

A Study of Semiconductors' Function in Contemporary Technology

Nidhi Sharma¹ and Dr. Meenal²

Department of Physics^{1,2}

Shri Khushal Das University, Pilibanga, Hanumangarh

Abstract: *By analyzing their unique physical and electrical characteristics that make them indispensable in electronics, this paper investigates the crucial role that semiconductors play in advancing technological progress. The different types of semiconductors are discussed based on their purity and properties. Additionally, while discussing current issues with materials, manufacturing, and the environment, the significant influence across a variety of industries, such as computing, telecommunications, and renewable energy, is also examined. This study highlights the significance of semiconductors in cutting-edge domains like quantum computing in addition to the integration of new technologies like artificial intelligence (AI) in the semiconductor industry. Finally, the sustainability initiatives, including research, that are being carried out by different companies are discussed.*

Keywords: Semiconductors, extrinsic semiconductors, intrinsic semiconductors, applications of semiconductors, challenges in semiconductor industry.

I. INTRODUCTION

Materials classified as semiconductors have a special, precisely controllable electrical conductivity that falls between that of conductors and insulators. They are crucial to modern electronics because their conductivity can be changed to achieve desired effects by changing their surroundings, such as by adding impurities or adjusting the temperature. Semiconductors are fundamental components of many different technologies.

Types of Semiconductors

Based on the level of purity, semiconductors are classified into 2 categories: Intrinsic and Extrinsic Semiconductors.

Intrinsic Semiconductors

Intrinsic semiconductors are those that are composed of only one element or compound and are hence free of impurities. The two most prevalent intrinsic semiconductors are germanium and silicon.

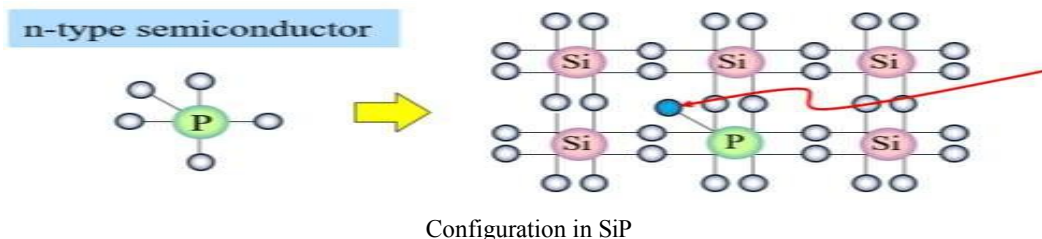
Extrinsic Semiconductors

Extrinsic semiconductors are semiconductors that have an impurity purposefully added to them in order to change their electrical conductivity. Doping is the process of adding impurities, also referred to as dopants, to a pure semiconductor. Doping can produce two different kinds of semiconductors: n-type and p-type.

N-type semiconductors: N-type doping is the process of adding an impurity to an inherent semiconductor, which results in an overabundance of electrons. For instance, phosphorus doping of silicon.

As seen in the case of intrinsic semiconductors, a silicon atom's outermost shell contains four electrons, each of which establishes covalent connections with nearby silicon atoms in the lattice. In contrast, phosphorus is a pentavalent atom, which means it contains five valence electrons. One electron remains unbonded as a result of the four valence electrons of phosphorus forming covalent bonds with the silicon atoms surrounding it when phosphorus atoms are doped into the pure silicon lattice. In this way, this semiconductor contains n-type dopants with electrons left over. This is beneficial since it makes the additional charge carriers available, which raises the material's conductivity.



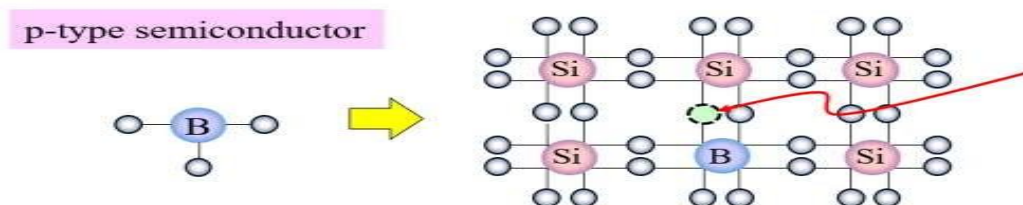


Source: https://www.shindengen.com/products/semi/column/basic/semi/semi_basic.html

P-type semiconductors

A p-type semiconductor is created when an impurity added to an intrinsic semiconductor causes holes to develop. The addition of trivalent boron to silicon serves as an illustration of this. A shortage of electrons is produced in the semiconductor lattice when boron is introduced to silicon. As a result, holes are created that carry positive charges.

Configuration in SiB



Source: https://www.shindengen.com/products/semi/column/basic/semi/semi_basic.html

Applications of semiconductors

Modern technology is built on semiconductors, which are employed in many different domains. The following are some of the main areas of semiconductors:

Electronics and Computing

Transistors: The fundamental components of contemporary electronics are transistors, which are composed of semiconductors. Bipolar junction transistors (BJTs) and field effect transistors (FETs) are the two varieties of transistors.

The emitter, which releases charge carriers, the base, which controls the transistor's current flow, and the collector, which gathers the charge carriers released by the emitter and base, are the three terminals of a BJT. Depending on how the p-type or n-type semiconductor is arranged, this type of transistor can be either NPN or PNP.

Because of their electric field-based operation, FETs regulate the circuit's current flow. FETs come in two varieties: Junction FETs (JFETs) and Metal-Oxide-Semiconductor FETs (MOSFETs).

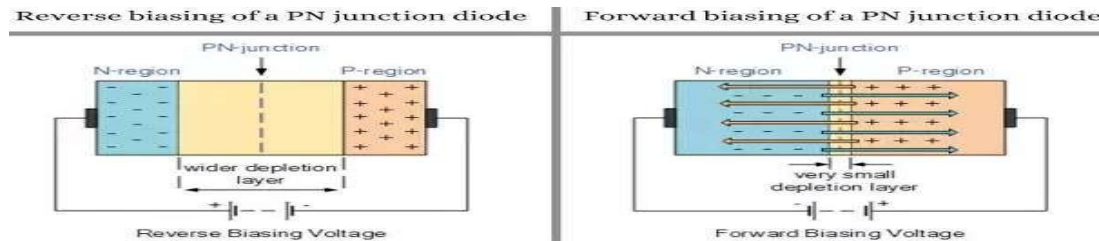
The following are the most common applications of transistors: electrical signal amplification in radio transmitters, audio equipment, and other circuits used for signal processing.

Power supply, motor control applications, and digital circuits all use fast on/off switching.

Transistors make up digital logic circuits, which enable sophisticated calculations in computers and other devices.

Diodes: Semiconductor devices called diodes only permit one direction of current flow. When it is forward biased, that is, when the anode is connected to a higher voltage than the cathode, current flows through the diode and from the anode to the cathode. Current does not pass through it when it is reverse biased.





Diode in reversed and forward bias form

Source: <https://www.atlearner.com/2019/07/pn-junction-diode.html>

The following are the most common applications of diodes

1. Diodes are used in rectifying power supply, which convert AC to DC.
2. Signal demodulation is the process of utilizing diodes to extract information from modulated signals, such as AM and FM.
3. Diodes are used in voltage regulation, which is the process of converting variable input voltage to constant output voltage. They are crucial for voltage referencing and power supply circuits.
4. They shield circuits from harm by preventing the flow of reverse current. Power supply units and battery management systems both use this.
5. Light Emitting Diodes (LEDs), a unique kind of diode that illuminates as current flows through it, are utilized in anything from digital screens to light bulbs.

Integrated Circuits (ICs)

When various transistors and diodes are combined onto a single chip, then it is known as an integrated circuit. It allows for complex functions within compact spaces. They are useful because of their small size, cost efficiency and better performance.

These are a few common applications of ICs

Computers and Smartphones: ICs form the foundation of computers, tablets, smartphones, etc. as they enable complex calculations along with data processing.

Military and Aerospace applications: Military equipment and aerospace technology for navigation, communication and control function devices.

Automotive Systems: ICs are used in engine management systems, security features like airbag control, power management systems and the infotainment systems in modern vehicles

Medical Devices: Implantable medical devices, diagnostic devices, patient monitoring systems, therapeutic devices and even such as MRI machines, ECG monitors etc. are designed using ICs.

Memory Devices

Semiconductors are also used in making memory devices. These devices are used for retrieving and storing data in electronic devices such as computers. They can be classified into 4 main categories

Primary Memory

It is the primary storage area for data in electronic devices. It is temporary and directly interacts with the CPU. RAM and ROM come under this category.

Secondary Memory

Also known as the external memory, it is non-volatile but doesn't directly interact with the CPU. It acts as a permanent storage area. Hard disks, solid state drives, optical discs and flash memory come under this category.

Cache Memory

It is a small type of volatile computer memory because of which high-speed data is accessed by the processor and hence enhances performance by storing frequently used data.



Magnetic Tape

It is used for backup because of its great capacity and low cost per bit. But it has a slower access time compared to other storage options.

Microprocessors

Microprocessors are advanced integrated circuits that are the central processing unit (CPU) of computers. They perform all the instructions, calculations and data processing needed for running software applications. Their evolution is driven by developments in semiconductors technology.

Microprocessors consists of an arithmetic logic unit (ALU), which executes the logical and arithmetic operations; control units, which directs the operation of a processor and acts as a communicator between the CPU and other components of the system; registers, which hold data for temporarily for processing and finally cache memory.

Since microprocessors are specialized ICs, their applications are similar to that of an IC.

Communication Technology

Wireless Communication: All the necessary functionality for signal processing, data transmission, and connectivity are provided by semiconductors. Various chips and ICs are used which convert electrical signals into radio waves and vice versa and hence, effective communication takes place. These are a few examples

Cellular Baseband Processors: These are processors that manage both voice and data transmission in mobile devices and hence make smooth connections. Not only this, they manage the communication protocols for mobile networks by doing tasks like encoding and decoding voice and data transmissions.

Bluetooth Transceiver: Used in mobile phones, headphones, etc. for short range wireless communication between devices.

Near Field Communication (NFC) Chips: Contactless communication, such as mobile payments, is possible because of these chips.

Network Infrastructure

Usage of semiconductors can enhance connectivity, communication, and data processing in network infrastructure. Some examples are:

Semiconductors act as the brain of routers and switches. Routers are used for connecting different networks and managing data traffic between them while switches are used to manage data traffic between devices under a single network.

Optical communication systems use light to transmit data and information over long distances using optical transmitter, optical fiber and optical receiver. Semiconductors are used to get high bandwidth, insignificant degradation of data and immunity to Electromagnetic Interference.

Satellite Communication: Satellite communication (Sat Com) is a critical technology because of which we have global telecommunications, broadcasting, internet connectivity, and navigation services today.

Transponders: These devices receive, amplify, and retransmit signals between the ground stations and satellite. These require ICs that handle the various functions of transponders.

GPS Receivers: These use semiconductors for processing of signals from satellite constellations and then provide accurate positioning in navigation systems.

Internet of Things (IoT)

Internet of Things (IoT) refers to the network of interconnected devices, vehicles, appliances and other objects that use sensors and softwares for network connectivity. Semiconductors act as the backbone for this technology as it enables devices to communicate, process data and do so much more.



Sensors: The semiconductors used in sensors collect data from the environment and then convert it to electrical signals. Hence, IoT devices are able to gather and transfer the information for analysis. The motion sensors used in surveillance systems to detect movement is one of the examples of this case.

Communication Modules: They are the reason behind connectivity between devices and networks. Here, the semiconductors provide the necessary processing power, data handling capabilities, and communication protocols for the function of modules.

Renewable Energy

Solar Energy Systems: Semiconductors constitute an enormous part of the solar energy system, especially solar cell technology.

Photovoltaic Cells: Commonly referred to as solar cells, these convert sun rays into electricity through photovoltaic effect. Silicon based cells are the most used cells in the majority of solar panels for the conversion of sunlight into electricity. A number of semiconductor layers are formed to absorb a large portion of the solar light spectrum with multijunction solar cells. This is better than the single junction cells since each layer has a different band gap and therefore, optimize light absorption.

Inverters: Inverters convert DC, from the solar panels to AC feeding into the electrical grid. While the power conversion with these inverters relies on the use of transistors, wider bandgap semiconductors have revolutionized the area. Wide bandgap semiconductors have brought out tremendous performance characteristics in terms of reduced power loss, greater switching speed, and increased temperature tolerance.

Power Management Systems

Semiconductors are used for power management as they help in the maximization of efficiency in energy conversion and produce lesser losses during transmission. Diodes and integrated circuits (ICs) manage power distribution in solar energy systems.

Wind Energy

IGBTs, IGCTs, thyristors and SiC are used for designing the components of the wind turbine system.

Control Systems

These are extremely important systems as they ensure safety and optimal performance. Semiconductors are used to adjust the turbine operations such as blade pitch or rotor operation based on wind conditions.

Power Conversion

Systems such as inverters and AC/DC converters for energy conversion from AC to DC or vice-versa are required. These ensure few energy losses and efficient switching and control of power. These use power semiconductors, especially IGBTs.

Grid Connection

Semiconductors manage the connection between the wind turbines and electrical grids. They maintain flow of electricity, efficiency and ensure that the wind turbine runs through errors without disconnecting from the electrical grid.

Electric Vehicles (EVs)

Battery Management Systems (BMS)

Semiconductors manage the charging and discharging of individual cells of the battery pack in EVs. The system makes it possible for optimized performance, longer battery life, and safety, as overcharging and overheating are prevented.



Advanced Driver Assistance Systems (ADAS) Semiconductors in electric vehicles process data from sensors, cameras, lidar, and radars. Smart features like adaptive cruise control, lane-keeping assistance, and collision avoidance are made possible by this processed data. Microprocessors and microcontrollers make these data processing systems very quick. In the same way, the smart systems that are used also need semiconductors that work with complex algorithms that learn to adapt to the driving environment and keep passengers safe.

Charging Systems: Cost-effective charging solutions such as high-speed chargers and more are designed using semiconductors. These chargers transfer power at high speed while ensuring that it is safe by checking the charging process.

Vehicle-to-Grid (V2G) Technology

With advanced semiconductor technologies, energy flow from EVs to the grid is bidirectional, allowing cars to feed back into the grid during peak demand periods.

Smart Grids

Smart Grids are a new big step in electricity distribution and management. They are essentially connected with advanced communication technologies and use renewable energy sources along with automated systems to improve power networks' efficiency, reliability, and sustainability.

Energy Storage Systems

These are highly important in balancing supply and demand in smart grids by helping control charging and discharging cycles in a manner that ensures maximum efficiency and longevity of storage systems.

Communication Systems

The robust communication networks are used to monitor and control the energy distribution of smart grids. PLC technology, by which data can be transmitted through existing power lines using special semiconductor devices, allows for real-time monitoring and management of the grid. AMI uses semiconductors to enable smart meters, which provide real-time information on energy consumption, allowing utilities to better manage demand.

Grid Automation and Control

Semiconductors have been an important component in the automation systems for achieving improved grid reliability and efficiency. They facilitate real-time processing and control functions, necessary in the management of DERs such as solar panels and wind turbines. Smart technologies will enhance the ability of utilities to better optimize energy flow and minimize peak demand while providing for stronger grid resilience.

Challenges in semiconductors tech

The semiconductor industry, although crucial to modern technology, has several significant technological limitations that affect its development and application. The main challenges are as follows:

Miniaturization Limits

The downsizing of semiconductors has pushed technology forward, making it possible to make electrical gadgets that are smaller, more powerful, and use less energy. Chips with 5nm and even 2nm technology are some of the most recent big steps forward in the semiconductor industry. But these new developments make people worry about the boundaries of Moore's Law, which says that the number of transistors on a device doubles about every two years. As semiconductor technology advances, it encounters substantial physical and technological limitations, including current leakage, heat dissipation, manufacturing complexity, and, most critically, quantum effects. Quantum mechanical phenomena have a big effect on how electrons behave at the nanoscale, making standard semiconductor physics less useful. Quantum confinement, tunneling, and ballistic transport are some of the most important phenomena.

High Manufacturing Costs

High manufacturing costs are the hallmark of the semiconductor industry, which results from a variety of inputs throughout the manufacturing process. Knowing these costs will enable companies to navigate the intricacies of semiconductor fabrication while competing in this fast-changing marketplace.



1. It costs a lot of money to do research and development on new semiconductor technology. As designs get more complicated, the costs of chips, tools, and intellectual property go through the roof. Every year, millions of dollars are spent on EDA (Electronic Design Automation) tools.
2. The price of raw materials, such as silicon wafers, metals (such copper and gold), and different chemicals needed in the making process, might change depending on the market. In semiconductor manufacturing, silicon wafers make up about 20–25% of the total cost of goods sold (COGS).
3. Engineers and technicians who work on production processes can make a lot of money, especially in places where the cost of living is high. Also, the costs of training to keep a skilled workforce add to the overall costs.
4. Geopolitical issues, tariffs, trade restrictions, and problems with the supply chain can all affect the availability and cost of the raw materials and parts needed to make semiconductors. These are outside factors that make production costs less reliable.

Environmental Concerns

The production of semiconductors has a massive environmental impact. The growing demand for these makes it inevitable to take into consideration ecological footprint and reduce the impacts.

High Power Consumption: High energy consumption increases the contribution to significant carbon footprints in the sector and stands at about 31% of the global greenhouse emissions. Besides, it uses almost entirely fossil fuel energy which increases the effect of this industry on climate change.

Water Usage: A few billion gallons a year are used in this sector. This poses a threat of depletion of resources and harm to local aquatic systems. Also, water wastes from manufacturing processes directly harm the local water bodies and eventually harm the aquatic ecosystem and the human being.

Chemical emissions: The production of semiconductors involves a number of hazardous chemicals, including fluorinated gases such as PFCs, HFCs, and NF₃. These emissions have high global warming potential (GWP) and significantly add to the greenhouse gas emissions released while manufacturing semiconductors.

Resource extraction impacts: Most of the raw materials essential for semiconductor production—silicon, copper, palladium, and rare earth elements—come from the destruction of habitats, soil degradation that leads to pollution in water bodies and mining activities that usually require large energy input.

Lifecycle Emission: Even after production of semiconductors, the active life of these devices continues to have emission effects.

Future trends in semiconductor research

The semiconductor industry is transforming due to advances in technology and changing market needs. Here are some of the main trends that will shape the future of semiconductor research:

Integration of AI and IoT

The integration of AI and IoT is significantly changing the semiconductor industry, which is developing smarter and more efficient devices. This synergy allows for better data processing and optimizes manufacturing processes as well as innovative applications in other sectors.

AI in Chip Design

Artificial Intelligence (AI) has made chip design better, which has helped the field of semiconductor technology grow. This integration has made design more efficient, improved performance, and cut down on time to market by a lot. A lot of this change is due to the fact that AI approaches have come a long way and can now automate certain parts of the design process. Engineers can now deal with the increasing complexity of current processors.

In the future, AI-powered EDA tools will automate every step of the process, from simulation to verification to optimization.



AI is becoming very important for optimizing PPA (Power Performance Area) metrics. This is because machine learning parameters show how different design choices will affect power consumption, and tools can look at all previous designs to find patterns that led to better performance and help make chips smaller without losing functionality.

Reinforcement learning (RL) is a new and cutting-edge way to use AI in chip designs. In Automatic Design Generation, RL algorithms learn from existing circuit designs to make new layouts that are better than those made by humans. In Iterative Improvement, RL systems get feedback on how well their designs work and keep getting better.

Edge Computing

The combination of AI and IoT, which both use semiconductor technology, is changing edge computing in a big way. This kind of convergence makes it possible to process data in real time and makes decision-making and operational efficiency better across all applications.

Semiconductors give edge computing devices the ability to do calculations. Cutting-edge devices made for edge computing might execute complicated computations right where they are, so there would be no need to send a lot of data to cloud servers. This is the most significant use for low latency/high responsiveness, like for self-driving cars and industrial automation. Keeping data on your own computer makes it safer since it lowers the chance of it being hacked while being sent to cloud servers. Designs for semiconductors are also focused on how much power they use. So, high computing performance with low power consumption is attainable thanks to power management methods including dynamic power management, voltage scaling, and optimized transistor designs. Semiconductors also make it feasible for edge devices to talk to one other and access services in the cloud network. This means that data may be shared and monitored in real time from a distance.

AI and IoT-integrated edge technologies also help automate industry, such predictive maintenance, which looks at equipment in real time to detect breakdowns and cut down on downtime by a lot.

Advanced Communication Technologies

The role of semiconductors in advancing communication technologies is very important, especially with the emergence of 5G and the anticipated transition to 6G. These tiny chips, which are essential for enabling faster data transmission, lower latency, and increased connectivity across various devices and networks, are packed with billions of transistors.

5G Technology

5G technology has very high data rates, low latency, and more capacity. This technique needs new, advanced semiconductors that can handle high-frequency impulses and analyze a lot of data. Because 5G uses millimeter waves, all of the radio frequency (RF) components need to be redesigned to work at these frequencies and meet the performance levels that the application needs. The semiconductor industry has made a lot of progress in meeting the needs of 5G. The goal of making smaller devices with more features is met by redesigning all of the electronic hardware to use System-on-Chip (SoC) technology. This allows processing, memory, and RF components to be connected on the same piece of silicon. Gallium nitride (GaN) and silicon carbide (SiC) are new materials that will make power handling and efficiency much better.

Transitioning to 6G

Development of 6G is in progress and is expected to provide data rates exceeding 1 Tbps along with ultra-reliable low-latency communication (URLLC). Advanced semiconductor technologies will be developed to enable applications such as holographic communication and immersive augmented reality experiences. The advent of 6G will further demand innovations in semiconductor technologies, such as:

Terahertz Frequency Bands: The usage of terahertz frequencies will result in the design of specific semiconductor devices which are capable of high-frequency operation.



AI Integration: Artificial intelligence would enhance the functionality of networks in 6G environments and will greatly demand semiconductors integrating built-in AI capabilities.

Quantum Computing and Neuromorphic Chips

The intersection of quantum computing, neuromorphic computing, and semiconductor technology represents a frontier in computational capabilities, promising to revolutionize various fields, from artificial intelligence to complex problem-solving. This overview explores how semiconductors facilitate these advanced computing paradigms, their implications, and the challenges they face.

Quantum Computing

Quantum computing is a big change in how computers work. It will let computers work in ways that conventional computers can't by using the rules of quantum mechanics. Semiconductors are very important for making and using quantum computing technology.

Semiconductors are used to control and make qubits, which are the basic units of quantum information. Also, microwave and radio-frequency pulses are used to control and modify qubits through semiconductor lines. These are used in semiconductor wiring to establish or entangle the qubit's microscopically small states with other qubits. This is an important step in performing quantum computing. Also, quantum computers need to be very cold to work properly so that quantum coherence can happen. Building these kinds of systems using cryogenic technology that works with semiconductors is a step toward making them smaller and getting rid of environmental noise that gets in the way of these kinds of processors.

Quantum computers are projected to be far better at doing calculations than classical computers, at least in terms of energy used per operation. This value gets more important when the energy needed for the computation keep going up in the different areas of activity where the computations are needed. Quantum computers can solve issues that classical computers can't or can only do extremely poorly, such simulating molecular interactions in drug discovery and optimizing complex systems in finance and logistics.

Neuromorphic Chips

Neuromorphic computing is a whole new way of doing things that tries to make computers work better by copying the structure and function of the human brain. Using semiconductor technology, it is possible to make neuromorphic devices that work like biological brain networks. Neuromorphic chips are built and work more like neurons and synapses than anything else in the brain's neural networks. Spiking neural networks process information by sending electrical signals in short bursts, which is quite similar to how biological neurons talk to each other.

In neuromorphic systems, memory and computation are in the same place, which is different from typical von Neumann designs, where memory is kept separate from processing units. This makes it feasible to process numerous things at the same time, which makes things more efficient and speeds up the process. Neuromorphic chips are naturally energy-efficient, therefore they use a lot less power than regular CPUs. For instance, AI models needed a lot of energy for training and inference, whereas a neuromorphic system can accomplish its job with only 20 watts of power.

In general, these kinds of neuromorphic devices would work with the semiconductor technology that is already utilized to make artificial neurons and synapses. This kind of adaptability would make it possible to make these devices bigger and use them in a variety of ways.

Sustainability Initiatives

The resource-intensive nature of semiconductor manufacturing, along with contributions that are at a higher order of magnitude to green gases than normal emissions from other industries, has led firms to initiate a variety of activities aimed at sustainability throughout their enterprises.



Energy-Efficient Manufacturing

Semiconductor manufacturing facilities (fabs) are adopting intelligent layouts and designs to optimize its energy consumption for developing advanced cooling systems and doing smart space utilization with efficient operation to ensure less energy consumption during every cell manufacturing process. Along with this, a marked shift towards renewable energy integration has occurred with solar and wind power within semiconductor manufacturing factories. Companies like Intel and TSMC have ambitious plans by 2030: they intend to get a considerable input of electricity from renewable power sources at the same time and achieve 100% renewability in their processing.

Emission Reduction Targets

Semiconductor companies usually set greenhouse gas (GHG) emissions reduction goals, such as the 70% reduction by 2025 set by Infineon; or Intel's zero emissions by 2040. Such targets expose that it is no longer sufficient to identify impacts but also act upon them. Introduction of very detailed monitoring and validation systems which would give the most sophisticated method of tracking the entire supply chain with respect to carbon emissions is now there. It would be the transparency that allows meeting regulatory expectations and fosters confidence in stakeholders.

Innovation in Green Technologies

Many companies are working on making semiconductor chips that use less electricity in electrical gadgets. These kinds of advancements are very important for solving the world's energy problems. They can also help technologies like AI and autonomous systems get better, which makes data centers work better and powers IoT gadgets and electric cars. The years of study into energy-efficient semiconductor technology should lead to more uses for new ideas that will help us build a more sustainable future. Biodegradable electronics are still in the early stages of development, nevertheless. If more research is done in a timely manner, biodegradable electronics could greatly minimize the environmental effect of numerous products, making technology more sustainable in the future.

II. CONCLUSION

In summary, this paper gave a full picture of semiconductors and explained how important they are to modern technology. Semiconductors are very important for many uses because they can carry electricity in certain situations. The semiconductor industry is facing both a problem and a chance as we move forward. To address the expanding needs of technology, notably in renewable energy and quantum computing, we need to make progress in material science and fabrication methods. The story of semiconductors is a great example of how people can work together to make technology better. The study has not only made it clear how important semiconductors are in their current uses, but it has also pointed to intriguing new advances that could change the way technology works.

REFERENCES

1. Gourav N. Semiconductors and Its Application. JETIR. July. 2018;5(7):217-221.
2. Real Life Applications of Semiconductor. <https://www.geeksforgeeks.org>. 07 May, 2024.
3. What Is A Semiconductor?. <https://www.indmall.in>.
4. The Role of Semiconductors in IoT And Smart Devices. <https://www.tessolve.com>. 24 June 2024.
5. How semiconductors enable the transition to green energy. <https://efficiencywins.nexperia.com>. 14 August, 2024.
6. Impact of Micro-/Nano-Electronics, Miniaturization Limit, and Technology Development for the Next 10 Years and after. <https://www.newswise.com>. 13 April, 2021.
7. Semiconductor industry – Challenges, latest trends and road ahead. <https://www.wtwco.com>. 22 November, 2023.
8. How AI is Transforming the Semiconductor Industry in 2024 and Beyond. <https://www.acldigital.com>. 2
9. February, 2024.



10. Quantum Computing in Semiconductors. <https://www.acldigital.com>. 19 April, 2024.
11. What Is Neuromorphic Computing?. <https://builtin.com/artificial-intelligence/neuromorphic-computing>. Dec 10, 2024.
12. Sustainability in the Semiconductor Industry: Initiatives by Top Companies. <https://www.mrlcg.com>. 31 July, 2024.

