From Technologies to IP Business Intelligence

RF GaN

Materials, Devices and Applications

Patent Landscape Analysis

February 2019

KnowMade
Patent & Technology Intelligence

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SCOPE OF THE REPORT

- This report provides a detailed picture of the patent landscape for **GaN RF technologies and devices**, covering **epiwafers** (GaN-on-SiC, GaN-on-Silicon), **RF semiconductor devices** (HEMT, HBT, etc.), **integrated circuits** (RFIC, MMIC), **circuit and operating methods**, and **packaging**, for all functions (**RF power amplifier**, **RF switch**, **RF filter**) and from **radio frequencies** (1 MHz – 6 GHz) to **microwaves** (6 GHz – 20 GHz), **mm-waves** (20 GHz – 110 GHz) and **terahertz** (100 GHz – 300 GHz)
- This report covers patents published worldwide up to **October 2018**.
- We have selected and analyzed more than **1,700 patent families** (inventions) relevant to the scope of this report.

Included

- Patents describing **GaN-based RF power devices** (HEMT, HBT, diodes, RFIC, MMIC, etc.) explicitly suitable for using in wireless communication, digital broadcasting, mobile communication base station, satellite ground station, aerospace, radar, electronic warfare equipment, military and space communication, etc.
- Patents pertain to **GaN-based power amplifier** (PA, LNA, Doherty PA, switch-mode PA, etc.), **RF switch** and **RF filter** (SAW, BAW, FBAR, etc.).
- Patents related to **modules/systems** which explicitly use **GaN-based RF power devices**.
- Patents claiming **GaN-based substrates/wafers/epiwafers** with improved **high-frequency** characteristics and explicitly suitable for using in **high power/high frequency applications** (RF, microwaves, mm-waves).

Excluded

- Patents describing RF power devices, modules or systems which can use **WBG materials** (SiC, GaN, etc.) without any embodiment or preferred solution on GaN.
- Patents related to **GaN-based high-voltage electronics and power devices** which have application value in **electric power conversion and electric power control** (power converter, power rectifier, power supply, etc.).
- Patents related to **GaN-based optoelectronics and photonics** (lightwaves).

KEY FEATURES OF THE REPORT (1/2)

- The report provides **essential patent data** for **GaN RF technologies and devices.**

- It provides **in-depth patent analyses** of **key technologies** and **key players** including:
  - Time evolution of patent publications and countries of patent filings.
  - Current legal status of patents.
  - Ranking of main patent applicants.
  - Joint developments and IP collaboration network of main patent applicants.
  - Key patents.
  - Granted patents near expiration.
  - Relative strength of main companies IP portfolio.
  - Key patents on technology issues.

KEY FEATURES OF THE REPORT (2/2)

- The report also provides an extensive **Excel database** with all patents analyzed in the report.

  This **patent database** allows multi-criteria searches, including:

  - Patent publication number
  - Hyperlinks to the original documents
  - Priority date
  - Title
  - Abstract
  - Patent assignees
  - Technical segmentation
  - Legal status for each member of the patent family

Disclaimer: This report **does not provide** any insight **analyses or counsel regarding legal aspects** or the validity of any individual patent. Knowmade is a research firm that provides technical analysis and technical opinions. Knowmade is not a law firm. The research, technical analysis and/or work proposed or provided by Knowmade and contained herein is not a legal opinion and should not be construed as such.

PATENT LANDSCAPE ANALYSIS

Benefits for customer

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

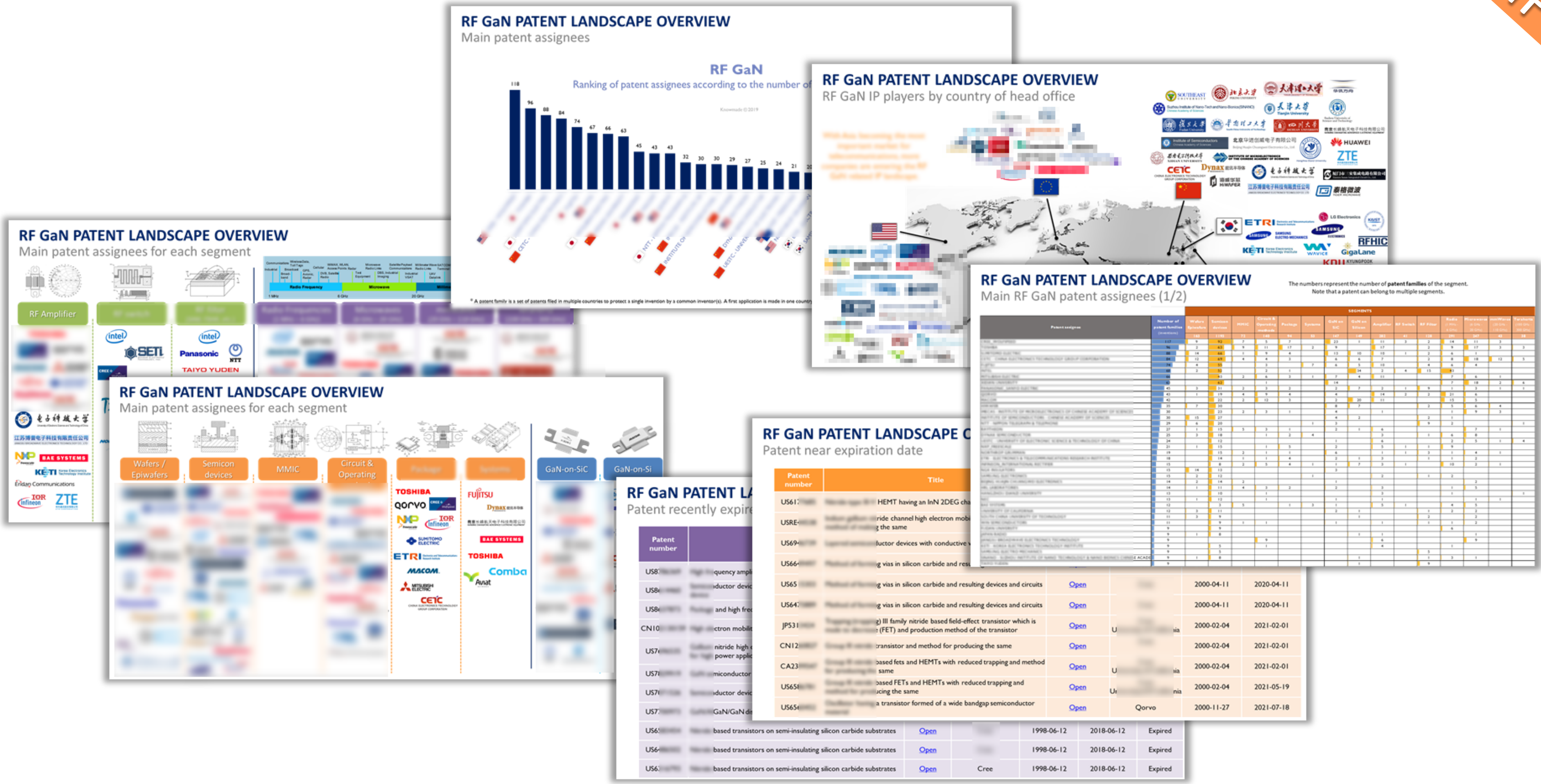
- Know the **key IP players**, their **key patents**, their IP/technology **strategy** and their **future intents**
- Identify **new entrants**, their **technology** and **market areas** of interest
- Follow the **technology trends** and identify **emerging technologies**
- **Benchmark** patent portfolios and know competitors' **strengths** and **weaknesses**
- Identify the **key patents** (seminal, blocking, valuable) and the **key technical solutions** that address hot technical issues
- Identify **free technologies** which can be used safely and mitigate the **risks of patent infringement**
- Identify **technologies to acquire** and potential **R&D partners**

Very complementary to market research

- Key market players
- Supply chain
- Technology Readiness Levels (TRL)
- Market product
- Emerging technologies/applications
- Forecast

RF GaN Patent Landscape Overview

Patent assignees, patent segmentation, expiring patents



RF GaN PATENT LANDSCAPE OVERVIEW
Main patent assignees

RF GaN
Ranking of patent assignees according to the number of

RF GaN PATENT LANDSCAPE OVERVIEW
RF GaN IP players by country of head office

RF GaN PATENT LANDSCAPE OVERVIEW
Main patent assignees for each segment

RF GaN PATENT LANDSCAPE OVERVIEW
Main patent assignees for each segment

RF GaN PATENT LANDSCAPE OVERVIEW
Main RF GaN patent assignees (1/2)

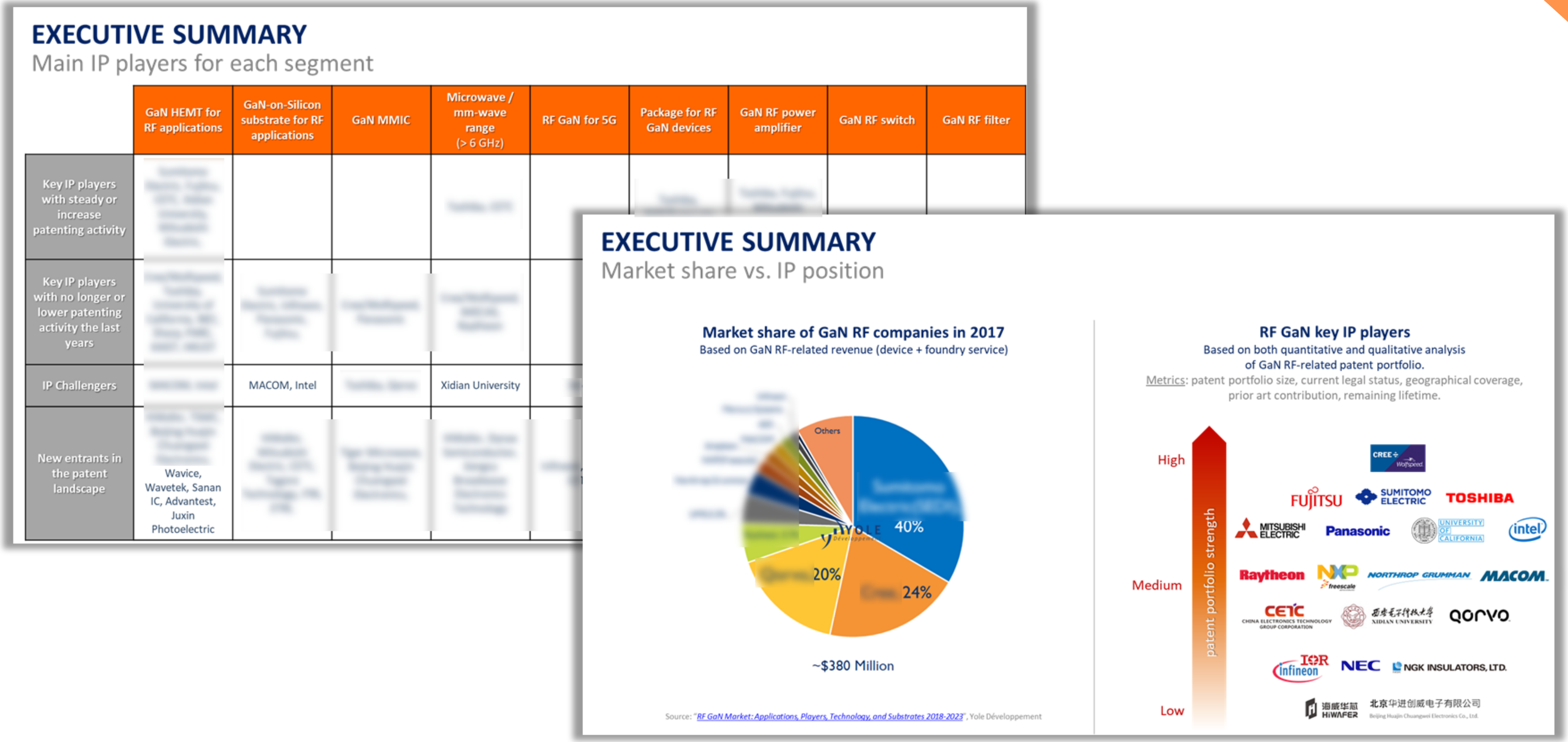
The numbers represent the number of patent families of the segment. Note that a patent can belong to multiple segments.

RF GaN PATENT LANDSCAPE O
Patent near expiration date

RF GaN PATENT LA
Patent recently expire

RF GaN Patent Landscape Overview

Key IP players and new entrants



EXECUTIVE SUMMARY

Main IP players for each segment

	GaN HEMT for RF applications	GaN-on-Silicon substrate for RF applications	GaN MMIC	Microwave / mm-wave range (> 6 GHz)	RF GaN for 5G	Package for RF GaN devices	GaN RF power amplifier	GaN RF switch	GaN RF filter
Key IP players with steady or increase patenting activity									
Key IP players with no longer or lower patenting activity the last years									
IP Challengers		MACOM, Intel		Xidian University					
New entrants in the patent landscape	Wavice, Wavetek, Sanan IC, Advantest, Juxin Photoelectric								

EXECUTIVE SUMMARY

Market share vs. IP position

Market share of GaN RF companies in 2017

Based on GaN RF-related revenue (device + foundry service)

~$380 Million

Source: "*RF GaN Market: Applications, Players, Technology, and Substrates 2018-2023*", Yole Développement

RF GaN key IP players

Based on both quantitative and qualitative analysis of GaN RF-related patent portfolio.

Metrics: patent portfolio size, current legal status, geographical coverage, prior art contribution, remaining lifetime.

GaN HEMTs for RF Applications

Patent assignees, IP dynamics, patent legal status, patent segmentation

GaN RF SEMICONDUCTOR DEVICES
Time evolution of patent publications

Time evolution of patent publications related to **GaN RF semiconductor devices** (HEMT, HBT, Diodes, etc.)
>1,190 patent families* (850+ concern GaN HEMT)

Based on the current trend, we expect at least 190 new GaN RF semiconductor device inventions for 2018.

GaN HEMT for RF Applications
Leading patent applicants

GaN HEMT for RF Applications
Ranking of patent assignees according to the number of their patent families*

* A patent family is a set of patents

GaN HEMT for RF Applications
Time evolution of IP players (2/3)

The numbers represent the number of patent families

RF GaN IP players with steady IP activity or showing a recent increase of patent filings

GaN RF SEMICONDUCTOR DEVICES
Main patent assignees (1/2)

The numbers represent the number of patent families of the segment.
Note that a patent can belong to multiple segments.

GaN HEMT for RF Applications
Strategy of IP players to improve the reliability of GaN RF HEMTs

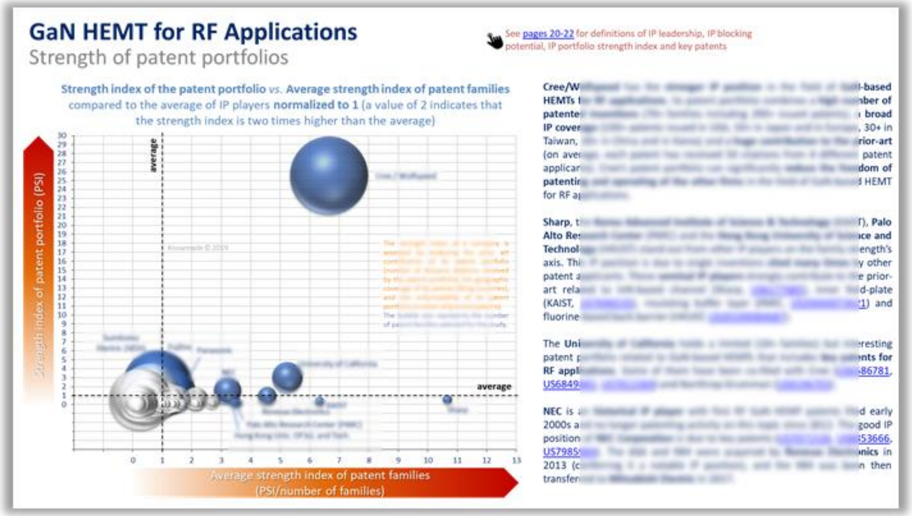
Here are listed only key players and new entrants detailed in previous parts.

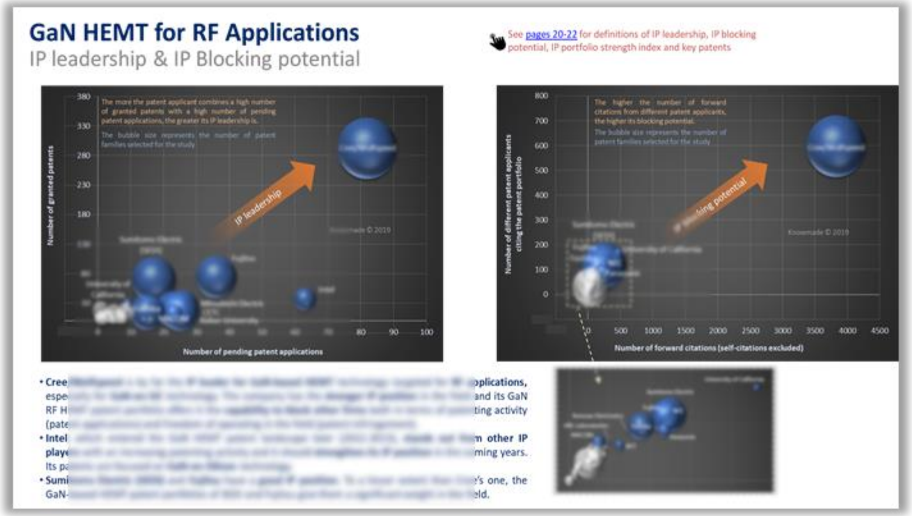
The numbers represent the number of patent families of the segment. Note that a patent can belong to multiple segments.

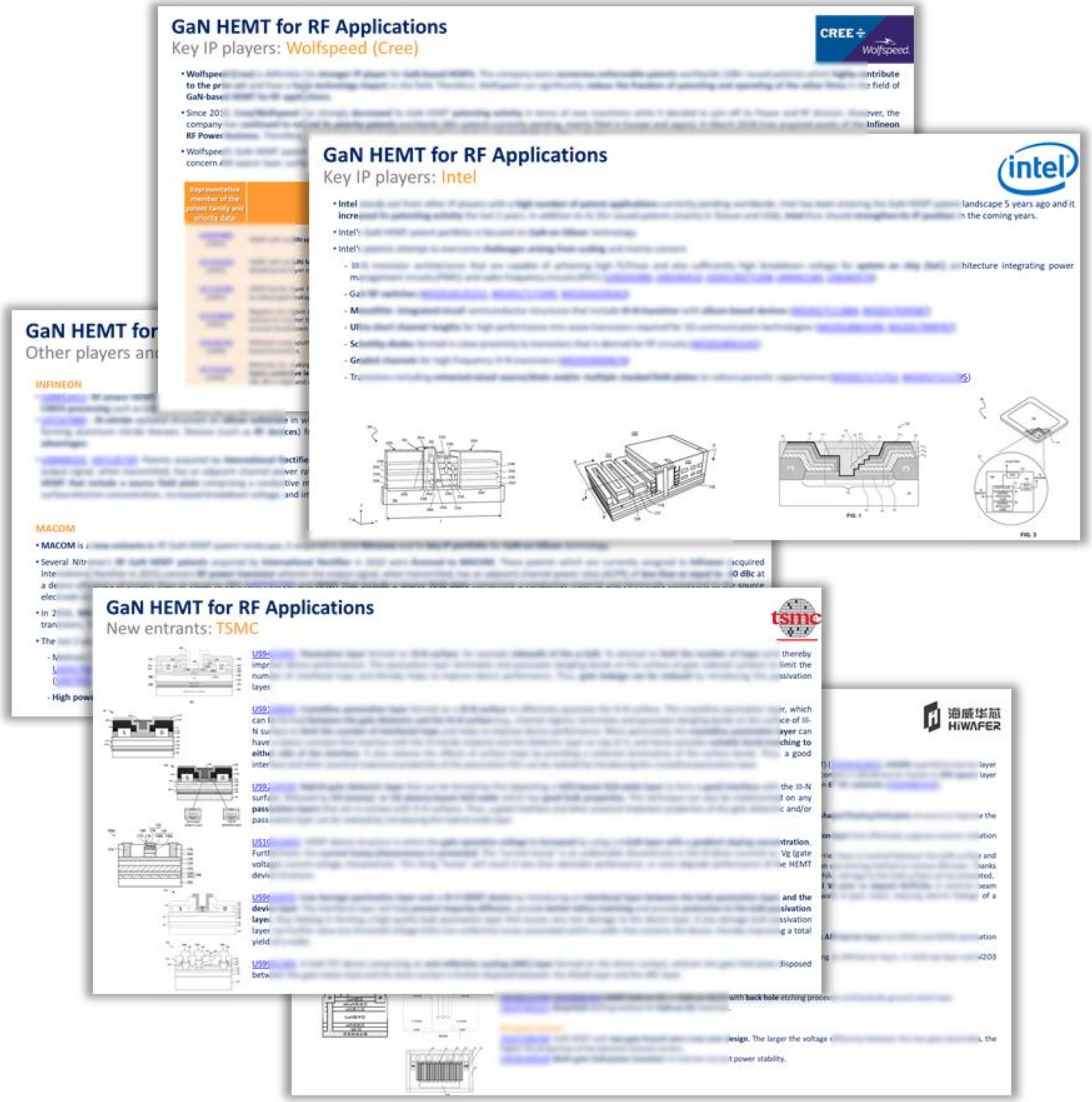
GaN HEMT for RF Applications
Main IP players and the current legal status of their patents

GaN HEMTs for RF Applications

Patent portfolio strength, focus on key player, focus on new entrants


GaN HEMT for RF Applications
Strength of patent portfolios
See pages 20-22 for definitions of IP leadership, IP blocking potential, IP portfolio strength index and key patents
Strength index of the patent portfolio vs. Average strength index of patent families compared to the average of IP players normalized to 1 (a value of 2 indicates that the strength index is two times higher than the average)


GaN HEMT for RF Applications
IP leadership & IP Blocking potential
See pages 20-22 for definitions of IP leadership, IP blocking potential, IP portfolio strength index and key patents


GaN HEMT for RF Applications
Key IP players: Wolfspeed (Cree)

GaN HEMT for RF Applications
Key IP players: Intel

GaN HEMT for
Other players an

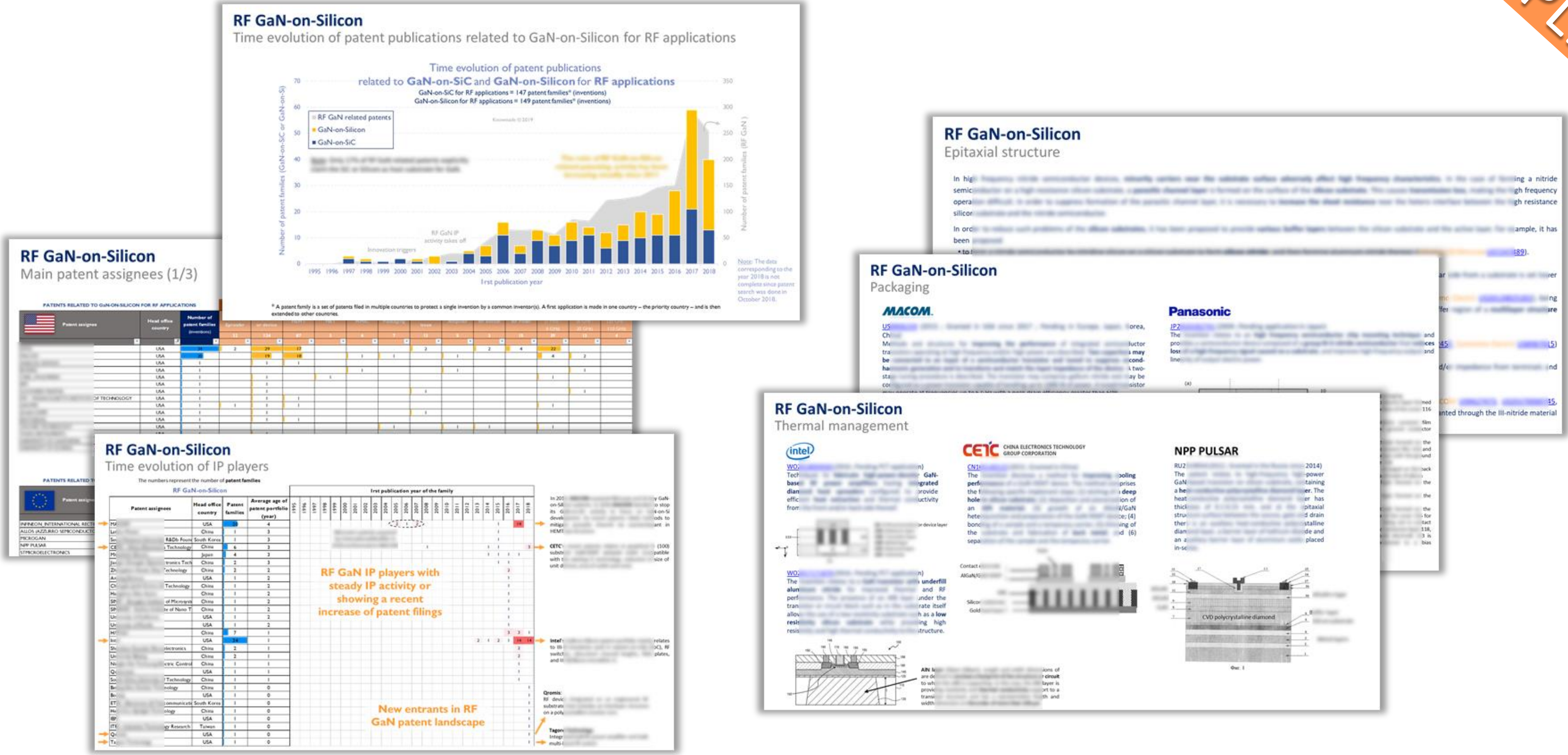
INFINEON

MACOM

GaN HEMT for RF Applications
New entrants: TSMC

RF Gan-on-Silicon Substrate

Patent assignees, IP dynamics, focus on epi-structures, packaging and thermal management



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

Note: The data corresponding to the year 2018 is not complete since patent search was done in October 2018.

* A patent family is a set of patents filed in multiple countries to protect a single invention by a common inventor(s). A first application is made in one country – the priority country – and is then extended to other countries.

RF GaN-on-Silicon
Main patent assignees (1/3)

PATENTS RELATED TO GaN-ON-SILICON FOR RF APPLICATIONS

RF GaN-on-Silicon
Time evolution of IP players

The numbers represent the number of **patent families**

RF GaN-on-Silicon

RF GaN IP players with steady IP activity or showing a recent increase of patent filings

New entrants in RF GaN patent landscape

RF GaN-on-Silicon
Epitaxial structure

RF GaN-on-Silicon
Packaging

RF GaN-on-Silicon
Thermal management

GaN MMICs

Patent assignees, IP dynamics, patent legal status, patent segmentation

GaN MMIC (Monolithic Microwave Integrated Circuit)

Leading patent applicants

GaN MMIC

Ranking of patent assignees according to the number of their patent families*

* A patent family is a set of patents filed in multiple countries to protect a single invention by a common inventor(s). A first application is made in one country – the priority country – and is then extended to other countries.

GaN INTEGRATED CIRCUIT FOR RF APPLICATIONS

Main patent assignees

GaN INTEGRATED CIR

Time evolution of patent

owave Integrated Circuit)

ations and terminals using a 0.15µm GaN-on-SiC process.

Qorvo

GaN MMIC (Monolithic Microwave Integrated Circuit)

Main IP players and the current legal status of their patents

GaN MMIC

Number of patent filings by main players and their current legal status

GaN MMIC (Monolithic Microwave Integrated Circuit)

Time evolution of IP players

The numbers represent the number of patent families

GaN MMIC

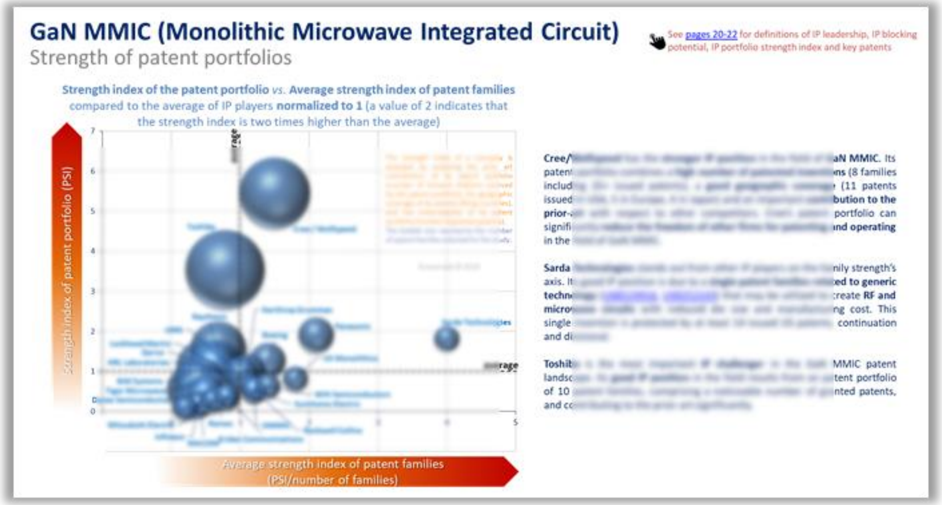
Historical GaN MMIC IP players with a lower patenting activity

GaN MMIC IP players showing a recent increase of patenting activity

New entrants in GaN MMIC related patent landscape

GaN MMICs

Patent portfolio strength, focus on key player, focus on new entrants

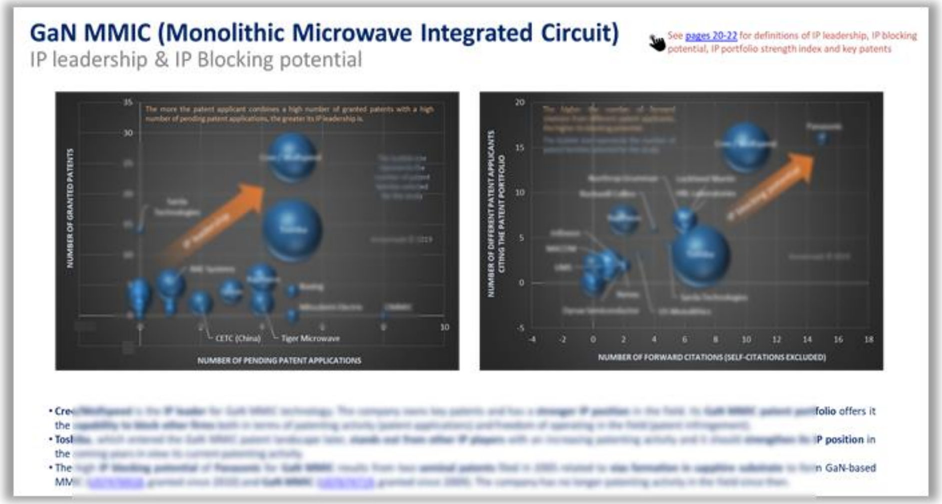


GaN MMIC (Monolithic Microwave Integrated Circuit)

Strength of patent portfolios

See pages 20-22 for definitions of IP leadership, IP blocking potential, IP portfolio strength index and key patents

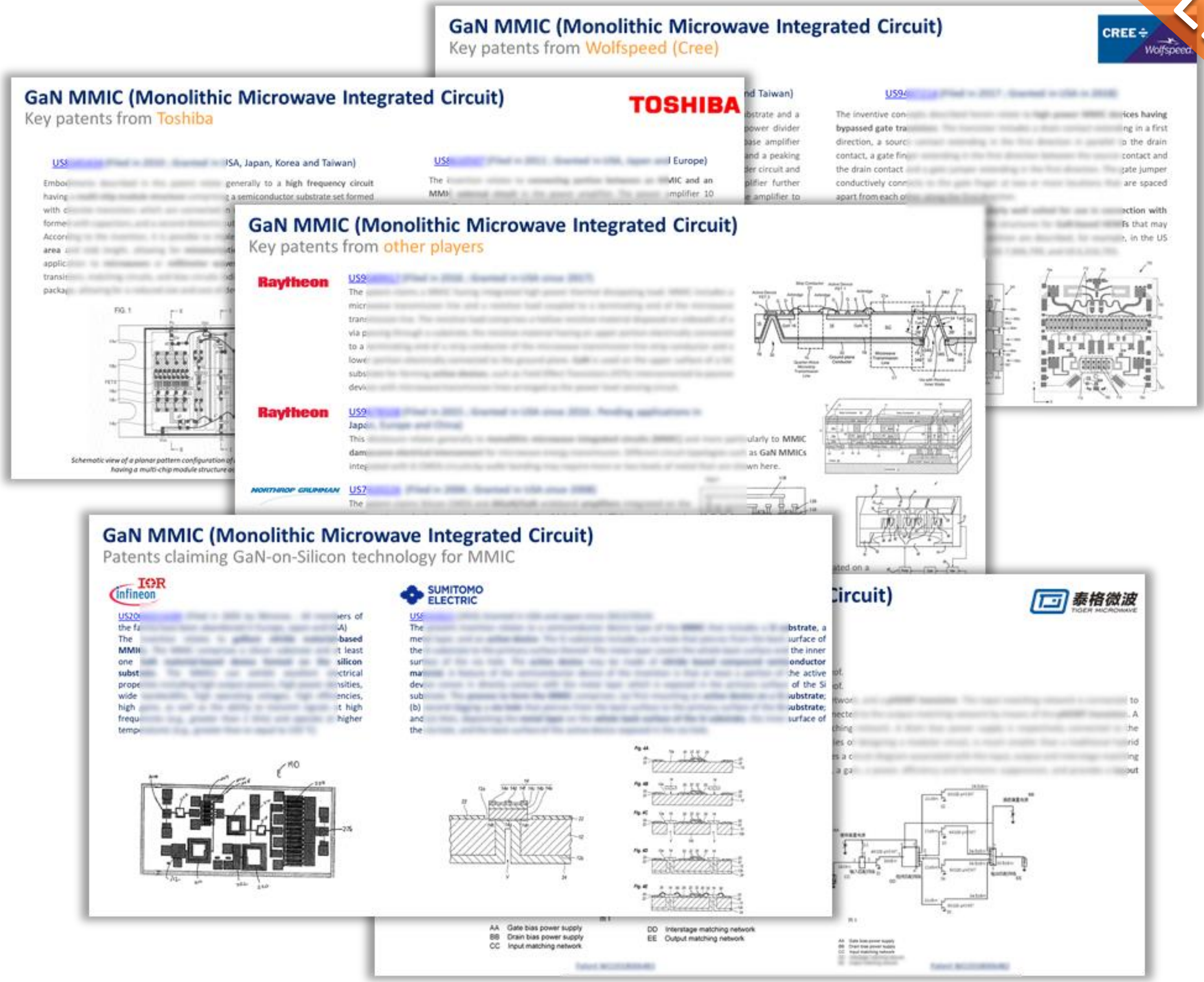
Strength index of the patent portfolio vs. Average strength index of patent families compared to the average of IP players normalized to 1 (a value of 2 indicates that the strength index is two times higher than the average)



GaN MMIC (Monolithic Microwave Integrated Circuit)

IP leadership & IP Blocking potential

See pages 20-22 for definitions of IP leadership, IP blocking potential, IP portfolio strength index and key patents



GaN MMIC (Monolithic Microwave Integrated Circuit)

Key patents from Wolfspeed (Cree)

GaN MMIC (Monolithic Microwave Integrated Circuit)

Key patents from Toshiba

GaN MMIC (Monolithic Microwave Integrated Circuit)

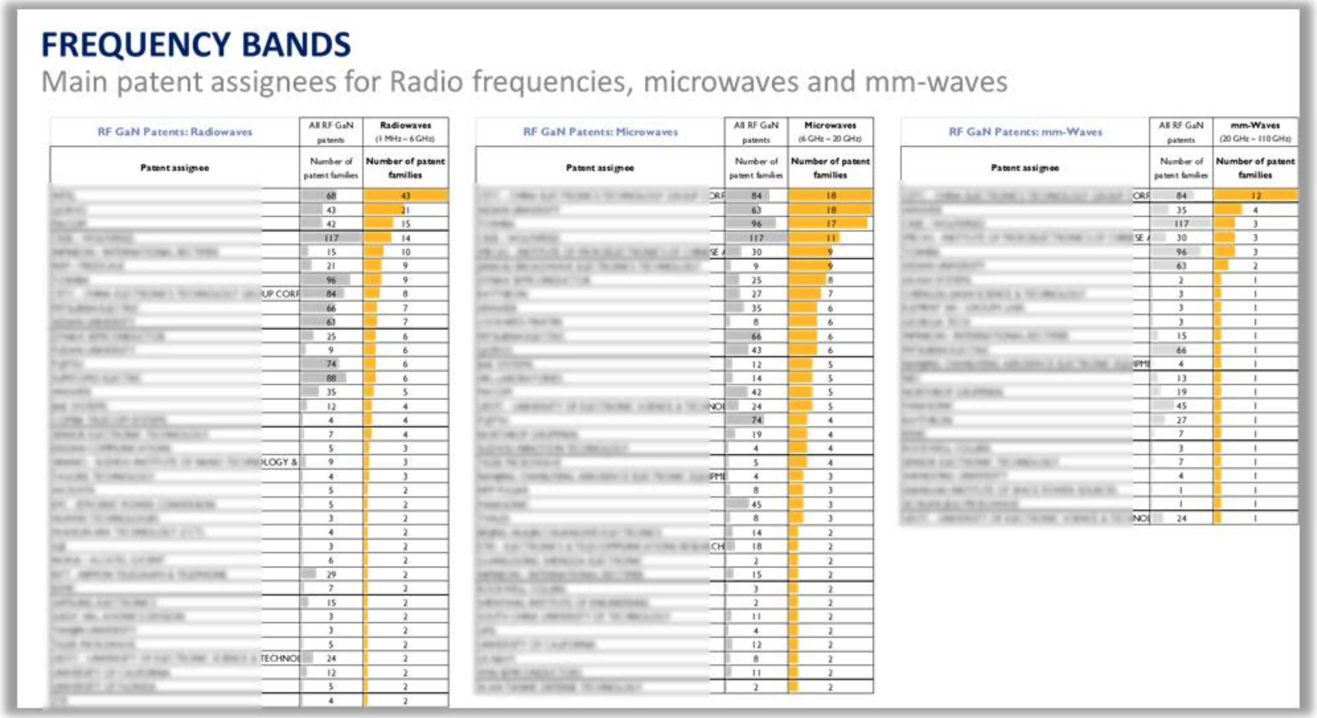
Key patents from other players

GaN MMIC (Monolithic Microwave Integrated Circuit)

Patents claiming GaN-on-Silicon technology for MMIC

GaN-based Microwaves/mm-Waves Technologies

Main patent assignees for microwaves/mm-waves and 5G wireless communications



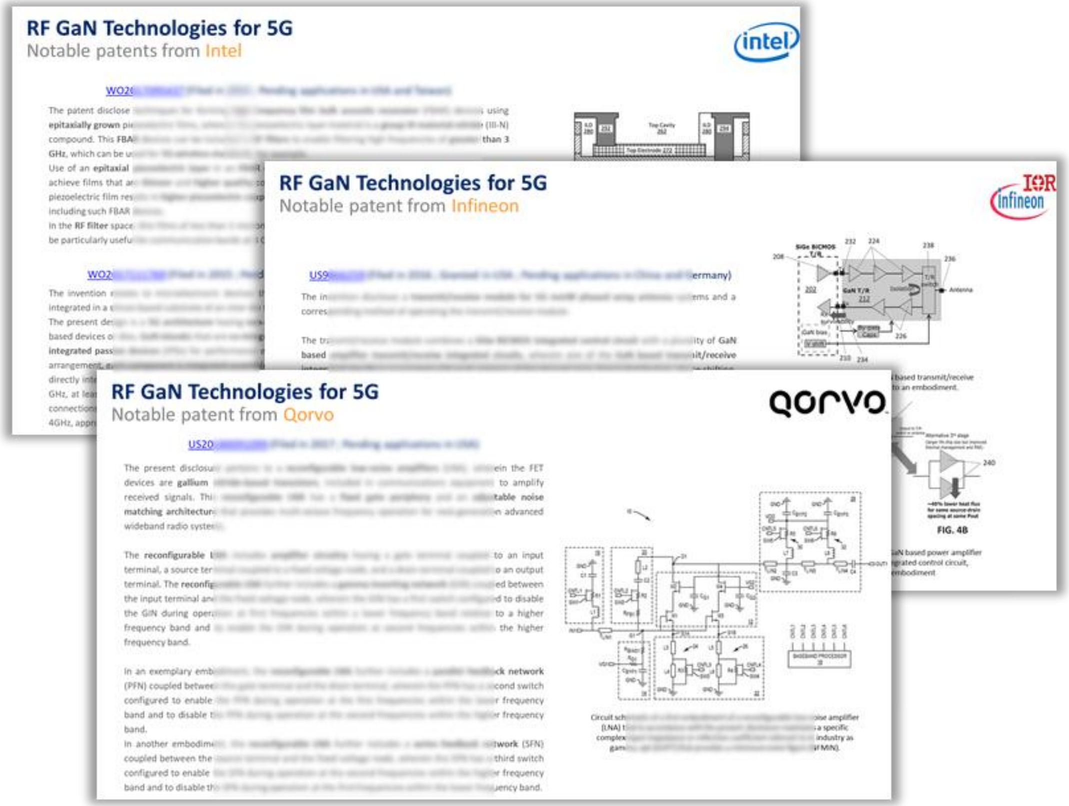
FREQUENCY BANDS

Main patent assignees for Radio frequencies, microwaves and mm-waves

RF GaN Patents: Radiowaves	All RF GaN patents	Radiowaves (1 MHz – 6 GHz)
Patent assignee	Number of patent families	Number of patent families
[redacted]	68	43
[redacted]	43	21
[redacted]	42	15
[redacted]	117	14
[redacted]	15	10
[redacted]	21	9
[redacted]	96	9
[redacted]	84	8
[redacted]	66	7
[redacted]	63	7
[redacted]	25	6
[redacted]	9	6
[redacted]	74	6
[redacted]	88	6
[redacted]	35	5
[redacted]	12	4
[redacted]	4	4
[redacted]	7	4
[redacted]	5	3
[redacted]	9	3
[redacted]	4	3
[redacted]	5	2
[redacted]	5	2
[redacted]	3	2
[redacted]	4	2
[redacted]	3	2
[redacted]	6	2
[redacted]	29	2
[redacted]	7	2
[redacted]	15	2
[redacted]	3	2
[redacted]	3	2
[redacted]	5	2
[redacted]	24	2
[redacted]	12	2
[redacted]	5	2
[redacted]	4	2

RF GaN Patents: Microwaves	All RF GaN patents	Microwaves (6 GHz – 20 GHz)
Patent assignee	Number of patent families	Number of patent families
[redacted]	84	18
[redacted]	63	18
[redacted]	96	17
[redacted]	117	11
[redacted]	30	9
[redacted]	9	9
[redacted]	25	8
[redacted]	27	7
[redacted]	35	6
[redacted]	8	6
[redacted]	66	6
[redacted]	43	6
[redacted]	12	5
[redacted]	14	5
[redacted]	42	5
[redacted]	24	5
[redacted]	74	4
[redacted]	19	4
[redacted]	4	4
[redacted]	5	4
[redacted]	4	3
[redacted]	8	3
[redacted]	45	3
[redacted]	8	3
[redacted]	14	2
[redacted]	18	2
[redacted]	2	2
[redacted]	15	2
[redacted]	3	2
[redacted]	2	2
[redacted]	11	2
[redacted]	4	2
[redacted]	12	2
[redacted]	8	2
[redacted]	11	2
[redacted]	2	2

RF GaN Patents: mm-Waves	All RF GaN patents	mm-Waves (20 GHz – 110 GHz)
Patent assignee	Number of patent families	Number of patent families
[redacted]	84	12
[redacted]	35	4
[redacted]	117	3
[redacted]	30	3
[redacted]	96	3
[redacted]	63	2
[redacted]	2	1
[redacted]	3	1
[redacted]	3	1
[redacted]	3	1
[redacted]	15	1
[redacted]	66	1
[redacted]	4	1
[redacted]	13	1
[redacted]	19	1
[redacted]	45	1
[redacted]	27	1
[redacted]	7	1
[redacted]	3	1
[redacted]	7	1
[redacted]	4	1
[redacted]	1	1
[redacted]	1	1
[redacted]	24	1



RF GaN Technologies for 5G

Notable patents from Intel

WO2[redacted]

The patent disclose [redacted] using **epitaxially grown** pi[redacted] (III-N) compound. This **FBA**[redacted] than 3 **GHz**, which can be u[redacted]

Use of an **epitaxial** [redacted] achieve films that a[redacted] piezoelectric film res[redacted] including such FBAR [redacted]

In the **RF filter** space [redacted] be particularly usefu[redacted]

WO2[redacted]

The invention [redacted] integrated in a [redacted] The present de[redacted] based devices o[redacted] **integrated pass**[redacted] arrangement[redacted] directly int[redacted] GHz, at lea[redacted] connection[redacted] 4GHz, appr[redacted]

RF GaN Technologies for 5G

Notable patent from Infineon

US9[redacted]ermany)

The in[redacted]ems and a corres[redacted]

The tr[redacted]ity of **GaN based** [redacted]it/receive [redacted]

[redacted] based transmit/receive [redacted] to an embodiment.

[redacted]aN based power amplifier [redacted]grated control circuit, [redacted]embodiment

RF GaN Technologies for 5G

Notable patent from Qorvo

US20[redacted]

The present disclosu[redacted]ein the FET devices are **gallium** [redacted] to amplify received signals. Thi[redacted]**table noise matching architectur**[redacted]n advanced wideband radio syste[redacted]

The **reconfigurable** [redacted] to an input terminal, a source ter[redacted]o an output terminal. The **reconfig**[redacted]ed between the input terminal an[redacted]d to disable the GIN during oper[redacted] to a higher frequency band and [redacted] the higher frequency band.

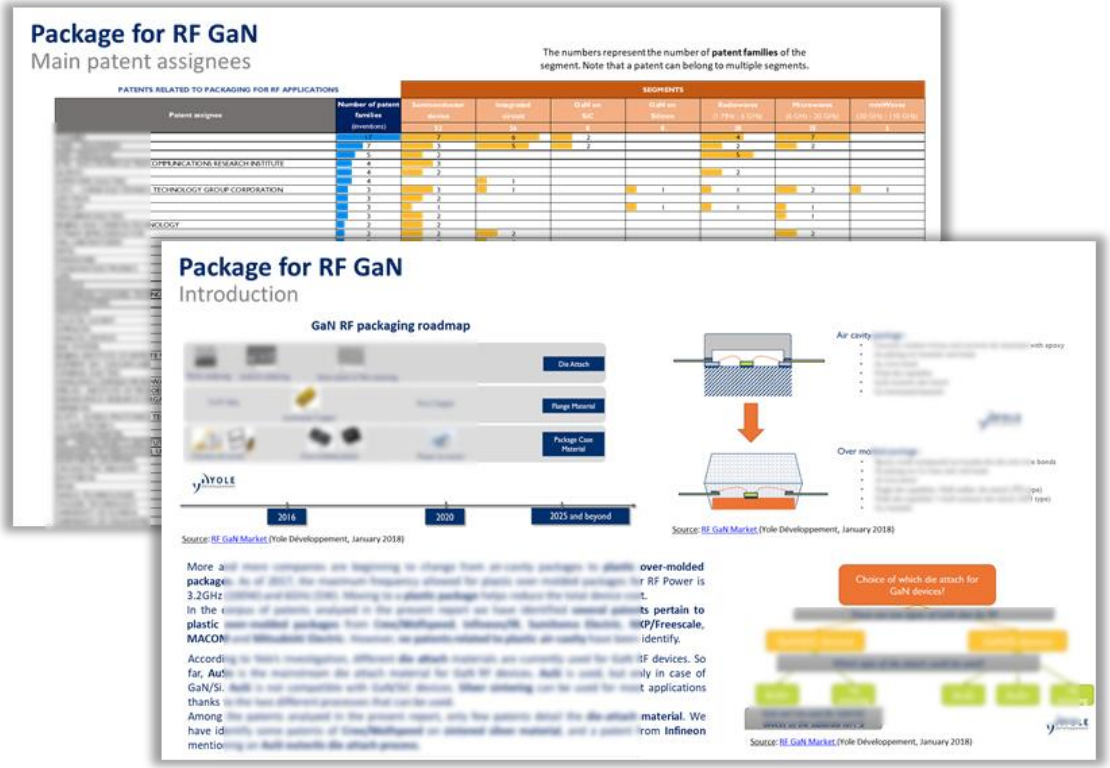
In an exemplary emb[redacted]**ck network** (PFN) coupled betwee[redacted]cond switch configured to enable [redacted]r frequency band and to disable t[redacted]r frequency band.

In another embodim[redacted]**twork** (SFN) coupled between the [redacted] third switch configured to enable [redacted]r frequency band and to disable th[redacted]ency band.

Circuit sch[redacted]ise amplifier (LNA) t[redacted] a specific complex[redacted] industry as gam[redacted]f MIN).

Package for RF GaN

Main patent assignees, plastic over-molded package, die-attach materials



Package for RF GaN

Main patent assignees

The numbers represent the number of patent families of the segment. Note that a patent can belong to multiple segments.

Package for RF GaN

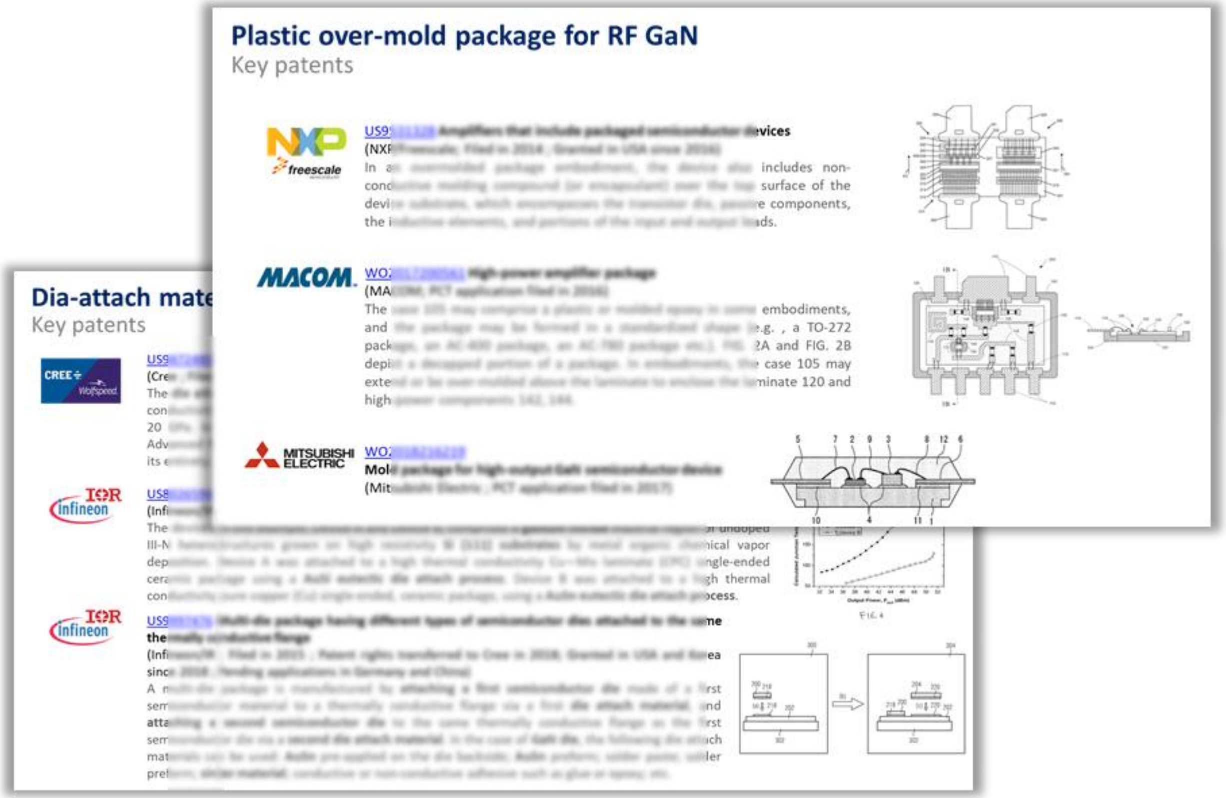
Introduction

GaN RF packaging roadmap

Source: RF GaN Market (Yole Développement, January 2018)

Source: RF GaN Market (Yole Développement, January 2018)

Source: RF GaN Market (Yole Développement, January 2018)



Plastic over-mold package for RF GaN

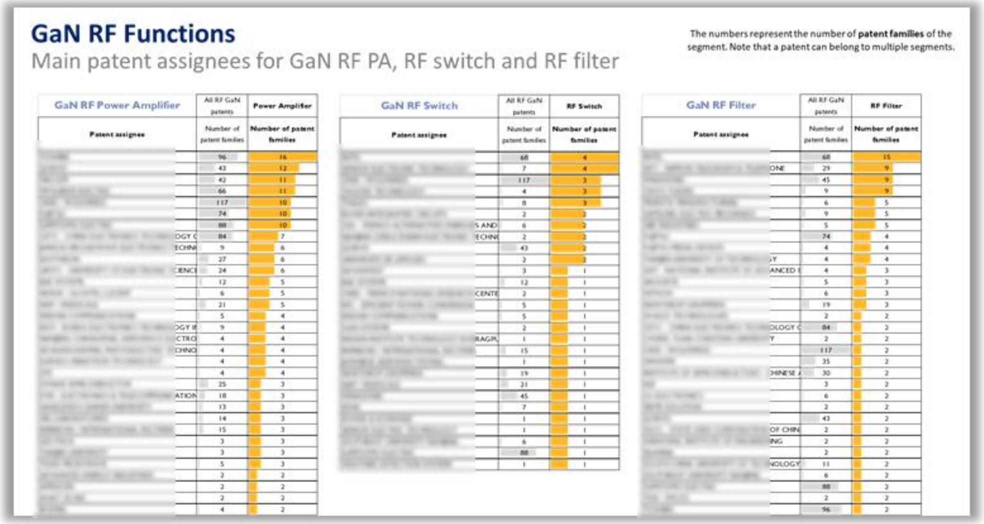
Key patents

Dia-attach mate

Key patents

Functions: Power amplifier / RF switch / RF filter

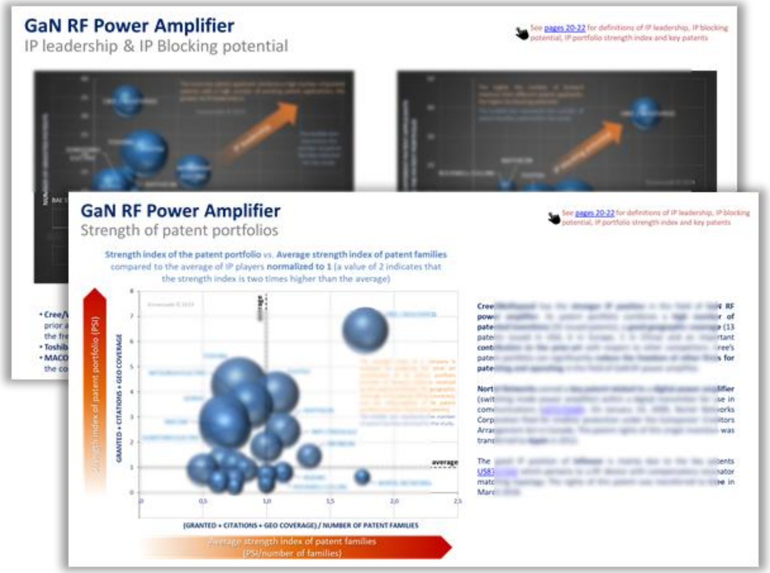
Key players and key patents for GaN-based RF power amplifier, RF switch and RF filters



GaN RF Functions

Main patent assignees for GaN RF PA, RF switch and RF filter

The numbers represent the number of patent families of the segment. Note that a patent can belong to multiple segments.



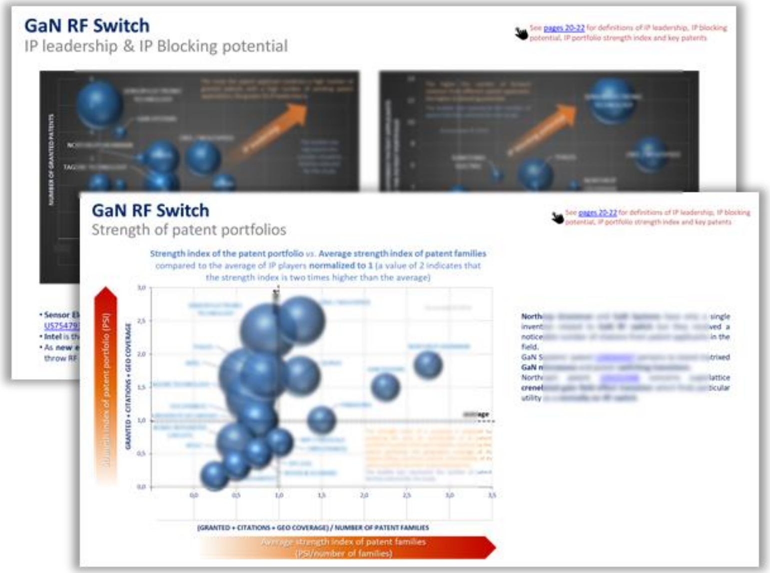
GaN RF Power Amplifier

IP leadership & IP Blocking potential

GaN RF Power Amplifier

Strength of patent portfolios

Strength index of the patent portfolio vs. Average strength index of patent families compared to the average of IP players normalized to 1 (a value of 2 indicates that the strength index is two times higher than the average)



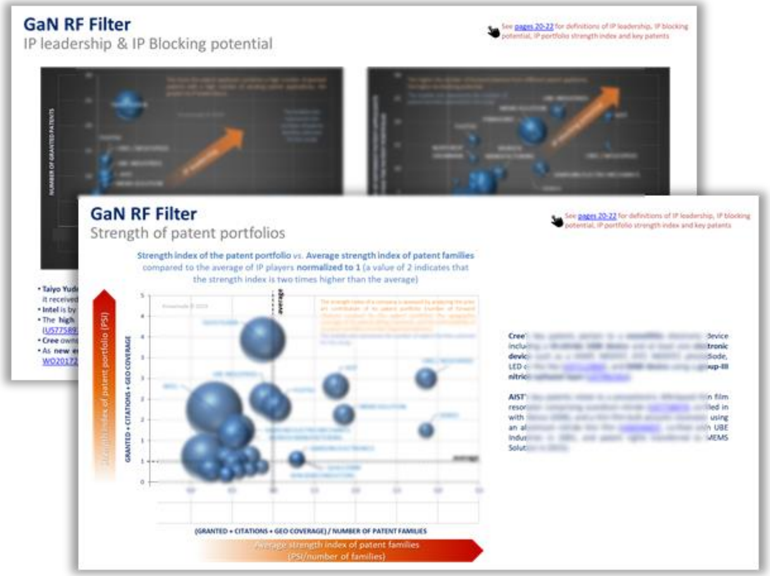
GaN RF Switch

IP leadership & IP Blocking potential

GaN RF Switch

Strength of patent portfolios

Strength index of the patent portfolio vs. Average strength index of patent families compared to the average of IP players normalized to 1 (a value of 2 indicates that the strength index is two times higher than the average)



GaN RF Filter

IP leadership & IP Blocking potential

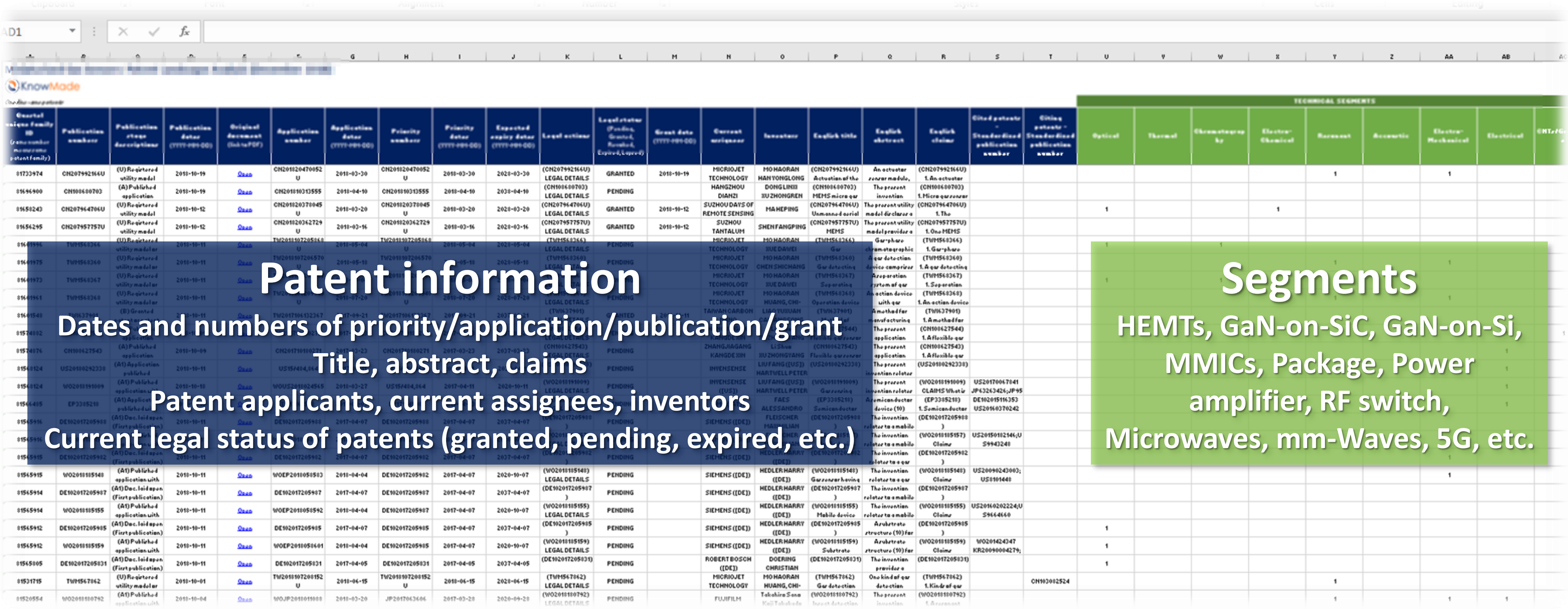
GaN RF Filter

Strength of patent portfolios

Strength index of the patent portfolio vs. Average strength index of patent families compared to the average of IP players normalized to 1 (a value of 2 indicates that the strength index is two times higher than the average)

Excel file with all patents analyzed in the report

Useful patent database allows multi-criteria searches



Patent information

Dates and numbers of priority/application/publication/grant

Title, abstract, claims

Patent applicants, current assignees, inventors

Current legal status of patents (granted, pending, expired, etc.)

Segments

HEMTs, GaN-on-SiC, GaN-on-Si, MMICs, Package, Power amplifier, RF switch, Microwaves, mm-Waves, 5G, etc.

ORDER FORM

RF GaN

Patent Landscape Analysis – February 2019

Ref.:KM19003

ORDER ONLINE

SHIP TO

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Postcode/Zip:

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Date:

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IBAN: FR76 1460 7003 6360 6214 5695 139
BIC/SWIFT: CCBPFRPPMAR

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DEFINITIONS

“Acceptance”: Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by signing the purchase order which mentions “I hereby accept Knowmade’s Terms and Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities, for its business needs) entering into the following general conditions to the exclusion of consumers acting in their personal interests.

“Contracting Parties” or “Parties”: The Seller on the one hand and the Buyer on the other hand.

“Intellectual Property Rights” (“IPR”) means any rights held by the Seller in its Products, including any patents, trademarks, registered models, designs, copyrights, inventions, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they have been registered or not and including any pending registration of one of the above mentioned rights.

“License”: For the reports and databases, 2 different licenses are proposed. The buyer has to choose one license:

1. One user license: a single individual at the company can use the report.
2. Multi user license: the report can be used by unlimited users within the company. Subsidiaries are not included.

“Products”: Reports are established in PowerPoint and delivered on a PDF format and the database may include Excel files.

“Seller”: Based in Sophia Antipolis (France headquarters), Knowmade is a technology intelligence company specialized in the research and analysis of scientific and technical information. We provide patent landscapes and scientific state of the art with high added value to businesses and research laboratories. Our intelligence digests play a key role to define your innovation and development strategy.

1. SCOPE

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.

1.2 This agreement becomes valid and enforceable between the Contracting Parties after clear and non-equivocal consent by any duly authorized person representing the Buyer. For these purposes, the Buyer accepts these conditions of sales when signing the purchase order which mentions “I hereby accept Knowmade’s Terms and Conditions of Sale”. This results in acceptance by the Buyer.

1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email or to the Buyer’s address. In the absence of any confirmation in writing, orders shall be deemed to have been accepted.

2. MAILING OF THE PRODUCTS

2.1 Products are sent by email to the Buyer:

- within [1] month from the order for Products already released; or
- 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.

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

The Seller shall by no means be responsible for any delay in respect of article 2.2 above, and including in cases where a new event or access to new contradictory information would require for the analyst extra time to compute or compare the data in order to enable the Seller to deliver a high quality Products.

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.

3. PRICE, INVOICING AND PAYMENT

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.

3.4 In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice at the stage in progress, and to take legal action for damages.

4. LIABILITIES

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:

a) damages of any kind, including without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or information) arising out of the use of or inability to use the Seller’s website or the Products, or any information provided on the website, or in the Products;

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 reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making the Products available, the Seller cannot guarantee that any Product will be free from infection.

5. FORCE MAJEURE

The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labor difficulties, equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not the fault of the Seller.

6. PROTECTION OF THE SELLER’S IPR

6.1 All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.

6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish the Product, or any part of it to any other party other than employees of its company. The Buyer shall have the right to use the Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use the Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmittals over any network (including any local area network);
- 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.

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.

KNOWMADE

Patent and Technology Intelligence

KnowMade
Patent & Technology Intelligence

WHAT WE DO

Knowmade helps customers to understand
the **competitive landscape**, follow **technology trends**, and find out **opportunities** and **threats** in terms of **technology** and **patents**.

- Interpreting the **competitive landscape** and **technology developments** throughout **patents** and **scientific information**.
- Turning **patents** and **scientific information** into **business intelligence tools** that give you the capability to
  - Understand your **competitive environment**
  - Be ahead of **technology trends**
  - Identify patent & technology **opportunities**
  - Assess patent & technology **risks**
  - Define your **IP** and **R&D strategy**
  - Monetize your **technologies** and know-how
  - Defend your **business**
- Strong **technology expertise** with an in-depth **knowledge of patents**.
- Highly **specialized** analysts in the following sectors:

Electronics, **Telecommunications** and **Photonics**

Compound semiconductors, Power electronics, Batteries, Memories, RF electronics, Wireless communications, Solid-state lighting & display, Photonics, MEMS Sensors & Actuators, Semiconductor manufacturing, Packaging & Assembly.

Life Sciences, **Healthcare** and **Agri-Food**

Medical devices, Medical imaging, Microfluidics, Biotechnology, Pharmaceutics, Food-processing

Patents
Technologies
Prior art
Scientific findings
Opportunities
Partners
Competitors
Newcomers
M&A targets

Patent landscape analysis
Scientific review
IP portfolio assessment
Patent valuation
Freedom-to-operate analysis
Litigation & licensing support
Patents linked to products
Technology scouting
Technology trends
Competitive IP landscape
Market trends
Reverse engineering

Make strategic decisions
Sustain competitive advantages
Speed R&D and enhance innovation process
Align R&D and IP with key business objectives
Strengthen IP portfolio and acquire technologies
Anticipate risks and defend core businesses
Explore new opportunities and monetize IP

WHAT WE PROPOSE

Dedicated analyses

Tailor-made analyses to meet your business needs and budgetary constraints

Prior art search

Freedom-to-operate analysis

Patent assessment

IP due diligence

Patent landscape analysis

Litigation & licensing support

Scientific literature analysis

Technology scouting

IP/Tech watch service

Off the shelf reports and analyses

Patent Landscape Analysis

Patent-to-Product Mapping

Patent Portfolio Analysis

Patent Monitoring Service

LIDAR for Automotive

Patent Landscape Analysis

April 2018

Knowles MEMS Microphones in Apple iPhone 7 Plus

Patent-to-Product Mapping

March 2017

Cree/Wolfspeed IP Profile

Patent Portfolio Analysis

April 2018

Workshops and trainings

Tailor made to respond your requests

Direct interaction between your team and our experts at your site

WHAT IS OUR ADDED VALUE

Patent Search

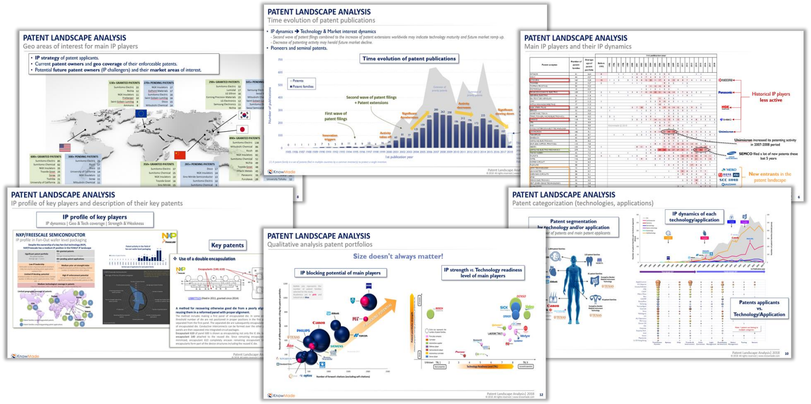
- ✓ **Strong technical expertise of our analysts with PhD degree**
  - Comprehensive search queries and keywords
  - Manual selection of relevant and related patents
  - Manual segmentation by technology & application

Analytics

- ✓ **State of the art statistical tools**
- ✓ **Innovative methodologies to deliver relevant IP analysis**
- ✓ **Business oriented data representation and graphics**

Results Analysis

- ✓ **Technical expertise**
  - Highly specialized analysts in your field
  - Benefit from knowledge capitalization
- ✓ **In-depth IP analysis combined with market data and reverse engineering ***
- ✓ **Customer support**



PATENT LANDSCAPE ANALYSIS
Geo areas of interest for main IP players
- **IP strategy** of patent applicants.
- Current **patent owners** and **geo coverage** of their enforceable patents.
- Potential **future patent owners** (IP challengers) and their **market areas** of interest.

PATENT LANDSCAPE ANALYSIS
Time evolution of patent publications
- IP dynamics → Technology & Market interest dynamics
  - Second wave of patent filings combined to the increase of patent extensions worldwide may indicate technology maturity and future market ramp up.
  - Decrease of patenting activity may herald future market decline.
- Pioneers and seminal patents.

Time evolution of patent publications

PATENT LANDSCAPE ANALYSIS
Main IP players and their IP dynamics

Historical IP players less active

Unimicron increased its patenting activity in 2007-2008 period

SEMCO filed a lot of new patents these last 5 years

New entrants in the patent landscape

PATENT LANDSCAPE ANALYSIS
IP profile of key players and description of their key patents

IP profile of key players
IP dynamics | Geo & Tech coverage | Strength & Weakness

NXP/FREESCALE SEMICONDUCTOR
IP profile in Fan-Out wafer level packaging

Key patents

Use of a double encapsulation

PATENT LANDSCAPE ANALYSIS
Qualitative analysis patent portfolios

Size doesn't always matter!

IP blocking potential of main players

IP strength vs. Technology readiness level of main players

PATENT LANDSCAPE ANALYSIS
Patent categorization (technologies, applications)

Patent segmentation by technology and/or application

IP dynamics of each technology/application

Patents applicants vs. Technology/Application

*** Our partners**

YOLE Développement
SYSTEM Plus CONSULTING
PISEO light.innovation.lab.services
BLUMORPHO

CUSTOM STUDY & CONSULTING

Tailor-made analysis to meet your needs and budgetary constraints

Prior art search

Evaluate the patentability of your invention in the course of a patent filing.
Invalidate competitor's patents in the course of patent litigation or in anticipation of one.
Make third-party observations concerning the patentability of competitor's inventions.

Patent landscape analysis

Understand the competitive environment and the technology trends from a patent perspective.
Identify key players, their IP strategy and their key patents.
Know IP collaborations, licensing agreements and litigation history.

Freedom-to-operate analysis

Assess the risks to infringe third-party patents.
Ensure that your products/processes can be safely manufactured, sold and used in specific countries without infringing patents held by others.

Litigation and licensing support

Evidence of infringement/non-infringement for offensive/defensive support.
Defend your position in licensing negotiation or patent litigation.

Patent assessment

Identify most valuable patents prior to patent acquisition/sales, licensing agreement, capital fundraising process, M&A or IP due diligence.
Estimate the financial value of your patent portfolio.

IP due diligence

Assess the patent portfolio of a company and reveal the SWOT matrix prior to patent acquisition/sale, licensing agreement or M&A.

Scientific literature analysis

Pinpoint key research findings and new emerging research fields, key laboratories and scientific experts, industrial/academic research collaborations, and identify prospective R&D partners.

Technology scouting

Identify, qualify and get access to external innovation.

IP & Technology watch service

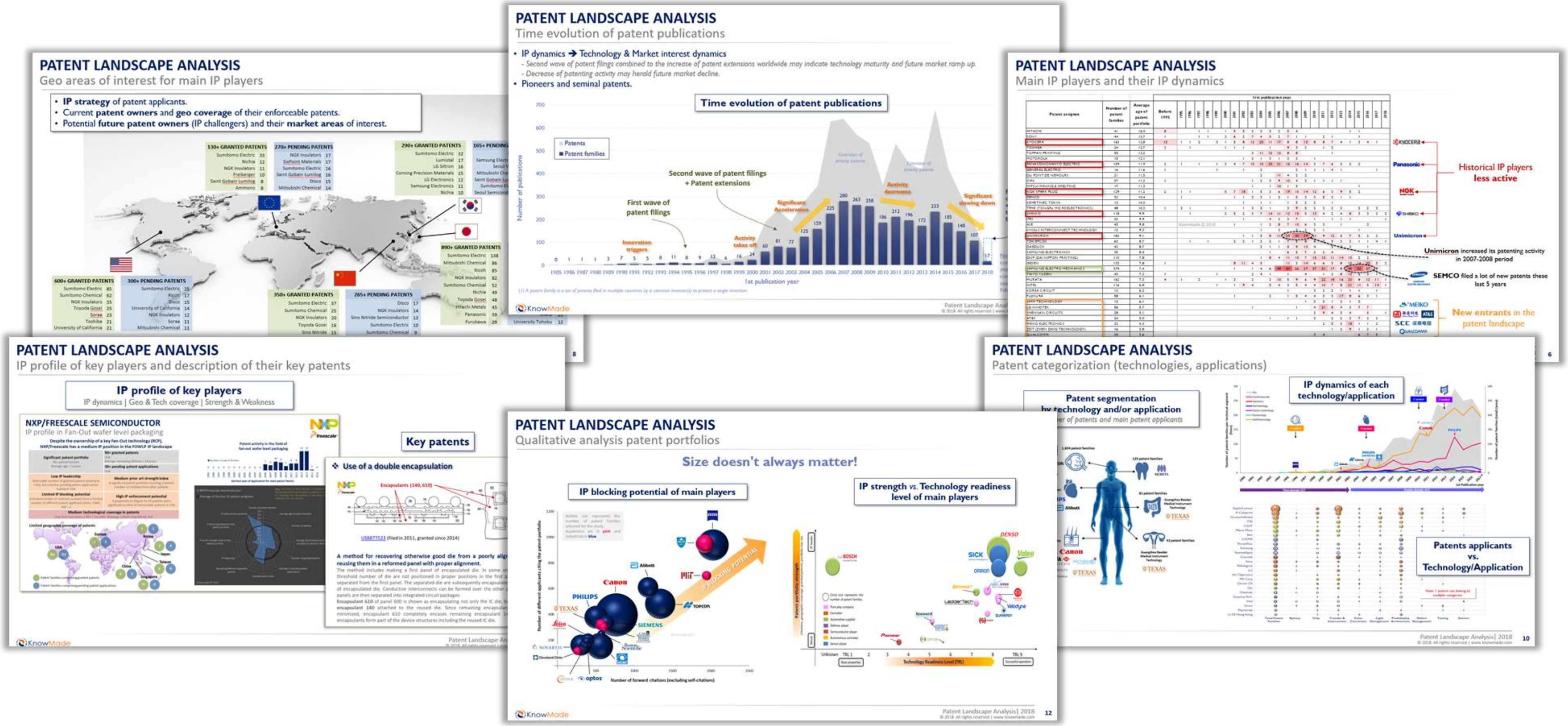
Follow IP/technology trends, keep a watch on your competitors and identify new entrants, anticipate the changes, early detect business opportunities and mitigate the risks.

OFF THE SHELF REPORTS

« Pre-packaged » analysis

Knowmade team of experts work all year long to **collect patent** and **scientific information**, **identify** and **analyze** the **trends**, the **challenges**, the **emerging technologies**, the **competitive environments**, and turn it into results to give you a **complete picture** of your **industry landscape**.

Every year, **Knowmade** publishes a comprehensive **collection of reports** in various technology fields. These **fact-based analyses** can provide you with the reliable information you need to advance your **business** and your **competitive position**.



PATENT LANDSCAPE ANALYSIS
Geo areas of interest for main IP players

- IP strategy of patent applicants.
- Current patent owners and geo coverage of their enforceable patents.
- Potential future patent owners (IP challengers) and their market areas of interest.

PATENT LANDSCAPE ANALYSIS
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- IP dynamics ➔ Technology & Market interest dynamics
- Pioneers and seminal patents.

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IP profile of key players and description of their key patents

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IP dynamics | Geo & Tech coverage | Strength & Weakness

NXP/FREESCALE SEMICONDUCTOR

Key patents

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Patent categorization (technologies, applications)

Patent segmentation by technology and/or application

IP dynamics of each technology/application

Patents applicants vs. Technology/Application

OFF THE SHELF REPORTS

2019 reports collection

COMPOUND SEMICONDUCTORS

- **GaN-on-Silicon Substrate: Materials, Devices and Applications** – Patent Landscape 2019*
- **RF GaN: Materials, Devices and Applications** – Patent Landscape 2019
- **Power SiC: MOSFETs, SBDs and Modules** – Patent Landscape 2019
- **Power GaN: Materials, Devices and Applications** – Patent Landscape 2019*
- **Patent Trolls in the Semiconductor Market** – Litigation Risk and Potential Targets 2017

POWER ELECTRONICS

- **Power SiC: MOSFETs, SBDs and Modules** – Patent Landscape 2019
- **Power GaN: Materials, Devices and Applications** – Patent Landscape 2019*
- **Fast Charging Technologies** – Patent Landscape 2019*
- **Wireless Power Charging** – Patent Landscape 2017

BATTERY AND ENERGY MANAGEMENT

- **Solid-State Batteries** – Patent Landscape 2019*
- **Battery Energy Density Increase** – Patent Landscape 2019*
- **Status of the Battery Patents** – Patent Landscape 2018
- **NMC Li-ion Batteries** – Patent Landscape 2017

RF DEVICES & TECHNOLOGIES

- **Antenna for 5G Wireless Communications** – Patent Landscape 2019*
- **RF Filter for 5G Wireless Communications** – Patent Landscape 2019*
- **RF GaN: Materials, Devices and Applications** – Patent Landscape 2019
- **RF Front End Module for Cellphones** – Patent Landscape 2018
- **RF Acoustic Wave Filters: SAW, FBAR, SMR-BAW** – Patent Landscape 2017

PHOTONICS & OPTOELECTRONICS

- **Silicon Photonics for Data Centers: Optical Transceiver** – Patent Landscape 2019*
- **VCSEL** – Patent Landscape 2018
- **LiDAR for Automotive** – Patent Landscape 2018

DISPLAY

- **MicroLED Displays** – Patent Landscape 2018

IMAGING

- **Facial & Gesture Recognition Technlogies in Mobile Devices** – Patent Landscape 2019*
- **VCSEL** – Patent Landscape 2018
- **LiDAR for Automotive** – Patent Landscape 2018
- **iPhone X Proximity Sensor and Flood Illuminator** – Patent-to-Product Mapping 2018

MEDICAL IMAGING & BIOPHOTONICS

- **Optical Coherence Tomography Medical Imaging** – Patent Landscape 2018
- **Biomedical Photoacoustic Imaging** – Patent Landscape 2015

SEMICONDUCTOR MANUFACTURING & PACKAGING

- **Hybrid Bonding for 3D Stack** – Patent Landscape 2019*
- **Fan-Out Wafer/Panel Level Packaging** – Patent Landscape 2019*
- **Fan-Out Wafer Level Packaging** - Patent Landscape 2016

MEMORY

- **Magnetoresistive Random-Access Memory (MRAM)** – Patent Landscape 2019*
- **3D Non-Volatile Memories** – Patent Landscape 2018
- **Patent Trolls in the Semiconductor Market** – Litigation Risk and Potential Targets 2017
- **TSV Stacked Memories** – Patent Landscape 2016

MEMS & SENSORS

- **MEMS Foundry Business IP Portfolio** – Patent Portfolio Analysis 2019*
- **Miniaturized Gas Sensors** – Patent Landscape 2019
- **LiDAR for Automotive** - Patent Landscape 2018
- **iPhone X Proximity Sensor and Flood Illuminator** - Patent-to-Product Mapping 2018
- **RF Acoustic Wave Filters** - Patent Landscape 2017
- **Knowles MEMS Microphones in Apple iPhone 7 Plus** - Patent-to-Product Mapping 2017
- **Consumer Physics SCiO Molecular Sensor** - Patent-to-Product Mapping 2017

BIOMEMS & MEDICAL MICROSYSTEMS

- **3D Cell Printing** – Patent Landscape 2019*
- **Circulating Tumor Cells Isolation** – Patent Landscape 2019*
- **Nanopore Sequencing** - Patent Landscape 2019*
- **Microfluidic Manufacturing Technologies** – Patent Landscape 2019*
- **Pumps for Microfluidics** - Patent Landscape 2017
- **Microfluidic Technologies for Diagnostic Applications** - Patent Landscape 2017
- **Fluidigm** - Patent Portfolio Analysis 2017
- **Non-Invasive Glucose Monitoring** - Patent Landscape 2015

BIOTECHNOLOGY & PHARMACEUTICS

- **Personalized Medicine** – Patent Landscape 2019*
- **3D Cell Culture Technologies** – Patent Landscape 2016

* Coming soon

Complete list of reports on www.knowmade.com

PATENT MONITORS

Take advantage of periodic updates on IP activities

CONTENTS

Monthly IP database (Excel file)

- New patent applications
- Patents newly granted
- Patents expired or abandoned
- Transfer of IP rights (re-assignment, licensing)
- Patent litigation & opposition

Quarterly report (PDF slide deck)

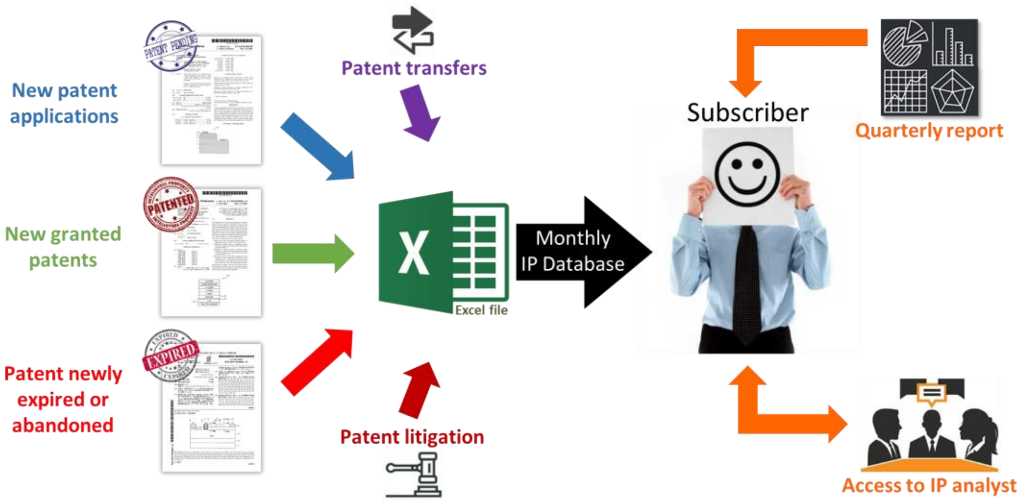
On a quarterly basis, this report will provide the IP trends over the three last months, with a close look to key IP players and key patented technologies.

Access to IP analysts (100h a year)

On-demand Q&A and discussion session with our analysts on specific patented technologies or company IP portfolios

ANNUAL SUBSCRIPTION

30 000 € per unit



WHY YOU SHOULD SUBSCRIBE

- ✓ Track your **competitors**, partners or clients
- ✓ Identify **newcomers** to your technology field
- ✓ Early detect **opportunities** and risks for your business strategy
- ✓ Be ahead of **technology trends**
- ✓ Identify emerging research areas and **cutting-edge technology** developments
- ✓ Mitigate patent **infringement risks**
- ✓ Take advantage of **free technologies**

PATENT MONITORS 2019

- ➢ GaN Power & RF
- ➢ GaN Opto & Photonics
- ➢ Li-ion Battery
- ➢ Post Li-ion Battery
- ➢ Solid-State Battery
- ➢ RF Acoustic Wave Filter
- ➢ RF Power Amplifier
- ➢ RF Front-End Module
- ➢ Microfluidics

If you are interested in more than one monitor or by an other topic, please contact us.
contact@knowmade.fr | www.knowmade.com

KnowMade
Patent & Technology Intelligence

KnowMade SARL
2405 route des Dolines
06902 Sophia Antipolis, France

www.knowmade.com
contact@knowmade.fr