الهندسة	الكلية
الكهرباء	القسم
Electronic Devices and Circuit Theory	المادة باللغة الانجليزية
مكونات و دوائر إلكترونية	المادة باللغة العربية
الثانية	المرحلة الدراسية
م.د. مصطفى عدنان حمود	اسم التدريسي
***n*-TYPE AND *p*-TYPE MATERIALS**	عنوان المحاضرة باللغة الانجليزية
	عنوان المحاضرة باللغة العربية
2	رقم المحاضرة
Electronic-Devices-and-Circuit-Theory-11th-Edition-Ebook	المصادر والمراجع

1.2 *n*-TYPE AND *p*-TYPE MATERIALS

A semiconductor material that has been subjected to the doping process is called an *extrinsic material*.

There are two extrinsic materials of immeasurable importance to semiconductor device fabrication: *n*-type and *p*-type materials. Each is described in some detail in the following subsections.

n-TYPE MATERIALS

Both n -type and p -type materials are formed by adding a predetermined number of impurity atoms to a silicon base. An n -type material is created by introducing impurity elements that have five valence electrons (pentavalent), such as antimony , arsenic , and phosphorus (See Figure 1).

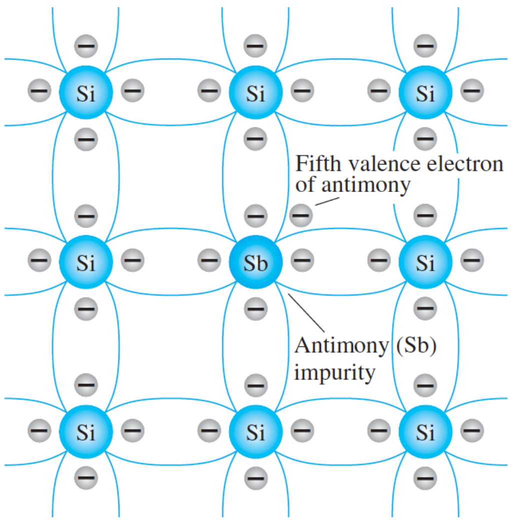

Figure 1: Antimony impurity in n-type material.

Note that the four covalent bonds are still present. There is, however, an additional fifth electron due to the impurity atom, which is unassociated with any particular covalent bond. This remaining electron, loosely bound to its parent (antimony) atom, is relatively free to move within the newly formed n - type material. Since the inserted impurity atom has donated a relatively “free” electron to the structure:

Diffused impurities with five valence electrons are called donor atoms.

The effect of this doping process on the relative conductivity can best be described through the use of the energy-band diagram of Figure 2. Note that a discrete energy level (called the donor level) appears in the forbidden band with an E_g significantly less than that of the intrinsic material. Those free electrons due to the added impurity sit at this energy level and have less difficulty absorbing a sufficient measure of thermal energy to move into the conduction band at room temperature.

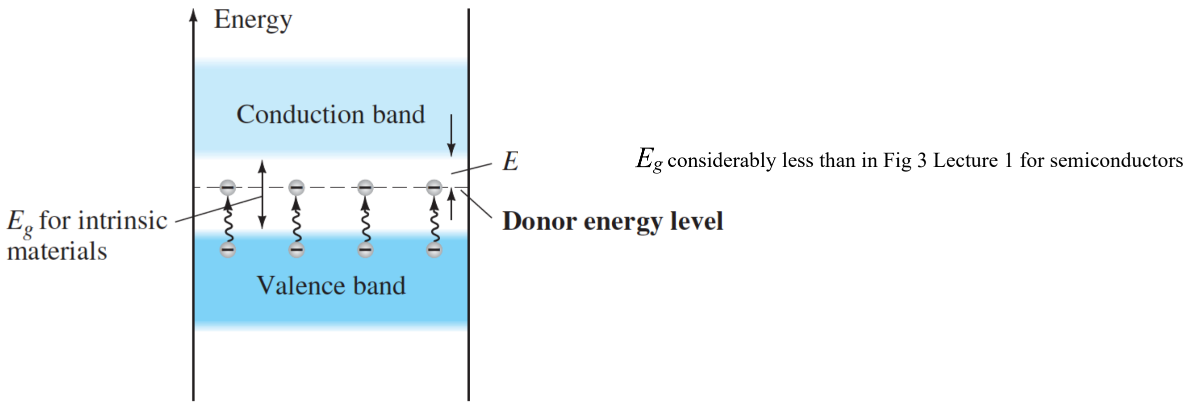

Figure 2: Effect of donor impurities on the energy band structure.

p-TYPE MATERIALS

The p -type material is formed by doping a pure germanium or silicon crystal with impurity atoms having three valence electrons. The elements most frequently used for this purpose are boron, gallium, and indium (See Figure 3).

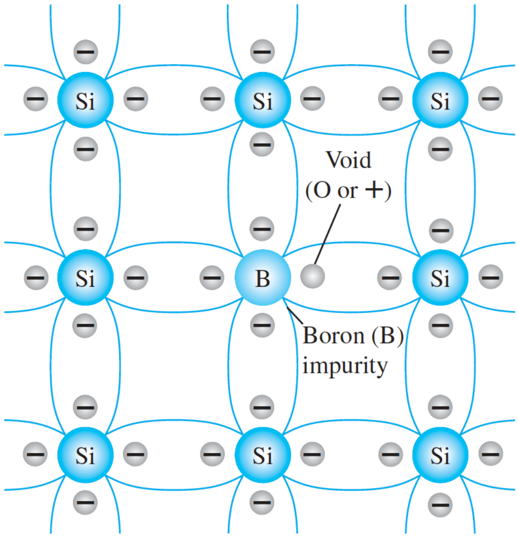

Figure 3: Boron impurity in p-type material.

Note that there is now an insufficient number of electrons to complete the covalent bonds of the newly formed lattice. The resulting vacancy is called a hole and is represented by a small circle or a plus sign, indicating the absence of a negative charge. Since the resulting vacancy will readily accept a free electron:

The diffused impurities with three valence electrons are called acceptor atoms.

2.2 ELECTRON VERSUS HOLE FLOW

The effect of the hole on conduction is shown in Figure 4 . If a valence electron acquires sufficient kinetic energy to break its covalent bond and fills the void created by a hole, then a vacancy, or hole, will be created in the covalent bond that released the electron. There is, therefore, a transfer of holes to the left and electrons to the right, as shown in Figure 4. The direction to be used in this text is that of *conventional flow* , which is indicated by the direction of hole flow.

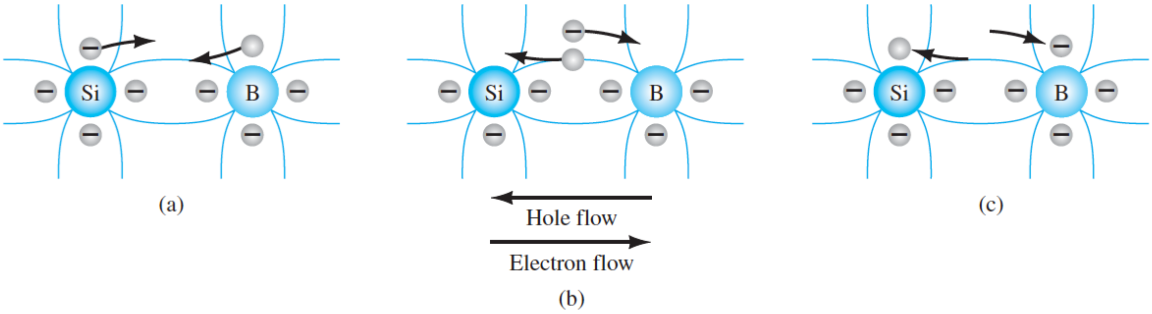

Figure 4: Electron versus hole flow.

3.2 MAJORITY AND MINORITY CARRIERS

In the intrinsic state, the number of free electrons in Ge or Si is due only to those few electrons in the valence band that have acquired sufficient energy from thermal or light sources to break the covalent bond or to the few impurities that could not be removed. The vacancies left behind in the covalent bonding structure represent our very limited supply of holes. In an n -type material, the number of holes has not changed significantly from this intrinsic level. The net result, therefore, is that the number of electrons far outweighs the number of holes. For this reason:

In an n-type material (Figure 5a) the electron is called the majority carrier and the hole the minority carrier.

For the p -type material the number of holes far outweighs the number of electrons, as shown in Figure 5b Therefore:

In a p-type material the hole is the majority carrier and the electron is the minority carrier.

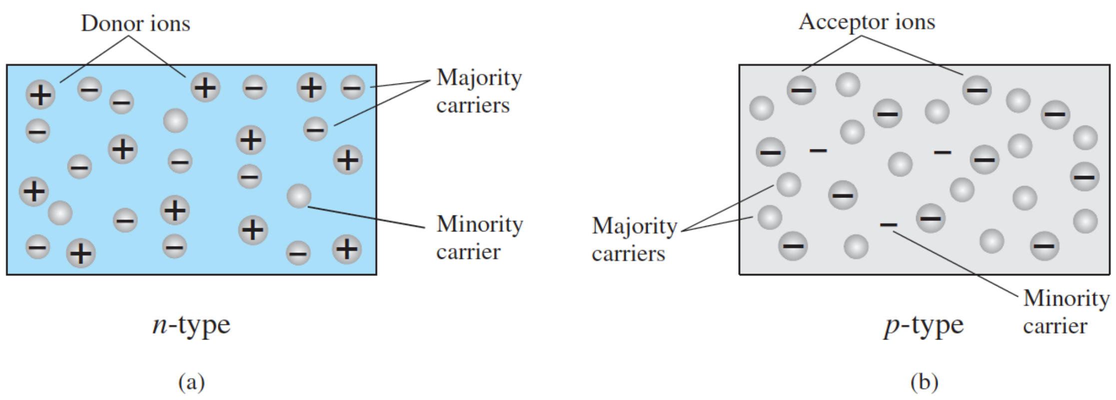

Figure 5:(a) n-type material; (b) p-type material.

4.2 SEMICONDUCTOR DIODE

Now that both n-and p-type materials are available, we can construct our first solid-state electronic device: The semiconductor diode is created by simply joining an n-type and a p-type material together, nothing more.

No Applied Bias (V = 0 V)

At the instant the two materials are "joined" the electrons and the holes in the region of the junction will combine, resulting in a lack of free carriers in the region near the junction, as shown in Figure 6 . Note in Figure 6 that the only particles displayed in this region are the positive and the negative ions remaining once the free carriers have been absorbed.

This region of uncovered positive and negative ions is called the depletion region due to the "depletion" of free carriers in the region.

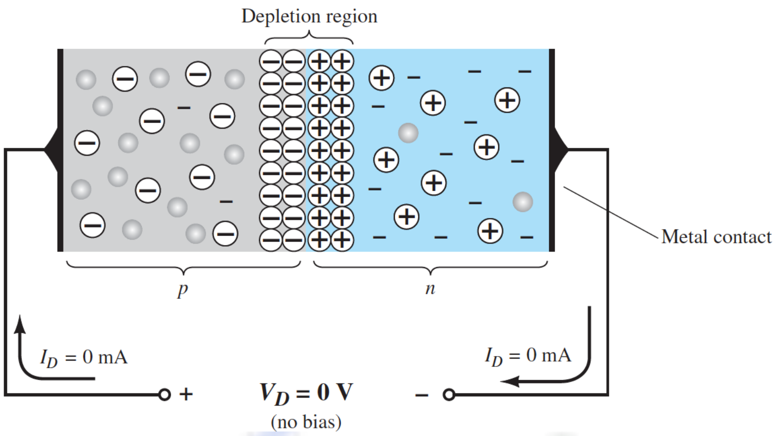

Figure 6: A p–n junction with no external bias

In the absence of an applied bias across a semiconductor diode, the net flow of charge in one direction is zero.

Reverse-Bias Condition ($V_D < 0$ V)

If an external potential of V volts is applied across the p – n junction such that the positive terminal is connected to the n-type material and the negative terminal is connected to the p-type material as shown in Figure 7, the number of uncovered positive ions in the depletion region of the n-type material will increase due to the large number of free electrons drawn to the positive potential of the applied voltage. For similar reasons, the number of uncovered negative ions will increase in the p-type material. The net effect, therefore, is a widening of the depletion region.

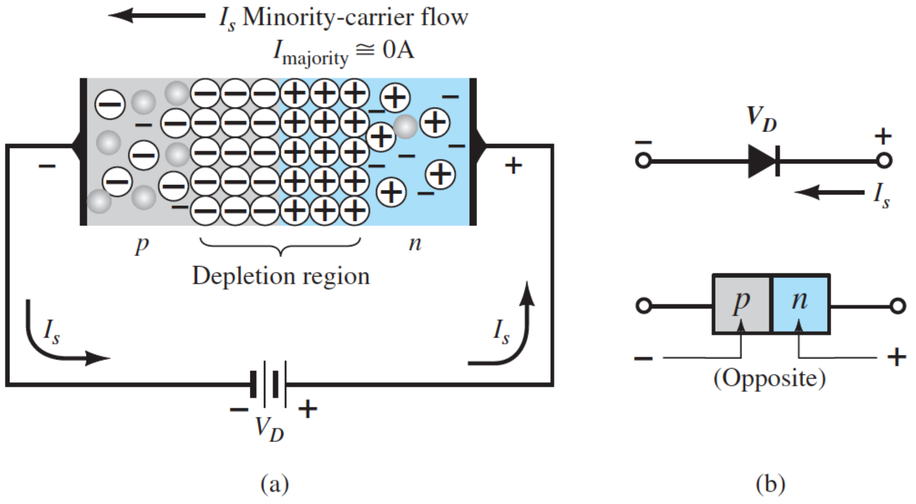

Figure 7: Reverse-biased p–n junction

Forward-Bias Condition ($V_D > 0$ V)

A forward-bias or "on" condition is established by applying the positive potential to the p-type material and the negative potential to the n-type material as shown in Figure 8. The application of a forward-bias potential V_D will "pressure" electrons in the n-type material and holes in the p -type material to recombine with the ions near the boundary and reduce the width of the depletion region as shown in Figure 8.

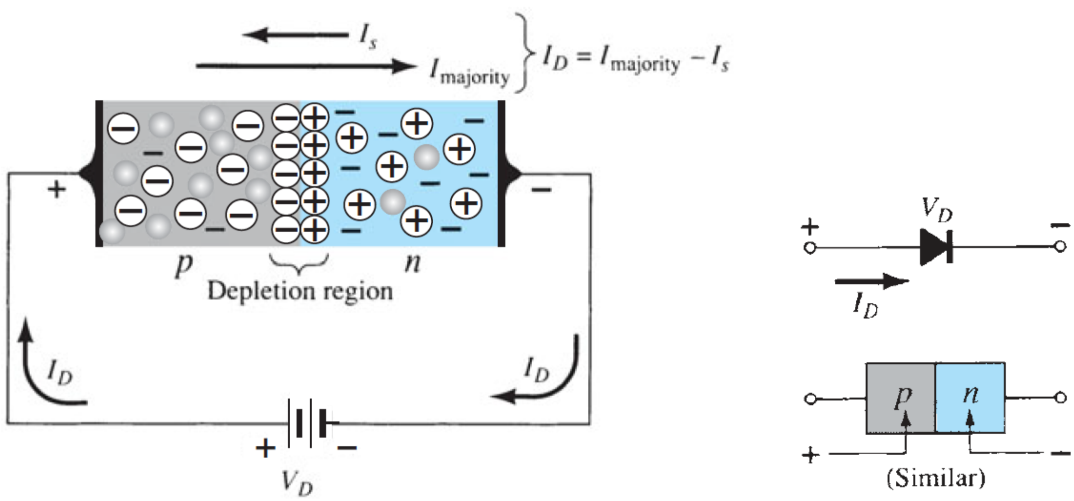

Figure 8: Forward-biased p–n junction

Breakdown Region

The reverse-bias potential that results in this dramatic change in characteristics is called the breakdown potential and is given the label V_{BV}.

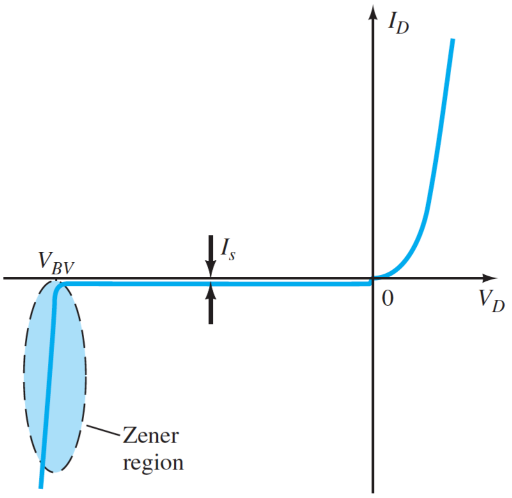

Figure 9:Breakdown region.