

ELECTRICAL ENGINEERING MATERIALS

Unit I : Introduction to Materials

Topic: Semiconductor Fundamentals

Important Questions with Answers (3rd Semester, Electrical Engg.)

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Short Answer Questions

Q.1 Define semiconductor. Mention any four applications of semiconductors.

Ans. A semiconductor is a material whose conductivity is more than that of an insulator but less than that of a conductor. Its conductivity can be changed by temperature, light and by adding a small amount of impurity.

Examples: Silicon and germanium.

Applications (any four):

1. **Diodes:** used as rectifiers to change AC into DC in power supplies and battery chargers.
2. **Transistors:** used as amplifiers and as electronic switches.
3. **Integrated circuits (ICs):** used in computers, mobile phones and control circuits.
4. **Solar cells:** convert sunlight directly into electricity.
5. **LEDs:** used in lamps, displays and indicators.
6. **Thyristors (SCR, TRIAC):** used for speed control of motors, light dimmers and fan regulators.
7. **Sensors:** thermistors and photodiodes are used to sense temperature and light.

Q.2 Define semiconductor. Discuss its engineering applications.

Ans. A semiconductor is a material whose conductivity is more than that of an insulator but less than that of a conductor. Its conductivity can be controlled by temperature, light and impurities. Because of this, semiconductors are used in many branches of engineering.

1. **Power control:** thyristors (SCR, TRIAC) are used for speed control of motors, light dimmers, fan regulators and battery chargers.
2. **Rectification:** diodes change AC into DC in power supplies and chargers.
3. **Amplification and switching:** transistors are used in amplifiers and in electronic switching circuits.
4. **Computing and communication:** integrated circuits (ICs) are used in computers, mobile phones and control circuits.
5. **Renewable energy:** solar cells convert sunlight directly into electricity.
6. **Lighting and display:** LEDs are used in lamps, displays and indicators.
7. **Sensing and measurement:** thermistors and photodiodes sense temperature and light.

Q.3 Write the characteristics of semiconductors.

Ans. The characteristics of semiconductors are given below.

1. Their conductivity is between that of conductors and insulators.
2. They have 4 valence electrons. The atoms are joined to each other by covalent bonds in a crystal.
3. At absolute zero temperature (0 K) a pure semiconductor behaves like an insulator.
4. Their resistance decreases when temperature increases. They have a negative temperature coefficient of resistance.
5. Their conductivity increases greatly when a small amount of impurity is added (doping).
6. Their conductivity increases when light falls on them.
7. They have two types of charge carriers, free electrons and holes.

Q.4 Name the commonly used semiconductor materials. Compare silicon and germanium.

Ans. Silicon (Si) and germanium (Ge) are the most commonly used semiconductor materials.

Point	Silicon	Germanium
Symbol	Si	Ge
Atomic number	14	32
Valence electrons	4	4
Forbidden energy gap	About 1.1 eV	About 0.67 eV
Working temperature	Can work at higher temperature	Works only at lower temperature
Leakage current	Less	More
Availability	Very easily available (obtained from sand), cheap	Rare and costly
Use	Most widely used	Used less now

Q.5 Define doping.

Ans. The process of adding a small amount of a suitable impurity to a pure semiconductor to increase its conductivity is called doping. The impurity which is added is called a dopant.

A pentavalent impurity (5 valence electrons) makes an N-type semiconductor. A trivalent impurity (3 valence electrons) makes a P-type semiconductor.

Q.6 Differentiate between intrinsic and extrinsic semiconductors.

Point	Intrinsic semiconductor	Extrinsic semiconductor
Meaning	Pure semiconductor with no impurity	Semiconductor in which impurity has been added (doped)
Examples	Pure silicon, pure germanium	Silicon or germanium doped with phosphorus or boron
Charge carriers	Number of electrons is equal to number of holes	Number of electrons is not equal to number of holes
Conductivity	Low	Much higher
Depends on	Mainly on temperature	Mainly on the amount of impurity added
Types	No types	N-type and P-type
Use	Rarely used directly	Used for making diodes, transistors and ICs

Q.7 Differentiate between P-type and N-type semiconductors.

Point	P-type semiconductor	N-type semiconductor
Impurity added	Trivalent (3 valence electrons)	Pentavalent (5 valence electrons)
Examples of impurity	Boron, aluminium, gallium, indium	Phosphorus, arsenic, antimony
Name of impurity	Acceptor	Donor
Majority carriers	Holes	Free electrons
Minority carriers	Free electrons	Holes
Electrical nature	Electrically neutral	Electrically neutral

Remember: A hole is the empty place left by a missing electron in a covalent bond. It behaves like a positive charge. Both P-type and N-type materials are electrically neutral as a whole.

Long Answer Question

Q.8 Explain intrinsic and extrinsic semiconductors. Describe N-type and P-type semiconductors with diagrams.

(a) Intrinsic semiconductor

A pure semiconductor is called an intrinsic semiconductor. In a pure silicon crystal, each atom has 4 valence electrons. It shares one electron with each of its 4 neighbouring atoms, forming 4 covalent bonds (Fig. 1).

1. At 0 K all the bonds are complete. There are no free electrons, so the crystal behaves like an insulator.
2. At room temperature heat energy breaks a few bonds. Each broken bond gives one free electron and leaves one hole behind. This is called an electron-hole pair.
3. So in an intrinsic semiconductor the number of free electrons is equal to the number of holes.

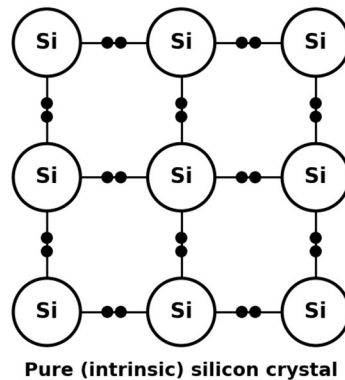


Fig. 1 Pure (intrinsic) silicon crystal

(b) Extrinsic semiconductor

When a small amount of impurity is added to a pure semiconductor, it becomes an extrinsic semiconductor. The process is called doping. Extrinsic semiconductors are of two types, N-type and P-type.

1. N-type semiconductor

A pentavalent impurity such as phosphorus, arsenic or antimony is added to pure silicon. The impurity atom has 5 valence electrons. Four of them form covalent bonds with four neighbouring silicon atoms. The fifth electron is not needed in any bond, so it becomes a free electron (Fig. 2).

1. The impurity atom gives away one electron, so it is called a donor.
2. Free electrons are the majority carriers and holes are the minority carriers.
3. The conductivity increases greatly.

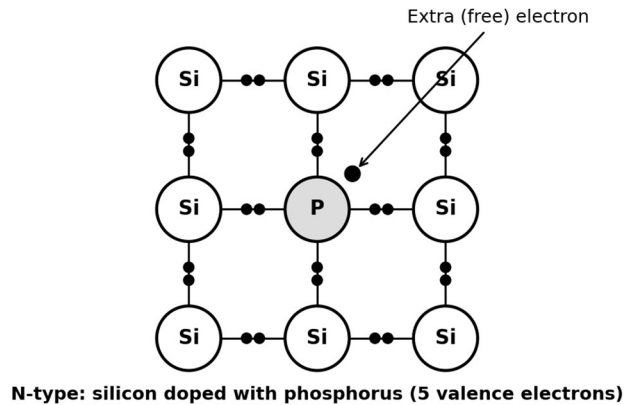


Fig. 2 N-type semiconductor

2. P-type semiconductor

A trivalent impurity such as boron, aluminium, gallium or indium is added to pure silicon. The impurity atom has only 3 valence electrons, so it can form only 3 complete covalent bonds. In the fourth bond one electron is missing. This empty place is a hole (Fig. 3).

1. The impurity atom is ready to accept an electron from a neighbouring atom, so it is called an acceptor.
2. An electron from a nearby bond can fill the hole, and in doing so it creates a new hole at its own place. In this way the hole moves through the crystal.
3. Holes are the majority carriers and free electrons are the minority carriers.

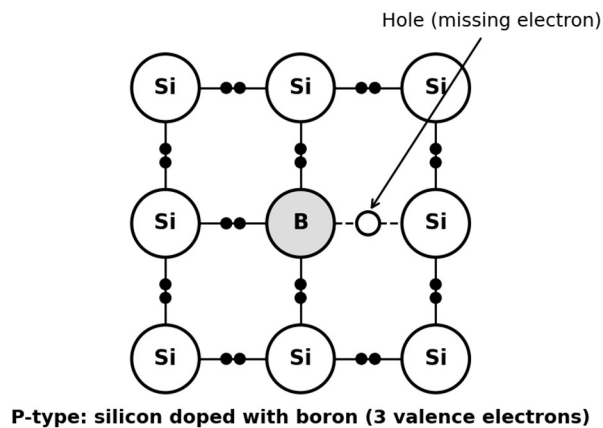


Fig. 3 P-type semiconductor

Note: The difference between P-type and N-type is given in the table of Q.7, and the difference between intrinsic and extrinsic is given in Q.6.

Points to Remember (for MCQ and True/False)

1. Semiconductors have 4 valence electrons. Silicon and germanium are the commonly used semiconductors.

2. At 0 K a pure semiconductor acts as an insulator.
3. A semiconductor has an almost empty conduction band and an almost filled valence band (at low temperature).
4. Resistance of a semiconductor decreases when temperature increases.
5. Doping means adding a small amount of impurity to a pure semiconductor.
6. In an intrinsic semiconductor, number of electrons = number of holes.
7. Pentavalent impurity gives N-type (donor, majority carriers are electrons).
8. Trivalent impurity gives P-type (acceptor, majority carriers are holes).
9. N-type and P-type materials are both electrically neutral.
10. Silicon gap is about 1.1 eV and germanium gap is about 0.67 eV. Silicon is more widely used.