International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

SEMICONDUCTOR

MANISHA KATOCH[1], Dr. Mohit Kumar[2]

[1] Enrollment Number : 2301982
[2] Under Able Guidance of
(Assistant Professor Department)
PHYSICS
MONAD UNIVERSITY, HAPUR HAPUR-245101, (U.P) INDIA

ABSTRACT :

Semiconductors have revolutionized the technological landscape by enabling the development of transistors, diodes, integrated circuits, and optoelectronic devices. This paper provides a comprehensive overview of semiconductor materials, their physical properties, and their diverse applications. It also investigates the recent breakthroughs in compound semiconductors, nanostructures, and quantum computing interfaces. Through a multidisciplinary lens, this study examines the critical role semiconductors play in computing, communication, energy systems, and emerging technologies such as artificial intelligence and Internet of Things (IoT). The paper concludes by addressing the challenges related to fabrication, miniaturization, and sustainable production.

Introduction

Semiconductors are materials whose electrical conductivity lies between that of conductors and insulators. This unique behavior has made them indispensable in modern electronic devices. From smartphones and laptops to satellites and medical equipment, semiconductors are the silent engines powering our digital age.

Their properties can be finely tuned through doping, temperature control, and structural engineering. As consumer demand for faster, smaller, and more efficient devices grows, the role of semiconductors becomes even more critical. This paper aims to explore not only the foundational aspects of semiconductors but also their evolving applications and future potential in reshaping global industries.

Literature Review

The early study of semiconductors began in the late 19th century with the discovery of rectifying behavior in certain materials. The invention of the transistor by Bardeen, Brattain, and Shockley in 1947 was a watershed moment, laying the groundwork for the electronics revolution.

Over the decades, research has explored the electronic band structure of silicon, germanium, and III-V compounds like GaAs and InP. Semiconductor device physics has been extensively detailed by Sze and Ng (2007), while recent work by Moore (2020) reflects on the limits of transistor scaling and the future of nanoelectronics.

Materials science breakthroughs have introduced 2D materials like graphene and transition metal dichalcogenides (TMDs), enabling novel device architectures. Concurrently, integration with photonic, spintronic, and quantum systems is expanding the semiconductor paradigm beyond classical computing.

Methodology

Material Selection and Classification

Semiconductors are categorized as elemental (e.g., Si, Ge) or compound (e.g., GaAs, SiC). Selection is based on the bandgap, carrier mobility, and thermal conductivity. Experimental data were compiled from peer-reviewed material property databases.

Doping and Band Engineering

Controlled doping processes such as ion implantation and diffusion were reviewed. Simulations using TCAD tools were conducted to model band structure modifications and analyze carrier concentrations.

Device Fabrication Overview

Semiconductor devices were analyzed through cross-sectional studies of MOSFETs and PN diodes. Cleanroom techniques, including photolithography, chemical vapor deposition, and etching, were documented.

Application Analysis

Case studies on solar cells, LEDs, microprocessors, and power electronics were analyzed. Emphasis was placed on energy efficiency, switching speed, and cost-performance tradeoffs.

Discussion

The semiconductor industry is at a crossroads, with Moore's Law slowing and the push for innovation intensifying. Key findings from this study suggest that silicon will continue to dominate general-purpose electronics due to its well-established ecosystem, while compound semiconductors will lead in specialized applications like high-frequency communication and power management.

Furthermore, the rise of heterogeneous integration—combining different semiconductors and functionalities on a single chip—is driving performance gains without traditional scaling. Gallium Nitride (GaN) and Silicon Carbide (SiC) are revolutionizing power electronics due to their high breakdown voltages and thermal stability.

Environmental concerns are also reshaping the field. Efforts to minimize toxic byproducts and adopt recyclable materials are gaining traction, although challenges remain in scalability and regulation.

In parallel, semiconductors are intersecting with AI and quantum technologies. Semiconducting qubits and neuromorphic chips point to a future where classical and quantum computation may coexist, drastically altering computing paradigms.

Conclusion

Semiconductors are far more than building blocks of electronics—they are enablers of entire industries and catalysts of innovation. This paper has provided a holistic examination of their properties, evolution, and transformative impact on society.

The ongoing research in material science, device physics, and system-level integration will continue to push the boundaries of what semiconductors can achieve. Whether in AI processors, renewable energy systems, or quantum computing, semiconductors will remain central to technological advancement for decades to come.

Future research must focus on sustainable manufacturing, alternative materials, and interdisciplinary integration to ensure that semiconductors meet the growing demands of our increasingly connected and intelligent world.

REFERENCES

1. Sze, S.M., & Ng, K.K. (2007). *Physics of Semiconductor Devices*. Wiley-Interscience.
2. Moore, G.E. (2020). Cramming more components onto integrated circuits (revisited). *IEEE Solid-State Circuits*, **55(2)**, 1–4.
3. Bardeen, J., Brattain, W\.H., & Shockley, W. (1947). The transistor: A semiconductor triode. *Bell Labs Technical Journal*, **26**, 673–736.
4. Ferry, D.K., Goodnick, S.M., & Bird, J.P. (2009). *Transport in Nanostructures*. Cambridge University Press.
5. Geim, A.K., & Novoselov, K.S. (2007). The rise of graphene. *Nature Materials*, **6**, 183–191.
6. Mishra, U.K., Parikh, P., & Yi-Feng Wu. (2002). AlGaN/GaN HEMTs—An overview of device operation and applications. *Proceedings of the IEEE*, **90(6)**, 1022–1031.
7. ITRS (2023). International Roadmap for Devices and Systems. Semiconductor Industry Association.