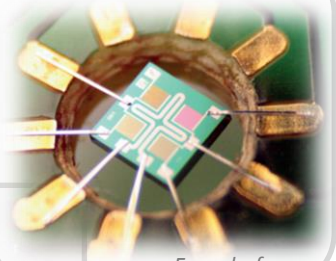
Miniaturized Gas Sensors

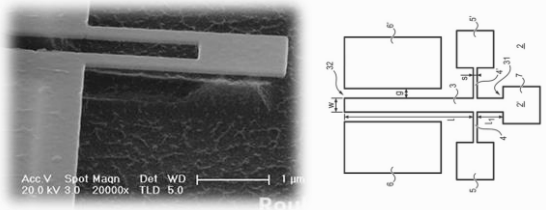
Patent Landscape Analysis

October 2016

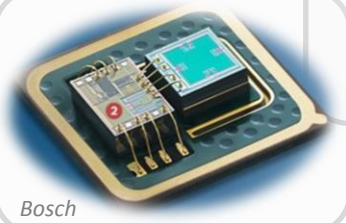
REPORT SAMPLE



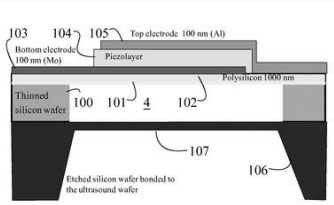
Fraunhofer

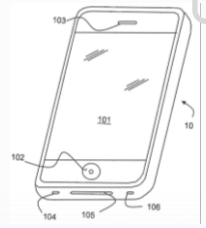


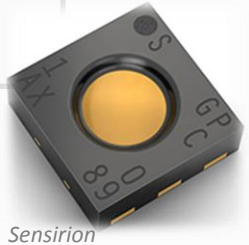
Caltech



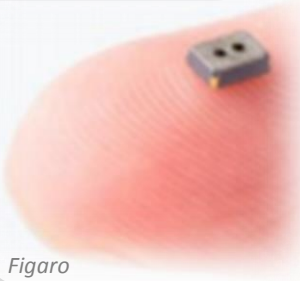
Bosch



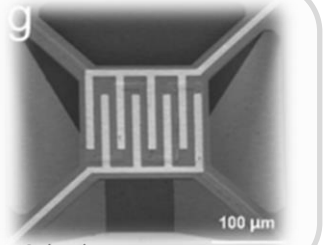




Sensirion



Figaro



Caltech

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Patent & Technology Intelligence

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KnowMade

Knowmade is a Technology Intelligence and IP Strategy consulting company specialized in analysis of patents and scientific information. The company supports R&D organizations, industrial companies and investors in their business development by helping them to understand their IP environment and follow technology trends. **Knowmade** is involved in Microelectronics & Optoelectronics, Compound Semiconductors, IC Manufacturing & Advanced Packaging, Power & RF Devices, MEMS & Sensors, Photonics, Micro & Nanotechnology, Biotech/Pharma, MedTech & Medical Devices. **Knowmade** provides Prior art search, Patent Landscape Analysis, Patent Valuation, Freedom-to-Operate Analysis, Litigation/Licensing support, Scientific Literature Landscape, Technology Scouting and Technology Tracking. **Knowmade** combines information search services, technology expertise, powerful analytics tools and proprietary methodologies for analyzing patents and scientific information. Knowmade's analysts have an in-depth knowledge of scientific & patent databases and Intellectual Property.

We Know Technology, We Know Patents

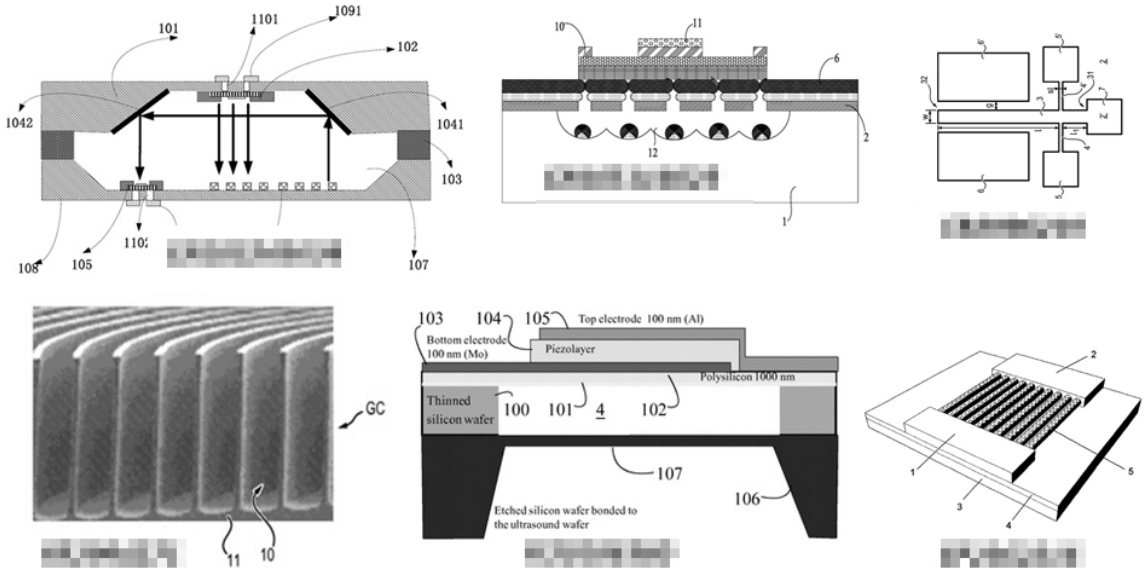
INTRODUCTION

Scope of the Report

- This report provides a detailed picture of the patent landscape for **miniaturized gas sensors.** They have mainly been developed to address the demand [illegible] **applications market** (home devices, wearable electronics and mobile phones).
- These applications are driving new gas sensors development to reduce cost, power consumption and size with **MEMS technology**. Therefore, in this report, these ga[illegible] sensors are named **MEMS gas sensors**.
- This report covers **patents published worldwide up to August 2016**.
- We have selected and analyzed more than **2,040 patents and patent applications** (1,050+ patent families) relevant to the scope of this report.

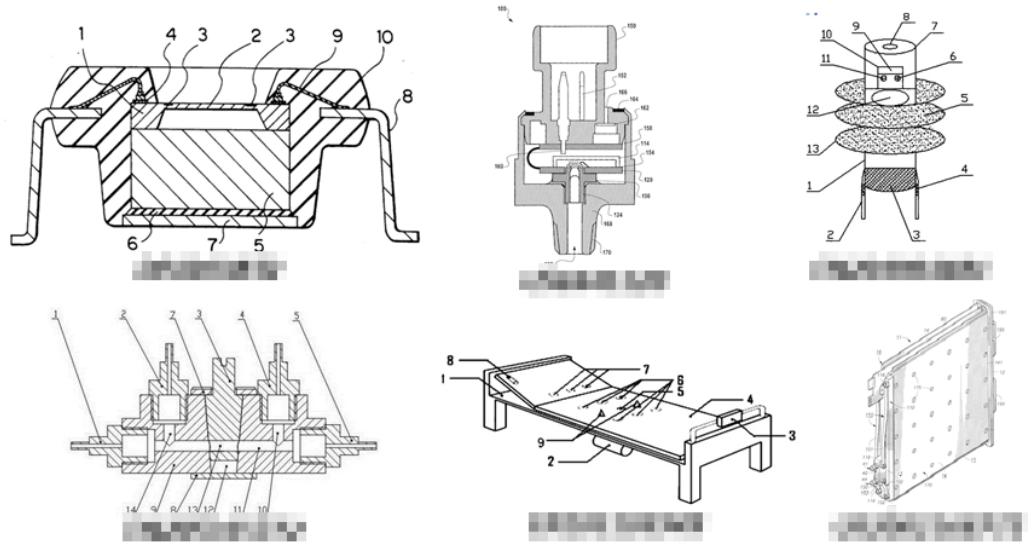
Included in the report

- *Patents related to **gas sensing technologies** with very innovative approaches, based on existing **MEMS/Semiconductor/Optical integration platforms** and manufactured by **micro-fabricating** processes.*



Not included in the report

- *Patents related to "large" scale gas sensors*
- *Patents related to gas rate or flow or pressure sensors*
- *Patents related gas leakage sensors if the leakage is detected thanks to a gas rate or flow or pressure sensor.*
- *Patents related to devices with a MEMS gas sensor which don't describe materials or processes used to manufacture it.*



INTRODUCTION

Key Features of the Report

- The report provides **essential patent data** for **miniaturized gas sensors.**

- It provides **in-depth patent analyses** of **key technologies** and **key players** including:
  - Time evolution of patent publications and countries of patent filings.
  - Current legal status of patents.
  - Ranking of main patent applicants.
  - Joint developments and IP collaboration network of main patent applicants.
  - Key patents.
  - Granted patents near expiration.
  - Relative strength of main companies IP portfolio.
  - Matrix patent applicants/technology issues for more than 20 players.

- The "MEMS gas sensor" **IP profiles of 18 key companies** is presented, including key patents, technological issues, partnerships, IP strength and latest market news:

  Bosch, AMS, Sensirion, Apix Analytics, Applied Sensor, Siemens, Figaro, Cambridge CMOS Sensors, Micronas, Spec Sensors, General Electric, Honeywell, NGK Spark Plugs, VTT, Fraunhofer, Caltech, CEA, ETRI

INTRODUCTION

Key Features of the Report

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

- This **useful patent database** allows multi-criteria searches, including:
  - Patent publication number
  - Hyperlinks to the original documents
  - Priority date
  - Title
  - Abstract
  - Patent assignees
  - Technical segmentation
  - Legal status for each member of the patent family

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

INTRODUCTION

Objectives of the Report

Understand the competitive environment from technology and patent perspective

- ✓ Understand technology & market from a patent perspective.
- ✓ Understand the patent landscape.
- ✓ Identify risks & opportunities.
- ✓ Comprehend key trends in IP and technology development.
- ✓ List the major players and the relative strength of their patent portfolio.
- ✓ Name new players.
- ✓ Identify IP collaboration networks between key players (industrial and academic).
- ✓ Position key players within the value chain and understand their strategic decisions.
- ✓ Understand the competitive landscape, your current and future competitors.
- ✓ Understand your competitors' strategic direction and future product offerings.
- ✓ Determine your competitors' strengths and weaknesses.
- ✓ Identify current legal status of patented technologies.
- ✓ Identify key patents by assignees and technology.
- ✓ Identify blocking and valuable patents.
- ✓ Overview of past and current litigations and licensing agreements.
- ✓ Avoid patent infringement.
- ✓ Appreciate the link between the patent landscape and market evolutions.
- ✓ Discover new markets & technology directions.
- ✓ Identify untapped areas and opportunities to direct R&D and patenting activity.

METHODOLOGY

Patent Search, Patent Selection, Patent Analysis (1/2)

- The data were extracted from the **FamPat worldwide database** (Questel-ORBIT) which provides 90+ million patent documents from offices.

- The search for patents was performed in **August 2016**, hence patents published after this date will not be available in this report.

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

- The **selection of the patents** has been done both **automatically** and **manually** (all details in next slides).

Number of selected patent families for miniaturized gas sensors:

1,058 over a number of returned results > 5,000

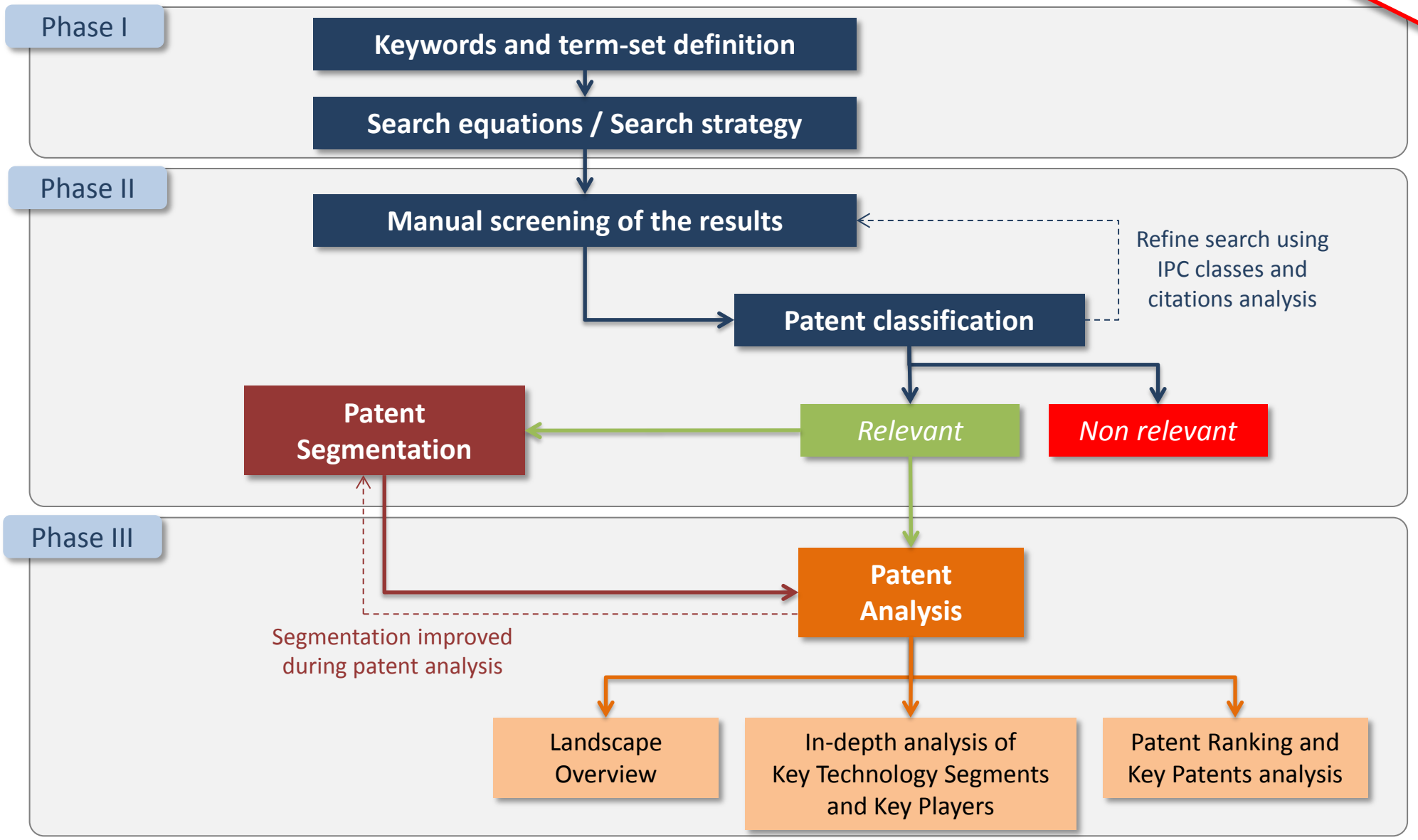
- The statistical analysis was performed with **Orbit IP Business Intelligence web based patent analysis software from Questel**.

- The patents were **manually categorized in technical segments** using keyword analysis of patent title, abstract and claims, in conjunction with expert review of the subject-matter of inventions (all details in next slides).

- For legal status of European (EP) and PCT (WO) patent applications, EPO Register Plus has been used. For legal status of US patents, USPTO PAIR has been used. For legal status of other patents, information have been gotten from their respective national registers.

METHODOLOGY

Patent Search, Patent Selection, Patent Analysis (2/2)

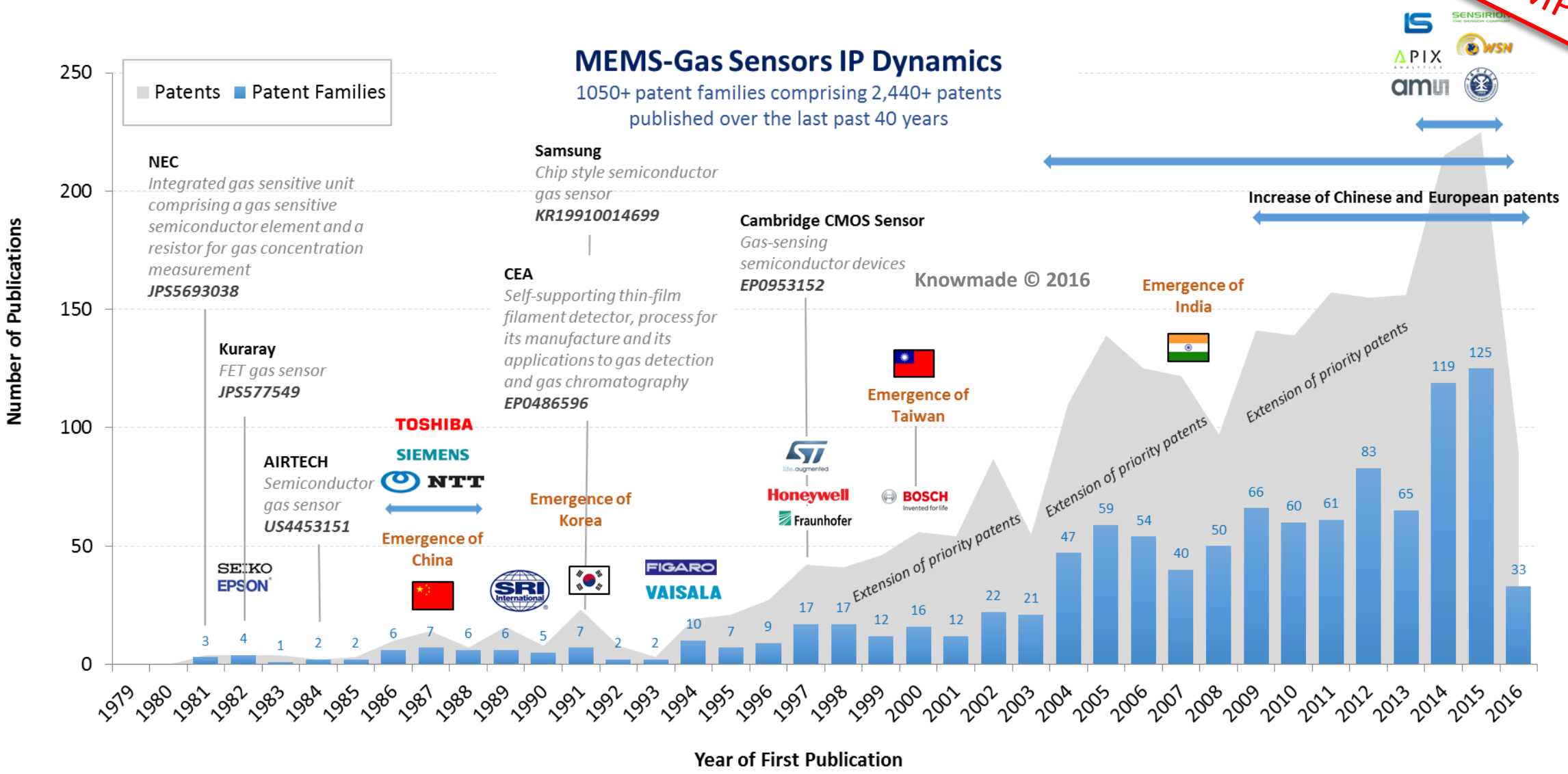


PATENT LANDSCAPE OVERVIEW

Time Evolution of Patent Publications

Note: The patent search was done in August 2016, thus the data corresponding to the year 2016 are not complete

REPORT SAMPLE



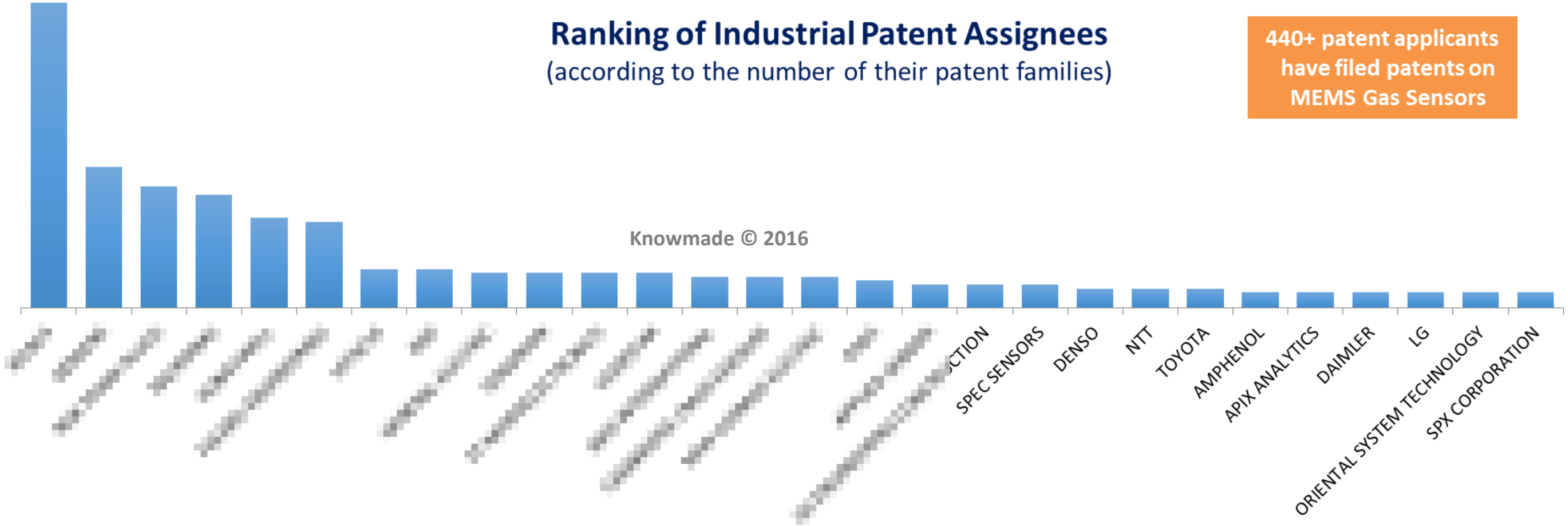
PATENT LANDSCAPE OVERVIEW

Main Industrial Patent Assignees

Ranking of Industrial Patent Assignees

(according to the number of their patent families)

440+ patent applicants have filed patents on MEMS Gas Sensors



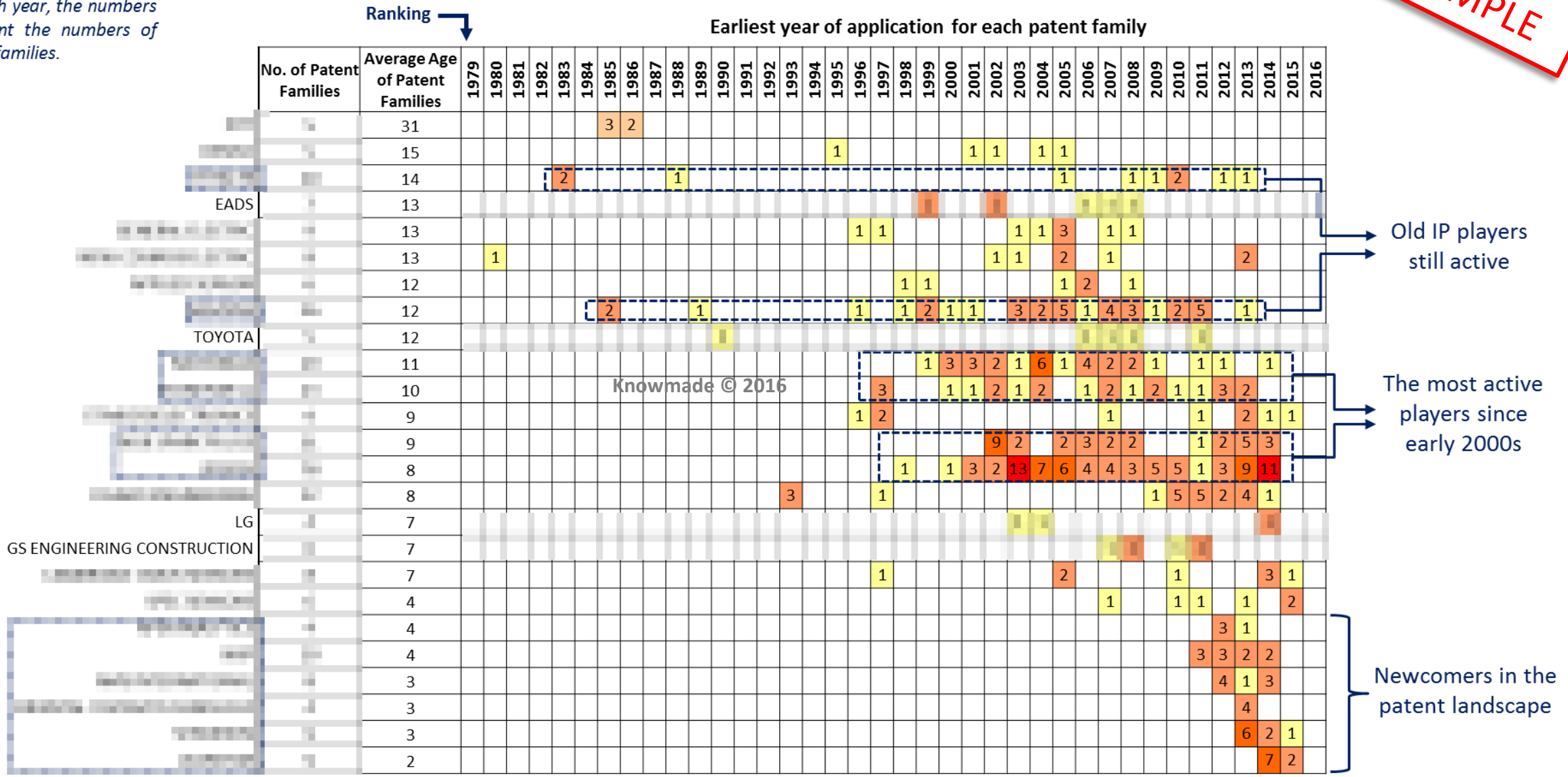
- In 2016, [redacted] acquired more than 85% of **Micronas** [redacted]
- [redacted] acquired **AppliedSensor** in 2014, CMOS [redacted] in 2015 and [redacted] in 2016.
- **APIX Analytics** is a spin-off of [redacted] founded in 2011 on the basis of R&D results on gas sensors from a partnership between [redacted]
- **Siemens includes Siemens Healthcare** and **Siemens Industry. LG** includes **LG Electronics, LG Chem** and **LG Innotek.**
- **NGK Spark Plugs** includes **NGK Spark Plugs** and **NGK Insulators.**
- **General Electric** includes **GE Security** and **General Electric** [redacted]
- **ST Microelectronics** includes **ST Microelectronics** and **SGS Thomson Microelectronics**, its name until 1998.
- **NTT** stands for **Nippon Telegraph and Telephone. Leanstar** stands for **Suzhou Leanstar Electronic Technology**.

PATENT LANDSCAPE OVERVIEW

Time Evolution of Industrial Patent Assignees

Note: The da… onding to the year 2015 … not be complete si… ing these year…

For each year, the numbers represent the numbers of patent families.



PATENT LANDSCAPE OVERVIEW

Countries of Patent Filing for Main Non-Profit Organisations Patent Assignees

	No Patent families	Europe	USA	China	Japan	Korea	Taiwan	India	WO
[redacted]	[redacted]	33	[redacted]	[redacted]	[redacted]	1			[redacted]
[redacted]	[redacted]	6	[redacted]	[redacted]	[redacted]				5
[redacted]	[redacted]	9	[redacted]						5
[redacted]	[redacted]	7	[redacted]	[redacted]	[redacted]				7
UNIVERSITY OF FLORIDA	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]		[redacted]		2	[redacted]			
[redacted]	[redacted]	2	1			[redacted]			2
[redacted]	[redacted]		1			4			
ITRI	[redacted]		[redacted]				[redacted]		
[redacted]	[redacted]	5		19					5
[redacted]	[redacted]	1	1	5	1				1
[redacted]	[redacted]			4					
[redacted]	[redacted]			20					
[redacted]	[redacted]			[redacted]					
CHINESE INSTITUTE OF MICROELECTRONICS	[redacted]			[redacted]					
SHANGHAI JIAO TONG UNIVERSITY	[redacted]			[redacted]					
XI'AN JIAOTONG UNIVERSITY	[redacted]			[redacted]					
SIMIT	[redacted]			[redacted]					
UNIVERSITY HARBIN SCIENCE & TECHNOLOGY	[redacted]			[redacted]					
NORTH UNIVERSITY OF CHINA	[redacted]			[redacted]					
SOOCHOW UNIVERSITY	[redacted]			[redacted]					

American and European Non-Profit Organisations

[redacted] except **Fraunhofer** which [redacted]

Korean and Taiwanese Non-Profit Organisations

They mainly file patents in th[redacted] patent extensions in Europe, U[redacted] which equally file domestic an[redacted]

Chinese Non-Profit Organisations

They only file patents in **China**, [redacted] University which file patents exten[redacted] and Japan.

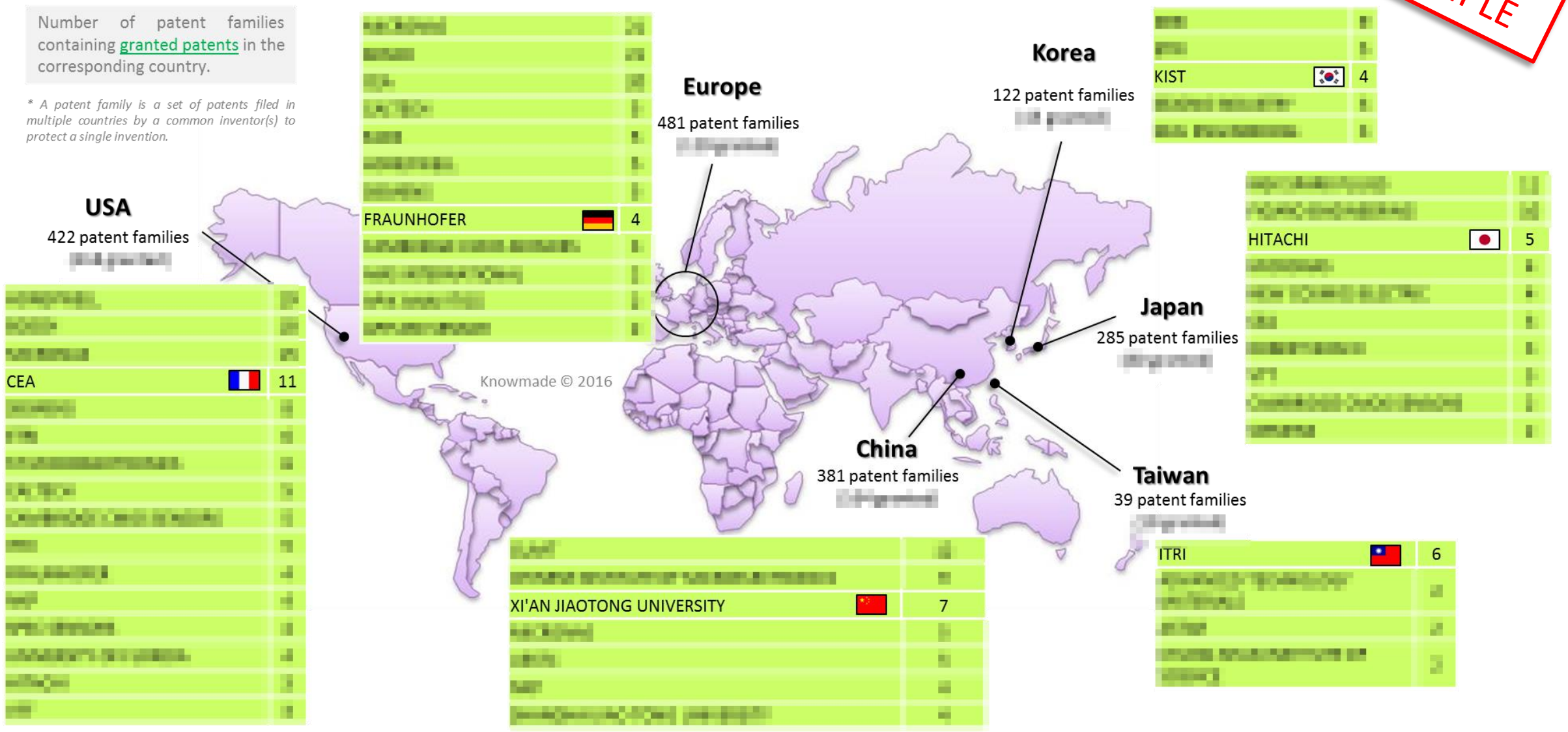
Countries are defined by the country code from the patent numbers. The number represents number of published patent families. Note that PCT (Wo) and European (EP) applications may hide other countries that are not yet published.

PATENT LANDSCAPE OVERVIEW

Mapping of Main Current Patent Holders

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.*



PATENT LANDSCAPE OVERVIEW

Patent Portfolio Summary of Main Industrial Patent Assignees

Patent Applicants	No. of patent families	Oldest priority year of the patent portfolio	Earliest publication year	No. of patent families filed / year (average)	No. of granted patents	No. of pending patents	No. of dead patent families	Average age of patents families (Year)	Number of patent families containing granted patents in the corresponding country							Number of patent families containing applications in the corresponding c							
									USA	Europe	Japan	Korea	China	Taiwan	India	USA	Europe	Japan	Korea	China	Taiwan	India	PC (WO)
Company A	1	1999	2000	0.4	10	2	2	12.7	1	5	1		1				2						
Company B	1	1998	1998	0.4	2	1	3	12.3		2							1						
Company C	1	2007	2009	0.8	2	0	4	6.8				2											
Company D	1	2007	2008	0.8	5	7	0	4.2	4							2	1						2
Company E	1	1995	1997	0.3	2	1	4	14.6	1		1						1						
Company F	1	1985	1986	0.2	0	0	5	30.6															

PATENT LANDSCAPE OVERVIEW

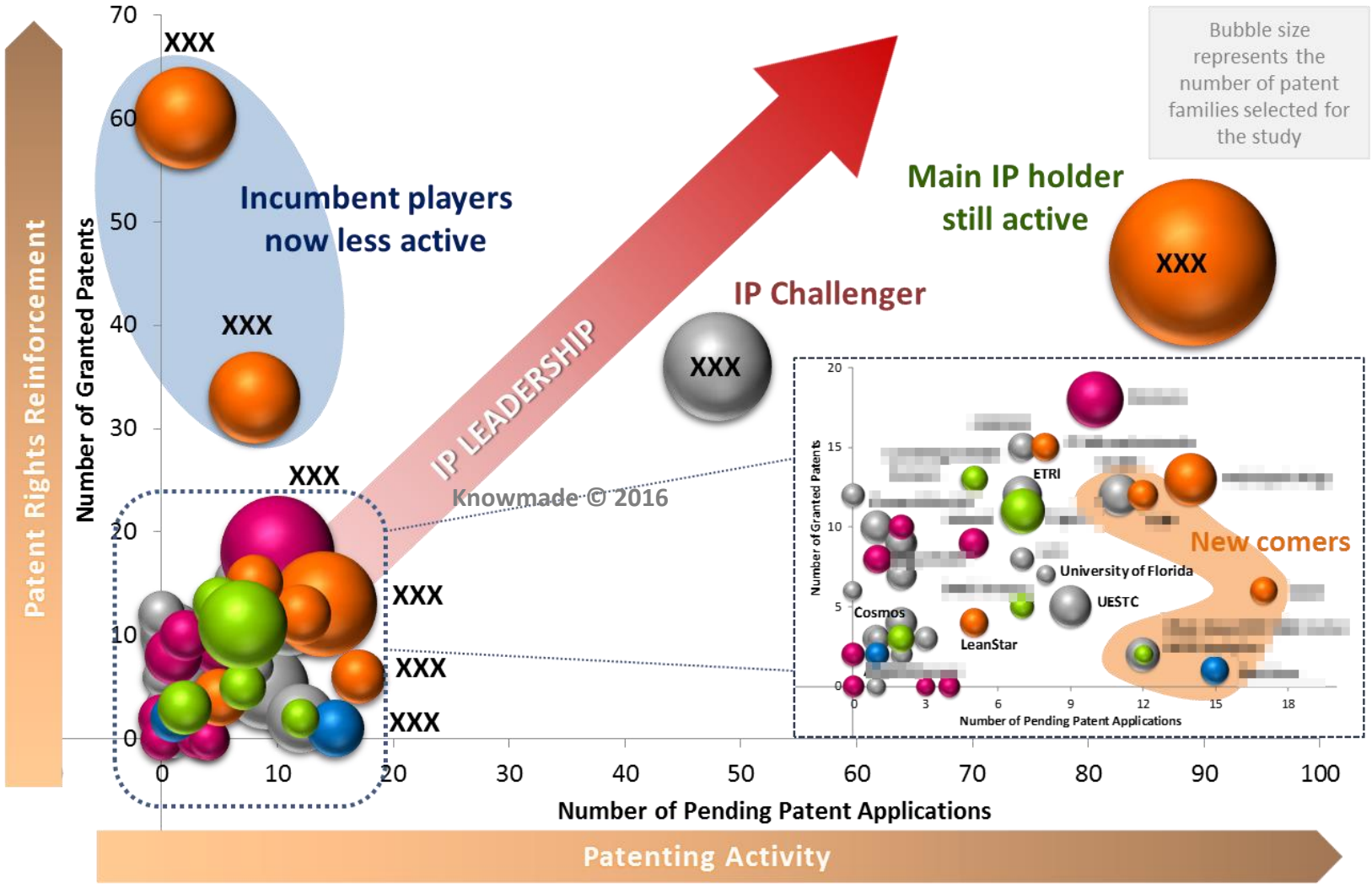
Most Cited Granted Patents (1/2)

Patent number	Patent Assignee	Title	Current Legal Status	Application date	Expiration date *	Number of Forward Citations	Age from Publication Date (Year)	Ranking Average Number of Forward Citations / Year	Main citing patent applica
U		ular species	GRANTED	1999-06-14	2019-06-14				
US2 66		cal systems nts	GRANTED						
US2 27		tform for evice arrays	GRANTED						
US2 64		ed analyzer ystem	GRANTED	2006-07-26	2027-02-02	68	7.1	9.6	Broadcom, Smiths detection, Thermo Fisher Scientific
US2 23		rated sensor	GRANTED	2003-05-22	2024-09-05	106	11.7	9.0	General Electric, Maui Imaging, Philips, Georgia Tech
US2 89	SIEMENS	ecting a	GRANTED						
US2 41			GRANTED						Robert Bosch, Silicon Laboratories, General electric, CREE
US2 40	ROBERT BOSCH	ment having producing ent	GRANTED						
U	CAMBRIDGE CMOS SENSORS	devices	GRANTED						
US2 49		otechnology ufacture	GRANTED						
US2 26	HONEYWELL	or arrays for gases, and the same	GRANTED						

** 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.*

PATENT LANDSCAPE OVERVIEW

IP Leadership of Main Patent Assignees



- **Company A** is leading the IP landscape with 40+ granted patents and 90+ pending patent applications, [redacted] are mainly related to FET, [redacted] sors and gas sensors with [redacted]

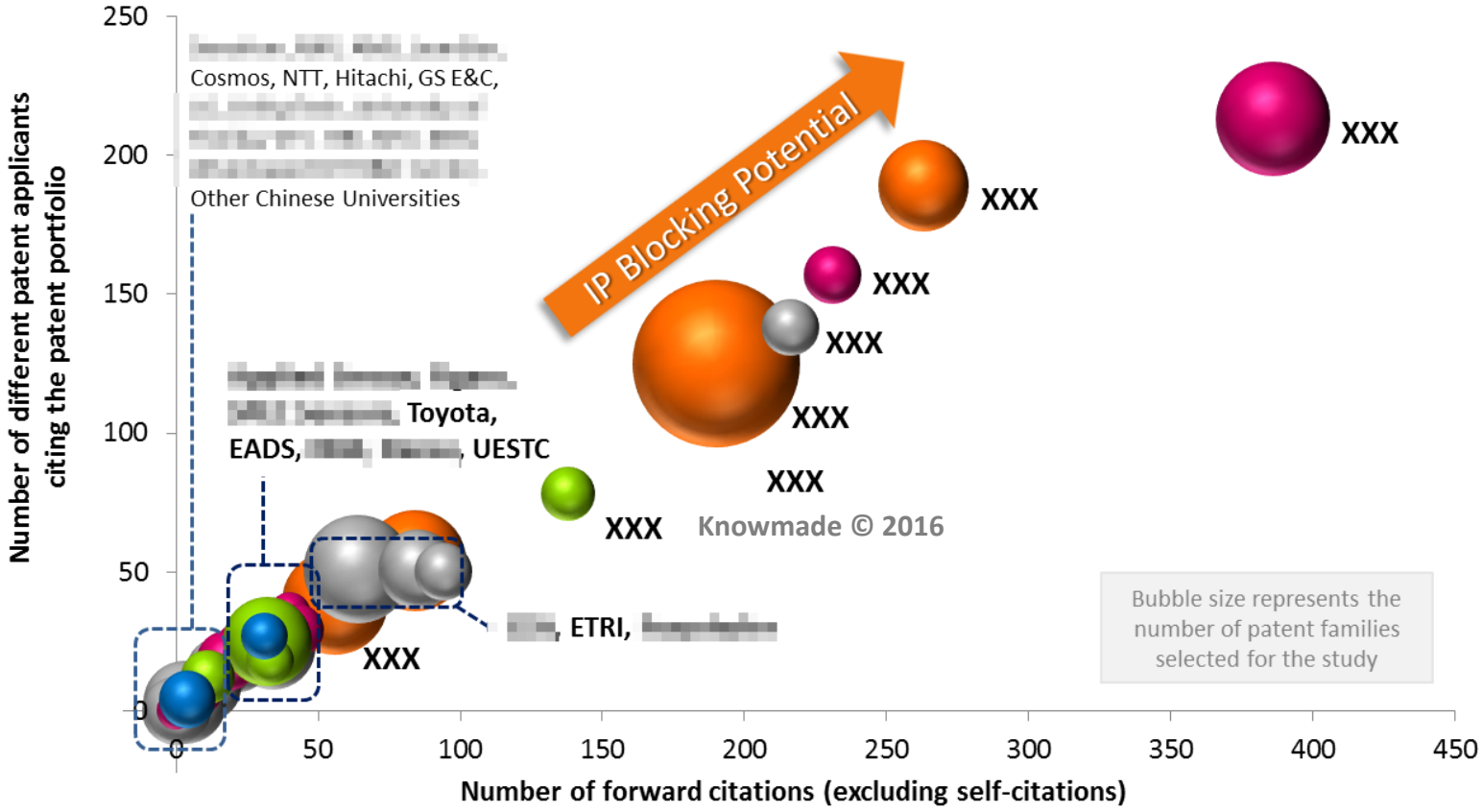
- **Company B** is an IP challenger with numerous granted patents and pending patent applications all over the world. [redacted] S, optical and FET gas sensor[redacted]

- **Company C** and **Company D** have a lot of enforceable patents but they have currently a lower amount of patents in pre-grant stage compared to **Company E, Company F, Company G, Company H, Company J, Company K, Company L** and **Company M. Company C** files patents on [redacted] MEMS gas sens[redacted] detector.

- [redacted] patents on MEMS Gas Sensors in 2011-2013, but they have already granted patents and noticeable number of pending patent applications. They have a worldwide IP Strategy, except [redacted] **center** which are [redacted]

PATENT LANDSCAPE OVERVIEW

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: This graph is at patent family level. The identification of a "blocking patent" requires an in-depth specific analysis of each patent documents composing the patent families.

- **Company A** and **Company B**, whose patent portfolios have the strongest strength index for prior art contribution, distinguish themselves with the **highest IP blocking potential**. Their patents relating to MEMS Gas Sensors received a lot of forward citations from a lot of different patent applicants. That means that they have the **capacity to hamper** the other firms' attempts to patent related inventions. Note that **Company A** and **Company B** hold respectively **XX granted patents** and **XX granted patents**, mainly in USA, Europe, Japan, China.

- Even if **Company C** has a large MEMS Gas Sensor patent portfolio (XXX+ alive patents worldwide), it **does not show the highest IP blocking potential**.

- Even if **Company D** holds the highest number of granted patents (XX granted patents worldwide), it **does not show the highest IP blocking potential**.

- Despite their weaker patenting activity, **Company E, Company F** and **Company G** have relatively high **IP Blocking potential**.

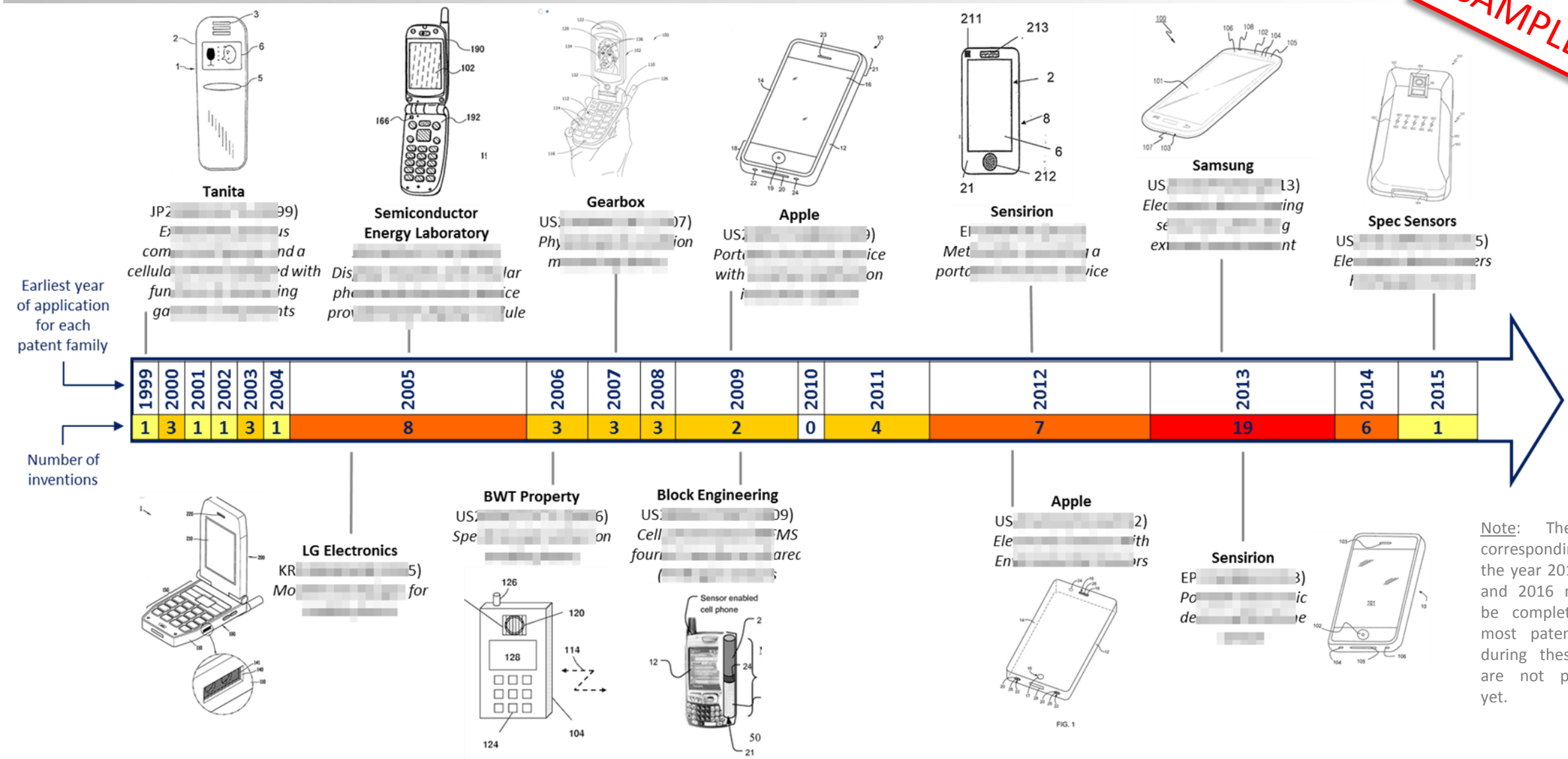
IP POSITON VS. MARKET POSITION

Comparison of IP and Market Position of Key Players (1/3)

	IP Position							Market Position		
Patent Applicants	No of patent families	Enforceability (No of granted patents)	R&D and patent activity (No of pending patents)	Geographic coverage (families size)	IP strength	Technological coverage	Main patented technologies for gas sensors	Gas sensors on the market (all applications)	Gas sensors on the market for consumer applications	Technology used gas sensors for consumer applications
BOSCH							Opt OS	Vari with	MEM ors fo	
MICRONAS									MEMS-FET gas sensors	
HONEYWELL		High					Opt al, Ele al	E ir e a s cor ors	Gas with IR d nical	
FIGARO				Japan, USA			Th S, Ele al	Va m sca MS-	M gas s t ele sor	
SENSIRION					Low		CM cal	Temperature, pressure and gas sensors for IoT applications	M oT	
SPEC SENSORS							Ele al,	Sm gas	Sma nical	
AMS*	Medium						M	Ga ts*	dete sors	ho OS
CAMBRIDGE CMOS SENSORS*			Low			Limited	CMO ical, Mi es	Ga ts*	(h micr MS-IR	CMOS with micro-hotplates/MEMS-IR
APPLIED SENSOR*							FET, Chemical, Electromechanical	Ga ts*		
NXP*							CMOS	N ts	N cts	

* AMS acquires Applied Sensor in 2014, CMOS environmental sensor business of NXP in 2015 and Cambridge CMOS Sensors in 2016.

Patents claiming mobile phones with gas sensors



Note: The data corresponding to the year 2014, 2015 and 2016 may not be complete since most patents filed during these years are not published yet.

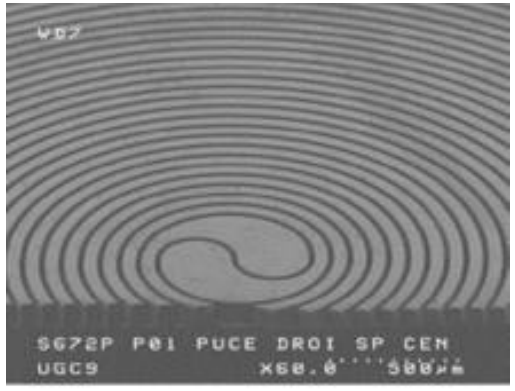
IP PROFILE OF KEY PLAYERS

CEA (French Alternative Energies and Atomic Energy Commission)

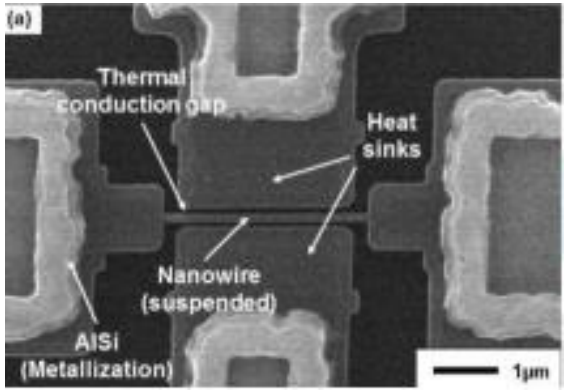
Company Profile

- The **French Alternative Energies and Atomic Energy Commission** or **CEA**, is a French public government-funded research organization in the areas of energy, defense and information technologies and health technologies. It maintains a cross-disciplinary culture of engineers and researchers, building on the synergies between fundamental and technological research. It is divided into 5 divisions: Nuclear energy (DEN), Technological research (DRT), Life sciences (DSV), Sciences of matter (DSM) and Military applications (DAM). Research on micro-batteries in CEA is now performed in LETI, the CEA institute specialized in micro-electronic devices. The research on gas sensors is performed in LETI and IRAMIS.

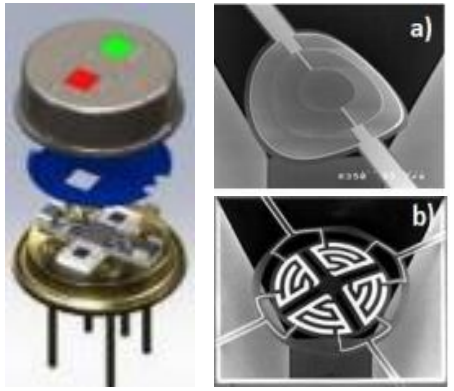
- CEA has created more than 150 start-ups in about 20 years, including 4 to develop gas sensors and detectors for them.
  - **Mir-Sense** was created in 2015 to develop photo-acoustic detectors. MirSense technology is the outcome of over 15 years of R&D in **III-V lab**, a common laboratory of **Alcatel**, **Thales** and the **CEA-Leti**. Up to now, there is no patents with Mir-sense as patent assignee. The company should develop its products on the basis of CEA patents licenses.
  - **eLichens** was created in 2014 and develops gas sensors with NDIR detectors for air quality analysis via lichens detection. There is no patents with eLichens as patent assignee. Up to now, the company should develop its products on the basis of CEA patents licenses.
  - **APIX Analytics**, formerly **APIX Technology,** was created in 2011. The company develops MEMS gas sensors. Their technology is the outcome of the partnership between **CEA-LETI** and **CALTECH**. **APIX Analytics** has 4 patent families related to MEMS-Gas Sensors.
  - **Ethera** was created in 2010 to develop sensors for Volatile Organic Compounds with optical detection systems for home air quality surveillance. There are only two patent families co-filed to Ethera and SEB in 2013 and 2014 for filtration device for air purification apparatus. Up to now, the company should mainly develop its products on the basis of CEA patents licenses.



Silicon MEMS Gas Chromatograph
Source: CEA



Silicon NEMS Gas detector
Source: CEA



NDIR sensor and IR micro-sources used in eLichens devices
Source: CEA

NEMo air quality sensor
Source: Ethera

MultiSense QCL based spectrometer module for gas analyzers
Source: MirSense

CEA (French Alternative Energies and Atomic Energy Commission)

Patent portfolio summary for MEMS gas sensors

Large Portfolio

1988 Oldest priority date

7.0 Patent family average age

[redacted] Patent families

[redacted] Granted patents

[redacted] Pending applications

[redacted] Dead Patent families

Medium Portfolio Strength

Medium IP Blocking Potential

High Leadership

Electrical

[redacted]

FET

CMOS/MOS

Chemical

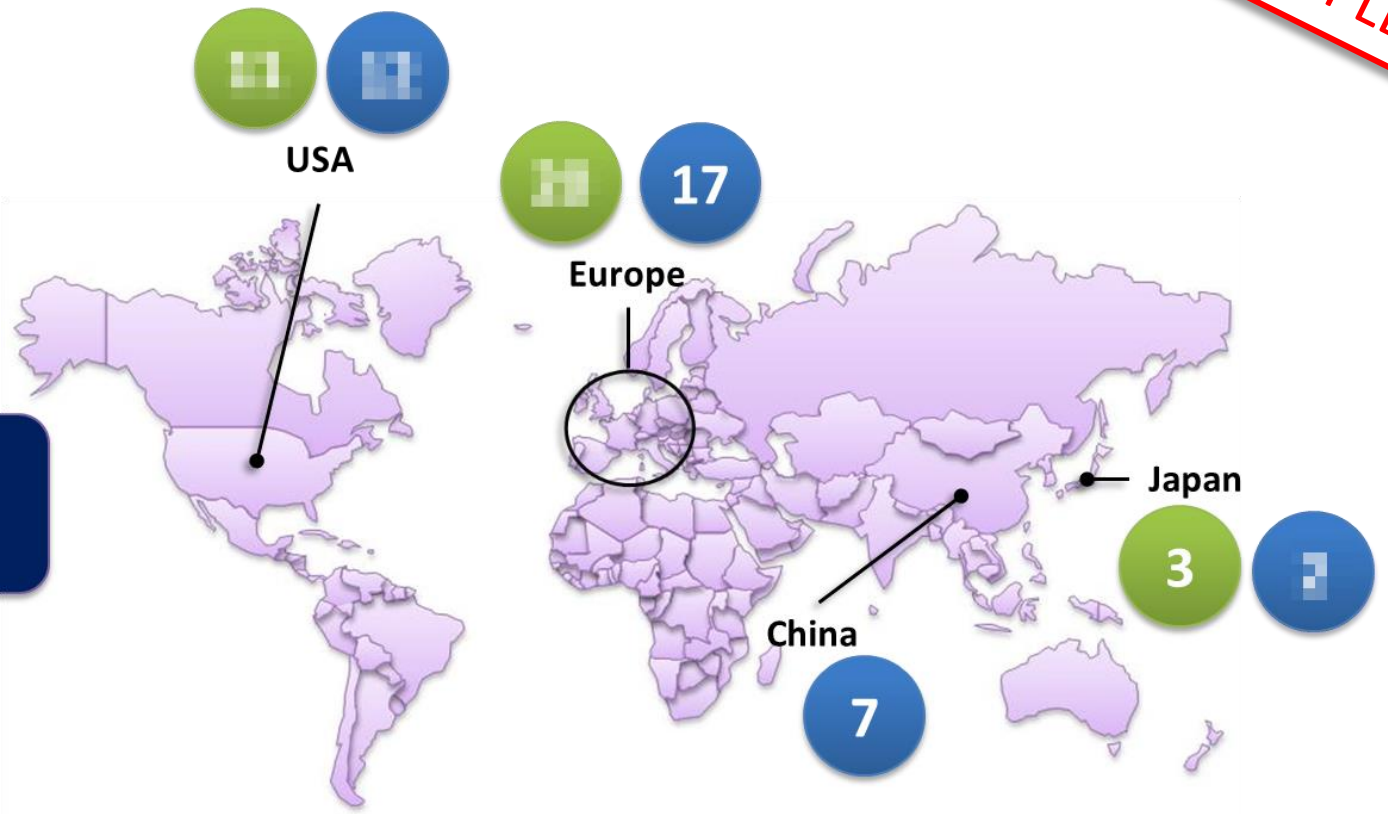
CNTs / Graphene

MEMS

Optical

Acoustic

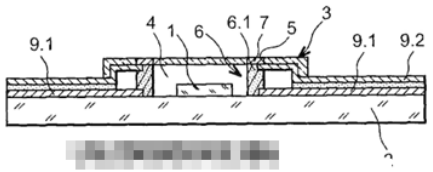
Thermal

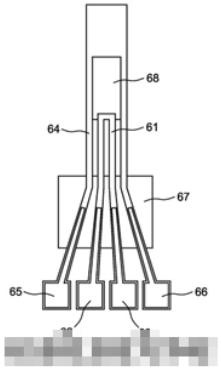


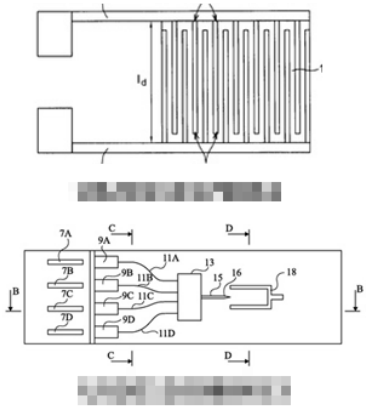
CEA (French Alternative Energies and Atomic Energy Commission)

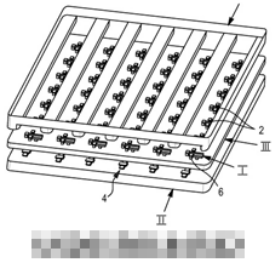
Key patents for MEMS gas sensors

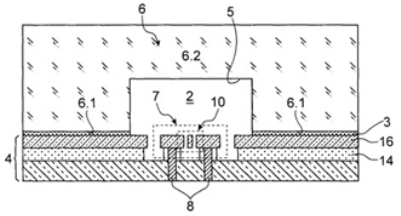
Patent number	English title	Application date	Current Legal Status	Expiration date *	Number of Backward Citations	Number of Forward Citations	Average Number of Forward Citations / Year
US2[redacted]386	[redacted]	[redacted]	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]742	[redacted]	[redacted]	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]361	[redacted]	[redacted]	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]542	[redacted]	[redacted]	PENDING	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]720	[redacted]	2014-07-21	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]453	[redacted]	[redacted]	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
E[redacted]	[redacted]	[redacted]	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
F[redacted]	[redacted]	2012-10-02	GRANTED	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]291	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
US2[redacted]301	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	Sensor for detecting chemical species or photons using a field effect transistor	1992-01-22	EXPIRED	2012-01-22	3	11	0.5

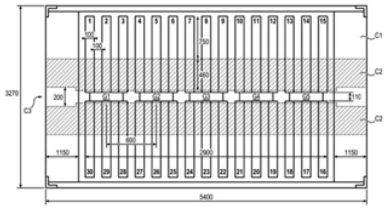






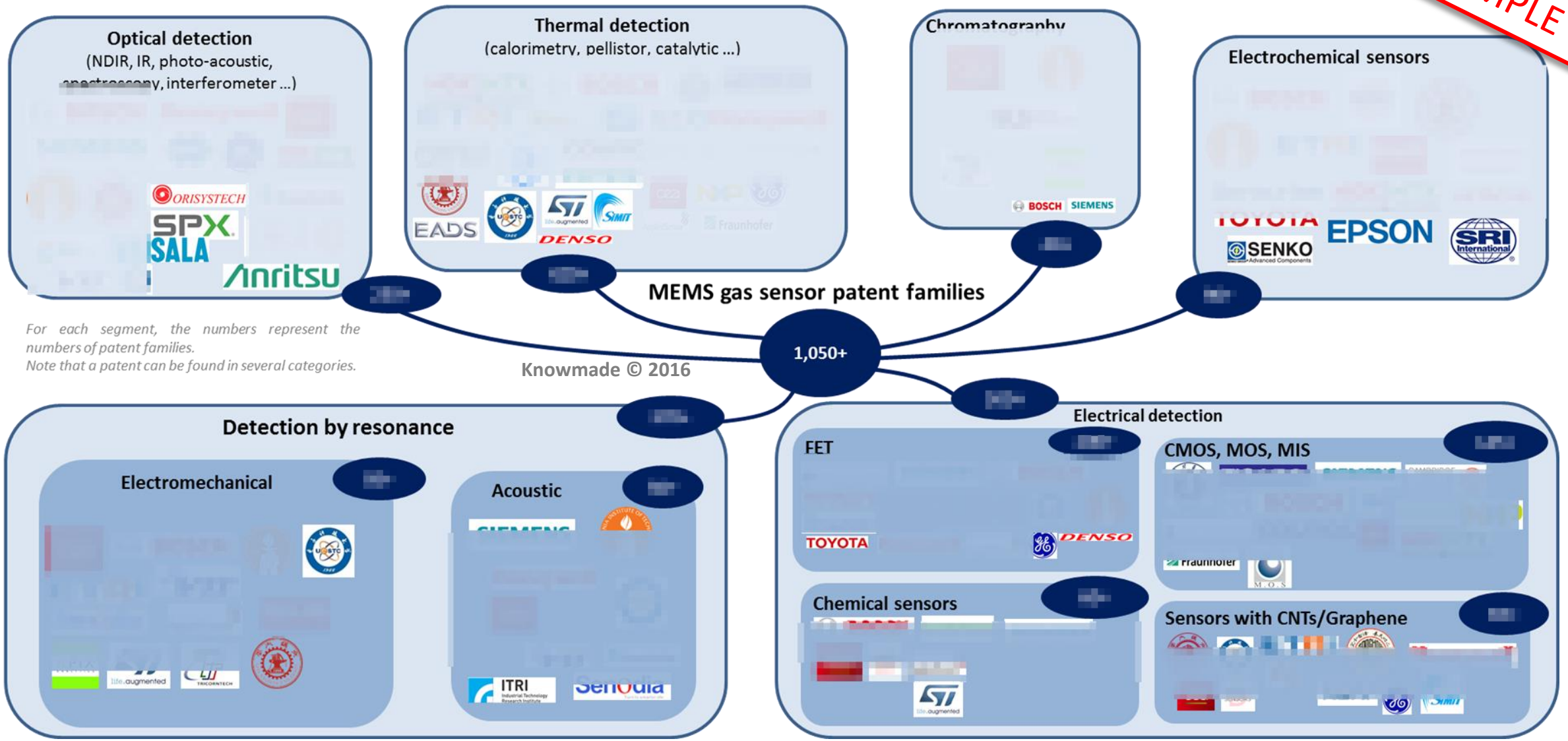






PATENT SEGMENTATION

Mapping of Technological IP Position of Key Players



For each segment, the numbers represent the numbers of patent families.
Note that a patent can be found in several categories.

PATENT SEGMENTATION

Matrix of Main Industrial Patent Assignees vs Technological Segments

Ranking →

For each segment, the numbers represent the numbers of patent families. Note that a patent can be found in several categories.

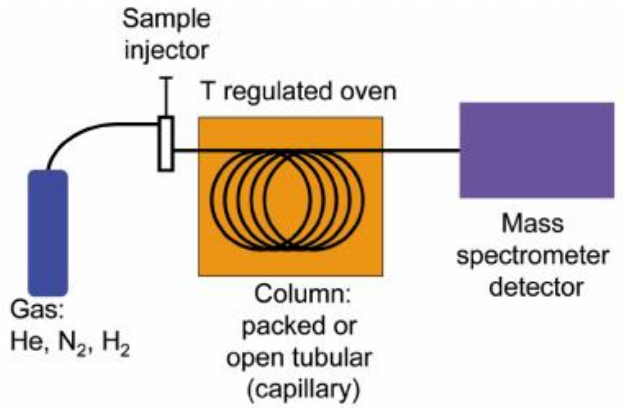
Patent assignees	No Patent families	Optical	Thermal	Chromatography	Electrochemical	Acoustic	Electromechanical	Electrical	MOS/CMOS/MIS	FET	Chemical	CNTs/Graphene
TOTAL	*1058*	230	420	43	90	51	95	500	147	200	62	65
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]		[redacted]			[redacted]	[redacted]			
[redacted]	[redacted]		[redacted]		[redacted]			[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]		[redacted]		[redacted]
[redacted]	[redacted]		[redacted]				[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]		[redacted]		[redacted]			[redacted]	[redacted]	[redacted]		
NXP	10		[redacted]		[redacted]			[redacted]	[redacted]	[redacted]		
LEANSTAR	9	[redacted]	[redacted]					[redacted]	[redacted]			
[redacted]	9		5					7	6		5	
[redacted]	9		5				2	4			2	
[redacted]	9	5	3		1		1	4	1	2		1
[redacted]	8		3				1	4	4			
[redacted]	8	1	6					3	1		1	
[redacted]	8	3	6					7	7	5		1
[redacted]	7	1	4				1	6			1	
[redacted]	6		3		6			4			3	1
[redacted]	6	3										
[redacted]	6		4				2	4		3	2	
[redacted]	5	1	3					2	1	2		
[redacted]	5		4					3		2		
[redacted]	4	4										
[redacted]	4		1	2			2	1		1		
[redacted]	4		2				1	1				

Miniaturized Gas Chromatography

Technology Description (1/2)

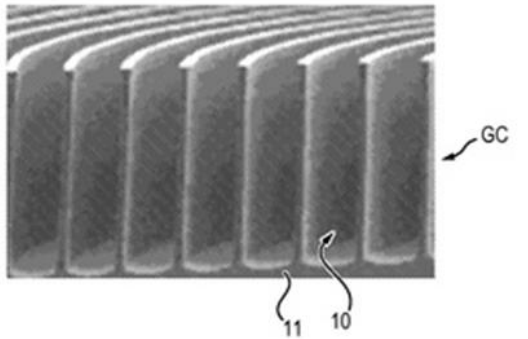
Gas Chromatography is a common type of chromatography used in analytical chemistry for separating and analysing compounds that can be va
without decomposition.

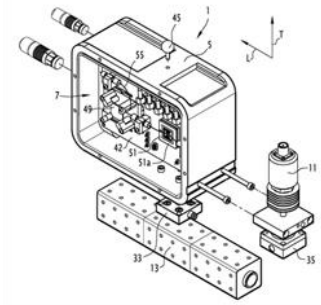
Principle

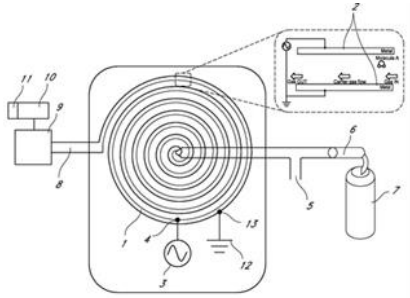


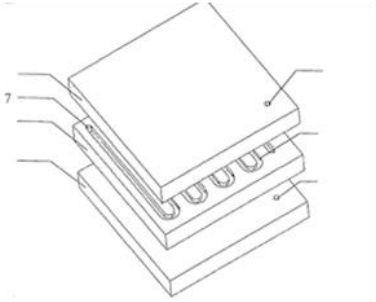
The gas to be analysed flows through **gas chromatograph** column dragged by an inert carrier gas. The different gas molecules interact differently with the column, leading to different duration to go trough it. As the gas molecules exit the end of the column, they are detected electronically. A gas chromatography column can be associated to a mass spectrometer to identify the different gas molecules.

Examples of gas chromatography devices for consumer applications









Miniaturized Gas Chromatography

Technology Description (2/2)

Gas sensing technology	Gases	Pros	Cons
PID/Chromatography	VOC & many gases	• Not a detector but an analyzer • Very efficient: ppm to ppb • Not impacted by environmental changes • 5+ years lifetime • Portable possible with MEMS	• Miniaturization issues • Cost

Miniaturized Gas Chromatography

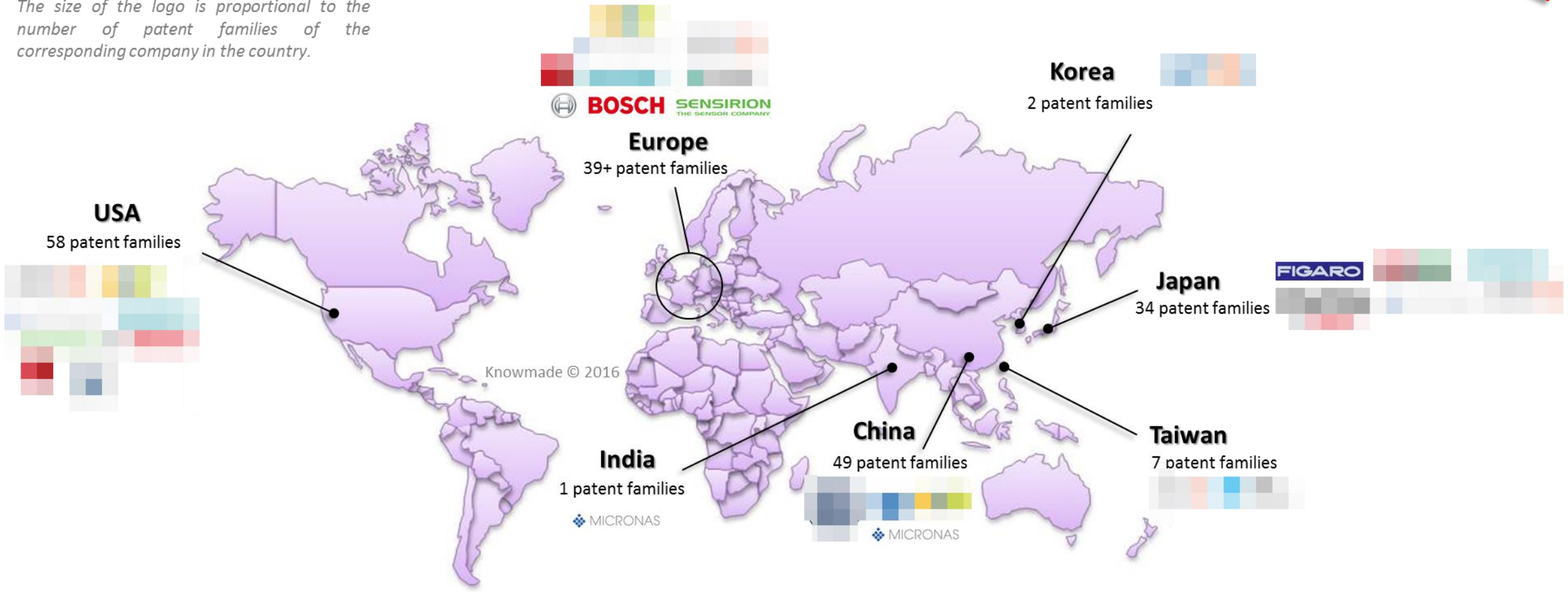
Patented Technology

- **XX patent families** focus on miniaturized gas chromatography in the study, including XX granted patents, XX pending patent applications and XX dead patent families.
- **First patent applications** on miniaturized gas chromatography were filed in **1988** by **Company A** (XXXX) and in **1990** by **Company B** (XXXX).
- Since 1995, there are XX patent applications per year on miniaturized gas chromatography, except in 2008 (**Companies …**), 2012 (**Companies …**) and 2013 (**Companies …**). **Company C** is a **MEMS gas sensor pure play company** created in **XXXX** on the basis of R&D results from **Company A** and **Company B.**
- **Recent patent applications** on miniaturized gas chromatography were filed by **Company E** and **Company F**. Since 2013, **Company E** filed XX patents and **Company F** XX patents. They focus on [redacted] gas chromatography devices.
- **Main patent assignees** that own patents on miniaturized gas chromatography are **Companies ….**
- **Current players on the market** for miniaturized gas chromatography are **Companies …**
  - **Company G** was acquired by **Company H** in 20XX**. Company G** sells process gas chromatograph using electromechanical gas detectors (XXX), mainly for analysis of natural gas, total-Sulphur, dihydrogen, dioxygen, hydrocarbons and THT. In 20XX, **Company H** acquired **Company I** patents rights for a patent family on Miniaturised gas chromatograph and injector for the same (XXX). This patent family has still granted patents in [redacted]
  - **Company J** sells VOC gas analysis devices based on micro-gas chromatography for [redacted] (XXX). **Company J** has XX patent families related to these devices (XXX, granted patents in [redacted]) and (XXX, granted patents in [redacted] and pending patent applications in [redacted] India).
  - **Company K** commercializes various gas analysers integrating their [redacted] miniaturized gas chromatography systems. Their technology is the outcome of the partnership between **Company L** and **Company M**.
  - **Company N** sells micro-processed gas sensors (XXX) combining a micro gas chromatograph and [redacted]. **Company N** has XX patent families in this segment.

Miniaturized MOS/CMOS/MIS Gas Sensors

Mapping of Main Patent Assignees

The size of the logo is proportional to the number of patent families of the corresponding company in the country.



Miniaturized MOS/CMOS/MIS Gas Sensors

Most Cited Patents

Patent number	Assignee	English title	Current Legal Status	Application date	Expiration date *	Number of Forward Citations	Age from Publication Date (Year)	Average Number of Forward Citations / Year
US		Me a	GRANTED	19 14	20 14	110	10.0	11.0
US			GRANTED	19 13	20 13	99	16.0	6.2
US		Ten for	EXPIRED	19 06	20 06			
US20 5			GRANTED	20 30	20 29			
US		M p r	GRANTED	19 30	20 30			
US20 1			GRANTED	20 30	20 09			
US20 9		E s	GRANTED	20 21	20 17			
US20 2	CAMBRIDGE CMOS SENSORS		GRANTED	20 08	20 11			
US20 6			GRANTED	20 25	20 07			
US		Met used	GRANTED	19 28	20 28			
CN1			GRANTED	20 26	20 26			
US			EXPIRED	19 02	20 02			
US20 1		Ap ar	GRANTED	20 24	20 22			
US20 4	Y	Met nical	GRANTED	20 03	20 03			

** 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.*

Miniaturized MOS/CMOS/MIS Gas Sensors

Granted Patents Near Expiration

Patent number	Assignee	English title	Current Legal Status	Application date	Expiration date *	Number of Forward Citations	Age from Publication Date (Year)	Average Number of Forward Citations / Year
G[redacted]23	[redacted]	[redacted]	GRANTED	19[redacted]5	2017-01-15	15	19.5	0.8
E[redacted]2	[redacted]	Meth[redacted]and	GRANTED	19[redacted]5	2017-05-05	2	18.7	0.1
DE[redacted]68	[redacted]	Meth[redacted]and	GRANTED	19[redacted]5	2017-05-05	[redacted]	[redacted]	[redacted]
JP[redacted]67	[redacted]	Ma[redacted]nd	GRANTED	19[redacted]8	2017-05-28	[redacted]	[redacted]	[redacted]
U[redacted]10	[redacted]	Metho[redacted]ssure	GRANTED	19[redacted]0	2017-05-30	[redacted]	[redacted]	[redacted]
U[redacted]30	[redacted]	[redacted]	GRANTED	19[redacted]3	2018-01-13	[redacted]	[redacted]	[redacted]
E[redacted]2	[redacted]	[redacted]	GRANTED	19[redacted]3	2018-01-13	[redacted]	[redacted]	[redacted]
DE[redacted]00	CAMBRIDGE CMOS SENSORS	[redacted]	GRANTED	19[redacted]3	2018-01-13	[redacted]	[redacted]	[redacted]
S[redacted]2	[redacted]	A me[redacted]gas sensor[redacted]h the method	GRANTED	19[redacted]7	2018-02-17	[redacted]	[redacted]	[redacted]

** 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.*

Excel Database

with all patents analyzed in the report with technology segmentation

This database allows multi-criteria searches and includes patent publication number, hyperlinks to the original documents, priority date, title, abstract, patent assignees, technological segments and legal status for each member of the patent family.

Gas Sensors for Consumer Applications Patent Landscape Analysis - October 2016

KnowMade

														Technological segments										
Family Number (FamPat Database)	Patent Number	Publication Date (yyyy-mm-dd)	Original Document (PDF)	Application Data	Application Date (yyyy-mm-dd)	Earliest Priority Date of the Patent Family	Title	Abstract	Claims	Current Patent Assignee(s)	Action Taken	Current Legal Status	Expiration Date (yyyy-mm-dd)	Optical	Thermal	Chromatography	Electrochemical	Acoustic	Electromechanical	Electrical	MOS_CMOS_MIS	FET	Chemical	CNTs_Graphene
59971522	US55	1996-05-07	Open	US08/	1994-07-13	1994-07-13	Metho	A	What is		LEGAL	EXPIRED					X			X		X		
43160349	US61	2000-12-19	Open	US08/	1997-12-10	1997-10-27	Integra	The	What is		LEGAL	GRANTED	2017-12-10		X									
858724	EP10	2000-09-20	Open	EP98	1998-12-04	1997-12-04	Gas	An	1. An	FLIR	LEGAL	GRANTED	2018-12-04											
14000881	FI94	1994-07-07	Open	FI94	1994-07-07	1994-07-07	Infrare	The			LEGAL	EXPIRED		X										
43040921	US58	1998-11-10	Open	US08/	1996-12-17	1996-12-17	Calori	A	We	SANDIA	LEGAL	GRANTED	2016-12-17											
14917215	US20	2009-07-30	Open	US11/	2006-07-26	2005-07-26	Ultra	An ultra	What is	DH	LEGAL	GRANTED	2027-02-02											
564839	GB97	1997-03-05	Open	GB97	1997-01-15	1997-01-15	Gas-	A gas-		CAMBRIDGE	LEGAL	GRANTED	2017-01-15											
14028596	EP-7	1997-09-17	Open	EP97	1997-02-19	1996-03-14	Semico	A	1. A		LEGAL	GRANTED	2017-02-19		X					X			X	
1858125	WO2	2009-10-15	Open	WOS	2009-04-08	2008-04-09	Multila	The	What is		LEGAL	PENDING	2029-04-08	X						X				X
14028596	US57	1997-09-18	Open	US08/	1997-02-26	1996-03-14	Semico	A	We		LEGAL	GRANTED	2017-02-26		X					X			X	
60325956	US58	1999-04-06	Open	US08/	1997-04-30	1997-04-30	Micro	A	I claim:	HONEYWEL	LEGAL	GRANTED	2017-04-30											
60325956	US58	1999-01-19	Open	US09/	1998-04-06	1997-04-30	Micro	A	I claim:	HONEYWEL	LEGAL	GRANTED	2017-04-30											
60249975	US48	1989-10-17	Open	US07/	1987-07-15	1987-07-15	Microe	The	We		LEGAL	EXPIRED	2006-10-17				X							
73135839	WO2	2016-06-02	Open	WOK	2015-11-17	2014-11-24	Gas	An	1.	LG INNOTEK	LEGAL	PENDING	2035-11-17											
14412334	DE20	2009-01-08	Open	DE20	2008-10-16	2008-10-16	Air	Air	1. Air	APPLIEDSEN	LEGAL	GRANTED	2019-01-08											
1476697	US53	1994-09-06	Open	US07/	1992-10-26	1992-10-26	Tempe	Planar	What is		LEGAL	EXPIRED	2011-09-06		X					X	X		X	
13631469	EP-8	1997-12-03	Open	EP97	1997-05-05	1996-05-31	Metho	The	1.	SIEMENS	LEGAL	GRANTED	2017-05-05											
13634387	US61	2000-09-05	Open	US09/	1997-01-28	1996-03-15	Device	PCT No.	What is	FRAUNHOFE	LEGAL	GRANTED	2017-01-28											
13634387	EP-8	1998-11-04	Open	EP97	1997-01-28	1996-03-15	Device	PCT No.	1. An		LEGAL	GRANTED	2017-01-28		X									
14024751	EP-8	1998-08-05	Open	EP97	1997-01-31	1997-01-31	Proces	To	1.		LEGAL	GRANTED	2017-01-31		X									
5403185	CN19	2007-04-04	Open	CN20	2006-09-25	2006-09-25	Microc	A micro	1. The		LEGAL	EXPIRED	2012-11-21	X										
13631469	DE59	2004-03-11	Open	DE59	1997-05-05	1996-05-31	Metho				LEGAL	GRANTED	2017-05-05				X			X	X	X	X	

ORDER FORM

Miniaturized Gas Sensors: Patent Landscape Analysis

October 2016

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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Check

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

In order to pay your invoice via PAYPAL, you must first register at www.paypal.com. Then you can send money to the KnowMade S.A.R.L. by entering our E-mail address contact@knowmade.fr as the recipient and entering the invoice amount.

RETURN ORDER BY

E-mail: contact@knowmade.fr
Mail: KnowMade S.A.R.L. 2405 route des Dolines, 06902 Sophia Antipolis, FRANCE

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☐ **€5,990 – Corporate license**

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I hereby accept Knowmade's Terms and Conditions of Sale
Signature:

Terms and Conditions of Sales

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

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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.

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.

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.

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06902 Sophia Antipolis, France

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contact@knowmade.fr