GRAPHENE
Technology Insight Report

Patent iNSIGHT Pro
Transform Patents to Intelligence

Note: The original version of this report dated Mar 31st, 2011 was reviewed and corrected in November, 2013 based on feedback received from our readers. Specifically, the patent search strategy has been improved upon in this new version.

Table of Contents

Introduction

Graphene is an allotrope of carbon, whose structure is one-atom-thick planar sheets of sp2-bonded carbon atoms that are densely packed in a honeycomb crystal lattice. The term graphene was coined as a combination of graphite and the suffix -ene by Hanns-Peter Boehm, who described single-layer carbon foils in 1962. Graphene is most easily visualized as an atomic-scale chicken wire made of carbon atoms and their bonds. The crystalline or "flake" form of graphite consists of many graphene sheets stacked together.

The carbon-carbon bond length in graphene is about 0.142 nanometers. Graphene sheets stack to form graphite with an interplanar spacing of 0.335 nm, which means that a stack of 3 million sheets would be only one millimeter thick. Graphene is the basic structural element of some carbon allotropes including graphite, charcoal, carbon nanotubes and fullerenes. It can also be considered as an indefinitely large aromatic molecule, the limiting case of the family of flat polycyclic aromatic hydrocarbons.

Because of its range of extraordinary properties, people are considering using graphene in a myriad of different applications. For example, because graphene is so strong, people want to use it to reinforce plastics, making them conductive at the same time. Because it's transparent and conducts electricity, people want to use it in applications like mobile phone screens, touch screens, TV screens and so on. People are also considering using it to go beyond silicon technology and make our integrated circuits even denser and speedier. Those are just few examples.

It is lighter than a feather, stronger than steel, yet incredibly flexible and more conductive than copper. It has been hailed as "the miracle material", its possible uses apparently almost endless.

Points covered:

➢ Overview of the top companies involved in graphene and their publication trend

➢ Focus on the methods of producing graphene

➢ Trends for current & emerging applications of graphene and their patent activity

➢ Companies focusing primarily on methods and applications of graphene

Patent Search Results

Using the commercial patent database [PatSeer](#) as our data source we used the following search query to create our patent set.

TAC– Title, Abstract, Claims   TACD – Full Text   IC– International Class   CPC– Cooperative Patent Class

TAC$:

(Graphene* or Graphenea or Grafen or graphen or grafeno)

AND

(IC:("C01B31/04" OR "C01B31/02" OR "B82Y30/00" OR "B82Y40/00" OR "C08K3/04" OR "B82B3/00" OR "H01B1/04" OR "C23C16/26" OR "B82Y99/00" OR "H01L21/336" or "B82B1/00")

OR

CPC:("C01B31/04" OR "C01B31/02" OR "B82Y30/00" OR "B82Y40/00" OR "C08K3/04" OR "B82B3/00" OR "H01B1/04" OR "C23C16/26" OR "B82Y99/00" OR "H01L21/336" or "B82B1/00"))

AND NOT

TACD:

(grapheme or graphane or graphyne or graph or graphs)

Class Description:

C01B31/04: Carbon; Compounds thereof -- Graphite

C01B31/02: Carbon; Compounds thereof -- Preparation of carbon

B82Y30/00: Nano-technology for materials or surface science, e.g. nano-composites

B82Y40/00: Manufacture or treatment of nano-structures

C08K3/04: Use of inorganic ingredients -- Carbon

B82B3/00: Manufacture or treatment of nano-structures

H01B1/04: Conductors or conductive bodies characterised by the conductive materials -- mainly consisting of carbon-silicon compounds, carbon, or silicon

C23C16/26: Chemical coating by decomposition of gaseous compounds -- Deposition of carbon only

B82Y99/00: Specific uses or applications of nano-structures -- Subject matter not provided for in other groups of this subclass

H01L21/336: Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof -- with an insulated gate

B82B1/00: Nano-structures formed by manipulation of individual atoms or molecules, or limited collections of

- The query was directed to search through the title, abstract and claims. Some multilingual terms referring to the same topic were added to the existing query and a patent set of 2697 records with one publication per family was generated and imported in Patent iNSIGHT Pro.

- After reviewing few results esp. from older publications, we came across some similar but irrelevant terms which we then excluded from full text and irrelevant class were also excluded using NOT operator.

- The publications included in the report are updated as of 11th November, 2013.

Technical Segmentation (Patent Categories)

To get deeper insights record set for Graphene was classified as follows:

By Methods

- CO2 Reduction
- Chemical Vapour Deposition (CVD)
- Epitaxial Growth
- Exfoliation
- Graphite Intercalation Compounds (GIC)
- Graphite Oxide Reduction
- Pyrolysis
- Sonication

By Applications

- Automobile
- Batteries
- Capacitor
- Carbon Nano Tube (CNT)
- Chemical Sensors
- Composite Materials
- Electrochemical Capacitors
- Electrophoretic Deposition
- Fuel Cells
- Graphene Biodevices
- Graphene Nanoribbons
- Integrated Circuits
- Light Emitting Diode
- Liquid Crystal Devices
- Lithium-ion Batteries
- Sensors
- Solar Cells
- Spray Coating
- Supercapacitor
- Thermoplastics
- Touch Screens
- Transfer Printing
- Transistors
- Transparent Electrode

IP Analysis

Publication Trend

What has been the publication trend for graphene?

Patents related to graphene can be traced back to 2000 and the real surge in the activity around this technology has happened in the last 5 years.

It's clear the current activity around these technologies is likely to continue seeing more innovation in the near future with more number of records being published as 2013 ends.
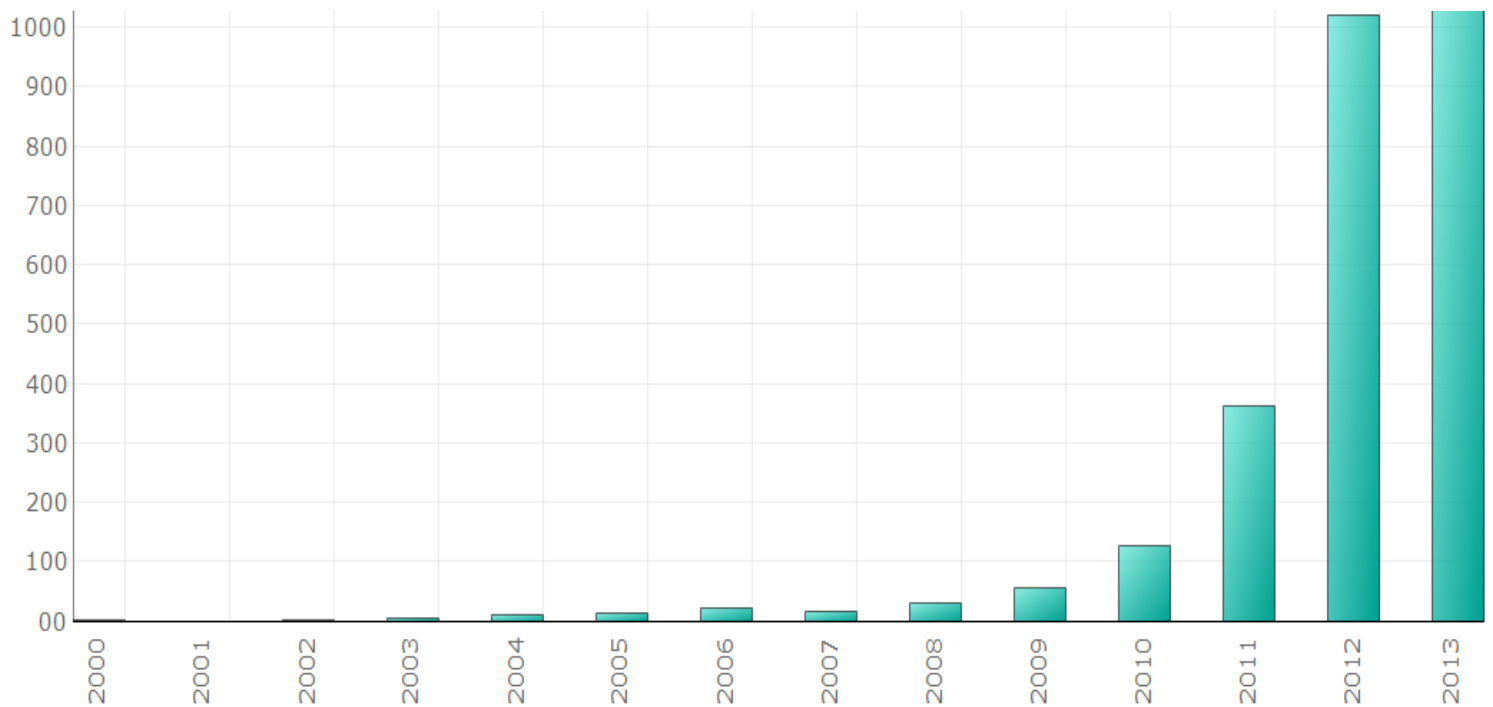
How we did it?

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

Top Players
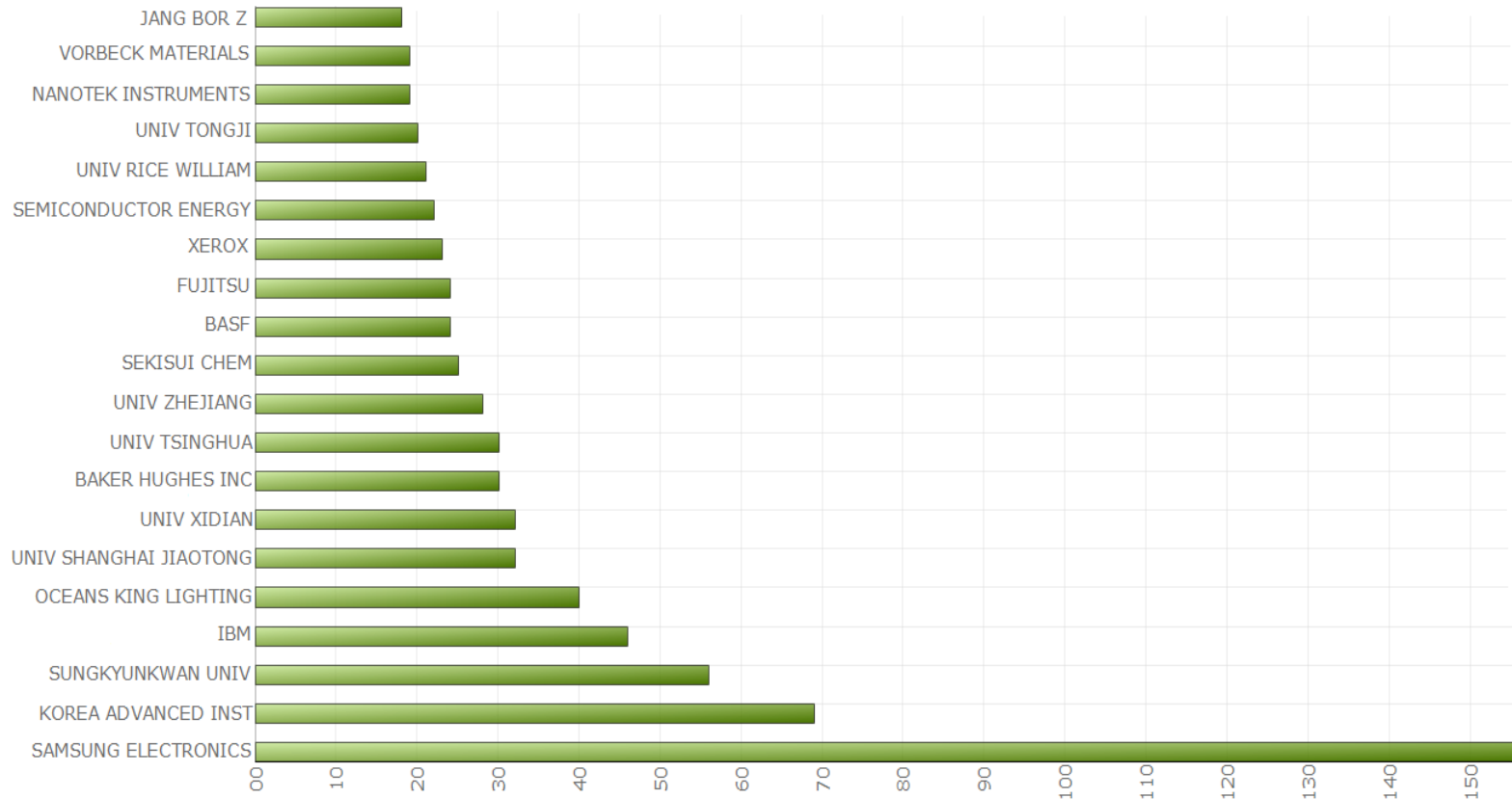
The top organizations are:

1. SAMSUNG ELECTRONICS CO
2. KOREA ADVANCED INST
3. SUNGKYUNKWAN UNIV
4. IBM CORP
5. OCEAN KING LIGHTING
6. UNIV SHANGHAI JAIOTONG
7. UNIV XIDIAN
8. BAKER HUGHES
9. UNIV TSINGHUA
10. UNIV ZHEJIANG
11. SEKISUI CHEM CO
12. BASF AG
13. FUJITSU LTD
14. XEROX CORP
15. SEMICONDUCTOR ENERGY LAB CO LTD
16. UNIV RICE WILLIAM
17. UNIV TONGJI
18. NANOTEK INSTRUMENTS INC
19. VORBECK MATERIALS CORP
20. JANG BOR Z

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.
The complete Assignee table in available in the following Excel file:
http://www.patentinsightpro.com/techreports/1113/List%20of%20Assignees.xls

Assignee Trends

Considering cumulative patent filing trends Samsung has the most remarkable figures for filings for graphene. Interestingly, Korea Advanced Inst also shows an increase in terms of filings.

Legend:
- ✚ BAKER HUGHES INC
- ● JANG BOR Z
- ✖ SAMSUNG ELECTRONICS CO
- ◆ UNIV RICE WILLIAM
- ✖ BASF AG
- ◆ KOREA ADVANCED INST
- ▲ SEKISUI CHEM CO LTD
- ▼ UNIV SHANGHAI JIAOTONG
- ▲ FUJITSU LTD
- ▼ NANOTEK INSTRUMENTS INC
- ■ SEMICONDUCTOR ENERGY LAB
- ✚ UNIV SOUTHEAST
- ■ IBM CORP
- ✚ OCEANS KING LIGHTING
- ● SUNGKYUNKWAN UNIV
- ✖ UNIV TONGJI
- ▲ UNIV TSINGHUA
- ■ UNIV XIDIAN
- ● UNIV ZHEJIANG
- ◆ VORBECK MATERIALS
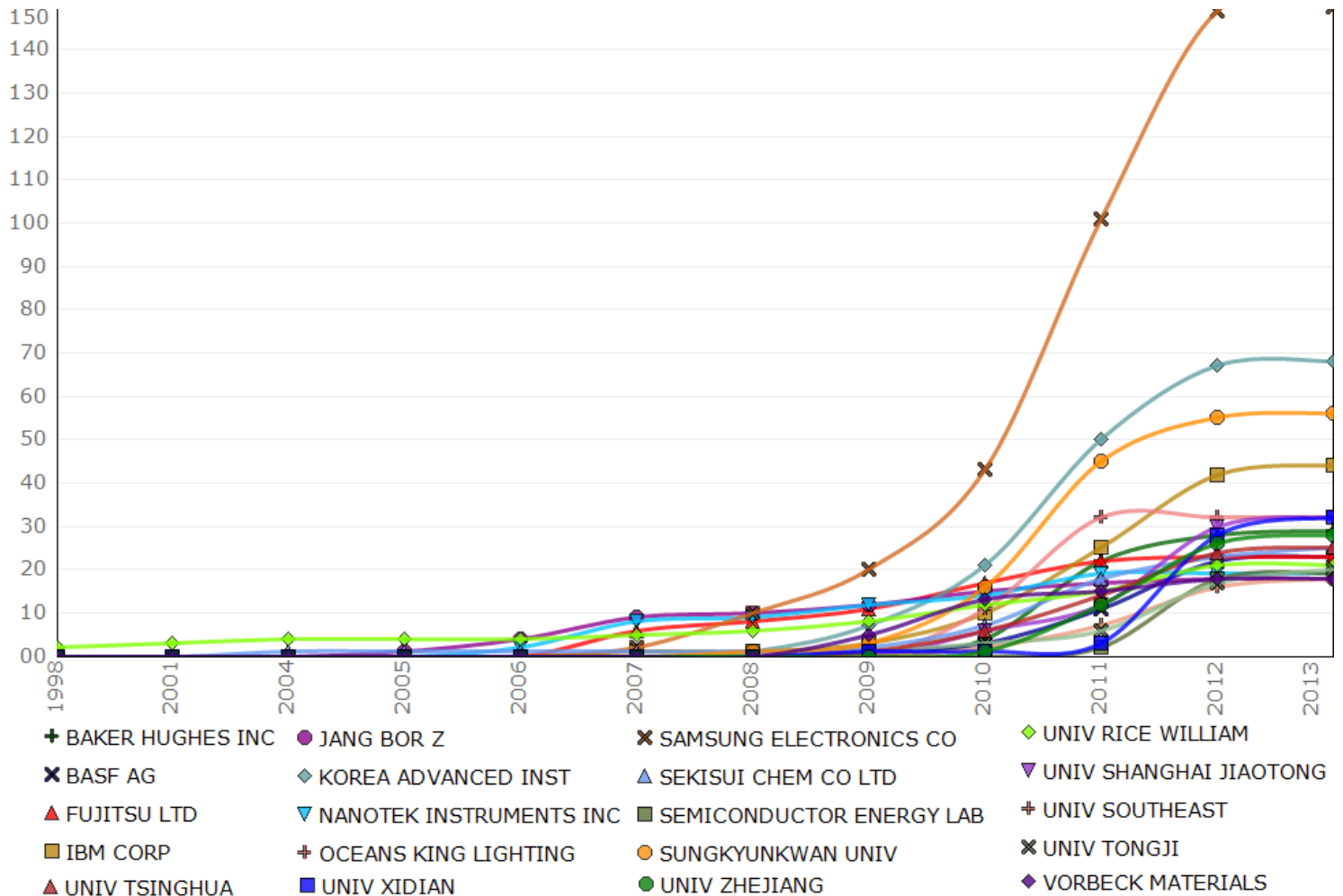
How we did it?

We applied filters on the filing years using the option provided in the Report Dashboard in Patent iNSIGHT Pro. The graph showing the cumulative filings of top 20 assignees with respect to time was created. The output was created in the form of a line graph to get a visual insight which could display comparisons across the assignees.

Research activity around world

How is research around graphene spread *across different countries?*

In terms of regional pockets where patent protection is being sought most frequently for these technologies, CN leads the count, followed by the US and KR. The table below ranks top priority countries and helps provide an indication of where innovation in this area is originating:
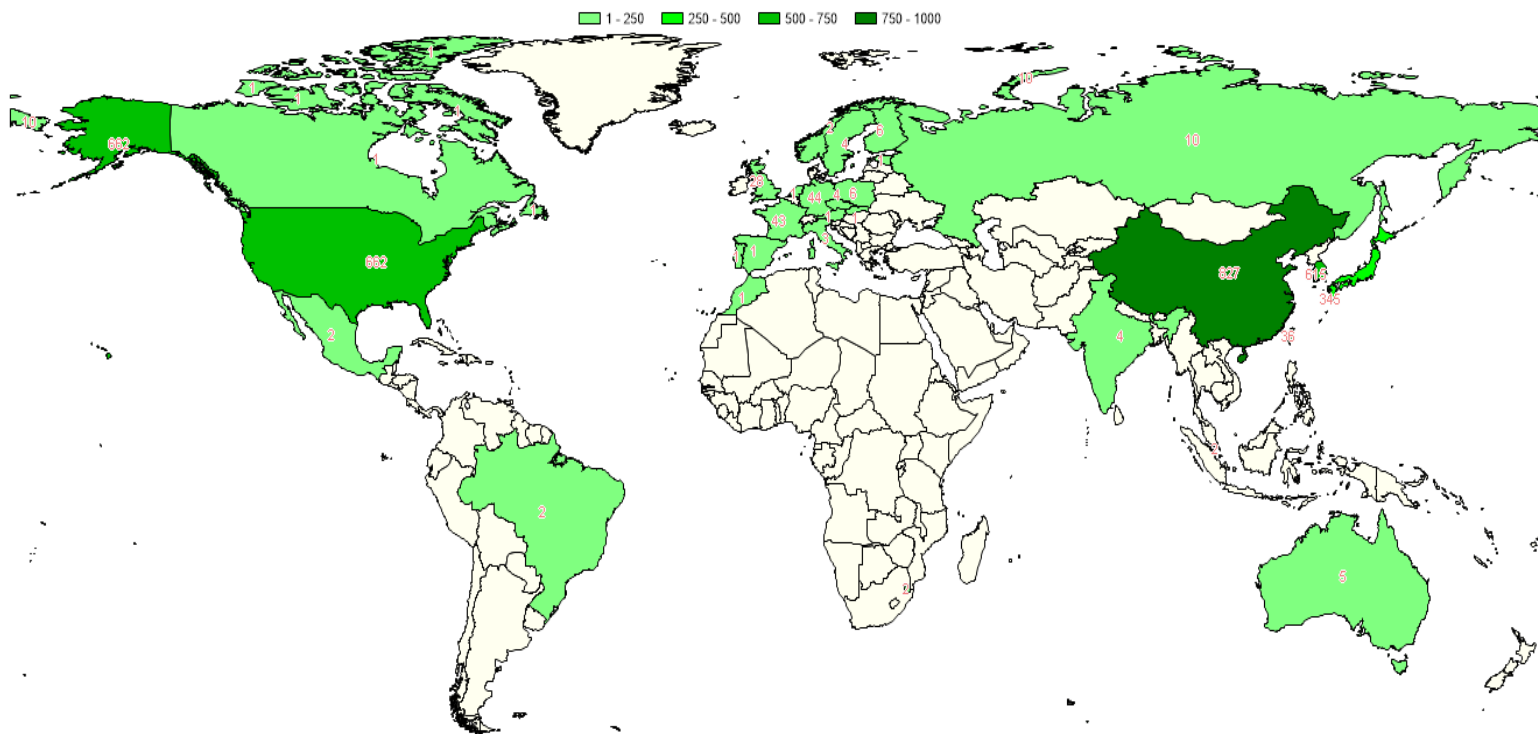
Country Code	Total
CN	827
US	662
KR	615
JP	345
DE	44

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	Avg. No. of Fwd Cites per Patents	Filing Trend (Absolute)	Filing Year Range	Key Inventor (Top 5)	Co-Assignees	Coverage (Includes families)					
							US	JP	DE	CN	KR	TW
SAMSUNG ELECTRONICS CO LTD	150 (5.6%)	0.01	1998 — 2013	2007-2013	CHOI JAE YOUNG(28) SHIN HYEON JIN(23) CHUNG HYUN JONG(20) SEO SUN AE(14) HEO JIN SEONG(13)	SUNGKYUNKWAN UNIV (14) UNIV YONSEI IACF(2) GEORGIA TECH RES INST(1) NPS CORP(1) UNIV INDUS(1)	112	36	1	32	141	2
KOREA ADVANCED INST SCI & TECH	68 (2.5%)	0.01		2008-2013	KIM SANG OUK(6) KIM JUN KYUNG(6) LEE KEON JAE(5) CHOI IN SUNG(5) LEE JAE KAP(4)	KCC CORP(1)	29	4	0	1	63	0
SUNGKYUNK WAN UNIV	56 (2.1%)	0.02		2008-2013	HONG BYUNG HEE(21) AHN JONG HYUN(12) KIM HYEONG KEUN(8) LEE HYO YOUNG(7) BAE SU KANG(7)	SAMSUNG ELECTRONICS CO LTD(14) KANEKA CORP(1) LP NANO LAB CO LTD(1) SRC CORP(1) UNIV SOONGSIL RES CONSORTIUM(1)	20	3	0	2	55	0
IBM CORP	44 (1.6%)	0.02		2007-2013	HAN SHU-JEN(7) GRILL ALFRED(7) CHANDRA BHUPESH(6) LIN YU-MING(6) TULEVSKI GEORGE S(5)	No Co-Assignee Present	43	5	11	9	2	7

Assignee	Count				Years	Inventors	Co-Assignees						
OCEANS KING LIGHTING SCIENCE	32 (1.2%)	0		2010-2011	WANG YAOBING(32) ZHOU MINGJIE(22) XINSHENG YUAN(10) MINGJIE ZHOU(10) LINGLONG ZHONG(4)	No Co-Assignee Present	4	0	0	32	0	0
UNIV SHANGHAI JIAOTONG	32 (1.2%)	0.03		2010-2013	SHOUWU GUO(4) YONG ZHANG(3) DI ZHANG(3) SHENMIN ZHU(2) ZIYONG YU(2)	PINGDINGSHAN DONGFANG CARBON CO LTD(1) SHANGHAI SWITCHDIY DIGITAL TECHNOLOGY CO LTD(1)	0	0	0	32	0	0
UNIV XIDIAN	32 (1.2%)	0.03		2009-2013	YUMING ZHANG(28) HUI GUO(26) KEJI ZHANG(25) TIANMIN LEI(23) PENGFEI DENG(11)	No Co-Assignee Present	0	0	0	32	0	0
BAKER HUGHES INC	29 (1.1%)	0.03		2010-2013	CHAKRABORTY SOMA(20) AGRAWAL GAURAV(17) JOHNSON MICHAEL H(8) MAZYAR OLEG A(5) XU ZHIYUE(4)	No Co-Assignee Present	29	0	1	7	0	0
UNIV ZHEJIANG	28 (1%)	0		2010-2013	LIN MA(7) WEIXIANG CHEN(7) GUOCHUANG HUANG(4) ZHEN WANG(4) KUN CHANG(3)	No Co-Assignee Present	0	0	0	28	0	0
SEKISUI CHEM CO LTD	25 (0.9%)	0.04		2004-2013	TAKAHASHI KATSUNORI(12) INUI NOBUHIKO(9) SAWA KAZUHIRO(8) TSUMURA KENSUKE(8) WADA TAKUYA(7)	UNIV NIIGATA(3) UNIV OITA(3) NAT INST FOR MATERIALS SCIENCE(1) UNIV TOHOKU(1)	5	21	0	6	3	3
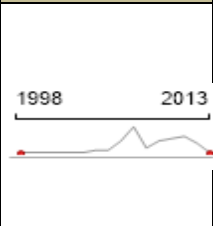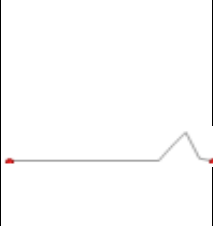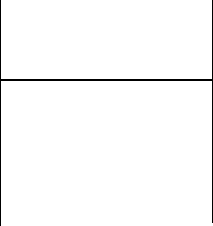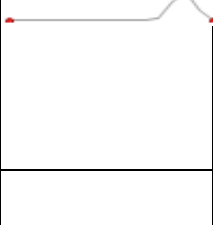
Assignee	Count	Value	Trend	Years	Inventors	Co-Assignee						
UNIV TSINGHUA	25 (0.9%)	0.04		2009-2013	FAN SHOU-SHAN(9) JIANG KAI-LI(9) LIN XIAO-YANG(5) ZHANG LI-NA(3) XIAO LIN(3)	HON HAI PRECISION IND CO LTD(1)	13	9	0	21	0	6
BASF AG	23 (0.9%)	0.04		2009-2013	MUELLEN KLAUS(9) FENG XINLIANG(9) IVANOVICI SORIN(6) YANG SHUBIN(4) EWALD BASTIAN(3)	No Co-Assignee Present	11	4	1	5	2	9
FUJITSU LTD	23 (0.9%)	0.04		2007-2012	SATO SHINTARO(5) ASANO KOJI(4) KONDO DAIYU(4) ASANO TAKAHARU(3) AWANO YUJI(2)	No Co-Assignee Present	6	15	0	3	1	1
UNIV RICE WILLIAM M	21 (0.8%)	0.05		1998-2012	TOUR JAMES M(13) GUO TING(3) HAFNER JASON H(3) LIU JIE(3) NIKOLAEV PAVEL(3)	No Co-Assignee Present	13	6	2	5	5	2
UNIV TONGJI	20 (0.7%)	0		2009-2013	ZHANG DONG(5) YAO XI(2) GUO YUNXIAN(2) AIJUN SHEN(2) ZHANG ZENGXING(2)	No Co-Assignee Present	0	0	0	20	0	0
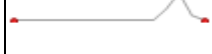
How we did it?

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	Avg. No. of Fwd Cites per Patents	Filing Trend (Absolute)	Filing Year Range	Key Assignees (Top 5)	Co-Inventors
JANG BOR Z	42 (1.6%)	0.02	1998 2013	2004-2012	NANOTEK INSTRUMENTS INC(19) JANG BOR Z(18) ZHAMU ARUNA(17) GUO JIUSHENG(5) WANG XIQING(4)	ZHAMU ARUNA(40) GUO JIUSHENG(10) CHEN GUORONG(8) SHI JINJUN(6) WANG YANBO(6)
ZHAMU ARUNA	41 (1.5%)	0.02		2005-2012	NANOTEK INSTRUMENTS INC(19) ZHAMU ARUNA(18) JANG BOR Z(17) GUO JIUSHENG(5) WANG XIQING(4)	JANG BOR Z(40) GUO JIUSHENG(10) CHEN GUORONG(8) SHI JINJUN(6) WANG YANBO(6)
WANG YAOBING	37 (1.4%)	0		2010-2012	OCEANS KING LIGHTING SCIENCE(32) OCEANKING DONGGUAN LIGHTING TECHNOLOGY CO LTD(3) LIU DAXI(1) WANG YAOBING(1) ZHOU MINGJIE(1)	ZHOU MINGJIE(25) XINSHENG YUAN(14) MINGJIE ZHOU(12) DAXI LIU(4) LINGLONG ZHONG(4)
HONG BYUNG HEE	29 (1.1%)	0.03		2009-2012	SUNGKYUNKWAN UNIV (21) SAMSUNG ELECTRONICS CO LTD(9) KOREA ADVANCED INST SCI & TECH(3) GRAPHENE SQUARE INC(2)	AHN JONG HYUN(13) KIM HYEONG KEUN(9) BAE SU KANG(7) CHOI IN SUNG(3) CHOI JEA BOONG(3)
CHOI JAE YOUNG	28 (1%)	0.04		2008-2012	SAMSUNG ELECTRONICS CO LTD(28) SUNGKYUNKWAN UNIV (5)	SHIN HYEON JIN(21) YOON SEON-MI(12) CHOI WON MOOK(5) LEE YOUNG-HEE(4) HAN GANG-HEE(3)

Inventor	Count	Value	Trend	Years	Assignees	Co-inventors
HUI GUO	28 (1%)	0.04		2009-2013	UNIV XIDIAN(26) XIAN ELECTRONIC SCIENCE AND TECHNOLOGY UNIV(2)	YUMING ZHANG(26) KEJI ZHANG(25) TIANMIN LEI(23) PENGFEI DENG(11) FENGQI ZHANG(6)
YUMING ZHANG	28 (1%)	0.04		2009-2013	UNIV XIDIAN(28)	HUI GUO(26) KEJI ZHANG(25) TIANMIN LEI(23) PENGFEI DENG(11) XIAOYAN TANG(7)
ZHOU MINGJIE	27 (1%)	0		2010-2012	OCEANS KING LIGHTING SCIENCE(22) HAI-YANG WANG LIGHTING SCIENCE AND TECHNOLOGY STOCK CO LTD(2) SHENZHEN OCEANS KING LIGHTING TECHNOLOGY CO LTD(2) SHEN ZHEN OCEAN S KING LIGHTING ENGINEERING CO LTD(1) OCEANKING DONGGUAN LIGHTING TECHNOLOGY CO LTD(1)	WANG YAOBING(25) XINSHENG YUAN(12) LIU DAXI(4) WU FENG(4) ZHONG LINGLONG(3)
KEJI ZHANG	25 (0.9%)	0.04		2012-2013	UNIV XIDIAN(25)	HUI GUO(25) YUMING ZHANG(25) TIANMIN LEI(21) PENGFEI DENG(11) FENGQI ZHANG(6)
TIANMIN LEI	25 (0.9%)	0.04		2011-2013	UNIV XIDIAN(23) XIAN ELECTRONIC SCIENCE AND TECHNOLOGY UNIV(2)	HUI GUO(23) YUMING ZHANG(23) KEJI ZHANG(21) PENGFEI DENG(11) FENGQI ZHANG(6)
SHIN HYEON JIN	23 (0.9%)	0.04		2008-2012	SAMSUNG ELECTRONICS CO LTD(23) SUNGKYUNKWAN UNIV(4)	CHOI JAE YOUNG(21) YOON SEON-MI(12) CHOI WON MOOK(4) LEE YOUNG-HEE(4) HAN GANG-HEE(3)
CHUNG HYUN JONG	21 (0.8%)	0.05		2007-2012	SAMSUNG ELECTRONICS CO LTD(20) KIM DONG-CHUL(1) SEO SUN-AE(1) WOO YUN-SUNG(1)	HEO JIN SEONG(14) SEO SUN AE(14) YANG HEE JUN(9) SEO DAVID(6) WOO YUN-SUNG(5)

CHAKRABORTY SOMA	20 (0.7%)	0.05		2010-2012	BAKER HUGHES INC(20)	AGRAWAL GAURAV(16) JOHNSON MICHAEL H(8) MAZYAR OLEG A(4) BUSSEAR TERRY R(3) XU ZHIYUE(3)
AGRAWAL GAURAV	17 (0.6%)	0.06		2010-2012	BAKER HUGHES INC(17)	CHAKRABORTY SOMA(16) JOHNSON MICHAEL H(5) XU ZHIYUE(4) DIGIOVANNI ANTHONY A(2) DUAN PING(2)
SEO SUN AE	15 (0.6%)	0.07		2007-2011	SAMSUNG ELECTRONICS CO LTD(14) KIM DONG-CHUL(1) SEO SUN-AE(1) WOO YUN-SUNG(1)	CHUNG HYUN JONG(14) HEO JIN SEONG(9) WOO YUN-SUNG(5) YANG HEE JUN(4) KIM DONG CHUL(3)

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.

Company activity across different methods

Which companies hold the maximum inventions across different production methods?

In the map, each company is connected to particular technology 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 held by company present in a particular technology.

How we did it?

First various methods 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 methods. A co-occurrence matrix was generated using the co-occurrence analyzer to map the different methods with assignees. The matrix was filtered for the top 20 Assignees and converted into the above Correlation map using an option provided in software. Also, links between same field types were removed using the option provided.

Company wise analysis across different applications

- The chart below shows research activity of companies across key applications.
- Samsung leads with records across all the application areas excluding batteries wherein Jang Bor Z & Aruna Zhamu have the maximum records.

Application	SAMSUNG ELECTRONICS	IBM CORP	KOREA ADVANCED INST	BAKER HUGHES INC	UNIV SHANGHAI JIAOTONG	OCEANS KING LIGHTING	UNIV TSINGHUA	UNIV RICE WILLIAM M	NANOTEK INSTRUMENTS	XEROX CORP	BASF AG	ZHAMU ARUNA	VORBECK MATERIALS	SUNGKYUNKWAN UNIV	JANG BOR Z	BAYER AG	UNIV ZHEJIANG	UNIV CALIFORNIA	SEKISUI CHEM CO LTD	UNIV TONGJI
Spray Coating	2	1	2	2	2			1		1			1							
Graphene Nanoribbons	3	3	4	1	1			8			5			1				1		
Touch Screen					2			1												
Fuel Cells	1		2					3			2	6	1		6	1	2			1
Liquid Crystal Devices	6		2			1											1	1		
Lithium-ion Batteries	2		2		2	7	1	7			5				5		3	1		
Transparent Electrode	17	4	7		1			3						7				2		
Graphene Biodevices			3															1		
Integrated Circuits	2	4			1	2		2		1	2		1	1			1	3		1
Supercapacitor	2		1			1		3	3	3		6	2		6			1		
Transistors	26	23	2				1	1	1	1		1	1	7				4		1
Sensors	16	4	4	8	14	10	5	8	1	2	3	2	13	4	2	3	9	8		4
Capacitor	9	3	1	2		1					2		9			5		2	1	1
Solar Cells	9	1	2	3				1			2		2				1	1		2
Carbon Nanotubes	46	23	22	28	7	4	14	18	17	14	14	15	14	6	15	14	5	12	4	1
Thermoplastics	1			1					3		2		2			4	1		8	

The table below shows research activity of companies across various all the applications.

Applications / Companies	Composite Materials	Thermoplastics	Carbon Nanotubes	Solar Cells	Capacitor	Sensors	Batteries	Light Emitting Diode	Transistors	Supercapacitor	Integrated Circuits	Graphene Biodevices	Transparent Electrode	Lithium-ion Batteries	Liquid Crystal Devices	Chemical Sensors	Fuel Cells	Touch Screen	Transfer Printing	Graphene Nanoribbons	Automobiles	Spray Coating	Electrochemical Capacitors
SAMSUNG ELECTRONICS CO LTD	23	1	46	9	9	16	5	2	26	2	2		17	2	6	1	1			3		2	5
KOREA ADVANCED INST SCI & TECH	9		22	2	1	4			2	1		3	7	2	2		2			4	1	2	
IBM CORP	6		23	1	3	4		1	23		4		4							3		1	
UNIV SHANGHAI JIAOTONG	22		7	3	2	14	2	2			1			1	2			2	1	1	1	2	
BAKER HUGHES INC	9	1	28			8	6														1	2	
UNIV ZHEJIANG	21	1	5	1		9	5				1			3	1		2		1				
OCEANS KING LIGHTING SCIENCE	21		4		1	10			1	1	2		7	1							1		
UNIV TSINGHUA	11		14		1	5	1		1					1	1								
UNIV RICE WILLIAM M	6		18	1		8	1		1	3			3					1	1	8		1	
NANOTEK INSTRUMENTS INC	7	1	17			1	2			3	2			1	7		3						1
BASF AG	4	2	14	2	2	3	4	1	1								2			5	2		1
XEROX CORP	7	3	14			2	1		1	3	1											1	
SUNGKYUNKWAN UNIV	1		6	2		4	3		7		1		7							1			
SEKISUI CHEM CO LTD	10	8	4		1		1																
ZHAMU ARUNA	5		15			2				6	2			5			6						
VORBECK MATERIALS CORP	5	2	14		9	13	3		1	2	1						1					1	

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
JANG BOR Z	5		15			2	1			6	2				5		6		
BAYER AG	9	4	14		5	3											1		
UNIV TONGJI	7		1	2	1	4	3		1		1						1		
UNIV CALIFORNIA	7		12	1	2	8	2	1	4	1	3	1	2	1	1	1			1

How we did it?

First various application areas 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, patents were categorized under different applications. A co-occurrence matrix for top 20 companies was generated and the resulting matrix was exported to Excel using the option provided for the same. Key application areas were filtered and resulting matrix was converted into a bubble chart.

Technology landscape for graphene applications

The contour map below represents different methods used for the production of graphene with respect to complete patent portfolio. Clusters for batteries, solar cells, fuel cells are close to each other as there is high degree of relevance between the records present in those technology areas. The nodes were coloured by companies.


Legend:
- SAMSUNG ELECTRO... — 37
- IBM CORP — 24
- JANG BOR Z — 10
- ZHAMU ARUNA — 9
- SUNGKYUNKWAN UNIV — 8

How we did it?

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

Analysis of key inventor groups of key Companies

The generated maps below highlight the key inventor groups of top four companies. In maps below the groups are created using network relationships and the records (blue dots) are positioned on the map based on their relationship to the Assignee and to the inventors listed on the graph. Key inventors present in the map, for instance, Liu Fei in case of KAIST and IBM appear in the middle of the graph. Samsung exhibits a reasonable amount of collaboration, as would usually be the case for a large multinational, which includes joint-research and collaboration on different patent applications with Sungkyunkwan University (SKKU), which is also one of the top five applicants. Also groups of inventors who file together will appear clustered together. Finally, only those inventors with 2 or more records are shown in the map.
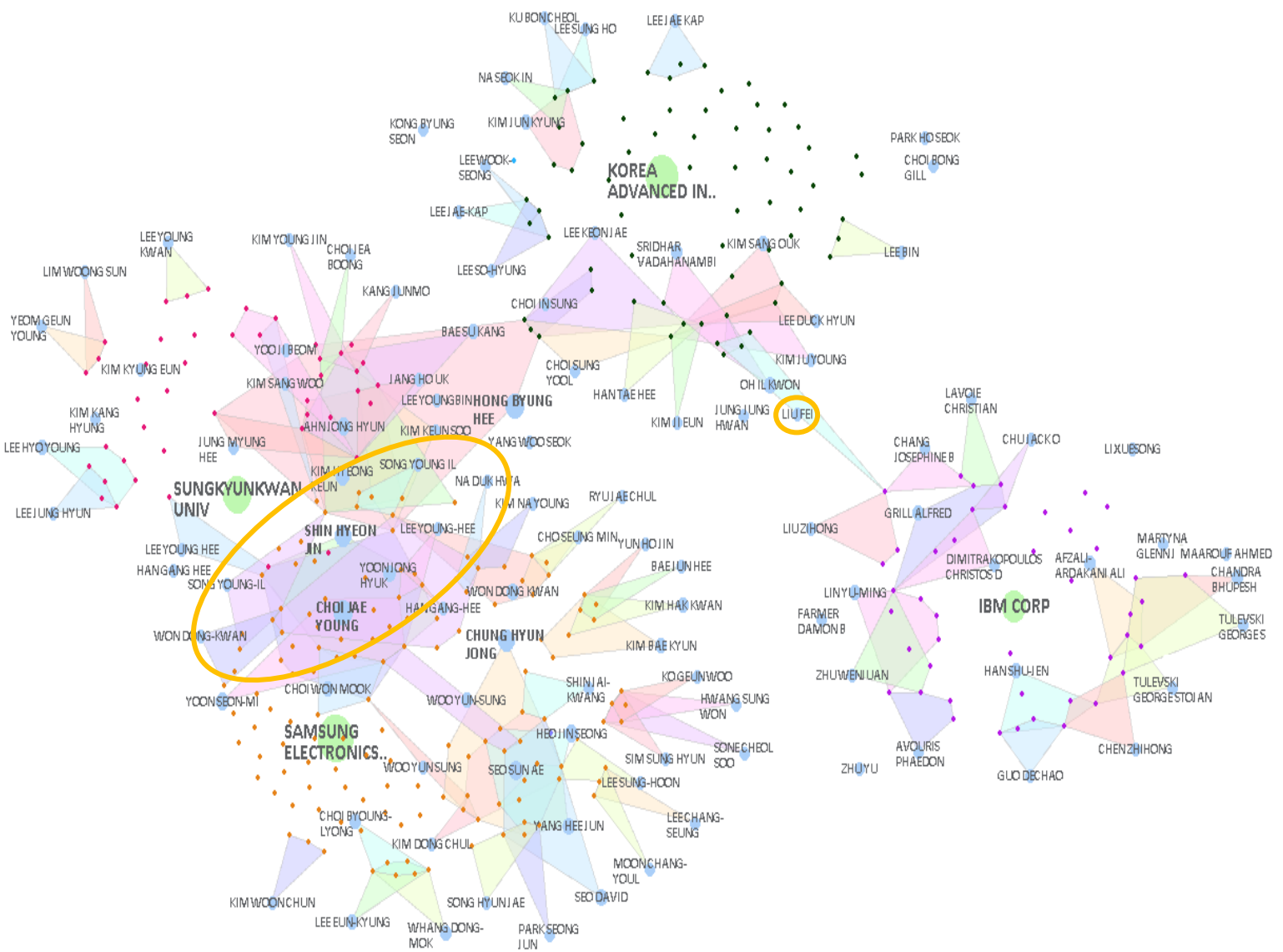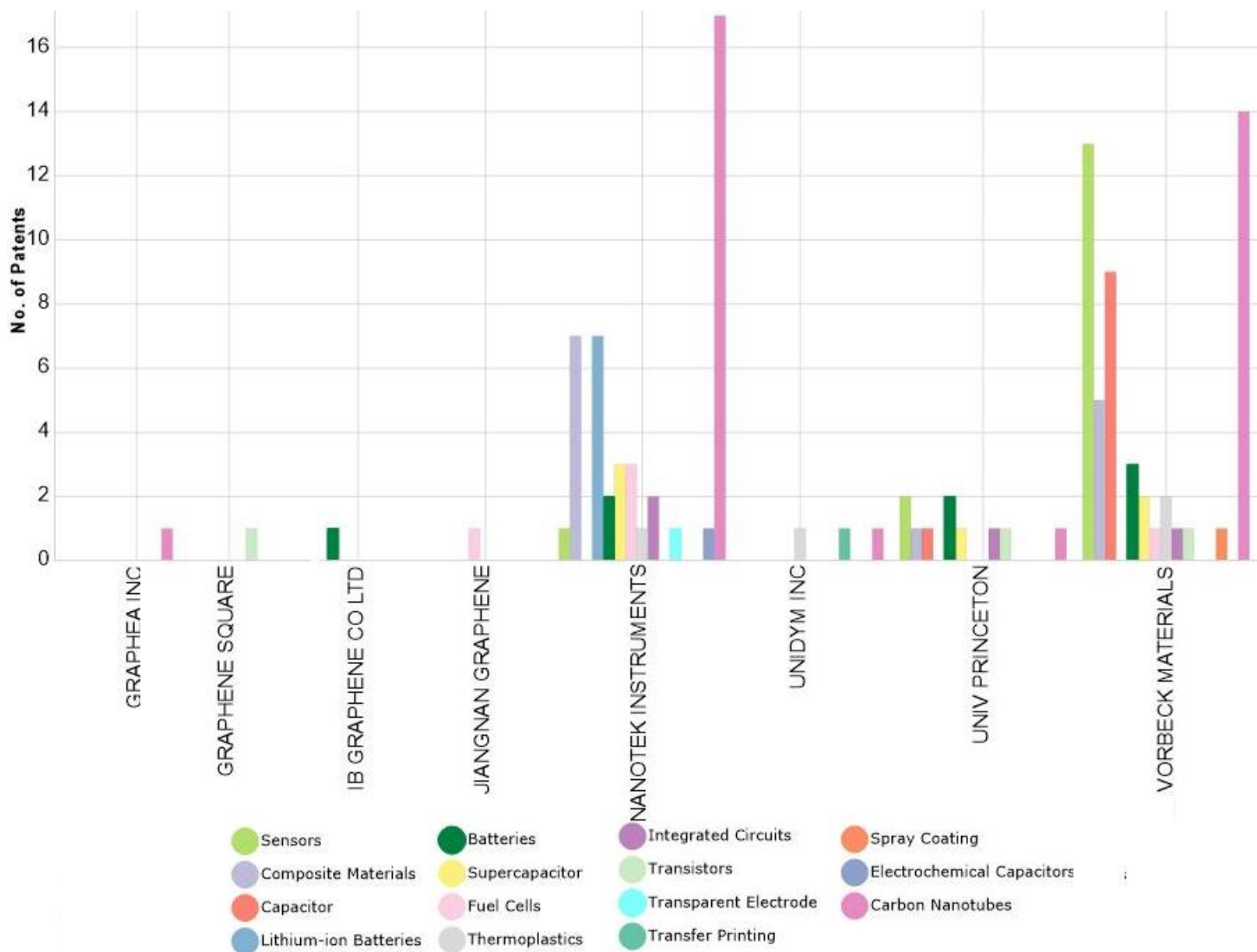

How we did it?

Using the VizMAP tool, patents of top four companies were loaded on the map. These were then expanded by their respective inventor names. The VizShade option was used to shade the inventors with potential overlapping patents between them.

Key companies across applications and methods of preparation of graphene

Applications:

Nanotek Instruments and Vorbeck Materials are active across all the application areas

Legend:
- Sensors
- Batteries
- Integrated Circuits
- Spray Coating
- Composite Materials
- Supercapacitor
- Transistors
- Electrochemical Capacitors
- Capacitor
- Fuel Cells
- Transparent Electrode
- Carbon Nanotubes
- Lithium-ion Batteries
- Thermoplastics
- Transfer Printing

How we did it?

We first created a group for companies focusing primarily around research around graphene using auto filter 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 clustered column chart.

Methods of preparation of Graphene:

Vorbeck is active in epitaxial growth as compared to all other companies
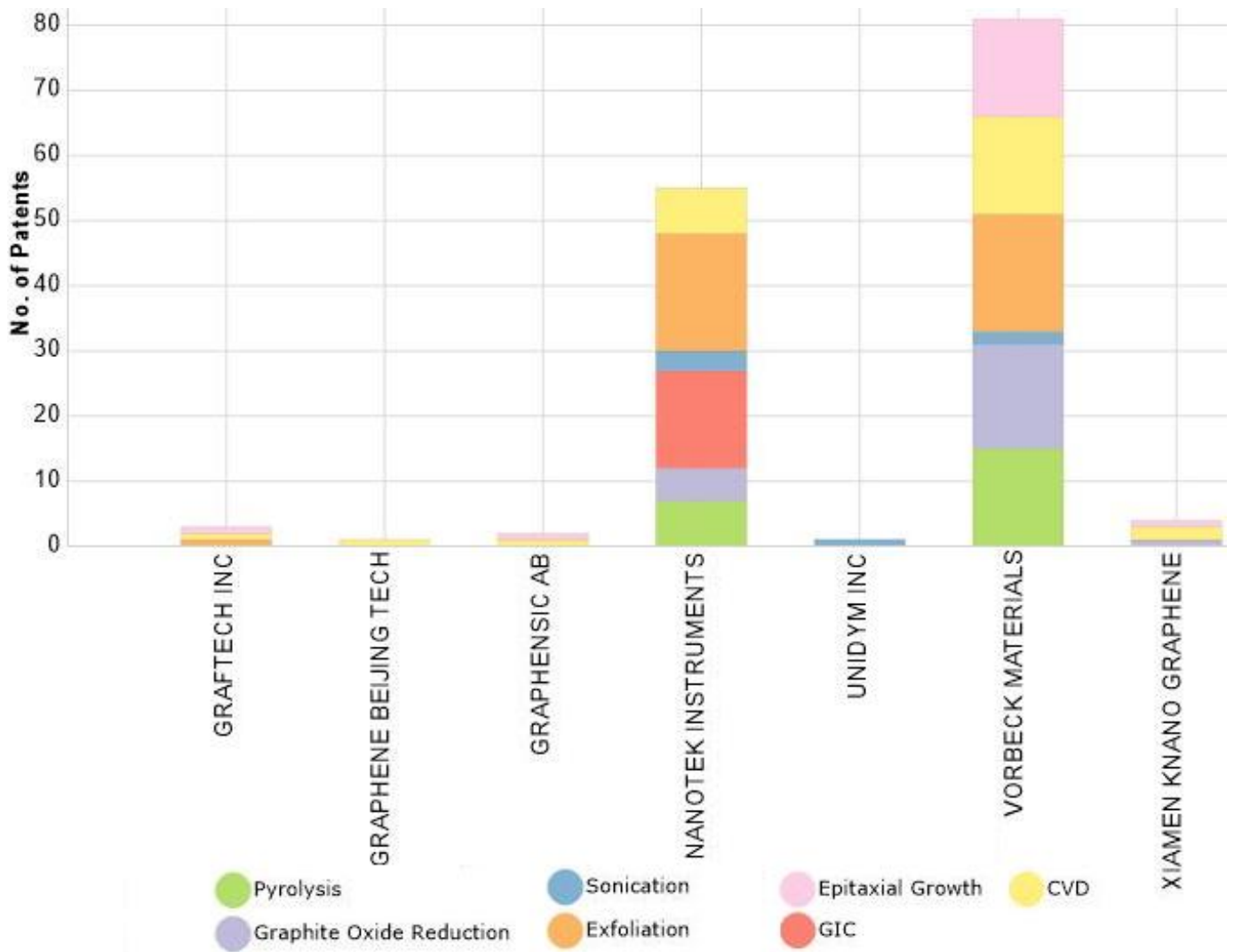
How we did it?

The group of companies created for previous analysis was correlated along with different methods using the co-occurrence analyzer and resulting matrix was represented as a stacked column chart.

Appendix: Search Strings Used for Categorization

Categorization: Methods

1. CO2 Reduction

CO2 Reduction	
(FT) contains (("carbon dioxide" or CO2) w/3 reduc*)	9 results

2. Chemical Vapour Deposition

Chemical Vapour Deposition	
(FT) contains ((chemical w/3 deposit*) or CVD)	835 results

3. Epitaxial Growth

Epitaxial Growth	
(FT) contains ((epitaxial w/3 (graphene or growth)) or SiC)	522 results

4. Exfoliation

Exfoliation	
(FT) contains (exfoliat* AND NOT ((exfoliat* w/5 compound*) or GIC* or "graphite* intercalate* compound*"))	359 results

5. Graphite Intercalation Compounds

Graphite Intercalation Compounds	
(FT) contains ((exfoliat* w/5 compound*) or GIC* or " graphite* intercalate* compound*")	55 results

6. Graphite Oxide Reduction

Graphite Oxide Reduction	
(FT) contains (graphite w/3 reduction)	298 results

7. Pyrolysis

Pyrolysis	
(FT) contains (pyrolysis or (Pyrolysis w/3 ethoxide*))	151 results

8. Sonication

Sonication	
(FT) contains (sonicat*)	184 results

Categorization: Applications

1. Automobiles

Automobiles	
(TAC) contains (automobile* or vehicle* or autocar* or "motor car" or car)	25 results

2. Batteries

Batteries	
(TAC) contains ((batter* or cell*) AND NOT (solar* or fuel*))	180 results

3. Capacitor

Capacitor	
(TAC) contains (capacitor* or condenser*) AND NOT (supercapacitor* or "super capacitor*")	174 results

4. Carbon Nanotubes

Carbon Nanotubes	
(TAC) contains ("carbon nanotube*" or CNT or (carbon w/2 nano*))	865 results

5. Chemical Sensors

Chemical Sensors	
(TAC) contains (chemical w/3 sensor*)	6 results

6. Composite Materials

Composite Materials	
(TAC) contains ((composite* w/3 material*) or polystyrene or "silicon wafer" or copper or nickel or (graphene w/3 matrix))	746 results

7. Electrochemical Capacitors

Electrochemical Capacitors	
(TAC) contains (electrochemical* w/2 capacitor*)	16 results

8. Electrophoretic Deposition

Electrophoretic Deposition	
(TAC) contains ((electrophoretic* w/3 (deposit* or coat* or paint*)) or EPD or electrocoat* or e-coating or ((cathodic or anodic) w/2 electrodeposit*))	6 results

9. Fuel Cells

Fuel Cells	
(TAC) 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*))	86 results

10. Graphene Biodevices

Graphene Biodevices	
(TAC) contains (DNA or biodevice* or biodevise*)	26 results

11. Graphene Nanoribbons

Graphene Nanoribbons	
(TAC) contains (nanoribbon* or (nano w/3 ribbon*) or GNR or (("nano-graphite" or "nano-graphene") w/3 ribbon*))	65 results

12. Integrated Circuits

Integrated Circuits	
(TAC) contains (((integrat* or monolithic) w/5 circuit*) or IC or chip* or microchip*)	98 results

13. Light Emitting Diode

Light Emitting Diode	
(TAC) contains (FOLED or (light* w/3 diode*) or OLED)	25 results

14. Liquid Crystal Devices

Liquid Crystal Devices	
(TAC) contains ((liquid w/2 crystal) or LCD)	29 results

15. Lithium-ion Batteries

Lithium-ion Batteries	
(TAC) contains (lithium w/3 (batter* or cell or cells)) AND NOT (fuel or solar or photovoltaic*or PV)	92 results

16. Sensors

Sensors	
(TAC) contains (sensor*)	476 results

17. Solar Cells

Solar Cells	
(TAC) contains (((cell or cells or batter*) w/5 (solar* or photovoltaic* or PV)) AND NOT (fuel w/2 (cells or cell or batter*)))	90 results

18. Spray Coating

Spray Coating	
(TAC) contains (spray w/3 coat*)	30 results

19. Supercapacitor

Supercapacitor	
(TAC) contains (supercapacitor* or "super capacitor*" or ultracapacitor* or (electric w/3 capacitor*) or "EDLC") AND NOT (capacitor*)	55 results

20. Thermoplastics

Thermoplastics	
(TAC) contains (thermoplast* or thermosoft*)	73 results

21. Touch Screen

Touch Screen	
(TAC) contains (touch* w/5 screen*)	9 results

22. Transfer Printing

Transfer Printing	
(TAC) contains (transfer w/3 print*)	8 results

23. Transistors

Transistors	
(TAC) contains (transistor* or FET or BJT)	166 results

### 24. Transparent Electrodes

Transparent Electrodes	
(TAC) contains ((transparent* w/3 (electrode* or film*)) or TCF)	116 results

Summary

This report categorizes and graphically analyzes graphene technologies. It is clear from the patenting trends in graphene-related patents and company portfolio and activity, that this is a rapidly emerging research-based area of technology. Looking at the trends in the classification of patents, this technology is now finding application in a diverse range of technological areas.

The first patent mentioning graphene was published in 1994 and the patenting of graphene-related technology took off rapidly in the 2000s. The largest patent portfolio is held by Samsung, and surprisingly the top two applicants are new entrants in the field.

Graphene has lots of amazing properties and each one has led to suggestions of an application. Some are likely in a few years, while others will be quite far into the future. The most likely to arrive first will be flexible electronic screens, which can be used on mobile phones, for example. A working prototype is expected in the next two years, but the costs are still too high for any marketable product.
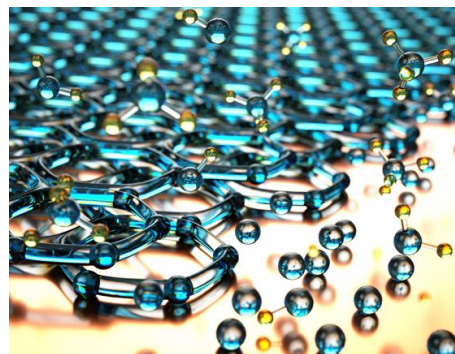
The development of this technology is still largely research-based, with a relatively large portion of academic participation, although real-world consumer applications such as flexible touch screen displays are getting closer to reality and could be widely available within the next few years. Graphene-related technologies are classified in a diverse range of places in the IPC and though the majority of sub-groups relate to the chemistry and processing of graphene, there are a significant and diverse range of application-specific classifications applied. Varying research strategies of the applicants are evident from the patent collaborations; Samsung exhibits a reasonable amount of collaboration, whilst other top applicants show none. The different nature of the top applicants is further highlighted by the technology landscape which reveals that, in contrast to the specialism evident from most applicants, Samsung is active in a very diverse range of graphene-related technology.

About Patent iNSIGHT Pro

Patent iNSIGHT Pro™ is a comprehensive patent analysis platform that allows you to accelerate your time-to-decision from patent analysis activities. Designed from inputs by experienced patent researchers, Patent iNSIGHT Pro easily blends into your existing Research workflow. Patent iNSIGHT Pro is used by leading legal services, Pharmaceutical & biotech, electronics companies and research organization across US, Europe, South America and India with more than 400 end users. Patent iNSIGHT Pro is developed and marketed by Gridlogics , a research driven IT Company specializing in providing intellectual property analysis and visualization solutions to aid R&D and corporate strategy.

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