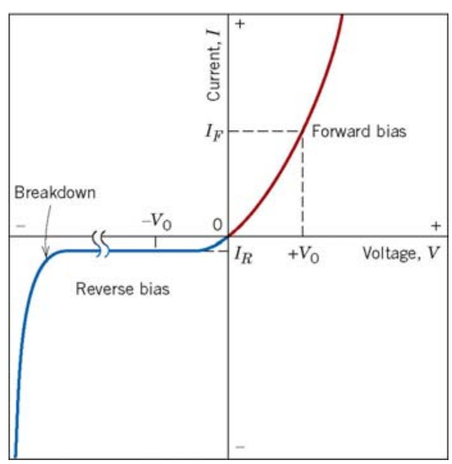
  Carrier flow through p-type and n-type regions; holes and electrons recombine at p-n junction; current flows.
- Reverse bias: negative terminal is connected to the positive side

  carrier flow away from p-n junction; carrier conc. greatly reduced at junction; little current flow.



Semiconductor devices (*cont.*)

- Current-voltage characteristics of a p-n junction for forward and reverse bias



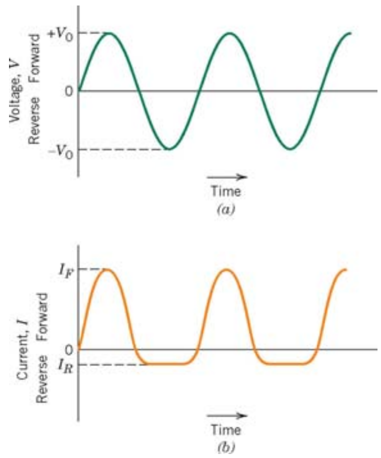
The current-voltage characteristics of a p-n junction for forward and reverse biases

Semiconductor devices (*cont.*)

- To convert alternating current to direct current

(a) input voltage

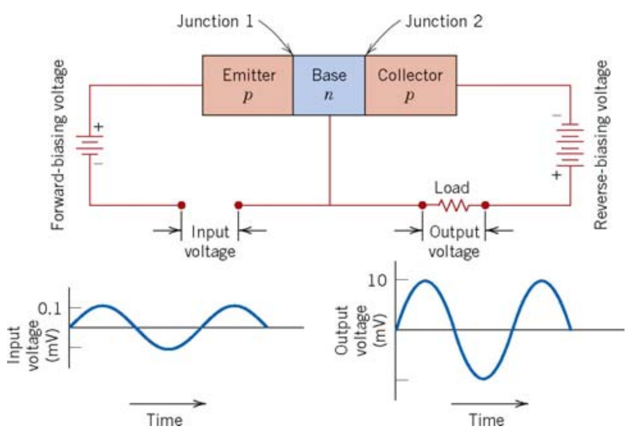
(b) output current after a rectifier

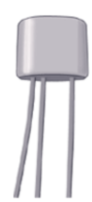


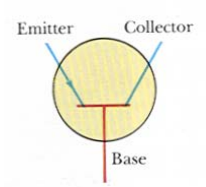
Voltage versus time for the input to a p-n rectifying junction

Semiconductor devices (*cont.*)

- p-n-p junction transistor

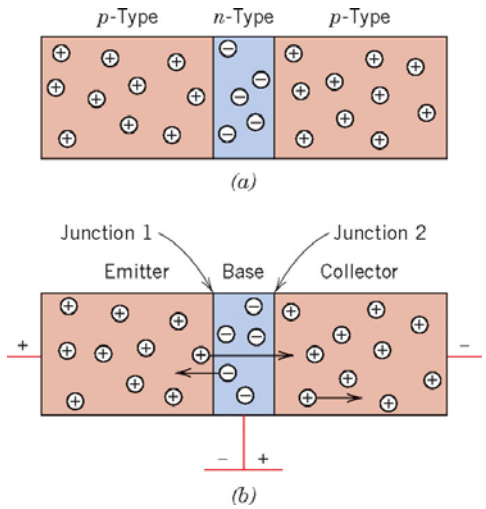


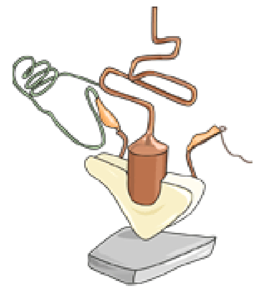




Semiconductor devices (*cont.*)

- p-n-p junction transistor

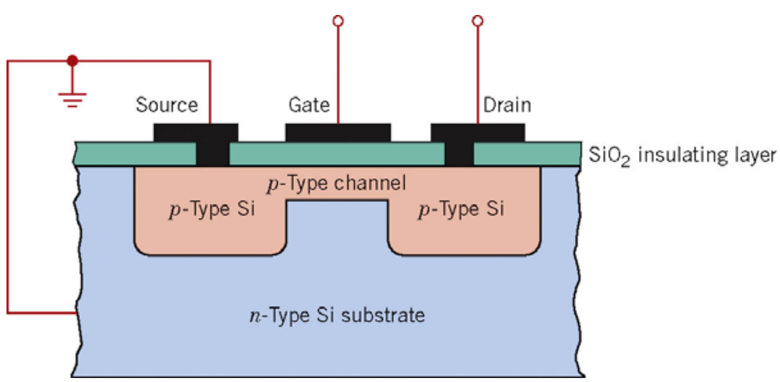




First transistor

Semiconductor devices (*cont.)*

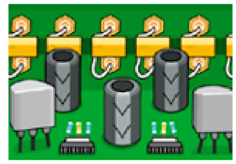
- Metal-oxide-semiconductor field-effect transistor(MOSFET)

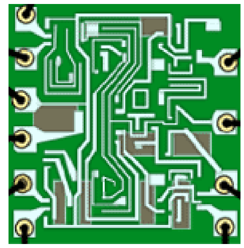


Schematic cross-sectional view of MOSFET transistor

Integrated circuit

- ☐ The limits with individual transistor
- ☐ Integrated circuit
  - 1958-59
  - Jack Kilby at Texas Instruments
  - Moore's law: the number of transistors per unit area has been doubling every 1.5 years
  - Gordon Moore: one of the early integrated circuit pioneers and founders of Intel Corporation
  - The Nobel Prize in Physics 2000 was awarded to Jack Kilby for the invention of the integrated circuit.





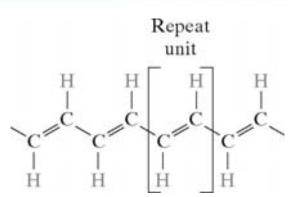
Electrical conduction in other materials

- ☐ Electrical conduction in ionic ceramics
- ☐ Electrical conduction in polymers

Table 18.4 Typical Room-Temperature Electrical Conductivities for 13 Nonmetallic Materials

Material	*Electrical Conductivity* $[(\Omega\text{-}m)^{-1}]$
Graphite	3×10^4–2×10^5
Ceramics	
Concrete (dry)	10^{-9}
Soda–lime glass	10^{-10}–10^{-11}
Porcelain	10^{-10}–10^{-12}
Borosilicate glass	$\sim 10^{-13}$
Aluminum oxide	$<10^{-13}$
Fused silica	$<10^{-18}$
Polymers	
Phenol-formaldehyde	10^{-9}–10^{-10}
Poly(methyl methacrylate)	$<10^{-12}$
Nylon 6,6	10^{-12}–10^{-13}
Polystyrene	$<10^{-14}$
Polyethylene	10^{-15}–10^{-17}
Polytetrafluoroethylene	$<10^{-17}$

Electrical conduction in conducting polymers



Summary

- Electrical conductivity and resistivity are:
  -- material parameters.
  -- geometry independent.
- Electrical resistance is:
  -- a geometry and material dependent parameter.
- Conductors, semiconductors, and insulators...
  -- differ in accessibility of energy states for
  conductance electrons.
- For metals, conductivity is increased by
  -- reducing deformation
  -- reducing imperfections
  -- decreasing temperature.
- For pure semiconductors, conductivity is increased by
  -- increasing temperature
  -- doping (e.g., adding B to Si (*p*-type) or P to Si (*n*-type).