كلية الرشيد الجامعة

هندسة تقنيات الاجهزة الطبية

ELECTRONIC CIRCUITS AND DEVICES

Introduction to semiconductor materials

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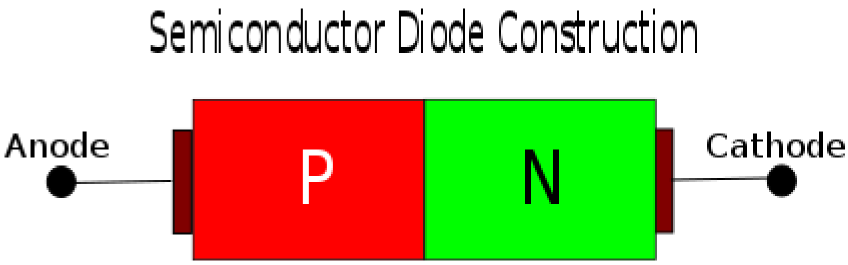
Introduction

Electronic devices such as diodes, transistors, and integrated circuits are made of a semi-conductive material. To understand how these devices work, we should have a basic knowledge of the structure of atoms and the interaction of atomic particles. An important concept introduced in this chapter is that of the pn junction that is formed when two different types of semiconductive material are joined. The pn junction is fundamental to the operation of devices such as the solar cell, the diode, and certain types of transistors.



1.2 SEMICONDUCTOR MATERIALS: Ge, Si, AND GaAs

The construction of every discrete (individual) solid-state (hard crystal structure) electronic device or integrated circuit begins with a semiconductor material of the highest quality.
Semiconductors are a special class of elements having a conductivity between that of a good conductor and that of an insulator.
In general, semiconductor materials fall into one of two classes: single-crystal and compound.
Single-crystal semiconductors such as germanium (Ge) and silicon (Si) have a repetitive crystal structure, whereas compound semiconductors such as gallium arsenide (GaAs), cadmium sulfide (CdS), gallium nitride (GaN), and gallium arsenide phosphide
(GaAsP) are constructed of two or more semiconductor materials of different atomic structures.

1.2 COVALENT BONDINGAND INTRINSIC MATERIALS

The fundamental components of an atom are the electron, proton, and neutron. In the lattice structure, neutrons and protons form the nucleus and electrons appear in fixed orbits around the nucleus. The Bohr model for the three materials is provided in Fig. 1.3 .

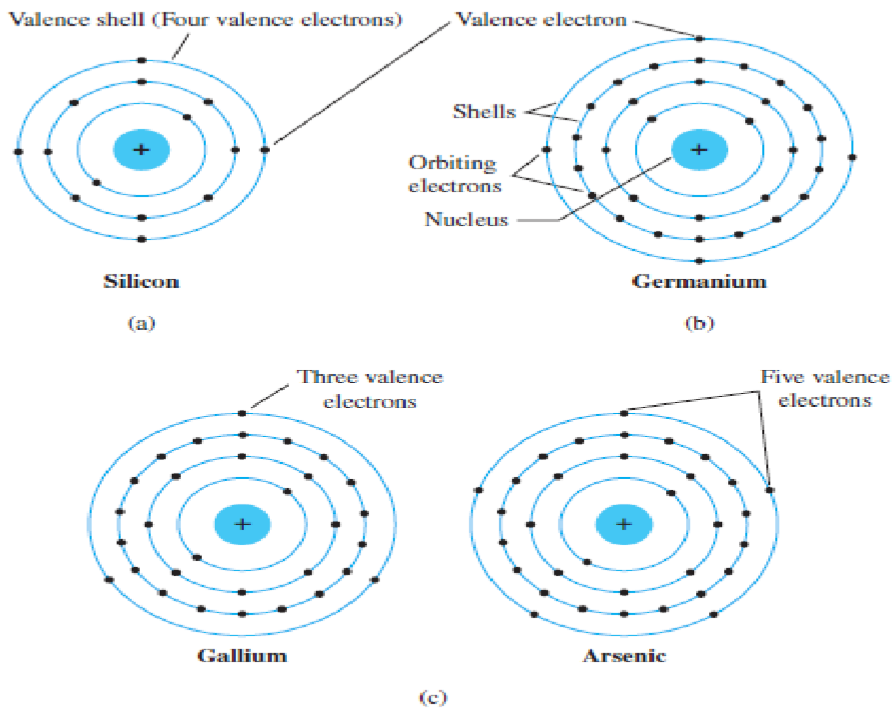


FIG. 1.3
Atomic structure of (a) silicon; (b) germanium; and (c) gallium and arsenic.

A s indicated in Fig. 1.3 , silicon has 14 orbiting electrons, germanium has 32 electrons, gallium has 31 electrons, and arsenic has 33 orbiting electrons (the same arsenic that is a very poisonous chemical agent). For germanium and silicon there are four electrons in the outermost shell, which are referred to as valence electrons . Gallium has three valence electrons and arsenic has five valence electrons. Atoms that have four valence electrons

are called tetravalent رباعي التكافؤ, those with three are called trivalent ثالثي التكافؤ , and those with five are called pentavalent . The term valence is used to indicate that the potential (ionization potential) required to remove any one of these electrons from the atomic structure is significantly lower than that required for any other electron in the structure.

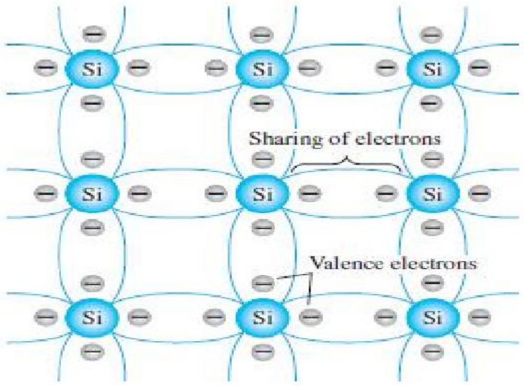


FIG. 1.4
Covalent bonding of the silicon atom.

This bonding of atoms, strengthened by the sharing of electrons, is called covalent bonding.

1.4 Resistance

As the operating point of a diode moves from one region to another the resistance of the diode will also change due to the nonlinear shape of the characteristic curve.

DC or Static Resistance: The resistance of the diode at the operating point can be found simply by finding the corresponding levels of VD and ID and applying the following equation:

$$RD=VD/ID$$

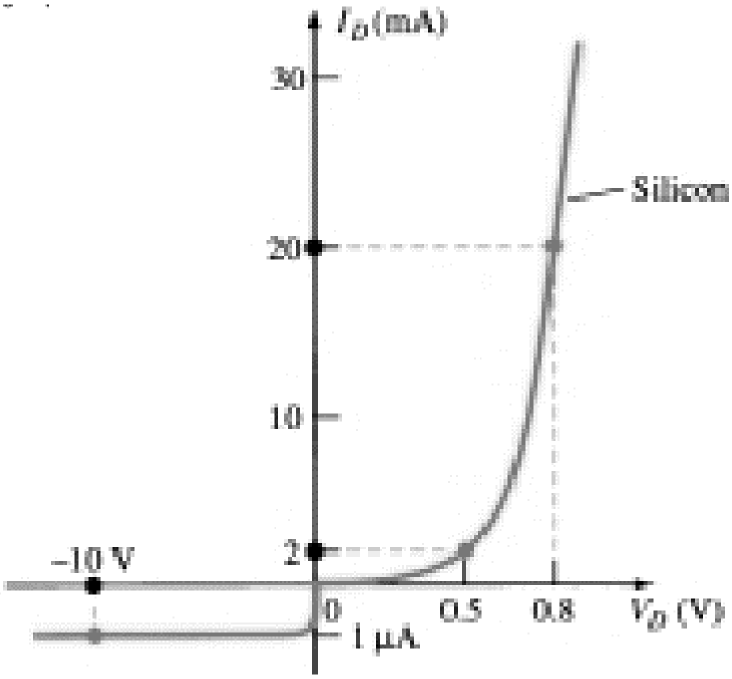
The dc resistance levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section of the characteristics. In general, therefore, the lower the current through a diode the higher the dc resistance level.

Example 1: *Determine the dc resistance levels for the diode of Figure below at*

$a)\ I_D = 2mA$

$,)\ I_D = 20mA,$

$c)\ V_D = -10V$



(a) At $I_D = 2$ mA, $V_D = 0.5$ V (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{0.5\text{ V}}{2\text{ mA}} = \mathbf{250\ \Omega}$$

(b) At $I_D = 20$ mA, $V_D = 0.8$ V (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{0.8\text{ V}}{20\text{ mA}} = \mathbf{40\ \Omega}$$

(c) At $V_D = -10$ V, $I_D = -I_s = -1\ \mu$A (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{10\text{ V}}{1\ \mu\text{A}} = \mathbf{10\ M\Omega}$$

Example 2:

Determine the currents I_{D_1}, I_{D_2}, and I_{R_1} for the network of Fig. 1-11.

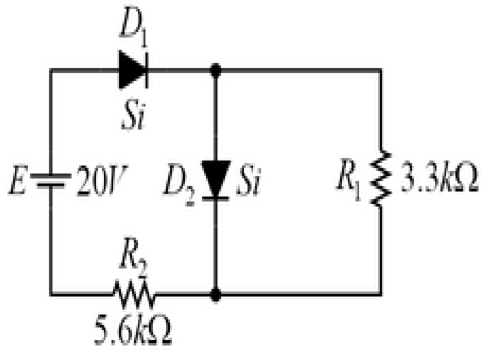


Fig. 1-11

Solution:

$$I_{R_1} = \frac{V_{D_2}}{R_1} = \frac{0.7}{3.3k} = 0.212mA.$$

Appling KVL yields:

$$-V_{R_2} + E - V_{D_1} - V_{D_2} = 0$$

and $V_{R_2} = E - V_{D_1} - V_{D_2} = 20 - 0.7 - 0.7 = 18.6V$,

with $I_{D_1} = \frac{V_{R_2}}{R_2} = \frac{18.6}{5.6k} = 3.32mA.$

Finally, $I_{D_2} = I_{D_1} - I_{R_1} = 3.32m - 0.212m = 3.108mA$.