Silicon Carbide (SiC)

Patent Landscape Analysis – May 2022

Figure out the IP strategy of main players and newcomers in the emerging SiC ecosystem.
A vertically-integrated innovation strategy combined with a global patenting activity provides multiple ways to overcome the high entry barrier in SiC industry and secure a market leadership for the next decade.

REPORT OUTLINE

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- Silicon Carbide (SiC)
- Patent Landscape Analysis
- May 2022
- PDF >200 slides
- Excel file >13,700 patent families
- Reference: KM22003
- 4,990 EUR for a multi-user license

KEY FEATURES

- Describing the **global patenting trends**, including time evolution of patent publications, countries of patent filings, etc.
- Identifying the **main patent assignees** and the **IP newcomers** in the different segments of the supply chain.
- Determining the status of their **patenting activity** (active / inactive) and their **IP dynamics** (ramping up, slowing down, steady).
- Identifying the **IP collaborations** (patent co-filings) and **IP transfers** (changes of patent ownership).
- Providing a detailed picture of the **Chinese SiC ecosystem** focusing on the patenting activity of Chinese entities.
- **Patents categorized** in 5 main supply chain segments and 10 main sub-segments: **bulk SiC & bare SiC wafers, epitaxial SiC substrates** (growth apparatus, finishing), **SiC devices** (diodes, planar MOSFETs, trench MOSFETs), **SiC modules** (thermal issues, parasitics, die-attach, encapsulation), **circuits**.
- **IP profile of main players**:
  - Patent portfolio **overview** (IP dynamics, segmentation, legal status, geographic coverage, etc.)
  - **IP strategy** and key patents.
  - **Recent IP activity**.
- **Excel database** containing all patents analyzed in the report, including patent segmentation and hyperlinks to an **updated online database**.

RELATED REPORTS

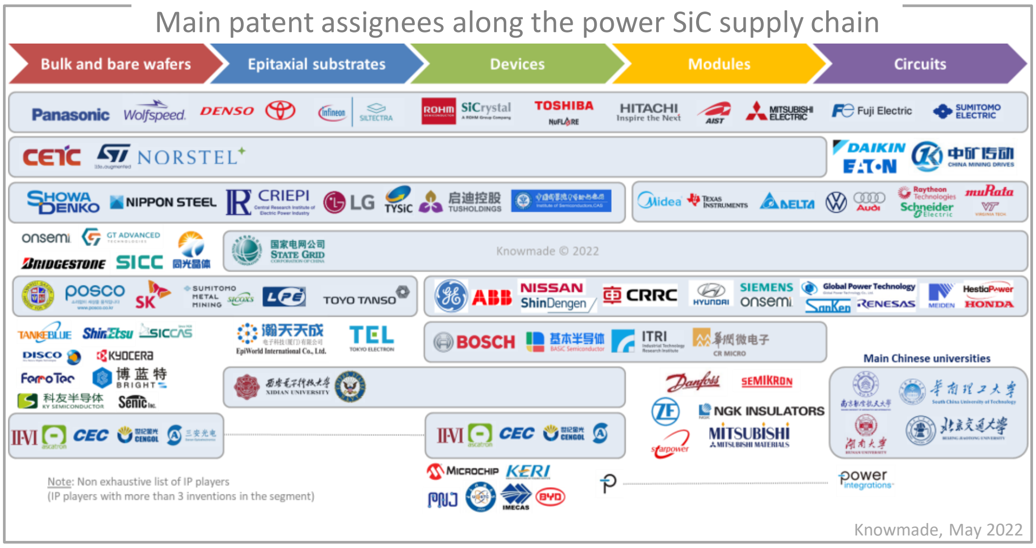
- Next-Generation Power Modules Patent Landscape 2021

Context of the report

The **Silicon Carbide** (SiC) power device market is growing fast, driven by the adoption of SiC technology in electric vehicle (EV) applications. The SiC power device market revenues exceeded 1 $B in 2021 and were earned by companies mainly located in Europe (**STMicroelectronics**, **Infineon**), in the US (**Wolfspeed**, **onsemi**) and in Japan (**Rohm Semiconductor**, **Mitsubishi Electric**, **Fuji Electric**). What's more, Yole Développement recently forecasted a multi-billion dollar SiC power device market for the next years, exceeding 6 $B in 2027 with an estimated CAGR of 34% in 2021-2027. Obviously, the other major nations in the semiconductor industry, including **China** and **South Korea**, have unveiled their ambitions to develop their own SiC industry. Yet their ability to build the whole supply chain required for power SiC technology in the short or mid-term has been questioned, especially regarding the establishment of a domestic supply for SiC wafers. Indeed, the entry barrier in SiC wafer business is remarkably high, as attested by the very limited number of companies currently able to mass produce large-area and high quality SiC wafers to power device makers, so that they can comply with the stringent device requirements expected from the EV industry.

In this context, **Knowmade** is releasing a **new patent landscape report** which aims to provide a comprehensive view of the **power SiC patent landscape** along the whole supply chain / value chain (bulk SiC & bare SiC wafers, epitaxial SiC substrates, SiC devices, SiC modules and circuits). Patent landscape analysis is a powerful tool to identify new players in emerging industries, way before they enter the market, while providing a better understanding of their expertise and know-how in a specific technology. Overall, the patenting activity (patent filings) reflects the level of R&D investment made by a country or a player in a specific technology, while providing a hint about the technology readiness level reached by the main IP players. What's more, the technology coverage along the value chain and the geographical coverage of the patent portfolios are narrowly related to the business strategy of IP players.

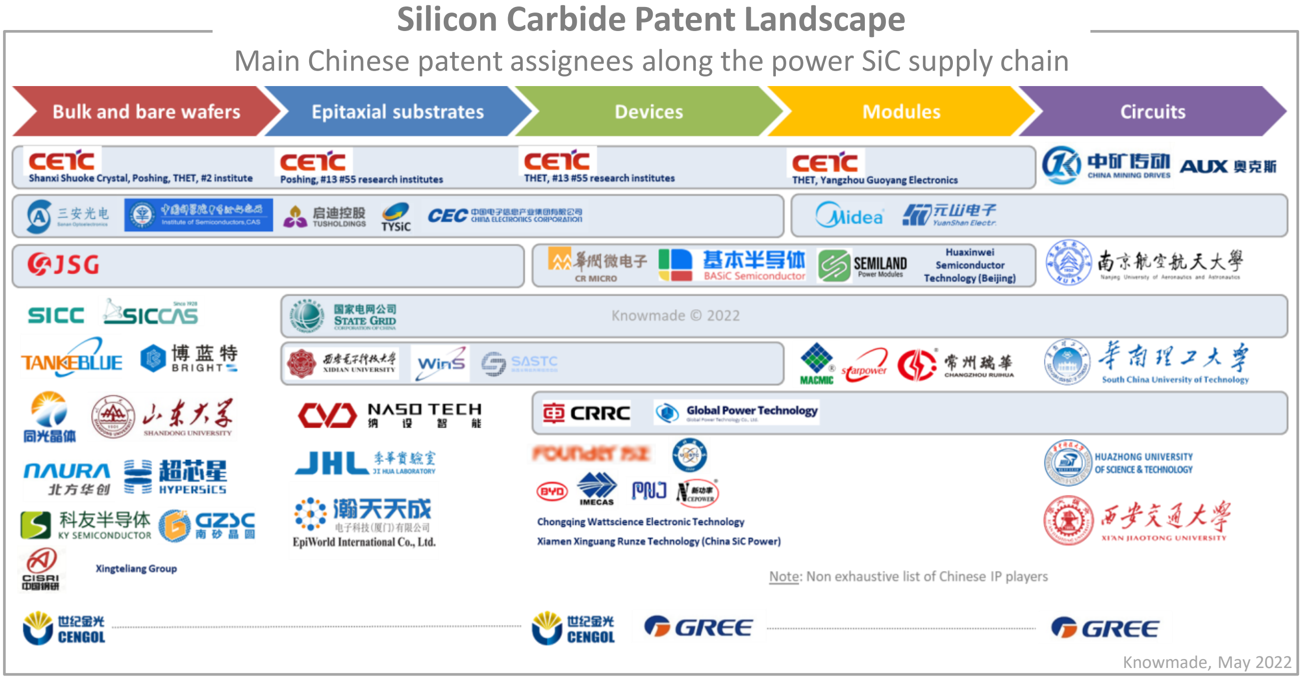
Silicon Carbide Patent Landscape



Driving the SiC industry on its way to SiC wafer supply security

Although historical IP players (**Wolfspeed**, **SiCrystal**, **II-VI**) keeps filing new patents, indicating a continuous improvement of their technology, **Sumitomo Electric** and **Showa Denko** took the IP leadership in the SiC substrate patent landscape. Furthermore, the patent landscape analysis identifies numerous established IP players in the bulk SiC patent landscape, having the expertise and know-how to join in or spin off new companies in the SiC wafer business, just like **SKC** establishing **Senic** in 2021. Especially in China, there is an impressive number of IP players engaged in SiC substrate R&D, and some of them are now stand-out players in the bulk SiC patent landscape (**SICC**, **Sinlight Crystal**, **TankeBlue**, **San'an**).

Eventually, the patent landscape analysis identifies the main companies engaged in the development of disruptive technologies addressing the cost and availability issues of SiC wafers (**Soitec**, **Toyota Tsusho / Kwansei Gakuin University**, **Sumitomo Metal Mining / Sicoxs**, **Infineon / Siltectra**, etc.).



Access to innovation all along the value chain as a short-cut to address timely the emerging power SiC market

While numerous companies are focusing on building a vertically-integrated supply chain to secure their SiC business in the long term, few of them have developed strong patent portfolios all along the SiC value chain, the exceptions being **Toyota** and **Denso** in Japan. Furthermore, many companies may have not anticipated Europe or China as key markets for their power SiC business, and need to strengthen their IP position in these geographic areas. Therefore, most leading companies need to combine internal innovation capabilities with external innovation sources, for instance through M&A operations (e.g., **onsemi / GTAT**, **ST / Norstel**, **Wolfspeed / APEI**, **Danfoss / Semikron**), licensing agreements (e.g., **II-VI / GE**) or IP collaborations (e.g., **Toyota / Denso**, **Audi / ABB**), to accelerate the deployment of their SiC technology. What's more, a global innovation strategy is not only important in building vertically-integrated manufacturing lines, thereby cutting supplier margins and securing the supply chain internally; it also enables players to not be limited in their development by technological and cost barriers at different levels of the supply chain, from material optimization to module integration. Thus, established players holding key patents at all stages of the supply chain can expect a long-term competitive advantage in the market, while newcomers are facing particularly high barriers to entry in the SiC industry. In this regard, the patent landscape analysis describes the IP strategy of main players to enhance their access to critical technologies all along the SiC value chain.

Silicon Carbide Patent Landscape

Leading players' SiC patent portfolio

Patent assignee	Ranking in the SiC power device market 2021 *	Number of patent families (inventions)	SEGMENTS (number of patent families): Bulk SiC	Epitaxial SiC wafers	SiC devices	SiC modules	Circuits	Growth of the patent portfolio between 2016 and 2021 (% change)
Mitsubishi Electric	6	1222	38	56	481	511	196	54%
Toyota group (including Denso)		1198	409	86	530	150	37	45%
Sumitomo Electric		940	239	156	476	70	9	24%
Fuji Electric	7	786	9	57	531	154	60	110%
Panasonic/Sanyo Electric		409	55	28	231	37	29	8%
Infineon (including Siltectra)	2	369	18	8	205	124	20	103%
Rohm (including SiCrystal)	4	367	41	10	169	121	40	66%
Toshiba (including Nuflare)	9	366	11	44	278	39	24	60%
Hitachi (excluding ABB power grids)		360	15	20	179	114	55	41%
Wolfspeed	3	329	43	34	222	25	15	12%
onsemi	5	76	8	1	49	15	4	62%
STMicroelectronics	1	54	5	8	36	3	1	46%

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IP profiles: focus on the top IP players' patent portfolios

The patent portfolio of the top 10 IP players and top 6 power device market players is analyzed: **Mitsubishi Electric**, **Sumitomo Electric**, **Infineon**, **Rohm**, **Toyota/Denso**, **Wolfspeed**, **Fuji Electric**, **Hitachi**, **Toshiba**, **STMicroelectronics**, **onsemi**, **Panasonic**. For each player, we provide an overview of its strength, its potential for reinforcement and the player's IP dynamics. The recent patenting activity of the player is then reviewed in light of recent announcements related to SiC and related challenges.

Useful Excel patent database

Patent database

This report also includes an extensive **Excel database with the 13,700+ patent families** (inventions) analyzed in this study. This useful patent database allows for **multi-criteria searches** and includes patent publication numbers, **hyperlinks to an updated online database** (original documents, legal status, etc.), priority date, title, abstract, patent assignees, patent's current legal status, and **segments** (bulk SiC, epitaxial SiC substrates, SiC diodes, planar SiC MOSFETs, trench SiC MOSFETs, SiC modules, circuits, etc.).

Companies mentioned in the report (non-exhaustive)

Mitsubishi Electric, Sumitomo Electric, Denso, Fuji Electric, Toyota Group, Panasonic, Infineon, Rohm, Toshiba, Hitachi, Showa Denko, Wolfspeed, Nippon Steel, Nissan, SICC, General Electric, CETC, Bridgestone, State Grid (SGCC), Shindengen Electric Manufacturing, LG Innotek, CRRC, ABB, Hyundai, Siemens, Synlight Crystal, San'an, Kansai Electric Power (KEPCO), Onsemi/GTAT, Century Goldray (CENGOL), Bosch, Sharp, Disco, POSCO, STMicroelectronics, Renesas Electronics, Sanken Electric, Shin-Etsu, Global Power Technologies, LG Chem, Kyocera, TankeBlue, II-VI, Toyo Tanso, NuFlare Technology, China Electronics Corporation (CEC), Microchip Technology, SK Siltron CSS, SKC, Meidensha Electric Manufacturing, FerroTec, BYD, Shanghai Hestia Power, EpiWorld, BASiC Semiconductor , TYSiC, Power Integrations, TUS-Semiconductor (TUS-Holdings), Daikin Industries, PN Junction Semiconductor, Mitsubishi Materials, KY Semiconductor, Sumitomo Metal Mining / SICOXS, Chongqing Wattscience Electronic Technology, LPE, Texas Instruments, Honda Motor, Danfoss, Semikron, Delta Electronics, Qorvo/United Silicon Carbide, NXP, Bright Semiconductor Technology, NAURA Technology Group, Guangzhou Summit Crystal Semiconductor (GZSC), Tokyo Electron, SENIC, Raytheon Technologies, Volkswagen group, Gree, NCE Power, YES POWERTECHNIX, Murata, FMIC - Founder Microelectronics, GlobalWafers, TsinSiC Semiconductor, AZ POWER, China SiC Power, GeneSiC Semiconductor, ZF, LG Electronics, Soitec, Cea, CISRI, Starpower, Macmic, Power Cube Semi, MapleSemi, WeEn Semiconductors, SemiQ, etc.

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