Market Overview and Technological Environment of 8 nanotech applications

Participants involved:

- Nanotechnology Industries Association
- Chamber of Commerce of Milano
- TecKnowMetrix

Nanotechnologies impacts the following areas of energy-production and –storage:
•batteries,
•fuel cells, and
•ultra-capacitors.

In all of the above areas, the impact of nanotechnologies as an enabling technology is based on a two-fold improvement of the most important parameters characterising the capacity and performance of energy-production and –storage devices:
Nanotechnologies enable an increase of both the **energy density** (i.e. how much total energy a device can hold, and the **power density** (i.e. how quickly a device can deliver that energy); both parameters make nanotechnology-enabled devices excellent components for the implementation of **smart grid** technology, allowing – in particular - smoothing short term disruptions in power quality, as well as longer term load levelling and peak shaving applications.

The overall market size of all three areas was estimated to have been 350 million USD and is forecast to reach 7,700 million USD (in 2012). [1]

Markets for nanotechnology-enabled energy-production and –storage are expected to take off from 2012. Robust sales growth opportunities are expected – in particular – for rechargeable batteries (Lithium-ion) and ultracapacitors based on an early adoption of nanomaterials in the processes and productions of these devices.

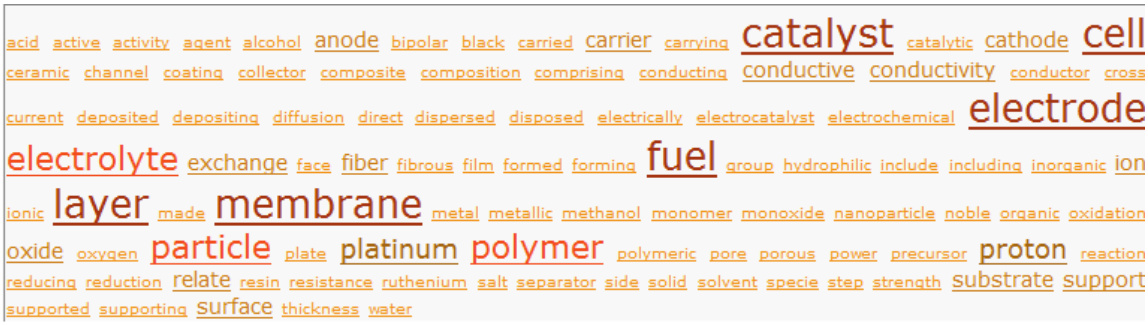
Fuel cells, very similar in concept to batteries, have always bring the interest of research and development in the academic and the industry, because they are high efficiency and in theory cheap to manufacture. Today, nanotechnology offers new processes and materials to break technological barriers that will make fuel cells a real alternative to gazoline. New ways of producing hydrogen (such as steam reforming in the petrochemical industry) and storing it are also a key factor to achieve this goal. With growing concerns such as environment (green house effect gazes) , economical concerns (employment, knowledge, independence to oil ...), challenges are great to produce a cheap fuel cell that would be a commercial success.

Currently, the wide-spread application of fuel cells is limited due to their high price; nanotechnologies, however, promise to provide a significant price reduction by lowering the cost of manufacturing resources and processes of the major fuel cell components: membranes, catalysts and electrodes, while furthermore increasing the efficiency of the resulting device.

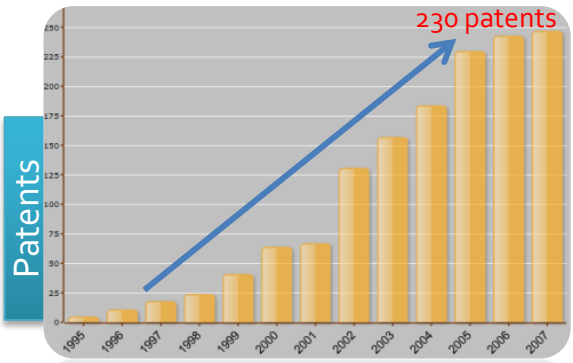
The market for fuel cell, hydrogen energy and related nanotechnologies was estimated to be worth 8.8 billion USD (in 2009) and forecast to reach 14 billion USD by 2014, with a compound average growth rate of 9.6%.[2]. Worldwide about 3870 organizations are involved in fuel cells, hydrogen energy and related nanotechnology and spent an estimated $8.4 billion in 2008. This market is estimated at $8.8 billion in 2009 and expected to increase to $More than 2180 organizations are involved in nanotechnology related to fuel cells and hydrogen energy and will spend a total of $4.7 billion for fuel cells and hydrogen energy incorporating nanotechnology. Of that $4.7 billion, about $2 billion in 2008 represents the value of nanotechnology for fuel cells and hydrogen energy separate from all other expenditures.

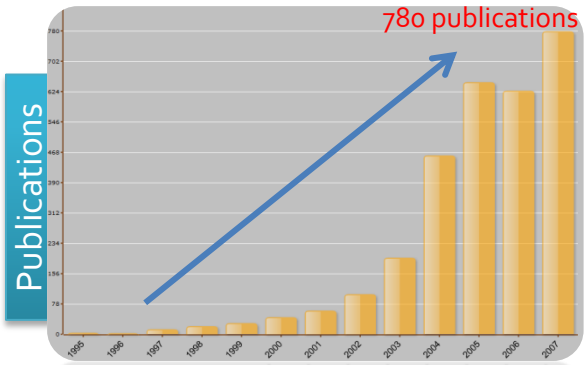
[1] LUX Research, *Nanomaterials State of the Market Q3 2008: Stealth Success, Broad Impact*
[2] iRAP report (2010):*Fuel Cells, Hydrogen Energy and Related Nanotechnology—A Global Industry and Market Analysis*

Energy production and storage
Fuel Cells



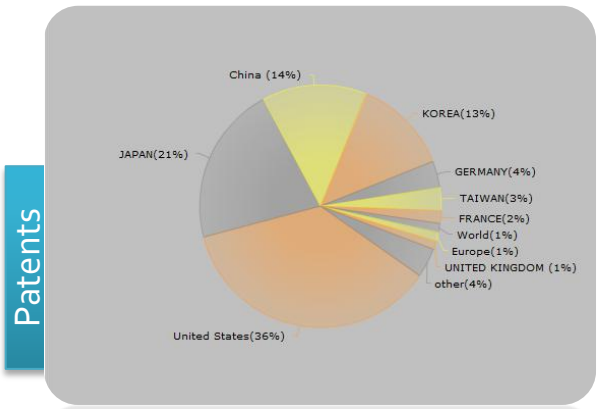
Timeline evolution of patent deposits and publication

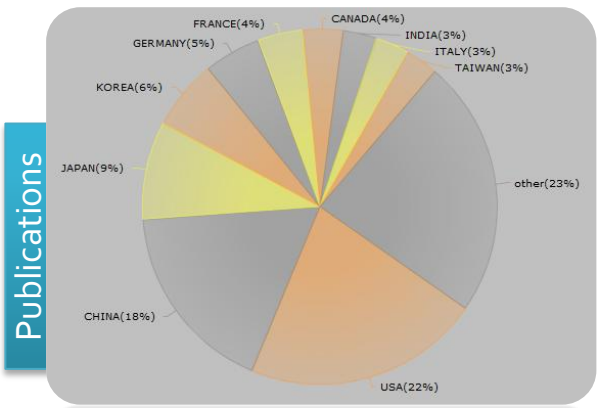




Patent deposits and publications have been steadily and strongly increasing since 1995 . The rate of increase is very similar with patent deposits and pulications, showing a strong interest from the public and private sector.It also shows a short time from research in laboratories to the patent.

Patent and publication repartitions from priority and organisation countries





Patent deposits and publications are dominated by Asia and the US.
The US is the main player with 36 % of the patent deposits and 22 % of the publications.
Asia is the main region with around half of the patent deposits (21 % Japan, China 14%, Korea 13%) and 35% of the publications.
European players are smaller in terms of patent deposits with Germany (4%) and France (2%) . But their level in terms of publications are similar to Korea (6%) . It shows a lack between public research and patents deposits , and maybe a need for a stronger presence from the private sector.

Energy production and storage
Fuel Cells

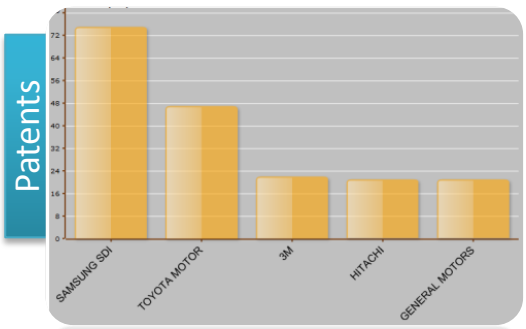
Fuel cells can provide electrical power for an extremely wide range of applications from utility power plants to distributed generation, domestic combined heat and power units, portable generator and power sources for portable electronic devices as well as providing motive power to a range of vehicles.
Before it can become a commercial success, fuel cells have to overcome and surmount economical and technical barriers .

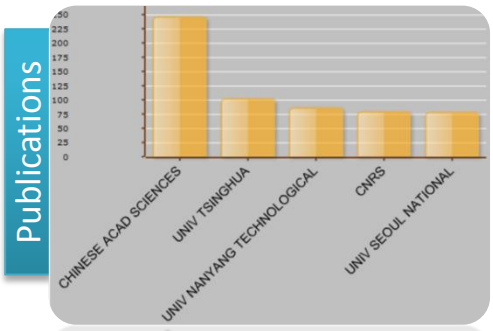
Those barriers are :
•Fuel cell cost: The DOE hydrogen program's 2015 target is $3/gge (projected, from distributed natural gas)
•Fuel cell efficiency : The DOE hydrogen program's 2015 target is 60%.
•Fuel cell durability. The DOE hydrogen program's 2015 target is 5000 hour durability, equivalent to approximately 150,000 miles of driving.
•Hydrogen storage and production

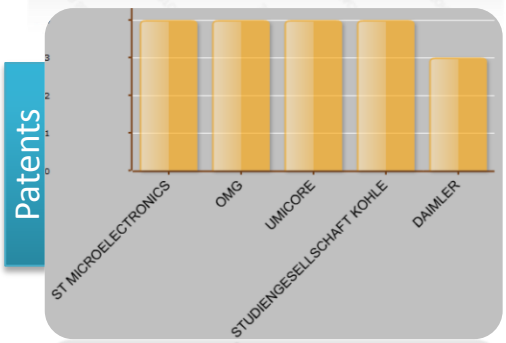
Most of the patents are related to electrodes, electrolytes and catalysts. Those patents includes process of manufactering , assembly and new materials. A lot of patents (500) are classified in the Technological class Solid Electrolyte which interests SOFC (solid oxyde fuel cell),a kind of fuel cell technology which has always been very attractive and strongly investigate . It finds its interest in any kind of applications . It is mostly used for stationnery applications even thought it interests the transportation sector too.

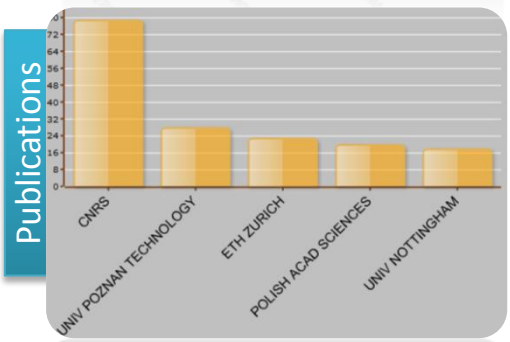
The components for PEM fuel cells market in North America is expected to rise at an average annual growth rate of 25.1% to $929 million in 2011.
The membrane for PEM fuel cells market is estimated at $334 million in 2011.
By 2011, it is expected that the functionalized hydrocarbons will be over 36% of the value of membranes for PEM fuel cells.
The bipolar plates, the gaseous diffusion layers and the catalyst ink market is estimated to reach $595 million in 2011, with average annual growth estimated at 24.7%. Source BCC research

Top 5 of the major actors in patents and publications







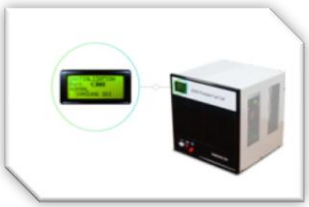


Energy production and storage
Fuel Cells

Focus on some major actors

SAMSUNG SDI

Samsung SDI is a korean company. Based on the rechargeable battery business which is essential for the mobile digital devices such as the Mobile phones and the lap top computers, Samsung SDI keep scontinuing the researches and developments of environment friendly energies for the new business of the products. This includes the batteries for xEV (Electric Vehicles), fuel cells and new generation solar cell technology.



Portable Fuel cell : PEMFC system

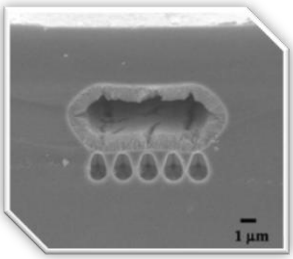
Umicore

Umicore is a Belgian-based multinational materials technology company, headquartered in Brussels. Umicore's pMembrain™ Membrane Electrode Assemblies offer fuel cell system OEMs the ability to realize the conversion of hydrogen into electrical energy as well as the conversion of water into hydrogen. When hydrogen generation and purification from fossil fuels are needed, Umicore's protonics™ fuel processing catalysts enable fuel cells to operate with a wide range of available energy sources.
Umicore is a recognized leader in catalysis, metal and precious metal compounds and materials.

pMembraine : Membrane for fuell cells

ST Microelectronics

STMicroelectronics produces one of the industry's broadest ranges of semiconductor products, from discrete diodes and transistors through complex System-on-Chip (SoC) devices to complete platform solutions that bundle chips with reference designs, application software, and manufacturing tools and specifications. With particular strengths in digital multimedia convergence and power applications, the Company is a major supplier to every industry segment, thanks to its broad range of leading-edge technologies and its rich pool of Intellectual Property (IP) resources.



Micro fuel cell

Studiengesellschaft Kohle mbH

The Studiengesellschaft Kohle mbH (SGK) is acting exclusively as a trustee for the non-profit organization Max-Planck-Institut für Kohlenforschung - and to some extent also for the Max-Planck-Institut für Bioanorganische Chemie - with the objective to exploit the research results of the Institute.
The Studiengesellschaft Kohle
•establishes research cooperations of the Institute with industrial partners
•applies for and owns patents based on research results of the institutes
•grants licenses to industrial partners prosecutes infringers of patents.

Poznan University of Technologie

Poznań University of Technology, PUT (is a university located in Poznań, Poland. Poznań University of Technology is known as one of the best technical universities in Poland. In 1995 it became the first Polish university to become a member of the Conference of European Schools for Advanced Engineering Education and Research (CESAER), an organisation comprising the best technical universities in Europe.

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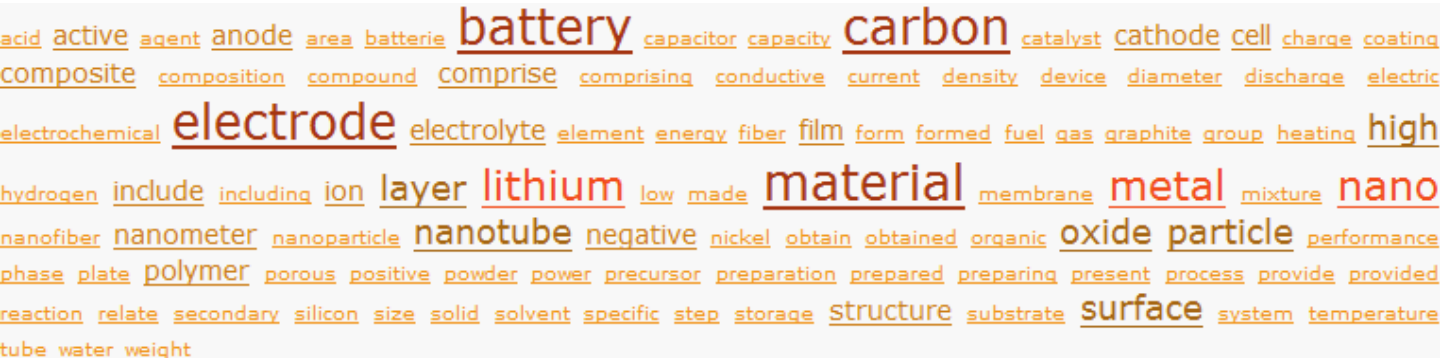
Ultracapacitor technology is aimed at a market estimated to grow to over $600 million by the year 2012, [2] while the total market for battery and ultracapacitor storage systems is forecast to grow from 1.5 billion USD in 2012 to 8.3 billion USD in 2016.[3]

With a new era of green technology in energy storage, a growing market of electric vehicles , batteries and ultracapacitors have to answer new needs in terms of efficiency , energy density ,durability and power. Nanotechnology offers new opportunities to fulfill those goals. Batteries are more interesting than ultracapacitors when we're talking about energy density but lack in power. **Ultracapacitors**, on the other hand, have been around since the 1960s, they are relatively expensive and only recently have begun to be manufactured in sufficient quantities to become cost competitive. The popularity of these devices is due to their long cycle life and high power density relative to batteries. In principle, ultracapacitors exhibit unlimited cycle life and maintenance-free operation as an alternative to batteries in power circuits.

[1] LUX Research, *Nanomaterials State of the Market Q3 2008: Stealth Success, Broad Impact*
[2] AZoNano: *Inventor Of Enable IPC's Ultracapacitor Technology to Present at ISEE'Cap 09*
[3] AZoNano: *Market for Battery and Supercapacitor Storage Systems for Smart Grid Applications Expect to Reach $8.3 Billion in 2016*

Energy production and storage
Ultracapacitors - Batteries



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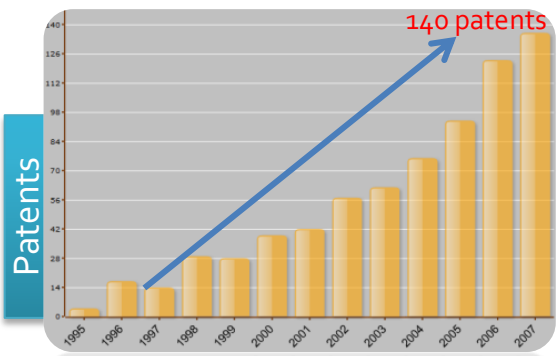

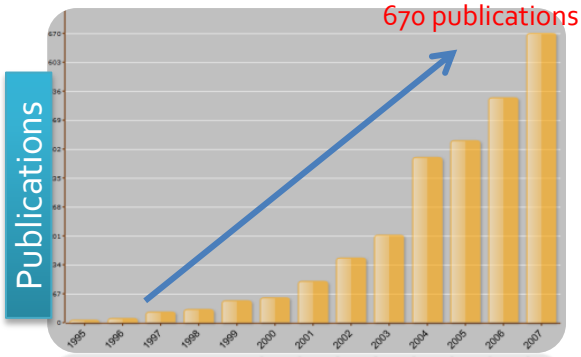

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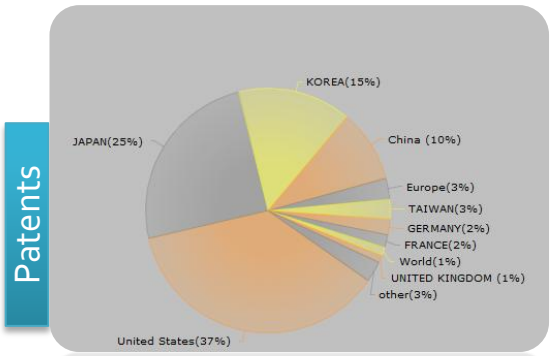

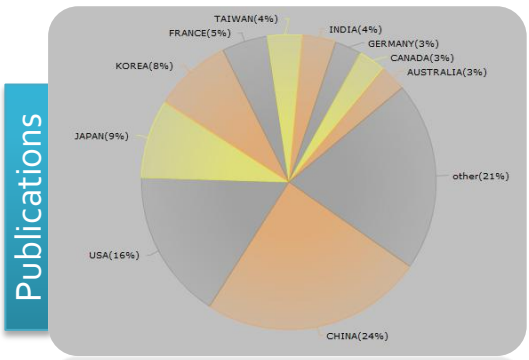

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European players are smaller in terms of patent deposits (Germany 2% ,France 2%). France is the fith with 5% of publications .
China is the strongest player in publication with 24 which shows the potential to become a leader in this area.

Energy production and storage
Ultracapacitors - Batteries

Ultracapacitors can be found in a range of electronic devices, from computers to cars. An ultracapacitor (supercapacitor or electric double-layer capacitor (EDLC)) stores more power than a battery and more energy than a capacitor. For this reason, it brings significant benefits in both "peak-assist" and "power-assist" applications.

Ultracapacitor technical barriers are :
•Cost.
•Energy storage density

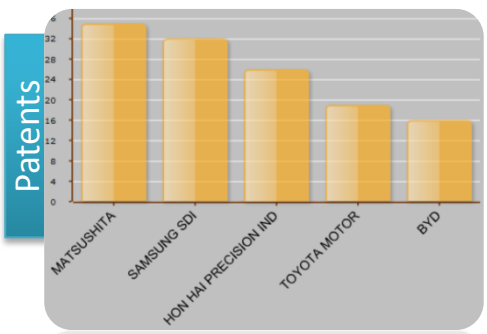
The global ultracapacitors market is expected to increase at a compound average annual growth rate (CAGR) of 25.3% over the forecast period 2009–2015. Global ultracapacitors sales from the automotive sector are expected to grow at an annual growth rate of more than 50% from 2010 due to the anticipated take-off of electric and hybrid vehicles.

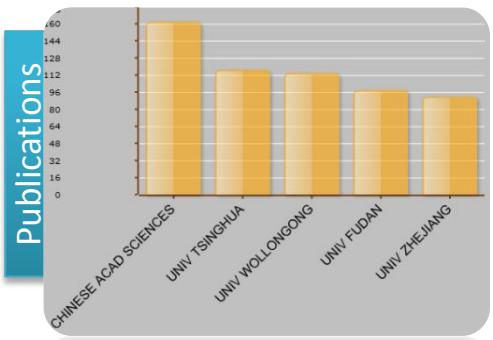
Batteries are the best known and most widely used means of storing electrical energy. Since their invention in the nineteenth century they have been used for provide portable, remote or backup electrical power in a whole range of situations. Today batteries are found in a wide variety of portable electrical and electronic devices from phones, computers and music players to torches, in automobiles, in small renewable energy storage systems for both commercial and domestic use and in a miscellany of other applications.

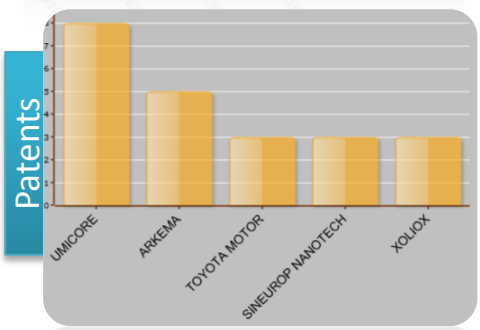
Batteries technical barriers are :

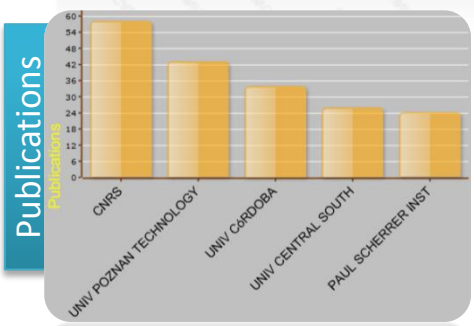
•Cost –The main cost drivers being addressed are the high costs of raw materials and materials processing, cell and module packaging, and manufacturing.
• Performance – The performance advancements required include the need for much higher energy densities to meet the volume and weight requirements in electric cars.
• Abuse Tolerance – Many Li batteries are not intrinsically tolerant to abusive conditions such as a short circuit (including an internal short circuit), overcharge, over-discharge, crush, or exposure to fire and/or other high temperature environments.
Life – The goal is to increase the number of cycles and the lifetime of batteries.

Top 5 of the major actors in patents and publications









Focus on some major actors

BYD Company Ltd

Established in February 1995, BYD Company Limited is a Hong Kong listed company with private enterprise background (SEHK: 1211). It is a key high-tech enterprise in China specializing in IT, automobile and new energy. BYD is committed to developing new green energy. It has developed electric vehicles, energy storage stations, solar power stations and other green energy projects. In the future, BYD will continue to lead the new energy revolution and help more countries in the world to get rid of oil pollution problems and relevant economic problems. It is the second biggest company in rechargeable batteries

Hon Hai Precision Ind

Foxconn (富士康) is the trade name of the Taiwan based firm Hon Hai Precision Industry Co. (Ltd.) . Foxconn is the largest manufacturer of electronics and computer components worldwide, and mainly manufactures on contract to other companies. Among other things, Foxconn produces the Mac mini, the iPod and the iPhone for Apple Inc.

Arkema

The Arkema Group was created in October 2004 from the reorganization of Total's Chemicals branch. It has three business segments: Vinyl Products, Industrial Chemicals, and Performance Products. Arkema produces and distributes high-quality multiwalled nanotubes (MWNTs). Its production capabilities, opened at the beginning of 2006, currently enable Arkema to manufacture 10 tons per year of high-purity MWNTs at its Lacq site (France). With this new facility, Arkema is planning a commercial development to fulfill the expectations of converters in the thermoplastics, epoxy resins, elastomers and coating sectors. Progress is also expected in the field of energy in which the use of carbon nanotubes should help manufacture energy-efficient batteries, super-capacitors and fuel cells.

SINEUROP Nanotech GmbH

SINEUROP-Nanotech GmbH is a private research laboratory, created in 1993 as a consulting company by previous research scientists of the Max Planck Institute for Solid State Research in Stuttgart. Through a cooperation contract, through common cooperative projects and through regional mediation by the Steinbeiss-Stiftung, SINEUROP has access to the research facilities of the Max-Planck-Institutes in Stuttgart. SINEUROP is synthesizing, purifying, characterizing, and selling carbon nanotubes, with special emphasis on single-walled carbon nanotubes. In addition, SINEUROP is working on industrial applications of carbon nanotubes, creating intellectual property in this field, and dealing with intellectual property. The company is a member of Nanotech Alliance, a strategic alliance of four independent small enterprises in Germany, China, Slovakia, and America, all of them founded by previous Stuttgart Max Planck scholars.

Paul Scherrer Institute : PSI

The Paul Scherrer Institute, PSI, is the largest research centre for natural and engineering sciences within Switzerland. They perform world-class research in three main subject areas: Structure of Matter; Energy and the Environment; and Human Health. By conducting fundamental and applied research, they work on long-term solutions for major challenges facing society, industry and science.

High energy supercapacitor
800 F boostcap by montena SA utilizing PSI electrode.

Until recently, almost 100 percent of solar cells were based on crystalline silicon (c-Si), the only major exception being the thin-film amorphous silicon (a-Si) material used for “solar calculators.” The success of materials other than crystalline silicon in the PV market has encouraged research and development work examining other kinds of materials like organic photovoltaic.

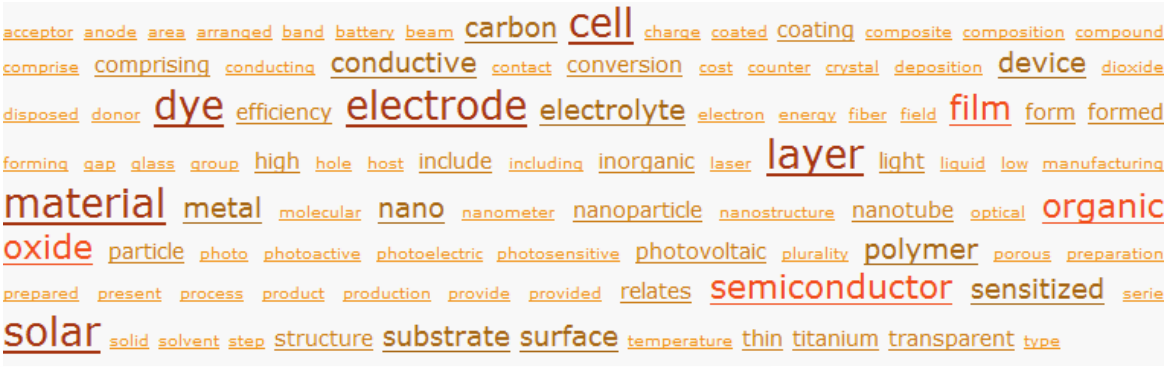
Organic photovoltaics represent only one of three types of solar cell technology that experienced a significant innovative push with the advent of nanotechnology; in different ways, nanotechnologies contribute to the following solar cell technologies:
•Crystalline and amorphous/thin film solar cells (silicon based solar cells)
•Dye solar cells (electrochemical thin layer solar cells)
•Organic solar cells / photovoltaics (photo active layers based on organic materials)

Organic photovoltaics (OPVs) are relatively cheap to fabricate but are not as efficient as silicon based materials. They can be used in a lot of applications and especially portable electronics which need more convenient source of energy .

One particular advantage of organic photovoltaics is their exceptionally easy manufacture by large-scale, high-throughput printing processes. Combined with the retained flexibility of the photoactive layer, organic photovoltaics can already be produced in large quantities using cheap materials and cheap, environmentally friendly manufacturing processes (OVPs can reduce production costs to as little as 25 percent that of the crystalline silicon technologies), and thereby off-setting their relatively low efficiency compared to solid solar cells.

One of the best-known organic photovoltaics is the so-called Grätzel cell (or Dye Sensitised Cell (DSC)), in which the electrons are produced by a light-absorbing dye and subsequently transfererd to nanostructured TiO_2 particles. The market for DSCs was estimated to be worth 1.5 billion USD (2004) and is forecast to grow at 20 to 40 percent per year.

Energy production and storage
Organic photovoltaic



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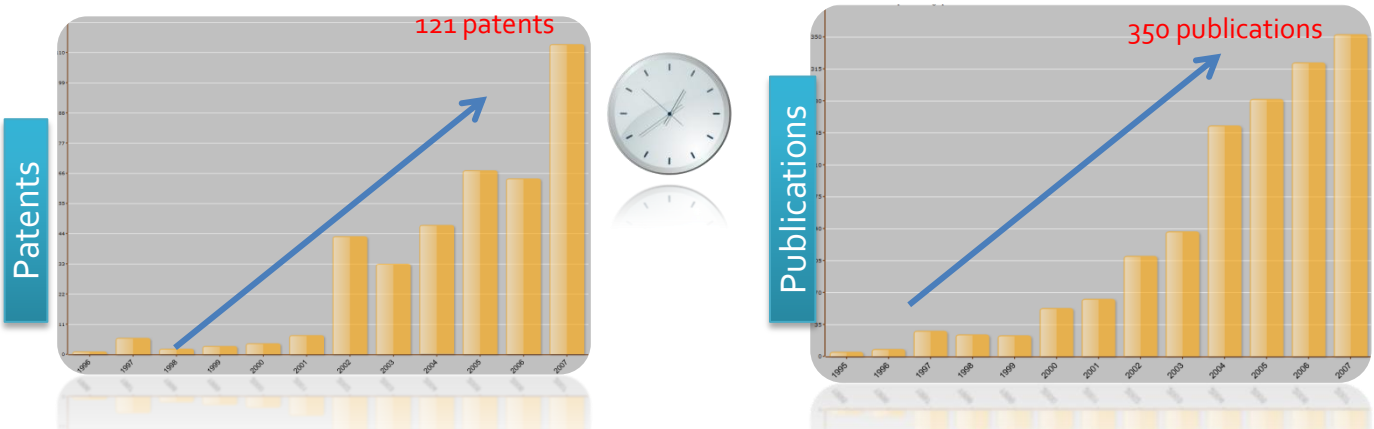

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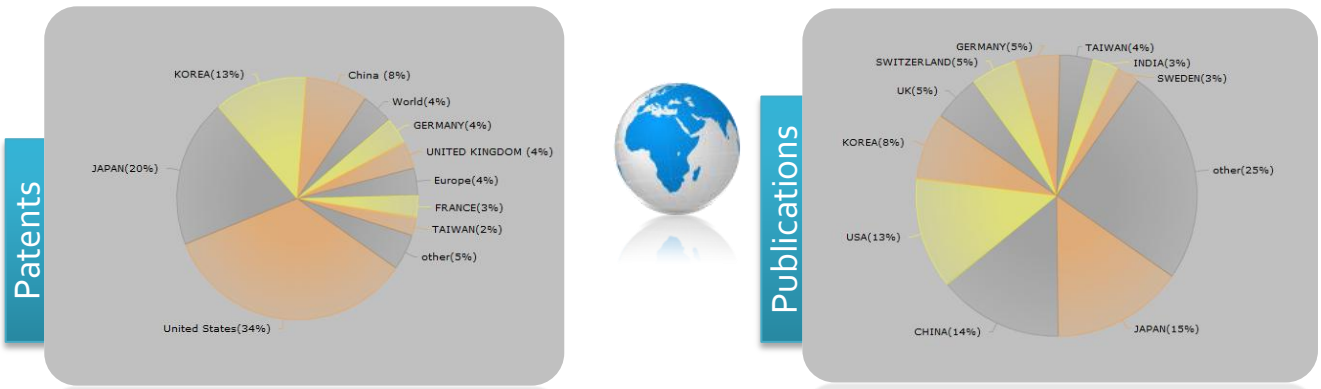

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China,Japan and the USA have around the same level of publications (13->14%).

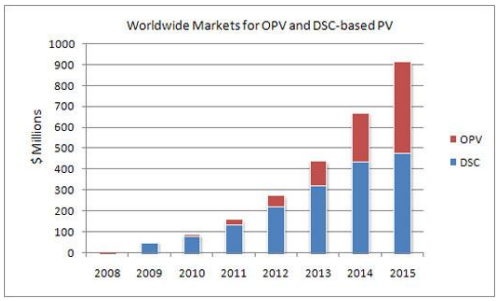
Energy production and storage
Organic photovoltaic

In the last two decades, new materials and more sophisticated architectures have advanced OPVs to the point that efficiencies exceeding 6 percent have been achieved, and 8-10 percent is likely within the next few years. Even more efficient are DSCs, hybrids that combine organometallic dyes and mesoporous inorganic oxides. Discovered in 1991, these devices have achieved efficiencies as high as 11 percent.

OPVs technical barriers are :
•Durability
•Cost
•Cell efficiency

The long-term hope for OPV rests as much in cost reductions as it does in efficiency improvements; the consensus is that at $0.50 per peak Watt, OPV cells to become competitive with other energy generating systems. And this point may be reached, not just thought better materials, but through better cell design and a move towards solution processed/printed manufacturing methodologies. As far as cell design goes, organic multi-junctions, also known as tandem cells, present a promising way to increase cell efficiencies.

Carbon nanotubes are also playing a growing role in research, both to enhance photoactive layers and to improve the performance of contacts. The choice of materials used as encapsulants for OPV is also very important since organic materials are so environmentally and thermally susceptible; organic materials suffer from long term stability issues, and no standard ways have been developed to determine the impact of ageing on performance.



Source : Nanomarket

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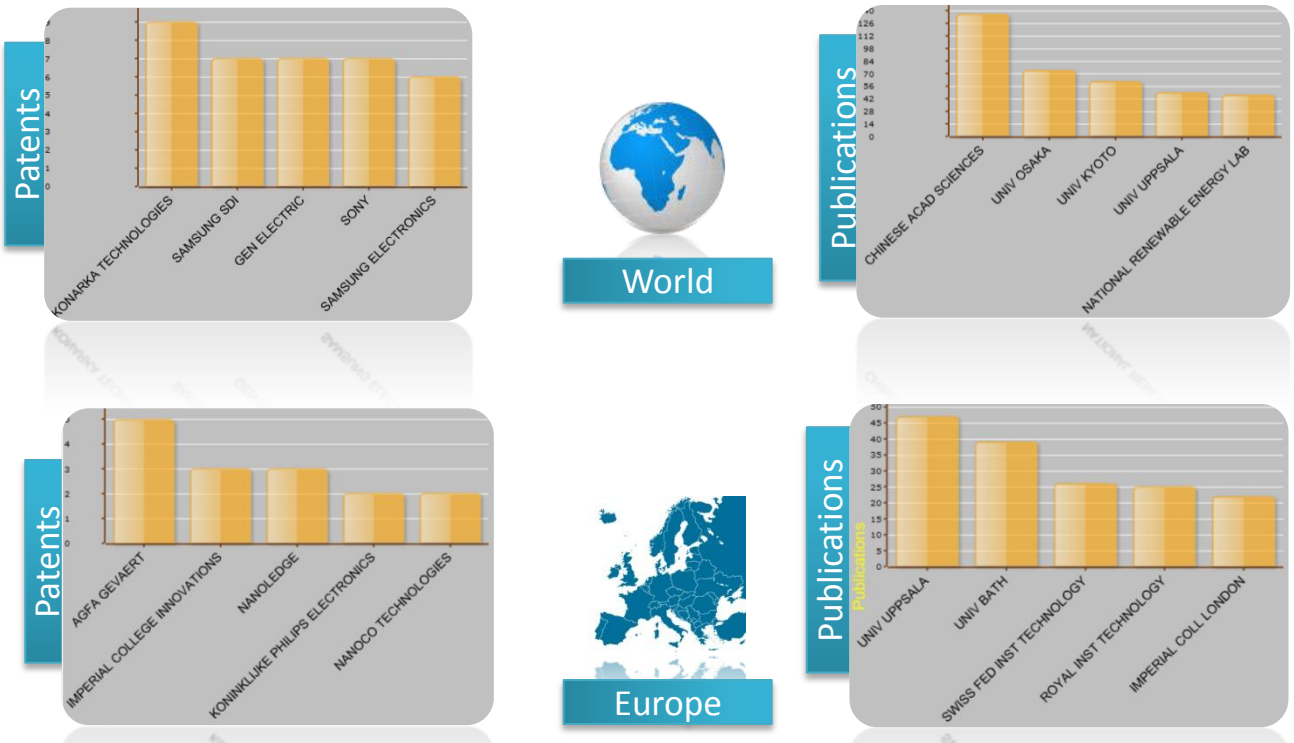


Energy production and storage
Organic photovoltaic

Focus on some major actors

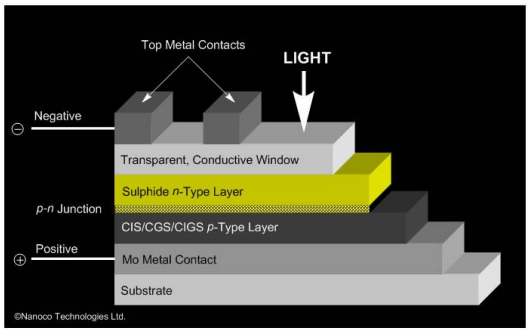
Konarka

Konarka Technologies, Inc. is a solar energy company based in Lowell, Massachusetts, founded in 2001 as a spin-off from University of Massachusetts. Konarka is recognized throughout the world as a leader in OPV (organic photovoltaic) technology – a 3rd generation solar technology that is rapidly emerging to compete with silicon based 1st and 2nd generation solar technologies. The company holds over 350 patents and filings covering every aspect of our proprietary chemistry and processes.

Konarka PowerPlastic (OPV)

NANOCO Technologies

Nanoco Group PLC and its operating subsidiary Nanoco Technologies Ltd partner major R&D and blue-chip industrial organisations in the development of applications incorporating semiconductor nanoparticles, "quantum dots".
Nanoco Technologies is unique in the nanomaterials market as a company that manufacture large quantities of quantum dots. Our molecular seeding process for the bespoke manufacture of these nanoparticles on a commercial scale is protected by worldwide patents.



Nanoco's advanced PV based QDs

National renewable energy lab

The National Renewable Energy Laboratory (NREL) is the nation's primary laboratory for renewable energy and energy efficiency research and development (R&D).
NREL's mission and strategy are focused on advancing the U.S. Department of Energy's and our nation's energy goals. The laboratory's scientists and researchers support critical market objectives to accelerate research from scientific innovations to market-viable alternative energy solutions. At the core of this strategic direction are NREL's research and technology development competencies. These areas span from understanding renewable resources for energy, to the conversion of these resources to renewable electricity and fuels, and ultimately to the use of renewable electricity and fuels in homes, commercial buildings, and vehicles. The laboratory thereby directly contributes to our nation's goal for finding new renewable ways to power our homes, businesses, and cars.

Uppsala University

T Uppsala University (Swedish: Uppsala universitet) is a research university in Uppsala, Sweden. Founded as early as 1477, it is the oldest such institution in the Nordic countries,[3] and for centuries has been one of Europe's most renowned seats of learning

AGFA

The Agfa-Gevaert Group develops, produces and distributes an extensive range of analog and digital imaging systems and IT solutions, mainly for the printing industry and the healthcare sector, as well as for specific industrial applications.

Concerning their electronic properties, single walled CNTs appear in fractions of conducting (i. e. metallic) nanotubes and semiconducting ones. The conductivity depends on the structural set-up (i. e. the chirality or "roll- up direction") of the tubes. Metallic tubes allow for current densities that are three orders of magnitude above the ones of copper or silver. They show a so called "ballistic electron conduction", a quantum mechanical effect which offers highest carrier mobilities and a low electro-degradation of the material.
Semiconducting tubes on the other hand give rise for the fabrication of nanoelectronic transistors, which have already been realized as prototypes. Due to their electronic properties and the appearance of both metallic and semiconducting tubes, CNTs are discussed as promising material in a future upcoming post silicon era in microelectronics and data storage.

The electronic properties of CNTs give also rise to a number of other applications such as electron emitters in new flat panel display types, electrode materials, fillers for antistatic and conductive plastic composites, electrode materials in electrochemical applications etc.

Based on their chemical properties exposing a large and reactive molecular surface, numerous bio-chemical functionalizations of CNTs have been realized, making them candidates for compound tracers or drug-delivery systems in the biomedical area.
However, research is in a very fundamental stage in this sector and items of biocompatibility and toxicity remain open at the moment.

Significant effort had been spent on the development of large scale production techniques. Meanwhile first industrial production plants are being established leading to decline of CNT-prices and giving rise for more widespread applications.

Medical technology, with annual growth rates of more than 10 percent, is one of the strongest growing sectors. On the European market, the annual turnover has already reached 80 billion euro. Considering the increasing life expectancy in Europe, it can be assumed that the need of medical technological devices and aids such as prostheses of all kinds will become even larger. Already now some gaps in the market are evident as can be shown with the example of leg amputations: In Europe, annually approximately 47 000 leg amputations are carried out. However, only approximately 50% of the patients can be supplied with a prosthetic leg, as most of the patients are too weak to attach the prostheses and use them appropriately. In the future, actuators could provide a solution to these kinds of problems.

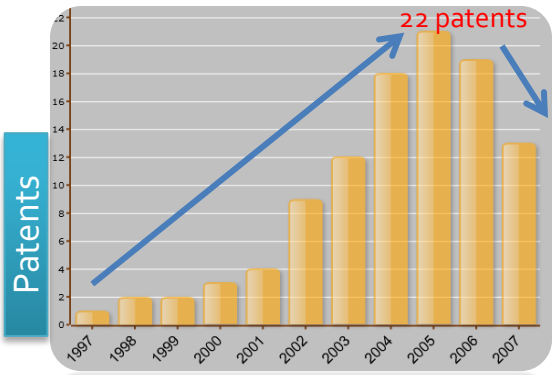
Actuators are devices that translate one energy input into another energy output (typically electronic stimuli into mechanical action (e.g. motion) and they have already become an integral part of robotics and automation. Logically, actuators might also be used as prostheses. Currently, the possibilities to do so are still very restricted as the energy required for actuators is quite high. Also, the effectiveness of the actuators is not that great and the weight of the actuators is another problem.

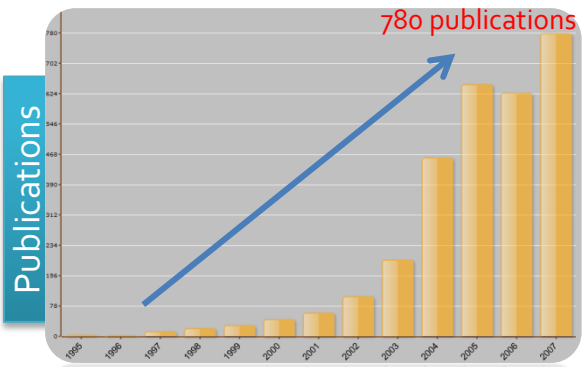
The use of new materials might prove to hold the answer to some or all of these problems: carbon nanotubes (CNT), very small tubes made from carbon which are approximately 10 000 times thinner than human hair. The actuators made from carbon nanotubes are said to have exactly the characteristics which are required for a prosthesis: they require very little energy, have a high system effectiveness and are light-weight. All these characteristics turn these actuators into candidates for the development of innovative prostheses which can be regarded as artificial muscles.

The emergence and establishment of **ortho-biologic products** and solutions is expanding. **orthobiologics products are products for tissue engineering applications. They are finalized at regenerate and restore damaged cartilage and bone.**
orthobiologic devices are based on animal tissue and the body's processes to fix damaged bones and joints. Orthobiologic products are intended to help repair or regenerate – instead of replace – damaged bone and tissue. Products vary from traditional metal implants, plates and screws to biologically-based products for hard and soft tissue regeneration. One product type are materials for bone replacement.
The fastest growing sector in orthopaedics is presently the market for **osseous graft substitutes** as part of the biomaterials market, in particular for spinal applications. **Bone grafting is a surgical procedure that replaces missing bone with material from the patient's own body, an artificial, synthetic, or natural substitute. Osseous graft substitutes are used for repairing bone defects and restoring bone structure.**

According to an analysis of Frost and Sullivan, a total turnover of $39.5 million was gained in 2005 in Europe with osseous graft substitutes. Continuous innovation should allow market growth to $114.9 million until end of 2010.
Since 2004 three different types of nanostructured bone replacement materials are available in the marketplace, sold by two companies. The world market volume in 2007 was €31.3 million. Within the next years it is assumed that there will be a slight increase in the market volume due to new players in this field. However, the overall market volume for nanostructured bone replacement materials will not change significantly within the next few years.
Depending on the country, strong regulations and approvals are the most common main barriers to innovation.

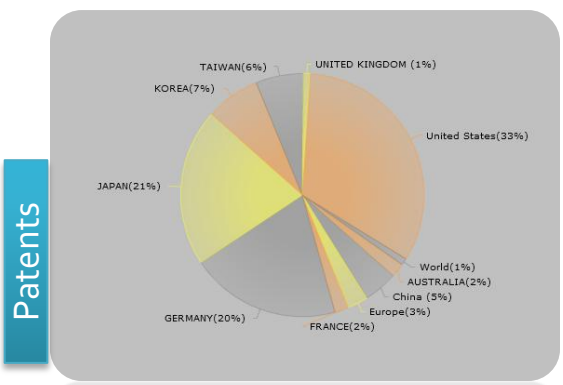
Timeline evolution of patent deposits and publication

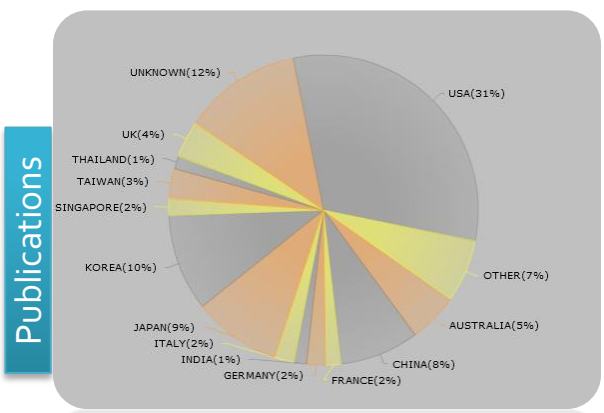




Patent deposits have been increasing since 2000, but we can notice a decrease since 2007 .In the meantime, the publications have increased showing a strong interest from the public sector

Patent and publication repartitions from priority and organisation countries

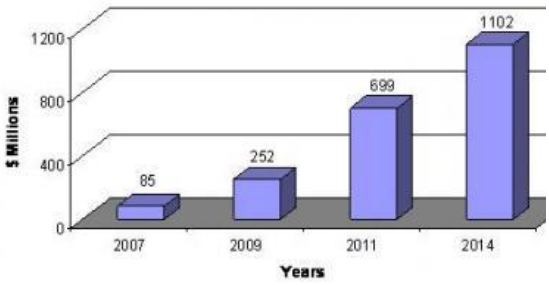


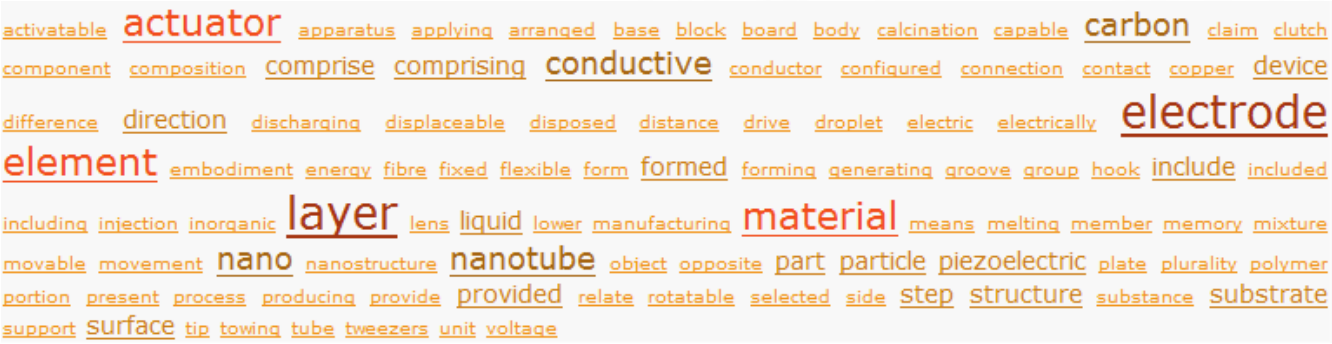


Patent deposits and publications are dominated by the US.
The US is the main player with 33 % of the patent deposits and 30 % of the publications.
Asia is the main region with around 40 % of the patent deposits (21 % Japan, Korea 7 %, China 5%)
Germany is the most activ European player in terms of patent activity (20%).
Half of the publications are made by the US (30%), and the Asian countires (Chine 8%, Korea 10 and Japan 9%)

"CNI is targeting four key application areas—field-emission flat-panel displays, conductive plastics, high-performance fibers, and advanced composite bulk-structural materials—which Colbert estimates represent about a $5 billion market value just for the SWNT sector.

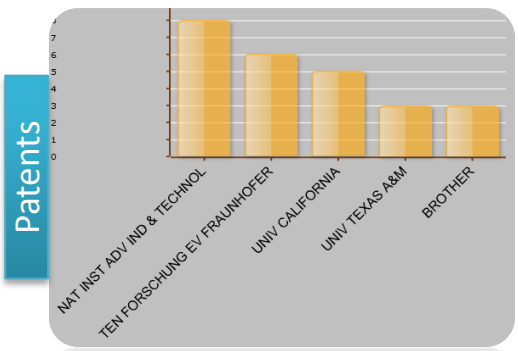
All these potential applications require SWNTs in commercial production at acceptable prices, almost certainly less than $1,000 per pound and perhaps as low as $100 per pound"

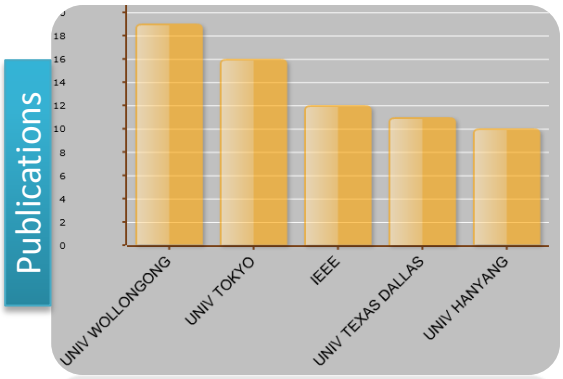




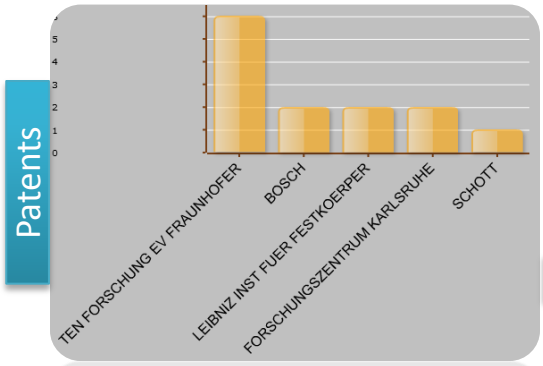
List of the most present terms in the corpus of patents

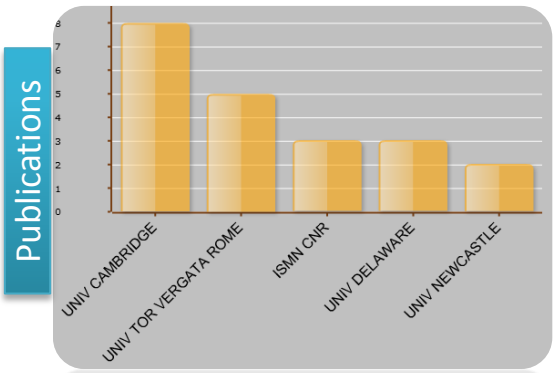
Top 5 of the major actors in patents and publications





We can see that the main actors are academics. However, there are many actors with 2 patents and we can find big industrial companies: Honeywell, Bosch, Epson.





Focus on some major actors

National Institute of Advanced Industrial Science and Technology (AIST)

National Institute of Advanced Industrial Science and Technology (AIST), led by President Dr. Nomakuchi, is not a government institution, although funded by Japanese government to a large extent. It has 6 research fields among which Nanotechnology, Materials and Manufacturing. AIST is engaged in discovery and development of nanometer-scale phenomena and materials, evaluation and nano-fabrication techniques, and techniques leading to industrial products.

AOI ELECTRONICS

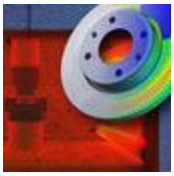
With company headquarters and main factory in Tokyo and satellite factories in Mainland China, Aoi employs approximately 1300 people and is a privately held corporation.

HONEYWELL

Honeywell International is a diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services; control technologies for buildings, homes and industry; automotive products; turbochargers; and specialty materials. Its sectors of application are aerospace, automation and specialty materials Honeywell has created a Technology Licensing Portal that allows one to either search or drill down for the technologies that Honeywell has available for external licensing. We invite you to explore the dynamic world of Honeywell's technology.

BOSCH

The Bosch Group is a leading global supplier of technology and services. In the areas of automotive and industrial technology, consumer goods, and building technology, some 280,000 associates. Each year, Bosch spends more than 3.5 billion euros, or eight percent of its sales revenue, for research and development, and applies for over 3,000 patents worldwide. Bosch researchers are therefore exploring the foundations in materials science and manufacturing engineering



Nanofibres have a broad variety of possible applications in many fields including electronics, medicine, mechanics, automotive, aerospace and acoustics. The fastest market growth is expected in electronics within the next few years. Growth of the nanofibre market is currently being driven by filtration applications. There is clearly a high interest in processing fluids - especially water - with higher purity levels. This market is most likely driven by water and wastewater treatment.

One of the main drivers is quality regulation. Future regulations are expected to become even more restrictive, which will most likely lead to a rising market penetration of membranes. At the end of the day the required filtration quality and price will decide over the market growth rate.

The US demand for membrane materials is expected to increase 8.2 % per year to $4.3 billion in 2012. Additionally, a growing number of industries are using membranes to reduce water use and waste disposal expenditures, and to improve water re-use and material recovery.

Value growth will be aided by the increasing use of value-added, high performance membranes, and a gradual shift toward higher value materials.

Micro filtration membranes will continue to account for the largest share of total demand, but represent a better established and more mature segment of the market. As a result, advances are projected to be stronger for ultra filtration and reverse osmosis membranes, both of which function in a variety of markets at a higher purity level. **Reverse osmosis is a liquid filtration method for removing many types of large atomic molecules from smaller molecules, by forcing the liquid at high pressure through a membrane with pores (holes) just big enough to allow the small molecules to pass through.It is most commonly known for its use in drinking water purification from seawater, removing the salt and other substances from the water molecules**.

However, the process is also used for filtering many other types of liquids.However, among major applications, gains are expected to be strongest for pervaporation membranes, albeit from a small base, because of their use in high-growth specialty markets such as chemical and industrial gas processing, as well as fluid treatment in wastewater, and medical and pharmaceutical markets. Other membrane separation technologies include gas separation, nanofiltration, dialysis and electro dialysis.

Additionally, "Frost and Sullivan" recognise for the US market the following industry trends:

- Continuing industry consolidation through mergers and acquisitions
- Rising potential in the potable water treatment, wastewater reuse and desalination market
- Continuing decrease in membrane prices opens up new markets
- Conventional treatment remains a key competition
- Improvement in membrane elements design and configuration to enhance treatment efficiency
- Integrated membrane systems produce high quality reclaimed water

Fig. 1 Global market for nanofibres

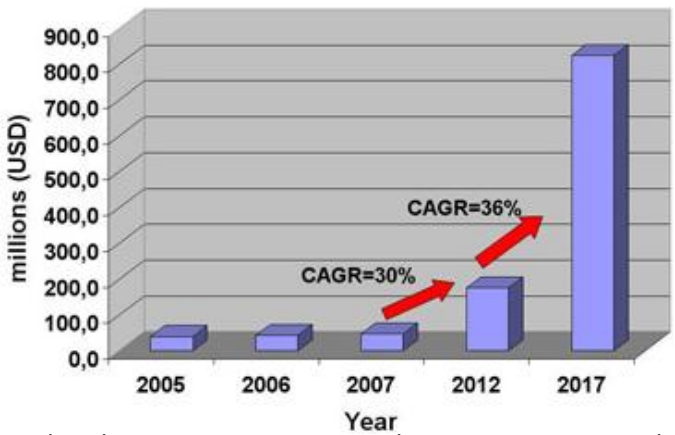
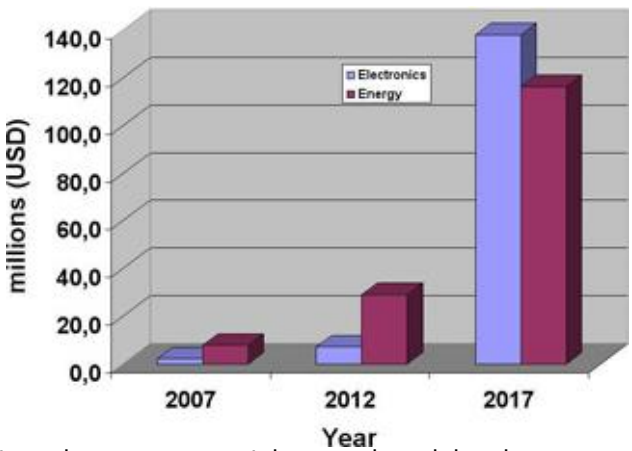


Fig. 2 Global fibre market for electronic and energy sector



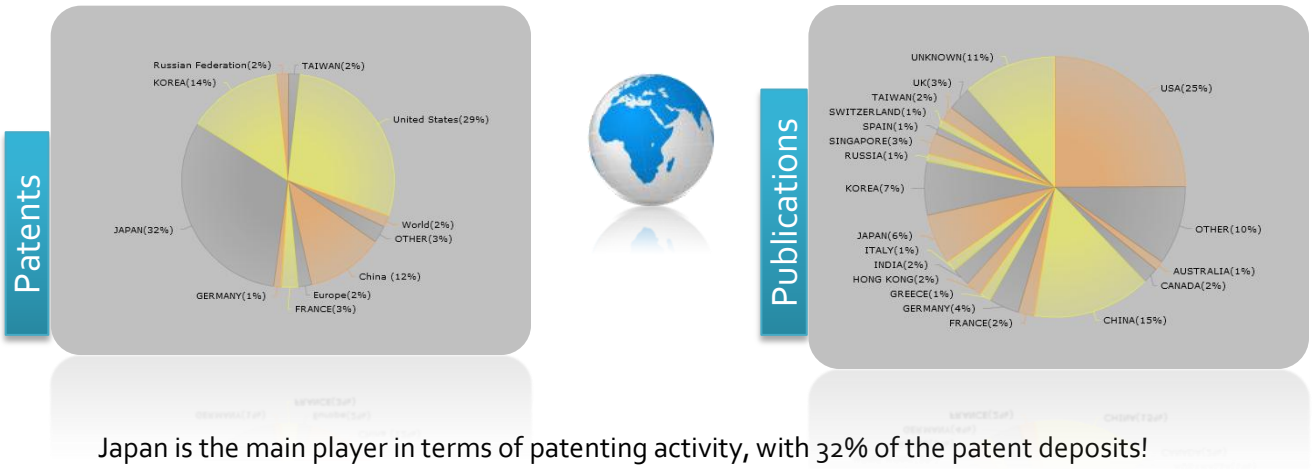
Within the EU numerous research institutions are involved in carbon nanomaterial research and development. The quantity of research as well as the transition from research to commercializable applications looks often much worse in comparison to other world regions. Taking the situation of CNT research and applications, the number of scientific publications and patent applications as well as of public funding activities ranges far behind those of the US and Japan. The situation is similar e. g. for graphene and aerogel research. Both recognized as promising materials for a variety of applications, one has to realize a vast majority of appropriate research to be localized currently within the USA.

European companies appear to be clearly reserved concerning both the utilization of carbon based nanomaterials and investments into appropriate R&D. Whereas in the electronics sector, including displays, Japan and other east asian countries as well as the US are fundamentally dominating applied and transfer research, the european position appears to be more promising in the areas of energy storage, environmental applications, composite materials and nano-toxicity research. Meanwhile, a number of european companies has shown an increasing interest in new electrode materials as well as in carbon based composite materials. In 2007 first large scale production plants for CNTs have e. g. been installed by Bayer Materials Sciences in Germany. In the area of more established carbon nanomaterials the european position is even more promising. In the carbon black sector for example european companies manufacture considerable amounts of the global production and appear to be competitive on the world markets. Evonik Industries e. g. provides an annual carbon black production capacity of around 160.000 metric tons. Its production plant is currently the second largest in the world.

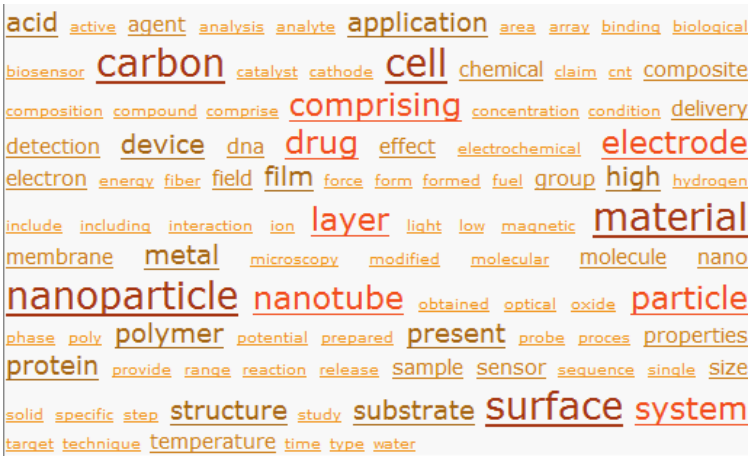
Timeline evolution of patent deposits and publication

Patent deposits have been increasing until 2008. We can notice a decrease in the publication activity since 2008.

Patent and publication repartitions from priority and organisation countries

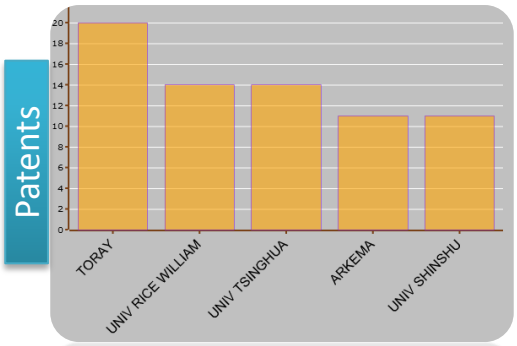


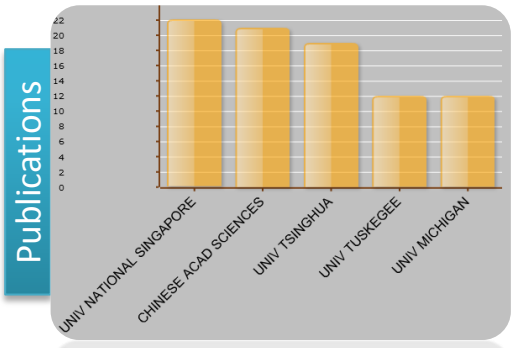
Japan is the main player in terms of patenting activity, with 32% of the patent deposits!
Publications are dominated by the US (29% of patent deposits and 25% of the total of publications).
China, with 12% of the patents and 15% of the publications is a very strong player for this applications
Germany and France are the two main European players.



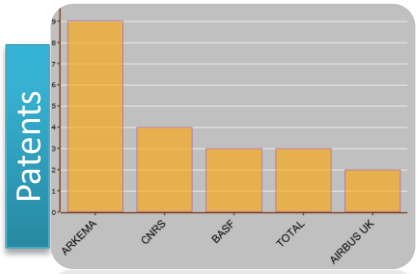
List of the most present terms in the corpus of patents

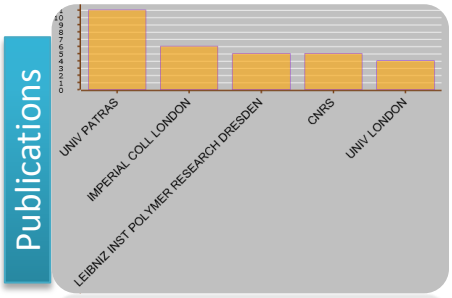
Top 10 and 5 of the major actors in patents and publications





Mitsubishi does not appear because we considered Mitsubishi Rayon and Mitsubishi Materials as being 2 different entities. However, the group Mitsubishi is leader for this application.





Focus on some major actors

MITSUBISHI

The Mitsubishi Groupis a japanise conglomerate consisting of a range of autonomous businesses which share the Mitsubishi brand, trademark and legacy.
It counts more than 200 companies, among which Mitsubishi Rayon and Mitsubishi Materials are very active in the field of CNT actuators.

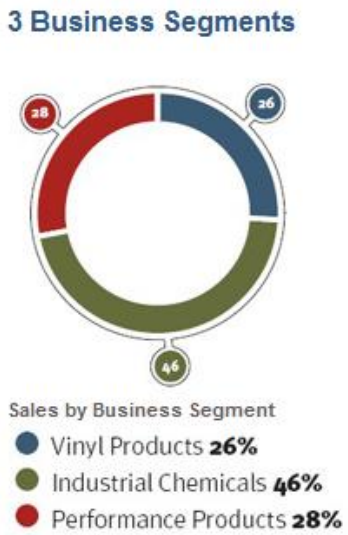
TORAY

Toray Group fuses nanotechnology into its operations, using organic synthetic chemistry, polymer chemistry and biotechniology as its core technologies. In addition to the Foundation Businesses of fibers & textiles and plastics & chemicals, Toray likewise promotes the global development of IT-related products, carbon fiber composite materials, pharmaceuticals and medical products, environment & engineering including water treatment and progress in other pivotal business fields.
Toray nanotech R&D is distinguished by the rigorous pursuit of nanotechnology and the integration of existing technologies with nanotech advances. The company uses this progress to take maximum advantage of dramatic performance improvements, the exhibition of new functions and other "nano effects" in rising to the challenges of "basic materials innovation" and "advanced materials and process design." There is a tendency for attention to concentrate on carbon nano-tubes and other "advanced materials and process creation" (with Toray naturally active in such R&D as well).

ARKEMA

R&D is a key component of Arkema's strategy, with approximately 1,400 researchers in six research and development centers in France, the United States and Japan. With an R&D budget in excess of 3% of revenue, Arkema is committed to research programs that produce ever more innovative, environmentally friendly and safe products, optimize our production plant performance and develop new processes.

Arkema has been named a winner of the 2007 Nano 50 Awards for the development of their controlled architecture polymers technology.



Synthetic nanometre sized delivery systems for therapeutic agents, and biologically active drug products, consist of at least two components, one of which is the active component.[1] Nanoparticle therapeutic systems are up to a million times larger than classical molecular drugs, giving rise to increasing complexity and diversity and scope for successful application against more challenging diseases. The increase in complexity furthermore enables a combination of the classical medical care disciplines of diagnosis, targeted delivery, and regenerative medicine into multi-tasking systems, such as 'theranostics'.

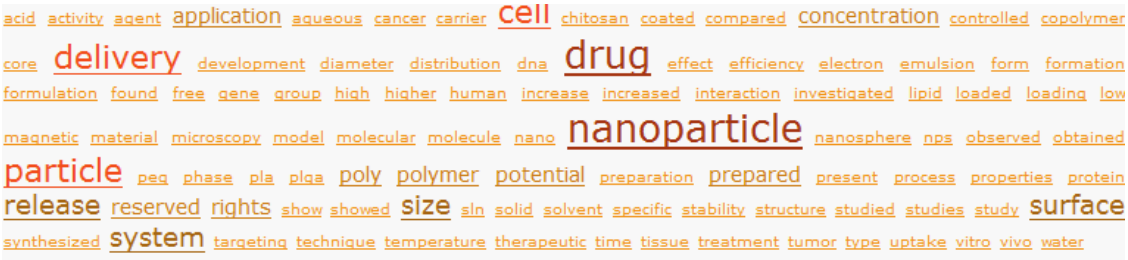
The field of nanoparticle drug deliver systems includes: [2]
•Vectors that will overcome the biological barriers:
-towards effective gene and protein delivery
-new routes of administration:oral, pulmonary, skin
•Cancer targeting
•Brain delivery (i.e. Tailored design to pass the blood-brain barrier)
•Combination of the potential of antibody targeting with nanoparticles and liposome technology

Many nanomedicine products are already commercialised, with the majority of innovations developed in the area of novel drug delivery tools (including new formulations of existing drugs, as well as entirely new drugs), of which most are based on liposomes and nanocrystals (and few others on virosomes, micells, polymers and resins). Many more nanomedicine products are in the pipeline with different lead times to market (i.e. under clinical trails Phase I, II and III).

One Market survey estimated the market for nanomedicine drug delivery products to be worth 5400 million UDS (at that time, the survey found 23 products on the market and 7 more in the pipeline), [3] while another conservatively evaluated the economic impact of nanoparticles in drug delivery products to be 1375 million USD in 2004 (2234 million USD in 2006), corresponding to a to a total market contribution of 0.25% in 2004. The latter survey predicted an increasing growth rate between 25% (in 2005) and 45% (in 2011) and a total market contribution of 1.36% in 2011. [4]

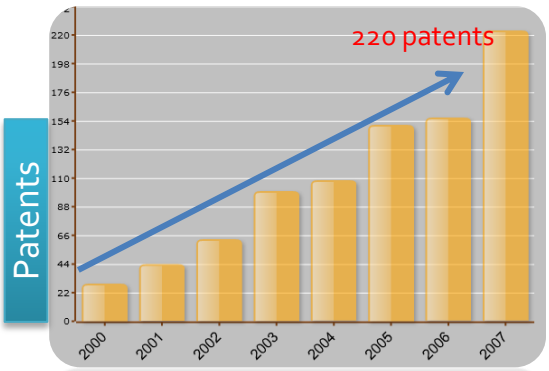
[1] ESF Forward Look on Nanomedicine2005
[2] Ruth Duncan, Presentation: 'Nanotechnology: Impact on Healthcare & Regulation'.
[3] VDI (20060: source: Zwexk et al. Nature Biotechs 2006.
[4] Visiongain 2006.

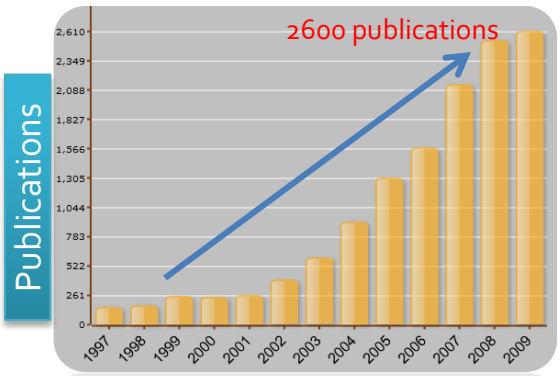
Nanoparticles for drug delivery



List of the most present terms in the corpus

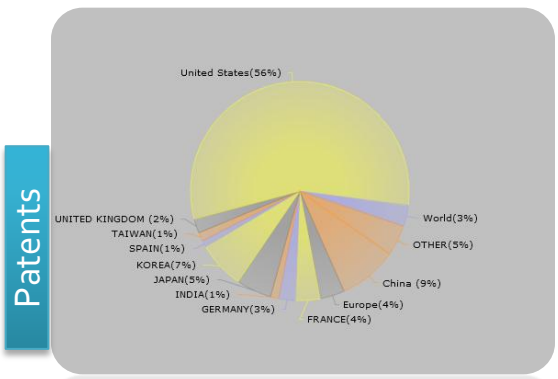
Timeline evolution of patent deposits and publication

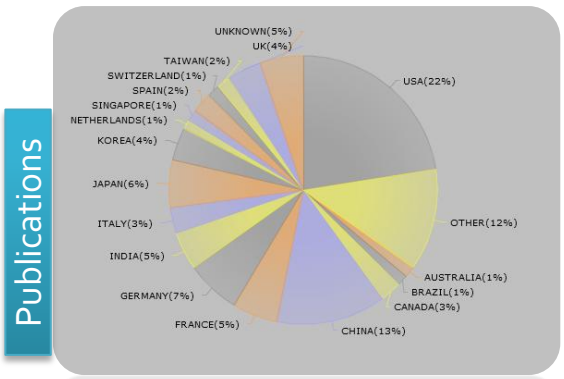




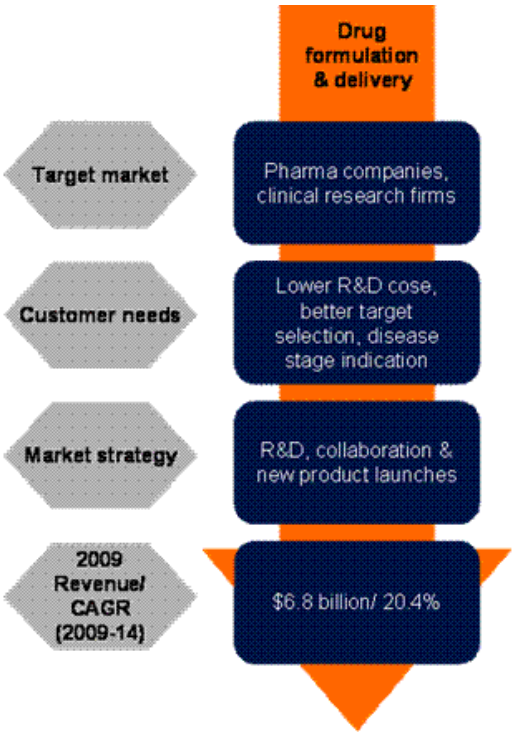
Patent deposits have been increasing steadily and strongly since 2000. We can notice a decrease in the publication activity since 2008. This application is therefore an application where the IP (patents) play an important role

Patent and publication repartitions from priority and organisation countries



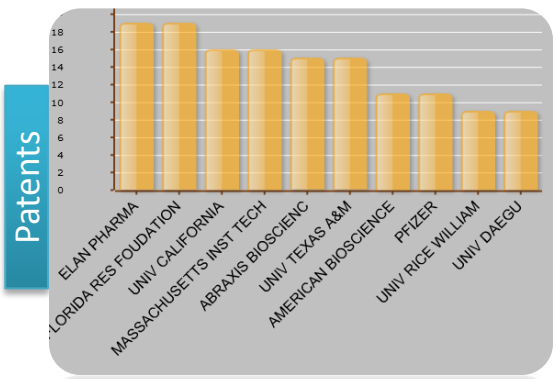


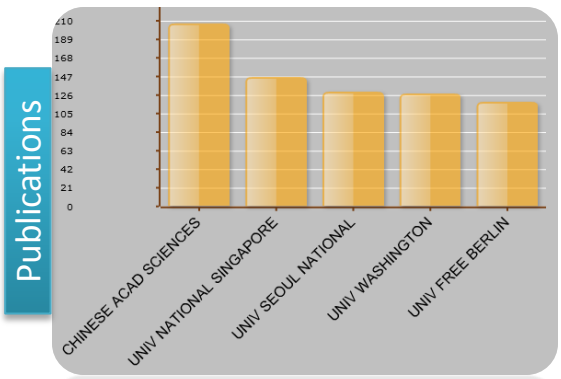
Patent deposits and publications are dominated by the US.
The US is the main player with 56 % of the patent deposits and 22 % of the publications!
China is the main player in Asia, with 9% of the patent deposits and 13% of the publications.
Germany and France are the two main european players with 3% and 4% of patent deposits respectively.



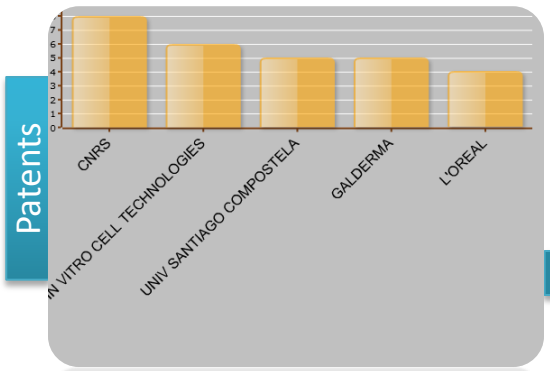
Source: Business Insight. Nanotechnology in Healthcare, January 2010

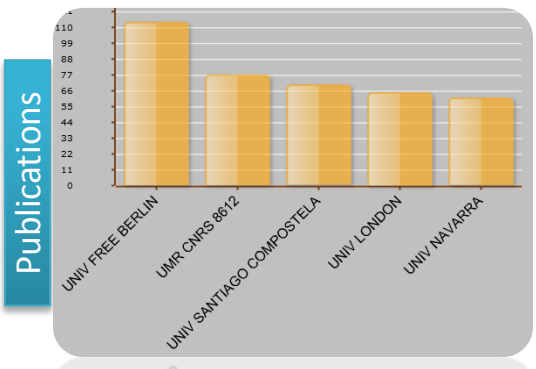
Top 10 and 5 of the major actors in patents and publications





We can see that the main actors are Pharma Companies, among them ELAN Pharma and PFIZER)



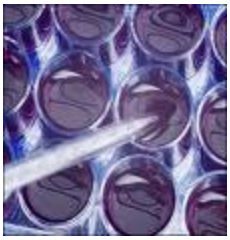


Focus on some major actors

ELAN PHARMA

Elan is a global pharmaceutical corporation. The company is present in the nanomedicine segment with its NanoCrystal technology. Its operations are divided into biopharmaceuticals (conducts research, development and commercial activities mainly in autoimmune, severe chronic pain, and neuroscience) and Elan Drug Technologies (concentrates on specialty pharmaceutical industry, inclusive of specialized drug manufacturing and delivery). Elan is mainly present in the US and Europe.

The company's NanoCrystal technology increases dissolution rate of paliperidone palmitate compound and enables formulating an aqueous suspension for once-a-month administration. This expertise can improve commercialization opportunities and is covered by foreign and US patents. It is a part of a suite of technologies, which the company's drug technologies division offers its third party clients.



In August 2009, Elan Drug Technologies got approval of a long-acting injectable formulation using NanoCrystal technology. According to Janssen (Ortho-McNeil-Janssen Pharmaceuticals' division) the US FDA approved INVEGA SUSTENNA, the once monthly atypical antipsychotic injection

In October 2007, Elan reported that Johnson & Johnson Pharmaceutical Research & Development, LLC submitted a new drug application to the FDA for paliperidone palmitate. Under the license agreement terms, Elan received payments once certain milestones were achieved and received royalty payments on the basis of sales of the injectable paliperidone palmitate formulation, when successfully commercialized.

PFIZER

Founded in 1849, Pfizer focuses on the research, development, manufacture and commercialization of pharmaceutical products related to therapeutic areas such as oncology, cardiovascular disease, urology and diabetes. Through subsidiaries, it operates in many countries across all continents.

In 2009, it claimed to have found that the aerosol delivery of fluticasone with nanosuspension was as efficient as intranasal dosing, and was able to achieve dose dependent lung deposition in asthma and chronic obstructive pulmonary disease.

In 2008, the University of Michigan (UM) Board of Regents approved the purchase of the Ann Arbor Pfizer property. UM will spend $108m to buy the 174-acre site.

Some new techniques are ways to measure quantitatively the interaction between proteins and other molecules including proteins. They can potentially revolutionise the field. Such approaches will probably be deployed on a micro or nano fluidics format and have come about because of the push to measure protein-protein contacts. They potentially offer a universal diagnostics platform.
The challenging question here is whether a new generation of molecular probes could be designed to trigger cellular metabolism and/or extra-cellular secretion of molecules that will be analysed, when circulating in the body fluids, with a better sensitivity, at lower cost, and with possible multi-parametric analysis.

The development of nanoscale sensors, either mechanical, or electrical or optical, and their integration info microscale devices offers enormous potential for cheap, POC diagnostic devices with high sensitivity. For example the integration of nanowires into transistor devices could deliver single event detection of target molecules bound to the wire. Other areas could include integrated optics for surface plasmon based sensing or patterned nano-crystal surfaces such as ZnO mats capable of providing electro-mechanical sensing of nanometre deflections driven by PicoNewton forces. The integration of unique sensing modalities arising from nanoscale manipulation of matter with mature, high volume, low-cost manufacturing common to the electronics and opto-electronics industries is envisaged to provide a route for nanotechnology from the lab to the patient.

There's a series of challenges associated with manufacturing and in particular low cost fabrication, which includes process optimisation, quality assessment, consistency and quality assurance. The challenge of going from lab scale prototypes to full manufacturing while still having to create an affordable solution is quite common. However, no strategies have been implemented and thus novel solutions have to be identified. Volume manufacturing should be seen as an essential part of the development of nanomedicine. As well as the issues of production at the nanoscale and the understanding of the surface chemistry issues, there is a need to develop macro technologies, such as printing, to enable the practical realisation of these devices on a human scale at reasonable costs with sufficient volume to meet demand.

Total market size for In Vitro Diagnostics

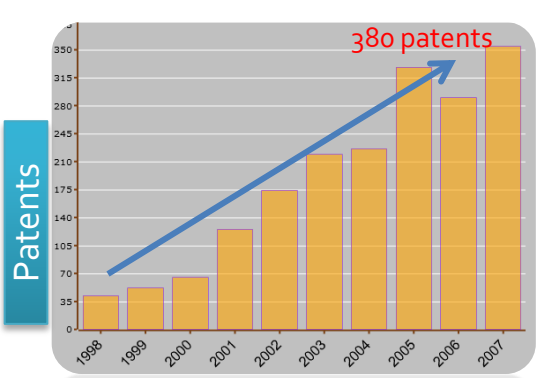
Market Size (M€)	2015	2020	2025
Hospital	200	700	1.500
Physician office (PoC)	-	1.000	1.500
Home	-	-	1.500

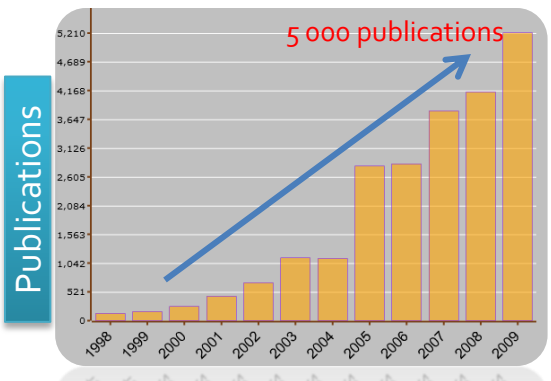
In vitro diagnostics markets are quite difficult to assess. In particular its evolution will heavily depend on regulatory decisions.
The trend towards POC diagnostics creates new societal, ethical and regulatory issues that will have to be addressed. The POC devices will not be an over-the-counter business but rather help and support doctors to diagnose or monitor patients and patients to monitor their treatment progress at home.
The movement of healthcare systems towards POC, especially its reimbursement policy will dramatically determine the emergence and growth of this industry.

Considering current market situation, United States and Europe dominate the global market for

medical biosensors, collectively capturing 70% share in 2008. The market in Asia-Pacific is projected to reach US$794 million by the year 2012. In medical diagnostics, majority of the biosensors (about 90%) are included in blood gas analyzers, electrolyte analyzers, glucose meters, and metabolite analyzers. Over half of the biosensors produced worldwide are employed in glucose meters. With a diabetes epidemic underway, there exists strong growth opportunities for diabetes management tools, such as glucose meters. The biosensors industry comprises of two types of participants including companies developing biosensor-based devices and developers of biosensor technology. Key players engaged in developing biosensor technology include AgaMatrix Inc., Cranfield Biotechnology Center, LifeSensors Inc., M-Biotech, and Nova Biomedical. Leading manufacturers of biosensor-based devices include - Abbott Point Of Care Inc., Affinity Sensors, Neosensors Limited, Siemens Healthcare Diagnostics Inc, Animas Corporation, LifeScan Inc., Medtronic Diabetes, and Roche Diagnostics Ltd.

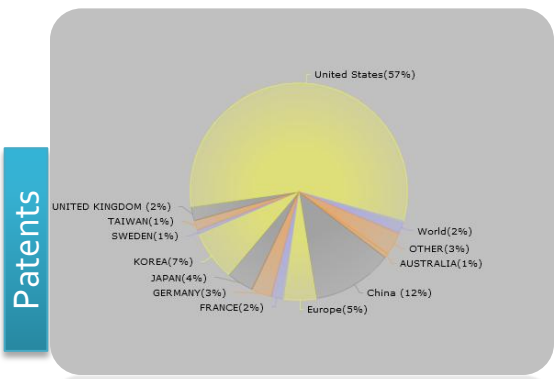
Timeline evolution of patent deposits and publication

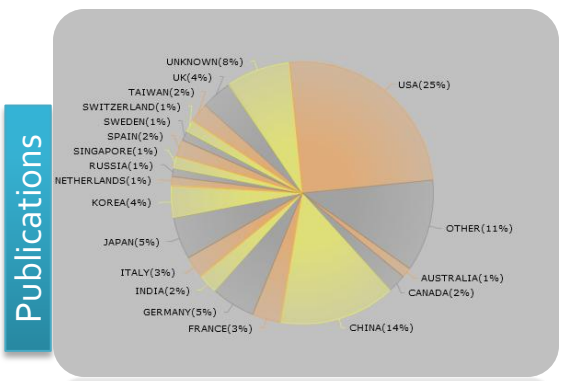




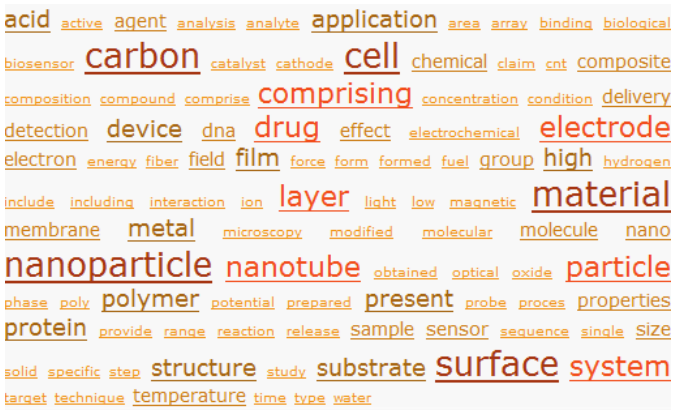
Patent deposits have been increasing steadily and strongly since 2000, which shows a big interest in this application. The range is broad, which explains the high number of publications.

Patent and publication repartitions from priority and organisation countries





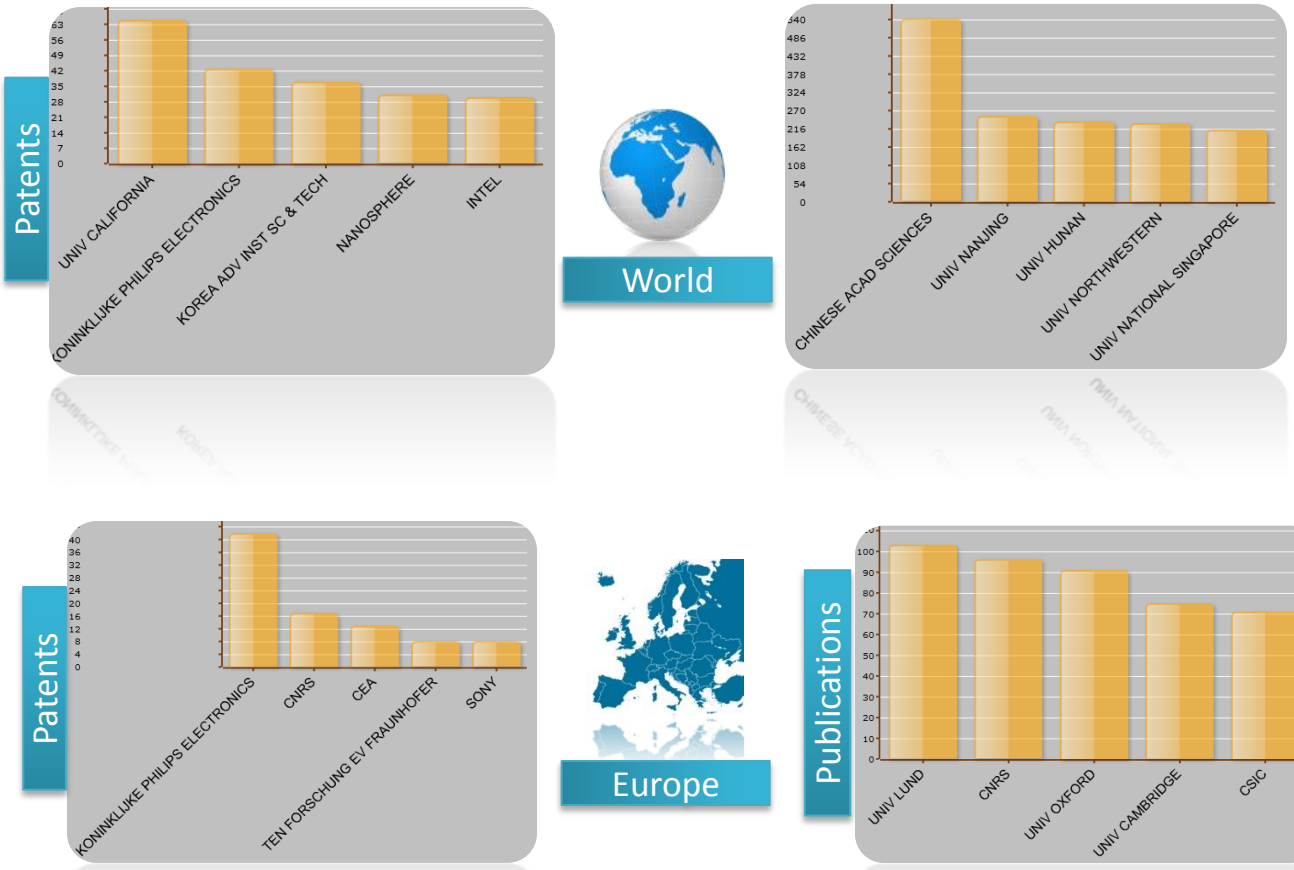
Patent deposits and publications are strongly dominated by the US, with 57% of the patent deposits!!. China is the main player in Asia, with 12% of the patent deposits and 14% of the publications. Europe accounts for about 15% of the patenting and publication activity.



List of the most present terms in the corpus

Source: Business Insight. Nanotechnology in Healthcare, January 2010

Top 10 and 5 of the major actors in patents and publications



Focus on some major actors

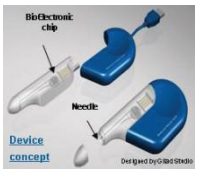
PHILIPS

Philips Research is one of the world's largest corporate research organizations. Philips Research investigates new biosensor technologies for bio-molecular diagnostics, aiming at reliable detection of extremely low concentrations (at the nano to femto-molar level), high speed (diagnostic result in minutes), and detection of biochemicals in raw biological samples (e.g. blood, saliva).

Its innovation is diverse, from open innovation to rupture innovation, through global demands

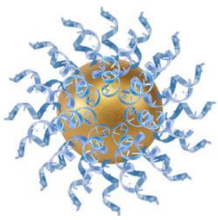
INTEL

INTEL is the worlwide leader in the microelectronic sector. It is positioning itself on the biosensors.
"We envision that by unlocking the synergies between silicon technology, molecular level sensing and biological systems, individual molecules from a tiny amount of a biological sample could be specifically detected and quantified using a silicon chip. These capabilities could potentially lead to powerful, cost effective tools for biomedical research and diagnostics and dramatically accelerate and enable personalized medicine. Using these tools, researchers could profile molecular variations, study efficacy of drug candidates or responses of biological systems to pollutants among other things."



NANOSPHERE INC

Nanosphere, Inc. is a nanotechnology-based healthcare company that was founded in 2000. Nanosphere's patent portfolio is comprised, on a worldwide basis of 80 issued patents and 150 pending patent applications, which, in either case, we own directly or for which we are the exclusive licensee.
Nanoparticles, as used in Nanosphere's Verigene® System and tests, are typically 13-20 nanometers (nm) in diameter. One nanometer is approximately one ten-thousandth (1/10,000) of the width of a human hair.



The electron and scanning probe microscopes market typically services the semiconductors and data storage industry, which in 2008 was worth approximately $178 billion. The market for electron and scanning probe microscopes for the semiconductors and date storage market was $793 million in 2008, growing to $1252 million by 2015.

Market drivers include increasing yields, increased demand for more sophisticated failure analysis techniques, increases in the complexity and performance level of devices used in electronic products, reduction of manufacturing costs, increased resolution, increasing device complexity and shrinking geometries.

Emerging markets for electron and scanning probe microscopes include bio-medicine and life sciences and nanotechnology and nanomaterials.

In the past, the development and broad application of instruments such as the scanning electron microscope (SEM), scanning probe microscope (SPM), and atomic force microscope (AFM) have opened up entirely new domains of knowledge – e.g., interpreting fracture, surface roughness, and adhesion at micron and submicron levels. To study features and phenomena at the nanoscale requires instruments capable of resolutions at the nano-, subnano-, and even picolevels.

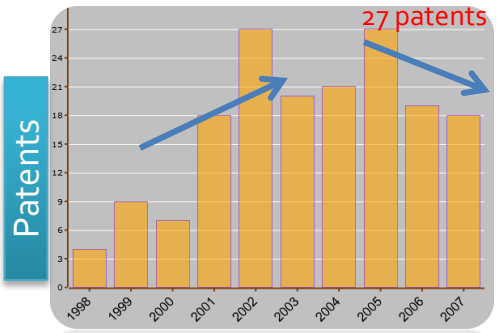
The challenge in nanomanufacturing will be not only to develop new experimental and analytical tools with a broader range of capabilities at the nanoscale (e.g., chemical analysis, surface and sub-surface defects, sub-surface properties, charge transport, spectroscopy), but these tools must also work in situ, real-time, non-intrusively or destructively, and under the variable conditions seen in processing (e.g., temperature, pressure, electrical and magnetic fields). As new instruments are developed, new methods of calibration and standardization and in concert, affordable calibration standards, must be developed to ensure the accurate interpretation of results. For calibration, measurement, and assembly, reproducible positioning and repositioning with nanometer accuracy is needed.

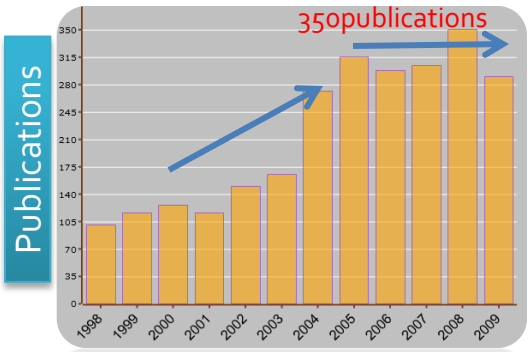
Biosample characterisation tools (SPM, NSOM)

There's growing demand for miniaturized non-invasive spectroscopic sensors, there have been many efforts to miniaturize optical spectrometers using various conventional technologies.

However they are not yet conducive to both dramatic miniaturization and also high spectral performance at low production cost.

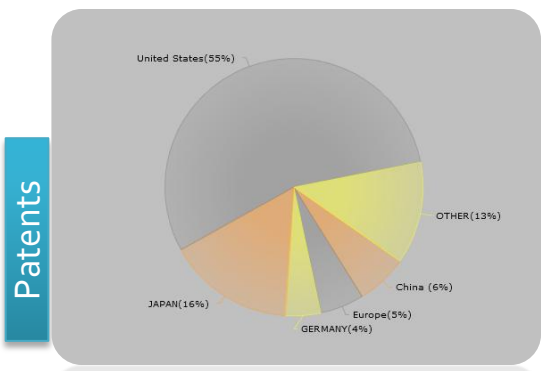
Timeline evolution of patent deposits and publication

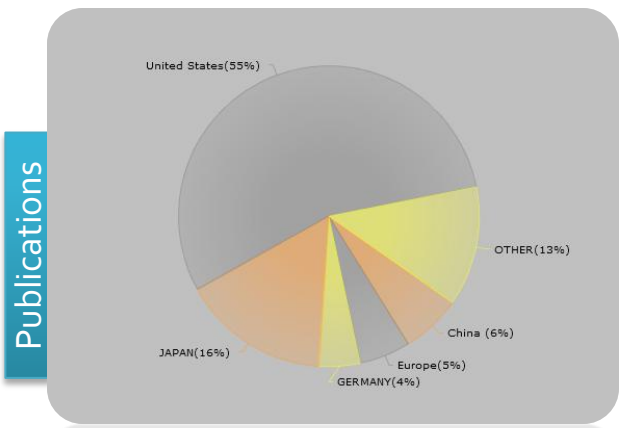




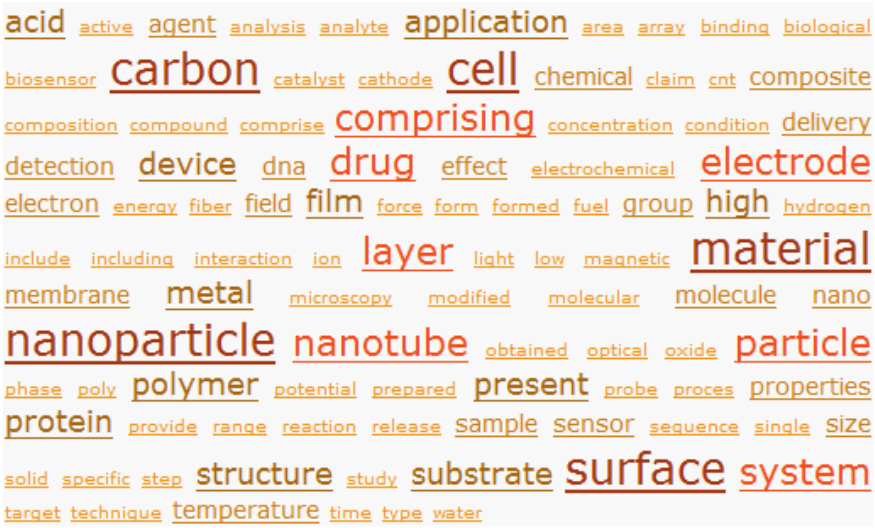
Patent deposits have been increasing slowly since 2000 and we notive a decrease in patent deposts since 2006. The same tendance is to be observed in the publications.

Patent and publication repartitions from priority and organisation countries





Patent deposits and publications are strongly dominated by the US, with 55% of the patent deposits!!. Japan is the main player in Asia, with 16% of the patent deposits and 16% of the publications. Germany is the European leader for this application.



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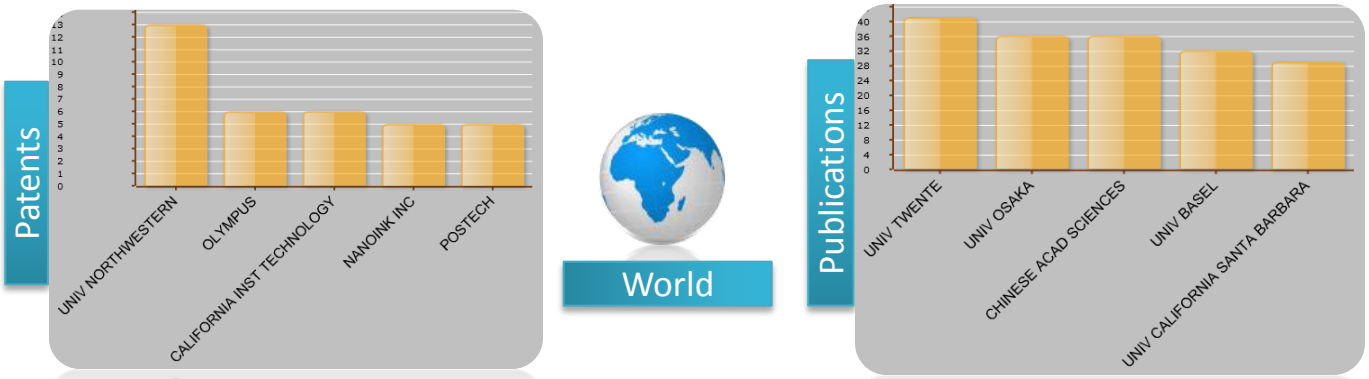
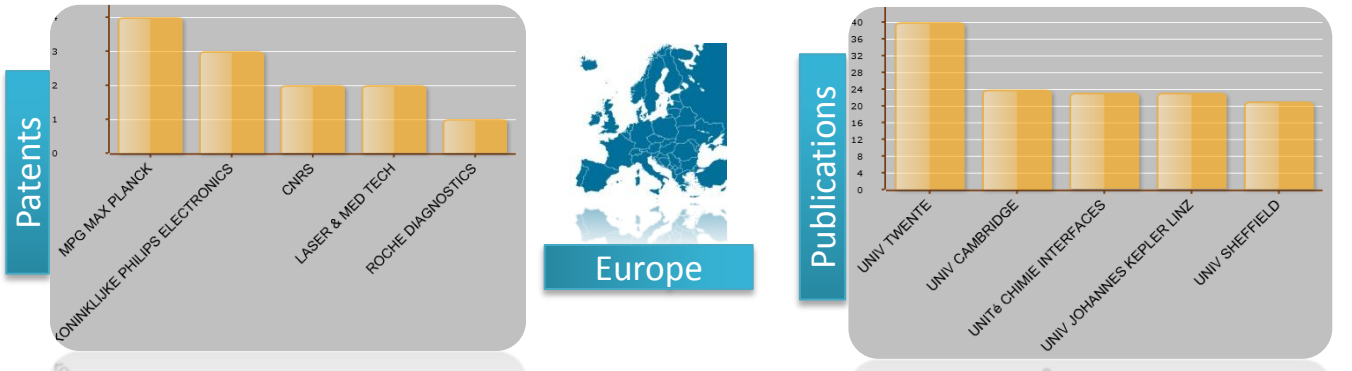




Biosample characterisation tools (SPM, NSOM)

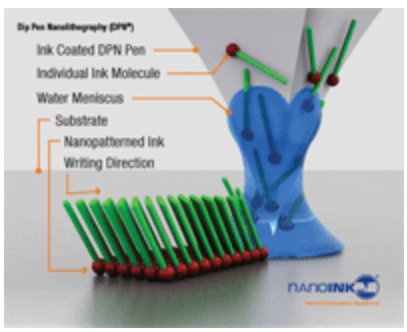
Focus on some major actors

OLYMPUS

Olympus was founded with the declared purpose of manufacturing microscopes that would garner recognition in the global market. The impetus for this drive was a deep sense of duty to help advance medical development through the domestic manufacture of microscopes.
Since then, Olympus confirmed its position as a camera manufacturer.
Olympus Corporation recently made a significant equity investment in AJ Industries (AJI) as a key part of its strategy to pursue nano-measurement markets in various industries. AJI is the leading innovator of micro and nano alignment and assembly, achieving cost-effective results in accuracy and speed. Olympus is partnering with AJI in the strategic development of technologies for nano/micro applications in the life sciences, medical devices and semiconductor industries.

NANOINK

NanoInk, Inc. is an emerging growth technology company specializing in nanometer-scale manufacturing and applications development for the life science and semiconductor industries. Using Dip Pen Nanolithography® (DPN®), a patented and proprietary nanofabrication technology, scientists are enabled to rapidly and easily create nanoscale structures from a wide variety of materials.
Dip Pen Nanolithography® (DPN) is an established method of nanofabrication in which materials are deposited onto a surface via a sharp probe tip. Molecules are transferred from the tip to the surface through a water meniscus which forms in ambient conditions as the tip nears the surface. DPN enables controlled deposition of a variety of nanoscale materials onto many different substrates



NORTHWESTERN UNIVERSITY

Northwestern University is a private institution founded in 1851 to serve the Northwest Territory (Ohio, Indiana, Illinois, Michigan, Wisconsin and parts of Minnesota). Total awards and grants for R&D represent approximately $477 million. Northwestern University has a long history of leadership in interdisciplinary research programs and centers. 27 University Research Centers and three research centers at Medical Affiliates support interdisciplinary research that spans a wide spectrum of areas:
-International Institute for Nanotechnology
-Nanoscale Science and Engineering Center
-Northwestern University Atomic and Nanoscale Characterization Experimental Center