SEMICONDUCTOR ELECTRONICS

CLASSIFICATION OF METALS, CONDUCTORS AND SEMICONDUCTORS

INTRODUCTION

Electronic instruments find applications across various fields such as telecommunication, entertainment, computers, nuclear physics, and more. While the history of electronic instruments began with the introduction of vacuum tubes, the significant progress seen in electronics today is largely attributed to the invaluable contributions of semiconductor devices.

Semiconductor devices offer several advantages over vacuum tubes. They are compact, consume less power, boast longer lifetimes, and exhibit greater efficiency. Additionally, they are cost-effective. These characteristics have led to the widespread replacement of vacuum tubes by semiconductor devices in nearly all applications. Consider the example of computers: early vacuum tube-based computers were massive, occupying entire rooms and capable of performing only basic calculations. In contrast, contemporary personal computers (PCs) are significantly smaller, yet highly capable of performing a multitude of operations. This transformation is a direct result of advancements in semiconductor technology.

In the upcoming sections, we will delve into the fundamental concepts of semiconductors. This foundational knowledge will provide the basis for understanding the operation of various semiconductor devices. We will further explore specific semiconductor devices, such as diodes and transistors, along with their applications.

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On the basis of conductivity.

Solids are broadly categorized based on the relative values of electrical conductivity (σ) or resistivity $\left(\rho = \frac{1}{\sigma}\right)$.

(i) Metals:

- Metals exhibit very low resistivity, indicating high conductivity.
- The resistivity (ρ) of metals is typically in the range of $10^{-2} - 10^{-8} \Omega.m$.
- The conductivity (σ) of metals is approximately $10^{2} - 10^{8}\ S.m^{-1}$.

(ii) Semiconductors:

- Semiconductors display resistivity or conductivity values that fall between those of metals and insulators.

- The resistivity (ρ) of semiconductors is generally in the range of $10^{-5} - 10^{6}\Omega.m$.
- The conductivity (σ) of semiconductors is around $10^{5} - 10^{-6}\ S.m^{-1}$.

(iii) Insulators:

- Insulators have high resistivity, indicating low conductivity.
- The resistivity (ρ) of insulators typically falls within the range of $10^{11} - 10^{19}\Omega.m$.
- The conductivity (σ) of insulators is approximately $10^{11} - 10^{-19}\ S.m^{-1}$

The provided values for resistivity (ρ) and conductivity (σ) serve as approximations to indicate their magnitude and may extend beyond the specified ranges. While relative resistivity values are crucial, they are not the sole criteria for distinguishing between metals, insulators, and semiconductors. Other distinctions will become evident as we progress through this chapter.

Our focus in this chapter lies in the examination of semiconductors, which can be categorized as follows:

(i) Elemental semiconductors: Silicon (Si) and Germanium (Ge).

(ii) Compound semiconductors, which include:

- Inorganic compounds: Cadmium Sulfide (CdS), Gallium Arsenide (GaAs), Cadmium Selenide (CdSe), Indium Phosphide (InP), and more.
- Organic compounds: Anthracene, doped phthalocyanines, etc.
- Organic polymers: Polypyrene, polyaniline, polythiophene, etc.

While most currently available semiconductor devices are based on elemental semiconductors such as Si or Ge, and compound inorganic semiconductors, developments since 1990 have introduced semiconductor devices utilizing organic semiconductors and semiconducting polymers. This signals the emergence of futuristic technologies like polymer electronics and molecular electronics.

Throughout this chapter, our focus will be on the study of inorganic semiconductors, specifically elemental semiconductors Si and Ge. The general concepts introduced here for discussing elemental semiconductors are applicable, to a large extent, to most compound semiconductors as well.