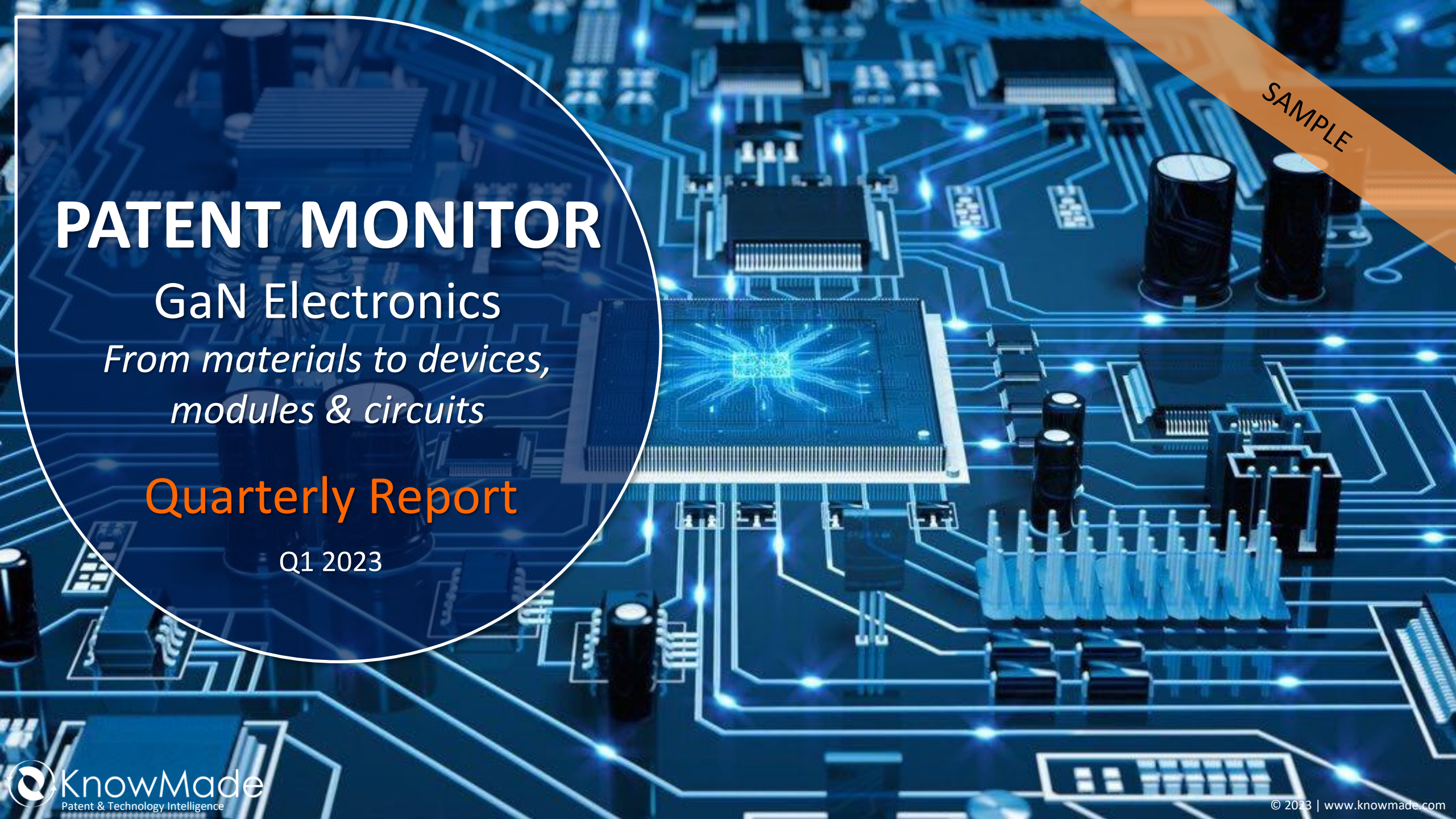


SAMPLE

PATENT MONITOR

GaN Electronics

From materials to devices, modules & circuits

Quarterly Report

Q1 2023

KnowMade
Patent & Technology Intelligence

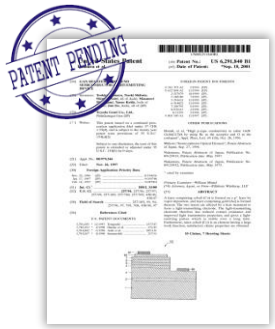
TABLE OF CONTENTS

INTRODUCTION

PATENT MONITOR

Take advantage of quarterly updates on IP activities

New patent applications



New granted patents

Patents newly expired or abandoned

Patent transfers & IP collaborations

MONITORING SERVICE

US patent litigations EU oppositions

Access to IP analyst for results presentation, Q&A sessions, additional research, and customization of the monitoring service.

Quarterly PDF reports highlighting the key trends and significant information, with a close look at the key IP players and patented technologies

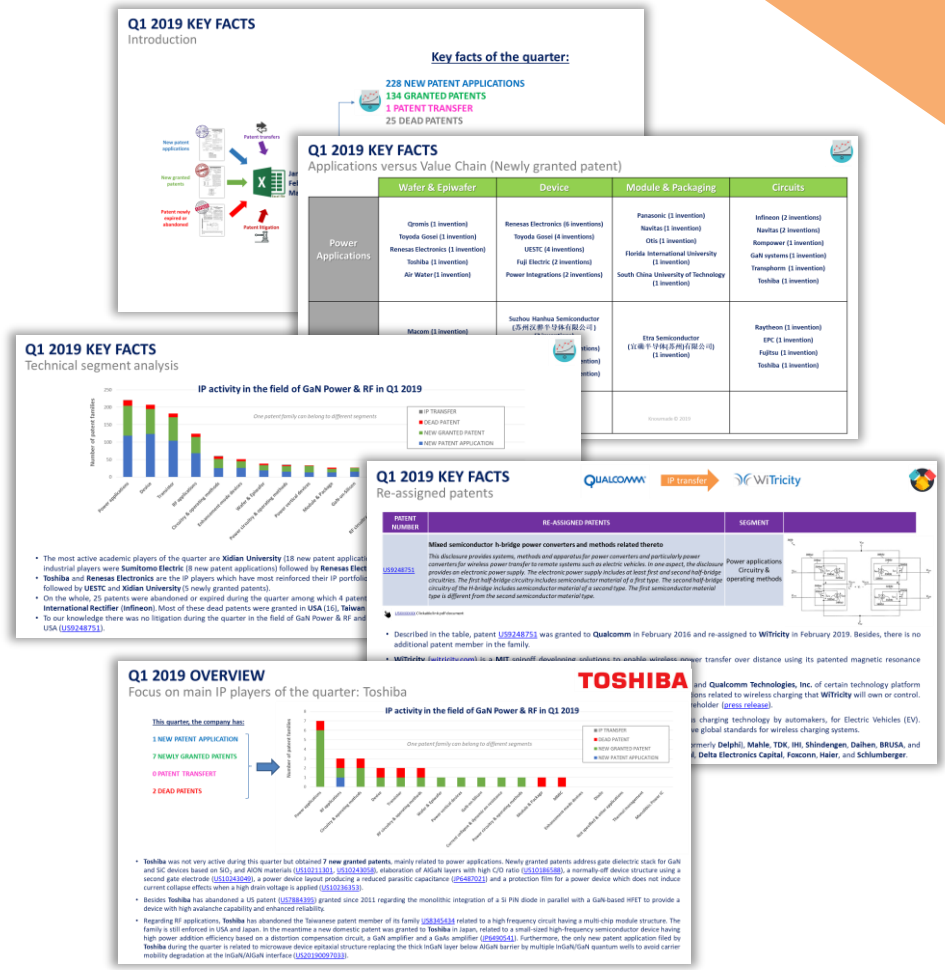
Updated Excel database to access all patents and relevant information

PATENT MONITOR

Quarterly report

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

- Main patent applicants, their notable patent filings and technologies.
- New entrants and their patents.
- Technology trends and notable patented technical solutions.
- Key patents newly granted, their owners and claimed inventions.
- Main IP right transfers (reassignments, licensing agreements).
- Key patents newly expired or abandoned, their owners and their potential market impact.
- Noteworthy news on patent litigation and opposition, plaintiffs and defendants, patents and products involved.



PATENT MONITOR

Quarterly IP database

SAMPLE

Segments
(a X indicate a patent belonging to the segment)

Publication numbers	Title	Abstract	Family legal status	Patent assignees	Non-Latin assignees	Re-assignments	Earliest application date	Earliest publication date	Earliest grant date	Expected expiry dates	Biblio summary	New invention s	New granted patent	Expired patents	Patent transfers	Patent litigation s	RF	Power	Other	Wafers & Epiwafer s	Devices	Modules & Packagin	Circuits & Applicati	Dynamic on-resistanc	e-mode	GaN-on-Si	Monolith ic integrati	Thermal manageme nt	Vertical devices
CN115311036 CN115117150 CN115117150	(CN115117150) GaN HEMT power device and preparation method thereof (CN115311036) GaN HEMT power device for realizing CASCODE mode	(CN115311036) The invention discloses a GaN HEMT power device for realizing a CASCODE mode, belonging to the technical field of semiconductors, and the device comprises a third substrate, a second middle layer, a buffer layer, a GaN layer and an AlGaN layer which are connected in sequence from bottom to top; the AlGaN layer is provided with a source electrode, a drain electrode and a grid electrode, wherein the source electrode and the drain electrode are both extended and connected into the GaN layer; the GaN HEMT power device comprises a GaN layer, a buffer layer, an AlGaN layer and an AlGaN layer, wherein a cavity is arranged in the GaN layer, the lower end of the cavity extends into the buffer layer, the upper end of the cavity is positioned below channels of a source electrode and a drain electrode, the AlGaN layer is connected with an e MOSFET device, the source electrode and a gri the enhanced silicon MOSFET device are used electrode and the grid electrode of the whole d GaN HEMT power device is used as the drain el whole device. According to the invention, the ca on the GaN layer, so that the thickness of the Ga the channel is reduced, the leakage channel is re leakage is reduced, and on the other hand, the d dimensional electron gas at the AlGaN/GaN increased, the performance of the device is imp CASCODE structure of the whole device can through a simple process.	GRANTED	CoolSemi	(CN115311036) 成都功成半		2022-08-24	2022-09-27	2023-01-17	(CN115117150B) 2042-08-24 (CN115311036A) 2042-08-24	Open		X					X			X			X		X		
WO2023/048160	(WO2023048160) Semiconductor substrate, semiconductor device, method for producing semiconductor substrate, and method for producing semiconductor device	(WO2023/048160) [Problem] To provide: a semiconductor substrate which is capable of improving the quality of a nitride semiconductor layer; a semiconductor device; a method for producing a semiconductor substrate; and a method for producing a semiconductor device. To further provide: a semiconductor substrate which is capable of improving the performance of a device; a semiconductor device; a method for producing a semiconductor substrate; and a method for producing a semiconductor device. [Solution] A semiconductor substrate according to the present invention is provided with: a heat transfer layer; a silicon carbide (SiC) layer that is formed on one main surface side of the heat transfer layer, while having a 3C crystal structure; a bonding layer that is formed between the heat transfer layer and the SiC layer; and a nitride semiconductor layer that is formed on one main surface of the SiC layer.	PENDING	Air Water University Public Corporation Osaka	(WO2023048160) エア・ウォーター株式会社 ([JP]) 公立大学法人大阪 ([JP])		2022-09-21	2023-03-30		(WO2023048160A1) 2025-03-22	Open	X							X	X				X				
WO2023/047364	(WO2023047364) Electric dynamic power conversion system	(WO2023/047364) There is provided an electric dynamic drive train for electric vehicles (EVs), the electric dynamic drive train including a high frequency direct current (DC)-DC converter and a DC-alternative current (AC) inverter. The high frequency DC-DC power converter includes a DC-DC controller connected to one or more core cells comprising a driver, a half-bridge connected to the driver, the half-bridge including high and low sides transistors in thermal contact with a cooling system including a heat spreader, an inductor and a capacitor connected to the half-bridge and a capacitor connected to the inductor. The high frequency DC-DC power converter enables having an almost instantaneous response time by reducing voltage drops between transients, enables generating a clean waveform signal improving the longevity of connected components, and enables the inverter and the motor in the EVs to be sized apart from one	PENDING	FTEX			2022-09-23	2023-03-30		(WO2023047364A1) 2025-03-23	Open	X						X					X			X	
		(CN115863332)																											

Patent information
Numbers, dates, assignees, title, abstract, claims, hyperlink to updated online database (legal status, original documents etc.)

Patent typology
New patent families, patent families newly granted, patents newly expired or abandoned, etc.

Patent segmentation
Supply chain
Technology
Applications

PATENT MONITOR

Year-round access to an IP analyst

Take advantage of **direct interaction with our analysts** by phone call and/or email for **result presentations**, **Q&A sessions**, **additional research** on specific technologies or companies' patent portfolios, and **customization of the monitoring service** by adding specific players and/or specific segments.

Examples of questions or requests:

- Could you tell me more about the **patent portfolio of this company**?
- What is exactly the **invention claimed** in these patents?
- Can you give me the **patents filed by this company** on these specific technologies?
- Can you shortly **analyze the patents** of this new entrant?
- What are the patents **issued in Japan and Korea** for this application?
- Please give me more details about this **patent litigation**.
- We want to file a new patent. Can you help us to **assess the prior-art** in this field?
- I would like to **invalidate these patents**. Could you do a prior-art search?
- Can you help me to identify in patents the **technical solutions** to solve this issue?
- I would like to assess my **freedom of operating** in USA. Can you provide me with the granted US patents covering this technology?
- I am looking for **free technologies** I could use safely without infringing valid IP rights. Can you provide me with newly expired patents related to this technology?
- I would like to **customize the monitoring service** to track my primary **competitor's IP activities**.
- I would like to **customize the monitoring service** to track patents related to a **specific topic**.

METHODOLOGY

Research strategy: a three-fold analysis

Supply chain-based analysis

Wafers & Epiwafers → Devices → Packaging & Modules → Circuits & Applications

Market-based analysis

- Power applications
- Not specified / other applications
- RF applications

Technology-based analysis

- Current Collapse/Dynamic on-resistance
- Normally-off transistors
- GaN-on-Si technology
- Monolithic integration
- Thermal management
- Vertical GaN devices

METHODOLOGY

Segment definition

Patents were categorized according to their current legal status, and their technologies/applications

SEGMENTATION BY LEGAL STATUS

NEW PATENT FAMILIES: Patent families published for the first time during the quarter (extensions from older patent families are excluded).

PATENT FAMILIES NEWLY GRANTED: Patent families granted during the quarter (granted patents from older patent families containing already granted patents are excluded).

PATENTS NEWLY EXPIRED/ABANDONED: Granted patents expired or abandoned during the quarter.

PATENT TRANSFER: Re-assignments during the quarter.

SEGMENTATION BY TECHNOLOGIES/APPLICATIONS

Market-based segmentation*:*

- **Power applications**

This segment includes all inventions explicitly related to power applications, from wafers/epiwafers, to devices and module/systems.

- **RF applications**

This segment includes all inventions explicitly related to RF applications, from wafers/epiwafers, to devices and module/systems.

- **Not specified and others applications**

Value chain-based segmentation*:*

This segmentation produces the following technological segments: **Wafers & Epiwafers**, **Devices**, **Modules & Packaging**, **Circuits & applications**.

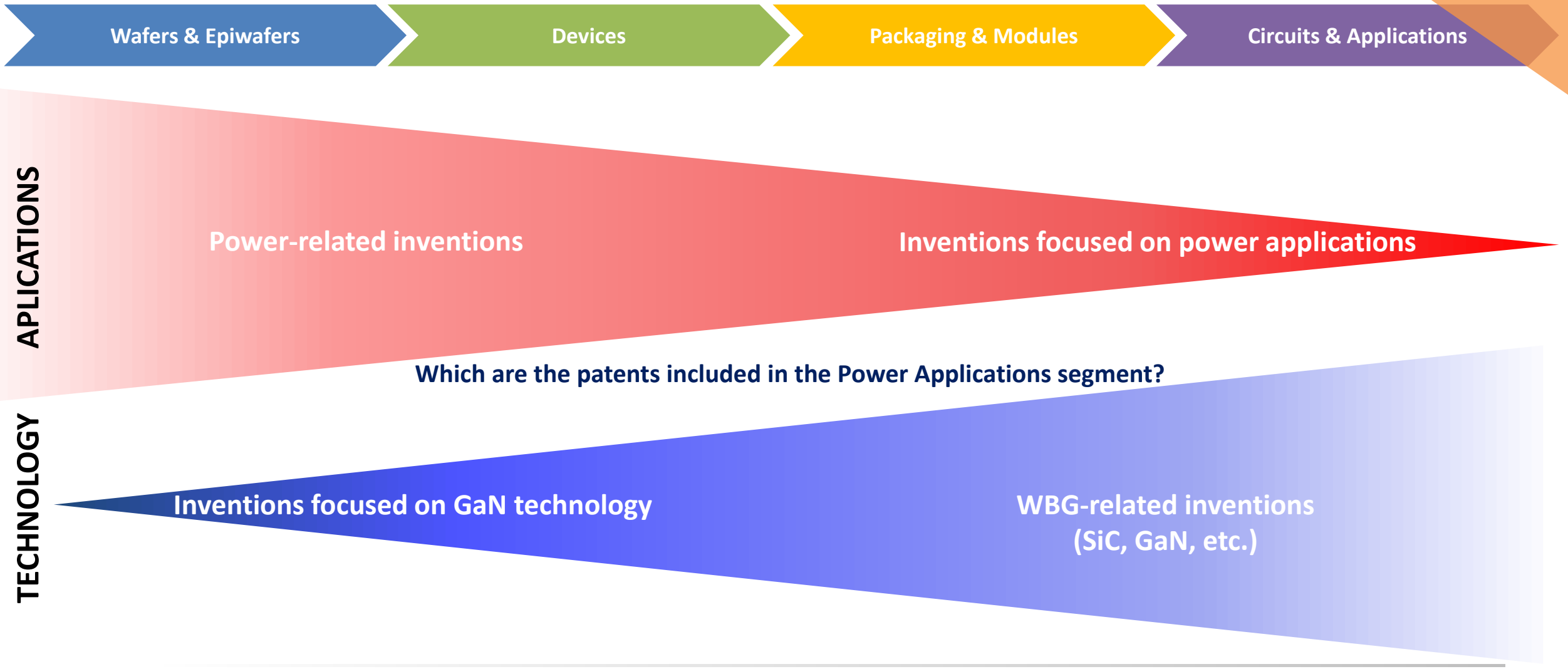
Challenge-based segmentation*:*

- **Current collapse & dynamic on-resistance** related issues
- **Enhancement-mode** devices
- **GaN-on-Silicon** technology
- **Monolithic integration** (Heterogeneous integration, power IC, MMIC, etc.)
- **Thermal management** and related reliability issues
- **Vertical power devices**

METHODOLOGY

Patent selection: Focus of the invention depends on its position on the supply chain

Due to different strategies of patent filings across the supply chain, the scope of the patent selection must be tuned according to the position in the supply chain, as illustrated below for power applications:



SAMPLE

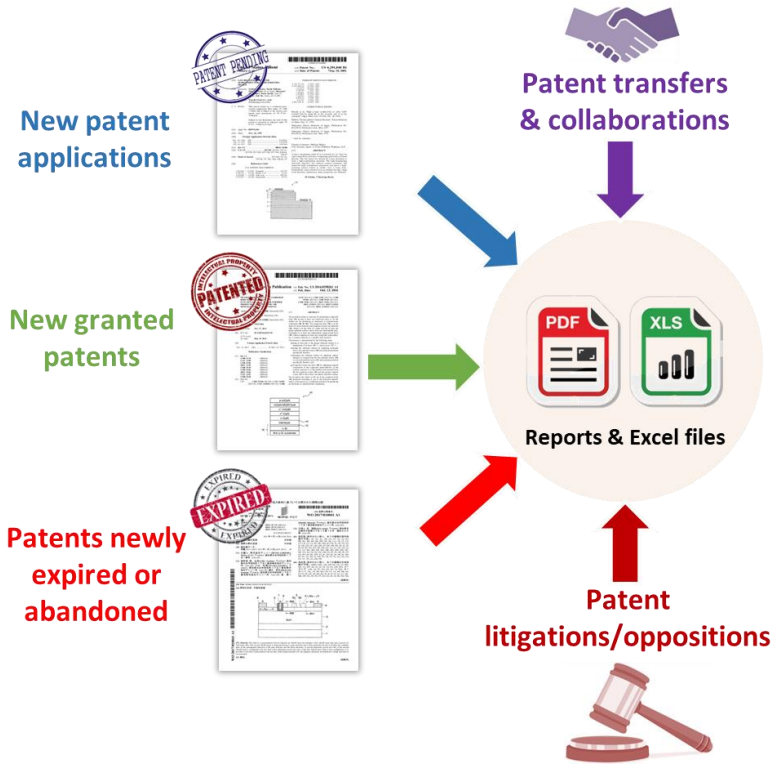
QUARTER OVERVIEW

Q1 2023 OVERVIEW

Key facts

Key facts of Q1 2023

(January, February, March)



431 New patent families (inventions)
318 Newly granted patent families
84 Abandoned or Expired patents
1 Patent transfer (change in ownership)

9 Noticeable IP collaborations (patent co-filings)

0 IP litigation (US)
0 Patent oppositions (EP)

15+ Newcomers identified

5 Key IP players selected and analyzed

Innoscience, intel, MITSUBISHI ELECTRIC, VIS 世界先進, Infineon

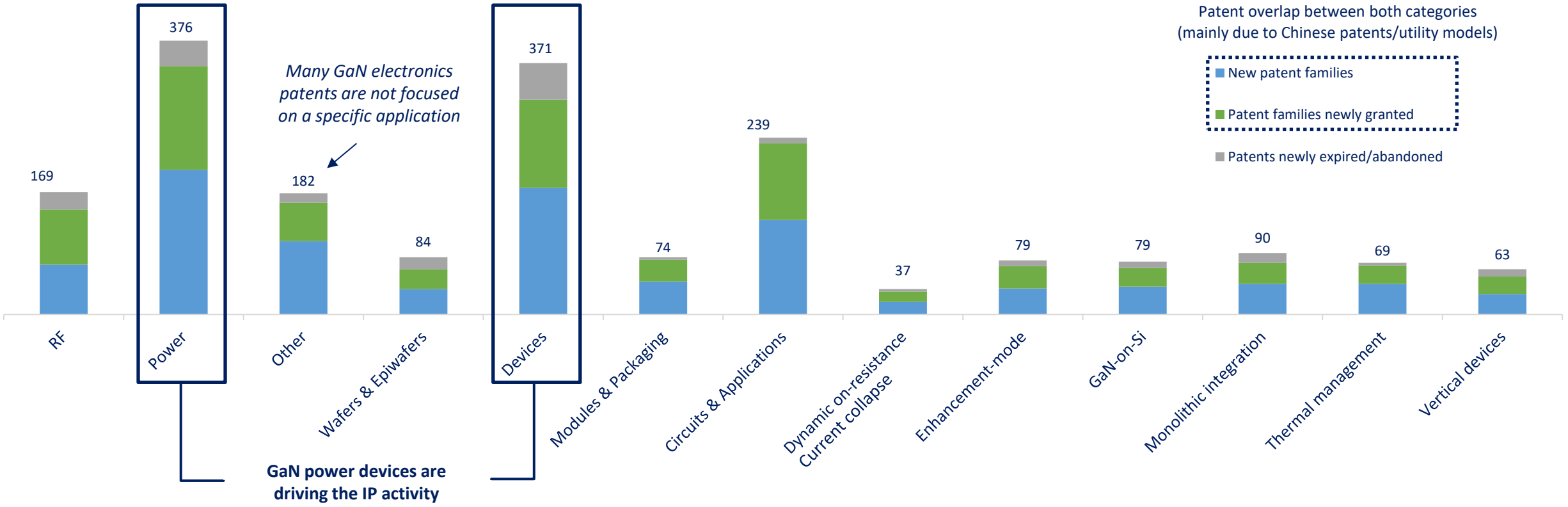
Clickable logo to IP profiles

Q1 2023 OVERVIEW

Where are focusing patenting activities?

GaN Electronics patenting activity (Q1 2023)

Number of patent families by legal category

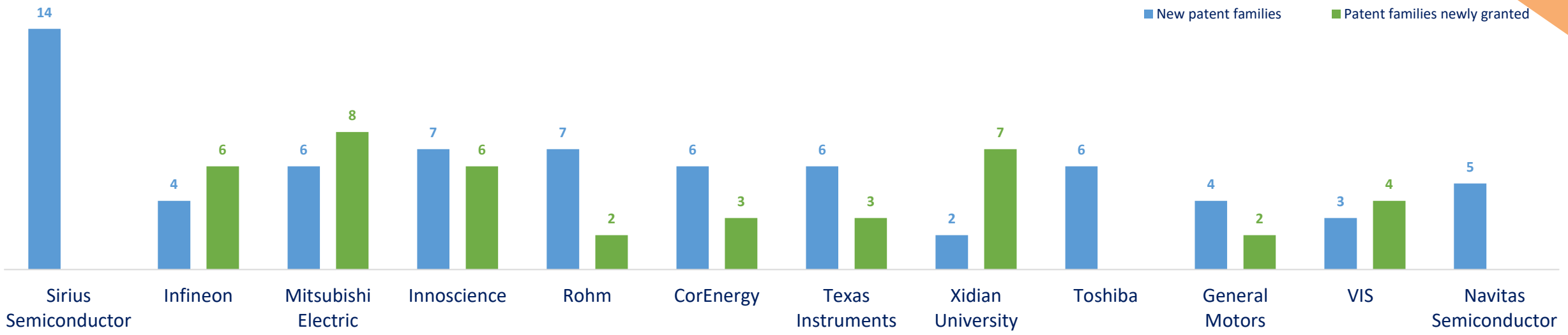


Q1 2023 OVERVIEW

Main Power GaN IP players

Power GaN patenting activity (Q1 2023)

Number of patent families by legal category



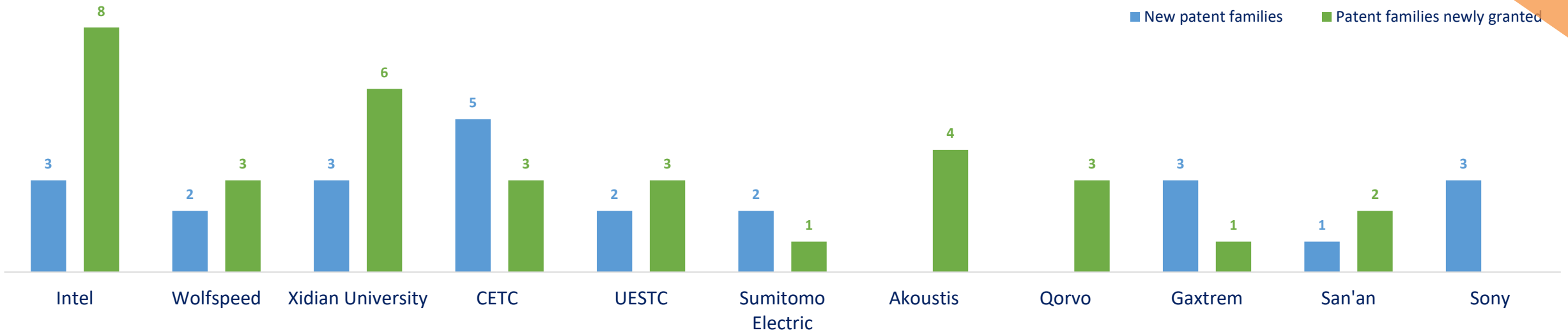
Many GaN electronics patent applicants do not necessarily specify the application field of their inventions

Q1 2023 OVERVIEW

Main RF GaN IP players

RF GaN patenting activity (Q1 2023)

Number of patent families by legal category



Many GaN electronics patent applicants do not necessarily specify the application field of their inventions

Q1 2023 OVERVIEW

Main players driving the GaN electronics patenting activity across the supply chain

Wafers & Epiwafers	Devices	Packaging & Modules	Circuits & Applications
intel	SIRIUS	Innoscience	Innoscience
HUAWEI	西安電子科技大學 XIDIAN UNIVERSITY	Lii SEMICONDUCTOR	MITSUBISHI ELECTRIC
CorEnergy	intel	Texas Instruments	Navitas
imec	Innoscience	SUMITOMO ELECTRIC	CETC
GSR SEMICONDUCTOR CO., LTD	ROHM SEMICONDUCTOR	东科半导体 DONGKE SEMICONDUCTOR	gm
	CETC	芯干线科技 WWW.X-IPM.COM 宽禁带功率器件专家	oppo
	TOSHIBA	OnMicro	ZF
	HUAWEI	GaXtrem 优 | 镓 | 科 | 技	东科半导体 DONGKE SEMICONDUCTOR
	UESTC		HUAWEI
	CorEnergy		ST
	nuvoTon		ABB

Q1 2023 OVERVIEW

Notable new inventions

Note: The full-texts of patents mentioned in this slide are available in the Excel database provided with the present report

Wafers & Epiwafers

soitec — EP4117041
Epi-structure w/ InAlN barrier

MACOM — WO2023/034078
Semiconductor wafers optimized for linear amplifiers

GaN-on-Si

TOSHIBA — US20230046560
HEMT epilayers w/ improved breakdown voltage

Shin-Etsu — WO2023/008034
a semiconductor device substrate providing good high frequency characteristics

Monolithic integration

imec — EP4117019
GaN/Si co-integration

HUAWEI — WO2023/001374
WBG and ultra-WBG co-integration

Thermal management

imec — EP4125113
Diamond layer integration for thermal management of GaN devices

Devices

GaN Systems — US20230080636
Drain structure to eliminate an increase of Rdson with aging

Infineon — US20230067452
Device structure to improve the conduction of an HEMT w/o detrimentally impacting V_{th}, I_g and linear region

ANALOG DEVICES — WO2023/014351
Impurity reduction techniques in GaN regrowth

WO2023/287456
High current and field-managed transistor

SweGaN — EP4123721
GaN device w/ recessed ohmic contacts

Current collapse/Dynamic Ron

ROHM SEMICONDUCTOR — US20230009662
HEMT structure to inhibit current collapse

E-mode

Infineon — US20230052141
p-GaN gate and recombination zone implemented by a floating ohmic contact

Monolithic integration

intel — US20230090106
N-polar/Ga-polar GaN co-integration for RF

IBM — US20230090017
GaN/Si co-integration

GlobalFoundries — US20230059665
GaN/Si co-integration

Packaging & Modules

wupatec — WO2023/031774
RF PA IC in a package w/ RF power transistor, input pre-matching circuit including an input shunt inductor and a stabilization network

Wolfspeed — US20230075505
Metal pillar connection topologies in a radio frequency transistor amplifier die for heterogeneous packaging

SUMITOMO ELECTRIC — US20230042190
GaN HEMT mounted by FO-PLP by using an RDL

Thermal management

Apple — US20230030746
Improved material configurations for integrated GaN power module

Texas Instruments — US20230060830
Power converter module w/ selective shielding for control IC chips

SONY — WO2023/013143
A semiconductor device improving heat dissipation from a RF GaN transistor

Monolithic integration

3DGS PowerCraft RF — WO2023/034600
Power amplifier system in a package

Circuits & Applications

Navitas — US20230090234
Systems and methods for reducing effects of leakage inductance in flyback dc-dc converters

NXP — US20230079916
T-match topology with baseband termination

Current collapse/Dynamic Ron

SKYWORKS — US20230091247
Amplification system having PA memory correction and/or current collapse correction

Power IC

CHAMPION — US20230054025
Synchronous bridge rectifier using planar switching elements

Navitas — US20230006539
Integrated power device with energy harvesting gate driver

MMIC

Wolfspeed — US20230040260
Compensation of trapping in GaN FET

Q1 2023 OVERVIEW

Main IP players and IP newcomers worldwide

Clickable logo to corporate websites

	Patent assignee	Number of new patent families (inventions)	SEGMENTS (number of new patent families) Wafers & Epiwafers	Devices	Modules & Packaging	Circuits & Applications
	All Players	431	41	204	53	152
	Intel	10	3	9		
	Rohm	8	1	7		1
	Toshiba	8	1	6	1	1
	Mitsubishi Electric	7	1	1	1	4
	Texas Instruments	6		3	2	1
	Sumitomo Electric	6	1	3	2	
	Navitas Semiconductor	5		1	1	4
	Infineon	4		3	1	
	General Motors	4			1	3
	Vanguard International (VIS)	4	1	3		
	Nuvoton	4		4		
	TSMC	3		2		1
	ZF	3				3
	Raytheon Technologies	3		2		1
	Wolfspeed	3		2	1	1
	WaveLord	3	1	2		
	STMicroelectronics	3		1		2
	Sony	3	1	2	1	
	CNRS	2			1	1
	Paris-Saclay University	2			1	1
	Sorbonne University	2			1	1
New	Japan Display	2		2		
	UMC	2		2		
	GaN Systems	2		2		
	Fujitsu	2	1	1	1	
	ABB	2				2
	Fuji Electric	2		1		1
	Tagore Technology	2				2
	Analog Devices	2		2		
	THERS	2	1	1		
	imec	2	2	1		
	Valeo	2				2
	Mercedes-Benz	2				2

Main IP players

New IP players

Q1 2023 OVERVIEW

Main IP players and IP newcomers in China

Clickable logo to corporate websites

Patent assignee	Number of new patent families (inventions)	SEGMENTS (number of new patent families)			
		Wafers & Epiwafers	Devices	Modules & Packaging	Circuits & Applications
All Players	**431**	**41**	**204**	**53**	**152**
Sirius Semiconductor	18		18		
Innoscience	15		9	3	6
CETC	11	1	6		4
Xidian University	10	1	10		
Huawei	9	3	5	1	2
CorEnergy	8	3	4	1	1
UESTC	6		5		1
Dongke Semiconductor *New*	5		1	2	2
Yangzhou Yangjie Electronic Technology	4		3	1	
GSR Semiconductor *New*	4	2	2		
Semiconductor Manufacturing Electronics	3	1	2		
X-IPM	3		1	2	
Gaxtrem	3		1	2	1
CoolSemi	3	1	3		
Zhejiang Xinke *New*	3		3		
Yuanshan Advanced Material Technologies *New*	3	1	2		
OPPO	3				3
Peking University	3		3		
Fudan University	3	1		1	1
San'an	3	1	2		
Advanced Micro Semiconductors	3		3		
Shenzhen University	3		3		
Lii Semiconductor *New*	3			3	
Ingacom Semiconductor	3		3		
OnMicro Electronics *New*	2			2	
Innotion Technology *New*	2				2
Shenzhen MTC	2	1	1		
SINANO	2		2		
Baigontek *New*	2		2		
Enkris Semiconductor	2		2		
Richsound Electronic Industrial *New*	2				2
HKUST - Hong Kong University of Science And Technology	2		2		
Shenyuan Technology *New*	2				2

Main IP players

SIRIUS

Innoscience

CETC

西安电子科技大学 XIDIAN UNIVERSITY

HUAWEI

CorEnergy

New IP players

东科半导体 DONGKE SEMICONDUCTOR

GSR SEMICONDUCTOR CO., LTD

RSR

OnMicro

RFint

Baigontek百功

Lii SEMICONDUCTOR

and Zhejiang Xinke, Yuanshan Advanced Material Technologies, Shenyuan Technology…

Q1 2023 OVERVIEW

Main players reinforcing their IP position across the supply chain

Wafers & Epiwafers	Devices	Packaging & Modules	Circuits & Applications
XIDIAN UNIVERSITY	intel	Lii SEMICONDUCTOR	MITSUBISHI ELECTRIC
晶湛半导体 Enkris Semiconductor	XIDIAN UNIVERSITY	东科半导体 DONGKE SEMICONDUCTOR	Innoscience
HC SEMITEK	Innoscience	MITSUBISHI ELECTRIC	Infineon
	VIS 世界先進	HITACHI Inspire the Next	USTC
	Infineon		amc TECHNOLOGY
			qorvo
			CETC

Q1 2023 OVERVIEW

Notable new granted inventions

Note: The full-texts of patents mentioned in this slide are available in the Excel database provided with the present report

Wafers & Epiwafers

AKOUSTIS — **US11557716**

Scandium incorporation in single crystal electronic devices

IQE — **US11557716**

Epitaxial layer which improves the acoustic transmission

Current collapse/Dynamic Ron

Raytheon Technologies — **US11545566**

GaN-HEMTs w/ reduced current collapse and power added efficiency enhancement

SUMITOMO CHEMICAL — **US11584693**

suppressing both leak current and current collapse in HEMT

E-mode

TOSHIBA — **US11581407**

A practical semiconductor device that has a high threshold voltage V_{th} using Mg-doped GaN layers

Devices

XIDIAN UNIVERSITY — **US11557682**

Low turn-on voltage GaN diodes having anode metal with consistent crystal orientation

Infineon — **US11557670**

HEMT with advantageous off-state leakage properties

GaN-on-Si

GlobalFoundries — **US11594626**

Bidirectional switches with active substrate biasing

E-mode

UMC — **US11616135**

an additional out diffusion barrier for p-GaN gate

Innoscience — **US11563097**

HEMT w/ metal gate having a trapezoidal cross-sectional shape; and a passivation layer directly contacting the metal gate

Monolithic integration

MONDE Wireless — **US11557539**

GaN/Si co-integration in RF circuits

Texas Instruments — **US11557673**

Hybrid semiconductor device

GlobalFoundries — **US11569374**

Implanted isolation for device integration on a common substrate

Vertical devices

NEXGEN POWER SYSTEMS — **US11575000**

Super-junction based vertical GaN JFET power devices

Packaging & Modules

Wolfspeed — **US11581859**

RF transistor amplifier package

Monolithic integration

MACOM — **US11600614**

Microwave integrated circuits including GaN devices on Si

BAE — **US11594626**

a flexible impedance network system for enabling efficient iterative design by leveraging a common wafer platform as the starting point for circuit design

Circuits & Applications

CCT — **US11552599**

Harmonic power amplifying circuit with high efficiency and high bandwidth and RF PA

DELTA — **US11576256**

Printed circuit board for gallium nitride elements

EATON — **US11586271**

Dynamic power sharing dual USB type C and power delivery receptacle

GaN Systems — **US11545889**

Deadtime optimization for GaN half-bridge and full-bridge switch topologies

Panasonic — **US11595038**

improving the switching speed when turning on the bidirectional switch element

Power IC

Infineon — **US11563322**

Unipolar power transistor and RC snubber

US11575377

Monolithic half-bridge circuit at a voltage of at least 300V

Innoscience — **US11600610**

Clamping circuit integrated on GaN semiconductor device

MMIC

QORVO — **US11564337**

Thermal structures for heat transfer devices and spatial power-combining devices

Q1 2023 OVERVIEW

Main players (outside China) reinforcing their IP position across the supply chain

Patent assignee	Number of patent families (inventions) newly granted	SEGMENTS (number of new patent families)			
		Wafers & Epiwafers	Devices	Modules & Packaging	Circuits & Applications
All Players	**318**	**32**	**142**	**35**	**124**
Intel	11		11	1	1
Mitsubishi Electric	10		3	2	7
VIS	8	1	7		
Infineon	7		5		3
STMicroelectronics	4		2		2
Akoustis	4	1	2	1	
Toyota Group	4	1	3		
Texas Instruments	3		2	1	
Qorvo	3				3
UMC	3		3		
CEA	3		2		1
Wolfspeed	3		1	1	1
Sumitomo Electric	3		2	1	
Eaton	2				2
Tagore Technology	2				2
Raytheon Technologies	2	1	1		
General Motors	2				2
GlobalFoundries	2		2		1
Delta Electronics	2				2
Siemens	2				2
TSMC	2	1	1		
Schneider Electric	2				2
X-FAB	2		2		
Rohm	2		2		
Hitachi	2			2	
Sumitomo Chemical	2	1	1		
THERS	2	1	1		
Shindengen Electric Manufacturing	2			1	1
Panasonic	2		1		1
Indian Institute of Science (IISc)	2			1	1

Main IP players

Q1 2023 OVERVIEW

Chinese players reinforcing their IP position across the supply chain

Patent assignee	Number of patent families (inventions) newly granted	SEGMENTS (number of new patent families)			
		Wafers & Epiwafers	Devices	Modules & Packaging	Circuits & Applications
All Players	**318**	**32**	**142**	**35**	**124**
Innoscience	13	1	8		5
Xidian University	13	6	8		
UESTC	5		2		3
CorEnergy	4	1	2		1
Lii Semiconductor	4			3	1
San'an	4		3		1
South China Normal University	4	1	3		
Dongke Semiconductor	3			2	1
Yuanshan Advanced Material Technologies	3	1	2		
AMC Technology	3				3
Ingacom Semiconductor	3		3		
Enkris Semiconductor	3	2	1		
CETC	3				3
Suzhou Xinquan Semiconductor Technology	2		1		1
Yangzhou Yangjie Electronic Technology	2		1	1	
Hangzhou Yunga Semiconductor Technology	2			1	1
Shenyuan Technology	2				2
SEMITRONIC	2				2
Richsound Electronic Industrial	2				2
Eagle Information	2				2
JT Microelectronics	2		2		
Shenzhen University	2		2		
Hatchip	2	1	1		1
HC Semitek	2	2			
IMECAS	2		1		1

Main IP players

Innoscience

西安电子科技大学 XIDIAN UNIVERSITY

Q1 2023 OVERVIEW

New IP in the public domain?

Patent assignee	Number of dead patents	SEGMENTS (number of new patent families)									
		Wafers & Epiwafers	Devices	Modules & Packaging	Circuits & Applications	Current collapse	Enhancement-mode	GaN-on-Si	Monolithic integration	Thermal management	Vertical devices
All Players	**84**	**19**	**59**	**4**	**9**	**4**	**9**	**10**	**16**	**4**	**12**
Wolfspeed	13	6	7						7		
Fujitsu	11		11		1	3	2				2
Furukawa Electric	8	1	7				2				4
Infineon	4	2	3				3	2			
Sumitomo Electric	3	2	2								2
Toshiba	3		3						1	1	
Intel	2	1	2					2	2		
General Electric	2		2					1	2		
AIST - National Institute of Advanced Indus	2		2						2		
Renesas Electronics	2		2				2				
Samsung Group	2		2								
Panasonic	2		2								
UESTC - University of Electronic Science & T	2		2					1			
Sharp	2		1	1							
WINSTREAM Technology	2				2						
NGK Insulators	2	2						1			

If a patent is dead (expired or abandoned), is it possible to make the formerly patented product?

An expired patent cannot be asserted against competitors. However, other live patents may still cover different parts, features or combinations described in the expired patent. Moreover, in some countries, a lapsed patent can be reinstated/restored by paying an additional fee plus the maintenance fee, and reasoning that delay or nonpayment of the maintenance fee within the prescribed period was unintentional.

Q1 2023 OVERVIEW

Notable dead patents

Note: The full-texts of patents mentioned in this slide are available in the Excel database provided with the present report

Wafers & Epiwafers | **Devices** | **Packaging & Modules** | **Circuits & Applications**

Devices

FURUKAWA ELECTRIC — **US6897495**

To provide a GaN-FET which has a small on-resistance

TOSHIBA — **US6933544**

Power normally-off GaN-FET w/ high avalanche withstand capability and ultra-low R_{ON}

E-mode

FURUKAWA ELECTRIC — **US7038253**

Power normally-off GaN-FET w/ a small R_{ON} and is capable of a large-current operation

Current collapse/Dynamic Ron

FUJITSU — **US11557670**

to reduce the drift time in the RF GaN-HEMT

Monolithic integration

Wolfspeed — **US7892974**

Method of forming vias in SiC and resulting RF devices and circuits

Vertical devices

UNIVERSITY OF CALIFORNIA — **US8937338**

CAVET with NH_3-MBE grown p-type GaN as a current blocking layer

FURUKAWA ELECTRIC — **JP4177124**

To provide a Power GaN diode in which voltage resistance is high and an ON voltage is low.

Packaging & Modules

Monolithic integration

Wolfspeed — **US7851909**

to accurately design and yield multistage GaN amplifiers that provide higher gain and power outputs (flip-chip integrated circuit)

Q1 2023 OVERVIEW

Main IP transfers (patent reassignment)

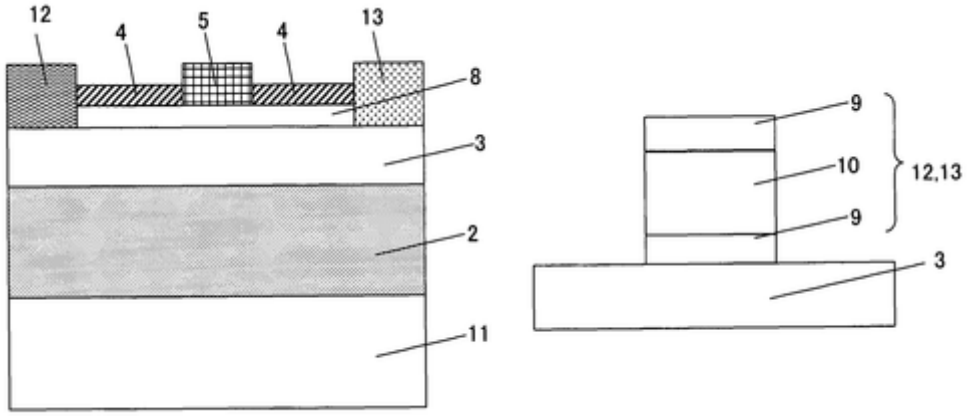
Wafers & Epiwafers | Devices | Packaging & Modules | Circuits & Applications

Thermal issues

FUJITSU → SUMITOMO ELECTRIC

US8222672

A Ta/Al lamination structure as an ohmic electrode for RF GaN devices



(Main claim) A semiconductor device comprising:
a substrate;
an n-type nitride semiconductor layer or an undoped nitride semiconductor layer over the substrate; and
a source electrode and a drain electrode being in direct physical contact with and being in ohmic contact with said n-type nitride semiconductor layer or said undoped nitride semiconductor layer;
wherein each of said source electrode and said drain electrode comprises:
a tantalum layer formed on said n-type nitride semiconductor layer or said undoped nitride semiconductor layer;
an aluminum layer formed on said tantalum layer and made of aluminum only; and
a metal layer formed on said aluminum layer and made of any one material of tantalum, nickel and palladium;
further comprising a compound layer of aluminum and any one material of tantalum, nickel and palladium between said aluminum layer and said metal layer; and
a gate electrode comprising a nickel layer and a gold layer formed on the nickel layer.

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Q1 2023 OVERVIEW

Main IP collaborations (patent co-filings)

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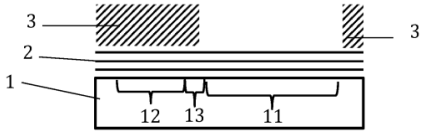
Wafers & Epiwafers | **Devices** | **Packaging & Modules** | **Circuits & Applications**

Monolithic integration

imec — EP4117019 — KU LEUVEN RESEARCH & DEVELOPMENT

GaN/Si co-integration



Thermal management

WO2023/048160 — 公立大学法人 大阪府立大学 Osaka Prefecture University

a heat transfer layer; a SiC layer that is formed on one main surface side of the heat transfer layer, while having a 3C crystal structure; a bonding layer that is formed between the heat transfer layer and the SiC layer; and a nitride semiconductor layer that is formed on one main surface of the SiC layer

imec — EP4125113 — UHASSELT

The method comprises the steps of:- providing a substrate, wherein at least a surface of the substrate is formed from a GaN material;- forming a 1st diamond layer on the surface of the substrate, wherein the 1st diamond layer is a nanocrystalline diamond layer, and wherein the 1st diamond layer is in physical contact with the surface of the substrate; and- forming a 2nd diamond layer on the 1st diamond layer, wherein the 2nd diamond layer is a poly-diamond layer.

cea — EP4120359 — THALES

HEMT for high frequency applications w/ reduced access resistance

E-mode

捷捷微电子 JIEJIE MICROELECTRONICS — CN115763250 — IMECAS

The invention realizes the high-threshold GaN-based enhanced HEMT by combining the reverse polarization effect of the cap layer and the intrinsic enhancement characteristic of the thin-barrier heterostructure Al (In, ga) N/(In, ga) N, effectively avoids the problems of insufficient P-type heavy doping and hole injection In the traditional manufacturing process of the P-type grid GaN cap layer.

Vertical devices

THE UNIVERSITY OF TOLEDO — US20230030549

Multi-layer hybrid edge termination for III-N power devices

Monolithic integration

3DGS — WO2023/034600 — PowerCraft RF

a RF PA SiP device including a substrate comprising one or more inductors, capacitors, and thin film resistors wherein the one or more are formed in, on, or about the substrate; an opening in the substrate comprising an iron core, wherein the iron core is formed in the substrate after the formation is create a RF PA SiP in the substrate; and one or more connectors, vias, resistors, capacitors, or other integrated circuits devices connected to create the RF PA SiP.

CentraleSupélec | université PARIS-SACLAY | SORBONNE UNIVERSITÉ | cnrs | ENSEA

WO2023/012194

Active electric compensation device with fast-switching structure

MAGNA — THE UNIVERSITY OF TENNESSEE KNOXVILLE

WO2023/278972

A charger for a vehicle includes a power factor correction (PFC) stage to convert AC input power to DC power; an inverter stage; and a transformer having first, second, and OBC coils, each being magnetically coupled for transmitting power therebetween.

Q1 2023 OVERVIEW

Main US patent litigation filed or closed

No US patent litigation involving GaN electronics related patents have been filed or closed in this quarter

Q1 2023 OVERVIEW

New EP oppositions filed

No new oppositions have been filed at the European Patent Office (EPO) against GaN electronics related patents

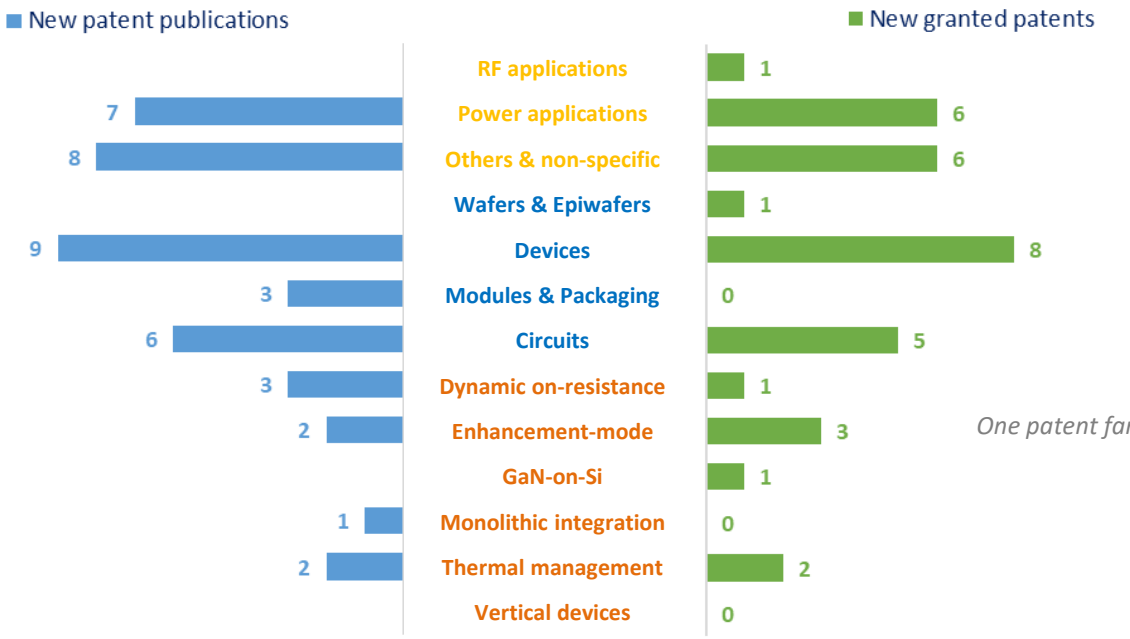
SAMPLE

IP profiles of key players

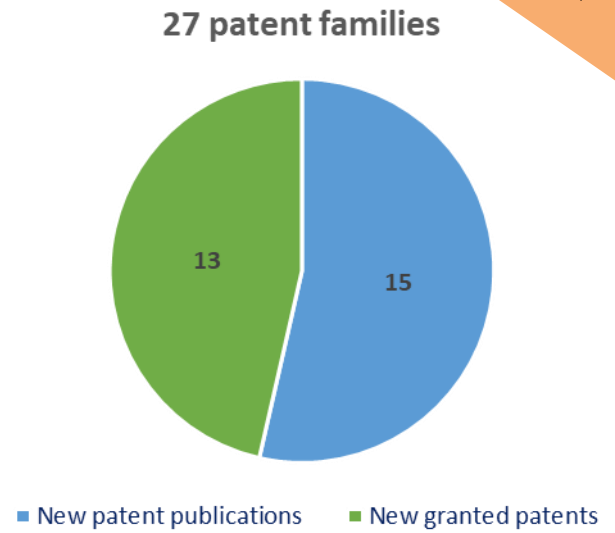
KnowMade
Patent & Technology Intelligence

Innoscience
IP profile

Note: The full-texts of patents mentioned in this slide are available in the Excel database provided with the present report



One patent family may belong to multiple segments



- **Innoscience** keeps strengthening its IP position for **GaN power devices**. Yet IP activities downward the supply chain (modules and packaging, circuits and applications) are on the rise. An invention relates to a **power IC with wafer-level dynamic on-resistance monitoring capability** (CN115769379).
- All **new patent families** have been filed in **China** only, but new members are expected to come up in the next few months. In comparison, most of the **newly granted patent families** include at least a pending member in the US or a granted member in the US (US11563097, US11600610 and US11600708).
- An invention relates to **thermal dissipation** in high-power RF devices. It describes a proper layout for thermal management. The patent application has been granted in China (CN113454790) and is still pending in the US (US20220376101).

Intel
IP profile

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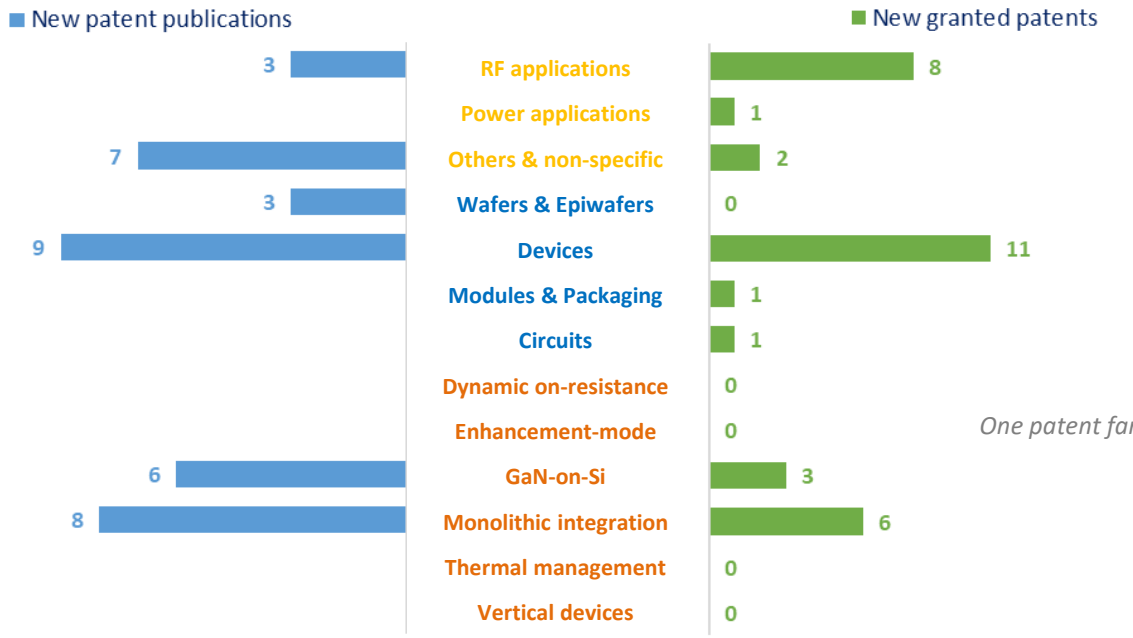
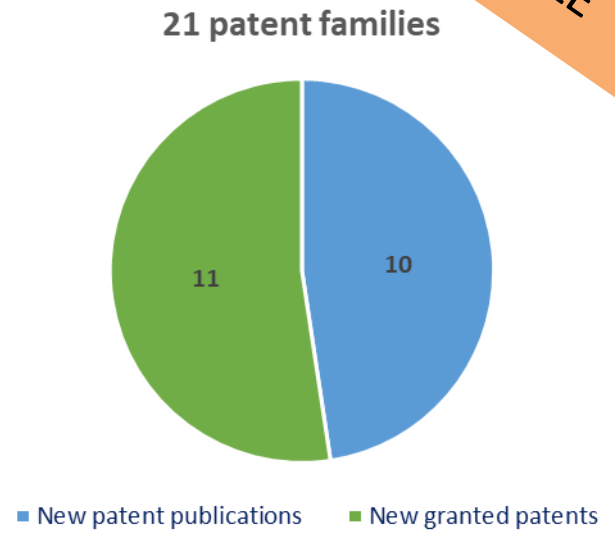


One patent family may belong to multiple segments



- **Intel**'s IP activity is strongly directed to challenges related to **monolithic circuits** in the **GaN-on-Si** platform (SoC), for either power and RF applications, although the activity of Q1 2023 put the emphasis on RF applications.
- Among the **newly patent families**, 3 inventions have been simultaneously filed in the US and Europe: EP4156245 (heterogeneous electrodes for RF processing), EP4152391 (N-polar/Ga-polar GaN co-integration for RF), and EP4141921 (epitaxial GaN on a patterned silicon substrate).
- A couple of US patents were **abandoned** during the quarter: US8896101 (non-planar III-N transistors having a III-N semiconductor channel that is compositionally graded in a manner that forms a 3-dimensional electron gas (3DEG) within the III-N semiconductor channel) and US10170612 (epitaxial semiconductor stacks for reduced defect densities in III-N device layers).

Mitsubishi Electric
IP profile

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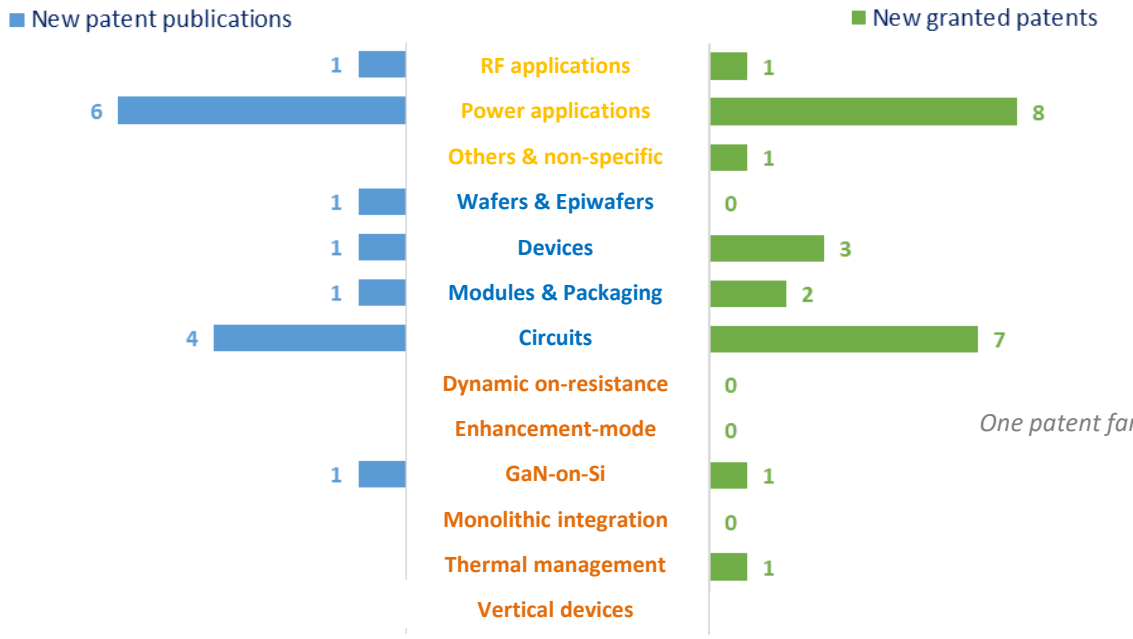
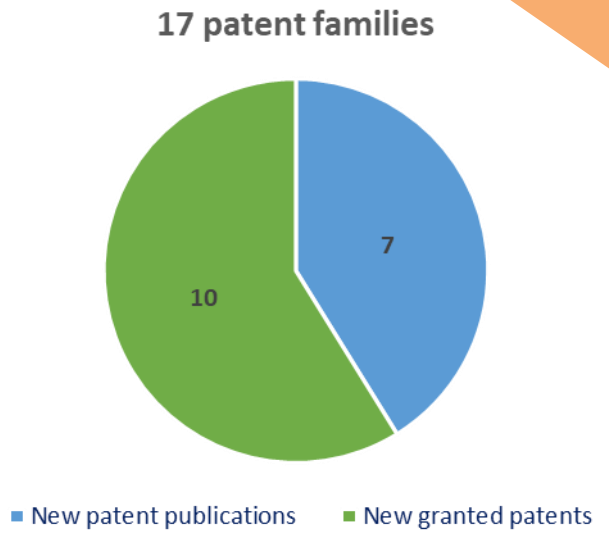


One patent family may belong to multiple segments



- This quarter, **Mitsubishi Electric**'s patenting activity has been focused on **circuits and power applications**. As such, few inventions are specific to GaN technology but relates to WBG technologies (SiC, GaN, diamond, etc.).
- For **RF applications**, an invention has been granted in Japan (JP7217808, GaN-on-diamond device structure w/ a source via hole) and a new patent application has been published (WO2023/026362, GaN-on-SiC epi-structure). For other applications, a patent was granted to **Mitsubishi Electric** regarding a GaN device that can operate as a **logic inverter** (US11552186).
- Only one application relates to **GaN-on-Si technology** (JP7231122 published and granted this quarter) and relates to the stress generated in a substrate of dissimilar material and GaN due to heating or cooling of the device.

Vanguard International Semiconductor

IP profile

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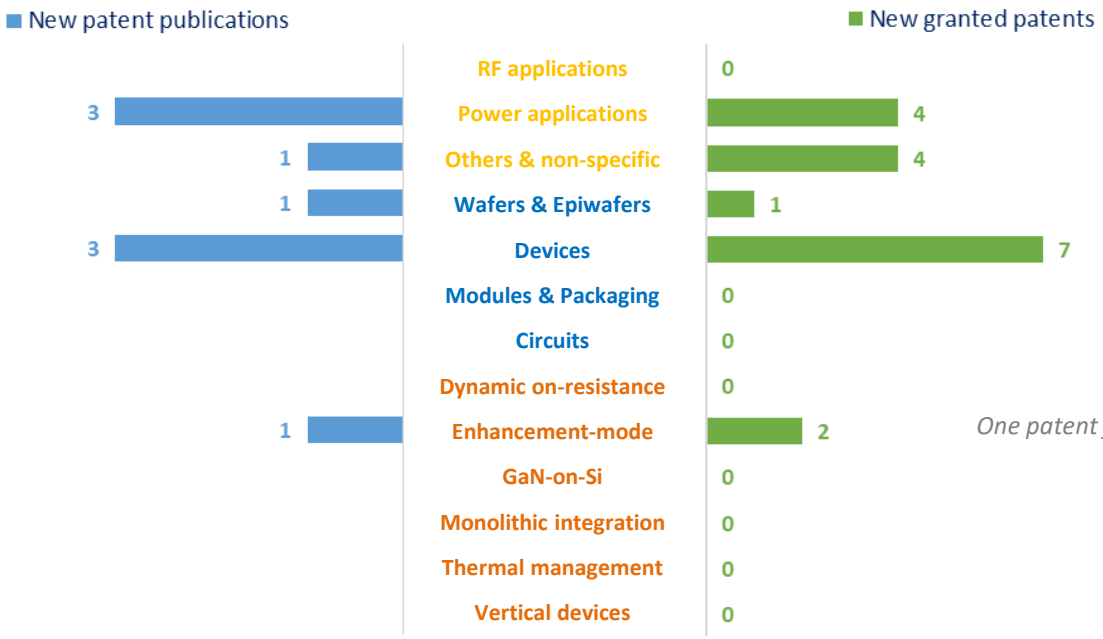
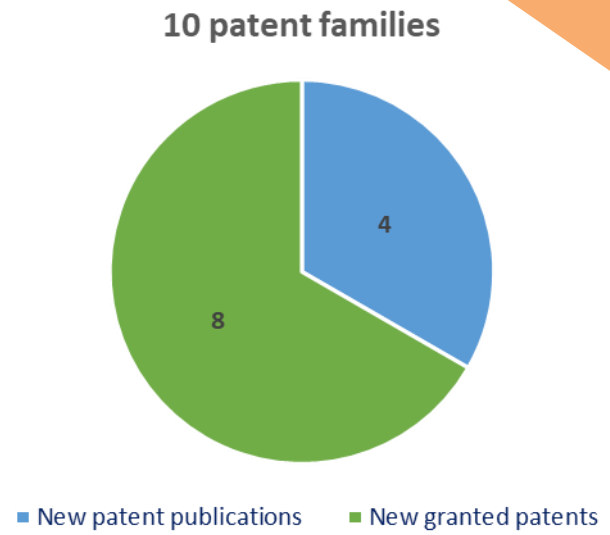


One patent family may belong to multiple segments



- During the quarter, **VIS** has strengthened its IP position in the **power GaN device** patent landscape, especially in **China** (6 new granted patent families) and **Taiwan** (2 new granted patent families). The Taiwanese patent applications were published during this very same quarter.
- Furthermore, **VIS** is looking to reinforce its patent portfolio in the US, with two new patent applications. Patent application US20230066042 relates to a GaN-HEMT epi-structure including a superlattice structure for stress management and an electrical isolation layer for reducing current leakage. Patent application US20230070031 focuses on the device structure (the doped compound semiconductor layer and the composition gradient layer between the channel layer and the barrier layer).

Infineon
IP profile

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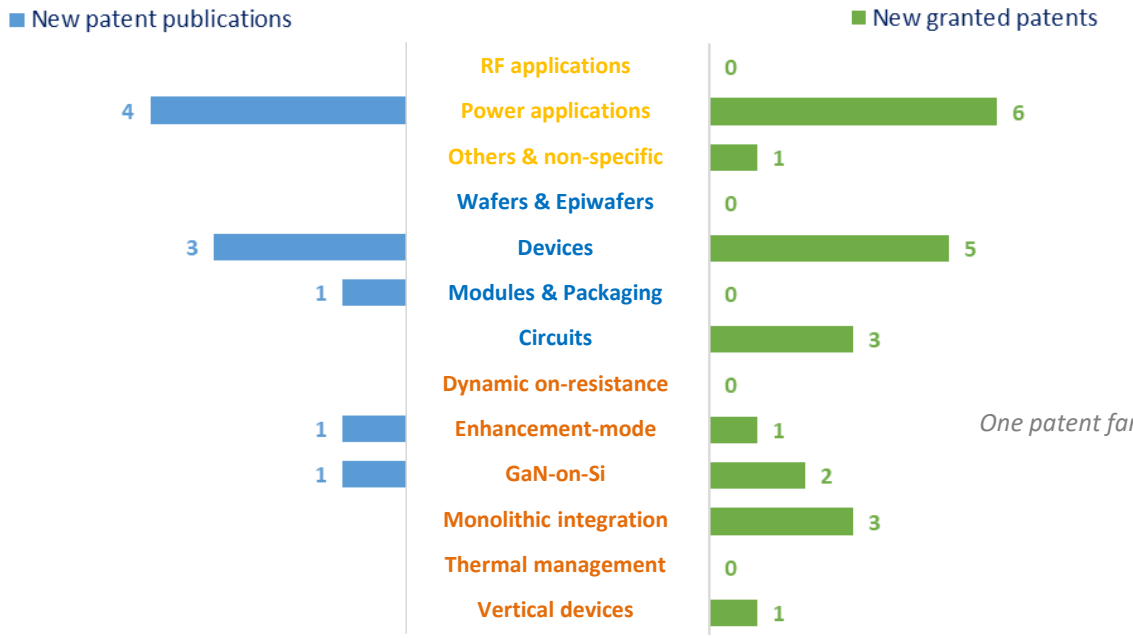
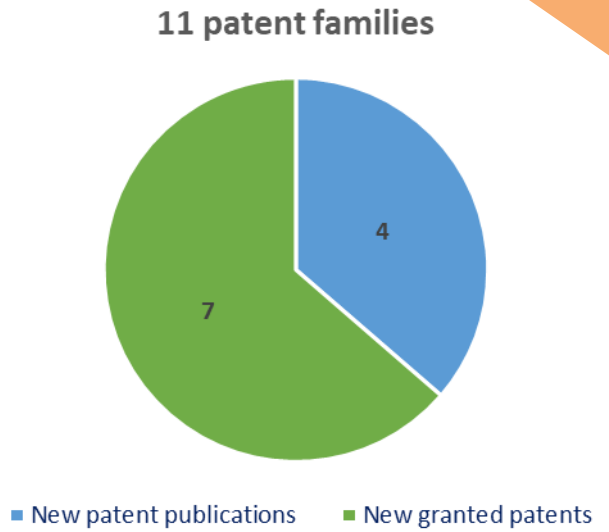


One patent family may belong to multiple segments



- Most of the patent families newly published or newly granted of **Infineon** are **triadic patent families** (protected or to be protected in the US, Europe and China).
- A new patent application (US20230093341) relates to **packages and modules with higher integration density** (Resin encapsulated package comprising an external recess w/ exposed electrical contacts).
- A new patent application relates to **GaN-on-Si e-mode HEMT** with a p-type semiconductor being arranged between an ohmic load contact, in particular a drain contact, and a gate contact of the transistor for an injection of holes into a portion of the transistor channel (US20230052141).
- **Infineon** strengthens its IP position related **monolithic power IC** with 3 new granted patent families: US11545485 (monolithically integrated capacitor), US11563322 (Unipolar power transistor and RC snubber), US11575377 (monolithically half-bridge circuit operating at more than 300 V).

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