Intrinsic Carrier Concentration

I. Definition Intrinsic semiconductor: A semiconductor material with no dopants. It electrical characteristics such as concentration of charge carriers, depend only on pure crystal.

II. To derive carrier concentration in thermal equilibrium condition that is in a steady state condition at a given temperature without any external excitation.

III. Practical an intrinsic semiconductor is one that contains relatively small amount of impurities.

Intrinsic Carrier Concentration

I. To obtain the electron density (number of electron per unit volume) in intrinsic semiconductor , we must evaluate the electron density in an incremental energy range dE.

II. Density n(E) is given by product of density states N(E) and a probability of occupying energy range F(E).

III. Thus the electron density is given by:

$$n = \int_0^{ETOP} n(E)dE = \int_0^{ETOP} N(E)F(E)dE$$

Intrinsic Carrier Concentration

Where n is in cm^{-3} and N(E) is in $(cm^{3-}eV)$-1.

The probability that an electron occupies and electronic state with energy E is given by Fermi-Dirac distribution.

$$F(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{kT}}}$$

k is Boltzman constant, t is temperature(K), E_F is Fermi level.

Intrinsic Semiconductor

- The Fermi energy is the energy at which the probability of occupation by an electron is exactly on half.

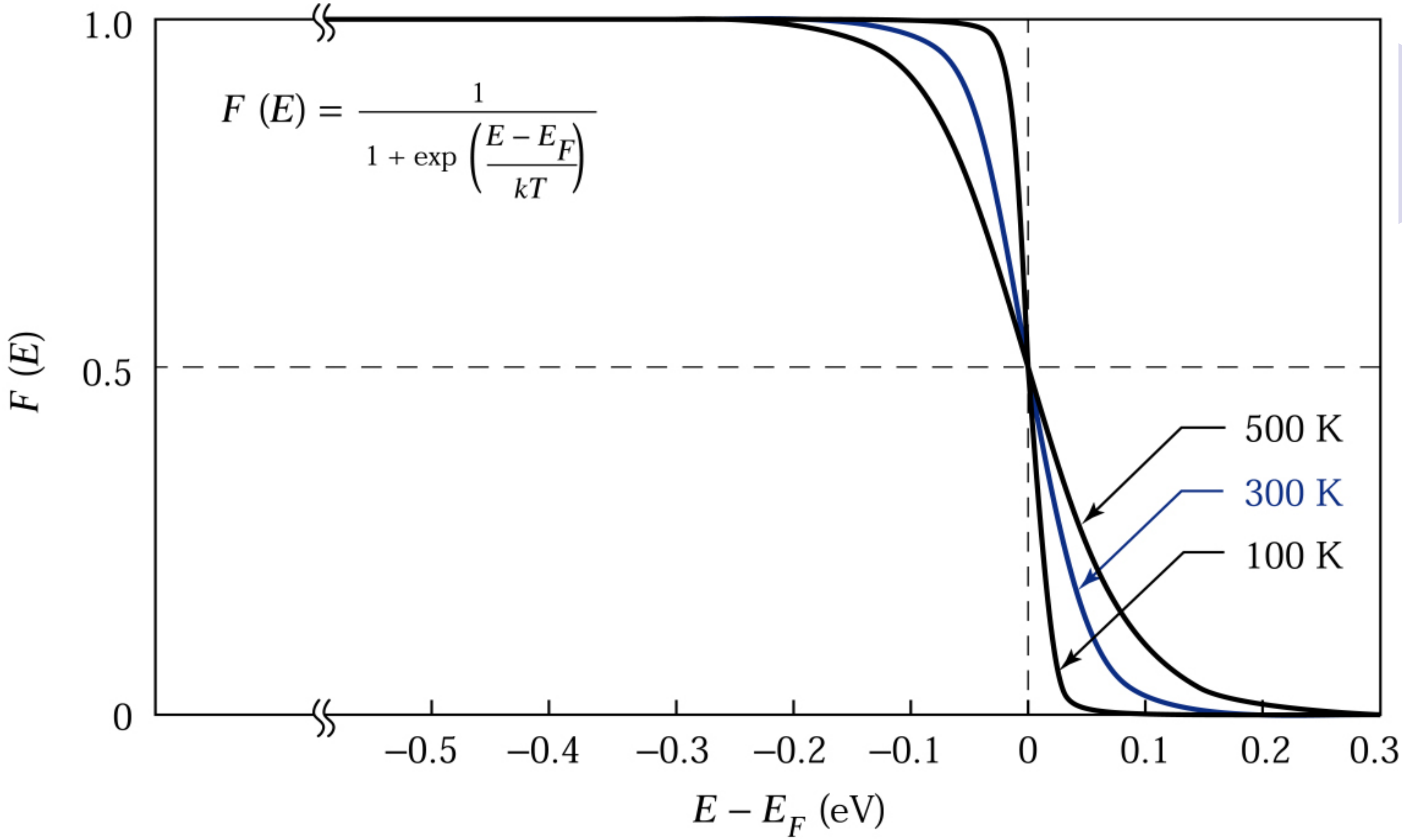
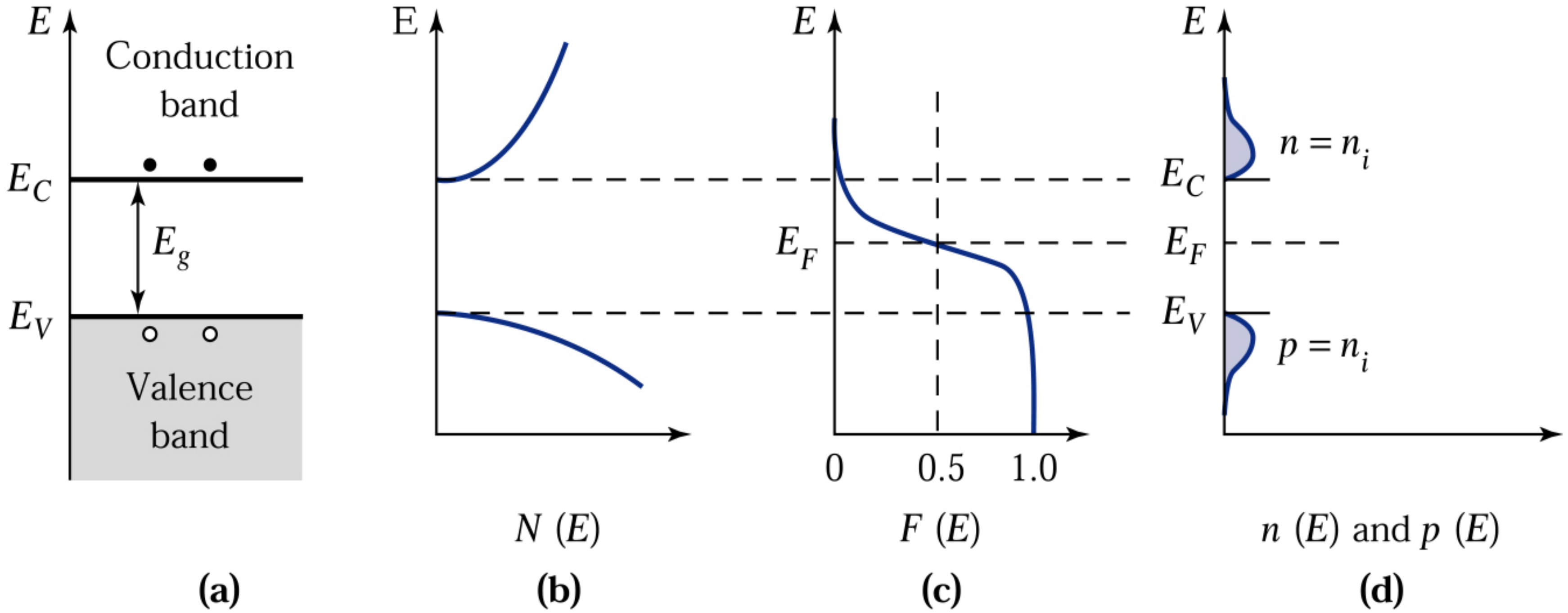


Figure 2.20. Fermi distribution function $F(E)$ versus $(E - E_F)$ for various temperatures.

Figure 2.21. Intrinsic semiconductor. (*a*) Schematic band diagram. (*b*) Density of states. (*c*) Fermi distribution function. (*d*) Carrier concentration.



Intrinsic Carrier Concentration

- There are large number of allowed states in the conduction band.
- However there will not be many electrons in the conduction band.
- Therefore the possibility for the electron to be in region is very low.
- If we refer to the bottom of the conduction band the electron density is equivalent to

Intrinsic semiconductor

- Electron density in the conduction band.

$$n = N_C \exp[{}^{-(E_C - E_F)}/_{kT}]$$

- $N_C = 2.86 \times 10^{19} cm^{-3}$ for silicon and $4.7 \times 10^{17} cm^{-3}$ for gallium arsenide.

$$p = N_V \exp[{}^{-(E_F - E_V)}/_{kT}]$$

- $N_V = 2.66 \times 10^{19} cm^{-3}$ for silicon and $7 \times 10^{18} cm^{-3}$ for gallium arsenide

Intrinsic Semiconductor

- In intrinsic semiconductor the number of electron per unit volume is equal to number of hole per unit volume in the valence band.

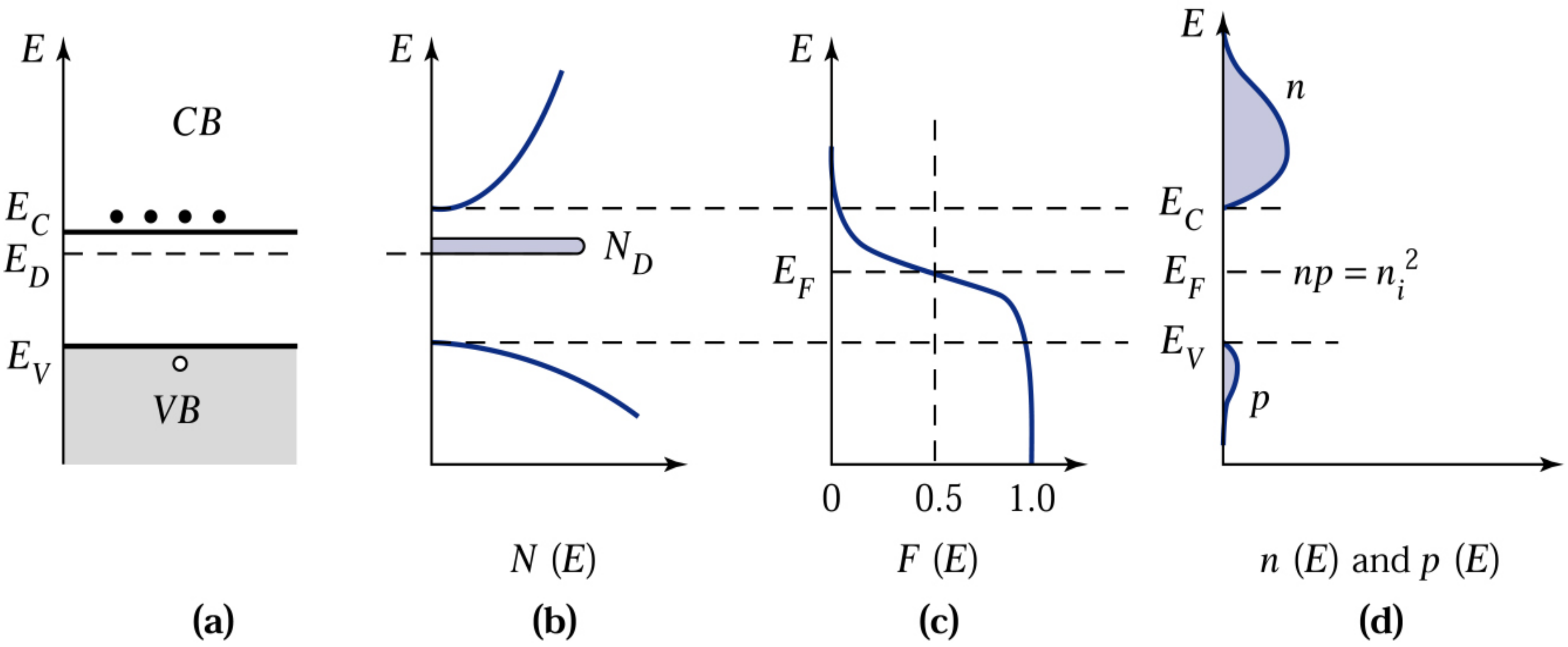
$$np = n_i^{\ 2}$$

- The larger the band gap the smaller intrinsic carrier density.

Nondegenerated Semiconductor

- For shallow donors in silicon there usually enough energy to ionize all donor impurities at room temp.
- This condition is called complete ionization.
- Therefore $n = N_D$
- $E_C - E_F = kT \ln (N_C/N_D)$
- Same case applies to hole.

Figure 2.26. *n*-Type semiconductor. (*a*) Schematic band diagram. (*b*) Density of states. (*c*) Fermi distribution function (*d*) Carrier concentration. Note that $np = n_i^2$.



- Reading assignment read on the Degenerated Semiconductor

Carrier Transport Phenomena (Carrier Drift)

Mobility

- Electrons move in all different direction.
- When small electric field E is applied to the semiconductor electron will experience force. –qE.
- The electron will accelerated along the field. In opposite direction.
- Additional component is called a drift velocity.

Mobility

- The momentum applied to an electron is momentum gained.

$$-q\varepsilon\tau_c = m_n v_n$$

$$v_n = -\left(\frac{q\tau_C}{m_n}\right)\varepsilon$$

- The drift velocity depend on the applied electric field.

Mobility

- The proportionality factor is called electron mobility

$$\mu_n \equiv \frac{q\tau_c}{m_n}$$

- Is important parameter in carrier transport because it describes how strongly the motion of electron in influenced by applied electric field.

Mobility

- Drift velocity

$$v_n = -\mu_n \varepsilon$$

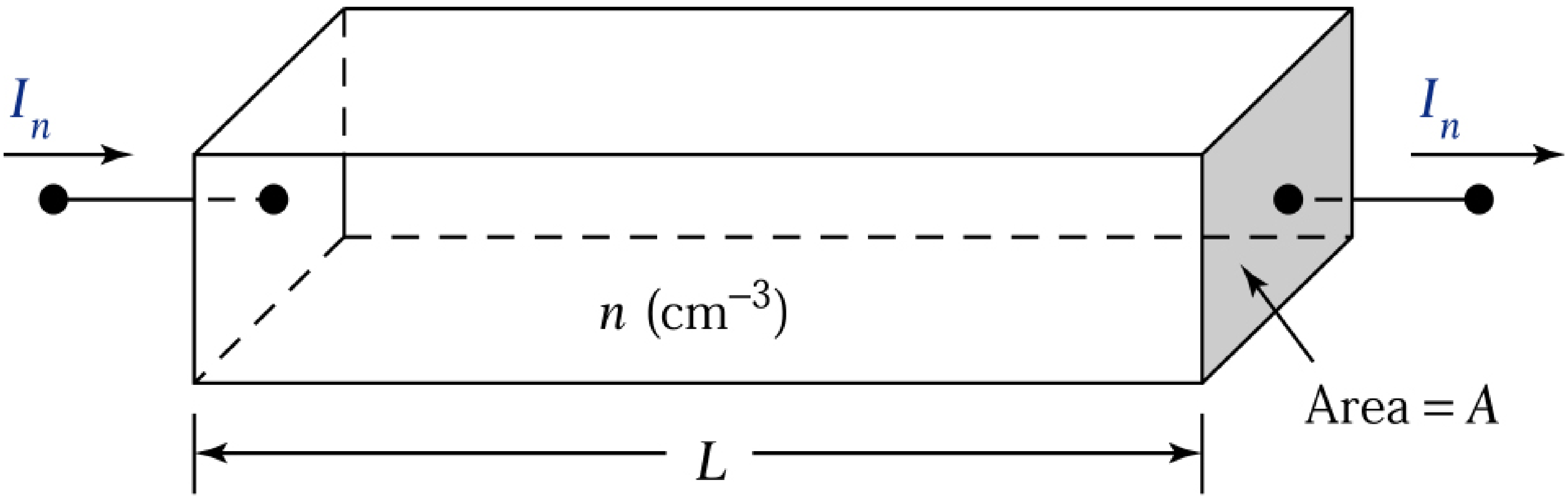
$$v_p = \mu_p \varepsilon$$

- Hole flows in the same direction as electric field.
- The mobility is influenced by impurity scattering and lattice scattering.

Current

- The transport carriers under the influence of an electric field produce drift current.

Figure 3.5. Current conduction in a uniformly doped semiconductor bar with length *L* and cross-sectional area *A*.



Resistivity

- Sample semiconductor of length L and cross section of A and an electron concentration of n electrons/cm^3.
- If we apply an electric field to the sample the electron current density J_n flowing in the sample should be product of charge (-q) on electron time the electron velocity.

$$J_n = -qnv_n$$

Resistivity

- Current density

$$J = J_n + J_p = (qn\mu n + qp\mu p)\varepsilon$$

- Conductivity

$$\sigma = q(n\mu_n + p\mu_p)$$

- Resistivity

$$\rho = \frac{1}{\sigma}$$