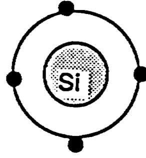
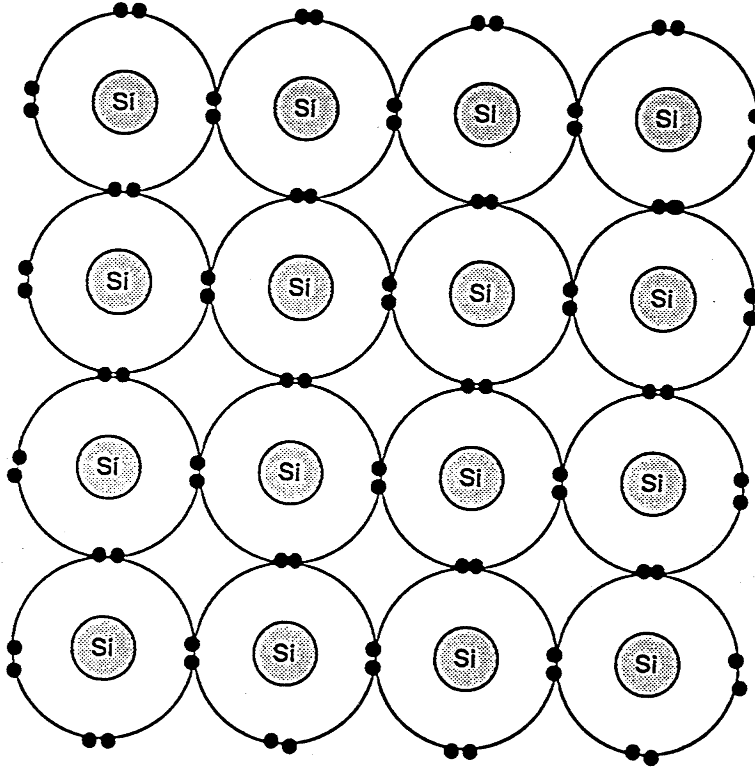
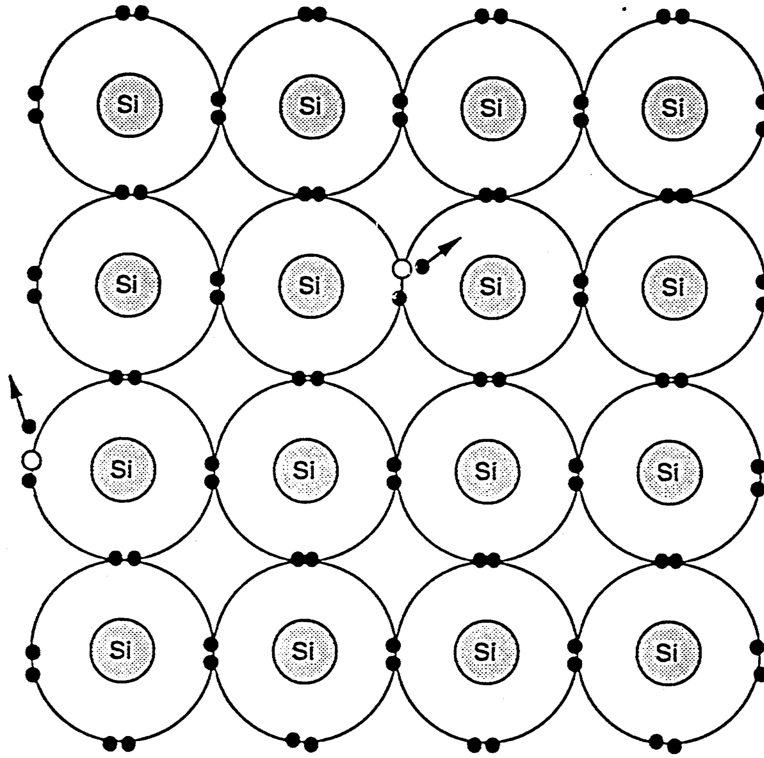
Covalent Bonding

Silicon is a Group IV Element:





Outer Orbitals are filled with 8 electrons by sharing

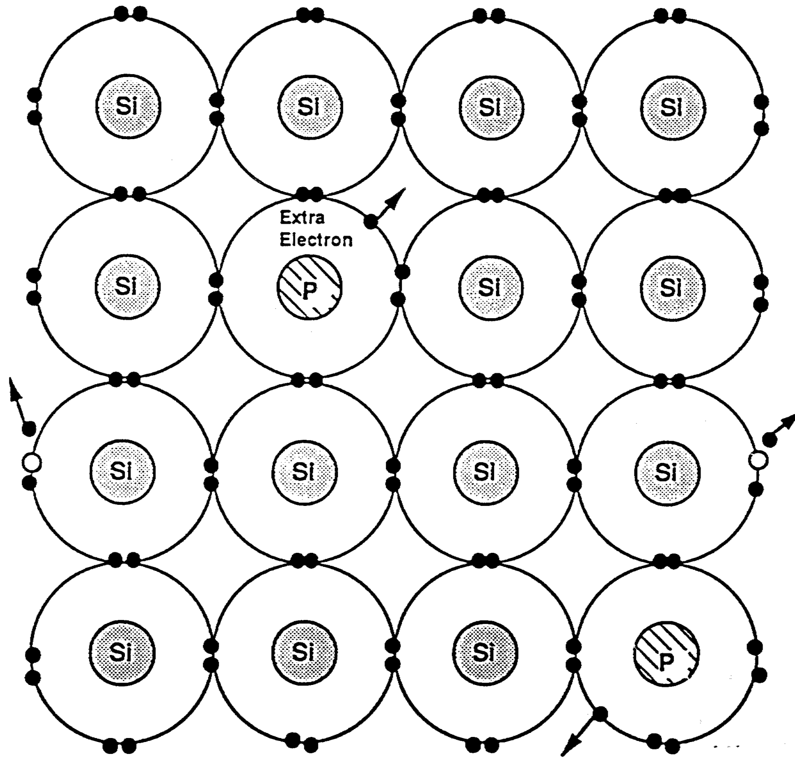


Electrons may gain enough energy to break away. This creates (1) A free electron, charge -q
(2) A free hole, charge +q

Doping

n-type

Add a group V element (P or As)



Number of electrons per cm ^{3} $= n_n$ Majority carriers

Number of holes per cm ^{3} $= p_n$ Minority carriers

$g_v(E)[1 - f(E)]$ yields the distribution of holes (unfilled states) in the valence band. Sample carrier distributions for three different assumed positions of the Fermi energy (along with associated energy band diagram, Fermi function, and density of states plots) are pictured in Fig. 2.16.

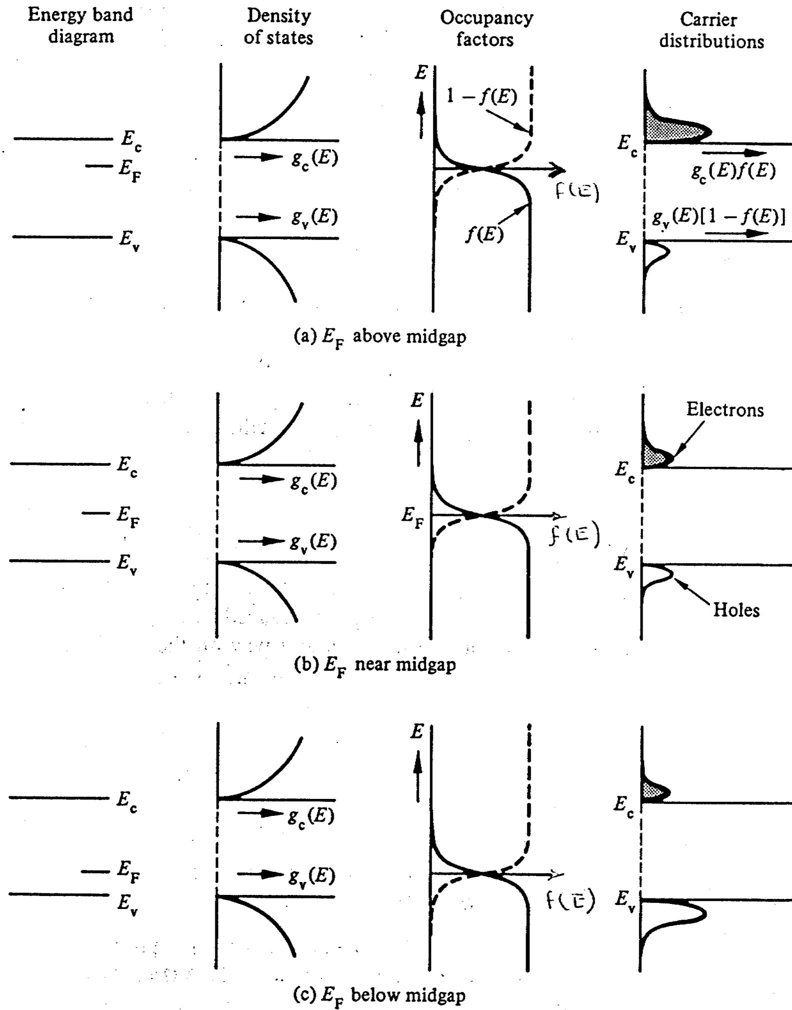
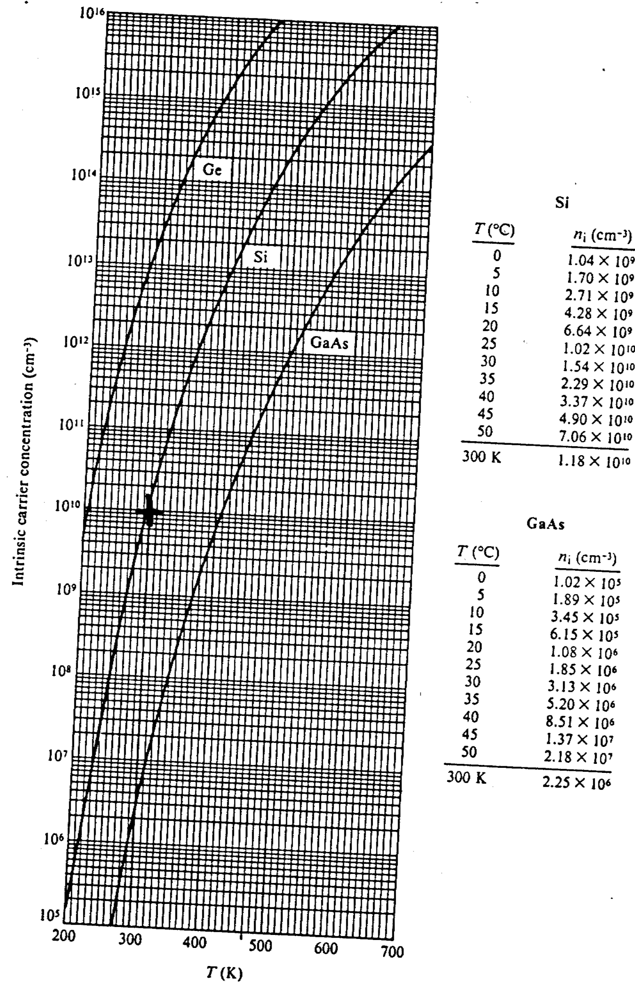


Fig. 2.16 Carrier distributions (not drawn to scale) in the respective bands when the Fermi level is positioned (a) above midgap, (b) near midgap, and (c) below midgap. Also shown in each case are coordinated sketches of the energy band diagram, density of states, and the occupancy factors (the Fermi function and one minus the Fermi function).



Si

T (°C)	n_i (cm^{-3})
0	1.04×10^{9}
5	1.70×10^{9}
10	2.71×10^{9}
15	4.28×10^{9}
20	6.64×10^{9}
25	1.02×10^{10}
30	1.54×10^{10}
35	2.29×10^{10}
40	3.37×10^{10}
45	4.90×10^{10}
50	7.06×10^{10}
300 K	1.18×10^{10}

GaAs

T (°C)	n_i (cm^{-3})
0	1.02×10^{5}
5	1.89×10^{5}
10	3.45×10^{5}
15	6.15×10^{5}
20	1.08×10^{6}
25	1.85×10^{6}
30	3.13×10^{6}
35	5.20×10^{6}
40	8.51×10^{6}
45	1.37×10^{7}
50	2.18×10^{7}
300 K	2.25×10^{6}

Fig. 2.20 Intrinsic carrier concentrations in Ge, Si, and GaAs as a function of temperature.

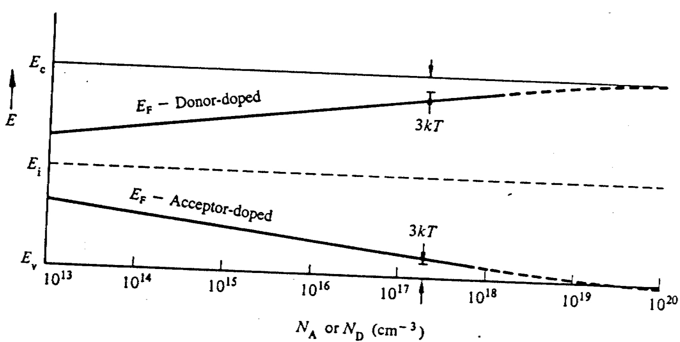
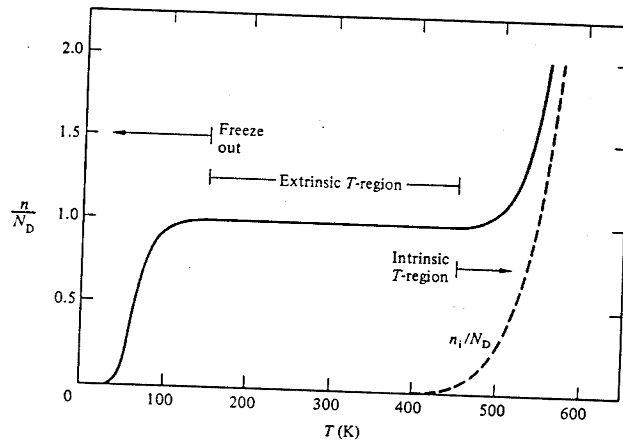


Fig. 2.21 Fermi level positioning in Si at room temperature as a function of the doping concentration. The solid E_F lines were established using Eq. (2.38a) for donor-doped material and Eq. (2.38b) for acceptor-doped material (kT = 0.0259 eV, and $n_i = 10^{10}/cm^3$).



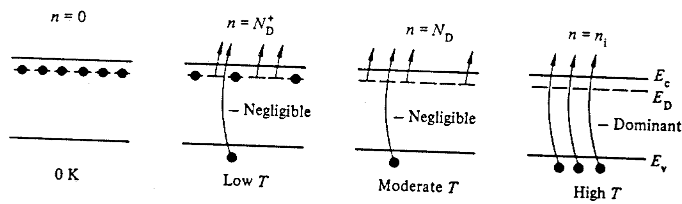


Fig. 2.22 (a) Typical temperature dependence of the majority-carrier concentration in a doped semiconductor. The plot was constructed assuming a phosphorus-doped $N_D = 10^{15}/cm^3$ Si sample. n_i/N_D versus T (dashed line) has been included for comparison purposes. (b) Qualitative explanation of the concentration-versus-temperature dependence displayed in part (a).