MITSUI & CO. GLOBAL STRATEGIC STUDIES INSTITUTE

Silicon Carbide Power Semiconductors Enter Full-Scale Adoption Phase with Killer App

— Module Diversification and Expanding Business Opportunities from the "Heart" of Popular Hybrid Vehicles —

Reina Ogawa
Industry Innovation Dept.
Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

Why This Technology?

Toyota's new RAV4, launched in Japan on December 17, 2025, marks the first use of SiC power semiconductors in a Toyota hybrid system. The previous-generation-RAV4 was the world's best-selling passenger vehicle in 2024 in terms of new car sales volume. The installation of silicon carbide (SiC) power semiconductors in hybrid vehicles—considered a real solution for electric vehicles by balancing environmental impact and economic efficiency—as well as in high-volume, popular models is expected to make 2026 an inflection point for the rapid adoption of SiC power semiconductors.

Summary

- Power semiconductors are incorporated into all types of electrical equipment, from home appliances and automobiles through to elements of infrastructure, and they serve as the heart of these devices. The SiC power semiconductor market is projected to reach JPY 2.9034 trillion by 2035, representing 6.4-fold increase over the level in 2025.
- The incorporation of SiC power semiconductors into the hybrid system of the next-generation Toyota RAV4, the world's best-selling vehicle in 2024, signaled the beginning of full-scale adoption in automotive systems.
- As demands for miniaturization, weight reduction, and greater reliability continue, all companies involved in SiC wafer manufacturing, front-end and back-end processes, and modularity in installation stand to benefit from this growth.

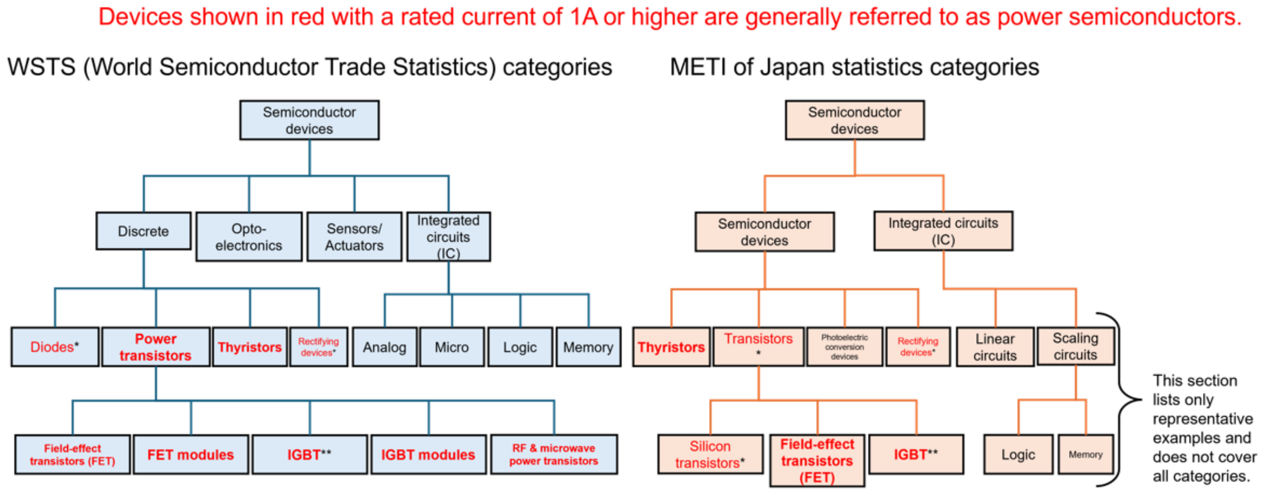
1. What are SiC Power Semiconductors?

1-1. What are Power Semiconductors?

Power semiconductors are capable of controlling large currents and voltages, and they are incorporated into all types of electrical equipment, from automobiles and home appliances through to trains, power transmission facilities, and other elements of infrastructure. Logic and memory can be likened to the human brain because they handle information processing and storage. In the same manner, power semiconductors can be likened to the heart, as they deliver electrical current throughout the entire device in the form required for proper operation. While their classification within semiconductor devices varies depending on the method used, they are categorically not integrated circuits (ICs) like logic and memory, which integrate large numbers of transistors onto a single wafer. The term "power semiconductors" collectively refers to semiconductor devices that handle large currents and voltages, operating as single transistors or combinations thereof (modules). The term also encompasses power transistors and diodes (Figure 1).

The global power semiconductor market is projected to grow roughly 2.2-fold over the next decade,

Figure 1: Classifications of power semiconductors within semiconductor device categories



* Some diodes, rectifying devices, and (silicon) transistors have low rated currents. Among the devices listed on the left, generally only those with a rated current of 1A or higher are classified as power semiconductors.
** An abbreviation of Insulated Gate Bipolar Transistor
Source: Compiled by MGSSI based on JEITA, Green Clean Semiconductor: An Easy Guide to Semiconductors
https://semicon.jeita.or.jp/book/docs/green_clean_semicon_1.pdf (Last accessed on November 5, 2025)

from JPY 3.5285 trillion[1] in 2025 to JPY 7.7710 trillion in 2035. Applications for automobiles, renewable energy, and communications/data centers are expected to be the primary drivers of this growth. More than half of this increase will be accounted for by next-generation power semiconductors. While silicon has traditionally been used as substrates (wafers) for conventional power semiconductors, next-generation power semiconductors are manufactured using wafers with chemical compositions other than silicon.

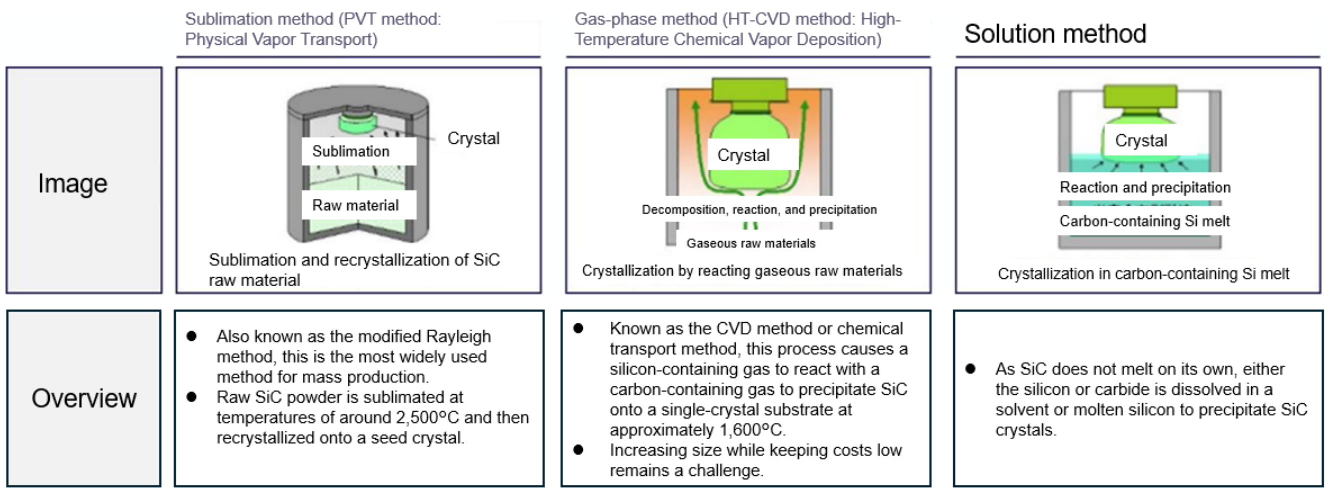
1-2. SiC Power Semiconductors as the Leading Contender among Next-Generation Power Semiconductors

Next-generation power semiconductors that make use of silicon carbide (SiC) wafers are referred to as SiC power semiconductors. As semiconductors are required to provide ever greater energy efficiency and performance year after year, the silicon conventionally used in power semiconductors is now approaching its physical limits in meeting requirements for thermal resistance and dielectric strength. This has led to the full-scale development of next-generation power semiconductors with far superior physical properties. Among next-generation power semiconductors, SiC power semiconductors currently account for the largest share of the market. The global market is expected to have reached JPY 455.8 billion in 2025 and grow to JPY 2.9034 trillion by 2035, representing a 6.4-fold increase over 2025. The greatest advantage that SiC power semiconductors have over other next-generation power semiconductors is their ability to directly apply the technologies for manufacturing power semiconductors that make use of silicon wafers. This enables manufacturers to keep development costs relating to production processes for devices following wafer production lower than those for other next-generation semiconductors, resulting in SiC devices taking the lead in mass production.

[1] Fuji Keizai, 2025 Edition: Current Status and Future Outlook of the Next-Generation Power Device-Related Market

While conventional silicon ingots[2] are produced by dipping a seed crystal into molten silicon, SiC is manufactured using a different process as it does not melt. Mass production primarily makes use of the sublimation method and the solution method (Figure 2). However, because SiC ingots take longer to produce than silicon ingots, the prices of the ingots and of the wafers sliced from them are higher than those of silicon. Accordingly, the shift from silicon to SiC has first begun in applications where the advantages of SiC—such as smaller size, lighter weight, and greater energy efficiency—justify the higher wafer cost, such as in trains, industrial equipment, and electric vehicles, including battery electric vehicles (BEVs) powered solely by batteries and hybrid electric vehicles (HEVs). Figure 3 illustrates the ranges of rated current and rated voltage by application, as well as the areas where the switch from silicon to next-generation semiconductors is progressing.

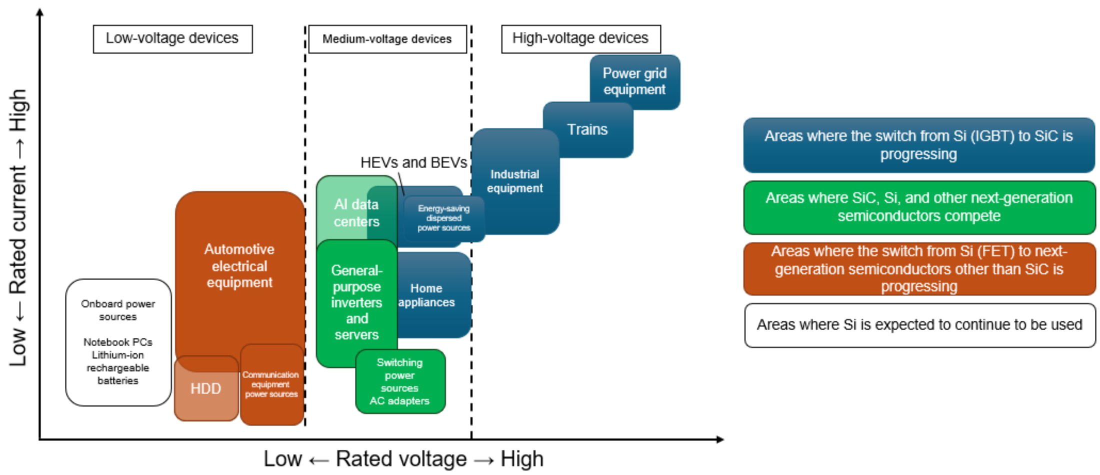
Figure 2: SiC ingot manufacturing methods and overview of the process



Source: Compiled by MGSSI based on "Domestic and International Trends Related to the Construction of Next-Generation Digital Infrastructure" by Ministry of Economy, Trade and Industry of Japan (published in October 2025) for the images, https://www.meti.go.jp/shingikai/sankoshin/green_innovation/industrial_restructuring/pdf/034_03_00.pdf (Last accessed on November 4, 2025) and based on various materials for the overview

[2] A lump of highly pure metal. Wafers used in semiconductor manufacturing are produced by slicing cylindrical ingots into thin discs and polishing them.

Figure 3: Performance requirements for power semiconductor by application and outlook for the switch from silicon to next-generation semiconductors



Source: Compiled by MGSSI based on various sources

2. Noteworthy Trends

2-1. Full-Scale Adoption of SiC Power Semiconductors Begins with Toyota's 6th Generation RAV4

SiC power semiconductors are most commonly applied in inverters, which convert the direct current (DC) supplied from an electrified vehicle's battery into alternating current (AC) to drive the motor. The plug-in hybrid model of Toyota's sixth-generation RAV4, which launched in Japan on December 17, 2025, adopted SiC power semiconductors for the first time in the company's hybrid systems. Due to the smaller size of the module, the height and weight of the hybrid system were reduced by 15% and 18% each, while the battery capacity was increased by 30%. This extended the electric driving range from 95 km of the previous model to 150 km. A driving range of 150 km means that, while still a plug-in hybrid vehicle, everyday driving can be covered using electricity from the battery alone. The previous fifth-generation RAV4 surpassed the US-based Tesla's Model Y[3], which had been the world's best-selling vehicle in 2023, to become the global best-selling vehicle in 2024, and its successor, the sixth-generation RAV4, is also planned for release worldwide. As growth in BEV sales remains slower than expected around the world, there is a growing trend of reassessing the value of HEVs as vehicles that balance environmental impact[4] and economic efficiency across the entire product lifecycle, from manufacturing to disposal, during the transition toward BEVs. In line with this trend, manufacturers are expected to continue adopting SiC power semiconductors.

2-2. Power Semiconductor-Related Companies Making Long-Term Investments in Development and Mass Production

As noted in the previous chapter, although the SiC power semiconductor market is expected to expand over the long term, its short-term growth path will not be smooth due to factors such as weaker-than-

[3] Within the electric vehicle sector, Tesla focuses on developing, manufacturing, and selling BEVs; and the company adopted SiC power semiconductors made by STMicroelectronics for its Model 3 inverter in 2017. The Model Y also makes use of similar SiC power semiconductors.

[4] In some cases, HEVs have a lower environmental impact than BEVs depending on battery manufacturing processes and disposal conditions, power supply configurations in the regions where the vehicles are used and charged, the use of biofuels, and other factors. https://www.jstage.jst.go.jp/article/jsaeronbun/56/4/56_20254372/_pdf

expected BEV sales—previously seen as a primary growth driver—and the rapid rise of Chinese competitors. Some companies, such as the Onsemi (US) and Mitsubishi Electric, have halted or postponed initially planned investments considering the balance between supply and demand, and others such as Wolfspeed (US) have been driven into management crises due to misjudged investment decisions, with Renesas Electronics recording losses as a result. On the other hand, European players including STMicroelectronics (Switzerland) and Infineon (Germany) are steadily investing in development and manufacturing across a broad range of fields, including automobiles, data centers, and renewable energy. What these companies have in common is that they are making investment decisions with the goal of sustaining and growing their businesses over the long term. Figure 4 shows trends in SiC power semiconductor development and manufacturing among power semiconductor-related companies.

Figure 4: Trends in SiC power semiconductors among major power semiconductor manufacturers

Company	Market share (2025 estimate*)	Overview
STMicroelectronics (Switzerland)	32.5	Has R&D facilities in Italy, mass-produces SiC wafers in Morocco and China, and manufactures devices at its 150 mm SiC wafer fabrication facilities in Italy and Singapore. Currently constructing a factory in China through a joint venture with Sanan Optoelectronics (China). Also constructing a fully vertically integrated facility in Italy, encompassing modules and packaging. This represents a multi-year investment of EUR 5 billion.
onsemi (US) (Semiconductor Components Industries, LLC)	23.6	Established in 1999 as a spin-off from the Semiconductor Components Division of Motorola (US). In 2022, expanded manufacturing capacity in the Czech Republic to 3 million wafers per year. In 2023, expanded its 200 mm SiC wafer manufacturing facility in South Korea, securing an annual production capacity of 1 million wafers. In 2024, announced plans to build a vertically integrated production facility in the Czech Republic with an investment of up to USD 2 billion. Halted additional investment in its South Korean plant in 2025 due to sluggish BEV sales, even though it had announced that its products had been adopted for use in plug-in HEVs by a US-based OEM. Acquired SiC JFET** business from Qorvo (US) in January 2025. Also targeting adoption in power sources for AI data centers.
Infineon Technologies (Germany)	16.5	The world's largest power semiconductor manufacturer. In 2024, opened the world's largest SiC power semiconductor factory in Malaysia. Invested EUR 2 billion in the facility as Phase 1 of the plan. Plans to invest up to EUR 5 billion in Phase 2. Has already secured six automotive OEM customers, along with others in the renewable energy and industrial sectors, and aims to achieve annual SiC revenue of EUR 7 billion and a 30% share of the global market by 2030. Developed CoolSiC JFET for AI data centers. Plans to launch mass production in 2026.
Wolfspeed (US)	11.8	Holds the leading share in SiC wafer manufacturing. Founded as a wafer manufacturer but later expanded into device production. However, filed for Chapter 11 bankruptcy protection under US federal law in June 2025 due to sluggish EV sales and the emergence of Chinese competitors. Announced completion of its restructuring in September.
ROHM (Japan)	8.1	Although sales declined significantly in 2024, its SiC power semiconductor modules were adopted for use in Toyota's EVs for the Chinese market. Announced a partnership with DENSO in this sector. DENSO has acquired a portion of ROHM's shares. In addition, its group company SiCrystal (Japan) has concluded a multi-year contract to supply SiC wafers to STMicroelectronics starting in 2024.
Mitsubishi Electric (Japan)	2.0	In October 2025, completed a new factory building for power semiconductors using 200 mm SiC wafers in Kikuchi City, Kumamoto Prefecture. Aims to transition to full-scale mass production in 2027. However, expansion investments have been postponed until the 2031 fiscal year or later. Aims to transition to mass production in 2027. Has also established a roadmap to reduce costs in cooperation with Coherent (US), a leading SiC substrate manufacturer in which it has invested. Expects to launch mass production of the J3 series for inverters used in electrified vehicles in 2026, while initially focusing on the railway and power sectors, where high performance and reliability are critical.
DENSO (Japan) and Fuji Electric (Japan)	1.8	In 2024, announced a joint investment totaling JPY 200 billion. Expansion is underway at DENSO sites in Aichi and Mie Prefectures, as well as at Fuji Electric's site in Nagano Prefecture. The company, which develops and manufactures power semiconductors for Toyota's BEVs, is expanding its Tsugaru Plant in Aomori Prefecture to bolster its shift toward SiC.
YJ (China) (Yangzhou Yangjie Electronic Technology Co., Ltd.)	0.8	Has decided to launch mass production of SiC power semiconductors featuring next-generation transistor structures around 2027. This follows the successful achievement of a 41% reduction in cell size compared with the previous generation. Working to increase SiC power semiconductor production capacity from the current 5,000 150-mm wafers per month to 20,000 wafers per month by 2027, while also transitioning to 200-mm wafers.
Renesas Electronics (Japan) electronics	-	In 2023, deposited USD 2 billion (approx. JPY 290 billion) with Wolfspeed and concluded a 10-year contract for the supply of SiC substrates. However, recorded losses following Wolfspeed's bankruptcy, and supported the company's restructuring. Suspended development of products and investments in factory facilities for SiC power semiconductors in response to environmental changes, including the emergence of Chinese competitors. The Kofu Factory (Kai City, Yamanashi Prefecture), which had been scheduled to mass-produce SiC devices, will instead be used to produce silicon MOSFETs and gallium nitride (GaN) devices.

* Estimated based on 2025 sales, the 2023 market share (TrendForce), and forecast figures from each company's IR materials and various announcements.

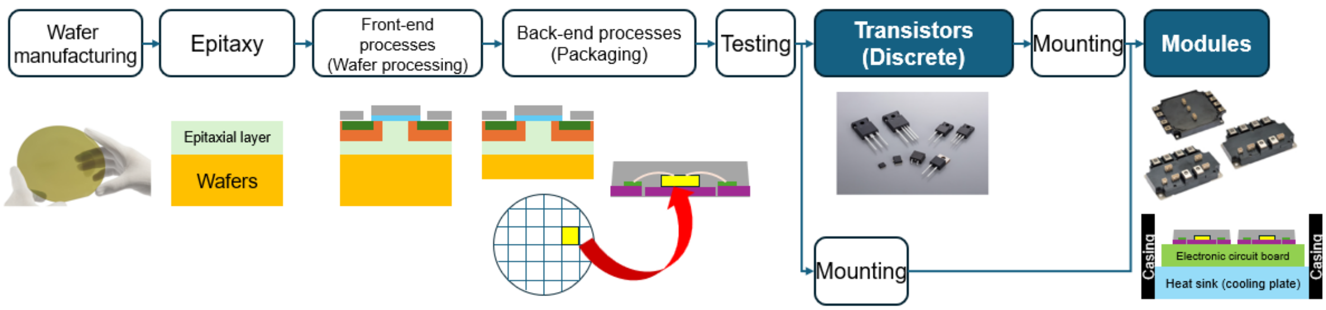
** An abbreviation of Junction Field Effect Transistor. SiC JFETs are expected to enable higher efficiency and performance in power supply equipment for artificial intelligence (AI) data centers, due to their low on-resistance, high voltage tolerance, and high-speed switching capabilities.

Source : Compiled by MGSSI based on various date

2-3. Module Design and Heat Dissipation/Cooling Technologies Growing in Importance for Ensuring Reliability

Figure 5 provides an overview of the power semiconductor manufacturing process. Modules are produced by placing and connecting (mounting) chips or transistors onto circuit boards. For SiC power semiconductors, wafer prices account for a large proportion of the cost of devices, and packaging and mounting technologies have a significant impact on performance. As a result, many companies maintain vertically integrated systems covering everything from wafer manufacturing through to module production, while combining in-house production with procurement from wafer manufacturers for SiC wafers and SiC epitaxial wafers with epitaxial layers.

Figure 5: Manufacturing process for power semiconductors (transistors and modules)



Note: The images are for illustration purposes only and do not reflect actual product dimensions or designs.

Source: Compiled by MGSSI based on various data
ROHM website https://www.rohm.co.jp/news-detail?news-title=2022-04-14_news_sicrystal25&defaultGroupId=false
(SiC wafers)
Fuji Electric website https://www.fujielectric.co.jp/products/semiconductor/power_discrete/index.html
(SiC discrete devices)
Mitsubishi Electric website https://www.mitsubishielectric.co.jp/semiconductors/powerdevices/products/power-module/sic-module
(SiC power modules)

In conventional silicon substrate design, development proceeded sequentially in line with the order of the manufacturing processes. However, as automotive OEMs and other power semiconductor users demand an increasingly higher degree of balance between miniaturization and high-current capability, it is becoming essential to eliminate backtrack in development. To achieve this, it is necessary to consider cooling methods when in module format from the chip and transistor development stages, and to ensure that chip and module designs are aligned. It is of particular note that as SiC power semiconductors are capable of resisting temperatures more than 50°C higher than silicon power semiconductors and handling larger currents, they generate more heat during operation. However, the surrounding materials are not as resistant to heat as SiC, making heat dissipation and cooling technologies increasingly important in preventing the thermal degradation of peripheral materials.

3. Future Prospects

Companies engaged in the development and manufacture of SiC power semiconductors are expected to continue investing in development and mass production in a manner that addresses demand and performance requirements from markets such as HEVs and other automotive applications, data centers, and renewable energy infrastructure.

It is becoming increasingly important to develop modules for HEVs and BEVs, which are seen as key killer apps. To achieve further miniaturization and weight reduction while ensuring reliability—namely, effective thermal countermeasures—the following four trends merit attention as proposals for new modules to replace the general-purpose 6-in-1 power modules, which integrate the devices required for current and voltage control and have traditionally been used for motor drives in electrified vehicles.

(1) Substrate-embedded modules: Designed to save space by embedding SiC power semiconductor chips directly into circuit boards. Europe is leading in this area, and in 2023, Infineon announced joint development with Schweizer Electronic (Germany).

(2) 2-in-1 molded modules: Designed to achieve miniaturization and high performance by integrating two transistors—previously mounted separately on circuit boards—into a single package. ROHM is mass-producing such modules, but its adoption requires advanced bonding technology to attach heat sinks (cooling plates) with fin-like structures for effective heat dissipation.

(3) 6-in-1 multifunctional modules: Designed to integrate various circuits and devices that previously required external components into general-purpose modules, while minimizing package thickness. Mitsubishi Electric and ROHM are both engaged in development.

(4) Multifunctional, dual-sided cooling modules: Designed to balance cost and performance by integrating SiC and silicon power semiconductors into a single package according to drive voltage and other requirements, while ensuring a high degree of heat dissipation by bonding heat sinks to both sides. At the Power Conversion and Intelligent Motion (PCIM) Expo, one of the world's largest power semiconductor exhibitions held in May 2025, ROHM, BASiC Semiconductor (China), and Silan Microelectronics (China) exhibited their products.

In the development of new SiC power semiconductor devices and modules—in addition to the services and solutions needed to accelerate changes in the development process—it will be necessary put forth proposals for new levels of performance and value with regard to manufacturing equipment and component materials. As such, all companies involved in the supply chain could be seen as standing to benefit from this market growth.