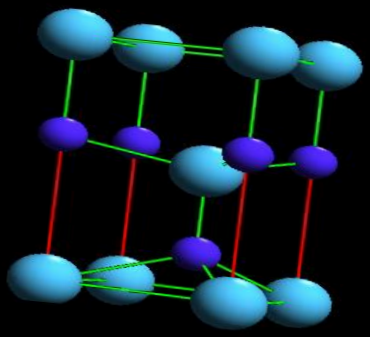
GRIDLOGICS



Gallium Nitride Technology Insight Report

This report covers patent analysis on all patents and applications published over last 10 years (2004 – 2014) in US covering the use of Gallium Nitride

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Introduction

GaN is a binary III-V direct bandgap semiconductor commonly used in LEDs. Its wide-band gap of 3.4 eV affords its special properties for applications in optoelectronic, high-power and high-frequency devices. Because GaN offers very high breakdown voltages, high electron mobility, and saturation velocity it is also an ideal candidate for high-power and high-temperature microwave applications like RF power amplifiers at microwave frequencies and high-voltage switching devices for power grids. Solutions that use GaN-based RF transistors are also replacing the magnetrons used in microwave ovens.

Gallium Nitride (GaN) transistor models have evolved from GaAs (gallium arsenide) transistor models; however there are many advantages GaN offers:

- Higher operating voltage (over 100-V breakdown)
- Higher operating temperature (over 150°C channel temperature)
- Higher power density (5 to 30 W/mm)
- Durable and crack-resistant material

GaN devices are often grown on SiC (silicon carbide) substrates, but to achieve lower-cost GaN devices, they can be grown on sapphire and silicon wafers. GaN's wide bandgap allows for higher breakdown voltages and operation at high temperatures. The high thermal conductivity of SiC makes it a better substrate than silicon for power amplifier applications that require good heat sinking.

It is very hard, mechanically stable wide bandgap semiconductor material with high heat capacity and thermal conductivity. In its pure form it resists cracking and can be deposited in thin film on sapphire or silicon carbide, despite the mismatch in their lattice constants.GaN can be doped with silicon (Si) or with oxygen to n-type and with magnesium (Mg) to p-type; however, the Si and Mg atoms change the way the GaN crystals grow, introducing tensile stresses and making them brittle. Gallium nitride compounds also tend to have a high spatial defect frequency, on the order of a hundred million to ten billion defects per square centimeter.

This report covers:

- Overview of top companies involved in applications of gallium nitride and their publication trend
- Focus on crystal structures, applications and physical properties of gallium nitride
- Trends for different applications of gallium nitride and their patent activity
- Analyzing key companies within gallium nitride

Patent Search Strategy

Using PatSeerfollowing searchquerywas usedto create patent set.

TAC– Title, Abstract, ClaimsPBC– Publication Country
PBY – Publication Year UC-US Classification

TAC:((Gallium wd1 Nitride*) or "GaN" or "III/V semiconductor")

AND

PBC:US

AND

PBY:[2004 TO 2014]

AND

UC:(257* or 438* or 372* or 117*)

Definitions to US Classifications

257	Active Solid-State Devices (e.g., Transistors, Solid-State Diodes)
438	Semiconductor Device Manufacturing: Process
372	Coherent Light Generators
117	Single-crystal, oriented-crystal, and epitaxy growth processes; non-coating apparatus therefor

- The query was directed to search through title, abstract and claims and was limited to US publications published during last 10 years
- Result set of 7888 records with one publication per family (INPADOC Families) was generated and imported in Patent iNSIGHT Pro

The publications included in the report are updated as of 6th September, 2014

Technical Segmentation (Patent Categories)

Crystal Structure	Applications	Physical Properties
• Rock Salt • Wurtzite • Zinc -Blende	• Amplifiers • Artificial Lighting • Automobile • Aviation • Biological Sensors • Blue Lighting • Blue Ray • Clean Energy • Defence • Detector • Displays • Flash Memory • Food • Fuel Cells • High Electron Mobility Transistor • High Resolution Printing • Hybrid Vehicle • Inverter • Laser Diodes • Laser Printer • LED • MMIC • Mobile Phone • Modulator • MOSFET • Nanotech for Medicines • Nanotubes • Optoelectronics • Photodiode • Radar • Satellite Communication • Solar Cells • Thin Film Batteries	• Metalorganic CVD • N-Type • P-Type

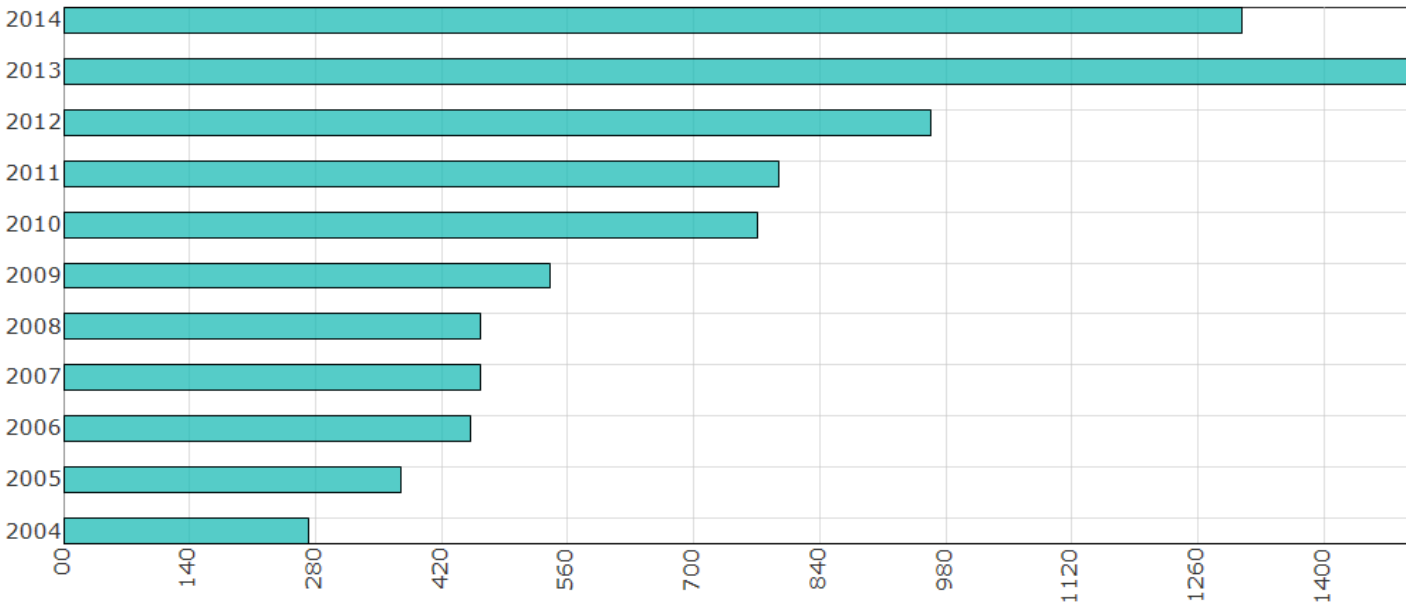
The categorization involved defining a search strategy for each topic and then conducting the search using the Advanced Searching capability in Patent iNSIGHT Pro. Details of search strings used for each category are given in Appendix.

IP Analysis

Publication Trend

It can be seen that publications for GaN are constantly rising from 2009 with the real surge in the activity around this technology has happened since 2012.

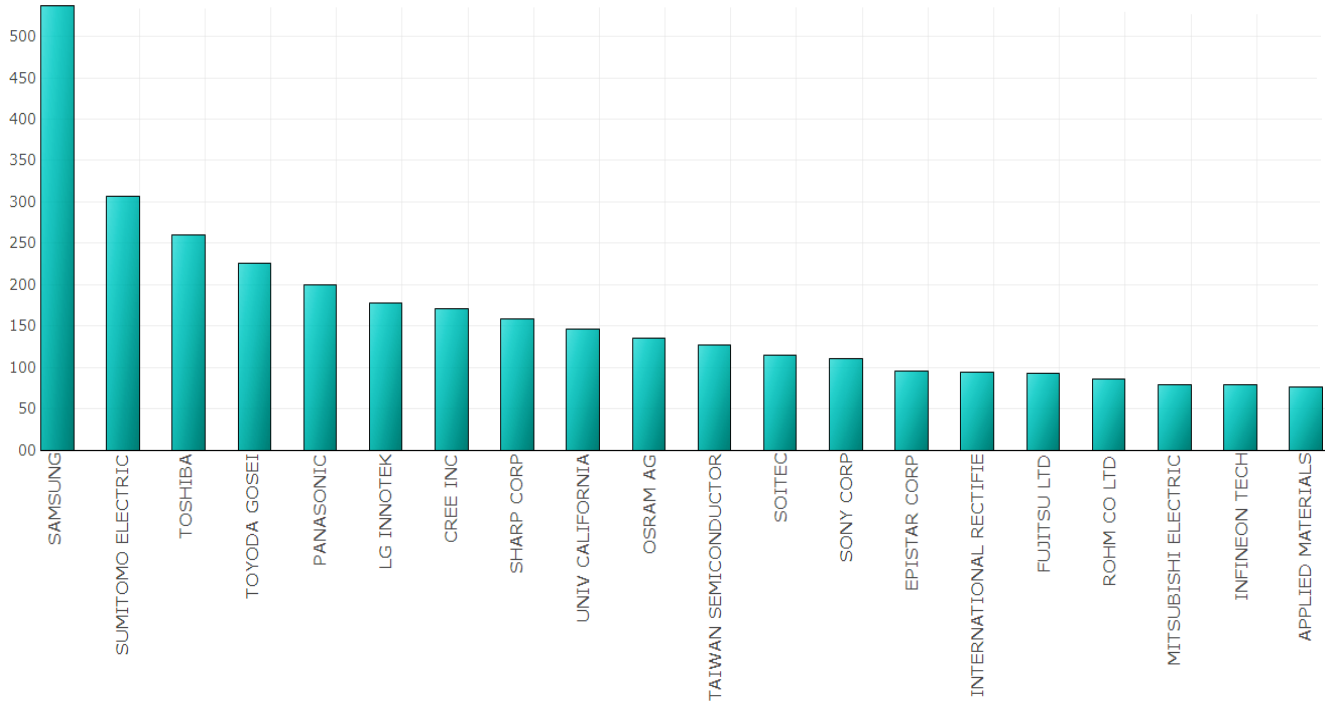
It's clear the current activity around these technologies is likely to continue seeing more innovation in the near future.



How we did it?

Once the patents were populated in Patent iNSIGHT Pro, the publication trend chart was generated on a single click using the dashboard tool.

Top Companies



Note: Records for Matsushita Electrical Ind Co Ltd have not been grouped with Panasonic Corp in spite of their merger with Panasonic, as some of the patents owned by both these companies have not been transferred to a single company.

The top organizationsare:

1. SAMSUNG GROUP
2. SUMITOMO ELECTRIC IND CO LTD
3. TOSHIBA CORP
4. TOYODA GOESI CO LTD
5. PANASONIC CORP
6. LG INNOTEK CO LTD
7. CREE INC
8. SHARP CORP
9. UNIV CALIFORNIA
10. OSRAM AG
11. TAIWAN SEMICONDUCTOR MFG LTD
12. SOITEC
13. SONY CORP
14. EPISTAR CORP
15. INTERNATIONAL RECTIFIER CORP
16. FUJITSU LTD
17. ROHM CO LTD
18. MITSUBISHI ELECTRIC CORP
19. INFINEON TECHNOLOGIES AG
20. APPLIED MATERIALS INC

How we did it?

Once the patents were populated in Patent iNSIGHT Pro, the assignee clean- up tools were used to normalize the names. Different cleanup tools were leveraged:

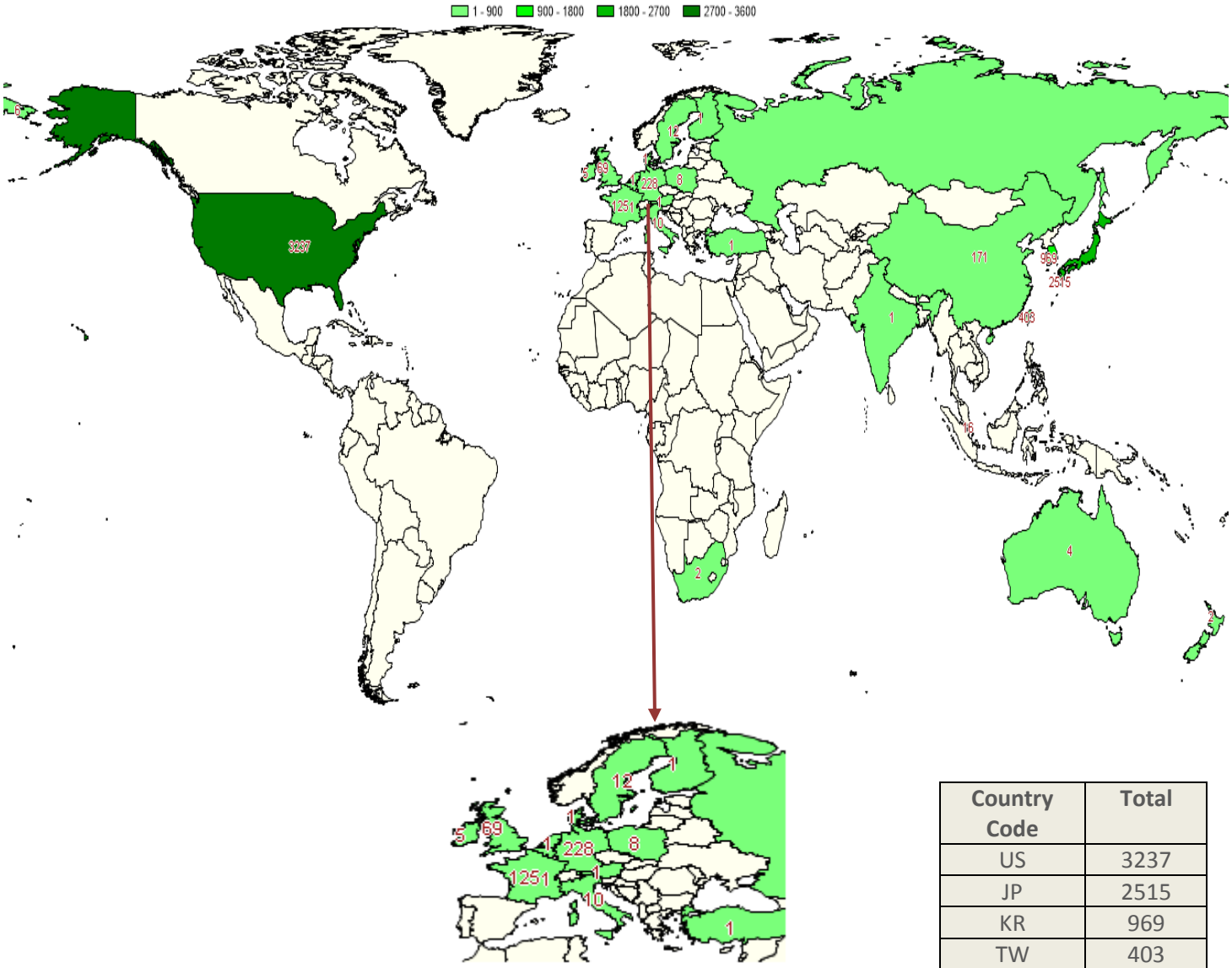
- To locate assignees for unassigned records
- To clean up records having multiple assignees
- To locate the correct assignee names for US records using the US assignments database
- To merge assignees that resulted from a merger or acquisition or name change.

The dashboard tool within Patent iNSIGHT Pro was used to find the top 20 assignees within the given patent set. A visual graph was created based on the results of the top assignees with the number of patents alongside each one. Thecomplete Assignee table in available in the following Excel file:
http://www.patentinsightpro.com/techreports/0914/List%20of%20Assignees.xls

Research activity around world

In terms of regional pockets where patent protection is being sought most frequently for these technologies, USleads the count, followed by the JPand KR.

The table below ranks top priority countries and helps provide an indication of where innovation in this area is originating:



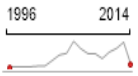
Country Code	Total
US	3237
JP	2515
KR	969
TW	403
DE	228

How we did it?

The map was generated using the Priority country coverage map option provided in the dashboard tool within Patent iNSIGHT Pro.

Companies - Key Statistics

Here we summarize key parameters of Top 15 companies such as filing trend, Top inventors in each company and Coverage of underlying patent families

Assignee	Total No. of Records	Filing Trend (Absolute)	Filing Year Range	Key Inventor (Top 5)	Co-Assignees	Coverage (Includes families)									
						US	WO	JP	DE	FR	CN	AU	CA	KR	IN
SAMSUNG GROUP	538 (6.8%)		1999-2014	LEE JAE HOON(41) OH JAE-JOON(23) JANG EUN JOO(21) SHIN JAI-KWANG(21) KIM JE WON(19)	JUN SHIN AE(1) KUMOH NAT INST TECH(1)	535	12	291	30	1	150	2	1	476	0
SUMITOMO ELECTRIC IND CO LTD	307 (3.9%)		2003-2014	UENO MASAKI(71) KYONO TAKASHI(60) YOSHIZUMI YUSUKE(58) AKITA KATSUSHI(56) ENYA YOHEI(47)	SONY CORP(2) SHARP CORP(1) TOYODA GOSEI CO LTD(1)	307	137	266	23	0	204	1	30	148	0
TOSHIBA CORP	261 (3.3%)		2001-2014	NUNOUE SHINYA(55) TACHIBANA KOICHI(22) TANAKA AKIRA(17) HIKOSAKA TOSHIKI(16) NAGO HAJIME(16)	SANDISK 3D LLC(1)	261	44	222	3	0	62	0	1	52	0
TOYODA GOSEI CO LTD	226 (2.9%)		1996-2014	MIKI HISAYUKI(32) SHIBATA NAOKI(21) OKUNO KOJI(18) NAGAI SEIJI(16) YAMAZAKI SHIRO(15)	LEUCHSTOFF BREITUNGEN GMBH(1) LITEC GBR(1) SUMITOMO ELECTRIC IND CO LTD(1) TRIDONIC OPTOELECT	225	86	154	20	0	89	8	0	51	1

					RONICS GMBH(1)									
PANASONIC CORP	201 (2.5%)		2001-2014	UEDA TETSUZO(57) YOKOGAWA TOSHIYA(56) KATO RYOU(21) TANAKA TSUYOSHI(20) YAMADA ATSUSHI(18)	No Co-Assignee Present	201	119	139	4	0	100	1	0	15	4
LG INNOTEK CO LTD	178 (2.3%)		2002-2014	SONG JUNE O(16) SON HYO KUN(15) LEE SUK HUN(13) JEONG HWAN HEE(13) KANG DAE SUNG(9)	No Co-Assignee Present	177	63	54	10	0	107	7	5	151	9
CREE INC	172 (2.2%)		2002-2014	SAXLER ADAM WILLIAM(23) WU YIFENG(16) PARIKH PRIMIT(13) BERGMANN MICHAEL JOHN(12) SHEPPARD SCOTT T(11)	No Co-Assignee Present	171	111	107	23	0	58	18	39	53	7
SHARP CORP	159 (2%)		2000-2014	ITO SHIGETOSHI(21) KAMIKAWA TAKESHI(19) TSUDA YUHZOH(14) HEFFERNAN JONATHAN(13) HOOPER STEWART EDWARD(13)	SUMITOMO ELECTRIC IND CO LTD(1)	159	38	115	3	0	70	5	0	12	2
UNIV CALIFORNIA	147 (1.9%)		2001-2014	DENBAARS STEVEN P(71) NAKAMURA SHUJI(69) SPECK	JAPAN SCIENCE & TECH AGENCY(10)	147	113	61	0	0	26	13	7	49	2

				JAMES(54) MISHRA UMESH K(23) SATO HITOSHI(10)											
OSRAM AG	136 (1.7%)		2000-2013	HAERLE VOLKER(40) HAHN BERTHOLD(27) STRAUSS UWE(18) EISERT DOMINIK(17) LELL ALFRED(11)	FREIBERGER COMPOUND MATERIALS GMBH(1)	136	102	108	110	1	78	1	3	58	0
TAIWAN SEMICONDUCTOR MFG LTD	128 (1.6%)		2004-2014	YU CHUNG-YI(22) CHEN CHI-MING(21) YU JIUN-LEI JERRY(18) YAO FU-WEI(17) CHEN DING-YUAN(16)	No Co-Assignee Present	122	3	9	3	0	80	0	0	22	0
SOITEC	115 (1.5%)		2003-2014	ARENA CHANTAL(25) LETERTRE FABRICE(24) GHYSELEN BRUNO(17) FAURE BRUCE(14) WERKHOVEN CHRISTIAAN J(10)	COMMISSARIAT A LENERGIE ATOMIQUE (2)	115	62	56	15	48	56	4	0	52	0
SONY CORP	111 (1.4%)		2000-2014	OKUYAMA HIROYUKI(20) BIWA GOSHI(19) OOHATA TOYOHARU(18) DOI MASATO(15) KURAMOTO MASARU(14)	SUMITOMO ELECTRIC IND CO LTD(2) UNIV TOHOKU(2) SONY SHIROISHI SEMICONDUCTOR INC(1)	111	21	99	6	0	61	3	1	33	0
EPISTAR CORP	96 (1.2%)		1999-2014	HSIEH MIN-HSUN(24) YAO CHIU-LIN(9)	No Co-Assignee Present	96	0	24	15	0	4	0	0	7	0

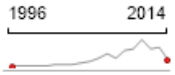
				HSU TA-CHENG(9) LIU WEN-HUANG(9) OU CHEN(9)											
INTERNATIONAL RECTIFIER CORP	95 (1.2%)		2001-2014	BEACH ROBERT(22) BRIERE MICHAEL A(21) BRIDGER PAUL(9) KINZER DANIEL M(6) PINER EDWIN L(6)	No Co-Assignee Present	95	33	52	17	1	6	2	0	7	0

How we did it?

From the Assignee 360° report options, we selected Top 15 Assignees and the different pieces of information we wanted to include in the singular display and then ran the report. The generated report was then exported to Excel using the option provided for the same.

Inventor - Key Statistics

Here we summarize key parameters of Top 15 Inventors such as filing trend, key associated companies and top 5 co-inventors.

Inventor	Total No. of Records	Filing Trend (Absolute)	Filing Year Range	Key Assignees (Top 5)	Co-Inventors
NAKAMURA SHUJI	91 (1.2%)		2001-2014	UNIV CALIFORNIA(69) JAPAN SCIENCE & TECH AGENCY(13) NICHIA CORP(8) CREE INC(5) SORAA INC(3)	DENBAARS STEVEN P(67) SPECK JAMES(47) SATO HITOSHI(11) FEEZELL DANIEL F(10) IZA MICHAEL(9)
DENBAARS STEVEN P	76 (1%)		2005-2014	UNIV CALIFORNIA(71) JAPAN SCIENCE & TECH AGENCY(9) CREE INC(2) BAKER TROY J(1) DENBAARS STEVEN P(1)	NAKAMURA SHUJI(67) SPECK JAMES(48) SATO HITOSHI(10) IZA MICHAEL(9) MISHRA UMESH K(9)
UENO MASAKI	71 (0.9%)		2004-2014	SUMITOMO ELECTRIC IND CO LTD(71) SONY CORP(1)	YOSHIZUMI YUSUKE(51) ENYA YOHEI(45) KYONO TAKASHI(44) SUMITOMO TAKAMICHI(32) AKITA KATSUSHI(25)
UEDA TETSUZO	66 (0.8%)		2000-2014	PANASONIC CORP(57) MATSUSHITA ELECTRICAL IND CO LTD(9) CBL TECHNOLOGIES INC(1)	UEDA DAISUKE(15) HIKITA MASAHIRO(14) TANAKA TSUYOSHI(14) UEMOTO YASUHIRO(10) TAKIZAWA TOSHIYUKI(8)
YOKOGAWA TOSHIYA	64 (0.8%)		2002-2014	PANASONIC CORP(56) MATSUSHITA ELECTRICAL IND CO LTD(8)	KATO RYOU(21) YAMADA ATSUSHI(19) INOUE AKIRA(18) FUJIKANE MASAKI(13) ISHIBASHI AKIHIKO(13)

SPECK JAMES	63 (0.8%)		2005-2014	UNIV CALIFORNIA(54) JAPAN SCIENCE & TECH AGENCY(9) SORAA INC(5) SEOUL VIOSYS CO LTD(1) SEOUL SEMICONDUCTOR CO LTD(1)	DENBAARS STEVEN P(48) NAKAMURA SHUJI(47) TYAGI ANURAG(8) HASKELL BENJAMIN A(7) MISHRA UMESH K(7)
KYONO TAKASHI	60 (0.8%)		2004-2012	SUMITOMO ELECTRIC IND CO LTD(60) SONY CORP(1)	UENO MASAKI(44) ENYA YOHEI(43) YOSHIZUMI YUSUKE(42) AKITA KATSUSHI(34) SUMITOMO TAKAMICHI(33)
YOSHIZUMI YUSUKE	58 (0.7%)		2007-2013	SUMITOMO ELECTRIC IND CO LTD(58)	UENO MASAKI(51) KYONO TAKASHI(42) ENYA YOHEI(40) SUMITOMO TAKAMICHI(32) AKITA KATSUSHI(26)
AKITA KATSUSHI	56 (0.7%)		2003-2013	SUMITOMO ELECTRIC IND CO LTD(56)	KYONO TAKASHI(34) YOSHIZUMI YUSUKE(26) UENO MASAKI(25) ENYA YOHEI(24) SUMITOMO TAKAMICHI(20)
NUNOUE SHINYA	55 (0.7%)		2006-2014	TOSHIBA CORP(55)	TACHIBANA KOICHI(22) HIKOSAKA TOSHIKI(16) NAGO HAJIME(16) SUGIYAMA NAOHARU(16) SAITO SHINJI(13)
BOUR DAVID P	48 (0.6%)		1998-2014	AVOGY INC(25) AVAGO TECHNOLOGIES GENERAL IP PTE LTD(7) PALO ALTO RESEARCH CENTER INCORPORATED(6) XEROX CORP(4) AVAGO TECHNOLOGIES ECBU IP (SINGAPORE) PTE LTD(1)	KIZILYALLI ISIK C(25) NIE HUI(25) PRUNTY THOMAS R(22) BROWN RICHARD J(21) EDWARDS ANDREW P(18)

ENYA YOHEI	47 (0.6%)		2009-2013	SUMITOMO ELECTRIC IND CO LTD(47) SONY CORP(1)	UENO MASAKI(45) KYONO TAKASHI(43) YOSHIZUMI YUSUKE(40) SUMITOMO TAKAMICHI(33) AKITA KATSUSHI(24)
KIZILYALLI ISIK C	43 (0.5%)		2007-2014	AVOGY INC(37) ALTA DEVICES INC(2) EPOWERSOFT INC(2) INTERNATIONAL RECTIFIER CORP(2)	NIE HUI(36) BROWN RICHARD J(27) BOUR DAVID P(25) EDWARDS ANDREW P(23) PRUNTY THOMAS R(23)
LEE JAE HOON	41 (0.5%)		2004-2014	SAMSUNG GROUP(41)	OH JEONG TAK(7) LEE JUNG HEE(6) CHOI HEE SEOK(5) KIM KI SE(5) LEE SU YEOL(5)
NIE HUI	41 (0.5%)		2011-2014	AVOGY INC(38) EPOWERSOFT INC(2) BROWN RICHARD J(1) EDWARDS ANDREW P(1) KIZILYALLI ISIK C(1)	KIZILYALLI ISIK C(36) BROWN RICHARD J(29) BOUR DAVID P(25) PRUNTY THOMAS R(24) EDWARDS ANDREW P(23)

How we did it?

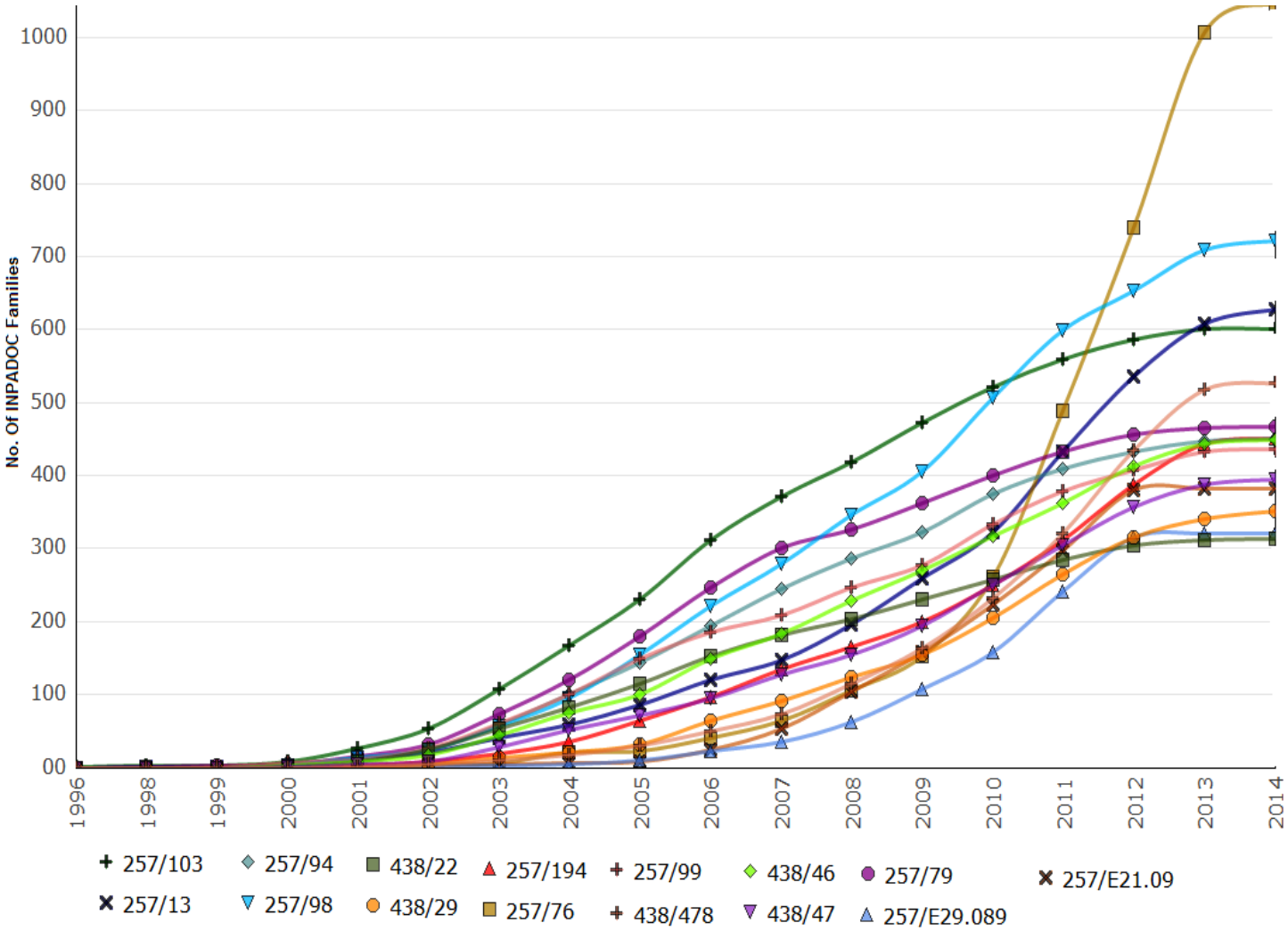
From the Inventor 360° report options, we selected the different pieces of information we wanted to include in the singular display and then ran the report. The generated report was then exported to Excel using the option provided for the same.

Filing Trend of Patents across Top 15 US Classifications

The chart shows the spread of patenting activity across various subclasses of technologies corresponding to US Class.

The brown trend line associated with **US Class 257/76 {Active solid-state devices with - Specified Wide Band Gap (1.5ev)**}shows an impressive spike from 2009 onwards.

In the chart, it can be seen that US Class 257/76and 257/98 are most favored subclasses under which 1048 and 721 patents have been categorized respectively. These arefollowed by 257/13, 257/103, 438/478, 257/79 under which 628, 601, 526,467patents have been categorized respectively.



How we did it?

Once the patents were populated in Patent iNSIGHT Pro, the filing trend chart for top 15 US full classeswas generated on a single click using the dashboard tool.

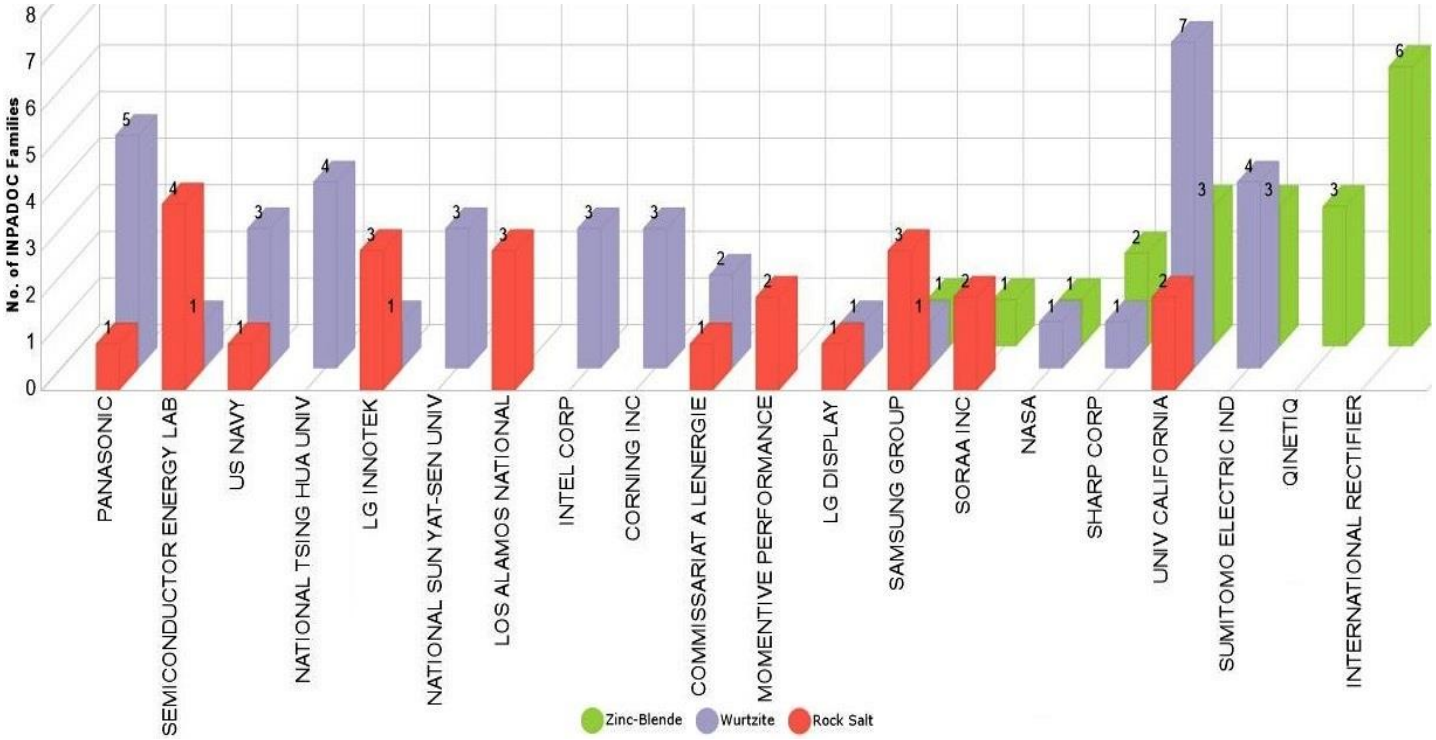
Definitions to US Classifications used for above analysis

US Class	Definition
257/103	Active solid-state devices (e.g., transistors, solid-state diodes) - Incoherent Light Emitter Structure -- With particular semiconductor material
257/13	Active solid-state devices (e.g., transistors, solid-state diodes) - thin active physical layer which is (1) an active potential well layer thin enough to establish discrete quantum energy levels or (2) an active barrier layer thin enough to permit quantum mechanical tunneling or (3) an active layer thin enough to permit carrier transmission with substantially no scattering (e.g., superlattice quantum well, or ballistic transport device) -- Heterojunction --- Incoherent Light Emitter
257/94	Active solid-state devices (e.g., transistors, solid-state diodes) - Incoherent Light Emitter Structure -- With heterojunction
257/98	Active solid-state devices (e.g., transistors, solid-state diodes) - Incoherent Light Emitter Structure -- With reflector, opaque mask, or optical element (e.g., lens, optical fiber, index of refraction matching layer, luminescent material layer, filter) integral with device or device enclosure or package
438/22	Semiconductor device manufacturing: process - Making Device Or Circuit Emissive Of Nonelectrical Signal
438/29	Semiconductor device manufacturing: process - Making Device Or Circuit Emissive Of Nonelectrical Signal -- Including integrally formed optical element (e.g., reflective layer, luminescent material, contoured surface, etc.)
257/194	Active solid-state devices (e.g., transistors, solid-state diodes) - Heterojunction Device -- Field effect transistor --- Doping on side of heterojunction with lower carrier affinity (e.g., high electron mobility transistor (HEMT))
257/76	Active solid-state devices (e.g., transistors, solid-state diodes) - Specified Wide Band Gap (1.5ev) Semiconductor Material Other Than Gaasp Or Gaalas
257/99	Active solid-state devices (e.g., transistors, solid-state diodes) - Incoherent Light Emitter Structure -- With housing or contact structure
438/478	Semiconductor Device Manufacturing: Process - formation of semiconductive active region on any substrate (e.g., fluid growth, deposition)
438/46	Semiconductor device manufacturing: process - Making Device Or Circuit Emissive Of Nonelectrical Signal -- Compound semiconductor
438/47	Semiconductor device manufacturing: process - Making Device Or Circuit Emissive Of Nonelectrical Signal -- Compound semiconductor --- Heterojunction
257/79	Active solid-state devices (e.g., transistors, solid-state diodes) - Incoherent Light Emitter Structure

257/E21.089	Active solid-state devices (e.g., transistors, solid-state diodes) - Processes Or Apparatus Adapted For Manufacture Or Treatment Of Semiconductor Or Solid-State Devices Or Of Parts Thereof (EPO) -- Manufacture or treatment of semiconductor device (EPO) --- Device having at least one potential-jump barrier or surface barrier, e.g., PN junction, depletion layer, carrier concentration layer (EPO) ---- Device having semiconductor body comprising Group IV elements or Group III-V compounds with or without impurities, e.g., doping materials (EPO) ----- Multistep processes for manufacture of device using quantum interference effect, e.g., electrostatic Aharonov-Bohm effect (EPO)
257/E21.09	Active solid-state devices (e.g., transistors, solid-state diodes) - Processes Or Apparatus Adapted For Manufacture Or Treatment Of Semiconductor Or Solid-State Devices Or Of Parts Thereof (EPO) -- Manufacture or treatment of semiconductor device (EPO) --- Device having at least one potential-jump barrier or surface barrier, e.g., PN junction, depletion layer, carrier concentration layer (EPO) ---- Device having semiconductor body comprising Group IV elements or Group III-V compounds with or without impurities, e.g., doping materials (EPO) ----- Deposition of semiconductor material on substrate, e.g., epitaxial growth, solid phase epitaxy (EPO)

Company activity acrossCrystal Structures

The chart below shows research activity of companies across different crystal structures. Univ California has research activity across all types of crystal structures.Intel and Corning focus only on Wurtzite.

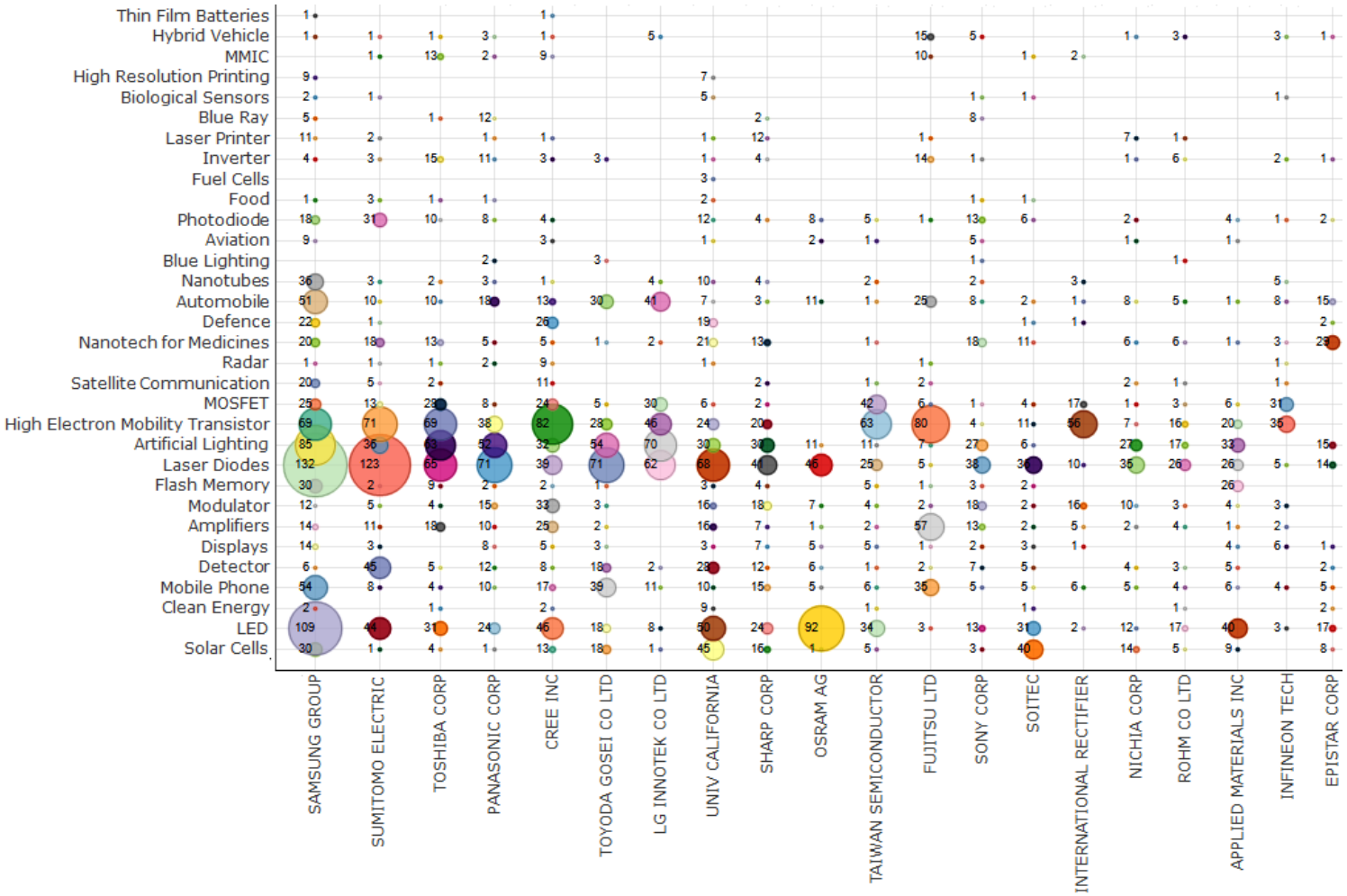


How we did it?

First various crystal structureswere identified by manual research. Then by using a combination of semantic analysis tools such as clustering tools and searching tools available in Patent iNSIGHT Pro, records were categorized under structures. A co-occurrence matrix was generated using the co-occurrence analyzer to map the different structures with assignees. The matrix was filtered for top 20assignees and was converted into column chart using the option provided in software for the same.

Company activity across Applications

The chart below shows research activity of companies across different applications. Cree leads in research around high electron mobility transistors and defence with 82 and 28 records respectively. Samsung and Univ California are the only companies focusing on high resolution printing with 9 and 7 records respectively.

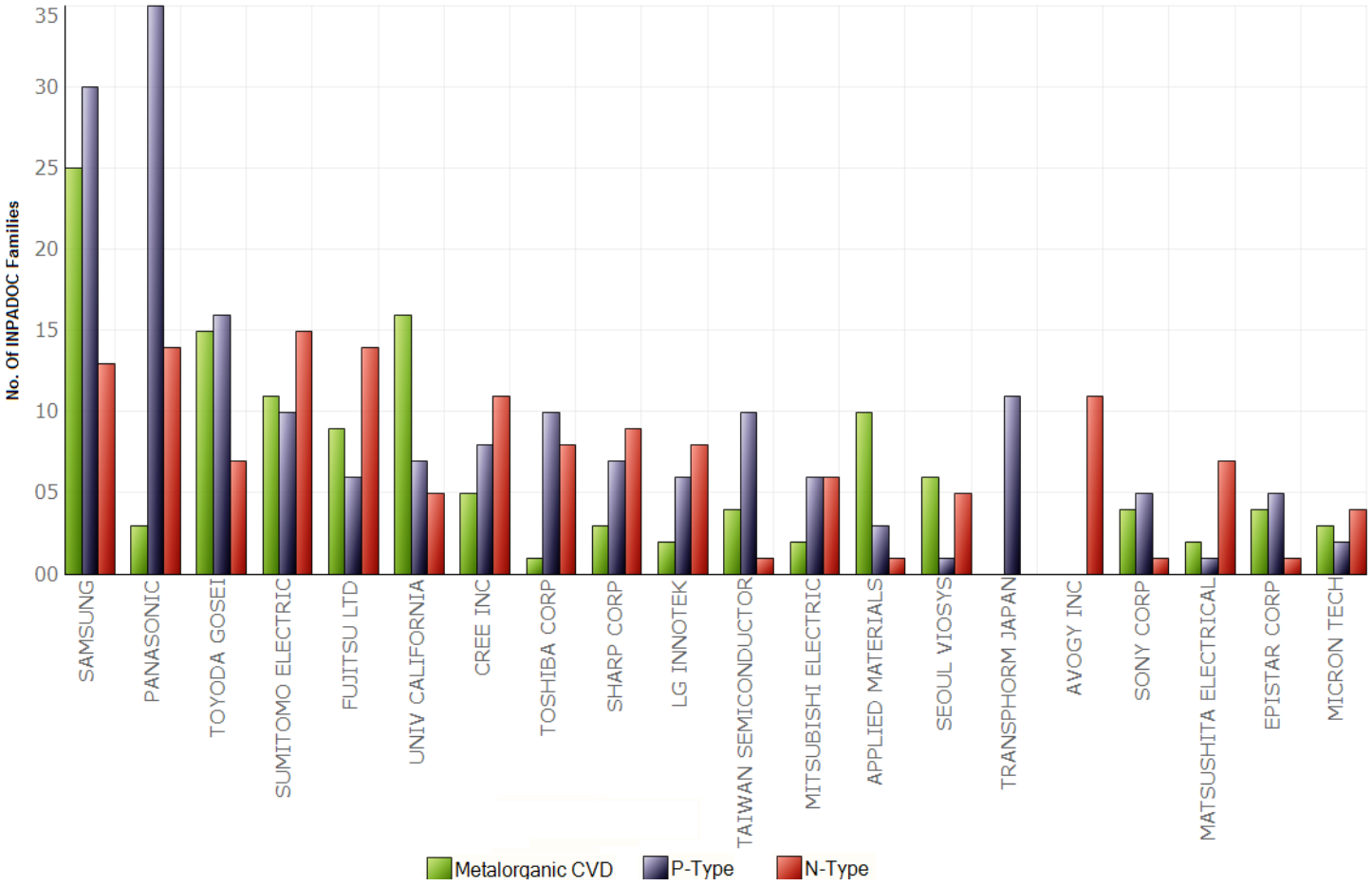


How we did it?

First various applications were identified by manual research. Then by using a combination of semantic analysis tools such as clustering tools and searching tools available in Patent iNSIGHT Pro, records were categorized under different applications. A co-occurrence matrix was generated using the co-occurrence analyzer to map the different applications with assignees. The matrix was filtered for the top 20 assignees and was converted into bubble chart using the option provided in software for the same.

Company activity acrossPhysical Properties

The chart below shows research activity of companies across different physical properties. Avogy focuses only in N-type.Panasonic leads in research across P-type. Sumitomo has fairly comparable portfolio across all the physical properties.



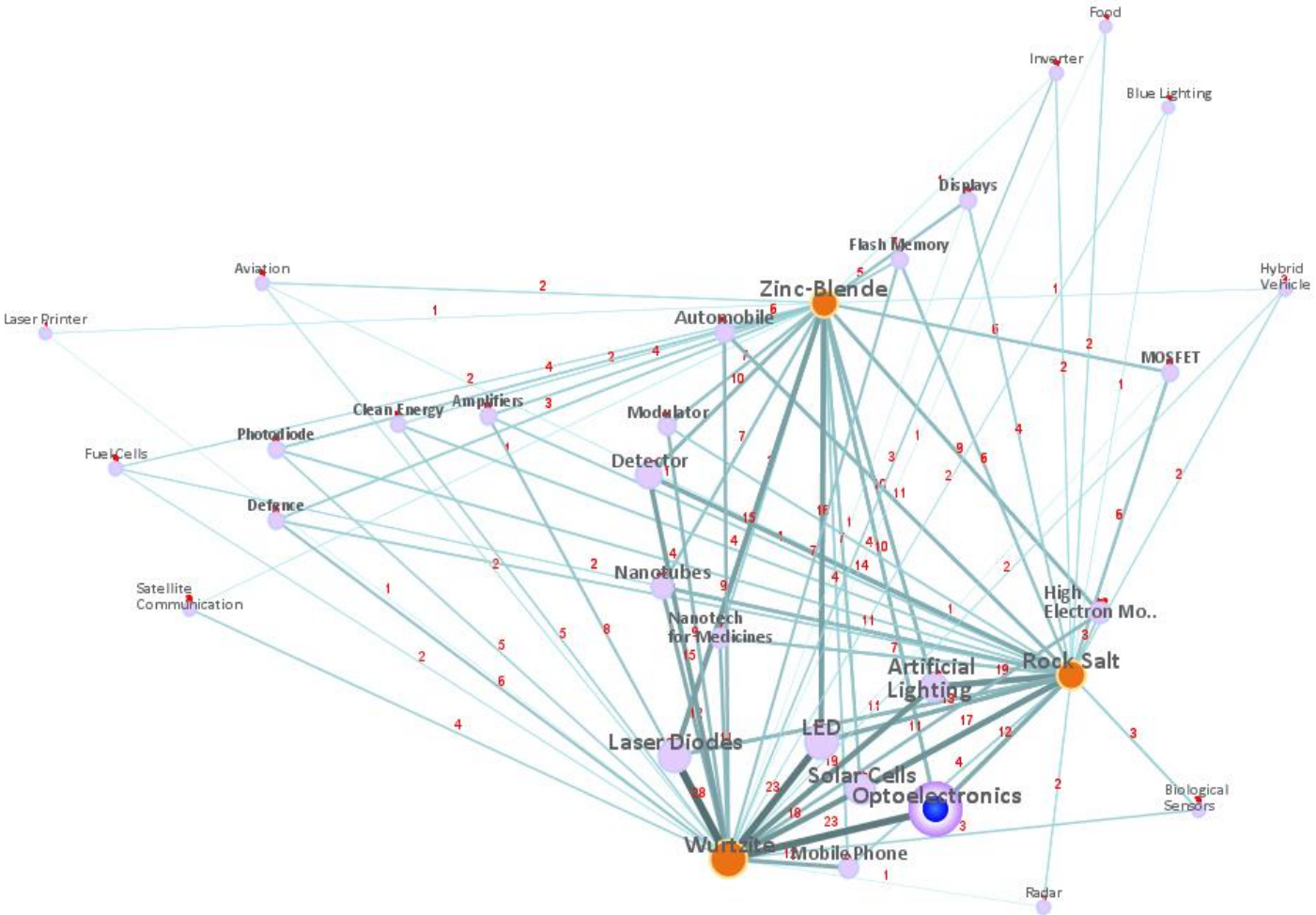
How we did it?

First various physical propertieswere identified by manual research. Then by using a combination of semantic analysis tools such as clustering tools and searching tools available in Patent iNSIGHT Pro, records were categorized under different properties. A co-occurrence matrix was generated using the co-occurrence analyzer to map the different properties with assignees. The matrix was filtered for the top 20assignees and converted into clustered column chart using the option provided in software for the same.

Gallium Nitride – Application Areas vs.Crystal Structures

In the map, each structure is connected through links whose thickness and color intensity is directly proportional to the number of records relating them. The number (in red) next to each line represents the number of records present in a particular crystal structure and application areas.

It can be seen Wurtzite crystal structure is used in more number of applications as compared to other crystal structures. Aviation,Defenceand Satellite industry industries use onlyWurtzite and Zinc Blende crystal structures.



Note: Orange nodes represent the crystal structure, whereas purple nodes refer toapplication areas.

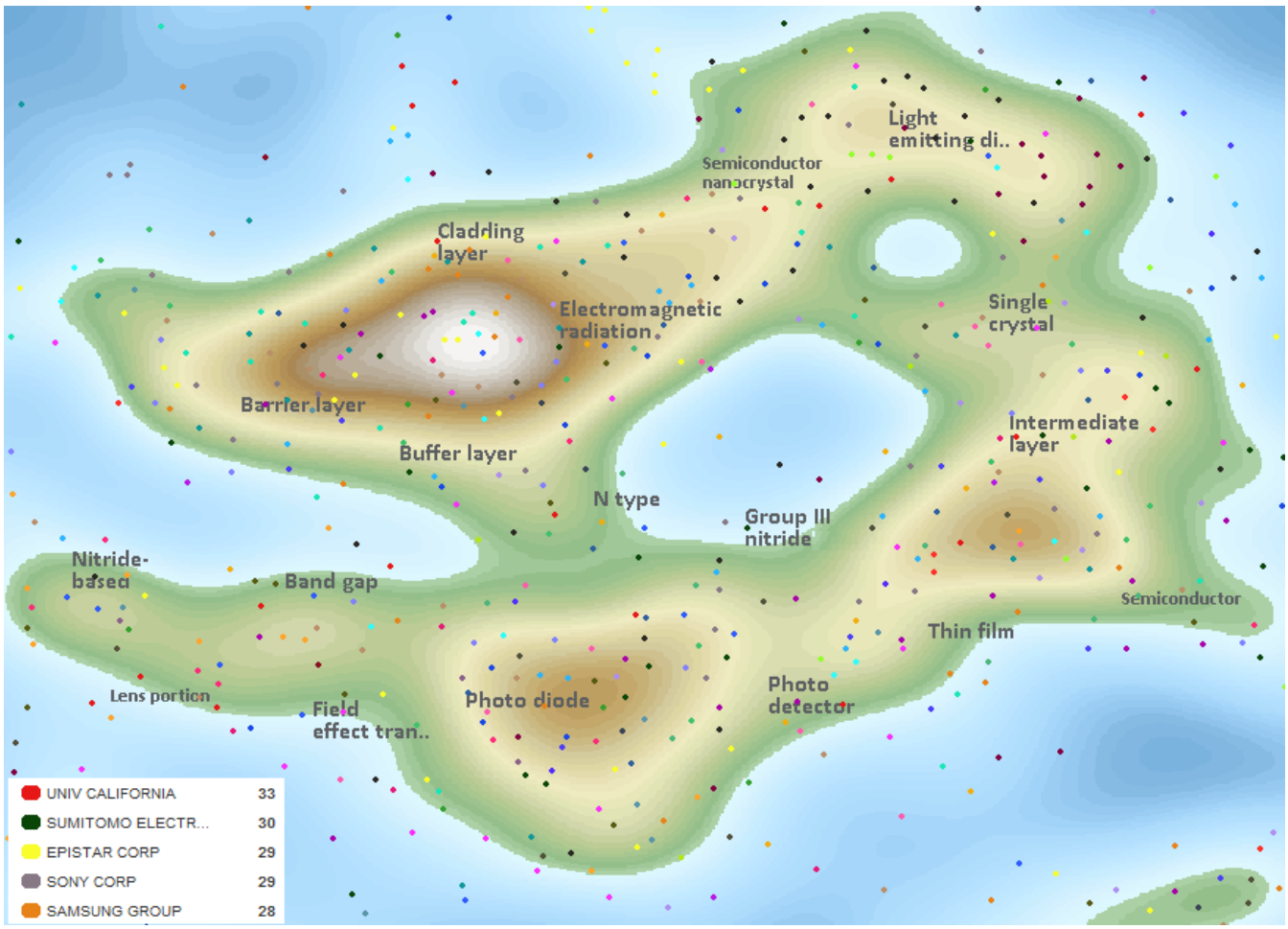
How we did it?

The clusters that were created for previous analysis were correlated using the co-occurrence analyzer and the resulting matrix wasrepresented as Correlation map. Also, links between same field types were removed using the option provided.

Landscape for Gallium Nitride applications

The contour map below represents key concepts for different applications of Gallium Nitridewith respect to complete patent portfolio.

Clusters for photo diode and photo detector appearcloser to each other as they share high contextual and conceptual similarity between them. The nodes were coloured by companies.



How we did it?

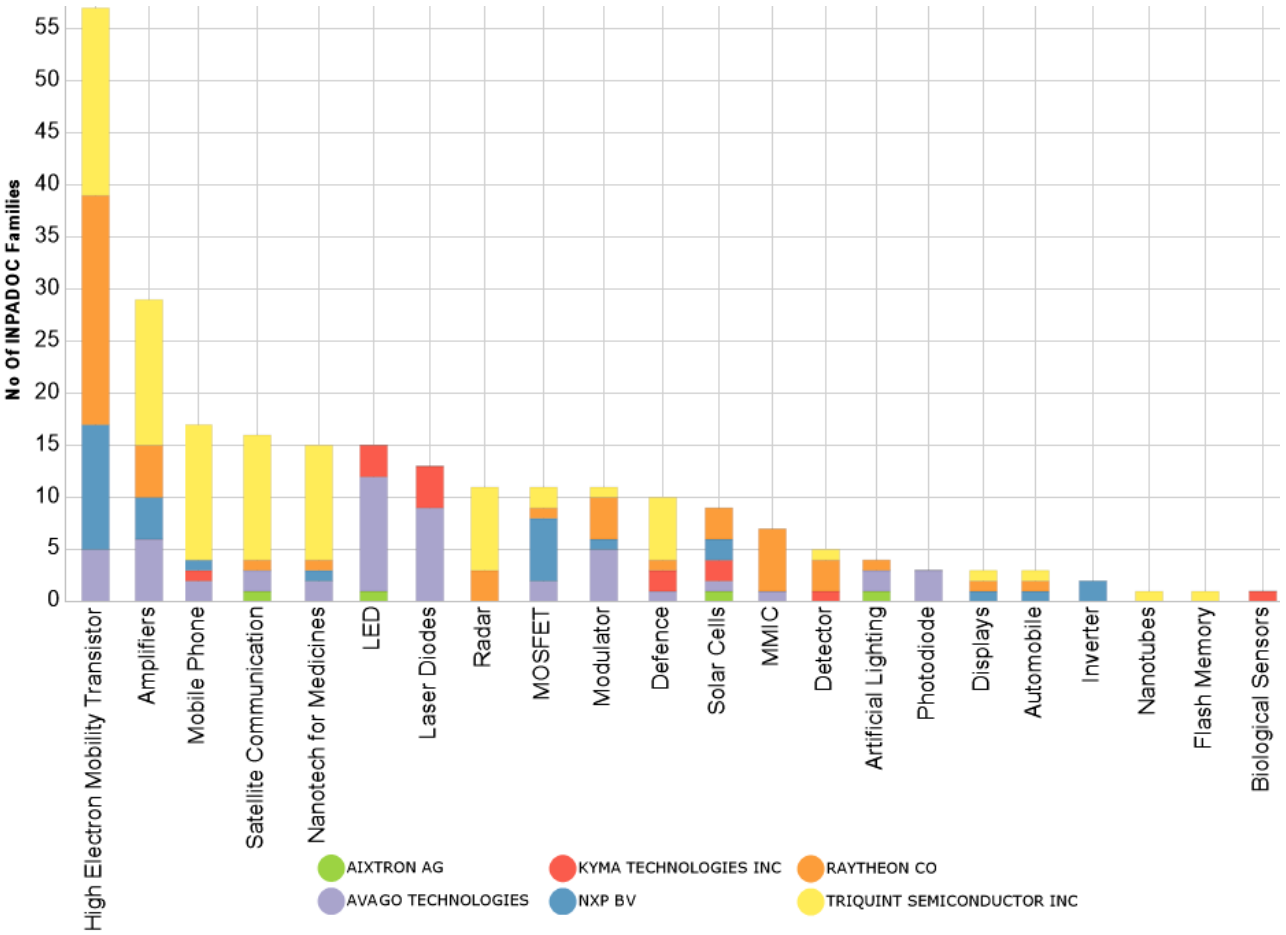
The VizMAP tool in Patent iNSIGHT Pro was used for this analysis. First the clusters for differentapplications were loaded on the map. They were analyzed on basis of their contextual similarity using title, abstract and claims as Text from the 'Context mode' option. We removed unrelated patents using the "Hide Unrelated records" option and one patent assignee using the options available in VizMAP.

Analysis of significant companies within Gallium Nitride

Application areas

The chart shows research activity of significant companies in different application areas.

It can be seen Triquint leads in research across satellite communication and has records present across most of the applications. Kymaand NXP are the only companies in biological sensors and inverter.



How we did it?

We first created a group for companies focusing primarily around research around gallium nitride using autofilter option. Using co-occurrence analyzer, we used that group as data filter to generate a matrix for those companies with respect to applications and resulting matrix was converted to a stacked column chart.

Assignee Landscape around application areas and crystal structure

The following table shows different applications and type of crystal structures used, but with the companies behind the records.

It can be seen Laser Diode has maximum number of individual companies (24) with wurtzite as crystal structure.

Crystal Structure (Column) / Applications (Row)	Total	Wurtzite	Zinc-Blende	Rock Salt
Total	109	56	34	36
LED	45	ALCATEL LUCENT SA; COMMISSARIAT A LENERGIE ATOMIQUE; COVALENT MATERIALS CORP; CRYSTAL IS INC; FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA; MITSUBISHI ELECTRIC CORP; NANOSYS INC; NATIONAL INST OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY; NATIONAL SUN YAT-SEN UNIV; NATIONAL TSING HUA UNIV; ONED MATERIAL LLC; PHOSTEK INC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SEOUL SEMICONDUCTOR CO LTD; SIXPOINT MATERIALS INC; SOITEC; SOUTHERN TAIWAN UNIV OF TECHNOLOGY; SUNG CHIEN-MIN; UNIV CALIFORNIA; UNIV CONNECTICUT; UNIV ILLINOIS; UNIV OF FLORIDA RESEARCH FOUNDATION INC	AMBERWAVE SYSTEMS CORP; HARVATEK CORP; HONG KONG APPLIED SCIENCE AND TECHNOLOGY RESEARCH INSTCO LTD; KENDALL DON L.; NASA; NM SPINTRONICS AB; OHIO UNIV; QINETIQ LTD; RICOH CO LTD; SORAA INC; TAIWAN SEMICONDUCTOR MFG LTD; TOPCO SCIENTIFIC CO LTD; UNIV CALIFORNIA; UNIV UTAH RES FOUND; UNIV OF FLORIDA RESEARCH FOUNDATION INC; VTERA TECHNOLOGY INC	ELOP ELECTROOPTICS IND LTD; GENERAL ELECTRIC CO; IPCO LLC; LOS ALAMOS NATIONAL SECURITY LLC; MITSUBISHI CHEM CORP; MOMENTIVE PERFORMANCE MATERIALS INC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SORAA INC; TECHNION RES & DEV FOUNDATION; TECHNION RESEARCH AND DEVELOPEMENT FOUNDATION LTD; THE BOEING CO
Laser Diodes	43	AGENCY FOR SCIENCE TECHNOLOGY AND RESEARCH; CORNING INC; COVALENT MATERIALS CORP; CRYSTAL ISINC;	AMBERWAVE SYSTEMS CORP; BINOPTICS CORP; NASA; OHIO UNIV;	GENERAL ELECTRIC CO; GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE

		DONGGUK UNIV INDUSTRY ACADEMIC COOPERATION FOUNDATION; FORSCHUNGSVERBUND BERLIN E.V.; MICRON TECHNOLOGY INC; MITSUBISHI ELECTRIC CORP; NATIONAL SUN YAT-SEN UNIV; NATIONAL TSING HUA UNIV; NICHIA CORP; PANASONIC CORP; SAINT-GOBAIN CERAMICS PLASTICS INC; SAMSUNG GROUP; SEIKO EPSON CORP; SEOUL SEMICONDUCTOR CO LTD; SIXPOINT MATERIALS INC; SOITEC; SUMITOMO ELECTRIC IND CO LTD; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; THE UNIV OF NOTRE DAME DU LAC; UNIV CALIFORNIA; UNIV ILLINOIS; UNIV NAT CHIAO TUNG	QINETIQ LTD; RICOH CO LTD; SHARP CORP; SORAA INC; SUMITOMO ELECTRIC IND CO LTD; TAIWAN SEMICONDUCTOR MFG LTD; TOSHIBA CORP; UNIV CALIFORNIA; UNIV OF FLORIDA RESEARCH FOUNDATION INC; UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION; WISCONSIN ALUMNI RESEARCH FOUNDATION	NATIONAL INST OF STANDARDS AND TECHNOLOGY; LG INNOTEK CO LTD; MITSUBISHI CHEM CORP; MOMENTIVE PERFORMANCE MATERIALS INC; PANASONIC CORP; RENSSELAER POLYTECH INST; UNIV NAT CHIAO TUNG
Solar Cells	36	FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA; IBM CORP; INTELLECTUAL DISCOVERY CO LTD; NANOSYS INC; ONED MATERIAL LLC; PHOSTEK INC; POSTECH ACAD IND FOUND; SEOUL SEMICONDUCTOR CO LTD; SIXPOINT MATERIALS INC; SOITEC; SUNG CHIEN-MIN; SVT ASSOCIATES INC; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; UNIV CALIFORNIA; UNIV ILLINOIS; UNIV NAT CHIAO TUNG; UNIV OF FLORIDA RESEARCH	HONG KONG APPLIED SCIENCE AND TECHNOLOGY RESEARCH INSTCO LTD; TAIWAN SEMICONDUCTOR MFG LTD; UNIV CALIFORNIA; UNIV UTAH RES FOUND; UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	ELMHURST RES INC; FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.; GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; INTERUNIV MICROELECTRONICS CENTRE VZW ; IPCO LLC; LOS ALAMOS NATIONAL SECURITY LLC; MOMENTIVE PERFORMANCE MATERIALS INC;

		FOUNDATION INC		Q1 NANOSYSTEMS CORP; RENSSELAER POLYTECH INST; SAMSUNG GROUP; SORAA INC; STICHTING IMEC NEDERLAND; TECHNION RESEARCH AND DEVELOPEMENT FOUNDATION LTD; THE BOEING CO; UNIV NAT CHIAO TUNG; WILLIAM MARSH RICE UNIV
Optoelectronics	35	AVOGY INC; COMMISSARIAT A LENERGIE ATOMIQUE; CORNELL RES FOUNDATION INC; CORNING INC; CRYSTAL IS INC; IBM CORP; INTEL CORP; NANOSYS INC; NATIONAL TSING HUA UNIV; NORTH CAROLINA STATE UNIV; ONED MATERIAL LLC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SAMSUNG GROUP; SEOUL SEMICONDUCTOR CO LTD; SOITEC; SOUTHERN TAIWAN UNIV OF TECHNOLOGY; THE UNIV OF NOTRE DAME DU LAC; UNIV CALIFORNIA; UNIV CONNECTICUT; US NAVY	AMBERWAVE SYSTEMS CORP; NASA; OHIO UNIV; QINETIQ LTD; SUMITOMO ELECTRIC IND CO LTD; TAIWAN SEMICONDUCTOR MFG LTD; UNIV CALIFORNIA; UNIV OF FLORIDA RESEARCH FOUNDATION INC; UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	ELMHURST RES INC; GENERAL ELECTRIC CO; JAPAN SCIENCE & TECH AGENCY; MOMENTIVE PERFORMANCE MATERIALS INC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; RENSSELAER POLYTECH INST; SORAA INC; THE BOEING CO

Artificial Lighting	35	AVOGY INC; LG DISPLAY CO LTD; LG INNOTEK CO LTD; NASA; NICHIA CORP; ONED MATERIAL LLC; PANASONIC CORP; POSTECH ACAD IND FOUND; SAMSUNG GROUP; SEMICONDUCTOR ENERGY LAB CO LTD; SOITEC; SUMITOMO ELECTRIC IND CO LTD; SVT ASSOCIATES INC; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; TROJAN TECHNOLOGIES; UNIV CALIFORNIA	HARVATEK CORP; MASSACHUSETTS INST TECHNOLOGY; RAMGOSS INC; SHARP CORP; TOPCO SCIENTIFIC CO LTD; UNIV CALIFORNIA; UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	COMMISSARIAT A LENERGIE ATOMIQUE; ELOP ELECTROOPTICS IND LTD; INTERUNIV MICROELECTRONICS CENTRE VZW ; LG CHEM LTD; LG DISPLAY CO LTD; LG INNOTEK CO LTD; Q1 NANOSYSTEMS CORP; RENSSELAER POLYTECH INST; SEMICONDUCTOR ENERGY LAB CO LTD; SEOUL VIOSYS CO LTD; SORAA INC; TECHNION RES & DEV FOUNDATION; THE BOEING CO; TORAY INDUSTRIES INC; UNIV NAT CHIAO TUNG; WILLIAM MARSH RICE UNIV
Detector	30	AGENCY FOR SCIENCE TECHNOLOGY AND RESEARCH; COMMISSARIAT A LENERGIE ATOMIQUE; CRYSTAL IS INC; NASA; ONED MATERIAL LLC; PANASONIC CORP; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SAINT-GOBAIN CERAMICS PLASTICS INC; SEOUL SEMICONDUCTOR CO LTD; SIXPOINT MATERIALS INC; SUMITOMO ELECTRIC IND CO LTD; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; UNIV CALIFORNIA; US NAVY	AKIYAMA HIDEFUMI; MASSACHUSETTS INST TECHNOLOGY; PFEIFFER LOREN N; SHARP CORP; UNIV CALIFORNIA; UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION INC; WEST KENNETH W; YOSHITA MASAHIRO	ELOP ELECTROOPTICS IND LTD; FUJI XEROX CO LTD; GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; INTERUNIV MICROELECTRONICS CENTRE VZW ; MOMENTIVE PERFORMANCE MATERIALS INC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; RENSSELAER POLYTECH INST; STICHTING IMEC NEDERLAND; TECHNION RES & DEV FOUNDATION; TECHNION RESEARCH

				AND DEVELOPEMENT FOUNDATION LTD; UNIV CALIFORNIA
Nanotubes	23	AGENCY FOR SCIENCE TECHNOLOGY AND RESEARCH; DONGGUK UNIV INDUSTRY ACADEMIC COOPERATION FOUNDATION; NANOSYS INC; ONED MATERIAL LLC; PHILIPS CORP; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SUNG CHIEN-MIN; UNIV CALIFORNIA; UNIV CONNECTICUT; UNIV OF FLORIDA RESEARCH FOUNDATION INC	AMBERWAVE SYSTEMS CORP; KENDALL DON L.; QINETIQ LTD; TAIWAN SEMICONDUCTOR MFG LTD; UNIV CALIFORNIA	COMMISSARIAT A LENERGIE ATOMIQUE; FUJI XEROX CO LTD; GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; INFINEON TECHNOLOGIES AG; INTERUNIV MICROELECTRONICS CENTRE VZW ; IPCO LLC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; Q1 NANOSYSTEMS CORP; SAMSUNG GROUP; WILLIAM MARSH RICE UNIV
High Electron Mobility Transistor	19	CORNELL RES FOUNDATION INC; CRYSTAL IS INC; INTEL CORP; MATSUSHITA ELECTRICAL IND CO LTD; NATIONAL SEMICONDUCTOR CORP; SEOUL SEMICONDUCTOR CO LTD; SHARP CORP; SIXPOINT MATERIALS INC; THE UNIV OF NOTRE DAME DU LAC; UNIV OF FLORIDA RESEARCH FOUNDATION INC	AMBERWAVE SYSTEMS CORP; INTERNATIONAL RECTIFIER CORP; QINETIQ LTD; RICOH CO LTD; TAIWAN SEMICONDUCTOR MFG LTD; UNIV CALIFORNIA; VTERA TECHNOLOGY INC	GENERAL ELECTRIC CO; KYOCERA CORP
Automobile	17	CORNELL RES FOUNDATION INC; MATSUSHITA ELECTRICAL IND CO LTD; NUTECH VENTURES; PANASONIC CORP; SAMSUNG GROUP	FRIJOUF ROBERT F.; INFINEON TECHNOLOGIES AG; NASA; NM SPINTRONICS AB; UNIV CALIFORNIA	INFINEON TECHNOLOGIES AG; IPCO LLC; LG INNOTEK CO LTD; PANASONIC CORP; Q1 NANOSYSTEMS CORP; RENSSELAER POLYTECH

				INST; SEMICONDUCTOR ENERGY LAB CO LTD; SORAA INC; TECHNION RESEARCH AND DEVELOPEMENT FOUNDATION LTD
Mobile Phone	16	AVOGY INC; COMMISSARIAT A LENERGIE ATOMIQUE; CORNELL RES FOUNDATION INC; IBM CORP; INTEL CORP; MICRON TECHNOLOGY INC; NATIONAL INST OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY; SEMICONDUCTOR ENERGY LAB CO LTD; SIXPOINT MATERIALS INC; UBE ELECTRONICS LTD; UNIV CONNECTICUT	HONG KONG APPLIED SCIENCE AND TECHNOLOGY RESEARCH INSTCO LTD; SHARP CORP; TOPCO SCIENTIFIC CO LTD	COMMISSARIAT A LENERGIE ATOMIQUE; Q1 NANOSYSTEMS CORP; SEMICONDUCTOR ENERGY LAB CO LTD; SORAA INC
Nanotech for Medicines	15	CORNELL RES FOUNDATION INC; FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA; NUTECH VENTURES; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SAMSUNG GROUP; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; THE UNIV OF NOTRE DAME DU LAC; UNIV CALIFORNIA; UNIV CONNECTICUT	NASA; QINETIQ LTD; UNIV CALIFORNIA	GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; Q1 NANOSYSTEMS CORP; RENSSELAER POLYTECH INST; UNIV CALIFORNIA; US NAVY
Modulator	14	AVOGY INC; CORNELL RES FOUNDATION INC; PANASONIC CORP; SAMSUNG GROUP; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; UNIV CALIFORNIA; UNIV CONNECTICUT; UNIV OF FLORIDA RESEARCH FOUNDATION INC	BINOPTICS CORP; KENDALL DON L.; RICOH CO LTD; SHARP CORP; UNIV CALIFORNIA; UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION INC	RENSSELAER POLYTECH INST

MOSFET	11		AMBERWAVE SYSTEMS CORP; INFINEON TECHNOLOGIES AG; INTERNATIONAL RECTIFIER CORP; KENDALL DON L.; RAMGOSS INC; TAIWAN SEMICONDUCTOR MFG LTD	BOARD OF REGENTS THE UNIV OF TEXAS SYSTEM; GENERAL ELECTRIC CO; LOS ALAMOS NATIONAL SECURITY LLC; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; TORAY INDUSTRIES INC
Flash Memory	11	INTEL CORP; NUTECH VENTURES; SEMICONDUCTOR ENERGY LAB CO LTD; UNIV OF FLORIDA RESEARCH FOUNDATION INC	CALIFORNIA INST OF TECHN; NAT INST OF ADVANCED IND SCIENCE	COMMISSARIAT A LENERGIE ATOMIQUE; FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.; SAMSUNG GROUP; SEMICONDUCTOR ENERGY LAB CO LTD; SORAA INC; UNIV CALIFORNIA
Displays	11	INTEL CORP	AKIYAMA HIDEFUMI; CALIFORNIA INST OF TECHN; FRIJOUF ROBERT F.; INFINEON TECHNOLOGIES AG; PFEIFFER LOREN N; WEST KENNETH W; YOSHITA MASAHIRO	Q1 NANOSYSTEMS CORP; TECHNION RESEARCH AND DEVELOPEMENT FOUNDATION LTD; TORAY INDUSTRIES INC
Amplifiers	11	CORNELL RES FOUNDATION INC; INTEL CORP; ONED MATERIAL LLC; POSTECH ACAD IND FOUND; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; SAMSUNG GROUP; UNIV CALIFORNIA; UNIV OF FLORIDA RESEARCH FOUNDATION INC	CALIFORNIA INST OF TECHN; UNIV CALIFORNIA; UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION INC	MOMENTIVE PERFORMANCE MATERIALS INC
Photodiode	10	NASA; PHILIPS CORP; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; UNIV CALIFORNIA; UNIV CONNECTICUT	BINOPTICS CORP; UNIV CALIFORNIA; UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION INC	GENERAL ELECTRIC CO; IPCO LLC; STICHTING IMEC NEDERLAND

Defence	9	ALCATEL LUCENT SA; CORNELL RES FOUNDATION INC; NUTECH VENTURES; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; THE UNIV OF NOTRE DAME DU LAC; UNIV CALIFORNIA	NM SPINTRONICS AB; UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION INC	PRESIDENT AND FELLOWS OF HARVARD COLLEGE; UNIV CALIFORNIA; WILLIAM MARSH RICE UNIV
Clean Energy	8	NANOSYS INC; ONED MATERIAL LLC; THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV; UNIV CALIFORNIA; UNIV OF FLORIDA RESEARCH FOUNDATION INC	UNIV CALIFORNIA	GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; INTERUNIV MICROELECTRONICS CENTRE VZW ; Q1 NANOSYSTEMS CORP
Satellite Communication	5	CORNELL RES FOUNDATION INC; CORNING INC; NANOSYS INC; UNIV CONNECTICUT	HONG KONG APPLIED SCIENCE AND TECHNOLOGY RESEARCH INSTCO LTD	
Inverter	5	AGENCY FOR SCIENCE TECHNOLOGY AND RESEARCH; MATSUSHITA ELECTRICAL IND CO LTD; PRESIDENT AND FELLOWS OF HARVARD COLLEGE	RAMGOSS INC	Q1 NANOSYSTEMS CORP
Biological Sensors	4	NATIONAL TSING HUA UNIV; PRESIDENT AND FELLOWS OF HARVARD COLLEGE		GOVT OF USA AS REPRESENTED BY THE SECRETARY OF COMMERCE THE NATIONAL INST OF STANDARDS AND TECHNOLOGY; PRESIDENT AND FELLOWS OF HARVARD COLLEGE; US NAVY
Aviation	4	NANOSYS INC	FRIJOUF ROBERT F.; NASA	Q1 NANOSYSTEMS CORP
Radar	3	FORSCHUNGSVERBUND BERLIN E.V.		ELOP ELECTROOPTICS IND LTD; TECHNION RES & DEV FOUNDATION

Hybrid Vehicle	3	MATSUSHITA ELECTRICAL IND CO LTD; PANASONIC CORP	INFINEON TECHNOLOGIES AG	
Fuel Cells	3	UNIV CALIFORNIA; UNIV OF FLORIDA RESEARCH FOUNDATION INC	UNIV CALIFORNIA	INTERUNIV MICROELECTRONICS CENTRE VZW
Food	2	PRESIDENT AND FELLOWS OF HARVARD COLLEGE		PRESIDENT AND FELLOWS OF HARVARD COLLEGE; Q1 NANOSYSTEMS CORP
Blue Lighting	2	THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIV		PANASONIC CORP
Laser Printer	1		SHARP CORP	

How we did it?

We selected “No. of Assignees” withinFacts to Analyze option present in co-occurrence analyzer. The clusters that were created for previous analysis were correlated and“Show Data” option was used to Drill out the companies.The resulting matrix was exported to excel using the option present.

Universities: Focus across Crystal Structure,Applications and Physical Properties

The following tables show focus areas across Crystal structures, applications and physical properties of top 20 universities. It can be seen across all the focus areas, Univ California has maximum number of records.

Crystal Structure

The table below represents top 20 universities and the different crystal structures of gallium nitride. It can be seen that there are 8 universities based out of Asia having research interest in crystal structures.

Crystal Structure (Column) / Universities (Rows)	Total	Zinc-Blende	Wurtzite	Rock Salt
Total	39	9	23	7
UNIV CALIFORNIA	12	3	7	2
NATIONAL TSING HUA UNIV	4		4	
NATIONAL SUN YAT-SEN UNIV	3		3	
UNIV OF FLORIDA RESEARCH FOUNDATION INC	2	1	1	
UNIV NAT CHIAO TUNG	2		1	1
THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARN	2		2	
WILLIAM MARSH RICE UNIV	1			1
UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	1	1		
UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION	1	1		
UNIV UTAH RES FOUND	1	1		
UNIV ILLINOIS	1		1	

UNIV CONNECTICUT	1		1	
TOHOKU UNIV	1	1		
SOUTHERN TAIWAN UNIV OF TECHNOLOGY	1		1	
SOGANG UNIV RESEARCH FOUNDATION	1			1
OHIO UNIV	1	1		
NORTH CAROLINA STATE UNIV	1		1	
INTERUNIVERSITAIR MICROELEKTRONICA CENTRUM	1			1
DONGGUK UNIV INDUSTRY ACADEMIC COOPERATION	1		1	
BOARD OF REGENTS THE UNIV OF TEXAS SYSTEM	1			1

Application Areas

It can be seen MMIC and hybrid vehicles can be a prospect research area for most of the universities. Univ California has the maximum number of records in the optoelectronic industry.

Applications (Column) / Universities (Rows)	Total	Nanotubes	Defence	Amplifiers	Laser Diodes	LED	Artificial Lighting	High Electron Mobility Transistor	Detector	Displays	Photodiode	Radar	Modulator	Nanotech for Medicines	Flash Memory	Biological Sensors	Automobile	Solar Cells	Clean Energy	MOSFET	Food	Blue Lighting	Mobile Phone	Fuel Cells	High Resolution Printing	Inverter	MMIC	Hybrid Vehicle	Laser Printer	Aviation
Total	340	28	48	51	124	128	65	77	61	14	24	2	38	53	7	11	22	96	21	25	6	1	17	5	11	5	4	5	4	3
UNIV CALIFORNIA	134	10	19	16	68	50	30	24	28	3	12	1	16	21	3	5	7	45	9	6	2		10	3	7	1			1	1
UNIV NAT CENTRAL	28			3	4	19	3	3	5	1	2			1			3	3		1			1					1		
UNIV NAT CHIAO TUNG	27		1		9	8	4	9		1	1		2				3	4	1	3			1			1	2	2		
NATIONAL TAIWAN UNIV	22		1	3	3	6	4	2	1		1		3	1				8	3	1										
UNIV ILLINOIS	17	4	3	2	10	5	4	7	4	1	3	1	6	6		1	1	8		4			1		4	1				
UNIVERSITY OF FLORIDA RESEARCH FOUNDATION INC	15	2	4	5	4	5	1	8	4	4			3	7	1	2	3	2	1	2	2		1	1		1		1		
NORTH CAROLINA STATE UNIV	12	1	8	1	3	2		1	4	2	1		3	3		1		3	1	3			1							
LEHIGH UNIV	11		2	8	5	5	3				1			7	2			2	2										2	
JAPAN SCIENCE & TECH AGENCY	9				8	2	1	1	1		2							2					1							
UNIV ARIZONA	8		2	1	4	4	3	3	3	1				1				4	1				1							
TSINGHUA UNIV	8	7				3	3	1												1										
NATIONAL TSING HUA UNIV	8				2	4		1	1					1		2		2	1	1	1		1							
INTERUNIVERSITAIR MICROELEKTRONICA CENTRUM	8	1		1	1	1	1	7	2									3	1					1			1			
THE HONG KONG UNIV OF SCIENCE AND TECHNOLOGY	7			5	1	3		7					1				1			2						1	1	1		2
YISSUM RESEARCH DEVELOPMENT	6	2	1	3	1	2			3		2		1				2	3	1											
UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	6				2		2	2	1	1	1		1	1			1	2												
UNIV LELAND STANFORD JUNIOR	6		2	2	1	2			3				1	1	1			1		1									1	
TRUSTEES OF BOSTON UNIV	6		5		4	5	1		1				1	1			1	4												
OSAKA UNIV	6	1			2	2	4											2												
CHANG GUNG UNIV	5			1		2	2	2	1					2							1	1								

Physical Properties

The table below represents top 20 universities across different physical properties of gallium nitride. Univ California and Japan Science and Tech lead the number of publicationsfor metal organic chemical vapour deposition. N-type is the least researched physical property as compared to others.

Physical Properties (Column) / Universities (Rows)	Total	Metalorganic CVD	N-Type	P-Type
Total	68	43	12	13
UNIV CALIFORNIA	28	16	5	7
UNIV NAT CHIAO TUNG	6	6		
JAPAN SCIENCE & TECH AGENCY	5	5		
UNIV NAT CENTRAL	4	3		1
TRUSTEES OF BOSTON UNIV	4	3	1	
INTERUNIVERSITAIR MICROELEKTRONICA CENTRUM	4	4		
UNIV ILLINOIS	3	1	1	1
YALE UNIV	2	1	1	
UNIV ARIZONA	2	1		1
THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARN	2		2	
NATIONAL TAIWAN UNIV	2	2		
NANJING UNIV	2	2		
CHANG GUNG UNIV	2	1		1
UNIV OF SEOUL INDUSTRY COOPERATION FOUNDATION	1	1		

UNIV OF CENTRAL FLORIDA RESEARCH FOUNDATION	1		1	
UNIV UTAH	1	1		
UNIV TOHOKU	1			1
UNIV SINGAPORE	1	1		
UNIV CENTRAL FLORIDA RES FOUND	1		1	
ULM UNIVERSITAT	1			1

How we did it?

We first created a group for universities using autofilter option. Using co-occurrence analyzer, we used that group as data filter to generate a matrix for those universities with respect to crystal structure, applications and physical properties separately. The resulting matrix was exportedto excelusing the option present.

Appendix: Search Strings Used for Categorization

Types	Search Query	Results
Rock Salt	(FT) contains (rocksalt OR "rock salt" OR halite OR (sodium* w/1 chloride*) OR "sodium chloride*" OR NaCl OR (rock* w/1 salt*)) AND NOT (((Wurtzite* OR "zinc iron sulfide" OR WZ) OR (Zincblende* OR zincblend* OR (zinc* w/1 (blend* OR blende*)) OR ZB)) OR ("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*"))	51
Wurtzite	(FT) contains ((Wurtzite* OR "zinc iron sulfide" OR WZ) AND NOT ((Zincblende* OR zincblend* OR (zinc* w/1 (blend* OR blende*)) OR ZB) OR (rocksalt OR "rock salt" OR halite OR (sodium* w/1 chloride*) OR "sodium chloride*" OR NaCl OR (rock* w/1 salt*)) OR ("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*")))	97
Zinc-Blende	(FT) contains ((Zincblende* OR zincblend* OR (zinc* w/1 (blend* OR blende*)) OR ZB)) AND NOT ((Wurtzite* OR "zinc iron sulfide" OR WZ) OR (rocksalt OR "rock salt" OR halite OR (sodium* w/1 chloride*) OR "sodium chloride*" OR NaCl OR (rock* w/1 salt*)) OR ("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*"))	45

Applications

Applications	Search Query	Results
Amplifiers	(FT) contains amplifier*	655
Artificial Lighting	(FT) contains (((artificial* w/2 Light*) AND tungsten) OR incandescent OR Halogen OR fluorescent OR "compact fluorescent" OR "infared heat lamp*" OR "ultraviolet light*")	1450
Automobile	(FT) contains (automobile* OR automotive* OR car OR cars OR vehicle* OR motorcar* OR autocar*)	633
Aviation	(FT) contains (aerospace* OR aeronautic* OR aircraft* OR aviation* OR aeroplane* OR airplane* OR rocket* OR spacecraft* OR "space station*" OR shuttlecraft* OR spaceship*)	114
Biological Sensors	(FT) contains (biolog* w/3 sens*)	55
Blue Light	(FT) contains (("blue w/2 light*) OR "blue-light-emitting diode*" OR "Blue light L.E.D." OR "blue/UV wavelength range Light*")	15
Blue Ray	(FT) contains ((((blu* w/1 ray*) OR Blu-ray OR bluray OR "blu ray") w/2 disc*) OR BD)	50
Clean Energy	(FT) contains ((wind* OR water* OR hydro* OR tidal OR solar* OR geothermal* OR clean* OR biomass OR renewable*) w/1 (turbine* OR power* OR energy*))	134
Defence	(FT) contains(defence* OR defense* OR warfare* OR military* OR missile* OR firearm* OR rifle* OR pistol* OR weapon* OR navy* OR submarine* OR naval* OR army OR "Combat Vehicle*")	309
Detector	(FT) contains (detector* OR detecter*OR Coherer)	678
Displays	(FT) contains ((display OR screen OR screens) AND NOT ((light* w/1 emit*) OR led))	311
Flash Memory	(FT) contains((flash* w/2 memory*) OR ((hard* OR compact* OR digital*) w/1 (disk* or disc*)) OR USB OR "Universal Serial Bus" ORDVD OR CD)	248
Food	(FT) contains (agricultur* OR food* OR farming OR husbandry OR "plant growth" OR "plant cultivat*" OR horticultur*)	52
Fuel Cells	(FT) contains ((fuel* OR "phosphoric acid" OR "proton exchange" OR electrolyte OR "molten carbonate" OR "alkaline electrolyte" OR "direct borohydride" OR "protonic ceramic" OR "solid oxide" OR "direct ethanol") w/5 (cell OR cells OR batter*) OR "fuel-cell*")	28

High Electron Mobility Transistor	(FT) contains ("High Electron Mobility Transistor" OR "High-electron-mobility transistor" OR (high* w/2 transistor*) OR HEMT OR "heterostructure FET" OR HFET OR "modulation-doped FET" OR MODFET)	1626
High Resolution Printing	(FT) contains (high* w/3 print*)	40
Hybrid Vehicle	(FT) contains (((hybrid* OR electric* OR "hybrid electric") w/3 (vehicle* OR car OR cars OR automobile*)) OR HEV OR HEVS)	107
Inverter	(FT) contains (inverter* OR invertor*)	219
Laser Diodes	(FT) contains ((laser* w/1 diode*) OR laserdiode*)	1963
Laser Printer	(FT) contains ((laser* w/1 print*) OR laserprint*)	74
LED	(FT) contains ("light-emitting diode*" OR LED OR "Light emitting diode*" OR (light* w/2 diode*)) AND NOT ("light emitting device*" OR "light-emitting device*" OR (light* w/2 device*))	1706
MMIC	(FT) contains ("Monolithic Microwave Integrated Circuit" OR MMIC)	92
Mobile Phone	(FT) contains ("mobile phone" OR ((mobile* OR cell OR cellular OR hand OR wireless*) w/1 (phone* OR device* OR devise*)) OR "cell phone" OR "hand phone" OR phone* OR telephone*)	694
Modulator	(FT) contains (modulator* OR modulater* OR modulation)	634
MOSFET	(FT) contains (MOSFET OR "Metal-Oxide-Semiconductor Field Effect Transistor*" OR "metal oxide semiconductor field effect transistor*" OR "MOS-FET" OR "MOS FET" OR "metal–oxide–semiconductor field-effect transistor*")	635
Nanotech for Medicines	(FT) contains (medic* OR drug* OR pharma* OR healthcare* OR "health-care*" OR "health care" OR Microelectromechanical* OR "MEMS" OR "BioMEMS" OR"micro-electro-mechanical" OR ((micro* OR nano*) w/1 (electromechanical*)) OR MEM OR NEM OR nanoelectromechanical* OR "NEMS" OR "BioNEMS" OR nanoneedle* OR (nano* w/1 needle*))	563
Nanotubes	(FT) contains ("carbon nanotube*" OR nanotube* OR "nano tube*" OR CNT OR SWNT* OR DWNT* OR TWNT* OR MWNT* OR (carbon w/2 nano*) OR ((carbon OR "Single Wall*" OR "Double Wall*" OR "Thin wall*" OR "multi wall*" OR "Single-Wall*" OR "Double-Wall*" OR "Thin-wall*" OR "multi-wall*" OR	298

	multiwall* OR thinwall* OR doublewall* OR singlewall*) w/5 (nanotube* OR nano-tube*)))	
Optoelectronics	(FT) contains (optoelectronic* OR (opto* w/1 electronic*))	1080
Photodiode	(FT) contains (photodiode* OR "photo diode*" OR "photo-diode")	398
Radar	(FT) contains ((radar* OR "RAdio Detection And Ranging") AND NOT (defence* OR defense* OR warfare* OR military* OR missile* OR firearm* OR rifle* OR pistol* OR weapon* OR navy* OR submarine* OR naval* OR army OR "Combat Vehicle*"))	72
Satellite Communication	(FT) contains (satellite* OR satelite* OR "space probes")	140
Solar Cells	(FT) contains (((photovoltaic* OR photovotaic* OR solar* OR PV) w/5 (cell* OR batter* OR (storage w/3 (element* OR device* OR devise*)))) OR photovoltaic* OR photovotaic* OR solar* OR PV)	826
Thin Film Batteries	(FT) contains (((thin* film*) w/5 (batter* OR cell OR cells OR (storage w/3 (element* OR devise* or device*)))) AND NOT (((photovoltaic* OR photovotaic* OR solar* OR PV) w/5 (cell* OR batter* OR (storage w/3 (element* OR devise* OR device*)))) OR photovoltaic* OR photovotaic* OR solar* OR PV))	3

Physical Properties

Physical Properties	Search Query	Results
Metalorganic CVD	(FT) contains (("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*") AND NOT (("p-type" OR "p type") OR ("n-type" OR "n type")))	354
N-Type	(FT) contains (("n type" OR "n-type") AND NOT (("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*") OR ("p-type" OR "p type")))	246
P-Type	(FT) contains (("p type" OR "p-type") AND NOT (("metal organic chemical vapour deposit*" OR "metalorganic chemical vapour deposit*" OR "MO-CVD" OR MOCVD OR "Metalorganicvapour phase epitaxy" OR MOVPE OR "organometallic vapour phase epitaxy" OR OMVPE OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*" OR "metal-organic chemical vapour deposit*" OR "metal-organic chemical vapor deposit*" OR "metal organic chemical vapor deposit*" OR "metalorganic chemical vapor deposit*") OR ("n-type" OR "n type")))	309

Summary

This report categorizes and graphically analyzes research around crystal structures, physical properties and applications of gallium nitrideandhighlights the key companies involved.

GaN with a high crystalline quality can be obtained by depositing a buffer layer at low temperatures. Such high-quality GaN led to the discovery of p-type GaN, p-n junction blue/UV-LEDs and room-temperature stimulated emission (indispensable for laser action).This has led to the commercialization of high-performance blue LEDs and long-lifetime violet-laser diodes, and to the development of nitride-based devices such as UV detectors and high-speed field-effect transistors.

High-brightness GaN light-emitting diodes (LEDs) completed the range of primary colors, and made applications such as daylight visible full-color LED displays, white LEDs and blue laser devices possible. The first GaN-based high-brightness LEDs were using a thin film of GaN deposited via MOCVD on sapphire. Other substrates used are zinc oxide, with lattice constant mismatch only 2%, and silicon carbide (SiC).Group III nitride semiconductors are in general recognized as one of the most promising semiconductor family for fabricating optical devices in the visible short-wavelength and UV region.

GaN HEMTs have been offered commercially since 2006, and have found immediate use in various wireless infrastructure applications due to their high efficiency and high voltage operation. Second generation technology with shorter gate lengths will be addressing higher frequency telecom and aerospace applications.

GaN based MOSFET and MESFET transistors also offer many advantages in high power electronics, especially in automotive and electric car applications.Nanotubes of GaN are proposed for applications in nanoscale electronics, optoelectronics and biochemical-sensing applications

The forecasted revenue for GaN power semiconductors is $1.75 billion by end of 2022 (after 10 years). Apart from power semiconductors, GaN is predominantly used in optosemiconductors, for LEDs and laser diodes. The total GaN semiconductors (including both, power and optosemiconductors) market revenue is expected to reach $2.6 billion by 2022.

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Note: In combination with above links, we also referred some non patent literature