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Topic: Semi-Conductors And Their Applications

Submitted to

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Submitted by

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Table of content

1) Introduction.....	
2) Semiconductors.....	
3) Types of Semiconductors.....	
3.1) Extrinsic semiconductors	
3.2) Intrinsic semiconductors	
4) Types of Doping	
4.1) N-type Doping	
4.2) P-type Doping	
5) Applications of Semiconductors.....	
6) Conclusion.....	
7) Bibliography.....	

1. Introduction

In the ever-evolving realm of technology, one fundamental component plays a crucial role in powering our modern devices and shaping our digital landscape: semiconductors. These remarkable materials have revolutionized countless industries and propelled the progress of our interconnected world. From the smallest microchips to advanced electronic systems, semiconductors serve as the foundation for a wide range of applications that have become integral to our daily lives.

At its core, a semiconductor is a material with an electrical conductivity between that of a conductor, like copper or silver, and an insulator, such as rubber or glass. This unique characteristic allows semiconductors to control the flow of electric current, making them invaluable for the design and production of electronic devices.

Semiconductors have had a profound impact on the field of electronics, enabling the development of increasingly powerful and compact devices. They are the heart and soul of transistors, which act as electronic switches, amplifiers, and signal regulators. The transistor, invented in the mid-20th century, marked a turning point in technology, paving the way for the miniaturization and integration of complex circuits, leading to the birth of modern computers, smartphones, and countless other electronic devices.

The applications of semiconductors extend far beyond consumer electronics. They are indispensable in industries such as telecommunications, automotive, aerospace, renewable energy, healthcare, and more. Semiconductors enable the efficient transmission and processing of data in telecommunications networks, enhancing our connectivity and enabling the rapid exchange of information worldwide. In the automotive sector, semiconductors power advanced driver-assistance systems (ADAS) and electric vehicle (EV) technologies, driving the development of safer and more sustainable transportation solutions.

Renewable energy sources, such as solar power, rely on semiconductors to convert sunlight into electricity through photovoltaic cells. Semiconductors also play a critical role in medical imaging technologies, allowing for more accurate diagnoses and innovative treatments.

As technology continues to advance, the demand for more powerful, energy-efficient, and versatile semiconductors grows exponentially. Researchers and engineers are constantly exploring new materials and manufacturing techniques to push the boundaries of what semiconductors can achieve.

In this exploration of semiconductors and their applications, we will delve into the underlying principles of semiconductor physics, delve into various types of semiconductors, including silicon and compound semiconductors, and explore the diverse array of industries and technologies that rely on semiconductors to drive innovation and progress.

From the foundations of semiconductor theory to the cutting-edge applications shaping our world, this exploration of semiconductors will shed light on the pivotal role they play in powering the technologies that have become an integral part of our modern lives.

2. Semiconductors

Semiconductors are materials that possess electrical conductivity characteristics between those of conductors and insulators. Unlike conductors, which allow electricity to flow easily, and insulators, which prevent the flow of electricity, semiconductors exhibit intermediate electrical conductivity.

The behaviour of semiconductors is governed by the movement of electrons within their atomic structure. In pure semiconductors, such as silicon or germanium, electrons are bound to their respective atoms. However, when subjected to certain conditions, such as the application of an electric field or the introduction of impurities, known as doping, the conductivity of semiconductors can be altered.

Examples of Semiconductors

Gallium arsenide, germanium and silicon are some of the most commonly used semiconductors. Silicon is used in electronic circuit fabrication, and gallium arsenide is used in solar cells, [laser diodes](#), etc.

3. Types of Semiconductors

There are two main types of semiconductors based on their composition: elemental semiconductors and compound semiconductors.

1. **Intrinsic semiconductors** are pure semiconducting materials that have an equal number of positively charged holes (resulting from missing electrons in the valence band) and negatively charged electrons (in the conduction band). Under normal circumstances, these electrons are not freely mobile, but they can be "excited" to higher energy levels by the application of energy, such as heat or light.

2. **Extrinsic semiconductors** are doped semiconductors where impurity atoms are intentionally introduced into the crystal lattice. Doping introduces extra charge carriers into the material, either in the form of additional electrons (n-type doping) or missing electrons, known as holes (p-type doping). This intentional modification of the semiconductor's atomic structure allows for more precise control over its electrical properties.

3. **Elemental Semiconductors:** Elemental semiconductors are made up of a single element from the periodic table. The most commonly used elemental semiconductors are silicon (Si) and germanium (Ge).

Silicon (Si): Silicon is the most widely used semiconductor material in the electronics industry. It has excellent thermal stability and is abundant in nature. Silicon-based semiconductors form the basis of most integrated circuits (ICs) and microchips. They have a band gap of approximately 1.1 electron volts (eV) at room temperature.

Germanium (Ge): Germanium was one of the first materials used in early semiconductor devices. It has a higher intrinsic carrier concentration than silicon, making it suitable for some specialized applications. However, its usage has become less common compared to silicon due to its higher cost and lower thermal stability.

4. **Compound Semiconductors:** Compound semiconductors are composed of two or more elements from different groups in the periodic table. They offer unique electrical and optical properties, making them valuable for specific applications such as high-frequency devices, optoelectronics, and power electronics.

Some examples of compound semiconductors include:

Gallium Arsenide (GaAs): GaAs is a compound semiconductor composed of gallium (Ga) and arsenic (As). It has a wider band gap (approximately 1.4 eV) compared to silicon, allowing for higher-frequency operation. GaAs is commonly used in high-speed electronic devices, microwave circuits, and optoelectronics, including light-emitting diodes (LEDs) and laser diodes.

Gallium Nitride (GaN): GaN is a wide-bandgap compound semiconductor with excellent electrical and thermal properties. It is used in power electronics, high-frequency devices, and optoelectronics. GaN-based devices can operate at higher voltages and temperatures, enabling efficient power conversion and high-speed operations.

Indium Phosphide (InP): InP is a compound semiconductor made up of indium (In) and phosphorus (P). It has a narrower band gap (around 1.35 eV) than silicon, making it suitable for high-speed transistors and photonic devices. InP-based materials are widely used in telecommunications, fiber optics, and high-frequency electronics.

4. Types of Doping

Doping is a deliberate process of introducing impurity atoms into a semiconductor material to alter its electrical properties. By selectively adding impurities, scientists and engineers can control the conductivity and behaviour of semiconductors, expanding their range of applications. Doping is a key technique used to customize the properties of semiconductors for specific purposes.

There are two primary types of doping in semiconductors: n-type doping and p-type doping. These types of doping involve introducing impurity atoms that provide additional charge carriers, either in the form of extra electrons or missing electrons (holes), respectively.

1. **N-type Doping:** In n-type doping, impurity atoms with more valence electrons than the host semiconductor are introduced into the crystal lattice. Commonly used impurity atoms for n-type doping include phosphorus (P), arsenic (As), and antimony (Sb). These impurities are known as donor impurities because they donate extra electrons to the semiconductor material.

When a donor impurity atom is incorporated into the crystal lattice, it creates an extra electron that is loosely bound to the atom. These electrons require less energy to be excited to the conduction band, making them mobile and increasing the conductivity of the material. The extra electrons from the donor impurities become the majority charge carriers in n-type doped semiconductors, carrying the current through the material.

2. **P-type Doping:** In p-type doping, impurity atoms with fewer valence electrons than the host semiconductor are introduced into the crystal lattice. Commonly used impurity atoms for p-type doping include boron (B), aluminium (Al), and gallium (Ga). These impurities are known as acceptor impurities because they accept electrons from the host semiconductor, leaving behind holes.

When an acceptor impurity atom is incorporated into the crystal lattice, it creates a "missing" electron, which is effectively a positive charge or a hole. The hole can move through the material and behave as a positive charge carrier. In p-type doped semiconductors, the holes become the majority charge carriers, conducting the current.

By selectively doping different regions of a semiconductor material, it is possible to create p-n junctions. A p-n junction is a boundary where a p-type region meets an n-type region within a single crystal lattice. This configuration forms the basis for many electronic devices, including diodes, transistors, and integrated circuits. The p-n junction allows for the control of current flow and the creation of various electronic functions.

Doping plays a crucial role in tailoring the electrical behaviour and performance of semiconductors, making them versatile and applicable to a wide range of technologies. By precisely controlling the type and concentration of impurities, engineers can design semiconductors to meet specific requirements for conductivity, voltage characteristics, and other desired properties.

5. Applications of Semiconductors

Semiconductors have a wide range of applications across various industries. Here are some of the key applications of semiconductors:

1. **Electronics and Integrated Circuits:** Semiconductors form the foundation of modern electronics and integrated circuits (ICs). They are essential for manufacturing microchips, which are at the core of computers, smartphones, tablets, and other electronic devices. Semiconductors enable functions such as signal amplification, switching, and data processing, making them vital for digital technology.
2. **Telecommunications:** Semiconductors play a crucial role in telecommunications networks. They enable the efficient transmission, amplification, and routing of signals in fiber-optic communication systems, satellite communication, and wireless networks. Semiconductors are essential components in modems, routers, transceivers, and other devices that facilitate data communication.
3. **Automotive:** Semiconductors are increasingly important in the automotive industry. They are used in advanced driver-assistance systems (ADAS) for features such as collision avoidance, adaptive cruise control, and lane-keeping assistance. Semiconductors also power electric vehicle (EV) technologies, including motor control, battery management, and charging systems.
4. **Renewable Energy:** Semiconductors play a vital role in renewable energy technologies, such as solar power. Photovoltaic cells, commonly made of semiconductor materials like silicon, convert sunlight into electricity. Semiconductors enable the efficient capture and conversion of solar energy, contributing to the growth of clean and sustainable energy sources.
5. **Lighting:** Light-emitting diodes (LEDs), which are based on semiconductors, have revolutionized the lighting industry. LEDs offer energy-efficient and long-lasting lighting solutions in various applications, including residential, commercial, and industrial lighting. Semiconductors also enable the development of organic light-emitting diodes (OLEDs) used in displays and lighting panels.

6. **Healthcare and Medical Imaging:** Semiconductors are used in medical imaging technologies such as X-ray machines, computed tomography (CT) scanners, and magnetic resonance imaging (MRI) systems. Semiconductors enable precise sensing, amplification, and processing of signals, contributing to accurate diagnoses and improved patient care.
7. **Aerospace and Defense:** Semiconductors are vital in aerospace and defense applications. They are used in radar systems, navigation systems, communication systems, and avionics. High-performance semiconductors enable efficient and reliable operation in harsh environments, contributing to the safety and functionality of aerospace and defense technologies.
8. **Consumer Electronics:** Semiconductors power a wide range of consumer electronics, including smartphones, tablets, smart TVs, gaming consoles, and wearable devices. They enable high-speed processing, memory storage, wireless connectivity, and advanced user interfaces, enhancing the functionality and user experience of consumer electronics.

These applications represent just a fraction of the diverse uses of semiconductors. As technology advances, new applications continue to emerge, demonstrating the critical role semiconductors play in driving innovation and shaping our interconnected world.

6. Conclusion

In conclusion, semiconductors are a cornerstone of modern technology with a wide range of applications across various industries.

They have revolutionized the field of electronics, enabling the development of integrated circuits and microchips that power our computers, smartphones, and other electronic devices. Semiconductors are instrumental in telecommunications, allowing for efficient signal transmission and reception in fiber-optic networks, satellite communication, and wireless systems. They also play a vital role in optoelectronics, facilitating energy-efficient lighting with LEDs, laser technologies, and photodetectors for imaging and sensing applications. Moreover, semiconductors are crucial in renewable energy systems, such as solar power, where they convert sunlight into electricity through photovoltaic cells. In automotive applications, semiconductors are integral to advanced driver-assistance systems and electric vehicle technology.

Furthermore, semiconductors find applications in healthcare, aerospace, defense, and consumer electronics, contributing to advancements in medical imaging, aerospace technology, and the proliferation of innovative consumer devices.

The continual progress in semiconductor technology, including advancements in materials, manufacturing processes, and device architectures, promises further breakthroughs and expanded applications in the future. With their exceptional versatility and transformative capabilities, semiconductors continue to shape our interconnected world, driving innovation and powering the technologies that enhance our daily lives.

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Television



Advanced Medical Care



Personal Computer

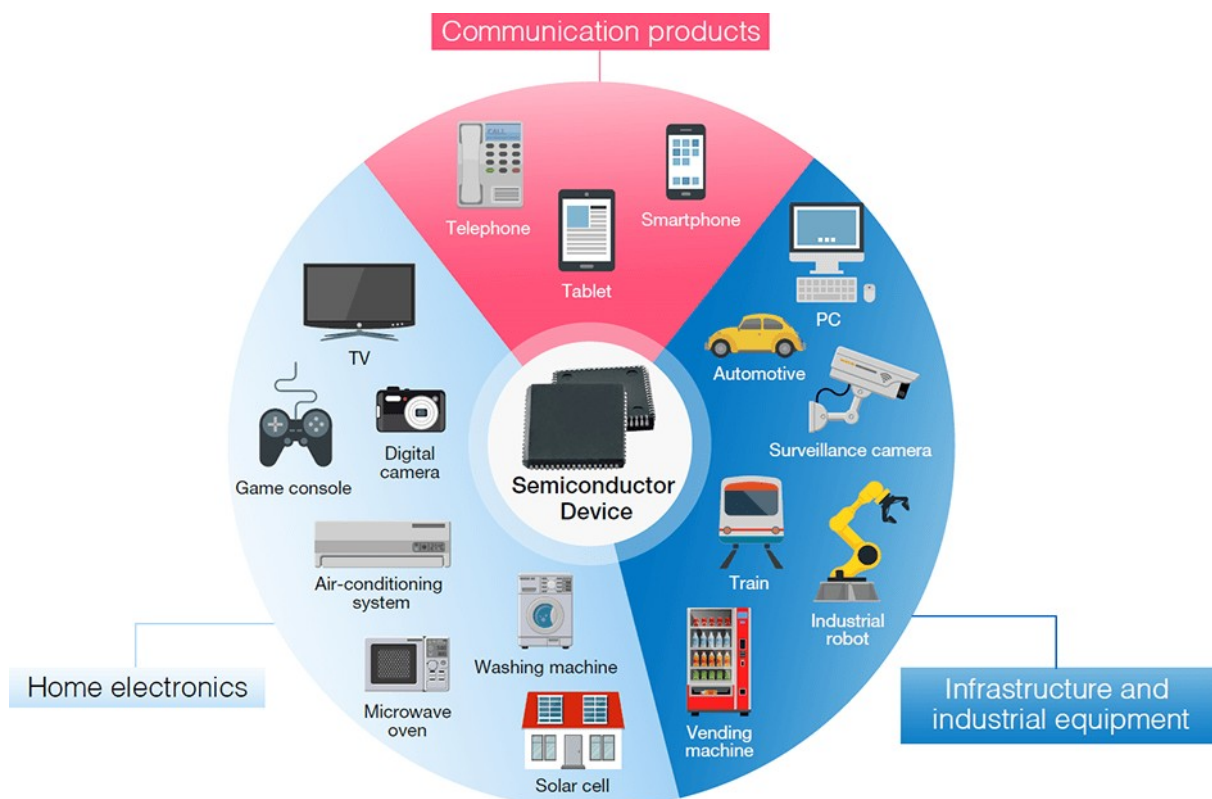
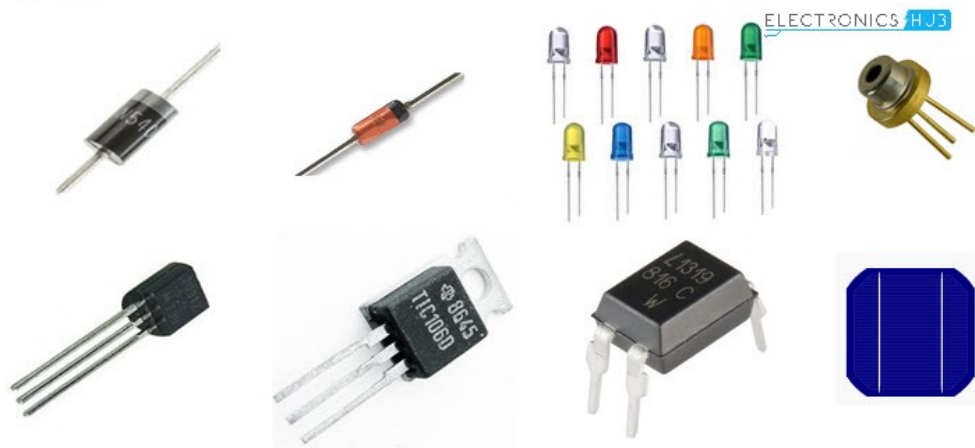


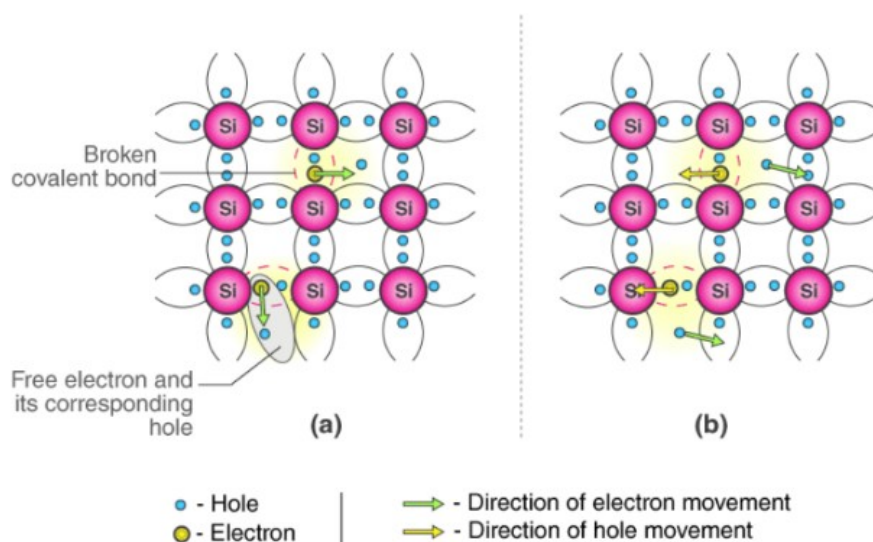
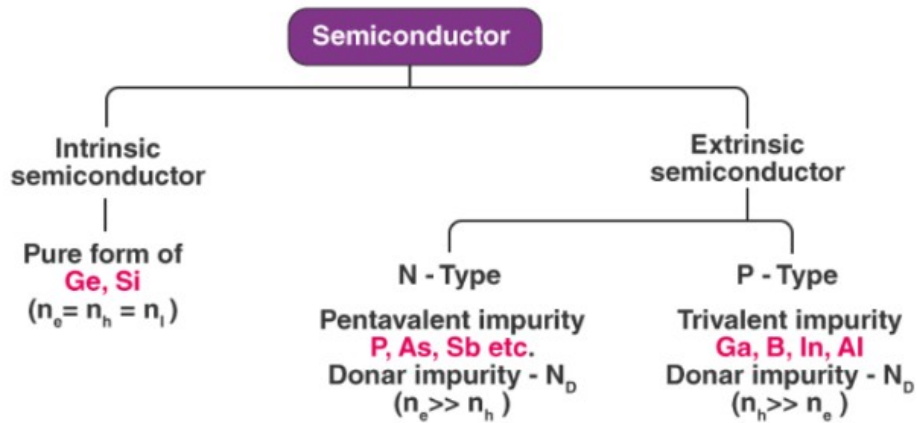
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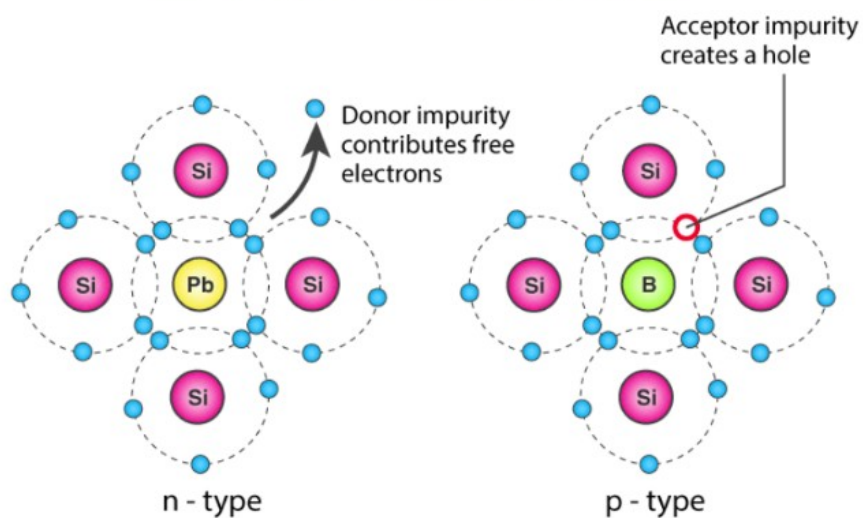
Automobile

Types of Semiconductor Devices





Extrinsic semiconductors



Classification of Extrinsic Semiconductor