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Research Article

Indian Semiconductor Knowledge Base: Where is the Gap?

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ABSTRACT

This paper attempts to map the Indian knowledge base in the semiconductor industry using two output indicators: publications and patents. Publication data was downloaded from the Web of Science database, and Patent data was downloaded from the WIPO Patentscope database. The result shows that scientific publications in this area are increasing rapidly. China is at the top, followed by the USA. India ranks among the top 10 countries in scientific publications. Similar to scholarly publications, patenting activities are also increasing rapidly. Japan is in the leading position in patents, followed by the US and China. Compound Annual Growth Rate reveals a clear divergence between scientific production and technological innovation. Many countries exhibit strong growth in publications but not in patents. A few countries in Asia (China, South Korea) translate their scientific activities into technological outputs. This shows their strong innovation ecosystems, industrial policy, and R&D commercialization strategy. India has a significant knowledge base in terms of its publication activity. However, there is a substantial gap in the commercialization of technology. The gap lies primarily in establishing a complete, self-sufficient, and innovative ecosystem. This requires focused R&D in manufacturing, raw materials, and advanced packaging, as well as a concerted effort to bridge the talent and skills mismatch across the entire value chain.

Keywords: Bibliometrics, Global Research Trends, India, Innovation Ecosystem, Patent Landscape, Patent, Semiconductor.

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INTRODUCTION

Semiconductors are the foundational technology of the modern digital world. These technologies are crucial in everyday life, including healthcare, computing, telecommunications, artificial intelligence, and defence systems. Because of its strategic importance, semiconductors have become central to the global political economy, technological sovereignty, and geopolitical dynamics.

India's journey in semiconductor innovation is a fascinating case study of a nation striving for technological self-reliance and integration into global value chains (Mani, 2025). While traditionally a leader in the IT services and chip design sector, the country has historically lagged in establishing a robust semiconductor manufacturing ecosystem. India's semiconductor industry has successfully developed a strong position in chip design, embedded systems, and software-oriented semiconductor services. However, India failed to achieve large-scale semiconductor fabrication and deep manufacturing capabilities. Multinational corporations played a crucial role in building India's semiconductor design ecosystem (Schwartz, 2017; Patra & Krishna, 2015). India has the potential to become an important node in the semiconductor global value chain, especially in packaging and design (Tadepalli *et al.*, 2024).

However, a recent, concerted push, largely driven by government initiatives, aims to fill the gap. Recognising the strategic importance of semiconductors, the Indian government launched its initial foray into semiconductor manufacturing in the early 1980s with the establishment of Semiconductor Complex Limited (SCL) in Mohali (SCL, n.d.).

Recognising the strategic importance of semiconductors, the Indian government has launched a mission-mode approach to catalyse the industry. The most significant policy is the India Semiconductor Mission (ISM), launched in 2021 with an outlay of ₹76,000 crore (*Home | India Semiconductor Mission*, n.d.). The mission aims to provide financial incentives and support for various segments of the semiconductor value chain. These policies have already started to yield results, with multiple projects approved and in various stages of construction across the country. Key milestones include the approval of new plants in

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states like Gujarat, Odisha, and Andhra Pradesh, with significant investments from both domestic and international companies.

This paper attempts to map India's technological capability using two widely recognised output indicators of scientific and technological performance, i.e., publications and patents. Scientific publications are considered a measure of research productivity, while patent counts indicate technological innovation activity. These two indicators provide valuable insights into the development of a country's science, technology, and innovation ecosystem (Moed, 2005; OECD, 2009). Publication and patent data are frequently employed in scientometric and innovation studies to evaluate national technological capability, research competitiveness, and innovation performance (Evangelista, 2005; Griliches, 1990).

LITERATURE REVIEW

There is a number of scholarly studies on the bibliometric aspects of semiconductor literature. Data from the engineering database, INSPEC, revealed the rapid, linear expansion of semiconductor literature after the 1980s, reflecting the importance of semiconductors in the global technological industry (Tsay *et al.*, 2000). In the early 2000s, semiconductor research across Asia, particularly in Japan, South Korea, and China, showed an upward trend (Tsay *et al.*, 2003; Guan and Ma, 2007). From 2020 onwards, research output in the semiconductor sector has increased steadily each year, indicating growing interest in applying AI to semiconductor manufacturing processes. China and South Korea are the leading contributors in this field (Won *et al.*, 2024). Among BRICS countries, China emerges as a major scientific contributor with rapidly expanding research output and international visibility. India also demonstrates growing participation, especially in semiconductor design, nanoelectronics, and engineering research (Valitova *et al.*, 2026).

Technological capability (Lall, 1992) is multidimensional and cannot be adequately measured through a single indicator alone (Coombs and Bierly, 2006). However, patents and scientific publications are complementary indicators widely used for measuring industrial knowledge stocks and innovation capability (Han, 2007). Bibliometric analysis on scientific papers and patents is used to identify technological trends and compare knowledge generation and diffusion (Pan *et al.*, 2022). There are a number of studies that have used bibliometric indicators such as publication counts, citation impact, collaboration networks, and thematic mapping to identify major research themes in a given field (Valitova *et al.*, 2026; Archibugi *et al.*, 2009).

Objectives

This study has the following objectives:

- To identify the leading countries in terms of publication and patent output and examine their respective shares in global scientific and technological production.
- To analyse India's position in global publication and patent activities.
- To examine the Compound Annual Growth Rate (CAGR) and overall trends in publications and patents.

Research Methods

This paper attempts to investigate India's technological capability in the semiconductor industry using literature data from the Web of Science (WoS) database. It is widely utilised in bibliometric and scientometric research. Patent data was downloaded from the PATENTSCOPE Database. It is an international patent search database developed and maintained by the World Intellectual Property Organization (WIPO).

Records were searched from SCI-EXPANDED (Science Citation Index Expanded), one of the major citation databases within the Web of Science platform maintained by Clarivate. The following search strings are used to retrieve records: Semiconductor (All Fields) or Semiconductors (All Fields) OR Semiconductor Lasers (All Fields) OR Semiconductor Optical Amplifier (All Fields) OR Semiconductor Manufacturing (All Fields) OR Organic Semiconductors (All Fields) OR Organic Semiconductor (All Fields) OR Semiconductor Optical Amplifiers (All Fields) OR Piezoelectric Semiconductor (All Fields). A total of 606,642 records were considered for analysis after removal of records from the year 2026 (Exclude – Publication Years 2026 AND Exclude – Final Publication Year).

Semiconductor patents are retrieved from the Patentscope database using the following IPC Codes. IPC codes are extracted from: https://ipcpub.wipo.int/. The following IPC Codes are used to download patent records on semiconductor B28D 5/00 (cutting or working SEMICONDUCTOR(S) material), H01L 21/00 (manufacture or treatment of SEMICONDUCTOR(S) devices), C30B (materials for SEMICONDUCTOR(S)) H01C (resistors formed from SEMICONDUCTOR(S) material), H01F 1/40 (selection of magnetic SEMICONDUCTOR(S) material), H01L (SEMICONDUCTOR(S) devices), H10 (SEMICONDUCTOR(S) devices), H10B 12/00 (SEMICONDUCTOR(S) DRAM devices), H10D 84/00-H10D 89/00 (SEMICONDUCTOR(S) integrated circuits), H01S 5/00 (SEMICONDUCTOR(S) lasers), H10B (SEMICONDUCTOR(S) memory devices), H10B 20/00 (SEMICONDUCTOR(S) ROM devices), H10B 10/00 (SEMICONDUCTOR(S) SRAM devices), G01R 31/26 (testing SEMICONDUCTOR(S) devices).

Research Limitations

This research attempts to map India's technological capability using two widely used output indicators. However, these indicators have several limitations. *First*, not all scientific research leads to patentable outcomes (Narin *et al.*, 1997). *Second*, patents are only proxy indicators of technological capability. The mere existence of patents does not automatically imply technological success, industrial application, economic value, or societal impact. *Third*, many patents are not commercialized; also, there are significant variations in patent quality, importance, and technological significance (Archibugi and Planta, 1996). *Fourth*, patenting activities vary across sectors, institutions, and countries. Finally, this research does not incorporate other important dimensions of technological capability, such as manpower and financial investment in research and development (R&D). Skilled manpower and R&D expenditure by governments, industries, and other institutions play a fundamental role in shaping scientific productivity and technological advancement. Therefore, future studies may incorporate additional indicators to provide a more holistic understanding of India's technological and innovation landscape.

RESULTS

The download records are stored in Microsoft Excel, and further analysis is carried out to trace the growth patterns and Compound Annual Growth Rate (CAGR) on both patent and publication data.

Growth of publications

A total of 606,642 publications on semiconductors were retrieved from the year 1965 to 2025 (61 years). The top 10 Countries and their publication counts in semiconductor research show that China is on top with 129,951 publications (21.42%). The United States ranks second, with 119,132 publications (19.64%). Japan ranks third with 54,671 (9.01%) publications. Germany and South Korea occupy the fourth and fifth positions with 47,445 (7.82%) and 44,235 (7.29%) publications, respectively. Russia ranks sixth with 31,699 publications (5.23%). India ranks seventh with 31,121 publications, accounting for 5.13% of the global total. Overall, the findings suggest that semiconductor research is highly concentrated among developed nations. The results also demonstrate the growing participation of emerging economies such as India and China. It is a major shift in the global scientific and technological landscape (Table 1).

The growth pattern shows that scholarly publications in the semiconductor research literature are increasing exponentially (from 615 in 1965 to 27,968 in 2025). The growth trajectory can be broadly divided into three phases (Figure 1).

The *Early Phase* (1965–1990), during which the US dominated research output. European countries (Germany, England, and France) also played strong roles. Followed by a *Transition Phase* (1990–2010), where Japan became a major contributor. However, research output from Germany and France remains stable. In *recent years* (2010–2025), Chinese dominance has been shown in this area.

The rapid rise of China is evident in the shift from its very few publications before 1990 to about 12,481 in 2025. Research outputs from the USA remained stable but declining in recent years (3,856 in 2019 but 3,328 in 2025). South Korean publications show a strong growth after 2000. South Korea is now emerging as a high-growth research nation. Russia shows a declining trend (strong earlier presence but decreasing in recent years). India showed steady growth. Japan and Germany showed moderate growth earlier but are now relatively stable. England and France showed stable but smaller shares compared to the USA and China. Taiwan is an emerging contributor, and its publications have risen significantly since 2000.

Overall, the scholarly publication patterns show a structural transformation of global scientific publication patterns in semiconductor research. Global scientific production is now shifting from Western dominance to a more Asia-centric multi-polar system.

Compound Annual Growth Rate (CAGR)

Compound Annual Growth Rate (CAGR) is a widely used metric to measure the average annual growth rate of a variable over a specified period. CAGR provides a smoothed annual growth rate over the specified period, assuming growth compounds over time. It helps in understanding the average annual growth despite fluctuations. CAGR is a commonly used method in scientometrics studies to measure growth in publications, citations, or research output using the following formula:

$$CAGR = \left(\frac{V_f}{V_i}\right)^{\frac{1}{n}} - 1$$

Where:

Vf = Final value

Vi = Initial value

n= Number of years

Table 2 shows the CAGR for the selected countries. China shows the highest CAGR at 20.76%, indicating very strong growth. South Korea also demonstrates significant growth with a CAGR of 19.56%.

India, the USA, Germany, Russia, and Taiwan exhibit moderate growth rates, generally ranging from 11% to 14%. These countries have consistently increased their values over the years.

Japan, France, and England show comparatively lower CAGRs, typically below 12%. The growth is still positive, but their growth trajectory has been less steep than that of the top performers.

Table 1: **Top 10 countries and their publication share in Semiconductor research.**

Sl. No.	Countries/Regions	Record Count	% of 6,06,642
1.	Peoples R China	1,29,951	21.42
2.	USA	1,19,132	19.63
3.	Japan	54,671	9.01
4.	Germany	47,445	7.82
5.	South Korea	44,235	7.29
6.	Russia	31,699	5.22
7.	India	31,121	5.13
8.	France	29,130	4.80
9.	UK	24,603	4.05
10.	Taiwan	19,754	3.25

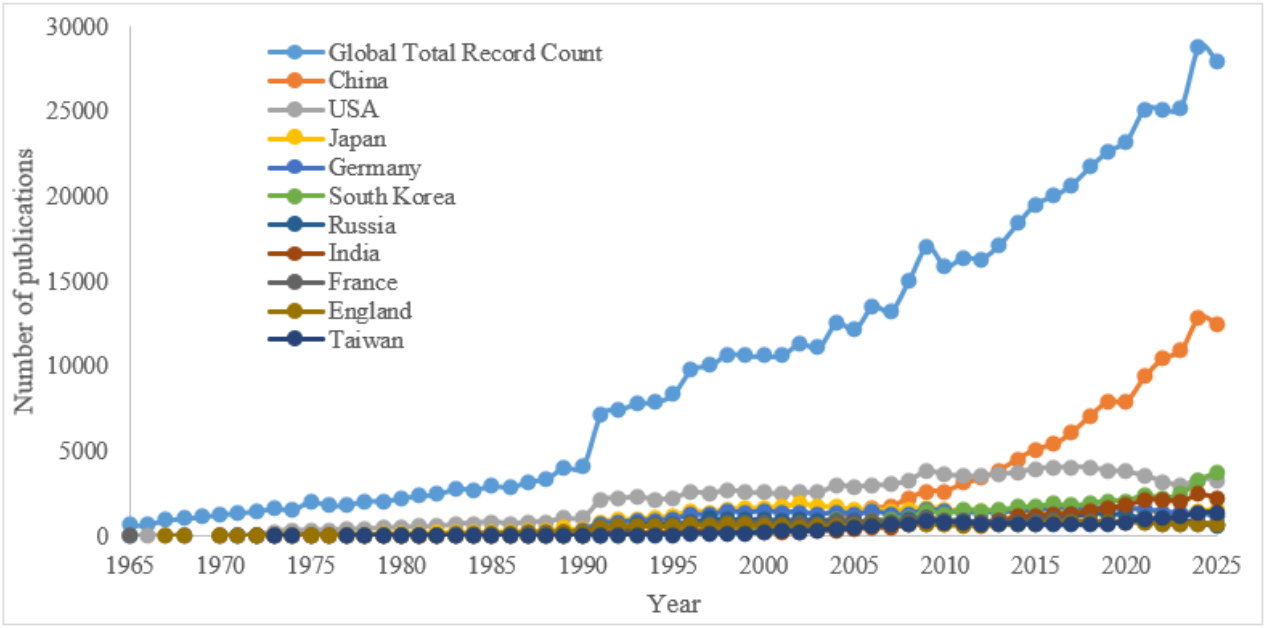

Figure 1: Growth of Semiconductor Industry Scholarly Publications.

Growth of semiconductor patents

Semiconductor patent data downloaded from WIPO Patentscope data for the period from 1977 to 2025. A total of 42,18,524 patents were identified globally using the IPC codes mentioned in the methodology section. The downloaded data show overall global growth, with growth observed after 2010. Global patents increased from 16,756 patents in 1977 to 177,609 patents in 2025.

The distribution of patents by the top 10 scholarly literature-publishing countries shows that Japan is in the leading position, with 97,495 patents (about 2.31%). The United States ranks second with 66,587 patents (approximately 1.58%). China ranks third with 39,940 patents (0.95%). Germany and South Korea also demonstrate substantial patent contributions with 22,856 patents (0.54%) and 19,150 patents (0.45%), respectively. France, the United Kingdom, and India contribute comparatively smaller shares. India recorded 3,844 patents, representing approximately 0.09% of the total patents. Although India's patent share remains relatively low compared to that of technologically advanced countries, the results indicate the country's growing engagement in semiconductor-related innovation and research. India's comparatively lower patent output may be attributed to limited semiconductor manufacturing infrastructure, lower commercialization of research, and dependence on imported technologies.

The growth pattern can be divided into three distinct phases. *Early Period* (1980s–1990s), where the United States dominated, and Japan emerged as a strong second leader. European countries (Germany, the UK, and France) contribute moderately. Followed by a *Transition Phase* (2000–2010), where growth was observed across all countries. Japan had a strong presence (e.g., 3802 in 2010), but South Korea began accelerating. This shows a clear shift toward Asia-led innovation systems. The *recent period*

(2010–2025) saw a strong rise in China's status as a major global player (Figure 2).

Overall, the patent data show a global transformation in patent activity, characterised by rapid growth. There is a major shift in innovation activity toward Asian countries.

CAGR of semiconductor patents

Table 3 presents the CAGR of semiconductor patents for selected countries. China shows the highest CAGR at 25.44%, indicating very strong growth. South Korea also demonstrates significant growth with a CAGR of 21.54%. Taiwan (15.70%), Japan (15.38%), France (13.38%), Germany (12.99%), the UK (10.25%), and the US (10.18%) are moderate growth countries. These countries have consistently increased their values over the years. India (9.94%) and Russia (3.49%) are lower-growth countries.

A comparative analysis of two CAGR tables (Tables 3 and 4), one for overall publications and the other for semiconductor patents, shows different dimensions of scientific and technological activity. Growth is generally higher and more volatile in semiconductor patents compared to overall publications (Chenoy *et al.*, 2019).

The comparison reveals a clear divergence between scientific production and technological innovation. Many countries exhibit strong growth in publications but not in patents (Platzer and Sargent, 2016). A few countries in Asia translate their scientific activities into high-impact technological outputs. This shows the importance of innovation ecosystems, industrial policy, and the capacity for R&D commercialization (Lamsal *et al.*, 2023; Krishna, 2021).

Table 2: **CAGR of selected countries.**

Country	CAGR	Period	Start Value	End Value	Remark
Peoples R China	20.76%	1975 to 2025	1.0	12481.0	High growth
South Korea	19.56%	1979 to 2025	1.0	3705.0	High growth
India	13.63%	1970 to 2025	2.0	2252.0	Moderate growth
USA	13.16%	1965 to 2025	2.0	3328.0	Moderate growth
Russia	12.53%	1971 to 2025	1.0	587.0	Moderate growth
Germany	12.52%	1965 to 2025	1.0	1185.0	Moderate growth
Taiwan	11.91%	1973 to 2025	4.0	1392.0	Moderate growth
France	11.29%	1965 to 2025	1.0	612.0	Lower growth
England	10.67%	1967 to 2025	2.0	714.0	Lower growth
Japan	9.60%	1972 to 2025	12.0	1548.0	Lower growth

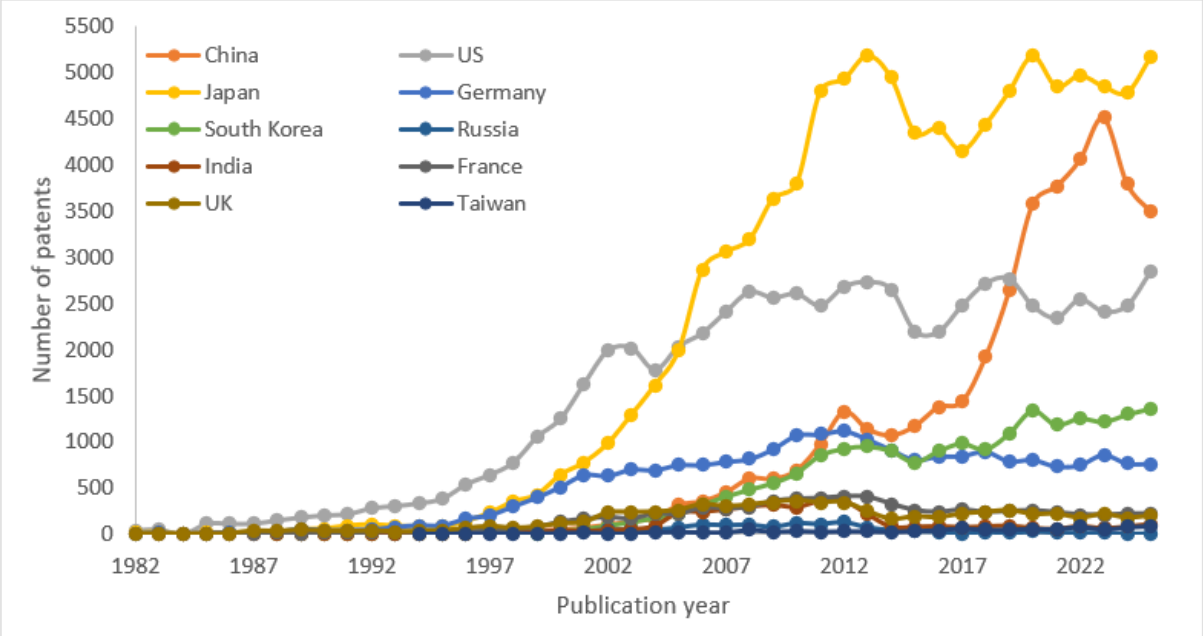

Figure 2: Growth of semiconductor patents.

Table 3: **CGAR of semiconductor patents of selected countries.**

Country	CAGR	Period	Start Value	End Value	Remark
China	25.44%	1989 to 2025	1	3495	High Growth
South Korea	21.54%	1988 to 2025	1	1365	High Growth
Taiwan	15.70%	1994 to 2025	1	92	Moderate Growth
Germany	12.99%	1982 to 2025	4	763	Moderate Growth
USA	10.18%	1982 to 2025	44	2844	Moderate Growth
UK	10.25%	1982 to 2025	3	199	Moderate Growth
France	13.38%	1982 to 2025	1	221	Moderate Growth
Japan	15.38%	1982 to 2025	11	5172	Moderate Growth
India	9.94%	1983 to 2025	2	107	Lower Growth
Russia	3.49%	1993 to 2025	3	9	Lower Growth

Table 4: **Comparison of the CAGR of publications and patents.**

Country	Publication CAGR	Patent CAGR	Remark
China	20.76%	25.44%	Strong growth in both, but faster in high-tech sectors. It shows China's technology-driven innovation expansion
South Korea	19.56%	21.54%	Consistently high growth, particularly strong in industrial innovation systems
India	13.63%	9.94%	Strong in research output but weak in technology commercialization
USA	13.16%	10.18%	Balanced growth in both, but slower patent growth relative to publications. It shows a mature innovation ecosystem
Russia	12.53%	3.49%	The major gap between research and innovation output indicates weak technology transfer mechanisms
Germany	12.52%	12.99%	Balanced and stable, mature innovation systems without extreme growth
Taiwan	11.91%	15.70%	Moderate research growth but stronger specialisation in the semiconductor industry
France	11.29%	13.38%	Balanced and stable, mature innovation systems without extreme growth
UK	10.67%	10.25%	Balanced and stable, mature innovation systems without extreme growth
Japan	9.60%	15.38%	Lower growth in publications, but strong in technology and patent production

CONCLUSION

Overall, the findings reveal that semiconductor patents are highly concentrated among technologically advanced economies with strong industrial R&D ecosystems. Furthermore, publication and patent productivity do not always correspond in proportion. Some countries may exhibit strong scientific publication but relatively lower patenting activity. Therefore, patent indicators should be interpreted alongside publications and other technological indicators to obtain a comprehensive understanding of national technological capability.

India has a significant knowledge base, with a strong research base and a large pool of engineering talent. However, there is a significant skills gap in the specialised areas of semiconductor manufacturing, such as fabrication and advanced packaging Initiatives are underway to train engineers and bridge this gap, but it remains a critical hurdle. India is a late entrant to a market dominated by established players in Taiwan, South Korea, China, and the United States, who have decades of experience, economies of scale, and advanced technology. The global focus on diversifying supply chains beyond a single region has created an opportunity for India to position itself as a reliable and secure manufacturing hub. India's existing strength in chip design and R&D can be leveraged to create a full-fledged ecosystem. India

has a strong foundation in semiconductor design and a clear vision for the future. The research gap lies primarily in the need to establish a complete, self-sufficient, and innovative ecosystem. This requires focused R&D in manufacturing, raw materials, and advanced packaging, as well as a concerted effort to bridge the talent and skills mismatch across the entire value chain.

ABBREVIATIONS

AI: Artificial Intelligence; **BHU:** Banaras Hindu University; **BRICS:** Brazil, Russia, India, China, and South Africa; **CAGR:** Compound Annual Growth Rate; **DRAM:** Dynamic Random-Access Memory; **INSPEC:** Information Services for Physics, Electronics, and Computing; **IPC:** International Patent Classification; **ISM:** India Semiconductor Mission; **IT:** Information Technology; **OECD:** Organisation for Economic Co-operation and Development; **R&D:** Research and Development; **ROM:** Read-Only Memory; **SCI-EXPANDED:** Science Citation Index Expanded; **SCL:** Semiconductor Complex Limited; **SiC-MOSFET:** Silicon Carbide Metal-Oxide-Semiconductor Field-Effect Transistor; **SRAM:** Static Random-Access Memory; **USA:** United States of America; **WIPO:** World Intellectual Property Organization; **WoS:** Web of Science.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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