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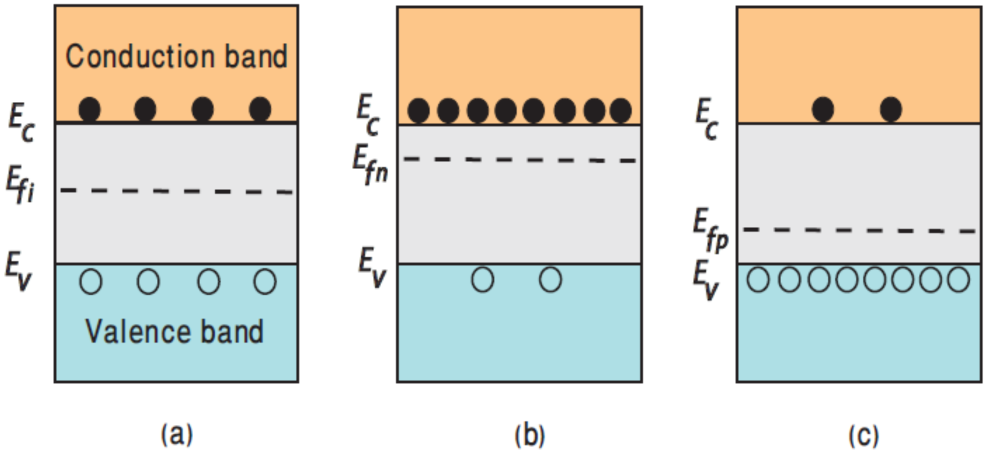

Figure 2: Energy band diagrams for (a) intrinsic, (b) n-type, and (c) p-type semiconductors. E_f is the Fermi energy level, and the letters i, n, p indicate intrinsic, n and p-type materials. E_c and E_v are the edges of the conduction and valence bands.

What is Holes and Electrons

In physics, a hole is an electric charge carrier with a positive charge, equal in magnitude but opposite in polarity to the charge on the electron. Holes and electrons are the two types of charge carriers responsible for current in semiconductor materials. A hole is the absence of an electron in a particular place in an atom. Although it is not a physical particle in the same sense as an electron, a hole can be passed from atom to atom in a semiconductor material. Electrons orbit the nucleus at defined energy levels called *bands* or *shells*. A hole forms in an atom when an electron moves from the so-called *valence band* (the shell outside the closed shells that is partially or completely filled with electrons) into the *conduction band* (the outer "cloud" from which electrons most easily escape from, or are accepted by, the atom).

Both electrons and holes are present in any semiconductor substance. Electrons flow from minus to plus, and holes "flow" from plus to minus. The more abundant charge carriers are called *majority carriers*; the less abundant are called *minority carriers*. In N-type semiconductor material, electrons are the majority carriers and holes are the minority carriers. In P-type semiconductor material, the opposite is true. In the processing of semiconductors, the number of charge carriers can be increased by a process known as *doping*, which consists of adding minute amounts of elements called *impurities*. Certain impurities, when added to a semiconducting element such as silicon, increase the number of electrons and produce an N-type material; other impurities increase the number of holes and produce a P-type material. Both N-type and P-type material are important in the manufacture of solid-state electronic components.

Semiconductor devices are the foundation of the electronic industry. Most of these devices can be constructed from a set of building blocks. The first building block is the metal-semiconductor interface as shown in Figure (3a). This interface can be used as a rectifying contact, i.e., the device allows current in one direction as in ohmic contact. By using the rectifying contact as a gate, we can form a MESFET (metal-semiconductor field-effect transistor), an important microwave device.

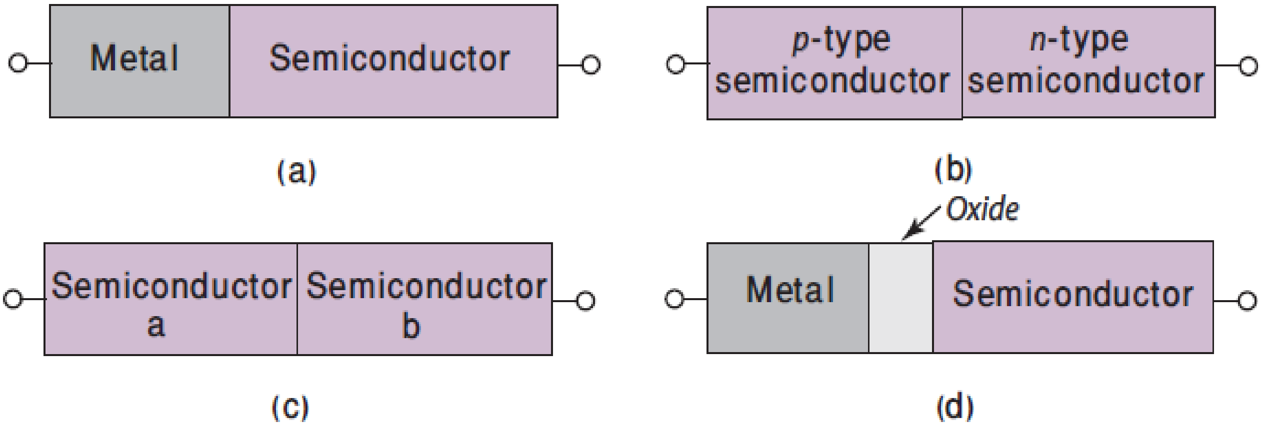

Figure 3: Basic device building blocks of (a) metal-semiconductor interface, (b) p-n junction, (c) heterojunction interface, (d) metal-oxide-semiconductor structure.

The second building block is the p-n junction, a junction of p-type and n-type materials indicated in Figure (3b). The p-n junction is the key compound for numerous semiconductor devices. By combining two p-n junctions, we can form the p-n-p bipolar transistor, and combining three p-n junctions to form a p-n-p-n structure, a switching device called a thyristor can be formed.

The third important building block is the heterojunction interface depicted in Figure (3c). It is formed between two dissimilar semiconductors, for example gallium arsenide (GaAs) and aluminium arsenide (AlAs) and is used in band gap engineering. Band gap engineering is a useful technique to design new semiconductor devices and materials. Heterojunctions and molecular beam epitaxy (MBE) are the most important techniques in which required band diagrams are devised by continuous band-gap variations. A new generation of devices, ranging from solid-state photomultipliers to resonant tunneling transistors and spin polarized electron sources, is the result of this technique.

The fourth building block is the metal-oxide-semiconductor (MOS) structure. It is a combination of a metal-oxide and an oxide-semiconductor interface indicated as in Figure (3d). The MOS structure used as a gate and the two semiconductor-metal oxide junctions are the source and drain; the result is the MOSFET (MOS field-effect transistor). The MOSFET is the most important component of modern integrated circuits, enabling the integration of millions of devices per chip.

For electronic application, semiconductors must be crystalline and must contain a well-controlled concentration of specific impurities.

☐Crystalline semiconductors are needed so the defect density is low. Since defects are electron and hole traps where e--h+ can recombine and disappear, short lifetime.

☐The role of impurities in semiconductors:

1.To provide a wide range of conductivity(III-B or V-P in Si).

2.To provide two types of charge carriers(electrons and holes) to carry the electrical current , or to provide two conductivity types, n-type(by electrons) and p-type(by holes)

☐Group III and V impurities in Si are dopant impurities to provide conductive electrons and holes. However, group I, II, and VI atoms in Si are known as recombination impurities(lifetime killers)when their concentration is low

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