

MORE ABOUT
SEMICONDUCTOR AND JUNCTION DIODES

Analog Electronics
Pujianto

Department of Physics Edu.
State University of Yogyakarta

We have known that ...

Materials can be categorized as

(1) **Conductors**, if there is no energy gap between the valence band and the conduction band.

It means that there is a free electron in conduction band. A free electron is a kind of electron which locates in conduction band. It can make a transition from the valence to conduction band easily.

(2) **Insulators**, if the energy gap between the valence band and the conduction band is more than 5 eV.

(3) Semiconductors, if the energy gap between the valence band and the conduction band is less than 2 eV.

Position of semiconductor elements in the Mendeleev Table

		Group				
↓	→	III	IV	V	VI	VII
Period						
II		B	C			
III			Si	P	S	
IV			Ge	As	Sc	
V			Sn	Sb	Te	I

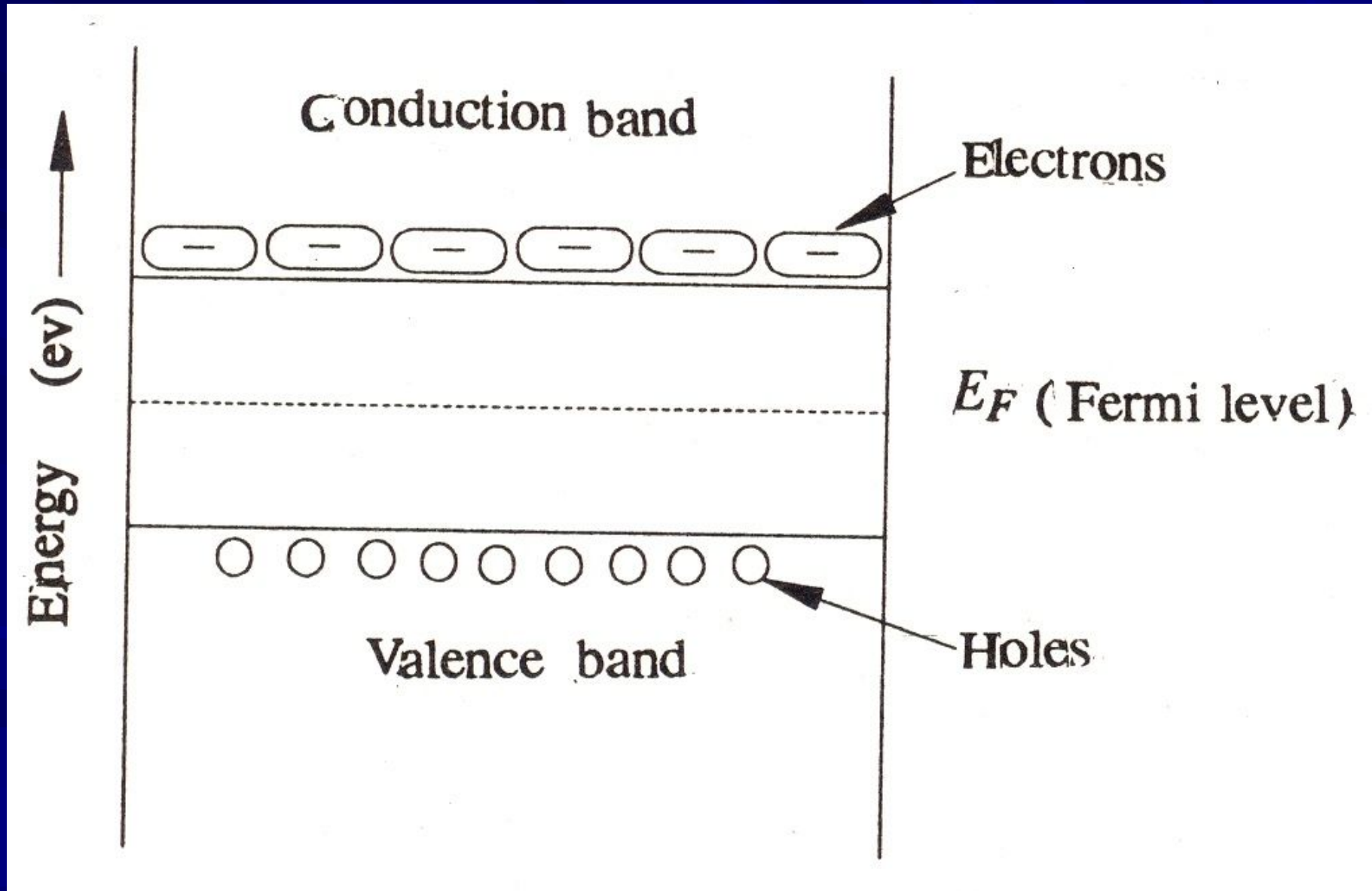
INTRINSIC SEMICONDUCTORS

A pure or intrinsic semiconductor has probabilities of an electron to excite from valence to conduction band. This electron is called as an intrinsic conduction electron which has a negative charge and leaves a hole (positive charge).

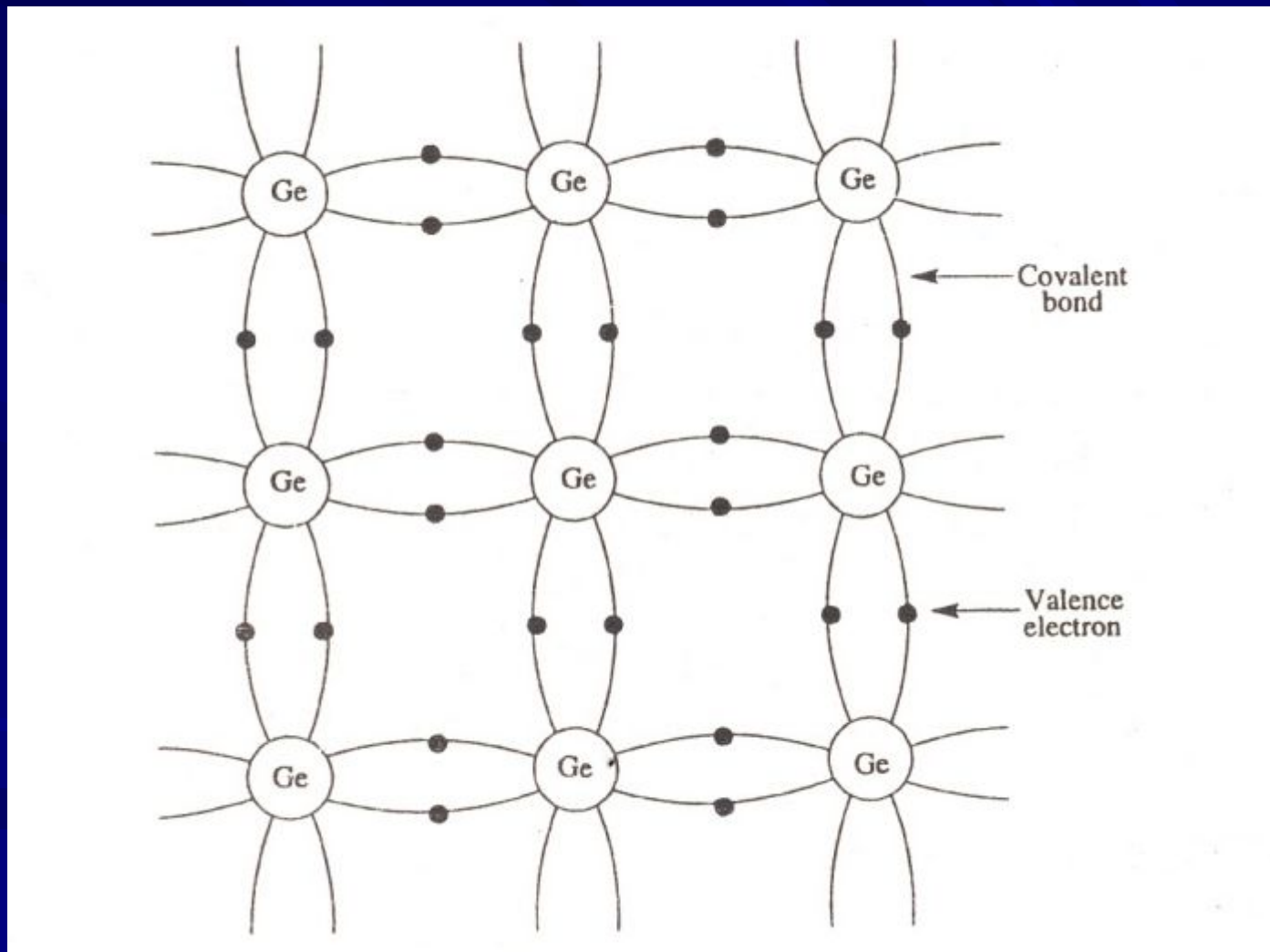
An intrinsic conduction electron can be a free electron but probability of this electron to excite from valence to conduction band is only happened in specific temperature.

When the temperature is raised there is a greater possibility of electrons being found above the Fermi level with an equal possibility of finding an electron vacancy so called "hole" below Fermi level.

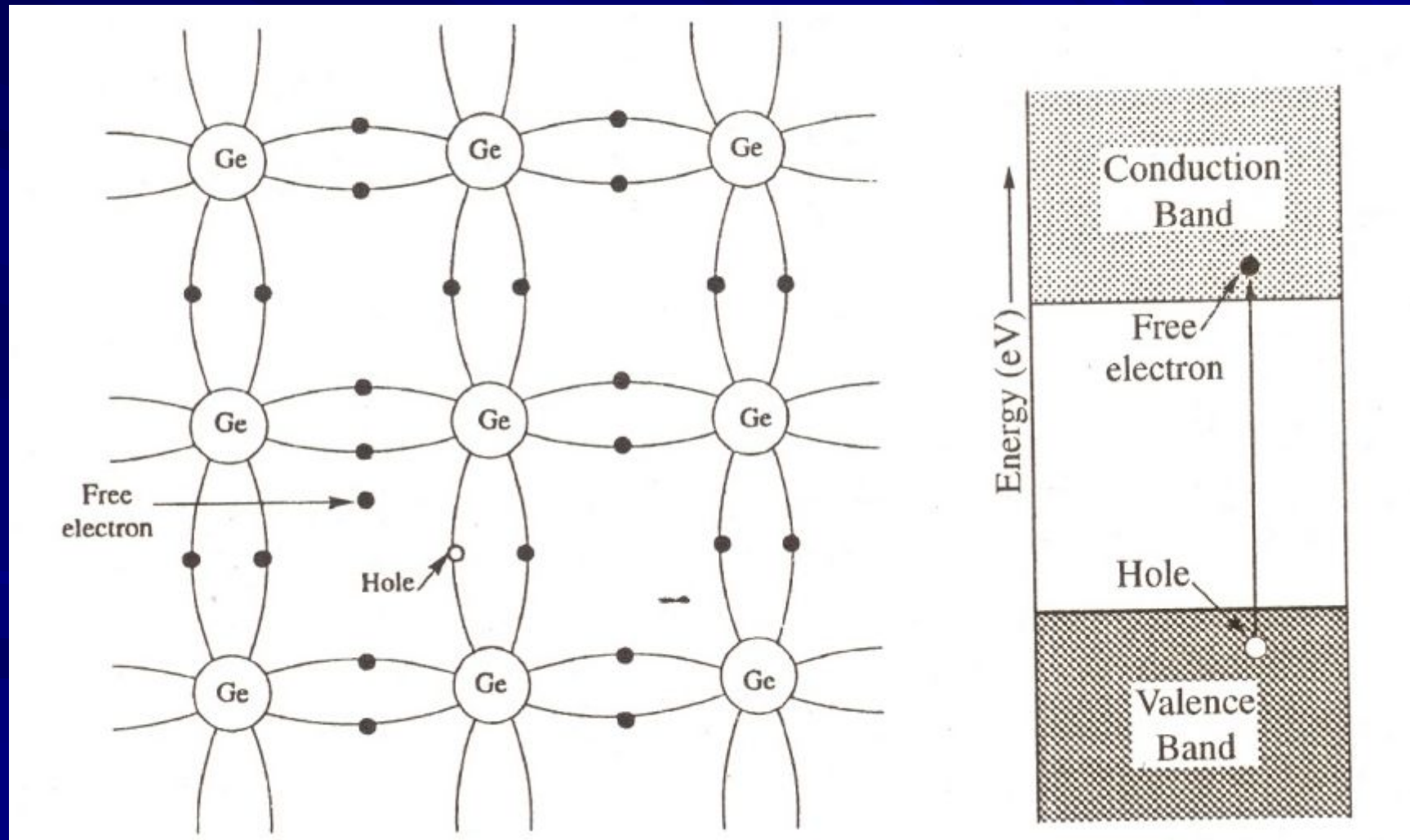
Fermi Level in Intrinsic Semiconductor at 0 K



A Simplified Representation of Crystalline Structure of a Semiconductor (Ge) at Absolute Zero



Crystalline Structure of Ge at room temperature and generation of electron-hole Pair in an Intrinsic Semiconductor (Ge)



EXTRINSIC SEMICONDUCTORS

Silicon and Germanium are well-known as semiconductors. Most of semiconductors are located at Group IV in Mendeleev Table.

Because of specific condition, some atoms (atom of metal) in one level above or below of Group IV can be done its function as atoms in Group IV. These semiconductors are called as **an extrinsic semiconductor**.

This process is called **doping**.

Doping is done after the semiconductor material has been refined to a high degree of purity.

N-Type Semiconductor

Germanium & Silicon are tetravalent.

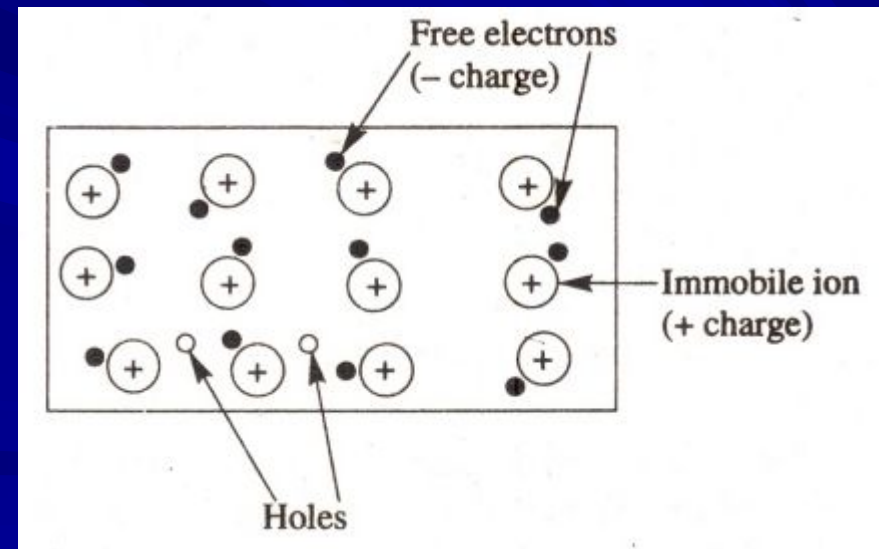
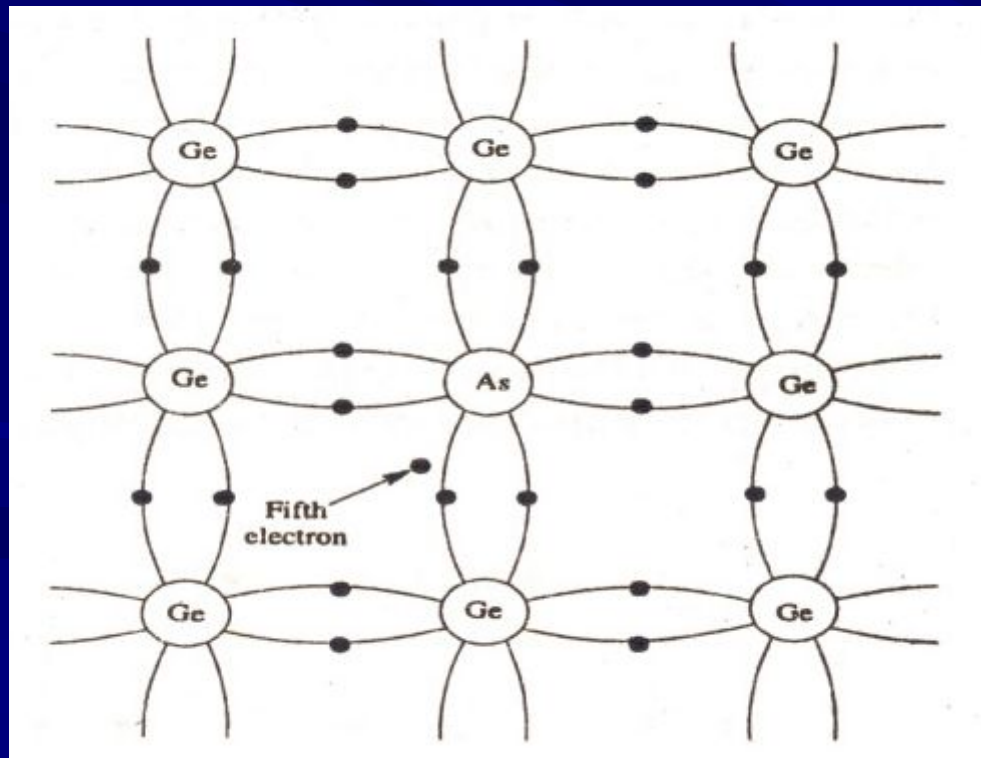
The impurity atoms may be either pentavalent or trivalent, i.e., from group V and group III of the periodic table.

If a small quantity of a pentavalent impurity (having 5-electrons in the outermost orbit) like Arsenic (As), Antimony (Sb) or Phosphorus (P) is introduced in Germanium, it replaces equal number of Germanium atoms without changing the physical state of the crystal.

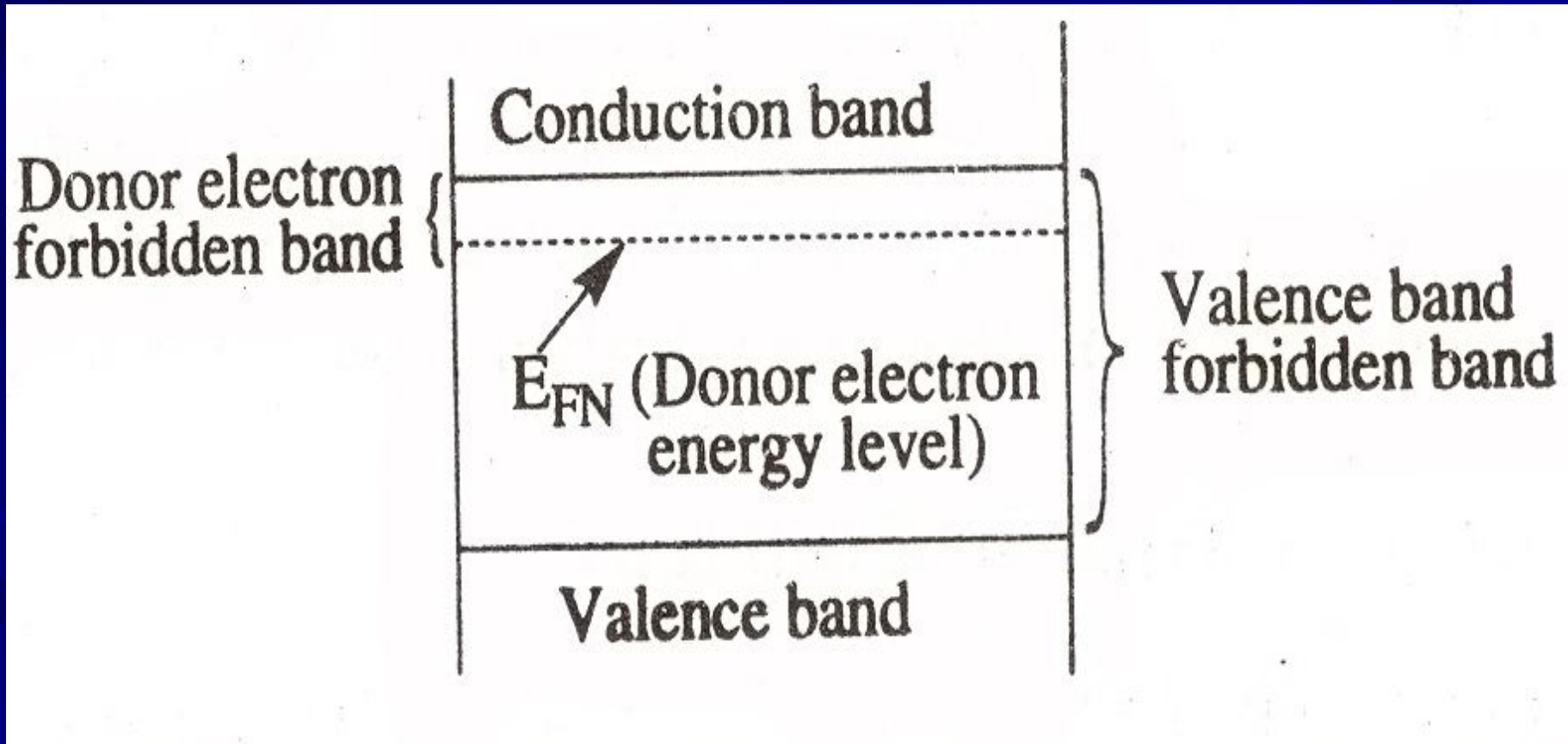
Each of the four out of five valency electrons of impurity (say Arsenic) enters into covalent bonds with Germanium, while the fifth valency electron is set free to move from one atom to the other.

The impurity is called **donor impurity** as it donates electron and the crystal is called **N-Type Semiconductor**.

In N-type semiconductors **the majority carriers of charge are the electrons** and **holes are minority carriers**.



Since N-type semiconductors have extra free electrons, and pure semiconductors do not, the energy band diagram for a doped semiconductor is slightly different from that of a pure semiconductor.



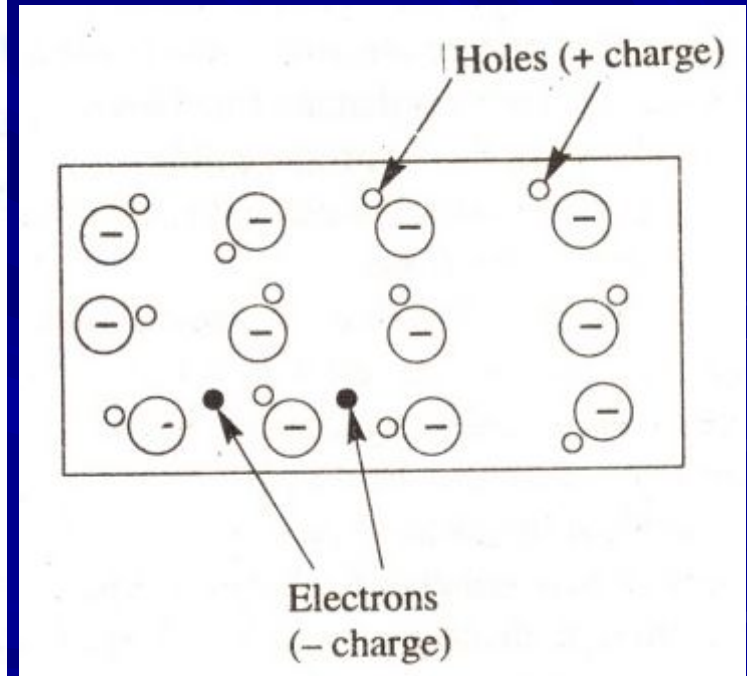
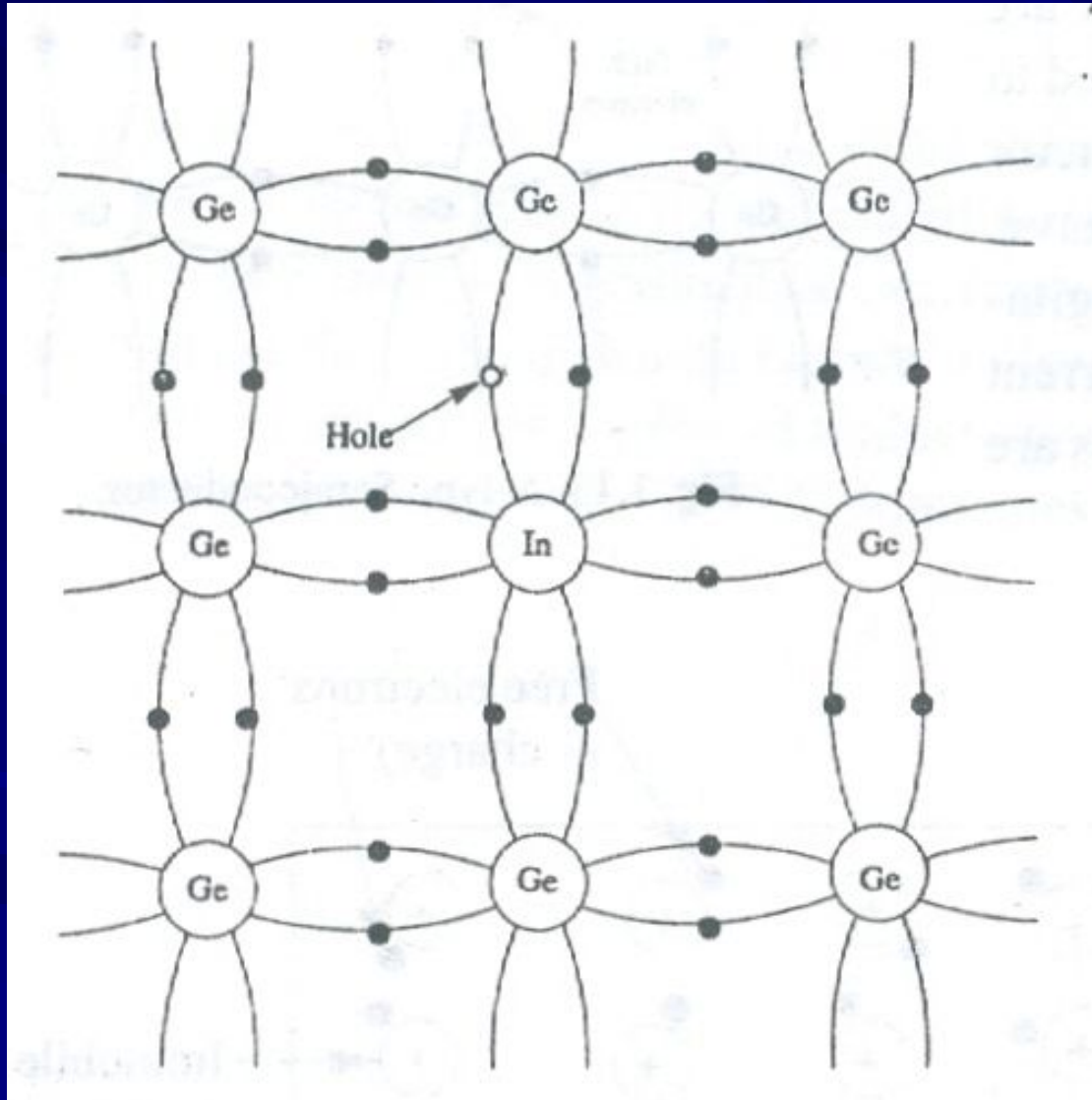
P-Type Semiconductor

When a trivalent impurity (having 3 electrons in outermost orbit) like Indium (In), Boron (B) or Gallium (Ga) is added in a Germanium intrinsic semiconductor, the impurity atoms will displace some of the Germanium atoms in the crystal during its formation.

In this case only three out of the four possible covalent bonds are filled while the fourth bond is vacant and the vacancy acts as a hole. Hence a hole moves relative to the electron in a direction opposite to the direction of electron, when an electron moves from one bond to other.

This trivalent impurity known as **the acceptor** .

In P-type semiconductors **the majority carries of charge are the holes.**



The energy band diagram of P-type semiconductor also differs from that of the pure superconductor.

Excess holes in P-type semiconductors introduce an acceptor energy level close to valence level.

