LECTURE 1

Introductory Lecture on Section A

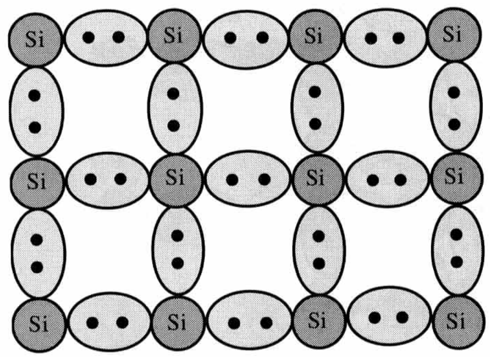
-Conducting Materials

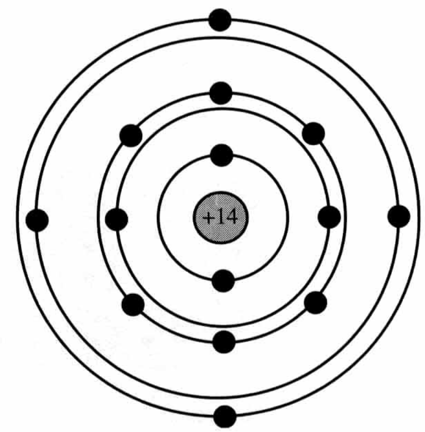
Topics to be covered

- Review of energy bands
- Description of materials
- Drift velocity
- Collision Time, Mean Free Path

Semiconductors: Si, Ge, and Compound (III-V, II-VI)

Covalent bonding: no free electrons at 0K





Four valence electrons

Figure 1–13 Simple representation of silicon atoms bonded in a crystal (left). The dotted areas are covalent or shared electron bonds. The electronic structure of a single Si atom is shown conceptually on the right. The four outermost electrons are the valence electrons that participate in the covalent bonds.

N-type dopants

P-type dopants →

II^B	III^A	IV^A	V^A	VI^A
	5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00
	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06
30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96
48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6
80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** 209

Figure 1–14 Portion of the periodic table relevant to semiconductor materials and doping. Elemental semiconductors are in column IV. Compound semiconductors are combinations of elements from columns III and V (or II and VI).

Dopants have

- to be compatible with processing (ex. slow diffusion through oxide)
- to have high solubility in Si

Intrinsic Semiconductor

Electron and hole generation occur at elevated temperature (above 0K).
n=p

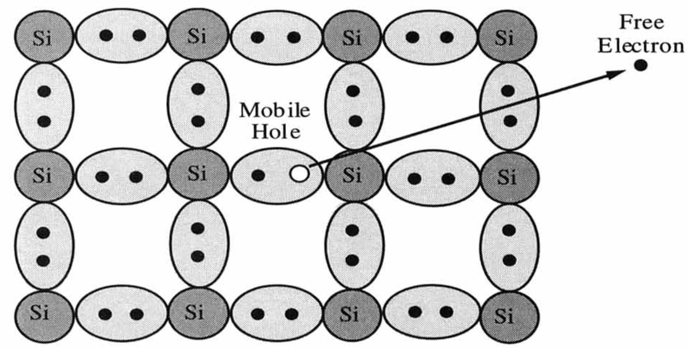


Figure 1–15 Electron (-) and hole (+) pair generation represented by a broken bond in the crystal. Both carriers are mobile and can carry currents in devices.

Energy Band Gap determines the intrinsic carrier concentration. n_i $E_{gGe} < E_{gSi} < E_{gGaAs}$

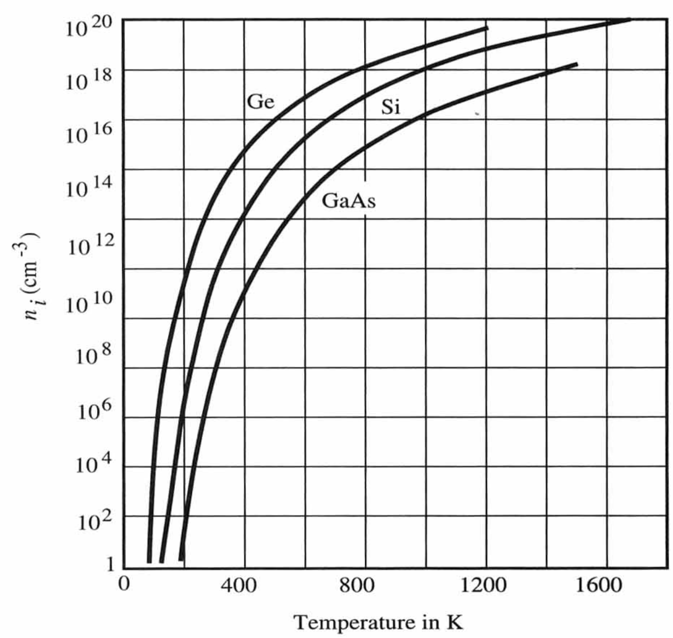


Figure 1–16 Intrinsic carrier concentration versus temperature in common semiconductors. After [1.9].

For devices we need concentrations: n and p>>n_i

Drift and Diffusion

- Since current is the rate of flow of charge , we shall be able calculate currents flowing in real devices since we know the number of charge carriers. There are two current mechanisms which cause charges to move in semiconductors. The two mechanisms we shall study in this chapter are *drift and diffusion*.

Electron Conductivity

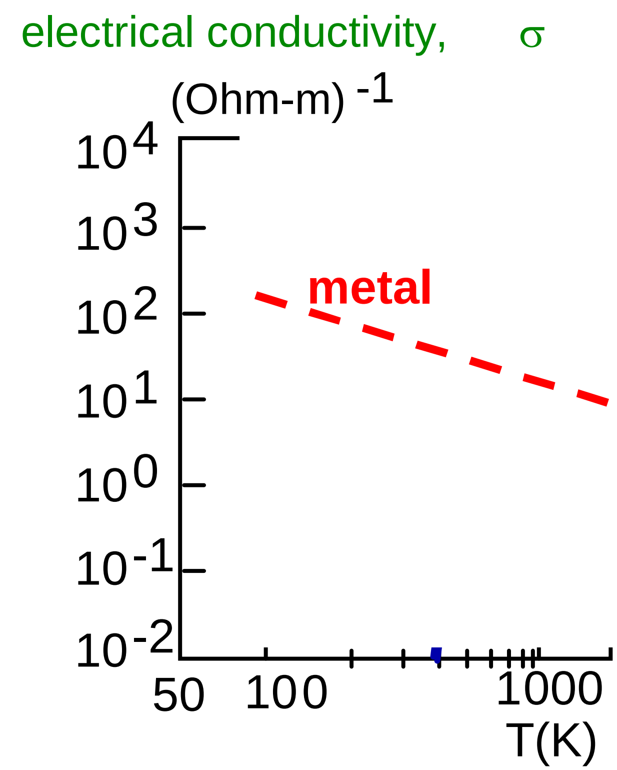
$$\sigma_e = n|e|\mu_e = 1/\rho$$

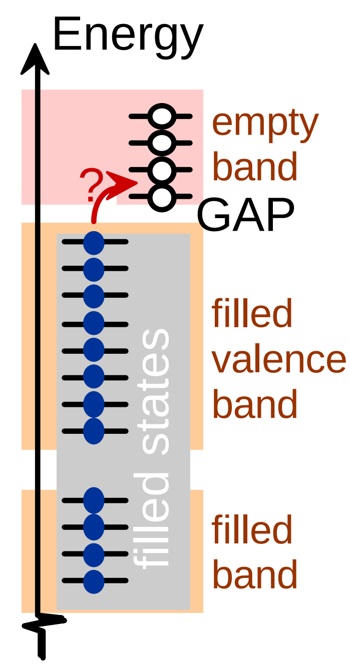
- **Metals**
  - Dominated by mobility, which decreases with increasing Temperature due to increased probability of scattering.

- **Intrinsic Semiconductors** (no dopants)
  - Dominated by number of carriers, which increases exponentially with increasing Temperature due to increased probability of electrons jumping across the band gap.

$$n_{electrons} \propto e^{-E_{gap}/kT}$$

n=electrons/m^3 (10^{16} for Si)





Carrier mobility vs T

$$\sigma = n|e|\mu_e + p|e|\mu_h \approx n|e|\mu_e = N_d|e|\mu_e$$

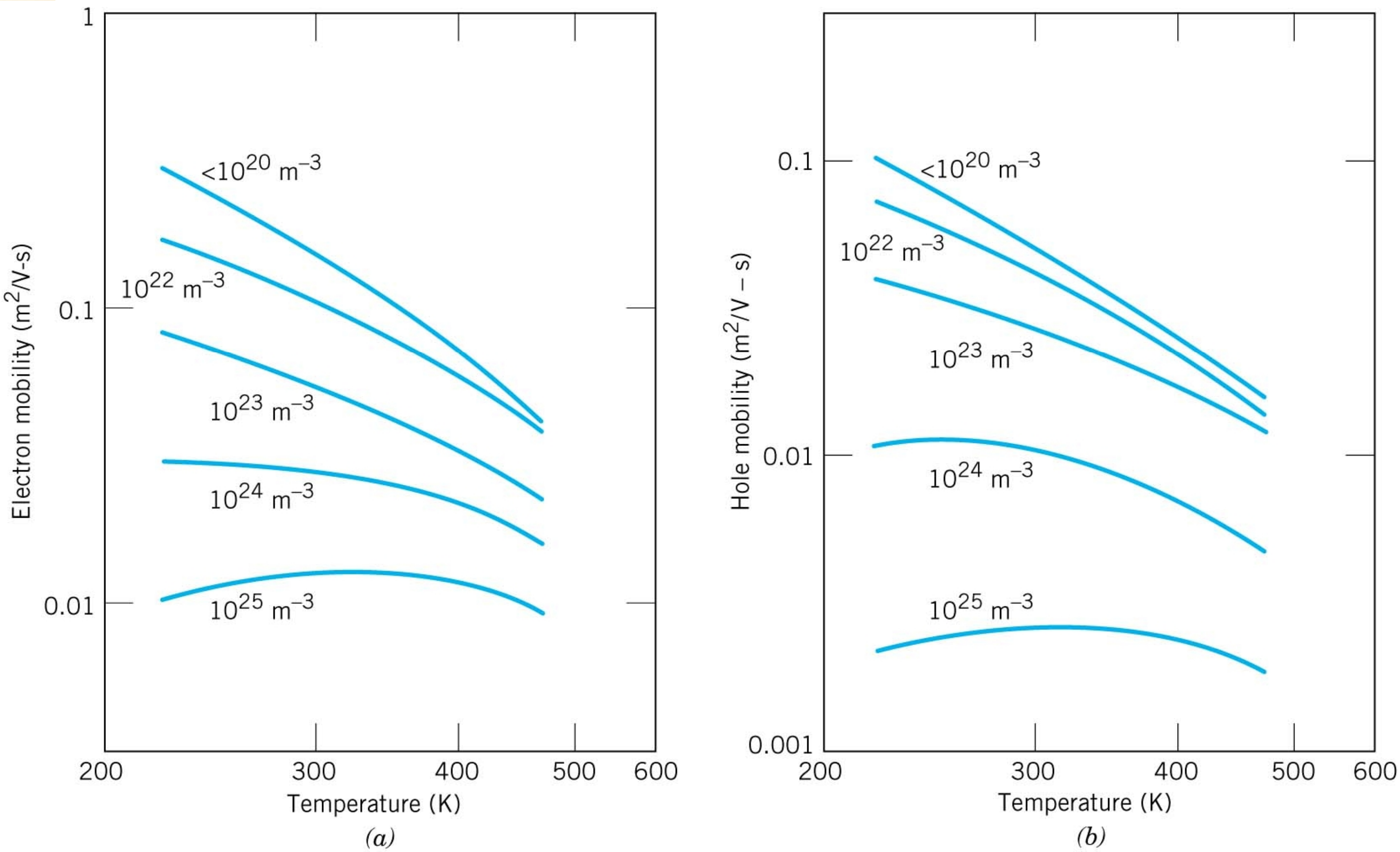


FIGURE 18.18 Temperature dependence of (*a*) electron and (*b*) hole mobilities for silicon that has been doped with various donor and acceptor concentrations. Both sets of axes are scaled logarithmically. (From W. W. Gärtner, "Temperature Dependence of Junction Transistor Parameters," *Proc. of the IRE,* **45,** 667, 1957. Copyright © 1957 IRE now IEEE.)