

# **Next-Generation Power Modules**

# Patent Landscape Analysis – January 2021

The advent of EV/HEV technology has acted as a catalyst for innovation, leading to an acceleration in applications for power module related patents since 2010. Who are the main IP players? How do they address the new challenges? Who are the new players and IP challengers taking the big opportunities arising from the emerging EV/HEV market?

#### **REPORT OUTLINE**

- · Next generation power modules
  - All power modules since 2010
  - WBG power modules since 1995
- Patent Landscape Analysis
- January 2021
- PDF >300 slides
- Excel file >7,000 patent families
- 3,990 EUR for a multi-user license
- Reference: KM20002

#### **KEY FEATURES**

- IP trends, including time-evolution of patent publications, countries of patent filings, etc.
- Patent segmentation:
  - WBG power modules.
  - Hybrid modules, IPM.
  - EV/HEV applications.
- Challenges: Reduction of parasitics, heat dissipation (sub-segment double sided cooling), Thermomechanical issues, miniaturization.
- Die-attach: Silver sintering, copper sintering, TLP.
- Encapsulation (sub-segment: molding encapsulation).
- · Ranking of main patent assignees.
- · Established IP players and new entrants in the WBG power module patent landscape.
- IP profile of main players:
  - Statistical analysis of patent portfolio including patent segmentation, legal status, time evolution, etc.
  - Noteworthy patents relating new products/technologies.
  - Recent IP activity.
- Excel database containing all patents analyzed in the report, including technology and application segmentations.

#### **RELATED REPORTS 2019/2020**

- Power SiC Patent Landscape 2019
- Power GaN Patent Landscape 2019
- GaN Power & RF Patent Monitor

# Power modules for EV/HEV applications: new requirements and new technologies have led to an acceleration in patent filings from 2010 to 2015

The last decade has seen EV/HEV applications driving packaging innovation in power electronics and creating new equations to solve for module makers, in particular further downsizing, higher power density, higher reliability and lower cost/higher manufacturability. On top of that, automotive OEMs are asking for highly standardized power modules, while most module makers focus on proprietary module designs through which they can offer more differentiating added value. In this context, automotive OEMs and Tiers-1 are expected to become more and more intrusive in the power module area.

Furthermore, EV/HEV applications are also pushing the adoption of new wideband gap (WBG) semiconductor technologies, especially SiC-MOSFETs whose commercial availability has continuously increased. However, to fully benefit from power SiC technology, it is crucial to enable high-temperature operation in SiC modules (200-300°C), e.g. through new packaging materials, as well as high-speed operation, by minimizing parasitic inductance.

As a result, the last decade was marked by extensive innovation in power module design and packaging, leading to a very high volume of patent publications: more than 7,000 inventions were disclosed, and more than 16,000 applications were filed. In this context, Knowmade has analyzed the recent patenting activity to identify the main IP players active in the next generation power module patent landscape and their IP dynamics.

# **Next-Generation Power Module Patent Landscape**

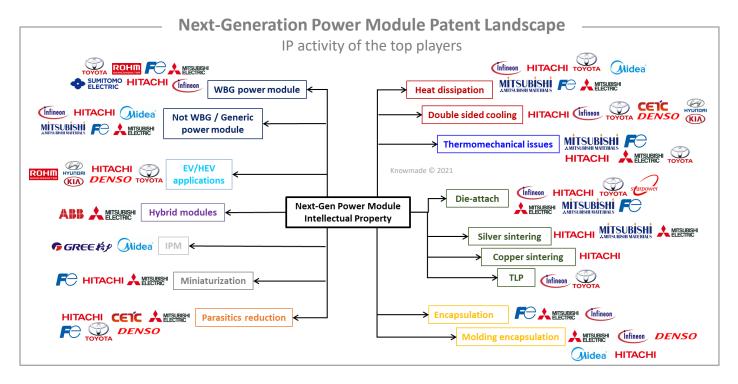


# The IP competition is becoming more global and module makers have been progressively joined by competitors from the EV/HEV supply chain

Top module makers in Europe (Infineon, Semikron) and Japan (Mitsubishi Electric, Fuji Electric, Hitachi) have been very active to keep their leadership in the power module patent landscape since 2010. Interestingly, major foreign module makers are increasingly competing with their counterparts in Europe, by filing more and more European patent applications. Certain automotive OEMs (Toyota Motor, Hyundai Motor) and Tiers-1 (Denso, Bosch) are now well-established patent assignees. In addition, several notable players from the EV/HEV supply chain have joined the IP competition: semiconductor (Cree/Wolfspeed), OEMs (Ford, BYD), and Tiers-1 (Valeo, Continental, ZF).



For EV/HEV applications, the difficult challenges have led to several IP collaborations between module makers/automotive Tiers-1 and automotive OEMs (**Hyundai Motor/Infineon**, **ABB/Audi**, **Toyota Motor/Denso**, **Valeo/Siemens**, etc. In China, major modules makers (**CRRC**, **Macmic**, **Starpower**) have demonstrated moderate patenting activity as of 2020, while new IP players have stepped up (**CETC**).



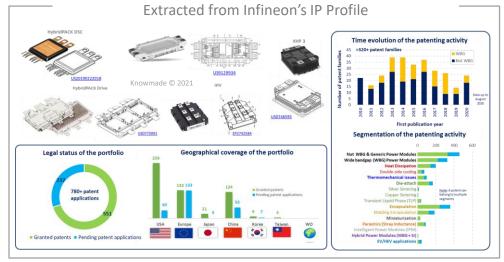
#### The WBG power module patent landscape dominated by leading SiC MOSFET IP players

Numerous IP players in the power module patent landscape have built up a significant portfolio of patent related to SiC MOSFET technologies, especially trench MOSFET technology (Rohm, Infineon, Fuji Electric, Toyota Motor, etc.) targeting automotive applications. Accordingly, they now develop their own technology for full-SiC power modules. Most of them already had a foot in power module technology, except Cree / Wolfspeed, which started from APEI's acquisition filing patents specifically for SiC power modules. Knowmade expects the number of patents for SiC power modules to continue growing in the next five years, as development is still ongoing for many module makers (at die and module levels). According to the present segmentation, IP players such as Hitachi, Mitsubishi Electric and Toyota Motor are also developing key technologies (reduction of stray inductance, silver and copper sintering, TLP for dieattach) to address WBG-related challenges. Lately, Knowmade has identified several newcomers to the WBG power module patent landscape, including Audi, On Semiconductor, Danfoss & Shindengen Electric Manufacturing.

# IP profiles: Focus on the top IP players' patent portfolios

The patent portfolio of nearly 40 leading players is statistically analyzed to provide an overview of its strength (number granted per segment), its potential for reinforcement (pending applications per segment) and the player's IP dynamics (number of new inventions per year for WBG and for non WBG/generic power modules). The 2010-2020 IP activity of the player is then reviewed in light of recent announcements related to WBG, EV/HEV and related challenges (new product, new package, new technology, new partnership, new project, etc.). Finally, the analysis focuses on the very latest patent publications.

# **Next-Generation Power Module Patent Landscape**



#### **Useful Excel patent database**

This report also includes an extensive Excel database with the 7,000+ patent families analyzed in this study. This useful patent database allows for multi-criteria searches and includes patent publication numbers, hyperlinks to the original documents, priority date, title, abstract, patent assignees, patent's current legal status, and technological and application segments.



#### **Companies mentioned in the report** (non-exhaustive)

Mitsubishi Electric, Fuji Electric, Midea, Mitsubishi Materials, Infineon Technologies, Toyota Motor, Denso, Hitachi, Samsung Electro Mechanics, Semikron Elektronik, Rohm, Siemens, Delta Electronics, Toshiba, Sumitomo Electric Industries, Yangzhou Guoyang Electronic, Starpower Semiconductor, Robert Bosch, Hyundai Motor, Gree Electric Appliances, Nissan Motor, Danfoss Silicon Power, Abb, Shindengen Electric Manufacturing, CRRC Times Electric, Toyota Central Research & Development Labs, Macmic Science & Technology, BYD, General Electric, Sanken Electric, State Grid Corporation Of China (SGCC), Panasonic, Murata Manufacturing, Showa Denko, Kia Motors, Ford Global Technologies, Calsonic Kansei, Meidensha Electric Manufacturing, On Semiconductor, ZF Friedrichshafen, Zhejiang University, Industrial Technology Research Institute (ITRI), Hitachi Metals, Delta Electronic, Renesas Electronics, Samsung Electronics, Cree Wolfspeed, Valeo, Audi, Hyundai, Renault, Waseda University, University of Sheffield, University of Cambridge, Virginia Tech, Fraunhofer, Kyocera, Dowa, University of Maryland, Tohoku University BMW, Honda Motor...

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segment	

- Technology coverage of IP portfolios
- Top patent assignees in each segment
- EV/HEV applications vs. Semicon. Device Technology
- Reduction of parasitics vs. Semicon. Device **Technology**

#### IP PROFILES OF KEY IP PLAYERS For each player:

- ·Statistical analysis of the portfolio (IP tends, geographical coverage, granted patents, pending patent applications, technology, technical challenges, applications)
- Noteworthy relating patents products/technology developments
- Description of the recent patenting activity

Japanese IP players				62
Mitsubishi Electric, Hi	tachi,	Denso,	Rohm,	Fuji
Electric, Toyota Mo	tor, S	umitom	o Elec	ctric,
Mitsubishi Materials,	Nissar	n, Sank	en Elec	ctric,
Toshiba, Murata, Shino	denger	n, Meide	en, Cals	onic
Kansoi				

**European IP players** 163 Infineon, ABB, Semikron, Bosch, Danfoss, Siemens, Valeo

US IP players	228
GE, Cree/Wolfspeed, Ford, On Semiconducto	or
Taiwanese IP players	265
Delta Electronics	
Korean IP players	274
Hyundai/Kia, Samsung Electronics/SEMCO	
Chinese IP players	282
Midea, CRRC, Starpower, Gree, SGCC, CETC,	BYD,
Macmic, Shenzhen Yitong Power Electronics	
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#### **ABOUT KNOWMADE**

**Knowmade** is a Technology Intelligence and IP Strategy consulting company specialized in analysis of patents and scientific information. The company helps innovative companies and R&D organizations to understand their competitive landscape, follow technology trends, and find out opportunities and threats in terms of technology and patents.

Knowmade's analysts combine their strong technology expertise and in-depth knowledge of patents with powerful analytics tools and methodologies to turn patents and scientific information into business-oriented report for decision makers working in R&D, Innovation Strategy, Intellectual Property, and Marketing. Our experts provide prior art search, patent landscape analysis, scientific literature analysis, patent valuation, IP due diligence and freedom-to-operate analysis. In parallel the company proposes litigation/licensing support, technology scouting and IP/technology watch service.

Knowmade has a solid expertise in Compound Semiconductors, Power Electronics, Batteries, RF Technologies & Wireless Communications, Solid-State Lighting & Display, Photonics, Memories, MEMS & Solid-State Sensors/Actuators, Semiconductor Manufacturing, Packaging & Assembly, Medical Devices, Medical Imaging, Microfluidics, Biotechnology, Pharmaceutics, and Agri-Food.



# ORDER FORM Next-Generation Power Modules

Patent Landscape Analysis – January 2021 Ref.:KM20002

SHIP TO	PAYMENT METHODS
Name (Mr/Ms/Dr/Pr):	Order online: Click here
Job Title:	Check To pay your invoice using a check, please mail your check to the
Company:	following address:  KnowMade S.A.R.L.
Address:	2405 route des Dolines, Le Drakkar D108 06560 Valbonne Sophia Antipolis
City:	FRANCE
State:	
Postcode/Zip:	contact your bank to complete the process. Here is the information you will need to submit the payment:
Country:	Payee: KnowMade S.A.R.L.  Bank: Banque Populaire Méditerranée, CAP 3000 Quartier du
VAT ID Number for EU members:	lac, 06700 St Laurent du Var IBAN: FR76 1460 7003 6360 6214 5695 139
Tel:	BIC/SWIFT: CCBPFRPPMAR
Email:	
Date:	www.paypal.com. You can then send money to KnowMade S.A.R.L by entering our email address (contact@knowmade.fr) as the recipient, and entering the invoice amount.

**RETURN ORDER BY** 

E-mail: contact@knowmade.fr

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All reports are delivered electronically in pdf format at payment reception.

\*The report can be shared with the employees of the company purchasing the report. Subsidiaries and joint-ventures are excluded. Please be aware that the report is watermarked on each page, with the name of the recipient and the organization (the name mentioned in the PO). This watermark also reaffirms that report sharing is not allowed.

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Mail: KnowMade S.A.R.L. 2405 route des Dolines, Le Drakkar D108,





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- 1.1 The Contracting Parties undertake to observe the following general conditions when agreed by the Buyer and the Seller. Any additional, different, or conflicting terms and conditions in any other documents issued by the buyer at any time are hereby objected to by the seller, shall be wholly inapplicable to any sale made hereunder and shall not be binding in any way on the seller.
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- within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.
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Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var

BIC or SWIFT code: CCBPFRPPMAR

IBAN:: FR76 1460 7003 6360 6214 5695 139

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3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the «BCE» + 7 points, in accordance with article L. 441-6 of the French Commercial Code. Our publications (report, database, tool...) are delivered only after reception of the payment.

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- b) any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.
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- 4.6 In the case where, after inspection, it is acknowledged that the Products contain defects, the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labor costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.
- 4.7 The deadlines that the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. If such deadlines are not met, it shall not lead to any damages or cancellation of the orders, except for non-acceptable delays exceeding [4] months from the stated deadline, without information from the Seller. In such case only, the Buyer shall be entitled to ask for a reimbursement of its first down payment to the exclusion of any further damages.
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- Licensing, leasing, selling, offering for sale or assigning the Product.
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