

Next-Generation Power Modules

Patent Landscape Analysis

January 2021

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- Noteworthy patents relating new products/technology developments
- Description of the recent patenting activity

Japanese IP players **62**

Mitsubishi Electric, Hitachi, Denso, Rohm, Fuji Electric, Toyota Motor, Sumitomo Electric, Mitsubishi Materials, Nissan, Sanken Electric, Toshiba, Murata, Shindengen, Meiden, Calsonic Kansei

European IP players **163**

Infineon, ABB, Semikron, Bosch, Danfoss, Siemens, Valeo

US IP players **228**

GE, Cree/Wolfspeed, Ford, On Semiconductor

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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SCOPE OF THE REPORT

- This report investigates the **power module** patent landscape, focusing on the following elements:
 - ✓ Wide-bandgap power modules
 - ✓ Wide-bandgap-related power modules
 - ✓ Generic power modules addressing critical challenges for next-generation of power modules (thermal dissipation, thermo-mechanical issues, management of parasitic signals, module miniaturization).
- This report covers patents published worldwide up to **August 2020**.
- We have selected and analyzed more than **7,000 patent families** (inventions) relevant to the scope of this report.



Included

- Patents describing **power modules** comprising semiconductor devices (HEMTs, MOSFETs, SBDs, PN diode, etc.) explicitly based on wide-bandgap materials (SiC, GaN, etc.), including **hybrid power modules**. At least a claim or an embodiment is focused on WBG devices.
- Patents describing **power modules** and applicable to semiconductor devices (HEMTs, MOSFETs, SBDs, PN diode, etc.) based on wide-bandgap materials (SiC, GaN, etc.). WBG devices are mentioned in the description as suitable power semiconductor devices for the power modules.
- Generic patents describing **power modules**, published after 2010, and addressing critical issues for next-generation power modules.

Excluded

- Power converters, systems, driving modules, etc.
- Old generic patents (published before 2010) describing power modules.

SCOPE OF THE REPORT

This **Next-Generation Power Modules IP report** reviews the patent portfolio of main patent applicants, with a focus on **EV/HEV modules** and **SiC power modules**, which are driving the innovation at design and packaging levels.

The **patent search** was completed in August 2020, and conducted in two steps:

1. Selection of all patents related to **WBG power modules**, including a great majority of **SiC power modules**, although a significant number of patents do not specify the WBG material.
2. Selection of patents related to **power modules** (generic modules & IGBT modules) that were **published between January 2010 and August 2020**, especially patents addressing **critical challenges for next-generation power modules** and more specifically challenges raised by **EV/HEV high requirements**.

While some power module manufacturers are introducing their second or third generation of **automotive power modules for EV/HEV**, the report aims to focus on **the very latest packaging technologies and materials** for power modules. For this reason, a time limitation was set in order to obtain a more relevant patent corpus to analyze. On the other hand, such a time limitation was not necessary for **WBG power modules**, since the patenting activity essentially started in the early 2010's.

The patent corpus is segmented in four challenges which are common to IGBT modules and SiC modules: **parasitics, heat dissipation, thermomechanical issues / thermal reliability** and **miniaturization**. However, in our understanding, overcoming these challenges will be even more critical for SiC power modules to become mainstream, since the added value of the technology depends on their capability to operate at **higher switching speed** and **higher temperature** than IGBT modules.

The patent corpus is segmented by key technologies that are developed for next-generation power modules, for instance in **die-attach** (copper and silver sintering, TLP bonding), in **encapsulation** (transfer molding), and **double-sided cooling structure**.

Furthermore, the report includes an additional segment for patents related to **EV/HEV applications**.

In this **Next-Generation Power Modules IP report**, the patent portfolios of **40 leading IP players** are analyzed **statistically** (number of granted/pending patents, geographic patenting areas, number of EV/HEV patents, etc.). For each player analyzed in this report, the **latest patenting activity** is briefly reviewed. Furthermore, for a selection of IP players, the patents related to disclosed power modules & packages are reviewed, while focusing on **key technologies** and **driving applications** previously mentioned.

KEY FEATURES OF THE REPORT

- The report provides **essential patent data** for the **next-generation power modules**.
- It provides **in-depth patent analyses** of **key technologies** and **key players** including:
 - Main IP dynamics and key trends.
 - IP leaders, most active players and newcomers.
 - IP portfolio strength of key players, and their technology/application focus.
 - Time evolution of patents filings by company, countries, and technology.
 - Current legal status of patents.
 - Joint developments, IP collaborations and IP transfers between key organizations.
 - Insights into the status of technologies, identifying trends for each technology/application.
 - Key patents.
- 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** (WBG power module, generic power module, heat dissipation, double sided cooling, thermomechanical issues, die-attach, silver sintering, copper sintering, TLP, encapsulation, molding encapsulation, miniaturization, parasitics, IPM, hybrid modules, EV/HEV applications, etc.).



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WHY STUDY THE PATENT LANDSCAPE

Understanding the **competitive landscape** and **technology developments** from a **patent perspective**

- To provide overall dynamics of the field.
- To know the **key IP players**, their **key patents**, their IP/technology **strategy** and their **future intents**.
- To identify **new players** or **companies** that are **under the radar**.
- To follow the **technology trends** and identify **emerging technologies**.
- To **benchmark** patent portfolios and know competitors' **strengths** and **weaknesses**.
- To identify **strategic and technological paths** players are following for technologies.
- To identify the **key patents** (seminal, blocking, valuable) and new solutions/technologies.
- To identify **free technologies** which can be used safely and mitigate the **risks of patent infringement**.
- To identify **technologies to acquire** and potential **R&D partners**



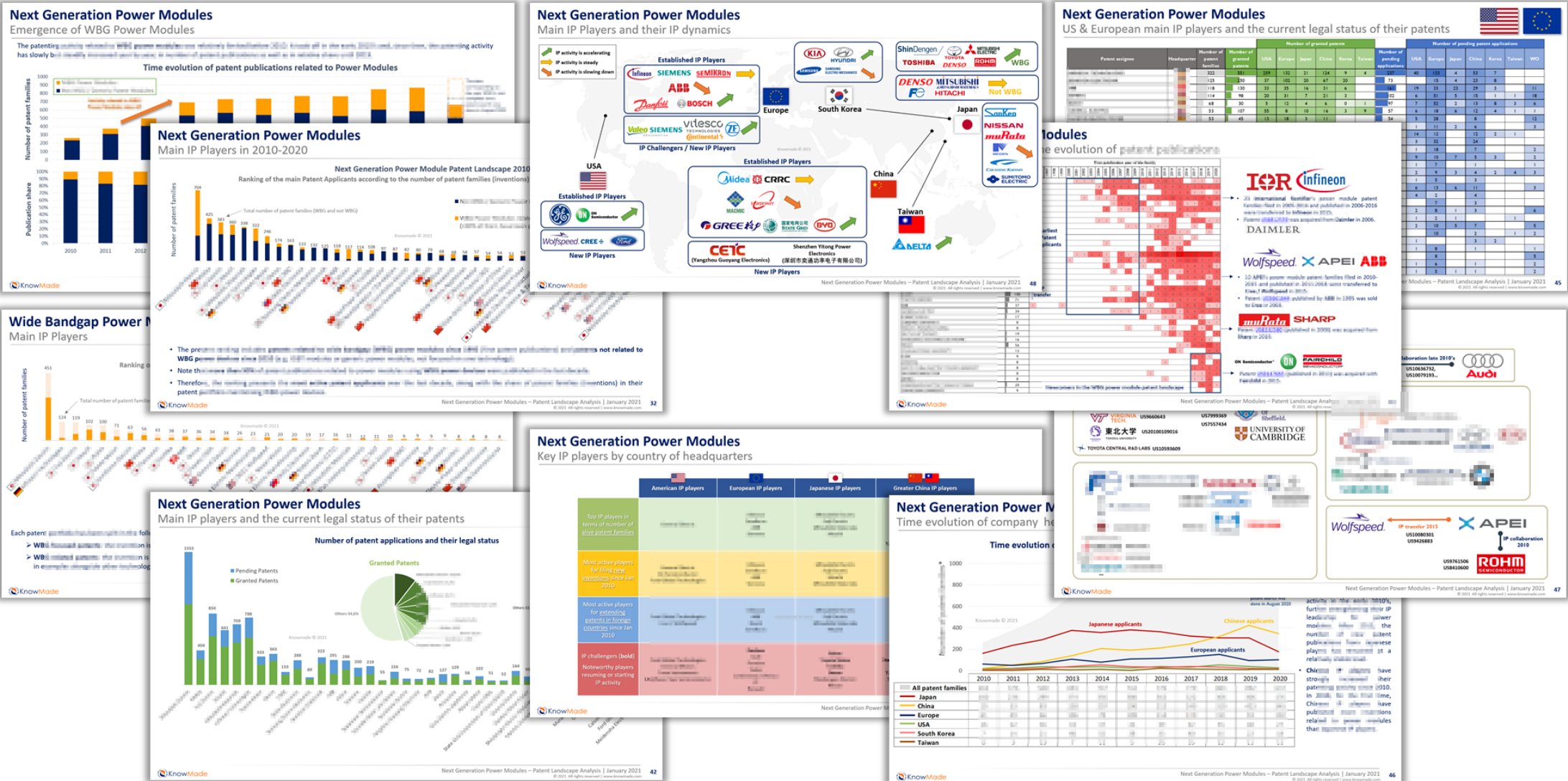
Very complementary to market research

Providing a different outlook of the competitors, technologies and markets

Patent Landscape Overview

General trends, Key patent assignees, Newcomers, IP collaborations, Patent legal status, Geo coverage

SAMPLE



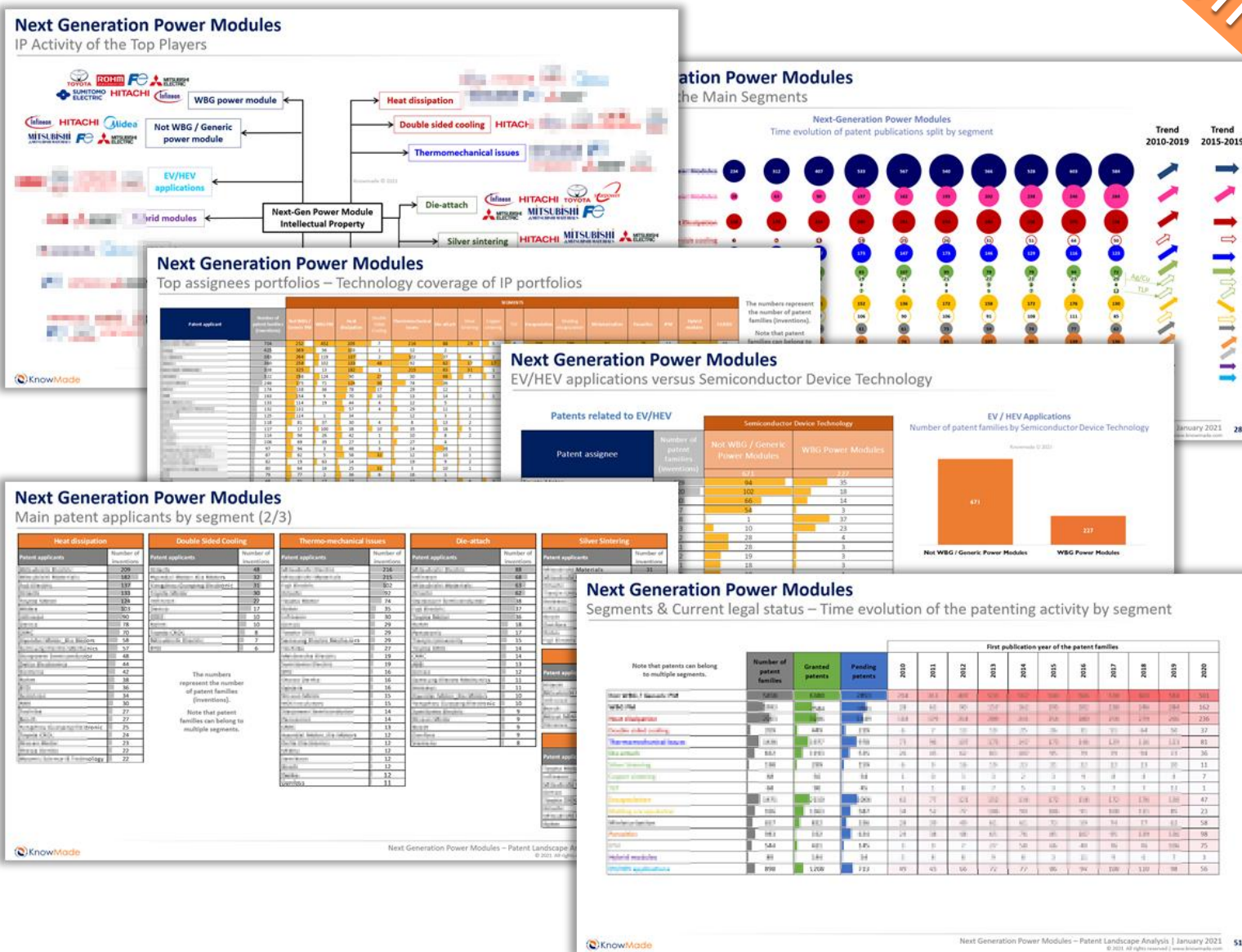
Segmentation

For each segment: General trends, Key patent assignees, Key patents

SAMPLE

The patents have been categorized in 16 segments:

- **Wideband gap power modules (WBG PM)**
- **Not WBG / Generic power modules**
- **Heat dissipation** (cooling systems, reduction of the thermal resistances in power module assemblies, thermal management)
 - **Double sided cooling**
- **Thermomechanical issues** (thermal reliability, fatigue, cycling, etc... high-temperature operation peeling, cracking, delamination, warpage/bow etc...)
- **Die-attach** (soldering, sintering, transient liquid phase/solid-liquid interdiffusion bonding, solid phase diffusion bonding, etc.)
 - **Silver sintering**
 - **Copper sintering**
 - **TLP**
- **Encapsulation** (potting, including direct potting, molding, including transfer molding, epoxy, silicone gel, cement, etc.)
- **Molding encapsulation**
- **Miniaturization**
- **Parasitics** (stray inductances, EMI, noise, surge voltages and currents, parasitic ringing/oscillations, etc.)
- **Intelligent power modules (IPM)**
- **Hybrid modules** (Si IGBT/SiC diodes or MOSFETs and GaN/Si cascode)
- **EV/HEV applications** (power train and charging)



IP portfolio summary, Noteworthy patents relating new products/technologies, Recent IP activity

For each player:

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

Japanese IP players:

Mitsubishi Electric, Hitachi, Denso, Rohm, Fuji Electric, Toyota Motor, Sumitomo Electric, Mitsubishi Materials, Nissan, Sanken Electric, Toshiba, Murata, Shindengen, Meiden, Calsonic Kansei

European IP players:

Infineon, ABB, Semikron, Bosch, Danfoss, Siemens, Valeo

US IP players:

General electric, Cree/Wolfspeed, Ford, On Semiconductor

Korean IP players:

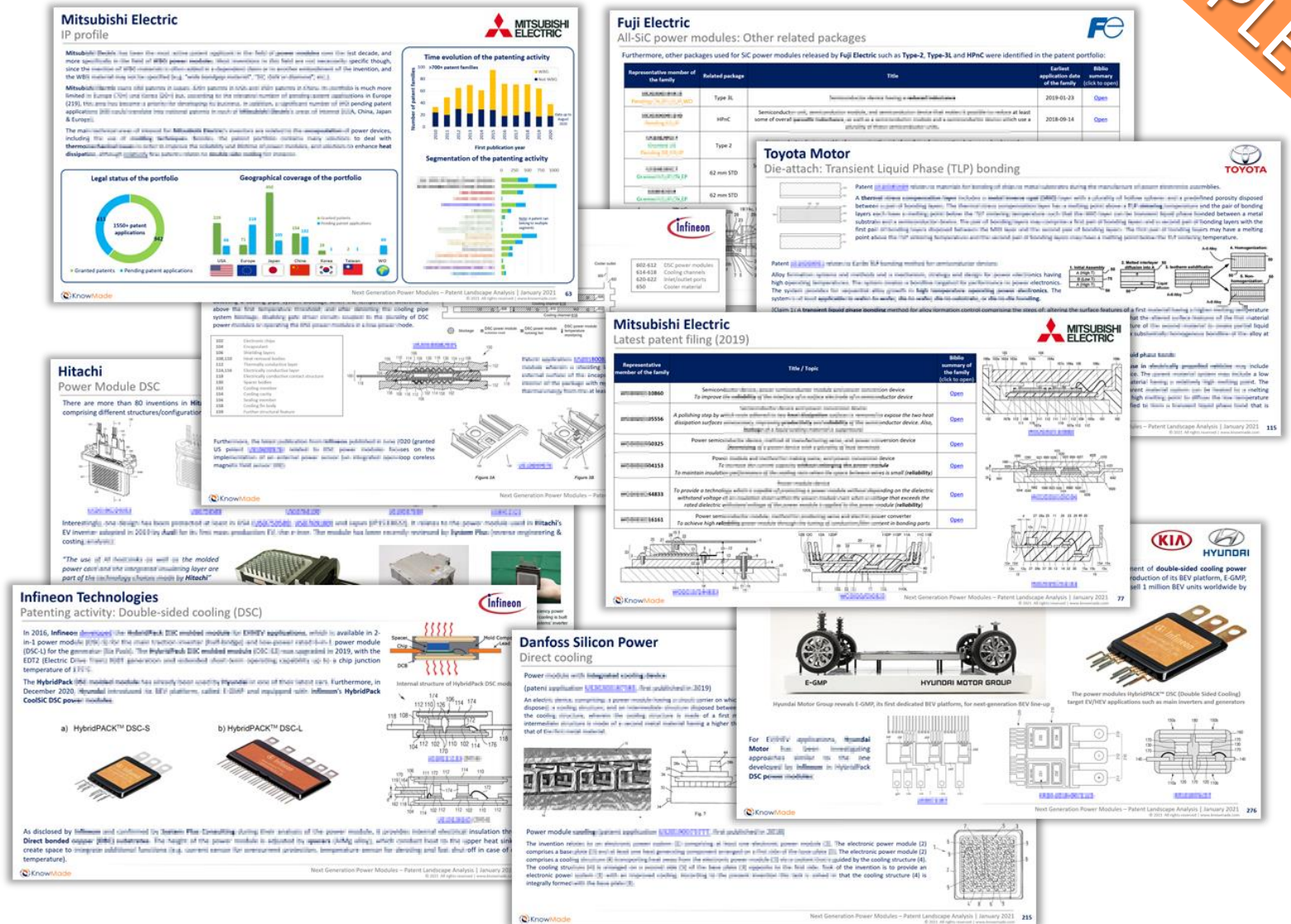
Hyundai/Kia, Samsung Electronics/SEMCO

Chinese IP players:

Midea, CRRC, Starpower, Gree, SGCC, CETC, BYD, Macmic, Shenzhen Yitong Power Electronics

Taiwanese IP players:

Delta Electronics



Useful patent database allows multi-criteria searches

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** (WBG power modules, Not WBG / Generic power modules, heat dissipation, double sided cooling, thermomechanical issues, die-attach, silver sintering, copper sintering, TLP, encapsulation, molding encapsulation, miniaturization, parasitics, IPM, hybrid modules, EV/HEV applications, etc.)

WBG power modules, Not WBG / Generic power modules, Heat dissipation (cooling systems, reduction of the thermal resistances in power module assemblies, thermal management), **Double sided cooling, Thermomechanical issues** (thermal reliability, fatigue, cycling, etc... high-temperature operation peeling, cracking, delamination, warpage/bow etc...), **Die-attach** (soldering, sintering, transient liquid phase/solid-liquid interdiffusion bonding, solid phase diffusion bonding, etc.), **Silver sintering, Copper sintering, TLP, Encapsulation** (potting, including direct potting, molding, including transfer molding, epoxy, silicone gel, cement, etc.), **Molding encapsulation, Miniaturization, Parasitics** (stray inductances, EMI, noise, surge voltages and currents, parasitic ringing/oscillations, etc.), **Intelligent power modules (IPM), Hybrid modules (Si IGBT/SiC diodes or MOSFETs and GaN/Si cascode), EV/HEV applications** (power train and charging)

ORDER FORM

Next-Generation Power Modules

Patent Landscape Analysis – January 2021

Ref.:KM20002

SHIP TO

Name (Mr/Ms/Dr/Pr):

Job Title:

Company:

Address:

City:

State:

Postcode/Zip:

Country:

VAT ID Number for EU members:

Tel:

Email:

Date:

PAYMENT METHODS

Check

To pay your invoice using a check, please mail your check to the following address:

KnowMade S.A.R.L.
2405 route des Dolines
06560 Valbonne Sophia Antipolis
FRANCE

Money Transfer

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Bank: Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var, France
IBAN: FR76 1460 7003 6360 6214 5695 139
BIC/SWIFT: CCBPFRPPMAR

Paypal

In order to pay your invoice via PAYPAL, you must first register at www.paypal.com. Then you can send money to the KnowMade S.A.R.L. by entering our E-mail address contact@knowmade.fr as the recipient and entering the invoice amount.

RETURN ORDER BY

E-mail: contact@knowmade.fr

Mail: KnowMade S.A.R.L., 2405 route des Dolines, 06560 Valbonne Sophia Antipolis, FRANCE

PRODUCT ORDER

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For French customer, add 20% for VAT.

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Signature:

Terms and Conditions of Sales

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2.2 Some weeks prior to the release date the Seller can propose a pre-release discount to the Buyer.

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2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in article 3.

2.4 The mailing is operated through electronic means either by email via the sales department. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that it is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity to the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to

produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior information to the Seller, even in case of delayed delivery. Any Product returned to the Seller without providing prior information to the Seller as required under article 2.5 shall remain at the Buyer’s risk.

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3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are expressed to be inclusive of all taxes. The prices may be reevaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.

3.2 Payments due by the Buyer shall be sent by cheque payable to Knowmade, PayPal or by electronic transfer to the following account:

Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var, France

BIC or SWIFT code: CCBPFRPPMAR

IBAN: : FR76 1460 7003 6360 6214 5695 139

To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be mentioned on the order.

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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4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products and for the use and interpretations he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

4.2 The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement

4.3 In no event shall the Seller be liable for:

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b) any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.

4.4 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

4.5 All the Products that the Seller sells may, upon prior notice to the Buyer from time to time be modified by or substituted with similar Products meeting the needs of the Buyer. This modification shall not lead to the liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

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.

4.8 The Seller does not make any warranties, express or implied, including, without limitation, those of saleability and fitness for a particular purpose, with respect to the Products. Although the Seller shall take

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- use in any timesharing, service bureau, bulletin board or similar arrangement or public display;

- Posting any Product to any other online service (including bulletin boards or the Internet);

- Licensing, leasing, selling, offering for sale or assigning the Product.

6.3 The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has sent the Products and shall personally take care of any related proceedings, and the Buyer shall bear related financial consequences in their entirety.

6.4 The Buyer shall define within its company point of contact for the needs of the contract. This person will be the recipient of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.

7. TERMINATION

7.1 If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be borne by the Seller, following this decision.

7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

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Any notices under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party.

The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

9. GOVERNING LAW AND JURISDICTION

9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Grasse, which shall have exclusive jurisdiction upon such issues.

9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.



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contact@knowmade.fr