SAMPLE REPORT

GaN Devices for Power Electronics

Patent Investigation

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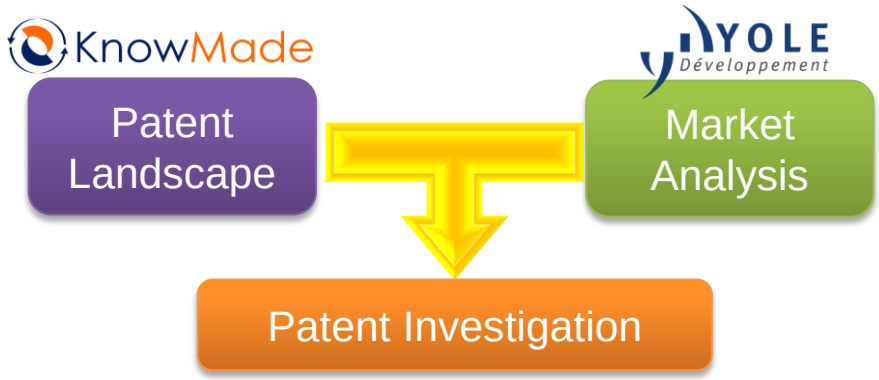
A New Type of Report Providing a Clear Link Between IP Situation and Market Evolutions

SAMPLE REPORT

A **Patent Investigation** allows understanding the **technology** & **market** from a **patent perspective**.

- More than describing the status of the IP situation, a **Patent Investigation** provides a missing link between **patented technological solutions** and **market**, **technological** and **business trends**.
- In-depth **technological analysis of patents** leads to understanding of **strategic decisions and positioning of key players** within the value chain.
- By combining their technical knowledge, **business understanding** and **patent search**, **Yole Développement** and **Knowmade** are able to provide **unique analysis** and **added value** in this report.



Yole & Knowmade's New Reports

- Essential patent data
- Patent analysis
- Technological segmentations
- Technology analysis
- Key players & key patents
- Market trends
- Market implication of IP landscape
- Full searchable patent database

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SCOPE OF THE REPORT

- This report provides a detailed picture of the patent landscape for **Power Electronics based on [illegible] materials.** All patents related to **GaN for power applications** were considered: substrates, epi-wafers, semiconductor devices, transistors, diodes, discrete components, power module, packaging, circuits and systems.

- This report covers **patents published worldwide** up to **April 2015**. We have selected and analyzed more than **4,900 patents** split in more than **1,960 patent families** relevant to the scope of this report.

- The patents have been **manually categorized** by
  - Technological segment: substrates & epi-wafers, semiconductor devices, discrete components, power modules, packaging, circuits and power systems.
  - Substrate for GaN: bulk, SiC, Si, Sapphire.
  - Technical challenges: E-mode, cascode, E/D-mode monolithic, vertical devices, current collapse, dynamic R-on, gate charge, breakdown voltage, stray inductance, thermal issues, chip-scale package.

- **Market data** from Yole Développement are also provided to add some context regarding business trends and metrics.

- This report provides a clear **link between** the **IP situation** and the **market evolutions**.

- Note that essential patent data on GaN-on-Silicon technology have been analyzed last year in our report “GaN-on-Silicon Substrate Patent Investigation” published in April 2014 (more details).

METHODOLOGY (1/2)

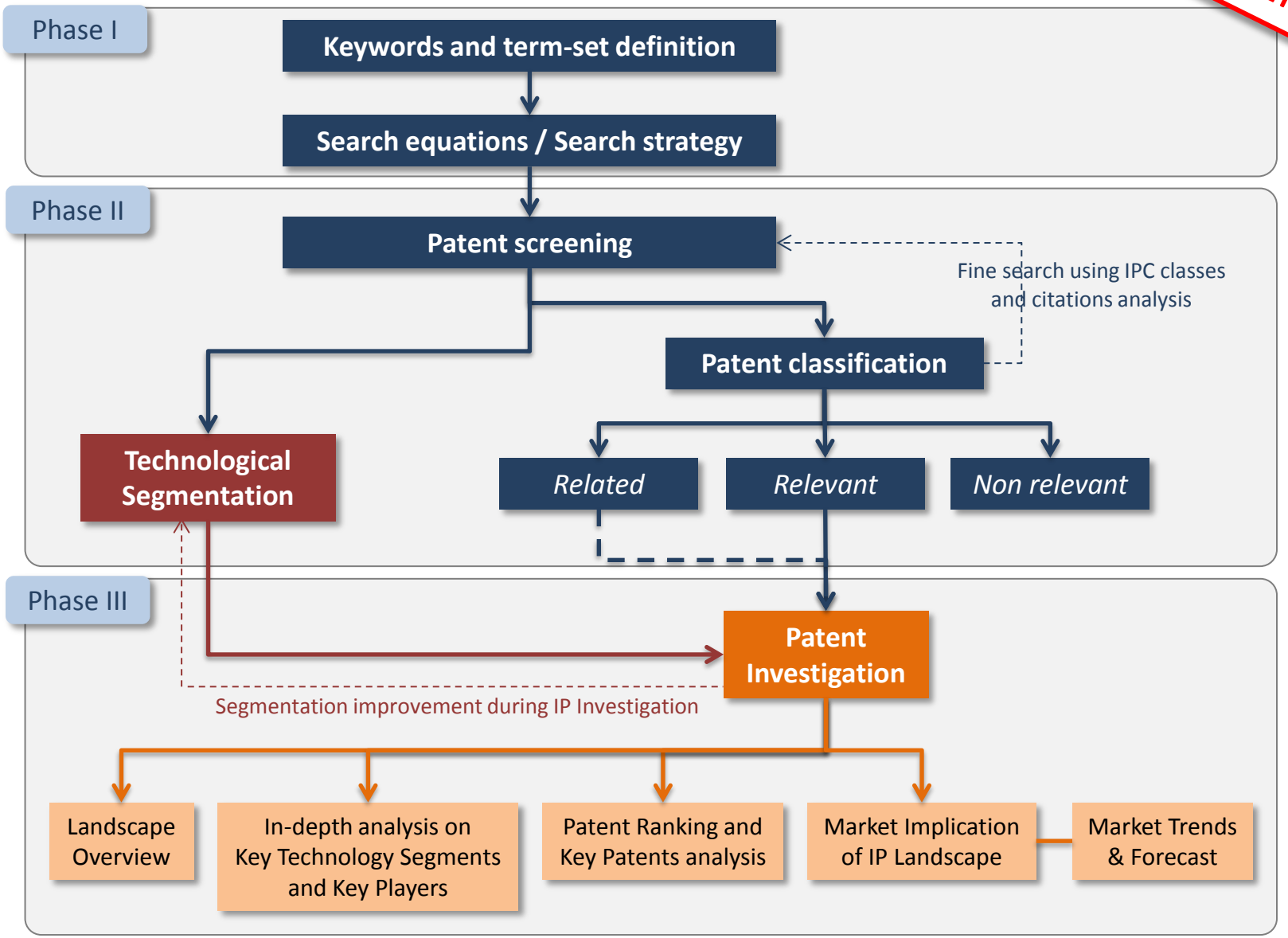
- The data were extracted from the **FamPat worldwide database (Questel-ORBIT)** which provides 80+ million documents from 95 offices.
- The patents search was performed in **April 2015**, hence patents published after this date will not be available in this report.
- The patent selection was done **manually**.

Number of selected patents for the Power GaN Patent Investigation:

1,962 patent families comprising 4,900+ patents

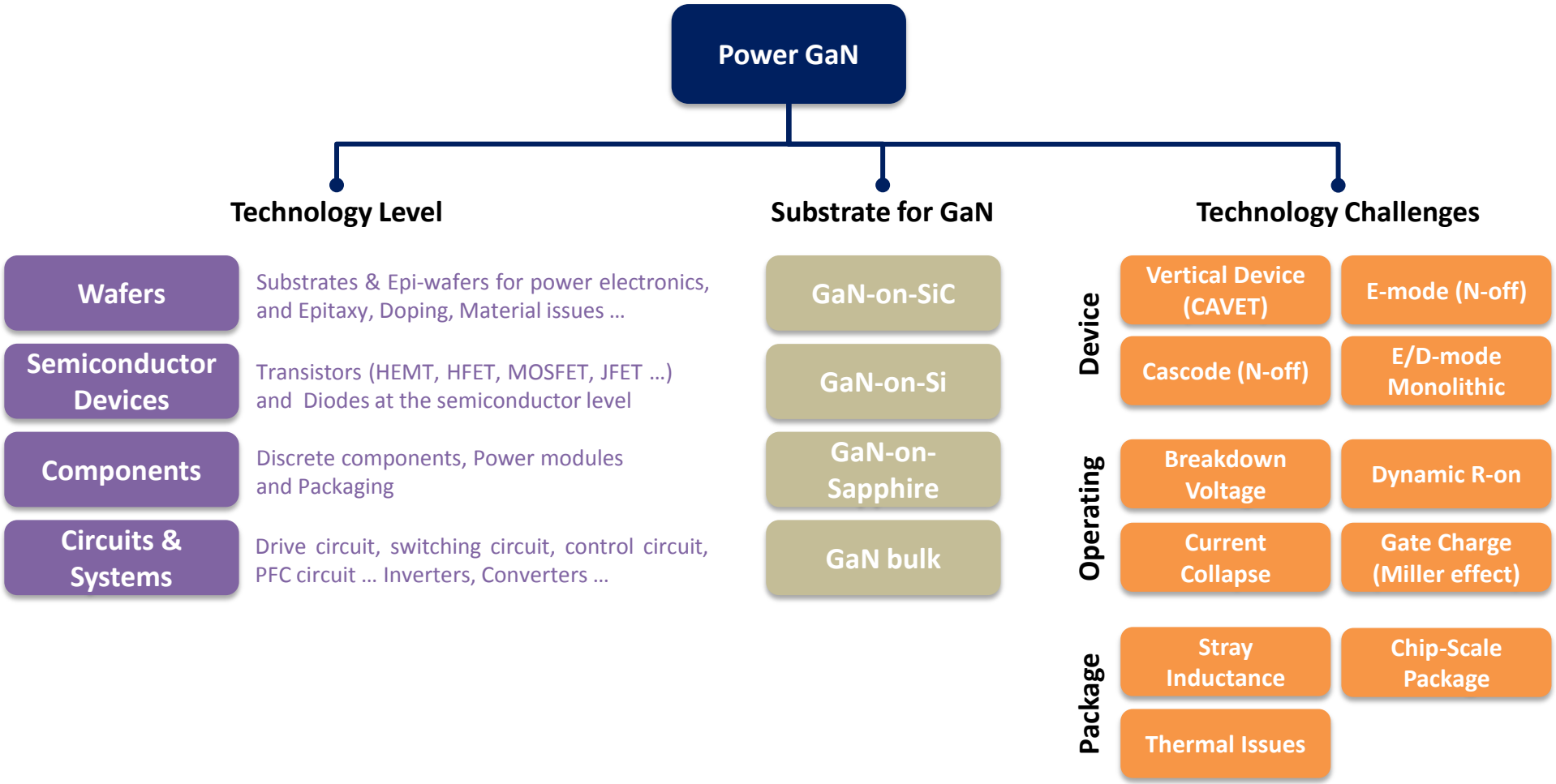
- The statistical analysis was performed with **Orbit IP Business Intelligence web based patent analysis software from Questel**.
- The patents were **manually categorized** using keyword analysis of patent title, abstract and claims, in conjunction with expert review of the subject-matter of inventions.
- A **patent family** is a set of **patents filed in multiple countries** to protect a single invention by a common inventor(s). The patents were organized according to **FamPat's family rules** (variation of EPO strict family http://www.epo.org/searching/essentials/patent-families/definitions.html): A *Patent Family* comprises patents linked by exactly same priority numbers (EPO strict family), plus comparison of priority and application numbers, specific rules by country and information gathered from other sources (national files, legal status …).

METHODOLOGY (2/2)



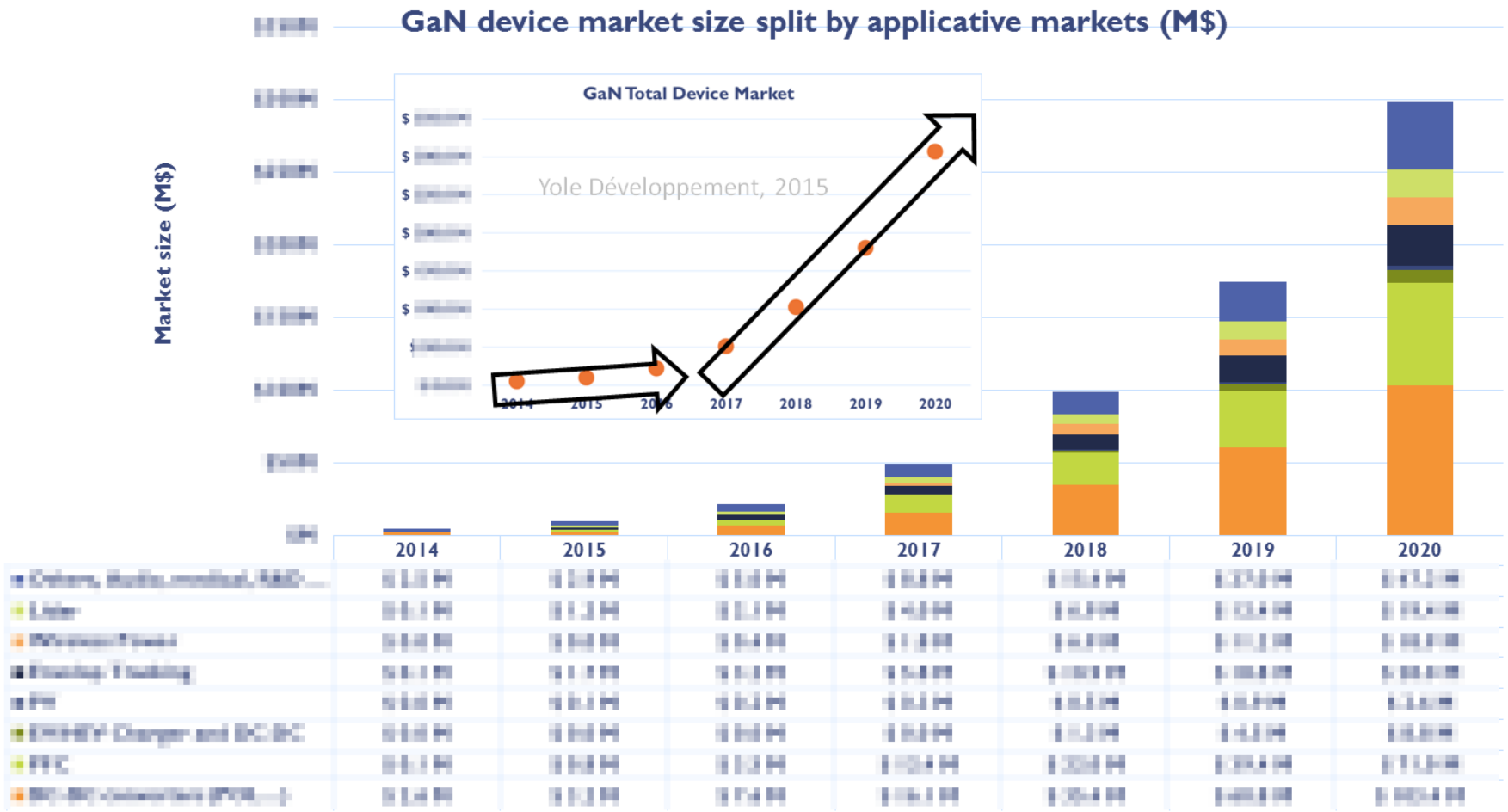
PATENT SEGMENTATION (1/3)

The **1,962 patents** were **manually categorized** using keyword analysis of patent title, abstract and c
conjunction with expert review of the object of inventions.
In this report we use the following patent segmentation:



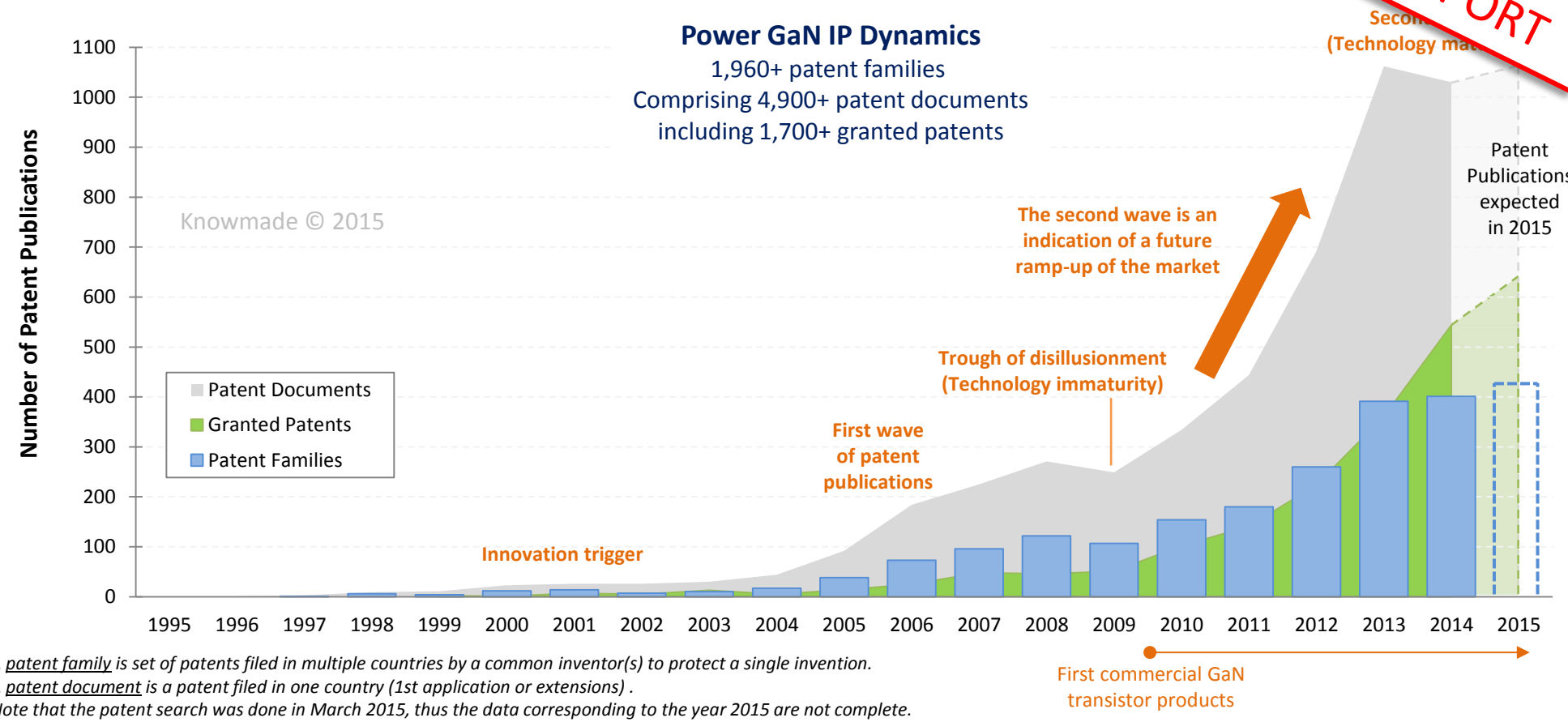
INTRODUCTION

GaN Devices in Power Application



IP OVERVIEW

Time Evolution of Patent Publications

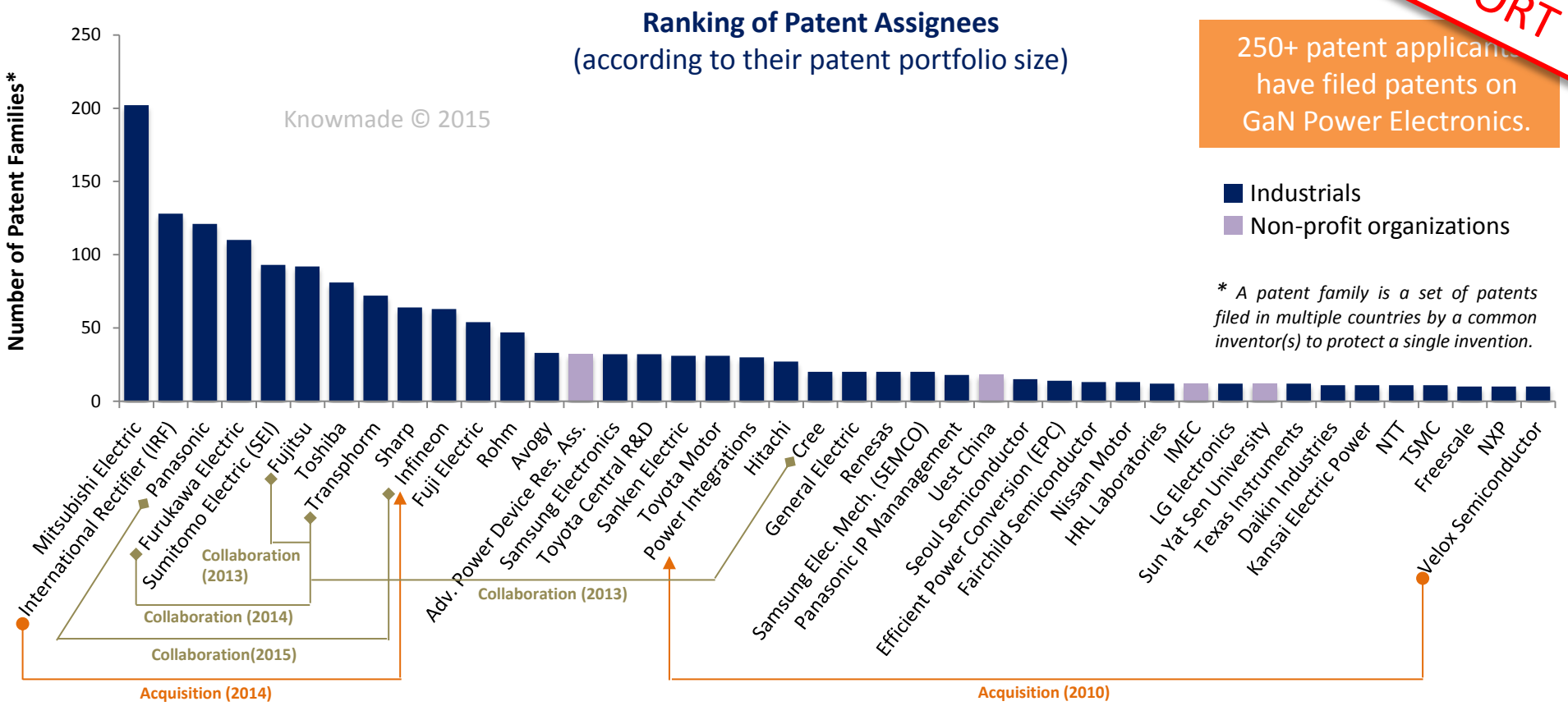


A patent family is set of patents filed in multiple countries by a common inventor(s) to protect a single invention.
A patent document is a patent filed in one country (1st application or extensions) .
Note that the patent search was done in March 2015, thus the data corresponding to the year 2015 are not complete.

Studies into the suitability of the GaN material for power applications began in 2006, and coincide with the first wave of patent filings. The number of patent publications has sharply increased since 2010 with the commercialization of first Power GaN devices. Currently, the **second peak of patent filings** combined to the **increase of granted patents** is a positive indication that **GaN Power market is ramping up**. So far, there are only a few players selling Power GaN products (Infineon/IR, EPC, GaN Systems and Transphorm) and the **GaN device market is still small**, estimated at $10M in 2015. But the **ramp-up will be quite impressive** starting in 2016. The market will multiply by 30 from now and reach more than $300M in 2020 (Yole Développement, GaN and SiC for power electronics applications, Jul 2015).

IP OVERVIEW

Power GaN Patent Assignees



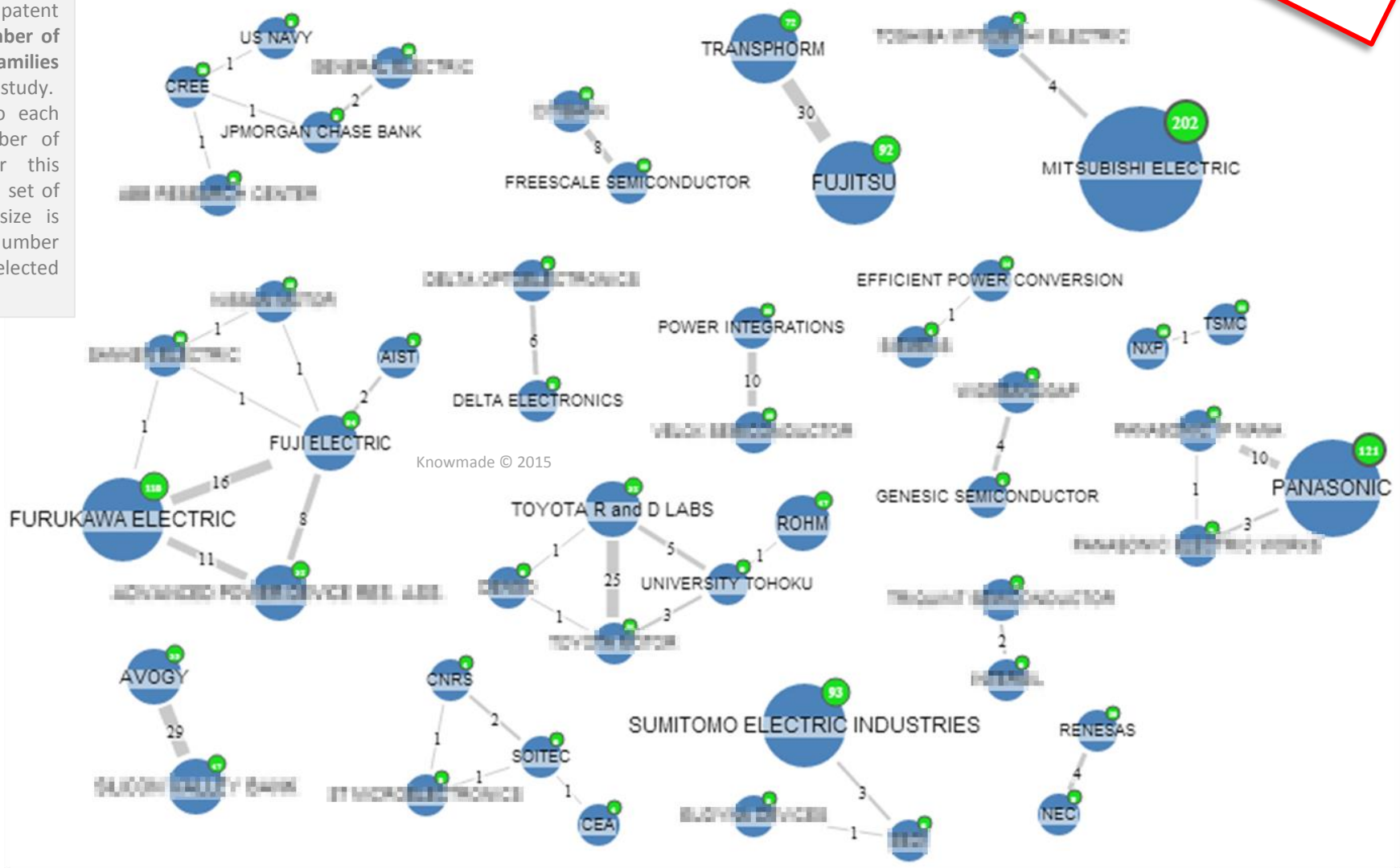
Other industrial patent assignees: Alpha & Omega Semiconductor, Toyoda Gosei, Delta Electronics, Japan Radio, NEC, Yaskawa, MicroGaN, RF Micro Devices (RFMD merged with Triquint = Qorvo), ABB Research Center, Delta Optoelectronics, Denso, Intersil, National Semiconductor, NGK Insulators, Northrop Grumman Systems, Schneider Electric, Soitec, Sumitomo Electric Device Innovations (SEDI), Dowa Electronics Materials, Eudyna Devices, Panasonic Electric Works, Schneider Toshiba Inverter, ST Microelectronics, Widebandgap, GaN Systems, Genesic Semiconductor, Hitachi Metals, Kansai Research Institute (KRI), Bosch, Siemens, Suzhou Jiexinwei Semi Tech, Triquint, Astriphey Applications, Azzurro Semiconductors (now ALLOS), Covalent Materials, Dynax Semiconductor, Emerson Network Power Energy, General Motors, IBM, Jiangsu Nenghua Microelectronic Technology Development, LG Innotek, Mersen, Philips, PowDec, Richtek Technology, Rockwell, Vishay Semiconductor, Daimler, Emcore, Enkris Semicondcutor, Adeka, Nippon Avionics, Thales, Arkansas Power Elec. Int. (APEI), Enphase Energy, General Motors, Kyocera, Lockheed Martin Corp., Nippon Steel & Sumitomo Metal ...

Other non-protfit organizations: University Tohoku, CEA, CNRS, US Navy, ETRI, Massachusetts Institute Of Technology (MIT), AIST, Fudan University, ITRI, Kyungpook National University, Nanjing University Of Aeronautics & Astronautics (Nuaa), National Chiao Tung University, Suzhou Inst. of Nano Tech. & Nano Bionics, Univ. of California, Agency for Sci. Tech. & Res. (ASTAR), California Inst. of Tech. (CalTech), Hong Kong Univ. of Sci. & Tech., Insti. of Semiconductors (Chinese Aca. Of Sci.), Inst. of Microelectronics (Chinese Aca. Of Sci.), CNES, Central Research Institute of Electric Power Industry (CRIEPI), Nagoya University ...

IP OVERVIEW

IP Collaboration Network

- Number in black on each link between patent assignees is the **number of co-assigned patent families** in the data set of the study.
- Number up right to each bubble is the number of patent families for this applicant in the data set of the study. Bubble size is proportional to the number of patent families selected for the study.



IP OVERVIEW

Power GaN Patent Assignees

- **Mitsubishi Electric**, a top Si power player already involved in SiC devices, is the top patent assignee in quantitative point of view with more than **200 patent families** related to the Power GaN domain, especially focused on [illegible]. **Mitsubishi Electric** has shown an interest in Power GaN technology quite recently, since 2010, with a strong increase of its patenting activity in this domain these last years. The company co-assigned several patents with [illegible].

- **International Rectifier (IR)**, with **120+ patents families** related to Power GaN, leads the time-to commercialization race of GaN Power devices. In 2009 the company launched its GaNpowIR™ GaN-based power device platform after five years of R&D on GaN-on-silicon epitaxial technology. In 2010 **IR** claimed the first commercial GaN-based integrated power stage devices (iP2010 and iP2011 family of devices). **IR** was acquired by **Infineon** in August 2014 (read more). [illegible]

- **Infineon**, as the market leader for power semiconductors, has pursued a partnership approach to accelerate their GaN development: e.g. intense collaboration with the **Fraunhofer** society, and involvement in two major German programs related to GaN technology—NeuLand (2010-2013) and HiPoSwitch (2011-2014). More than **60 patent families** related to Power GaN have been selected for this study.
  Infineon acquired **International rectifier** in Aug. 2014 with a focus on their GaN-on-Silicon technology and intellectual property (read more). This acquisition is an important step for **Infineon** [illegible] selected for this study. **International Rectifier** developed [illegible] **Infineon** recently announced a partnership with **Panasonic** for a jointly development of GaN devices based on Panasonic's normally-off GaN-on-Silicon transistor structure integrated into Infineon's SMD packages. In this context **Panasonic** has [illegible].

IP OVERVIEW

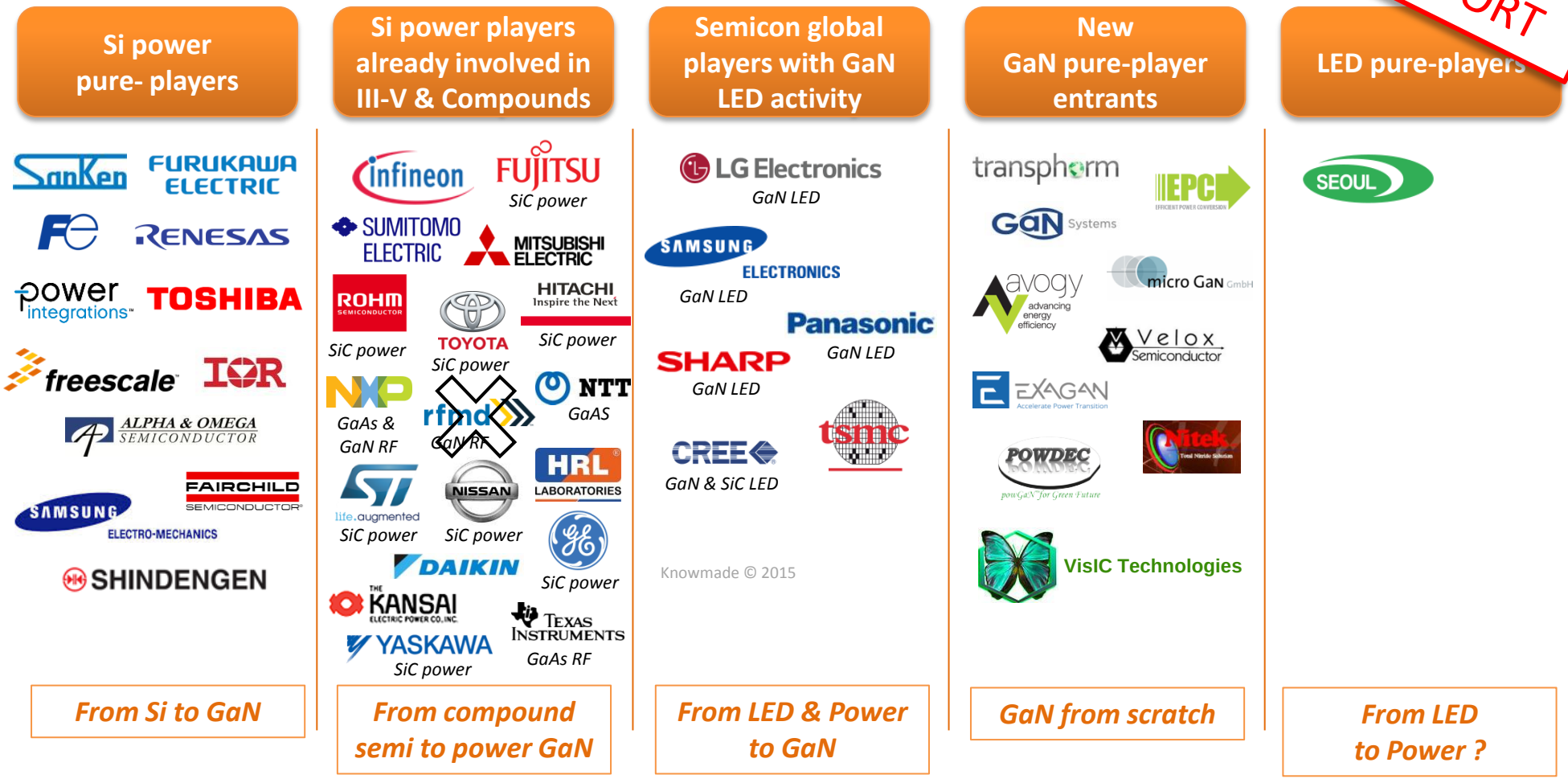
Power GaN Patent Assignees

- **Panasonic** developed its normally-off GaN power technology (original N-off gate injection transistor GIT). In 2009, it demonst… first monolithic integration of a six-HEMT inverter circuit. Panasonic Electric Works merged with Panasonic in Jan 2012. For this study, … have selected [redacted]

- **Transphorm** is a new GaN pure-player entrant. More than **70 patent families** related to Power GaN were selected for this study. The company introduced the 600V GaN-on-SiC products (EZ-GaN™ platform) in 2011, and the 600V GaN-on-Si Diode & HEMT in 2013. **Transphorm** obtained in 2013 a non-exclusive worldwide patent license agreement to **Cree** (GaN HEMT & Schottky diode), and in 2014 an exclusive worldwide license to **Furukawa Electric**'s extensive GaN power device portfolio, which includes about [redacted] US issued patents and [redacted] Japanese issued patents. **Transphorm** also has certain rights to sublicense these patents (read more). [redacted] not yet appear in patent databases. The co-assigned patent families could be revealed in the next month[redacted] **Furukawa Electric** has had research on Power GaN since the 1990s, but the company hasn't been able yet to commercialize the technology on its own. Converting orphaned IP to revenue by patent licensing isn't an easy road, but **Furukawa Electric** found a strategic partner that is well-positioned and well-funded to bring its technology to market.
  Transphorm, **Fujitsu** and **Fujitsu Semiconductor** announced in 2013 that they have reached an agreement whereby Fujitsu Semiconductor and Transphorm will integrate their gallium-nitride (GaN) power devices for power supplies businesses (read more). The three companies have also agreed that both Fujitsu and Fujitsu Semiconductor will take a minority equity position in Transphorm. Transphorm acquires Fujitsu's GaN Power Conversion business, and the two companies announced the formation of a new company: **Transphorm-Japan**, a wholly-owned subsidiary of Transphorm (read more). The present report includes [redacted]
  Transphorm began a partnership with [redacted] in 2014 to co-develop and co-market GaN-based products and power system solutions. [redacted]

IP OVERVIEW

Power GaN Patent Assignee – Origin of GaN Involvement

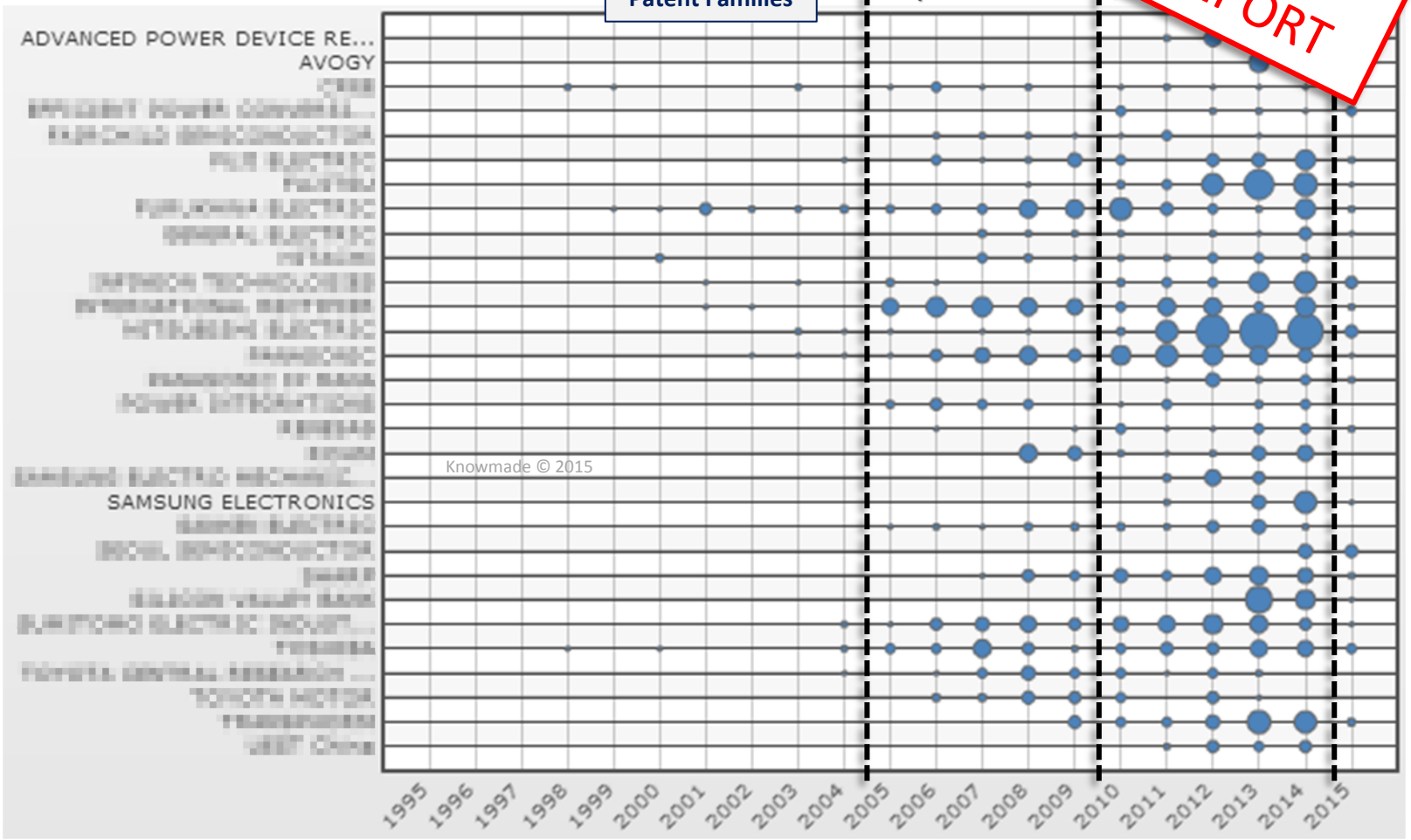


- **Infineon** acquired **International Rectifier** (Aug. 2014).
- **Panasonic** licenses their N-off GaN transistor out to **Infineon** in 2015.
- **Transphorm** obtained in 2013 a non-exclusive worldwide patent license agreement to Cree (GaN HEMT & Schottky diode). In 2014 it obtained exclusive licensing rights to **Furukawa** Electric's GaN patent portfolio
- **Fujitsu Semiconductor** and **Transphorm** collaborate (business integration of their GaN power device solutions in Nov 2013. Start of mass production of **Transphorm**'s GaN power devices in Jan 2015).
- **NXP** and **Freescale** merged in March 2015.
- **Velox Semiconductor** acquired by **Power Integrations** in 2010.

IP OVERVIEW

Time Evolution of Patent Publications

Dates are defined from the earliest publication date for each patent family. Bubble size is proportional to the number of published patent families.
Note: The data corresponding to the year 2015 may not be complete since the patent search was done early March 2015



Note:
- ❖Infineon acquired IR in 2014.
- ❖Licensing agreements Infineon/Panasonic, Transphorm/Furukawa
- ❖Collaborations Transphorm/Fujitsu
- ❖Silicon Valley Bank co-assignee of Avogy's patents

- The **first wave** of patent publications between 2005 and 2009 is mainly due to [redacted]
- **Mitsubishi** and **Fujitsu** have shown an interest in Power GaN technology since 2010 with a significant increase of their patenting activity in this domain.
- The patents published in the **second period** (2010-2014) mainly originate from [redacted]

ANNOUNCED GAN TRANSISTOR PRODUCTS

Studies into the suitability of the GaN material for power applications began in 2006.

2009

- SanKen — **800 V / Si GaN FET** Nov. 2008
- RENESAS — **1260 V / Si GaN Noff FET** Dec. 2009
- IOR — **GaNpowerIR™ Gen 1.1** 2009

2010

- micro GaN GmbH — **600 V / Si GaN HFET** May 2010
- EPC — **200 V / Si GaN Noff HEMT (eGaN)** Mar. 2010
- IOR — **30 V / Si Point-of-Load** 2010

First commercial GaN-based integrated power stage devices (iP2010 and iP2011 family of devices).

2011

- transphorm — **600V / SiC E Z-GaN Transistor** 2011 (EZ-GaN™ platform)
- Microsemi — **200 V / Si E-mode GaN FET** Mar. 2011

2012

- IOR — **600 V / Si GaN FET** 2012
- VisIC Technologies — **900 V / SiC GaN E-MOSHEMT** 2012
- ifmd — **650 V / SiC GaN HEMT** 2012 — STOP

2013

- FUJITSU — **150 V / Si GaN HEMT** Jul 2013 → Mass production in 2014
- FUJITSU — **600 V / Si GaN Transistor test** 2013
- transphorm — **600 V / Si Diode & GaN HEMT** 2013
- IOR — **100 V / Si GaN FET Cascode configuration** 2013 (GaNpowerIR™ Gen 2.1)

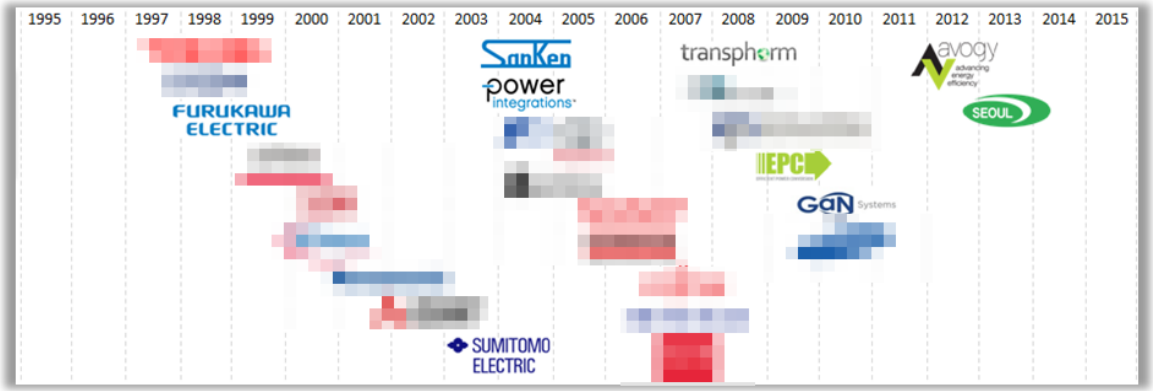
2014

- GaN Systems — **100 V & 650 V / Si GaN Noff HEMT** May 2014 (GaNPX™ pacakge)

2015

- VisIC Technologies — **650 V / Si GaN Noff MISHEMT** May 2015
- transphorm — **600 V / Si GaN Transistor in a TO-247 Packagre** Mar. 2015

First Appearance of Key Players in the Power GaN IP arena



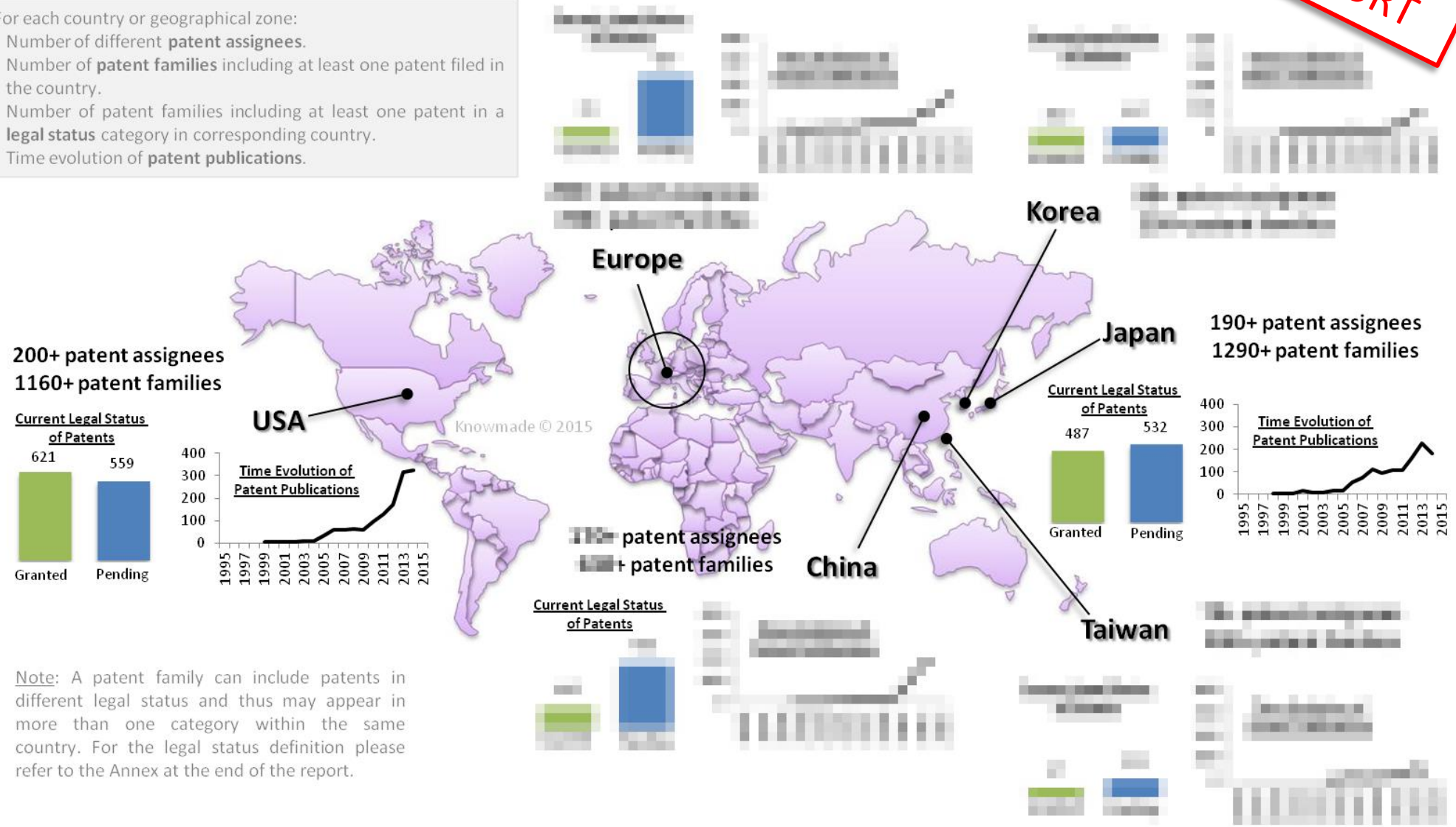
Commercially available

* IR's GaN devices are only for specific clients

IP OVERVIEW

Mapping of Patenting Activity

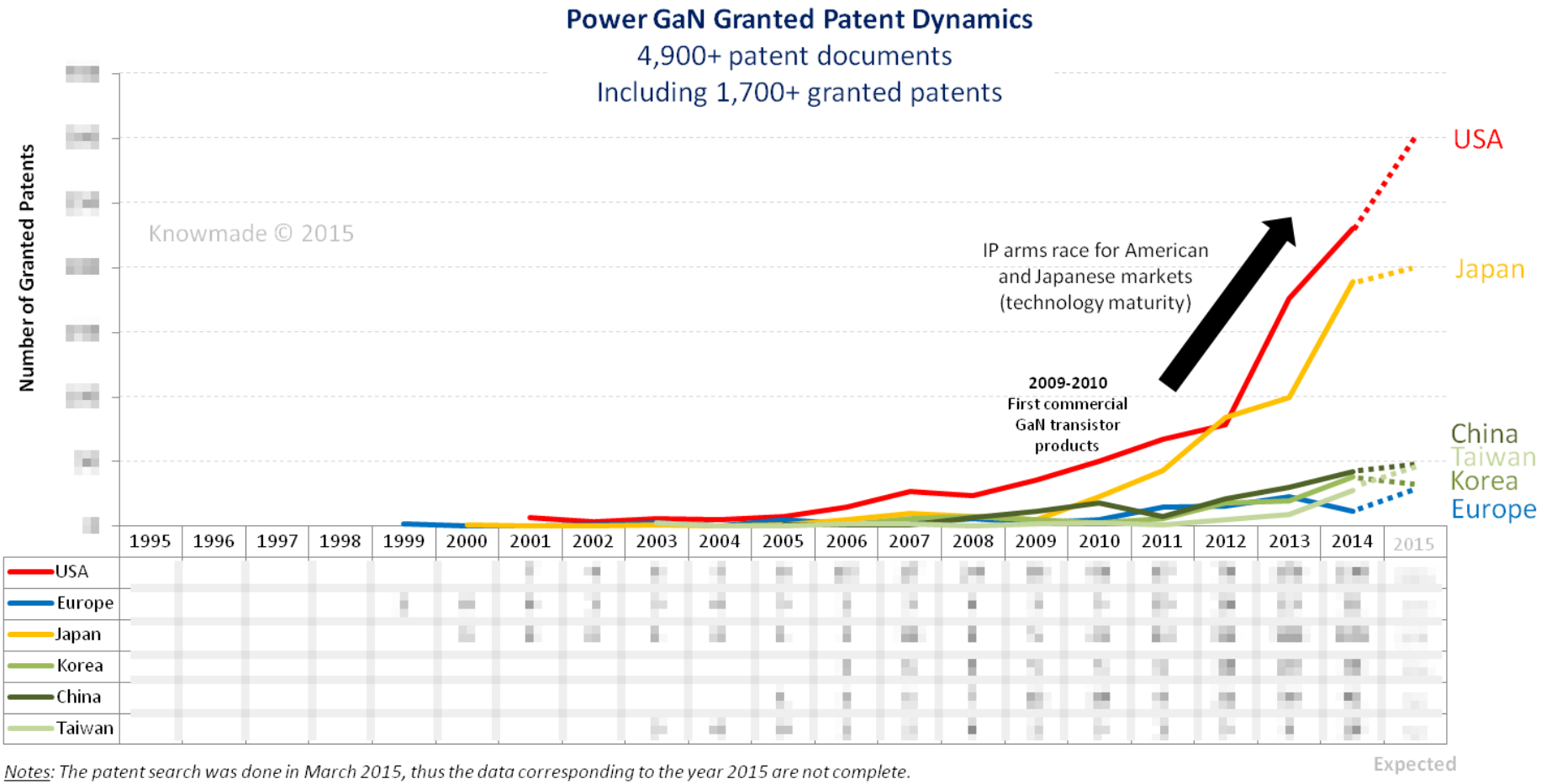
For each country or geographical zone:
- Number of different **patent assignees**.
- Number of **patent families** including at least one patent filed in the country.
- Number of patent families including at least one patent in a **legal status** category in corresponding country.
- Time evolution of **patent publications**.



Note: A patent family can include patents in different legal status and thus may appear in more than one category within the same country. For the legal status definition please refer to the Annex at the end of the report.

IP OVERVIEW

Time Evolution of Granted Patents by Country



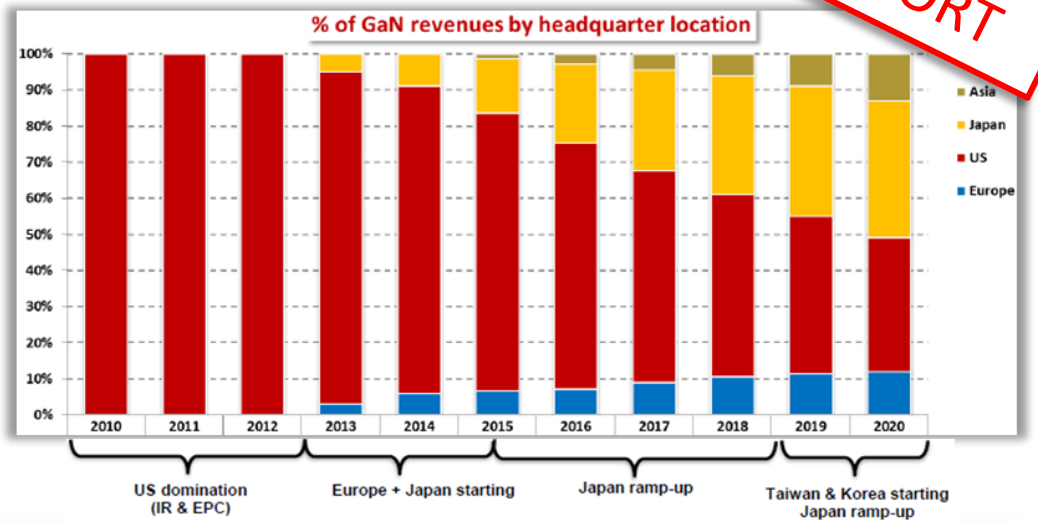
Notes: The patent search was done in March 2015, thus the data corresponding to the year 2015 are not complete.

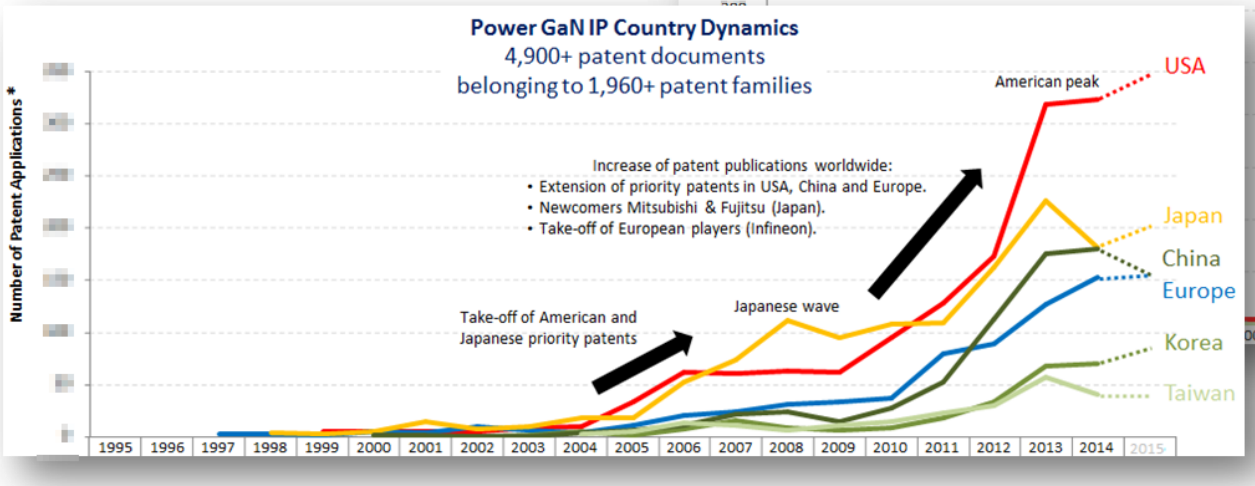
IP OVERVIEW

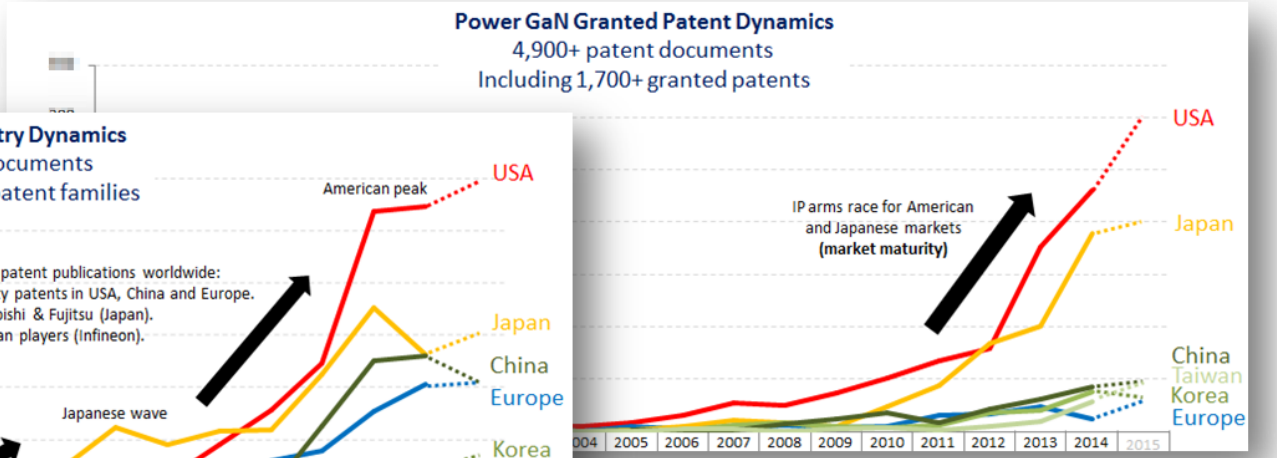
Market Domination Results From Previous IP Lead Period

A lead period in patenting activity and patent grants heralds a future market domination.

The market domination of USA until 2013 is consistent with its lead in terms of granted patents from 2005 to 2010.
Japan, witness of an increase of its enforceable patents since 2010, is ramping up and enlarges its market share.







IP OVERVIEW

Patent Litigations and market evolution

To this date, no litigation cases related to Power GaN domain have been filed*.
But this could change.

In a patent infringement action, the **potential sales volume plays a major role** for assessing the damage award.

So far, the **GaN device market is still at its early stage** ($10M in 2015 according to Yole Développement). There are only **a few players selling power GaN devices**. As the GaN needs to compete with the incumbent silicon technology, the priority of GaN players is to educate the end users to adopt GaN devices. **GaN players are in a cooperative mode to promote the GaN technology all together.**
The GaN power industry is **consolidating** in preparation for significant growth, and recent movements show that the GaN industry is taking shape as mergers, acquisitions and license agreements are settled. In this context, the **IP just begins to be used as leverage** by companies to negotiate licensing and supply agreements (Infineon/Panasonic, Transphorm/Furukawa).

Power GaN domain emerged in terms of patents less than 20 years ago and the number of granted patents was increasing greatly only these last 5 years. According to our analysis, **the Power GaN IP is mature enough**. As the market ramps up (93% 2016-2020 CAGR according to Yole Développement) and more players enter into the market, there will be competition between different players in the future. When **GaN players go into a competitive mode**, **a strict enforcement of critical patents by major Power GaN players may lead to first patent litigations in the coming years**.

*IR sued EPC in 2009 for theft of trade secrets. Two companies reached settlement in 2013. The settlement will result in the payment of royalties to IR on the sale of GaN on Si based power devices from 2015-2023, subject to an offset in certain cases. The IR/EPC sue is not linked directly to IP infringement. The settlement between IR and EPC in 2013 is also a way for two companies to put the dispute behind them and continue their journey in GaN business.

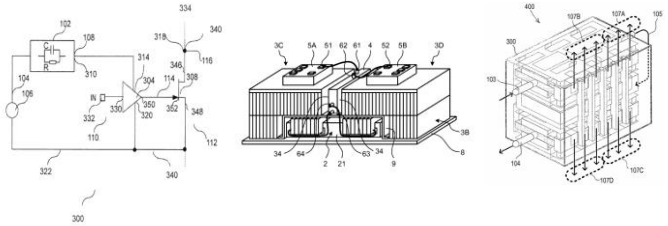
TECHNOLOGY SEGMENTATION

Patent Family Split by Technology Segment

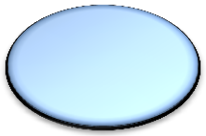
1960+ patent families on GaN power electronics

A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention.

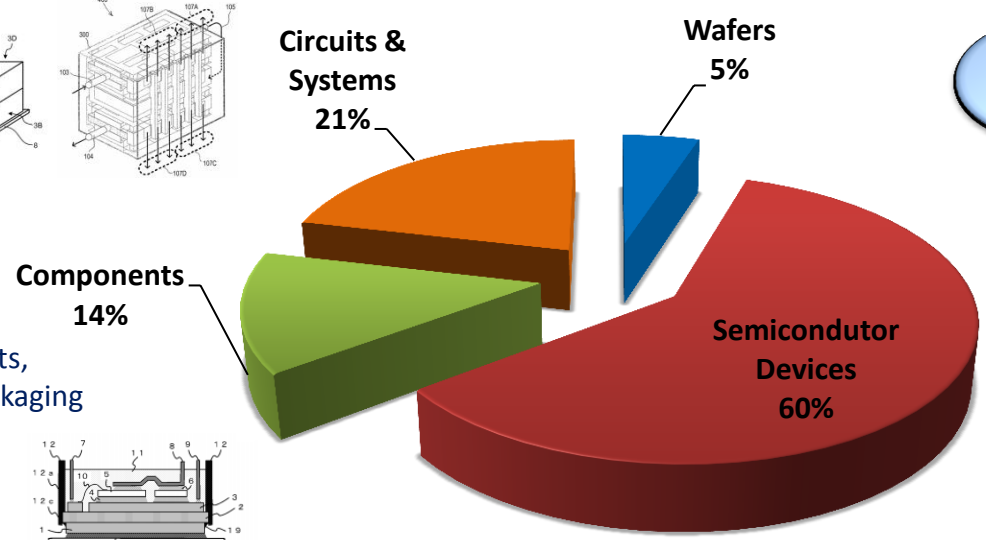
Circuits (drive circuit, switching circuit, control circuit, PFC circuit …) and Electronic Systems (inverters, converters …)



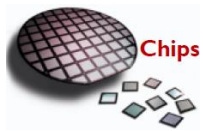
Substrates & Epi-wafers for power electronics, and Epitaxy, Doping, Material issues …

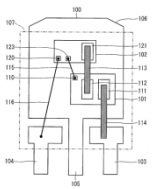


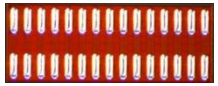
GaN-on-XX



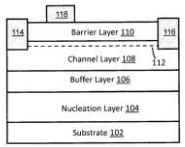
Discrete components, Power modules and Packaging

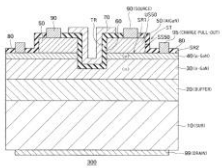


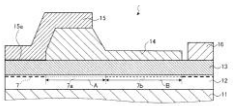


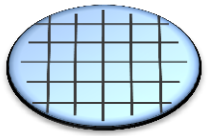


Transistors (HEMT, HFET, MOSFET, JFET …) and Diodes at the semiconductor level







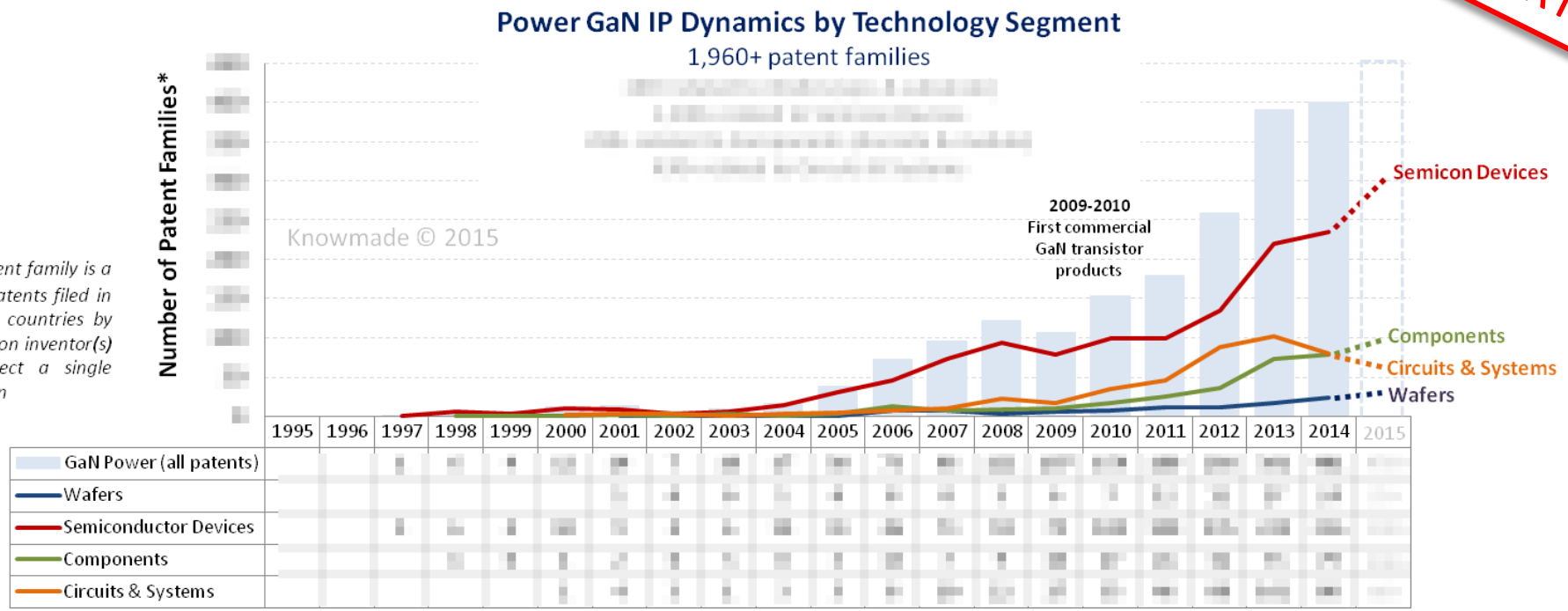


Processed wafer

TECHNOLOGY SEGMENTATION

Time Evolution of Patent Publications Split by Technology Segmen

SAMPLE REPORT



* *A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention*

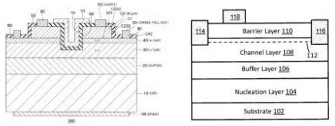
Notes: 1) A patent can be found in several categories. 2)The patent search was done in March 2015, thus the data corresponding to the year 2015 are not complete.

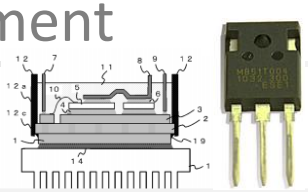
- Patenting activity on **GaN Power Semiconductor Devices** (transistor & diodes at semiconductor level) took-off in 2004-2005. The main pioneer patent applicants of the 2004-2010 period are [redacted] Today, "Semicon Device" patents account for **60%** Power GaN patents.
- The number of patent applications related to **GaN Power Components** (discrete, module & package) and **Circuits & Systems** increased in a second time over the 2010-2015 period while the first Power GaN devices were commercialized. "Power Components" patents were mainly filed by [redacted] while "Circuits & Systems" patents were mainly filed by [redacted]
- Patents claiming **GaN substrates** and **GaN templates** especially developed for power applications appeared in mid-2000s, and a steady increase of patent publications was observed over the 2010-2015 period. Main patent applicants are epi-makers both with merchant business ([redacted]) and no merchant business ([redacted]).

TECHNOLOGY SEGMENTATION

Main Patent Assignees by Technology Segment

GaN-on-XX





Wafers

100+ patent families
60+ patent assignees

CREE
EPIGAN
imec
SEOUL
NGK
NGK INSULATORS, LTD.
TOYOTA
TOYOTA CENTRAL R&D LABS., INC.

Semiconductor Devices

1200+ patent families
220+ patent assignees

NISSAN
EPC
NTT
Velox Semiconductor
TOYODA GOSEI
freescale semiconductor
NEC
ALPHA & OMEGA SEMICONDUCTOR
TEXAS INSTRUMENTS
JRC
New Japan Radio Co.,Ltd.
micro GaN GmbH
ABB
rfmd
cea
GaN Systems

Components

280+ patent families
70+ patent assignees

TOHOKU UNIVERSITY
RENESAS
SAMSUNG
TEXAS INSTRUMENTS
life.augmented
avogy advancing energy efficiency
GaN Systems
power integrations
EPC
micro GaN GmbH

Circuits & Systems

430+ patent families
120+ patent assignees

FURUKAWA ELECTRIC
DELTA
power integrations
avogy advancing energy efficiency
EPC
TEXAS INSTRUMENTS

TECHNOLOGY SEGMENTATION

Matrix Key IP Players / Technology Segments

The colored c… light the main features … Note that a … several catego…

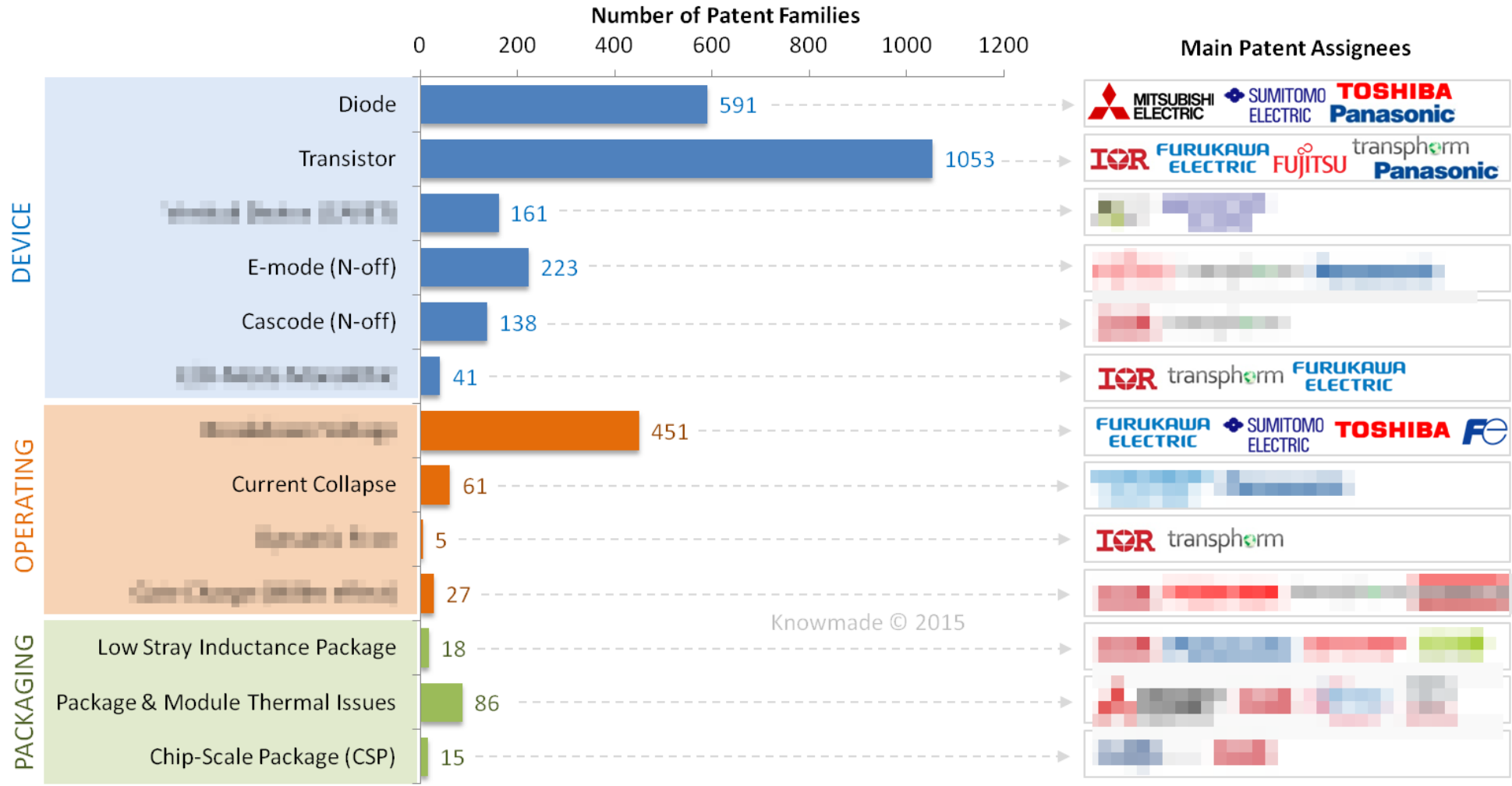
Patent Assignees	Number of Patent Families	TECHNOLOGY SEGMENT				SUBSTRATE FOR GAN			
		Wafer	Semiconductor Device	Component	Circuit & System	GaN-on-SiC	GaN-on-Si	GaN-on-Sapphire	GaN Bulk
Alpha & Omega Semiconductor	9	0	8	1	0	1	0	3	1
[illegible]	33	0	28	2	3	0	0	0	20
[illegible]	20	2	15	1	0	14	2	3	1
Efficient Power Conversion (EPC)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	12	0	0	2	3	0	1
[illegible]	[illegible]	3	43	7	3	15	13	2	2
[illegible]	[illegible]	9	70	6	15	6	10	6	2
[illegible]	[illegible]	8	96	6	5	4	20	11	0
[illegible]	[illegible]	0	3	2	0	0	1	0	0
[illegible]	[illegible]	0	13	7	10	8	3	2	6
[illegible]	[illegible]	0	35	22	7	6	11	1	1
[illegible]	[illegible]	7	68	37	21	20	43	19	4
[illegible]	[illegible]	0	6	1	0	0	0	0	0
[illegible]	[illegible]	0	18	65	126	10	6	1	5
[illegible]	[illegible]	0	4	5	0	1	2	1	0
[illegible]	[illegible]	4	56	9	68	12	14	12	5
Power Integrations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	15	3	0	4	4	1	1
[illegible]	[illegible]	3	33	11	0	5	5	8	5
[illegible]	[illegible]	1	48	3	3	12	15	9	2
[illegible]	[illegible]	0	19	5	7	1	3	1	1
[illegible]	[illegible]	2	15	0	0	0	0	2	0
[illegible]	[illegible]	5	41	12	6	3	8	2	0
[illegible]	[illegible]	5	75	10	11	9	5	1	24
[illegible]	[illegible]	0	64	12	10	5	14	1	2
[illegible]	[illegible]	2	24	9	4	1	1	1	1
Transphorm	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	0	8	1	1	0	2	3	0
[illegible]	8	0	0	7	1	0	0	0	0

TECHNICAL CHALLENGES

Patent Family Split by Technology Challenges

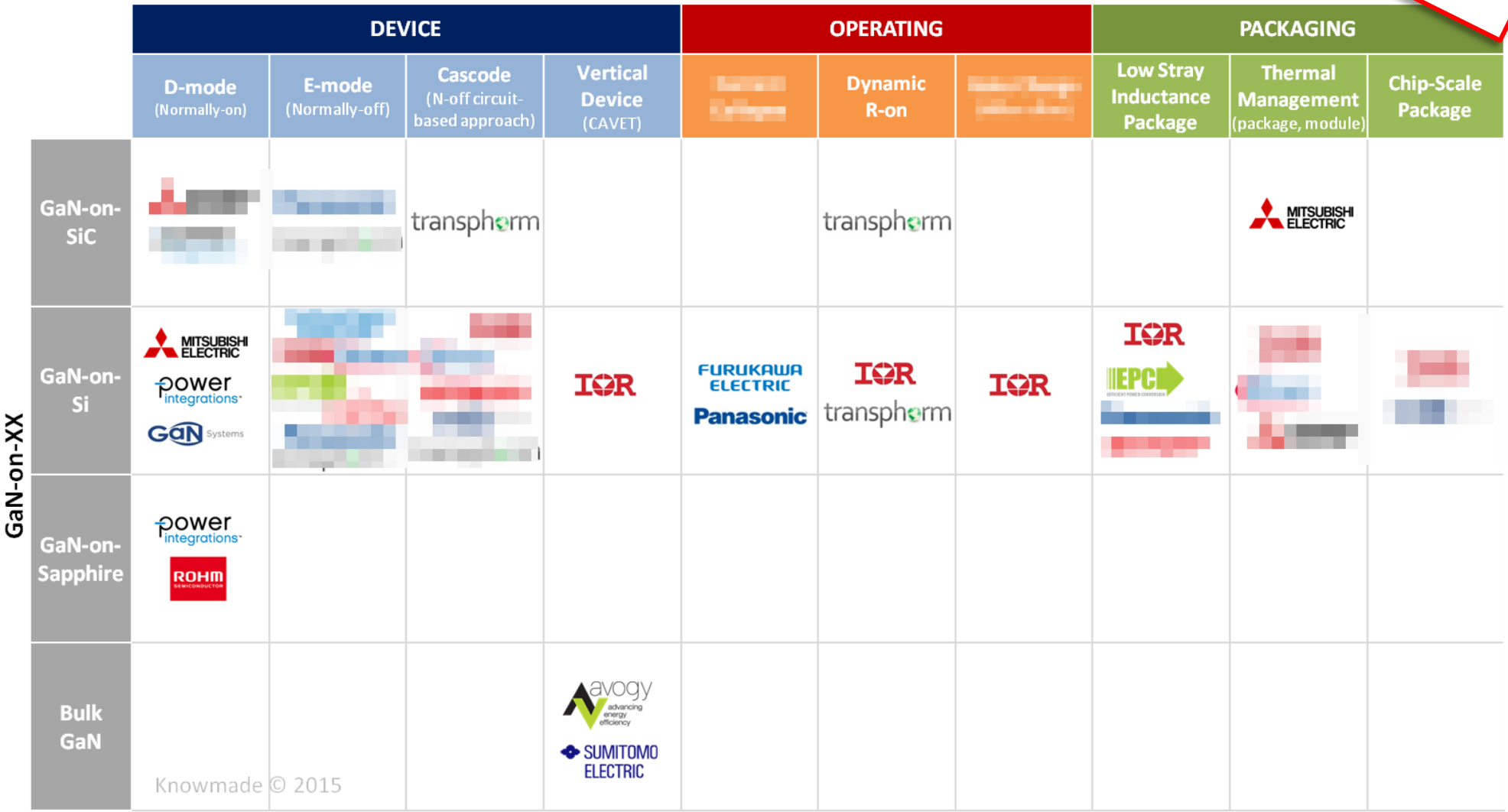
1960+ patent families on GaN power electronics

A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention.
Note that a patent family can be found in several categories



TECHNICAL CHALLENGES

GaN Power Transistor - Patent Differentiation of Key IP Players



TECHNICAL CHALLENGES

Matrix Key IP Players / Technology Challenges

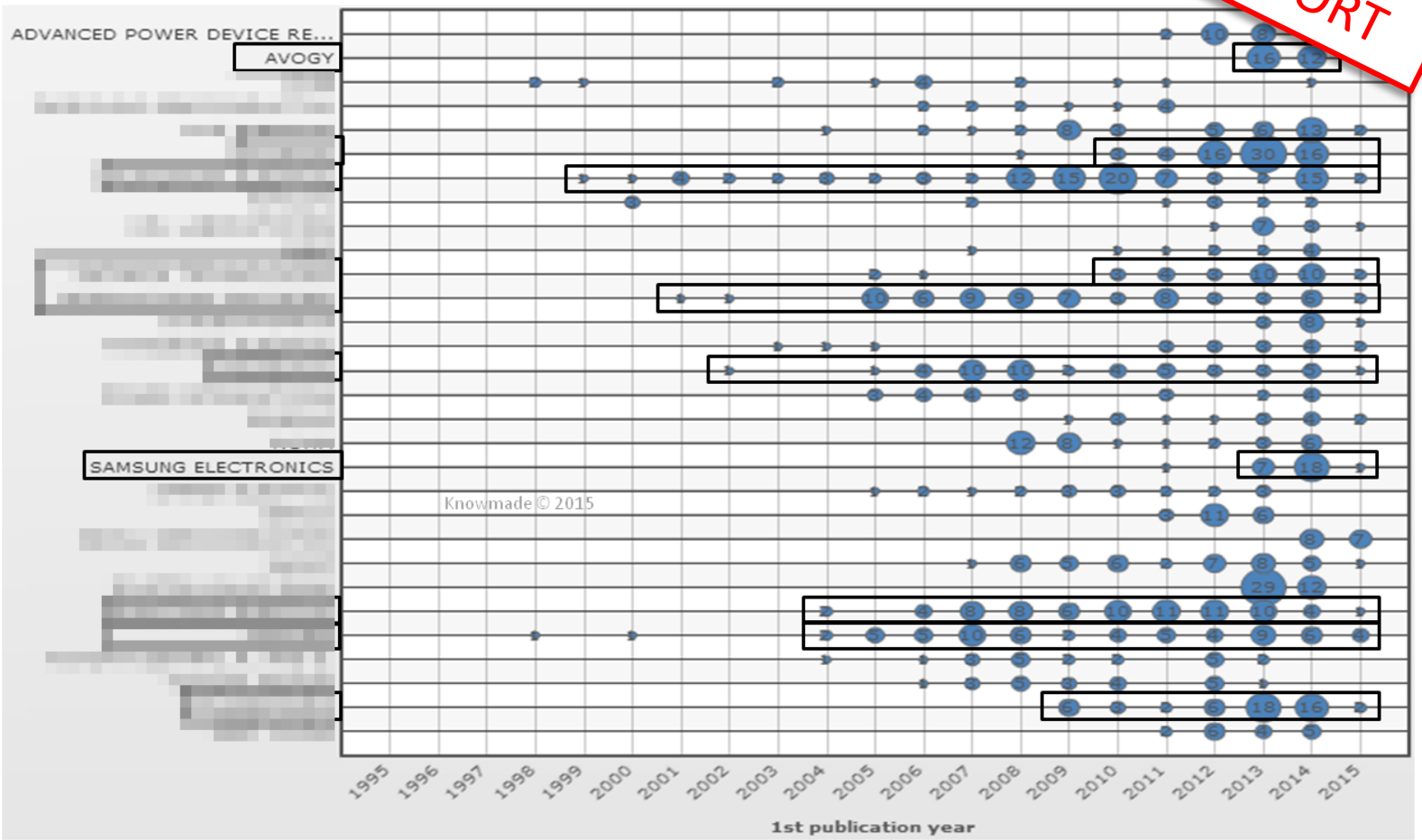
The colored c… light the main features … Note that a … several catego…

Knowmade © 2015 Patent Assignees	# Patent Families	DEVICE						OPERATING				PACKAGING		
		Diode	Transistor	CAVET	E-mode (N-off)	Cascode (N-off)	E/D-mode Monolithic	Breakdown Voltage	Current Collapse	Dynamic R-on	Gate Charge (Miller effect)	Low Stray Inductance	Thermal Management	Chip-Scale Pacakge (CSP)
[redacted]	9	6	4	0	2	1	0	0	0	0	0	0	0	0
[redacted]	33	15	22	23	1	0	0	1	0	0	1	0	2	0
[redacted]	20	8	16	2	1	1	0	2	0	0	1	0	0	0
Efficient Power Conversion (EPC)	[redacted]													
[redacted]	[redacted]							2	0	0	2	0	0	0
[redacted]	[redacted]							31	4	0	0	0	0	0
[redacted]	[redacted]							14	4	0	0	1	0	0
[redacted]	[redacted]							50	15	0	0	0	3	1
[redacted]	[redacted]							0	0	0	0	0	1	3
[redacted]	[redacted]							9	0	0	0	0	4	0
[redacted]	[redacted]							6	0	0	1	0	8	1
[redacted]	[redacted]							15	0	1	8	4	15	7
[redacted]	[redacted]							0	0	0	0	0	0	0
[redacted]	[redacted]							21	0	0	1	0	16	0
[redacted]	[redacted]							0	0	0	0	0	0	0
[redacted]	[redacted]	37	54	3	22	0	0	[redacted]				3	1	0
[redacted]	[redacted]	12	20	2	2	4	2	[redacted]				0	4	0
[redacted]	[redacted]	1	18	3	5	1	0	[redacted]				0	0	0
[redacted]	[redacted]	6	21	2	2	0	0	[redacted]				0	3	0
[redacted]	[redacted]	19	29	3	9	5	2	[redacted]				0	0	1
[redacted]	[redacted]	6	15	0	7	0	1	[redacted]				0	1	0
[redacted]	[redacted]	3	13	9	3	0	0	[redacted]				0	0	0
[redacted]	[redacted]	16	44	1	3	11	0	[redacted]				3	0	0
[redacted]	[redacted]	39	33	25	4	1	0	[redacted]				0	2	0
[redacted]	[redacted]	38	43	0	9	10	0	[redacted]				1	0	0
[redacted]	[redacted]	2	12	6	7	0	0	[redacted]				0	7	0
Transphorm	[redacted]							[redacted]						
[redacted]	[redacted]	7	4	0	0	1	0	3	0	0	0	0	2	0
[redacted]	[redacted]	0	1	0	0	0	0	0	0	0	0	0	3	0

SEMICONDUCTOR DEVICES

Time Evolution of Main Patent Assignees

Dates are defined from the earliest publication date for each patent family. Bubble size represents the number of published patent families. The data corresponding to the year 2015 may not be complete since the patent search was done early March 2015

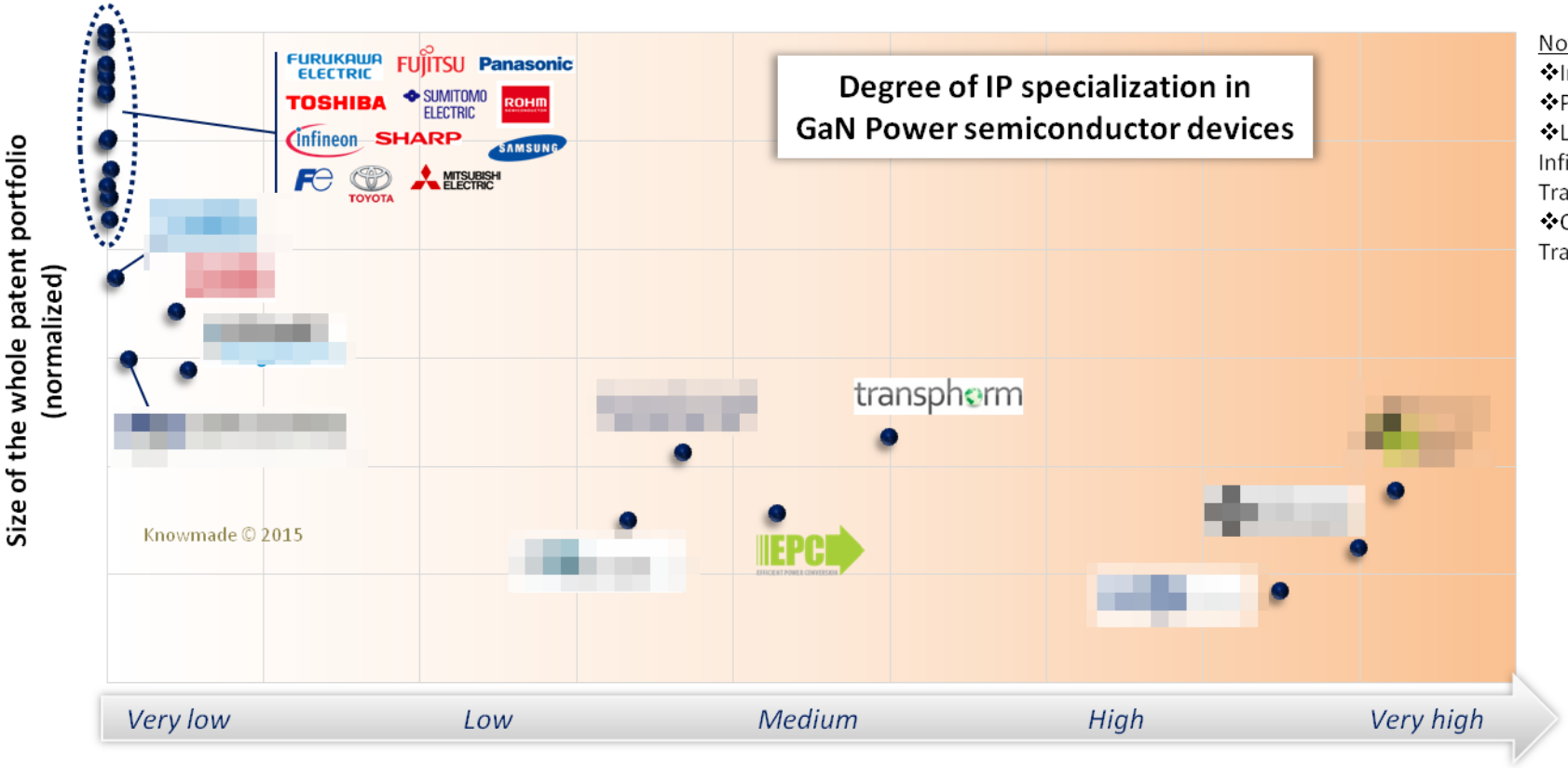


Note:
- ❖Infineon acquired IR in 2014.
- ❖Licensing agreements Infineon/Panasonic (2015), Transphorm/Furukawa (2014), Transphorm/Cree (2013)
- ❖Collaborations Transphorm/Fujitsu (2013)
- ❖Silicon Valley Bank co-assignee of Avogy's patents

Furukawa, the top patent assignee in terms of patent filings on GaN power semiconductor devices**,** has continuously filed patents on this field since the [illegible] **International Rectifier** (acquired by **Infineon** in 2014), **Panasonic**, **Sumitomo** electric and **Toshiba** have shown a steady IP interest in the GaN power semiconductor devices since [illegible] **Fujitsu**, originally a Si Power players also involved in III-V & Compounds, is appeared lately in [illegible] **Transphorm** and **Avogy**, as new GaN pure-player entrants, started their patenting activity in [illegible] significant patent publications the last couple of years.

SEMICONDUCTOR DEVICES

Degree of Specialization



Note:
- Infineon acquired IR in [illegible]
- POWI acquired Velox in 2010.
- Licensing agreements Infineon/Panasonic (2015), Transphorm/Furukawa (2014)
- Collaborations Transphorm/Fujitsu (2013)

The degree of specialization of a company represents the percentage of patents filed in a specific field over the whole patent portfolio of the company. It is an indicator of the patenting activity on a specific field.

Big companies such as **Furukawa**, **Panasonic**, **Infineon**, **Fujitsu**, **Mitsubishi** … cover a wide range of technologies with their patent portfolios, thus they have a **very low specialization degree** in GaN power semiconductor devices. **International Rectifier (IR)** and **Power Integrations (POWI)**, originally Si Power pure players, show [illegible] specialization degree. **GaN Systems**, [illegible] and [illegible] stand out with a very high specialization degree, their patent portfolios are mainly dedicated to GaN power semiconductor devices. **POWI** and **Infineon** gained IP focused on GaN power semiconductor devices thanks to [illegible]

SEMICONDUCTOR DEVICES

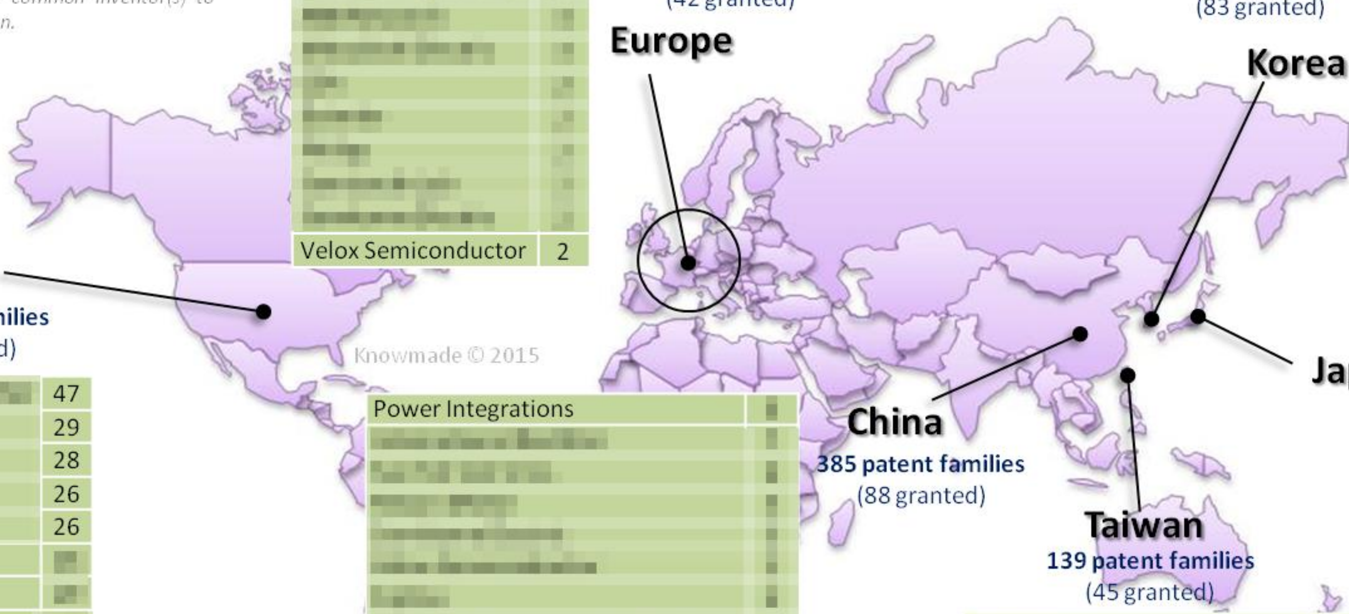
Mapping of Main Current Patent Holders

SAMPLE REPORT

Number of patent families* containing **granted patents** in the corresponding country.

** A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention.*

1220+ patent families on Semiconductor Devices
640+ patent families including at least one granted patent



USA

[illegible]	47
[illegible]	29
[illegible]	28
[illegible]	26
[illegible]	26
Transphorm	[illegible]
Avogy	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Fuji Electric	[illegible]
Sanken Electric	[illegible]

Europe

International Rectifier	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Velox Semiconductor	2

Korea

[illegible]	29
Transphorm	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Power Integrations	[illegible]

China

Power Integrations	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Fairchild	[illegible]
Transphorm	[illegible]

Japan

Furukawa	[illegible]
Sumitomo Electric	[illegible]
International Rectifier	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Taiwan

[illegible]	8
[illegible]	8
Transphorm	[illegible]
Power Integrations	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

SEMICONDUCTOR DEVICES

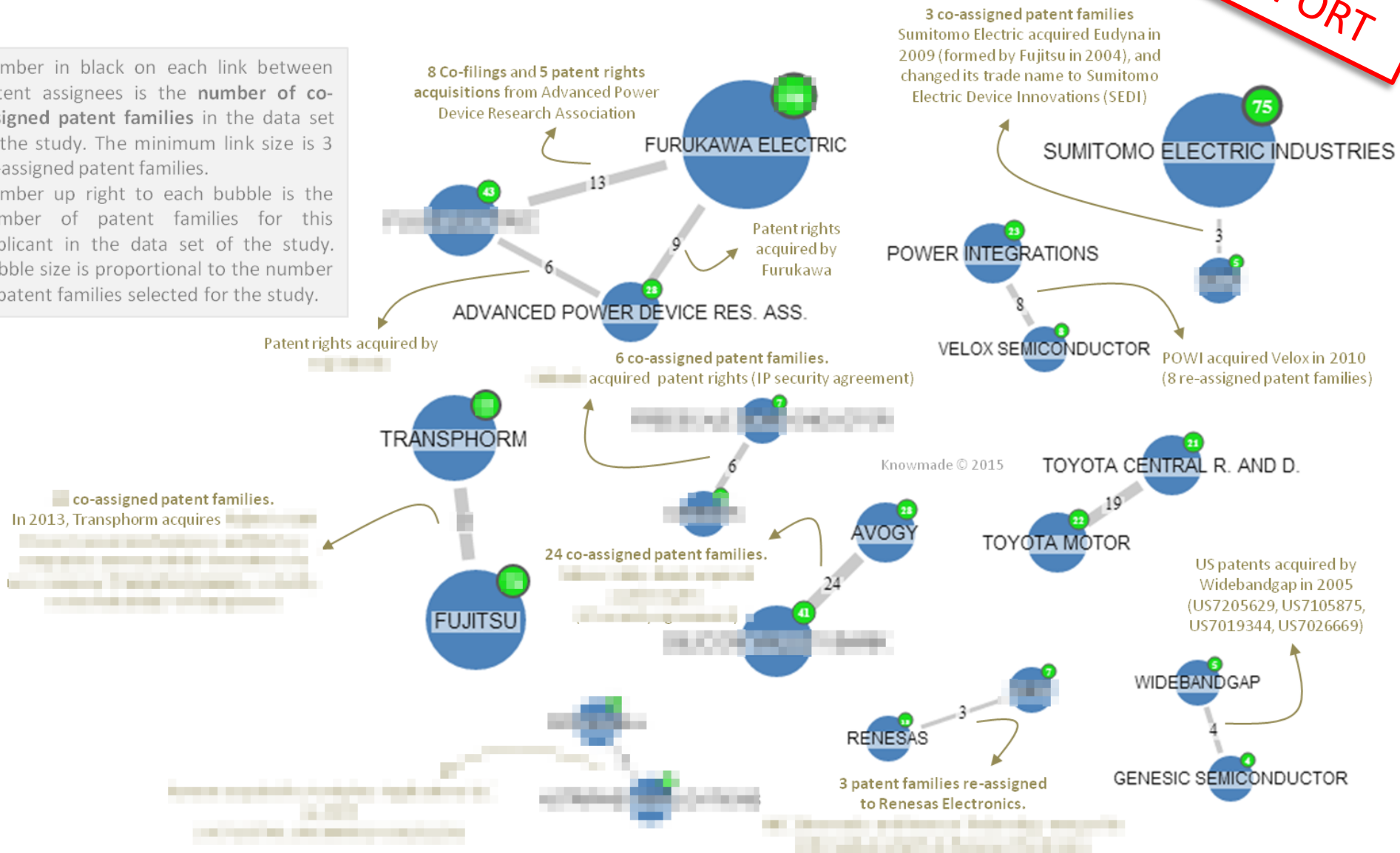
Power GaN IP Players

- **3220+ patents** split in **1220+ patents families**.
- **1540+ pending patents** split in **770+ patent families**, and **1210+ granted patents** split in **640+ patent families**.
- Few academics are active on GaN power semiconductor devices,
- **International Rectifier** (IR) has currently the most important with **granted patents** from patent families. It is the main current IP holder in granted patents) and (8 granted patents), and it has a strong IP position in Japan as well. **Infineon/IR** are leading the patenting activity in **Europe** where together they have pending patents. **Infineon** shows a significant interest for with 22 pending patents.
- **Fujitsu** owns currently **granted patents** on GaN power semiconductor devices, mainly in **Korea** and , and it has a strong IP position in . **Fujitsu** has **strongly increased its patenting activity** on GaN semiconductor devices as revealed by the number of pending patents the company has in the different offices, making **Fujitsu** the **main patent applicant** in the domain across the world with **pending patent applications** ( ). This demonstrates a growing interest of **Fujitsu** in GaN power semiconductor devices, and it **should become** in all those countries in the near future.
- **Transphorm** has currently a granted patent portfolio ( ) focused on with a significant presence in and . With **140+ patents currently in the pipeline**, **Transphorm** is currently the patent applicant. It is strengthening its IP position in **Japan** , **China** (31),
- **Furukawa** holds **granted patents** on GaN power semiconductor devices and is currently the main patent owners in **Japan**.
- **Power Integrations** holds **enforceable patents** on GaN power semiconductor devices ( ), mainly in **USA**, but with a significant presence in as well.
- **Asian** companies have a strong IP position in **USA** ( ) for patents related ton GaN power semiconductor devices, but they are practically non-existent in Europe.
- hold most of granted patents in Korea, but Korean companies (**Samsung**, **Seoul Semiconductor**, **LG**) have increased their patenting activity and are currently the main patent applicants on Korean territory.

SEMICONDUCTOR DEVICES

IP Collaboration Network

- Number in black on each link between patent assignees is the **number of co-assigned patent families** in the data set of the study. The minimum link size is 3 co-assigned patent families.
- Number up right to each bubble is the number of patent families for this applicant in the data set of the study. Bubble size is proportional to the number of patent families selected for the study.



SEMICONDUCTOR DEVICES

Summary of Main Assignees' Patent Portfolio

SAMPLE REPORT

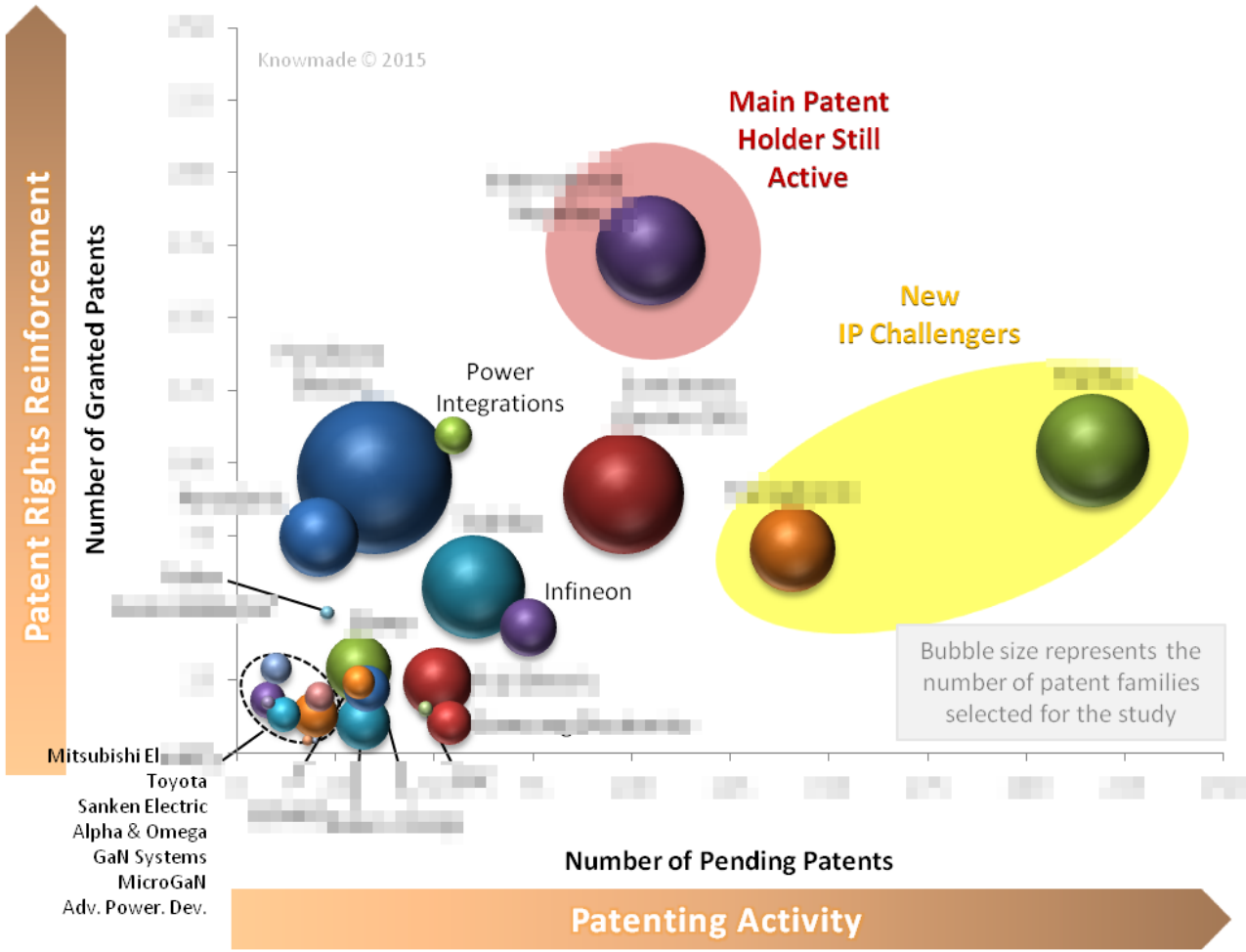
Patent Assignees	No. of patent families*	Oldest priority year of the patent portfolio	No. of patent families filed / year (average)	No. of alive patents (granted or pending)	Average size of patent families (No. of alive patents / family)	Average age of patent families (Year)	No. of patent families containing granted patents	No. of patent families containing pending patents	No. of dead patent families	No. of patent families containing granted patents in the corresponding country						No. of patent families containing pending patents in the corresponding country						
										US	EP	JP	KR	CN	TW	US	EP	JP	KR	CN	TW	PCT (WO)
	96	1998	6.0	130	1.4	7	61	30	19													
	75	2002	6.3	187	2.5	6	38	43	10													
										26		13	29	4	8	42	7	49	3	56	37	13
										47	8	27	8	7	8	31	30	16				17
										26		23	1			15	1	26	2	16		1
Transphorm		2007																				
		2000	3.5	95	1.9	7	31	20	6	28		21		3		4	1	8		3		15
		2003	3.9	75					5	10		12				11	5	16		8		9
		2006	5.1	60					8													
		2004	3.5	117					0													
		2006	4.1	42					5													
		2010	7.0	33					9													
		2011	9.3	55					0													
		2009	5.4	64					0													
Power Integrations																						

: highest value in column
: lowest value in column

** A patent family is a set of patents filed in multiple countries by a common inventor(s) to protect a single invention.*

SEMICONDUCTOR DEVICES

Leadership of Patent Assignees

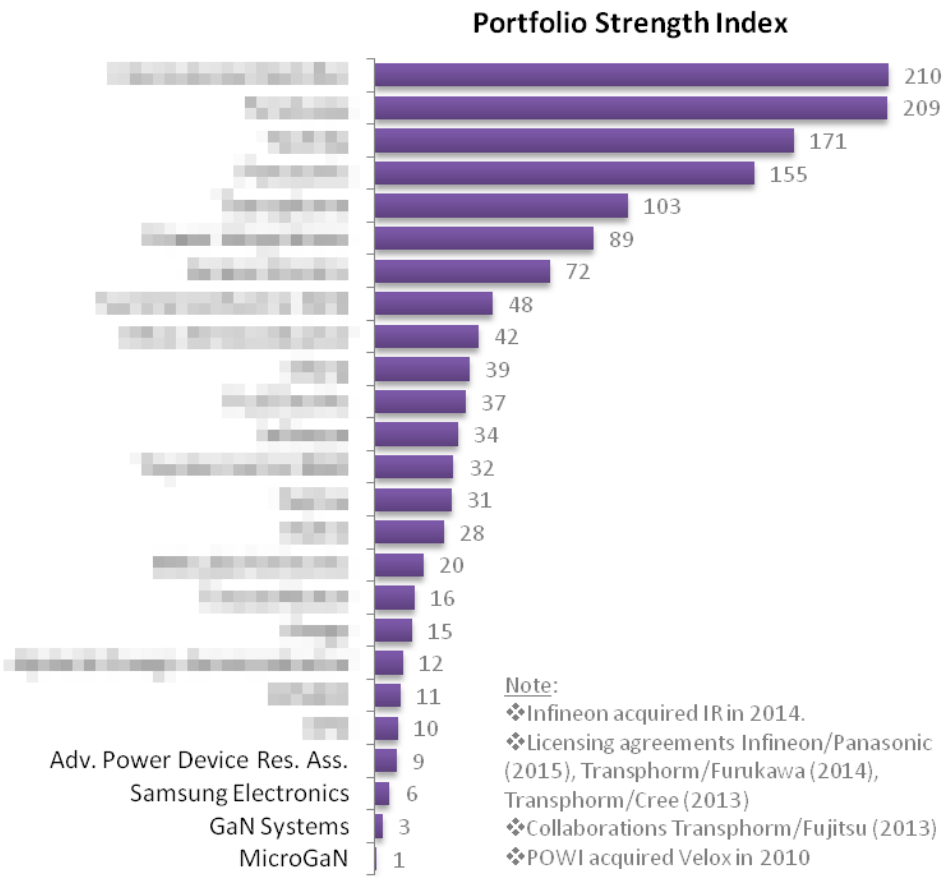


Notes: Infineon acquired IR in 2014 ; Licensing agreements Infineon/Panasonic (2015), Transphorm/Furukawa (2014), Transphorm/Cree (2013) ; Collaborations Transphorm/Fujitsu (2013) ; POWI acquired Velox in 2010.

- **International Rectifier** (acquired in 2014) has patents on devices. It is enforceable and it still activity (100+
- New challengers are becoming major forces in the IP landscape, expanding their patent portfolio with many new patent applications
- **Sumitomo Electric**, mainly focused on vertical devices, has a noticeable patenting activity associated with already granted patents giving it a sizeable IP significance in GaN power semiconductor devices.
- **Panasonic**, **Furukawa** and have a lesser current patenting activity but they are IP arena with a signifi patents on GaN devices.

SEMICONDUCTOR DEVICES

Strength Index of Patent Portfolios



Note:
- Infineon acquired IR in 2014.
- Licensing agreements Infineon/Panasonic (2015), Transphorm/Furukawa (2014), Transphorm/Cree (2013)
- Collaborations Transphorm/Fujitsu (2013)
- POWI acquired Velox in 2010

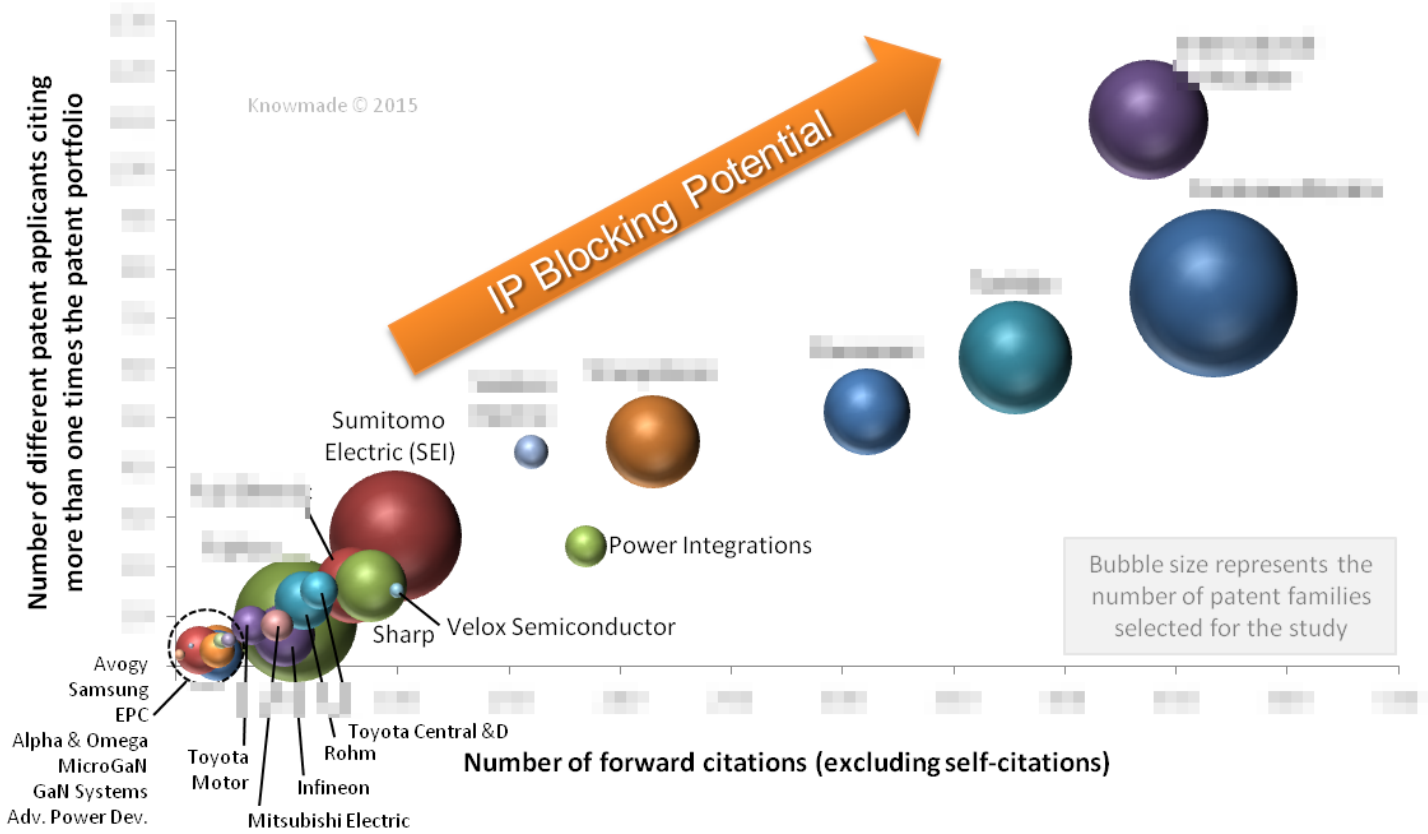
$$\text{Portfolio Strength Index} = \left[\text{No. of patent families}\right] \times \left[\frac{\text{citation ratio of patent families}}{\text{citation ratio over all "semiconductor devices" patent families}}\right]$$

International Rectifier and **Furukawa** [redacted] hold several "seminal" patents with a significant blocking potential for Power GaN IP players.
The patents of [redacted] receive 3 times more citations than the average of key IP players of this report.
[redacted] ee respectively in terms of portfolio [redacted] in terms of their portfolio strength index. Their patents get almost 4 times more citations than the average of key IP players of this report. Note that the patents from [redacted] receive 5 times more citations. These citations come mainly from Transphorm, Alpha & Omega, International Rectifier and Panasonic.
Sumitomo Electric and **Fujitsu** have a [redacted] and thus show [redacted] their large size of patent portfolio. **Sum**[redacted] on vertical devices, while **Fujitsu** sta[redacted] power semiconductor devices quite r[redacted] later than **Furukawa**.

In practice, only **IR**, **Transphorm**, **EPC** and **GaN Systems** have products on the market. [redacted] IP strength index of the [redacted] GaN market is still at its e[redacted]nking of the companies i[redacted], as most of them just be[redacted]

SEMICONDUCTOR DEVICES

IP Blocking Potential of Main Patent Assignees

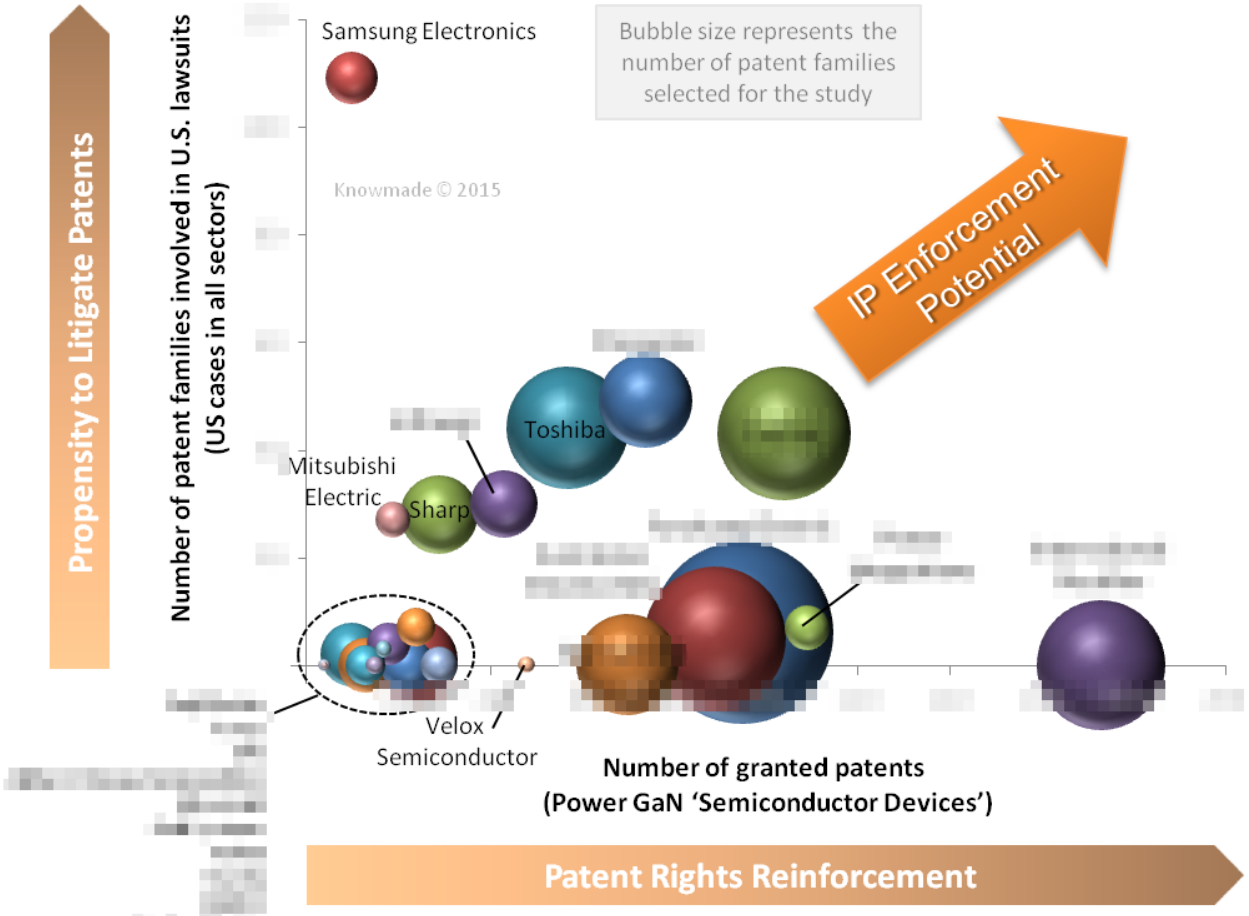


The more the number of forward citations from different patent applicants is high, the more the capacity to hamper the other firms' attempts to patent a related invention is important.
Note, however, that the identification of a "blocking patent" requires an in-depth specific analysis of each patent documents.

- **International Rectifier** (acquired by Infineon in 2014) relative impact factors and IP blocking potential. Their patents on GaN power semiconductor devices received
- **Toshiba** and **Panasonic** show **Transphorm**, **Power Integrations** and
- **Fujitsu** have blocking potential its patenting activity on GaN power semiconductor devices recently.

SEMICONDUCTOR DEVICES

Potential Future Plaintiffs



- To this date, [redacted] GaN domain h[redacted]
- **Samsung Elec**[redacted] US patents, bu[redacted] GaN power s[redacted] the company [redacted] patent in 2011
- **International** [redacted] semiconducto[redacted] patent portfol[redacted] the company [redacted] and its IP er[redacted] domain is thu[redacted] acquisition of [redacted] important pro[redacted]
- **Fujitsu** combi[redacted] its US patents [redacted] patents. Thus[redacted] future dangerc[redacted]
- **Furukawa** hol[redacted] "seminal" pate[redacted] to litigate its [redacted] given to Trans[redacted] GaN patent po[redacted]
- Power GaN d[redacted] less than 20 y[redacted] patents was [redacted] years. The G[redacted] power applica[redacted] be expected in[redacted]

SEMICONDUCTOR DEVICES

Granted Patents Near Expiration

SAMPLE REPORT

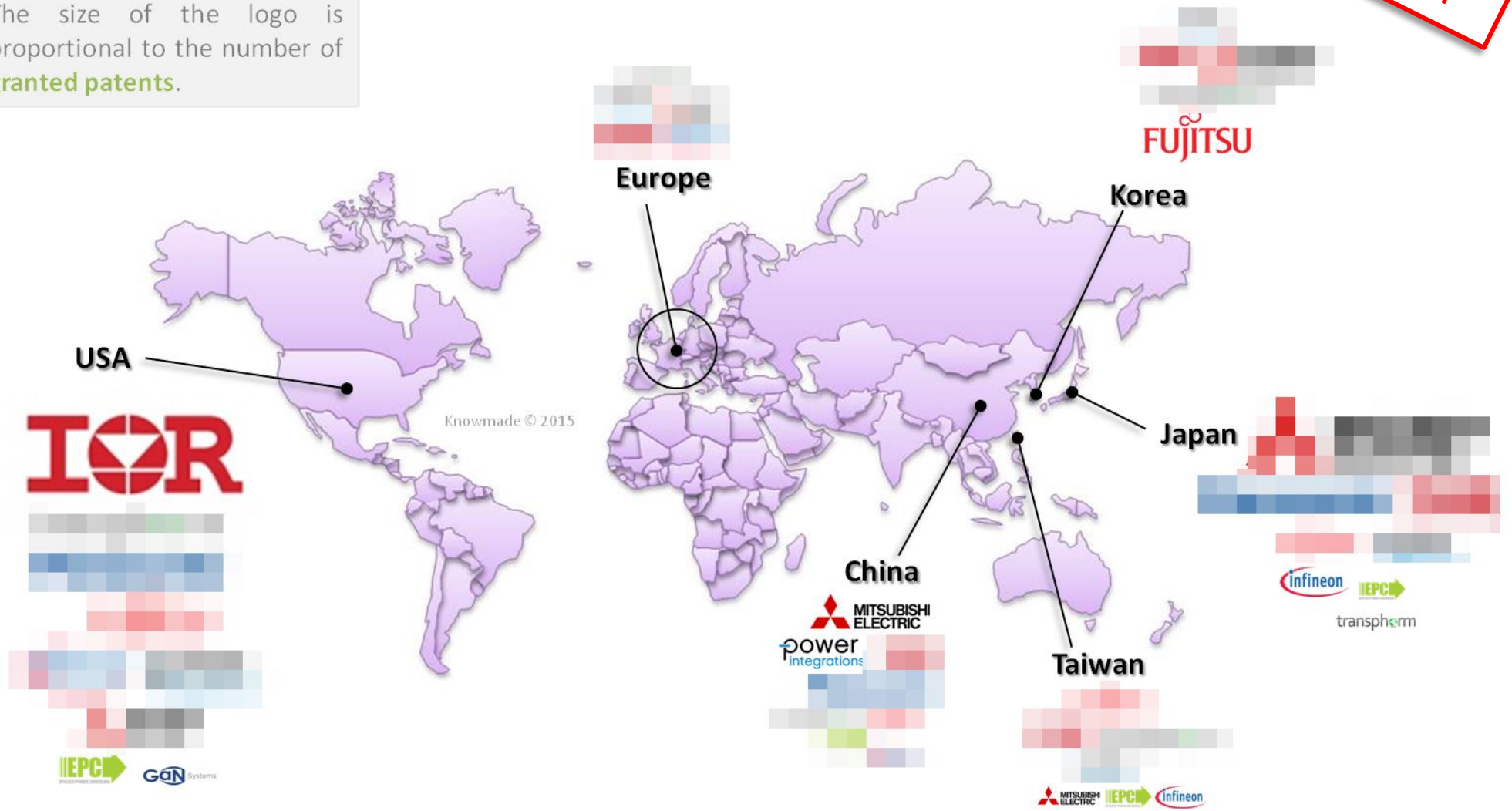
Title	Publication Number (Link to patent)	Current Patent Assignee(s)	Expected Expiration Date *
Compound semiconductor element resistible to high voltage.			2016-10-17
Controllable semiconductor structure for use instead of JFET, MESFET.			2016-10-29
		Cree from 2009 (former applicant: Daimler)	2017-09-17
		Daimler	2017-06-03
		Sony	2017-12-03
		Banque National de Paris from 1999 (former applicant: International Rectifier)	2018-01-14
		Daimler Cree from 2009 (former applicant: Daimler) Daimler	2018-05-22
Insulated gate type bipolar transistor and the production method			2018-06-10
Field-controlled high-power semiconductor devices			2018-06-10
High breakdown voltage resurf HFET			2018-08-12

** Expected Expiration Date is dependent on the accuracy and timeliness of the information provided by the patent offices. This indicator may change at any time without notice based on new information received from the patent offices. No decision should be made based solely on this indicators.*

FOCUS ON KEY POWER GAN PLAYERS

Mapping for Patents In-Force (granted)

The size of the logo is proportional to the number of granted patents.



FOCUS ON KEY POWER GAN PLAYERS

Geographical Distribution of Granted Patents and Pending Patents

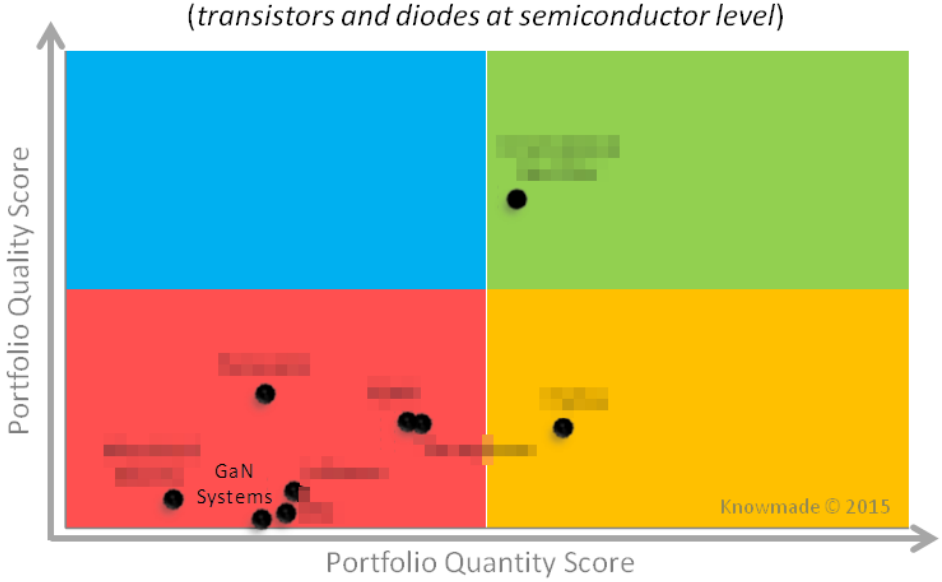
Patent Assignee	Patent Families	Alive Patents	Granted Patents	Number of granted patents in the corresponding country						Pending Patents	Number of pending patent applications in the corresponding country						
				USA	Europe	Japan	Korea	China	Taiwan		USA	Europe	Japan	Korea	China	Taiwan	PCT (WO)
[redacted]	[redacted]	75	19	9	0	4	0	4	2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	110	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	254	51	10	67	1	68	43	14
[redacted]	[redacted]	[redacted]	3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	17	2	2	2	2	1	1	4
[redacted]	[redacted]	[redacted]	56	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	141	35	51	2	1	46	0	6
[redacted]	[redacted]	[redacted]	234	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	177	68	61	27	0	0	1	20
[redacted]	[redacted]	[redacted]	159	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	315	39	51	72	7	56	1	71
[redacted]	[redacted]	242	103	50	0	42	0	11	0	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	195	83	35	6	16	4	12	7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	311	97	62	1	2	16	6	10	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

: highest value in column

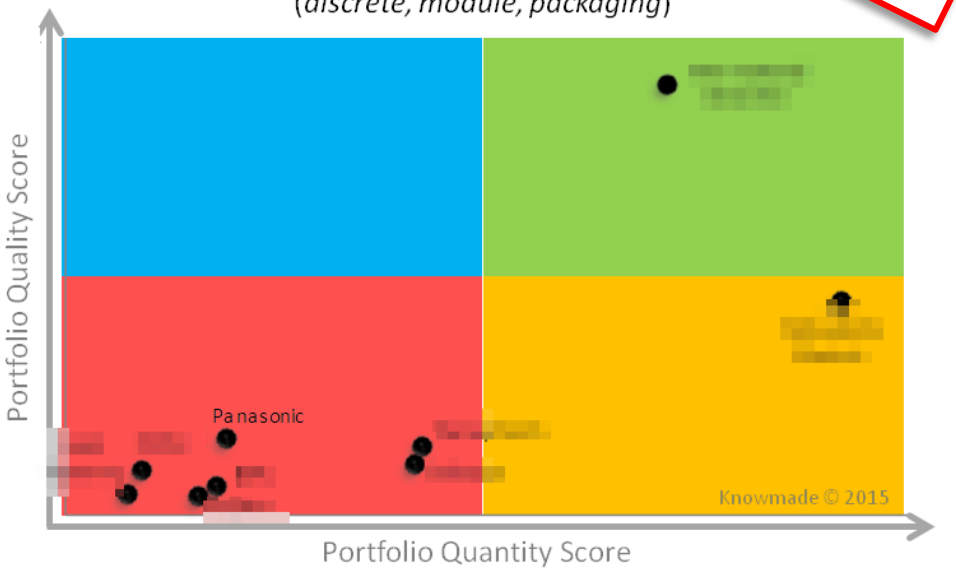
FOCUS ON KEY PLAYERS

Patent Portfolio Quantity/Quality Score*

GaN Power Semiconductor Devices
(*transistors and diodes at semiconductor level*)



GaN Power Components
(*discrete, module, packaging*)

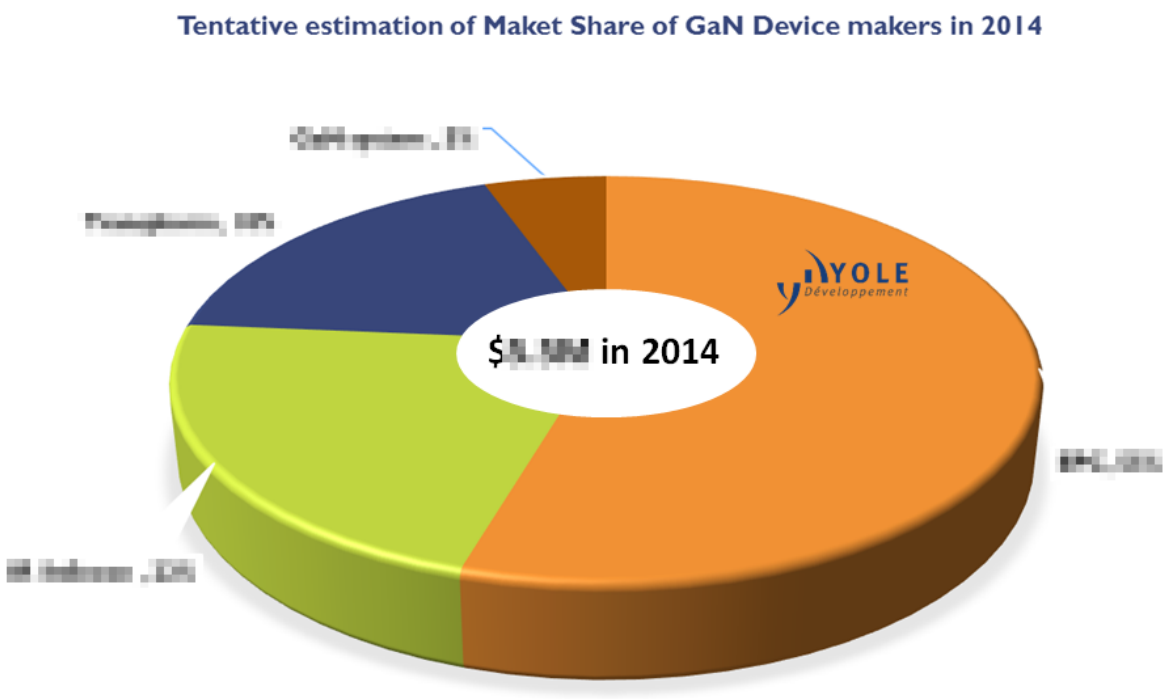


We use Knowmade's proprietary KQ2* framework to identify strength of patent portfolio in Power GaN domain. Figures above depict the competitive positioning of key Power GaN players, in segments "*Semiconductor Devices*" and "*Components*". The patent assignees are compared on the basis of **Quantity Score** and **Quality Score**. We use our proprietary algorithm based on bibliographical information of patents* to calculate and rank the patent portfolios.

- The green region comprises of the assignees with the best patent portfolios, which are exemplary in terms of quantity and quality of patents. [redacted] is the only assignee lying in the green domain. [redacted] best patent portfolio in area of Power GaN.
- [redacted] are the only assignees lying in the orange region for *Semiconductor Devices* and *Components* category respectively. Their patent portfolio lacks on quality because of [redacted]
- Most of the key Power GaN players form a cluster in the red region with patent portfolio lacking on both patent quantity and quality. Their patent portfolios may rise in future after successful prosecution of their pending patents and/or more citations added.

**See evaluation metrics for portfolio KQ2 score in Annex at the end of the report.*

TENTATIVE ESTIMATION OF MARKET SHARE OF GaN DEVICE MAK



- **IR/Infineon** supplies to specific clients only. **International Rectifier** has the best patent portfolio in Power GaN, and the **IR/Infineon** combined company has the strongest IP arm to front the growing of GaN power market.
- **Transphorm** is the most important IP challenger in the Power GaN area, ahead of other GaN start-ups like **EPC** and **GaN Systems**. Its patent portfolio and partnerships (Fujitsu, On Semiconductor) put it in a strong position to take a leading role in the GaN device market.
- **EPC** has a strong focus on low voltage (< 200 V) GaN while the others more focus on 600V devices.
- **Panasonic** has postponed their 600V devices in 2016

FINANCIAL INVESTMENT TO PURE GAN PLAYERS

In 2015, around **$100M** in investments have been made in different GaN startups, as indicated in the following [illegible] financing will enable these companies to ramp up in production and expand their sales and marketing activities for their fu[illegible] growth.

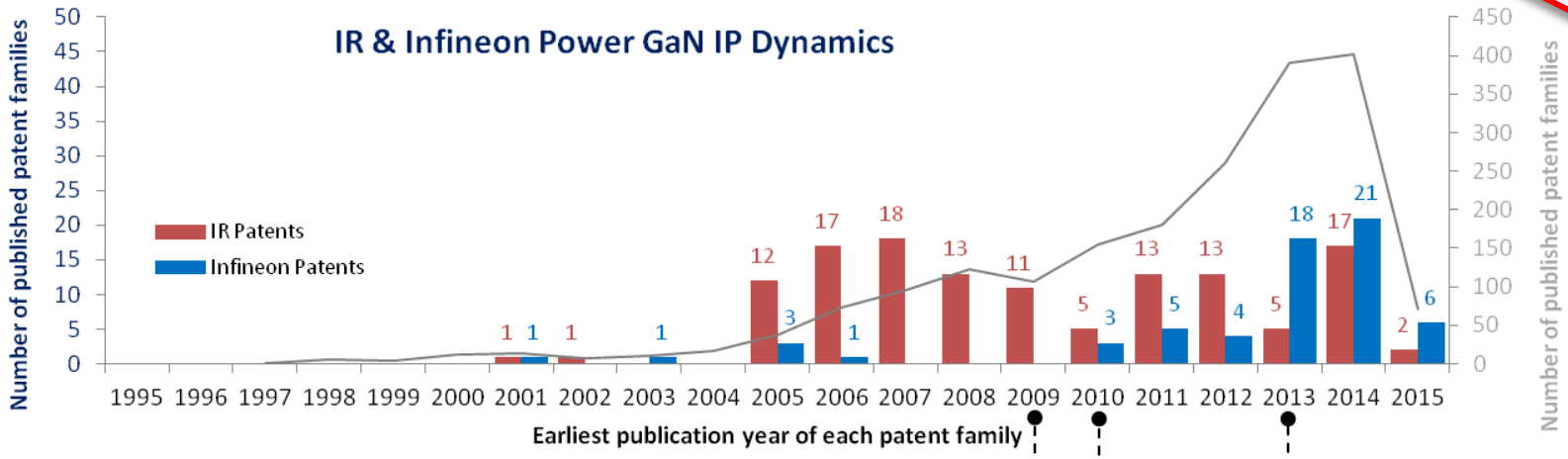
Yole Développement considers that **these investments reflect the confidence in the GaN device market and investors' willingness to provide funds to accelerate production capabilities.**

It is noteworthy to point out that **Transphorm** has received more than $220M in 9 rounds. This impressive investment may be largely related to its strong IP portfolio.

Company name	Investment	Date	Venture funds	Total investment	IP Situation
GaN Systems	$20M	May 2015	[illegible]	Series C, Series A & B: Undiscolased amount	[illegible]
Exagan	$6.3 M (€5.7M)	June 2015	[illegible]	First round	[illegible]
Transphorm	$70M	June 2015	[illegible]	Total investment $221.2M in 9 rounds	[illegible]

INTERNATIONAL RECTIFIER (IR) / INFINEON

IR acquired by Infineon in 2014



Note: Patent search was done in March 2015, thus the data corresponding to the year 2015 are not complete.

GaNpowerIR™ Gen 1.1

First GaN power device
iP2010 family

GaNpowerIR™ Gen 2.1
First Cascode 100V GaN product in mass production.

NeuLand project
(2010-2013)

HiPoSwitch project
(2011-2015)

- First patent applications : [redacted]
- Oldest priority year: [redacted]
- Patent average age: 6 years.
- IP collaboration: IP collaboration with [redacted] on patents related to [redacted] Patent rights of [redacted] (backside via for GaN devices) acquired from [redacted] in 2010.
- Main patent assignees cited by IR's patents: Panasonic, Toshiba, Cree.
- Main patent assignees citing IR's patents: Infineon, Fujitsu, Panasonic.

- [redacted]
- [redacted]
- [redacted]
- IP collaboration: Acquisition of IR in 2014. Note that this acquisition does not yet appear in patent databases. The re-assignment of patents should be reveal in the next months.
- Main patent assignees cited by Infineon's patents: International Rectifier, Toshiba, Cree.
- Main patent assignees citing Infineon's patents: Toshiba, National Semiconductor.

INTERNATIONAL RECTIFIER (IR) / INFINEON

IR acquired by Infineon in 2014

Power GaN Patent Portfolio's Features

[redacted] patents split in [redacted] patent families

[redacted] granted patents
Mainly in USA

[redacted] pending patents
Mainly in [redacted]

1350+ backward citations / 790+ forward citations

High Strength Index

[redacted]

[redacted] IP blocking potential

[redacted]

[redacted] IP enforcement potential

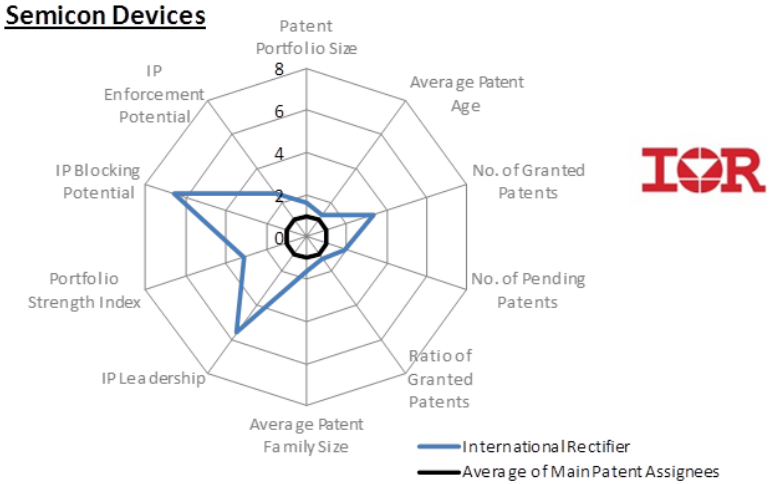
No propensity to litigate patents, as for now, but a [redacted]

Technology Level
Wafers
Semicon Devices
Components
Circuits & Systems

Technology Issues
[redacted]
E-mode (N-off)
Cascode (N-off)
E/D-mode Monolithic
Breakdown Voltage
Current Collapse
Dynamic R-on
Gate Charge (Miller Effect)
Stray Inductance Package
[redacted]

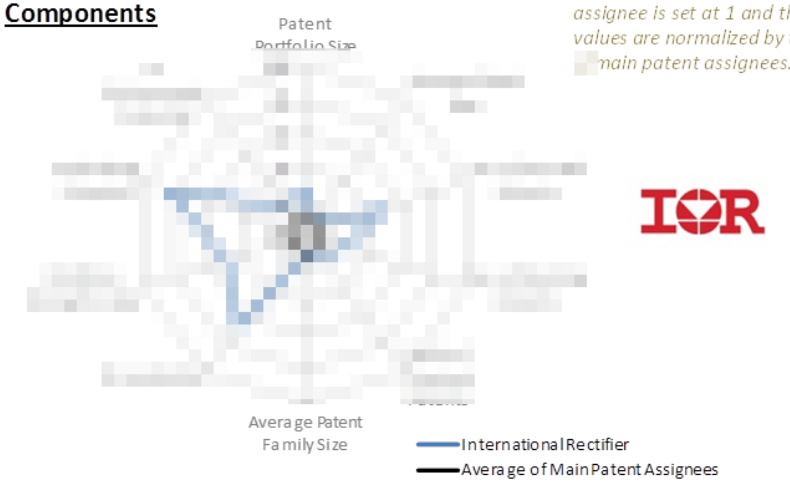
Substrate for GaN
GaN-on-SiC
GaN-on-Si
GaN-on-Sapphire
GaN Bulk

Semicon Devices



Components

Note that the average of main patent assignee is set at 1 and the company values are normalized by the average [redacted] main patent assignees.



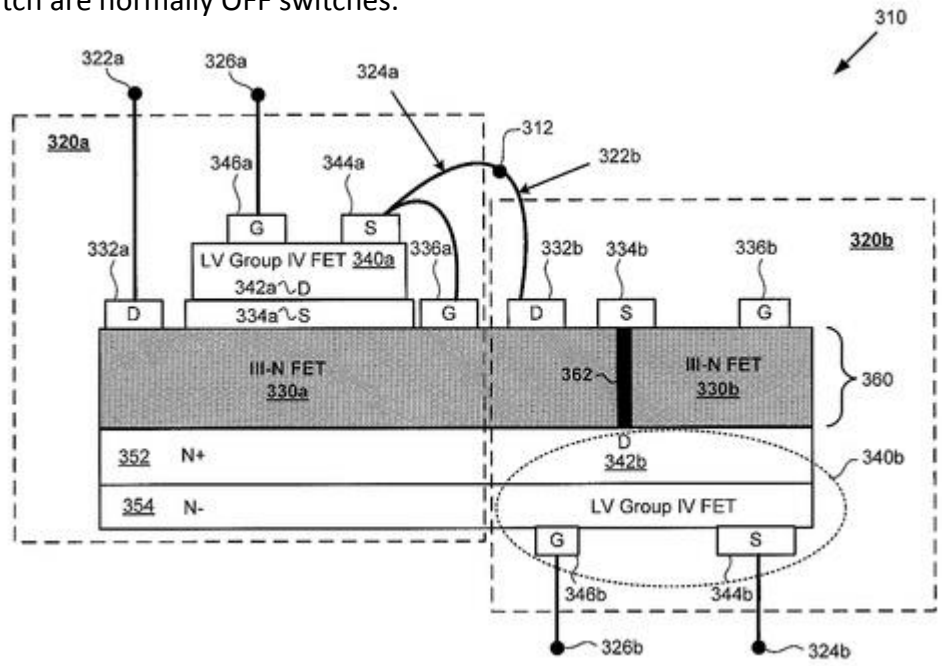
INTERNATIONAL RECTIFIER (IR) / INFINEON

Most Recent Patents

Integrated half-bridge circuit with low side and high side composite switches

US9041067 (2014). Counterparts filed in Europe and Japan.

There are disclosed herein various implementations of an integrated half-bridge circuit with low side and high side composite switches. In one exemplary implementation, such an integrated half-bridge circuit includes a III-N body including first and second III-N field-effect transistors (FETs) monolithically integrated with and situated over a first group IV FET. The integrated half-bridge circuit also includes a second group IV FET stacked over the III-N body. The first group IV FET (340a, 340b) is cascoded with the first III-N FET (330a, 330b) to provide one of the low side (320b) and the high side (320a) composite switches, and the second group IV FET (340a, 340b) is cascoded with the second III-N FET (330a, 330b) to provide the other of the low side (320b) and the high side (320a) composite switches. The first and second III-N FETs are normally ON FETs, and the low side composite switch and the high side composite switch are normally OFF switches.



INTERNATIONAL RECTIFIER (IR) / INFINEON

Most Recent Patents

Power transistor arrangement and method for manufacturing the same

US2014217596 (2013).

Counterparts filed in Germany and China.

Various embodiments provide a power transistor arrangement. The power transistor arrangement may include a carrier; a first power transistor having a control electrode and a first power electrode and a second power electrode; and a second power transistor having a control electrode and a first power electrode and a second power electrode. The first power transistor and the second power transistor may be arranged next to each other on the carrier such that the control electrode of the first power transistor and the control electrode of the second power transistor are facing the carrier.

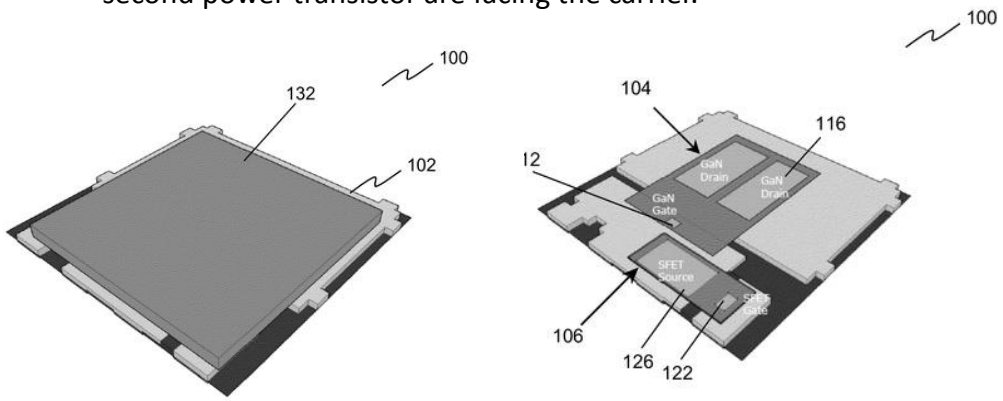
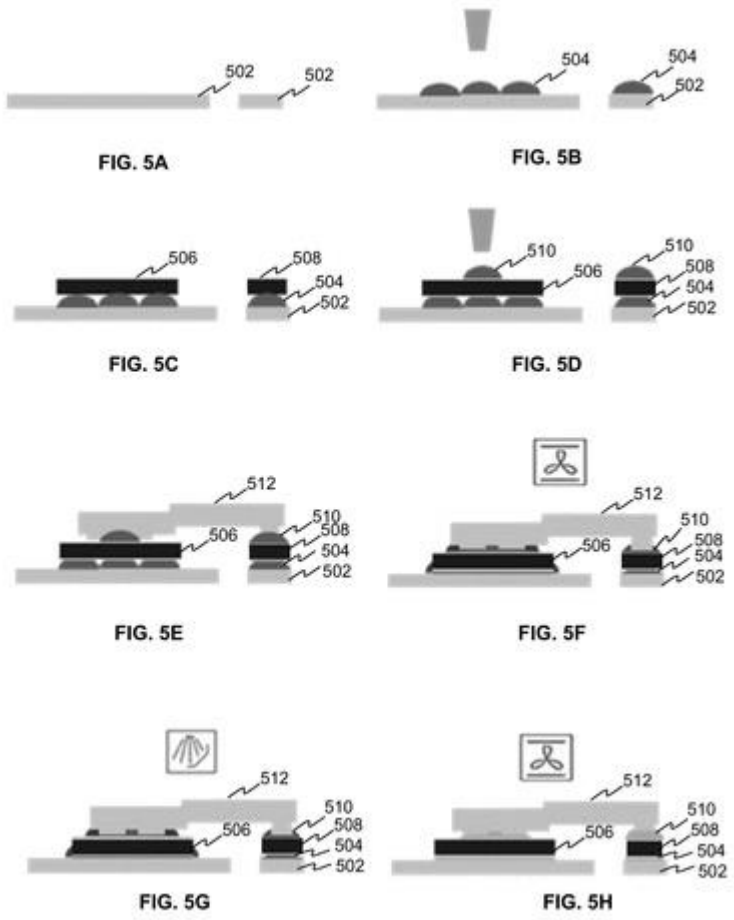


FIG. 2



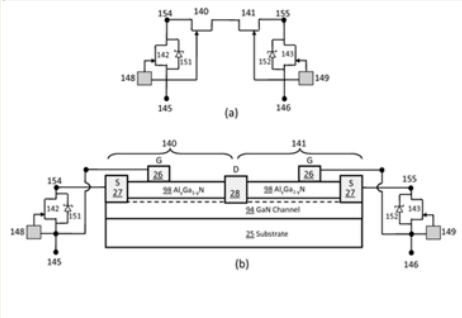
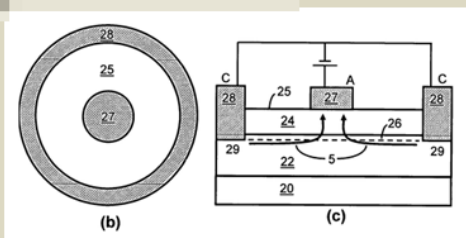
TRANSPHORM / TRANSPHORM JAPAN

Noteworthy News

- **June 2015**, Transphorm raised $70M, leading to $221.2M in total (read more).
- **Mar 2015**, Transphorm announces industry's first 600V GaN transistor in a TO-247 package (read more).
- **Mar 2015**, Transphorm and ON Semiconductor announced the start of production of co-branded GaN power devices (read more).
- **Feb 2015**, Transphorm's key partner Yaskawa Electric launches the mass production of 4.5 kW residential PV inverters with GaN power module, based on Transphorm's EZ-GaN™ platform (read more).
- **Jan 2015**, Transphorm and Fujitsu Semiconductor announce the start of mass production of Transphorm's GaN power devices (read more).
- **Sept 2014**, ON Semiconductor and Transphorm partner to deliver GaN-based power system solutions with industry leading energy efficiency (read more).
- **Aug 2014**, Transphorm partners with Tata Power Solar on India's most-efficient PV inverter. Under the partnership, Transphorm will supply GaN transistors, while Tata Power Solar will locally manufacture and market the GaN-powered solar inverters. The first PV Inverter product is scheduled to be released in early 2015 (read more).
- **May 2014**, Transphorm obtains exclusive licensing rights to Furukawa Electric's GaN patent portfolio (read more).
- **Dec 2013**, Transphorm acquires Fujitsu's GaN Power Conversion business, and the two companies announced the formation of a new company: Transphorm-Japan, a wholly-owned subsidiary of Transphorm (read more).
- **Nov 2013** Transphorm and Fujitsu to Integrate GaN Power Device Businesses (read more).
- **Nov 2013**, Transphorm's 600V GaN Power Conversion Adopted by Delta Electronics (read more).
- **Aug 2013**, Cree announced that it signed a non-exclusive worldwide patent license agreement with Transphorm that provides access to Cree's extensive family of patents related to GaN HEMT and GaN Schottky diode devices for use in the field of power conversion devices (read more).
- **Mar 2013**, Transphorm scales up to 200 mm wafers with AIX G5+ GaN-on-Si system from AIXTRON (read more).
- **Feb 2013**, Transphorm teams with Yaskawa to implement its new 600V GaN half-bridge module a in 4.5kW PV power conditioner (read more).
- **Feb 2013**, Transphorm enables the world's first GaN-based high power converter (read more).

TRANSPHORM / TRANSPHORM JAPAN

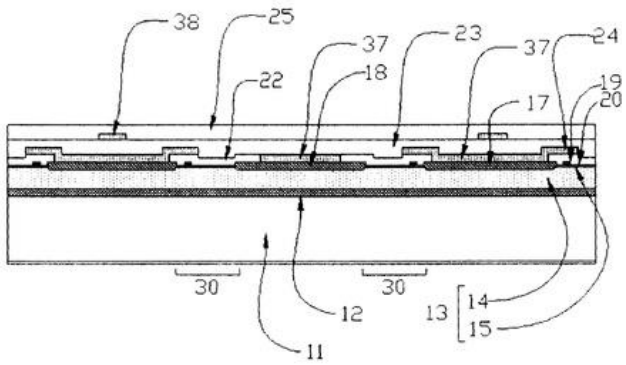
Key Patents

KEY PATENT FAMILY Patent number (representative member of the patent family), earliest application date, title and principal drawing	KEY FEATURES
III-nitride bidirectional switches US7875907 (2008) 	• Matrix converter technology is enabled by these bidirectional switch designs. Matrix conversion directly converts AC to AC, thus eliminating the need for a large DC filter capacitor. The matrix converter is composed of a set of bidirectional switches, thus permitting both generation and motoring using the same set of switches.Further, the matrix converter permits an optimized power factor and harmonic content of input currents and three-level voltage switching for reduced voltage stress. • The switches haveimproved performance, e.g., lower loss, smaller size system, and fewer components over conventional devices and allow for very compact designs of high power circuits. • Patents filed in USA, Europe and Japan via a PCT application. • Patents granted in USA and Europe. • 39 forward citations from Panasonic, Infineon, International Rectifier …
[redacted] 	• Large source to drain barrier in the off state, low off state leakage, and low channel resistance in the access regions. • Patents filed in USA, China and Taiwan via a PCT application. • Patents granted in USA and Taiwan. • More than 60 forward citations from Fujitsu, International Rectifer, Infineon, Samsung …
[redacted] 	• Planar Schottky dioc[redacted] currents. • Patents filed in USA, [redacted] • 6 granted patents (US[redacted]) • More than 60 forwar[redacted]

High density gallium nitride devices using island topology

US8791508 (2011). Counterpart filed in Canada, China, Europe, Japan and Korea.
Patent granted in Canada since Nov. 2013 and in USA since Jul. 2014.

A Gallium Nitride (GaN) series of devices—transistors and diodes are disclosed—that have greatly superior current handling ability per unit area than previously described GaN devices. The improvement is due to improved layout topology. The devices also include a simpler and superior flip chip connection scheme and a means to reduce the thermal resistance. A simplified fabrication process is disclosed and the layout scheme which uses island electrodes rather than finger electrodes is shown to increase the active area density by two to five times that of conventional interdigitated structures. Ultra low on resistance transistors and very low loss diodes can be built using the island topology. Specifically, the present disclosure provides a means to enhance cost/effective performance of all lateral GaN structures.



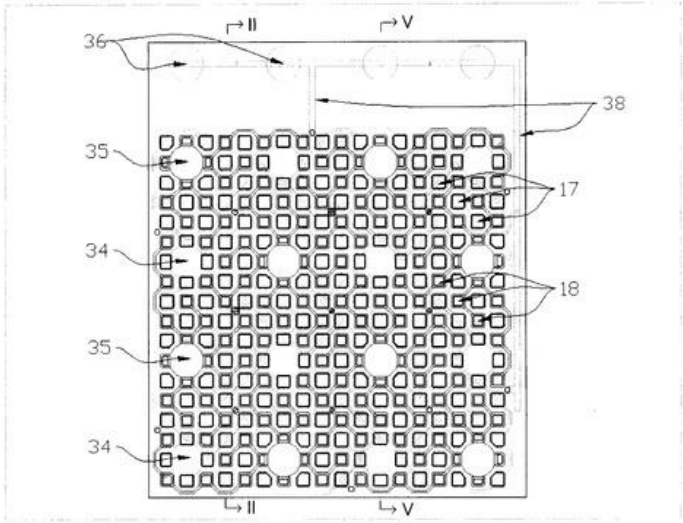


FIG. 1

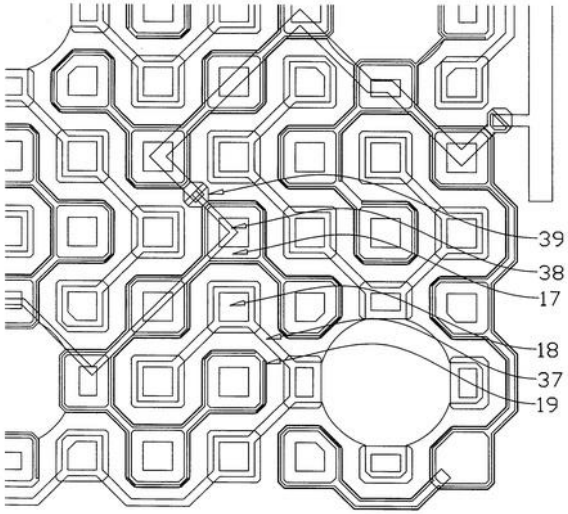


FIG. 4A

ORDER FORM

GaN Devices for Power Electronics: Patent Investigation (September 2015)

SHIP TO

Name (Mr/Ms/Dr/Pr):
_____

Job Title:
_____

Company:
_____

Address:
_____

City:
_____

State:
_____

Postcode/Zip:
_____

Country:
_____

VAT ID Number for EU members:
_____

Tel:
_____

Email:
_____

Date:
_____

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

KnowMade S.A.R.L.
2405 route des Dolines, BP 65
06902 Valbonne Sophia Antipolis
FRANCE

Money Transfer

To pay your invoice using a bank money wire transfer please contact your bank to complete this process. Here is the information that you will need to submit the payment:

Payee: KnowMade S.A.R.L.
Bank: Banque populaire St Laurent du Var CAP 3000 - Quartier du lac- 06700 St Laurent du Var
IBAN: FR76 1560 7000 6360 6214 5695 126
BIC/SWIFT: CCBPFRPPNCE

Paypal

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Mail: KnowMade S.A.R.L. 2405 route des Dolines, 06902 Sophia Antipolis, FRANCE

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Terms and Conditions of Sales

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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.

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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.

Terms and Conditions of Sales

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 St Laurent du Var CAP 3000 - Quartier du lac- 06700 St Laurent du Var

BIC or SWIFT code: CCBPFRPPNCE

IBAN: : FR76 1560 7000 6360 6214 5695 126

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.

Terms and Conditions of Sales

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.