

POWER SiC: MOSFETs, SBDs and Modules

Patent Landscape Analysis – January 2019

The SiC power device market outlook is promising as market adoption is ongoing. Who are the current key IP players for MOSFETs, SBDs and power modules, and who will have the best IP position in the coming years?

REPORT OUTLINE

- Power SiC: MOSFET, SBDs and Modules
- Patent Landscape Analysis
- January 2019
- PDF >130 slides
- Excel file with >3,800 patents
- €6,490 for a multi-user license



KEY FEATURES

- **Competitive landscape** from a patent perspective, offering a very complementary vision to market research.
- **Key patent owners**, their IP and technology strategies and their future intents.
- **New entrants**, their technology and their market areas of interest.
- Know competitors' **strengths** and **weaknesses** in terms of patents and technologies.
- Follow **technology developments**, identify emerging technologies and know **key technical solutions** to solve hot technical issues.
- Identify **free technologies** which can be used safely and to mitigate the risks of **patent infringement**.
- Identify technologies to acquire and **potential R&D partners**.
- Benefit from a useful **Excel database** with all patents analyzed in the report, including technology segmentation.

LINKED REPORTS

- [Power SiC 2018](#) (Yole Développement)
- [Power GaN 2018](#) (Yole Développement)
- [Cree-Wolfspeed](#) (Yole Développement)
- [Wolfspeed C2M 1200V SiC MOSFET C2M0025120D](#) (System Plus Consulting)
- [Power Module Packaging 2018: Material Market and Technology Trends](#) (System Plus Consulting)

Power SiC intellectual property (IP): leadership of Japanese players, strong presence of automotive companies, and Chinese new entrants.

The 2016-2018 period has been crucial for the whole SiC industry. **SiC MOSFETs**, commercially available for several years, **are gaining the confidence** of numerous customers and have clearly begun to penetrate into different applications. They follow the first commercially available **SiC diodes** that appeared on the market over 18 years ago and **gradually changed the market**. According to Yole Développement's report [Power SiC 2018](#), the **SiC device market** is expected to grow steadily, from \$302M in 2017 to **more than \$1.5B in 2023**, at a Compound Annual Growth Rate (CAGR) of 31%.

In this report, Knowmade has thoroughly investigated the **patent landscape related to SiC-based power electronics**, covering **MOSFETs, Schottky Barrier Diodes (SBDs) and power modules**. Today, there is a dichotomy in power SiC patents, with new activity from Chinese players on one side and leadership of Japanese players and the strong presence of automotive companies on the other.

Key IP players for SiC MOSFETs, SBDs and power modules

	Planar SiC MOSFET	Trench SiC MOSFET	SiC SBD	SiC Power Module
Key IP players still active	General Electric	Denso Corporation Fuji Electric	Mitsubishi Electric	Hitachi
Key IP players with lower patenting activity since 2015	CREE/Wolfspeed Fuji Electric	CREE/Wolfspeed	CREE/Wolfspeed Panasonic	Mitsubishi Electric
IP Challengers		Toyota Motor Toyota CRDL Rohm	Fuji Electric Sumitomo Electric	Rohm CREE/Wolfspeed
IP new entrants	Hestia Power Century Goldray CRRC Times Electric SGCC UESTC	Century Goldray UESTC SGCC	Shenzhen BASiC Semiconductor Beijing Yandong Microelectronic Century Goldray Semiconductor SGCC	* Danfoss Silicon Power Tyco Tianrun Semiconductor, Yangzhou Guoyang Electronic Wancheng Electric Vehicle Operation

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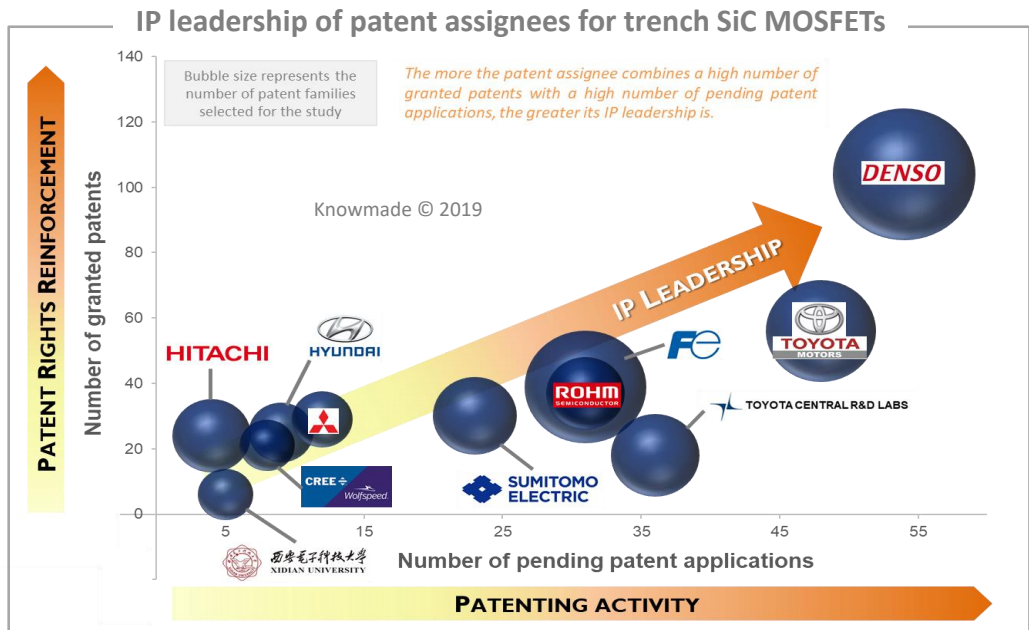
Japanese integrators are leading SiC MOSFET-related patenting activity

We witnessed a remarkable **acceleration** in patent filing related to **SiC MOSFETs** between **2011** and **2015**, concomitant with the **commercialization of the first SiC MOSFET products**. **Japanese integrators** – especially **Denso** and **Fuji Electric** – have **taken the lead** in **SiC MOSFET** related patenting activity. **China** has entered the SiC MOSFET patent landscape in recent years, starting with R&D players in 2011, who were followed by major state-owned integrator companies in 2015 such as **State Grid Corporation of China (SGCC)**, **CRRC** and SiC pure player foundry **Century Goldray**, which was established in 2010 to address the whole power SiC supply chain. A common feature of these new entrants is that **they intend to develop IP on both planar and trench MOSFET structures**. **Taiwan** has a long standing R&D player in SiC MOSFETs with **ITRI**, but there was no industrial player until 2016, when **Hestia Power** emerged, focused on cost effective planar junction barrier Schottky (JBS) diode-integrated MOSFET structures. We note that current **leading SiC device makers** like Cree/Wolfspeed, Rohm, Infineon and STMicroelectronics own some key patents but **do not necessarily have strong IP leadership**.

Planar SiC MOSFETs vs. Trench SiC MOSFETs

CREE/Wolfspeed has taken the lead in the **planar SiC MOSFET** IP race, well ahead of its main competitors **Mitsubishi Electric** and **Fuji Electric**. The analysis of **Cree’s patent portfolio** shows it can effectively **limit patenting activity in the field and control the freedom-to-operate in most countries** including Japan. In fact, patenting activity from competitors is not ramping up and does not threaten **CREE’s** IP leadership. The strong leadership of **CREE/Wolfspeed** as well as the growing maturity of planar SiC MOSFET technology could explain a slowdown in patenting activity since 2015.

Denso leads the IP race in **trench SiC MOSFETs**, well ahead of **Fuji Electric**. However, the latter could seriously challenge in coming years, provided that a significant number of its pending patent applications are granted. The situation differs from planar SiC MOSFETs, with various patent applicants such as **Toyota Motor, Toyota Central R&D Laboratories (CRDL), Sumitomo Electric** and **Rohm** still active. There seems to be more room for challengers in the **trench SiC MOSFET** IP competition, although **Denso** is actively strengthening its leadership through the collaboration with **Toyota Motor** and **Toyota CRDL** in the context of the acceleration of SiC power technologies’ development for electric and hybrid electric vehicle (EV/HEV) applications. **CREE/Wolfspeed’s** IP portfolio is relatively small in **trench SiC MOSFETs** with respect to planar SiC MOSFETs, but the company owns several key patents as it started to patent important inventions before most competitors.



A significant fraction of patents related to **trench SiC MOSFETs** concern the **protection of the gate oxide material** from electric field concentration in certain portions of the gate. In this report we go through **recent developments** from major IP players to address reliability issues due to **gate oxides**.

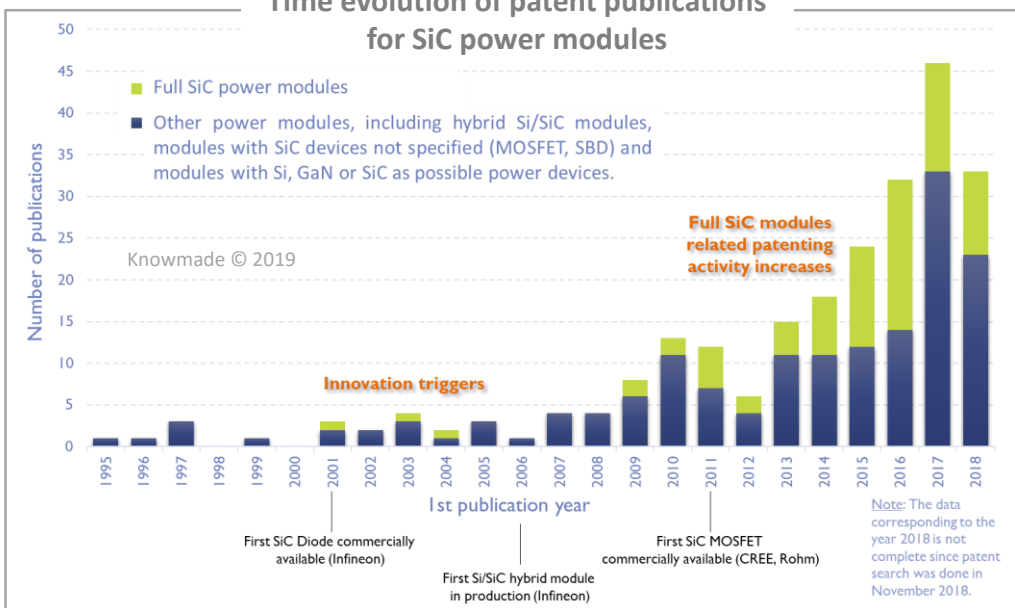
SiC SBDs: revealing the recent patenting activity from key players and new entrants

CREE/Wolfspeed and **Mitsubishi Electric** share the IP leadership in **SiC SBDs**, and with **Fuji Electric** and **Sumitomo Electric** they are currently the **most active patent applicants**. In this report we detail the **recent patents** from **key IP players** and **new entrants**. Most patent applicants address **reliability** issues related to the **edge termination** regions, including **Mitsubishi Electric, Fuji Electric, Toshiba** and **Panasonic**. Additionally, both **CREE/Wolfspeed** and **Mitsubishi Electric** are developing Schottky devices with a **superjunction** structure. Some new inventions deal with increasing **current capability** of JBS diodes, including from **Panasonic, Denso, Fuji Electric**, and **Infineon**, and improving the **stability** when the device temperature rises, in patents from **Panasonic** and **Fuji Electric**. **New entrants** are exclusively **Chinese** players, including **Century Goldray** and **SGCC**. Their patents mainly relate to **JBS diodes** and are only filed in China for the moment.

Full SiC power modules

The share of **full SiC module-related patents** has been **growing since 2012**. **Mitsubishi Electric** is leading the **SiC power module** IP race with key patents mostly focused on **hybrid Si/SiC modules**. In this report we detail the **patent portfolio** of the main IP leaders like **Mitsubishi Electric, Hitachi, Rohm** and **CREE/Wolfspeed** and the **new entrant** **Danfoss Silicon Power**. **Rohm’s** recent patenting activity puts the emphasis on the use of **full SiC modules in electric vehicles**, stressing solutions to efficient heat dissipation, the reliability of power module assemblies operating at high temperature and the reduction of stray inductance. **Danfoss** filed four patents related to **full SiC MOSFET modules** in 2018, focusing on enhancement of performance through optimized layout of interconnects inside the module.

Time evolution of patent publications for SiC power modules



COMPANIES MENTIONED IN THE REPORT (NON-EXHAUSTIVE)

Denso, Cree, Wolfspeed, Fuji Electric, Toyota Motor, Mitsubishi Electric, Sumitomo Electric, Rohm, General Electric, Hitachi, Toyota Central R&D Labs, Xidian University, Panasonic, Hyundai Motor, CRRC Times Electric, Century Goldray Semiconductor, Infineon, State Grid Corporation of China (SGCC), Hestia Power, Nissan Motor, Siemens, NXP, Toshiba, Philips, Microsemi, Littelfuse, IXYS, Monolith Semiconductor, Renesas Electronics, Bosch, ABB, Shindengen Electric Manufacturing, Showa Denko, Kansai Electric Power, On Semiconductor, Beijing Yandong Microelectronic, Tyco Tianrun Semiconductor Technology, Shenzhen Basic Semiconductor, Sharp, Guangdong Midea, Siemens, Danfoss Silicon Power, Wancheng Electric Vehicle Operation, Yangzhou Guoyang Electronic, Tyco Tianrun Semiconductor Technology, Schneider Electric, Dynex Semiconductor, Honda Motor, etc.

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AUTHORS**Dr. Rémi Comyn**

Rémi works for Knowmade in the field of Compound Semiconductors and Electronics. He holds a PhD in Physics from the University of Nice Sophia-Antipolis in France in partnership with CRHEA-CNRS, also located in Sophia-Antipolis, France, and the University of Sherbrooke in Québec, Canada. Rémi has also worked in a compound semiconductor research laboratory as a research engineer.

Contact: remi.comyn@knowmade.fr

**Dr. Nicolas Baron**

Nicolas is CEO and co-founder of Knowmade. He manages the development and strategic orientations of the company and personally leads the Electronics & Telecom department. He holds a PhD in Physics from the University of Nice Sophia-Antipolis, and a Master of Intellectual Property Strategies and Innovation from the European Institute for Enterprise and Intellectual Property (IEEPI) in Strasbourg, France.

Contact: nicolas.baron@knowmade.fr

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Specialized in the analysis of patents and scientific information, **Knowmade** provides technology intelligence and IP strategy consulting services. The company supports the business development of R&D organizations, industrial companies, and investors by helping them to understand the competitive landscape, follow the technology trends, and find out opportunities and threats in terms of technology and patents.

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