

# RF GaN

## Patent Landscape Analysis – February 2019

*The RF GaN market is developing fast, driven by mm-wave, 5G and defense applications. Do current leading market players have the right IP portfolios to face huge opportunities for GaN devices?*

### REPORT OUTLINE

- RF GaN
- Patent Landscape Analysis
- February 2019
- PDF >190 slides
- Excel file with >3,700 patents
- €6,490 for a multi-user license
- Ref.: KM19003



### 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

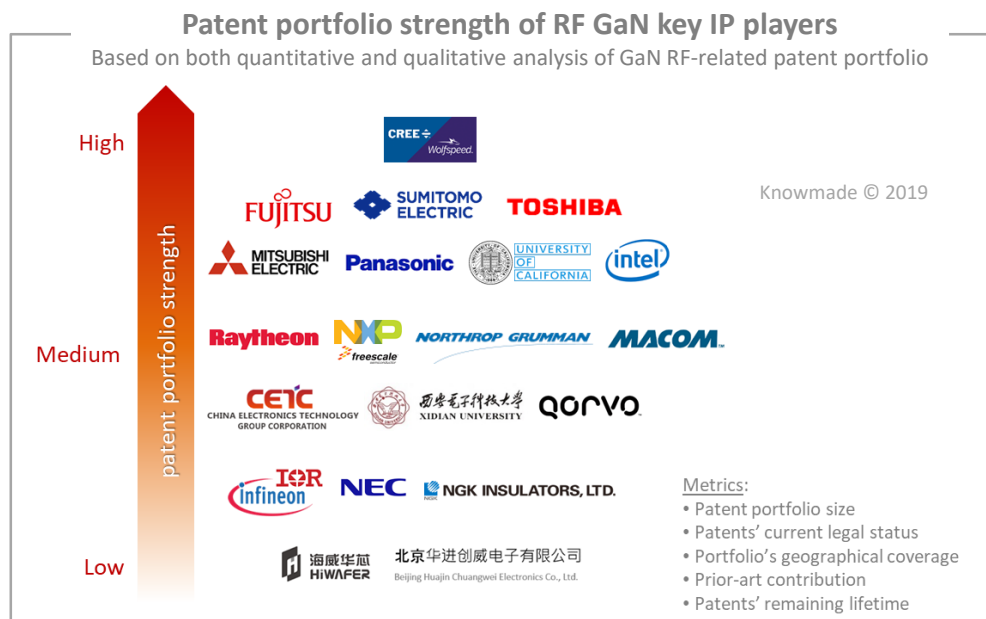
- [RF GaN Market: Applications, Players, Technology, and Substrates 2018-2023](#) (Yole Développement)
- [Qorvo QPF4006 39GHz GaN MMIC Front End Module](#) (System Plus Consulting)
- [RF Power Market and Technologies 2017: GaN, GaAs and LDMOS](#) (Yole Développement)

### RF GaN intellectual property (IP): domination of American and Japanese players, weak presence of Europeans, and numerous Chinese new entrants

In recent years, the **radiofrequency (RF) GaN market** has grown impressively and has reshaped the RF power device industry landscape. The **GaN RF industry** continues to **ramp up**, driven by **telecom and defense** applications, and with 5G implementation coming, the RF GaN market is developing fast. According to Yole Développement's report [RF GaN 2018](#), the total RF GaN market size is expected to increase from \$380M in 2017 to \$1.3B by 2023.

In this report, Knowmade has thoroughly investigated the **patent landscape related to GaN-based RF technologies and devices**.

We have selected and analyzed more than **3,750 patents** published worldwide up to October 2018 and grouped into more than 1,700 patent families. These patents pertain to **RF GaN epiwafers** including GaN-on-SiC and GaN-on-Silicon, **RF semiconductor devices**, including HEMTs and HBTs, **integrated circuits**, including RFICs and MMICs, **operating methods and packaging**, for all functions, such as RF power amplifiers (PAs), RF switches and RF filters and from **radio frequencies <6GHz to microwaves >6GHz and mm-waves >20GHz**.



### American and Japanese players dominate the RF GaN-related IP landscape

**Cree (Wolfspeed)** indisputably has the **strongest IP position**, especially for **GaN HEMTs on SiC substrates**. **Sumitomo Electric**, the market leader in RF GaN devices, is well positioned but far behind **Cree**. Furthermore, Sumitomo Electric **has been slowing down** its patenting activity while other Japanese companies like **Fujitsu**, **Toshiba** and **Mitsubishi Electric** are increasing their patent filings and thus today have **strong patent portfolios** as well. **Intel** and **MACOM** are currently the **most active** patent applicants for RF GaN, both especially for **GaN-on-Silicon** technology, and are today the main **IP challengers** in the RF GaN patent landscape. Other companies involved in RF GaN market, such as **Qorvo**, **Raytheon**, **Northrop Grumman**, **NXP/Freescale**, and **Infineon**, hold some key patents but do not necessarily have a strong IP position. **CETC** and **Xidian University** dominate the Chinese patent landscape with patents on GaN RF technologies targeting **microwave** and **mm-wave** applications. The emerging foundry **HiWafer** entered the IP landscape three years ago and is today the most serious **Chinese IP challenger**.

## GaN-based HEMTs for RF applications

**Cree (Wolfspeed)** has taken the lead in the **GaN HEMT IP race** for RF applications, especially for **GaN-on-SiC** technology, well ahead of its main IP competitors **Sumitomo Electric** and **Fujitsu**. The analysis of **Cree's RF GaN patent portfolio** shows it can effectively **limit patenting activity** in the field and control the **freedom-to-operate** of other firms in most key countries. **Intel**, which entered the GaN HEMT patent landscape later, is currently the **most active** patent applicant and it should **strengthen its IP position** in coming years, especially for **GaN-on-Silicon** technology. **New entrants** in the **GaN RF HEMT** related patent landscape are **mainly Chinese players** like **HiWafer**, **Sanan IC** and **Beijing Huajin Chuangwei Electronics**. Other noticeable new entrants are Taiwan's **TSMC** and **Wavetek Microelectronics**, Korea's **Wavice** and **Gigalane**, Japan's **Advantest**, and America's **MACOM** and **ON Semiconductor**. In the report we detail both **key patents** and **recent patents** held by **key IP players** and **new entrants**.

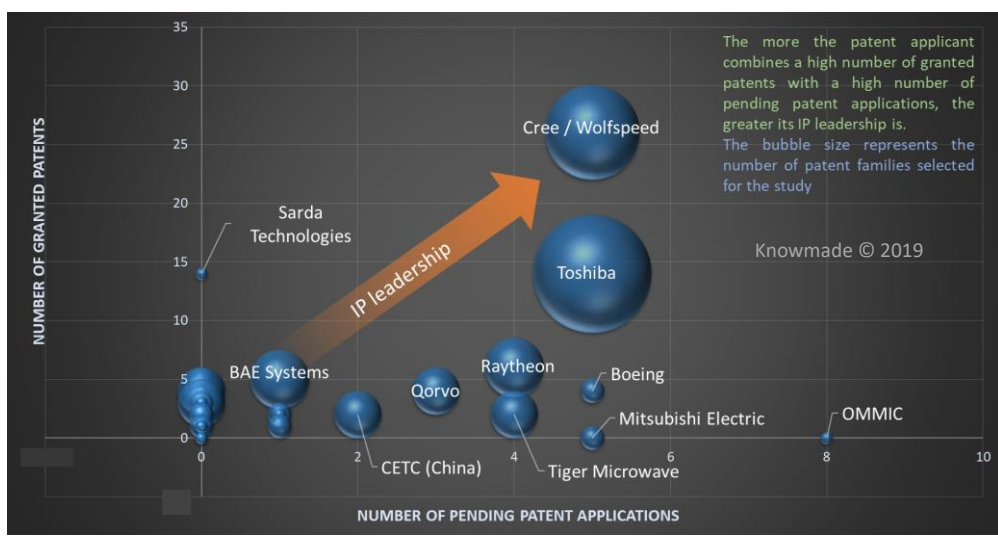
### GaN-on-Silicon substrates for RF

Only few patents explicitly claim the type of host substrate for GaN. The patent filings related to **RF GaN-on-Silicon** have been **increasing steadily since 2011**. The main patent assignees are **Intel** and **MACOM**, followed by **Sumitomo Electric**, **Infineon**, **Panasonic**, **HiWafer**, **CETC**, **Fujitsu** and **Mitsubishi Electric**. In the report we detail the patents claiming inventions to **suppress the parasitic channel layer** formed near the surface of the silicon substrate which adversely affect high frequency characteristics, and we focus on patents related to **packaging** for GaN-on-Silicon devices and **thermal management**.

### GaN MMICs

More than 30 entities have filed patents related to GaN MMICs, and **Toshiba** and **Cree (Wolfspeed)** have the **most important patent portfolios**. **Cree** has the **strongest IP position** in the field, but **Toshiba**, which entered the GaN MMIC patent landscape later, is currently the **most active** patent applicant and it should **strengthen its IP position** in coming years in view of its current patenting activity. **Toshiba's** recent patents pertain to **packages for GaN MMICs**, and **MMICs** that can enhance **power resistance** of a capacitor connection line, which are capable of **maintaining and withstanding voltages** necessary for each MIM capacitor, and being **downsized**. The main new entrants in the GaN MMIC related patent landscape are **Tiger Microwave** and **Beijing Huajin Chuangwei Electronics**. In this report we detail the **key patents** owned by companies like **Cree (Wolfspeed)**, **Toshiba**, **Raytheon**, **Northrop Grumman**, **MACOM** and **Qorvo**, and we focus on some patents claiming **GaN-on-Silicon** technology for MMICs.

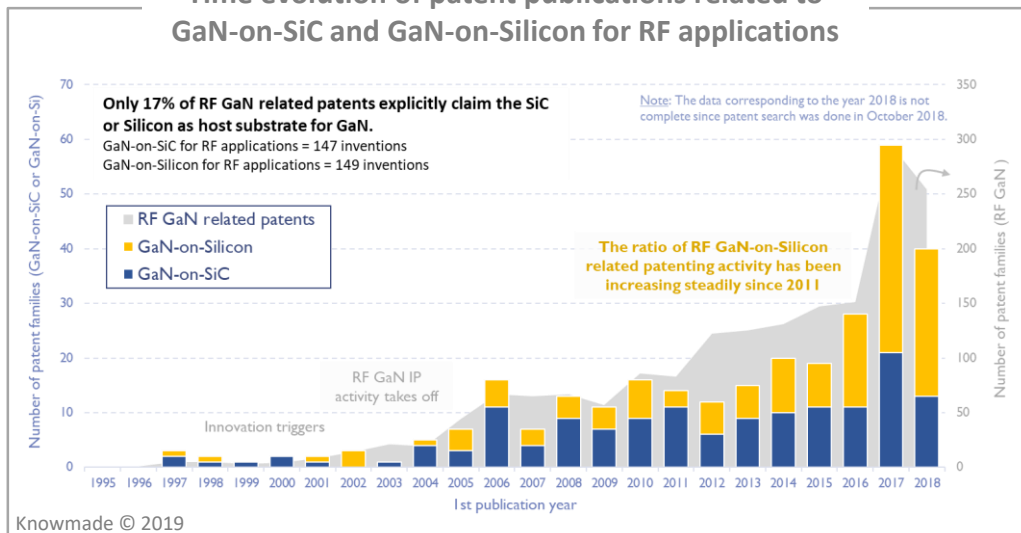
### IP leadership of patent assignees for GaN MMICs



### Microwave/mm-wave range >6 GHz and 5G wireless systems

In the report we have analyzed **RF GaN-related** patents claiming inventions for frequencies in the **microwave/mm-wave range** from **CETC**, **Xidian University**, **Toshiba**, **Wolfspeed** and **HiWafer**, and we highlight inventions **explicitly targeting 5G wireless systems**.

### Time evolution of patent publications related to GaN-on-SiC and GaN-on-Silicon for RF applications



### RF amplifier, RF switch, RF filter

In the report we analyzed the relative **IP position of patent assignees** for functions like RF PAs, RF switches and RF filters. **Cree (Wolfspeed)** has taken the lead in the GaN RF PA related patent landscape. **Toshiba**, **Fujitsu**, **Mitsubishi Electric**, **Qorvo**, **Raytheon** and **Sumitomo Electric** are the other main **IP players**, and **MACOM**, which entered the GaN RF PA patent landscape later, **stands out from other IP players** with its increasing patenting activity. **Intel** is currently the **most active player** in terms of patent filings related to **GaN RF switches**, and **Tagore Technology** is the most notable **new entrant** to the field. More and more patents claim **RF filters using III-nitride epitaxial layers**, and currently **Intel** is by far the main patent applicant for **GaN RF filter**.

### Packaging for RF GaN

**Toshiba** is the **most active IP player**, especially on **packaging** for RF semiconductor amplifiers and MMICs. In the report we detail patents related to **plastic over-molded packages** from **Cree (Wolfspeed)**, **Infineon**, **Sumitomo Electric**, **NXP/Freescale**, **MACOM**, **Mitsubishi Electric**.

**Companies Mentioned In The Report (Non-exhaustive)**

Cree/Wolfspeed, Sumitomo Electric, Qorvo, Fujitsu, CETC (China Electronics Technology Group Corporation), Toshiba, MACOM, Mitsubishi Electric, Intel, Northrop Grumman, Panasonic, NXP/Freescale, Raytheon, Infineon/International Rectifier, HiWafer, NTT (Nippon Telegraph & Telephone), Beijing Huajin Chuangwei Electronics, Dynax Semiconductor, NGK Insulators, Samsung Electronics, NEC, HRL Laboratories, Japan Radio, TSMC, US Navy, WIN Semiconductors, BAE Systems, Lockheed Martin, Tiger Microwave, Boeing, UMS, Eridan Communications, OMMIC, Remec, Rockwell Collins, Sarda Technologies, Thales, US Monolithics, Jiangsu Broadwave Electronics Technology, UBE Industries, Xidian University, Institute of Semiconductors - Chinese Academy of Sciences, IMECAS (Institute of Microelectronics of Chinese Academy of Sciences), ETRI (Electronics & Telecommunications Research Institute), UESTC (University of Electronic Science & Technology of China), University of California, Fudan University, South China University of Technology, SINANO (Suzhou Institute of Nano Technology & Nano Bionics - Chinese Academy of Sciences), Hangzhou Dianzi University, KETI (Korea Electronics Technology Institute), CEA (French Alternatives Energies and Atomic Energy Commission), etc.

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