

# POWER GaN

## Patent Landscape Analysis – November 2019

*Which patent owners are ready to dominate the GaN power market in coming years?*

### REPORT OUTLINE

- Power GaN
- Patent Landscape Analysis
- November 2019
- PDF >270 slides
- Excel file with >9,500 patents
- €6,490 for a multi-user license
- Ref.: KM19009



### KEY FEATURES

- See the **competitive landscape** from a patent perspective, offering a very complementary vision to market research.
- Identify **key patent owners**, their IP and technology strategies and their future intents.
- Discover **new entrants**, their technologies and market areas.
- Know competitors' **strengths** and **weaknesses** in terms of patents and technologies.
- Be ahead of **technology trends**, 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 GaN 2019: Epitaxy, Devices, Applications and Technology Trends](#) (November 2019) – Yole Développement
- [Navitas 650V GaNFast Power IC Family](#) (May 2019) – System Plus Consulting
- [GaN-on-Sapphire HEMT Power IC by Power Integrations](#) (July 2019) – System Plus Consulting

### Power GaN intellectual property (IP): high-voltage power semiconductor leaders, a core set of strong IP players and numerous newcomers

Things are starting to change for GaN power electronics ! **Power GaN is entering mainstream consumer applications** with the adoption of GaN HEMT by Chinese OEM Oppo in its 65W fast chargers. In addition, GaN is getting attention from various OEMs and Tier1s in the **automotive industry**. GaN is also expected to penetrate **industrial and telecom power supply applications** (datacom, base-stations, UPS, etc.). Yole Développement projects that the GaN power market will be worth over **\$350M by 2024**, with a compound annual growth rate (CAGR) of 85%.

The power electronics industry is familiar with the companies that are actively promoting GaN technology, such as **EPC, GaN Systems, Transphorm, Navitas, Exagan, Infineon** or **ON Semiconductor**. Today, more companies are either joining the market, have announced ambitions to do this, or have betrayed their intentions through their patent publications. **Many firms have GaN power patenting activity**, and a core set of strong companies, with strong technology and IP, are ready to dominate the GaN power market in coming years.

In this report, Knowmade has thoroughly investigated the **patent landscape related to GaN-based technologies and devices for power electronics applications**. We have selected and analyzed more than **9,500 patents and patent applications** published worldwide up to May 2019 and grouped into more than 4,100 patent families. These patents pertain to **epiwafer** (GaN-on-Si, GaN-on-Sapphire, etc.), **semiconductor power devices** (D-mode, E-mode, vertical device, p-doping, etc.), **integration** (SiP, SoC, monolithic integration, etc.), **circuit and operating methods** (cascode, half-bridge, power IC, etc.), and **packaging** (thermal management, stray inductance, etc.), **for all functions** (switch, converter, rectifier, inverter, etc.) and **applications** (power supply, PV, EV/HEV, UPS, fast charging, wireless charging, etc.).

Key patent assignees by segment

	E-mode transistor	Cascode topology (Noff circuit-based approach)	Monolithic integrated E/D-mode transistors	Power IC (SoC)	Vertical transistor	Vertical diode	Selective area P-doping	GaN-on-Silicon for power applications
Key IP players with decreasing or no longer IP activity								
Key IP players showing steady or increasing patenting activity			No key IP player showing increasing IP activity					
New entrants in the patent landscape								

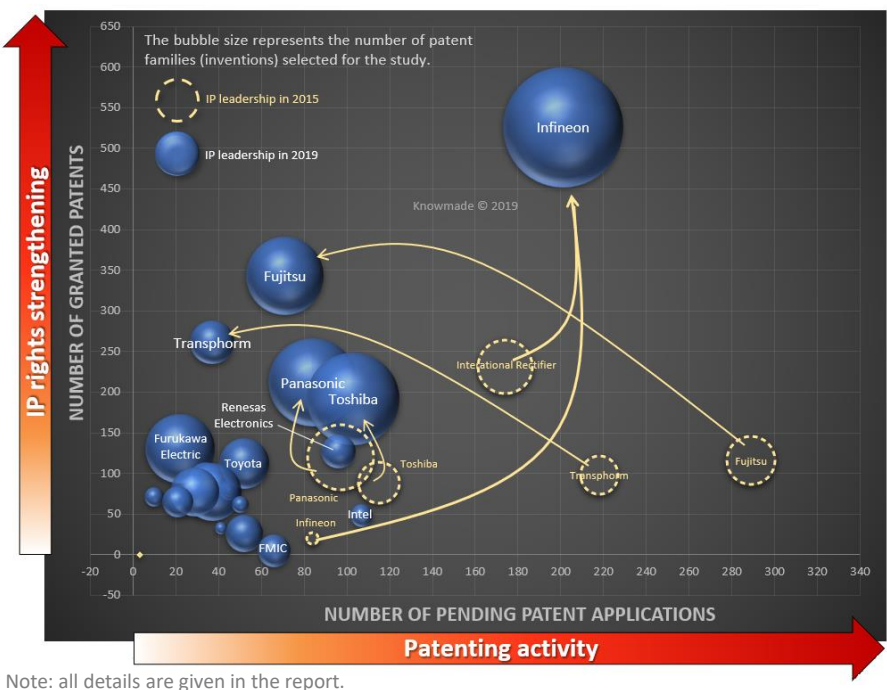
Note: many segments are analyzed in the report.

Since our previous Power GaN report, published in 2015, IP benchmarks herald changes in the GaN power industry and the ramp-up of GaN power market.

**All power electronics market players are present** in the Power GaN patent landscape: Infineon, Fuji Electric, Toshiba, Sankei Electric, ON Semiconductor, STMicroelectronics, Renesas Electronics, Texas Instruments, Dialog Semiconductor, Power Integrations and Nexperia. Most of them are **intensifying their Power GaN patenting activity** and are **enlarging their IP geographic coverage** from the US and Japan to new key regions for the GaN power market, namely Europe and China.

In just a few years, **Infineon** and **Transphorm** have reached the **strongest IP position** in the patent landscape. This offers them the **capability to limit the freedom-to-operate of competitors** who develop GaN technology for power electronics. **Infineon** definitely has the strongest IP portfolio to front the growing of GaN power market. **Transphorm** is a major force in the power GaN IP arena, well ahead of the other GaN pure-players, **EPC, GaN Systems, Navitas, Exagan** or **VisiC**. According to our analysis, **Transphorm** today has the dream patent portfolio for all those who want to benefit from strategic advantages in GaN power electronics market. Some weak signals lead us to believe the first 650 V GaN-on-Si FETs from **Nexperia** announced in November 2019 may use **Transphorm’s** patents.

**Evolution of IP leadership related to Power GaN (2015–2019)**



Note: all details are given in the report.

No matter how GaN providers manufacture power devices, they must consider GaN power patents held by **Infineon, Transphorm, Furukawa Electric, Panasonic, Toshiba** and **Fujitsu**. They must also watch other players that are strengthening their IP position such as **EPC, Renesas, ON Semi, Toyota, TI, TSMC, Intel, Toyoda Gosei** and **Sanken**. **More newcomers** of different types are entering the Power GaN patent landscape. **Startups** include **Exagan, Navitas, Cambridge Electronics, GaNPower** and **Innoscence**. New **substrate providers** include **Qromis, AirWater** and **Zing Semiconductor**. **Foundries** include **FMIC, HiWafer, Simgui, Nuvoton, Sinopower** and **VIS**. **Integrators** include **Nissan, Shindengen Electric Manufacturing, Nidec, Kyocera, Hella, Renault, Apple, Midea, Huawei** and **Velodyne Lidar**. **China has made an impressive move** into Power GaN IP with numerous entrants since 2017.

**GaN-on-Silicon and GaN-on-Sapphire**

In the report we detail the IP landscape related to GaN-on-Silicon and GaN-on-Sapphire. The **GaN-on-Silicon patent landscape** is characterized by the presence of numerous GaN pure-play companies and numerous Chinese new entrants. In the **GaN-on-Sapphire patent landscape**, Power Integrations is the best-known player. However, numerous other players have also developed IP related to GaN-on-Sapphire for power applications, including **CorEnergy, Powdec** and **Seoul Semiconductor**.

**Normally-off**

**Infineon** leads the IP landscape related to **cascode topology** thanks to key patents from **International Rectifier** acquired in 2014. **Fujitsu** and **Transphorm** have strong patent portfolios related to **E-mode GaN transistors**. **Infineon, EPC** and **Renesas** are currently the most active IP players. In the report we have identified key patents from key IP players and new entrants for both cascode and E-mode transistors. Furthermore, we map the different **solutions claimed in patents to make E-mode transistors**.

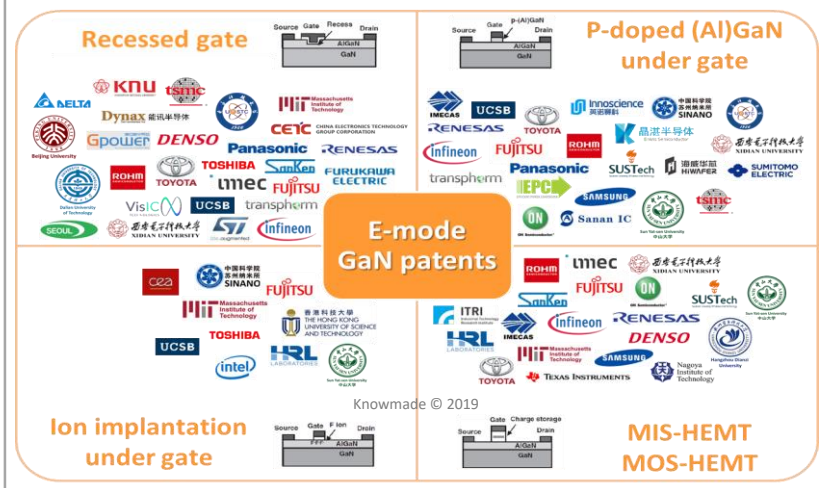
**Integration**

We have been witnessed of a **growing IP activity** for **power GaN System-on-Chip** with **Infineon/IR, Intel** and **Navitas** as the main patent applicants. **Infineon** and **Intel** have been developing IP for monolithically integrating GaN power devices with other kind of devices such as RF circuits and LEDs, and/or Si CMOS technology. On the other hand **Navitas’s** patents focus on all GaN Power IC. Other players hold patents on **monolithic integration** such as **Intel, Dialog, Power Integrations, Transphorm, Exagan, ON Semiconductor, GaN Systems, TI, EPC, TSMC**. Some other companies recently filed patents related to **GaN-on-Silicon-on-Insulator** for power electronics.

**Vertical power device**

**Vertical power devices** still attract significant attention of patent applicants. **Nexgen** (formerly **Avogy**) is the **main patent owner**, but it has stopped its patenting activity, like **Fujitsu** and **Furukawa**. Today, **Toyoda Gosei, Fuji Electric, Sumitomo Electric** and **Toyota** are leading the **vertical power device** IP landscape. Several players are developing IP on **vertical devices on silicon substrates** including **CEA/Renault, Vishay, Renesas, Bosch, Fuji Electric, Furukawa Electric** and **M-MOS Semiconductor**. This report highlights **selective ion implantation** and **selective p-GaN regrowth** to form selective p-type regions.

**Main patent assignees by type of E-mode GaN HEMT**



**Current collapse and driving applications**

We see important IP activity to suppress **current collapse**, with **Fujitsu, Panasonic** and **Toshiba** as main patent assignees. We identify IP players claiming solutions to prevent this dynamic on-resistance increase (field plates, surface passivation, hole injections). In the report we also highlight **Power GaN patents explicitly targeting EV/HEVs** from **CEA/Renault, Toyoda Gosei, Denso, Toyota, CACTi, KOYJ, Shinny, Sentec, China Motor** and **Egtronics**, **fast charging** from **Powdec** and **Shinny** and **wireless charging** from **EPC, Panasonic, Navitas, Rohm**, and **Hosiden**.

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

Infineon, International Rectifier, Toshiba, Panasonic, Fujitsu, Furukawa Electric, Transphorm, Sumitomo Electric, Sharp, Toyota Motor, Toyota Central R&D Labs, Fuji Electric, Xidian University, Toyoda Gosei, Renesas Electronics, UESTC, Nexgen, Avogy, Sanken Electric, University Beijing, Founder Microelectronics IC, Rohm, Intel, Seoul Semiconductor, Samsung Electronics, Sun Yat Sen University, Texas Instruments, On Semiconductor, TSMC, Mitsubishi Electric, HRL Laboratories, Power Integrations, CorEnergy, Denso, NXP, Freescale, Nexperia, SINANO, CEA, Gpower, EPC, IMECAS, Imec, Qorvo, Delta Electronics, Institute of Semiconductors, NTT, LG Electronics, Samsung Electro Mechanics, Cree, Wolfspeed, Hitachi, CETC, LG Innotek, Navitas Semiconductor, Sciocs, Sumitomo Chemical, NEC, ETRI, Macom, Nitronex, Innoscience, Nexperia, Enkris Semiconductor, Gan Systems, Japan Radio, Midea, MIT, STMicroelectronics, Epistar, Exagan, Richtek Technology, HKUST, Soitec, Epigan, NGK Insulators, Peking University, Bosch, IBM, Murata Manufacturing, Siemens, Alpha & Omega Semiconductor, Coorstek, General Electric, Hiwafer, SUSTech, Foshan Tk Semiconductor, University of California, VisIC Technologies, CNRS, Dowa Electronics Materials, Powdec, SNU, ITRI, Ku Leuven, Qromis, Sanan IC, SETi, Vishay, A\*STAR, Cambridge Electronics, Dialog Semiconductor, Dynax Semiconductor, Ganpower, Globalfoundries, Huawei, Simgui, University of Florida, Air Water, IQE, M-MOS Semiconductor, University of Sheffield, Zing Semiconductor, Allos Semiconductors, Arizona State University, Fraunhofer, Hella, KETI, Korea Advanced Nano Fab Center, Kyocera, Nuvoton, Shin-Etsu, Sigetronics, Sony, University of Illinois, University of South Carolina, US Navy, Alstom Transport, ASTRI, Caltech, Nissan Motor, North Carolina State University, Renault, Sixpoint Materials, Velodyne Lidar, etc.

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## AUTHOR



### Dr. Nicolas Baron

Nicolas is CEO and co-founder of Knowmade. He manages the development and strategic orientation of the company and personally leads the Semiconductor 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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- 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.

## 8. Miscellaneous

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.

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.