Technology Insight Report

Aerogel Material

Patent iNSIGHT Pro
Transform Patents to Intelligence

Material sciences and technology have given us innovations ranging from silicon, polymers, float glass, carbon fiber, ceramics, optic fiber and so much more which has become a part of the world we live in. Nearly every discovery or innovation around a breakthrough material is usually followed by a big impact in the way things are made and the way we live. The invention of Aerogels although still relatively a recent innovation, with its unique properties is one that has so much future potential applications. With researchers and scientists still making incremental innovations around this fascinating new material, we thought it would be great to get some insights into the patent landscape of Aerogels and explore the promises it holds.

Overview

Introduction to Aerogels

Aerogel is a manufactured material with the lowest bulk density of any known porous solid. It is derived from a gel in which the liquid component of the gel has been replaced with a gas. The result is an extremely low-density solid with several remarkable properties, most notably its effectiveness as a thermal insulator. It is nicknamed frozen smoke, solid smoke, solid air or blue smoke due to its translucent nature and the way light scatters in the material; however, it feels like expanded polystyrene (styrofoam) to the touch.

Source: http://en.wikipedia.org/wiki/Aerogel

A Brief History

Aerogel was first created by Samuel Stephens Kistler in 1931, as a result of a bet with Charles Learned over who could replace the liquid in 'jellies' with gas without causing shrinkage.

Aerogels are produced by extracting the liquid component of a gel through supercritical drying. This allows the liquid to be slowly drawn off without causing the solid matrix in the gel to collapse from capillary action, as would happen with conventional evaporation. The first aerogels were produced from silica gels. Kistler's later work involved aerogels based on alumina, chromia and tin oxide. Carbon aerogels were first developed in the late 1980s.

In 1931, to develop the first aerogels, Kistler used a process known as supercritical drying. By increasing the temperature and pressure he forced the liquid into a supercritical fluid state where by dropping the pressure he could instantly gasify and remove the liquid inside the aerogel, avoiding damage to the delicate three-dimensional network. While this can be done with ethanol, the high temperatures and pressures lead to dangerous processing conditions. A safer, lower temperature and pressure method involves a solvent exchange. This is typically done by exchanging the ethanol for liquid acetone, allowing a better miscibility gradient, and then onto liquid carbon dioxide and then bringing the carbon dioxide above its critical point. A variant on this process involves the direct injection of supercritical carbon dioxide into the pressure vessel containing the aerogel. The end result of either process removes all liquid from the gel and replaces it with gas, without allowing the gel structure to collapse or lose volume.

Source: http://en.wikipedia.org/wiki/Aerogel

Aerogel Facts

Aerogels are the world's lightest solid materials, composed of up to 99.98% air by volume

Aerogels are a diverse class of amazing materials with properties unlike anything else

Transparent superinsulating silica aerogels exhibit the lowest thermal conductivity of any solid known.

Ultrahigh surface area carbon aerogels power today's fast-charging supercapacitors.

Ultrastrong, bendable x-aerogels are the lowest-density structural materials ever developed.

Source: http://www.aerogel.org

Types of Aerogel

The various compositions of aerogels include:

Silica Aerogel

Silica aerogel is the most common type of aerogel. It is a silica-based substance, derived from silica gel

Metal Oxide Aerogel

Metal oxide aerogels are important as they can act as catalysts for various chemical transformations, matrices for explosives, precursors for other materials (such as carbon nanotube catalysts). These aerogels exhibit a colorful properties depending on the oxide used to produce them.

Carbon Aerogel

Carbon aerogels are composed of particles with sizes in the nanometer range, covalently bonded together.

Silica, Alumina, Titania, Zirconia: Clear with Rayleigh scattering blue or white
Iron Oxide: Rust red or yellow, opaque
Chromia: Deep green or deep blue, opaque
Vandia: Olive green, opaque
Neodymium Oxide: Purple, transparent
Samarium Oxide: Yellow, transparent
Holmium Oxide, Erbium Oxide: Pink, transparent

Organic & Carbon Aerogels

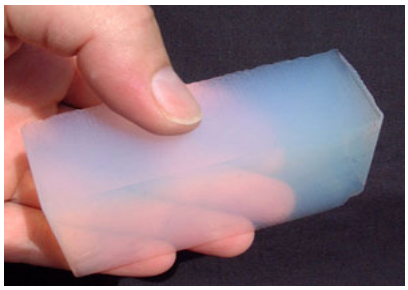
An organic aerogel is an aerogel with a framework primarily comprised of organic polymers. Organic aerogels are made from resorcinol formaldehyde, phenol formaldehyde, melamine formaldehyde, cresol formaldehyde, phenol furfuryl alcohol, polyacrylamides, polyacrylonitriles, polyacrylates, polycyanurates, polyfurfural alcohol, polyimides, polystyrenes, polyurethanes, polyvinyl alcohol dialdehyde, epoxies, agar agar, agarose,

Carbon aerogels are composed of particles with sizes in the nanometer range, covalently bonded together. They have very high porosity.

Alumina Aerogels

These aerogels are made with aluminium oxide and are used as catalysts, especially when "metal-doped" with another metal.

Snapshots of Aerogels



Source: http://www.aerogel.org

Source: http://en.wikipedia.org/wiki/Aerogel

Semiconducting Metal Chalcogenide Aerogels

Semiconducting metal chalcogenide aerogels possess a unique combination of porosity, optical translucency, and photoluminescence, and show great promise for use as chemical sensors and energy applications such as photovoltaics and extraction of hydrogen from water using sunlight as the energy source. They consist of a network of interconnected nanoparticles which form a sponge-like, open-celled, nanoporous framework.

Metal Aerogels

Metal aerogels combine the unique properties of metals with the unique properties of aerogels. They exhibit high specific surface areas and are electrically conductive.

Uses & Application of Aerogel

• Commercially, aerogels have been used in granular form to add insulation to skylights.

• Transparent silica aerogel would be very suitable as a thermal insulation material for windows, significantly limiting thermal losses of buildings. One research team has shown that producing aerogel in a weightless environment can produce particles with a more uniform size and reduce the Rayleigh scattering effect in silica aerogel, thus making the aerogel less blue and more transparent.

• Its high surface area leads to many applications, such as a chemical adsorber for cleaning up spills. This feature also gives it great potential as a catalyst or a catalyst carrier.

• Aerogel particles are also used as thickening agents in some paints and cosmetics.

• Aerogels are being tested for use in targets for the National Ignition Facility.

• Aerogel performance may be augmented for a specific application by the addition of dopants, reinforcing structures, and hybridizing compounds. Using this approach, the breadth of applications for the material class may be greatly increased.

• Commercial manufacture of aerogel 'blankets' began around the year 2000. An aerogel blanket is a composite of silica aerogel and fibrous reinforcement that turns the brittle aerogel into a durable, flexible material. The mechanical and thermal properties of the product may be varied based upon the choice of reinforcing fibers, the aerogel matrix, and opacification additives included in the composite.

• NASA used aerogel to trap space dust particles aboard the Stardust spacecraft. The particles vaporize on impact with solids and pass through gases, but can be trapped in aerogels. NASA also used aerogel for thermal insulation of the Mars Rover and space suits.

• The US Navy is evaluating aerogel undergarments as passive thermal protection for divers.

• Aerogels are also used in particle physics as radiators in Cherenkov effect detectors. ACC system of the Belle detector, used in the Belle Experiment at KEKB, is a recent example of such use. The suitability of aerogels is determined by their low index of refraction, filling the gap between gases and liquids, and their transparency and solid state, making them easier to use than cryogenic liquids or compressed gases. Their low mass is also advantageous for space missions.

Aerogel Jewelry

While traditionally valuable jewelry has been made of the material and elements which are rare in nature, aerogel has found its way into this segment. Aerogem, a jewelry design brand has created a line of aerogel pendants. Marketing it as “Fortune Magazine’s Technology To Watch” and claiming aerogels are rarer than diamonds the material could become a future fashion statement.

Image source:
http://www.aerogem.com/

Aerogel Toothpaste

Aerogels are known to have been used as a thixotropic agent in cosmetics and toothpaste. This goes to show other than its light weight and thermal insulation properties, other physical aspects of aerogel will bring out newer applications for this material as research

• Resorcinol-formaldehyde aerogels (polymers chemically similar to phenol formaldehyde resins) are mostly used as precursors for manufacture of carbon aerogels, or when an organic insulator with large surface is desired. They come as high-density material, with surface area about 600 m^2/g.

• The first residential use of aerogel as an insulator is in the Georgia Institute of Technology's Solar Decathlon House where it is used as an insulator in the semi-transparent roof.

• Metal-aerogel nanocomposites can be prepared by impregnating the hydrogel with solution containing ions of the suitable noble or transition metals. The impregnated hydrogel is then irradiated with gamma rays, leading to precipitation of nanoparticles of the metal. Such composites can be used as catalysts, sensors, electromagnetic shielding, and in waste disposal. A prospective use of platinum-on-carbon catalysts is in fuel cells.

•Aerogel can be used as a drug delivery system due to its biocompatibility. Due to its high surface area and porous structure, drugs can be adsorbed from supercritical CO2. The release rate of the drugs can be tailored based on the properties of aerogel.

• Dunlop has recently incorporated aerogel into the mold of its new series of tennis racquets, and has previously used it in squash racquets.

• Carbon aerogels are used in the construction of small electrochemical double layer supercapacitors. Due to the high surface area of the aerogel, these capacitors can be 1/2000th to 1/5000th the size of similarly rated electrolytic capacitors. Aerogel supercapacitors can have a very low impedance compared to normal supercapacitors and can absorb or produce very high peak currents. At present, such capacitors are polarity-sensitive and need to be wired in series if a working voltage of greater than about 2.75V is needed.

• Chalcogels have shown promise in absorbing the heavy metal pollutants mercury, lead, and cadmium from water.

• Aerogel is used to introduce disorder into superfluid helium-3.

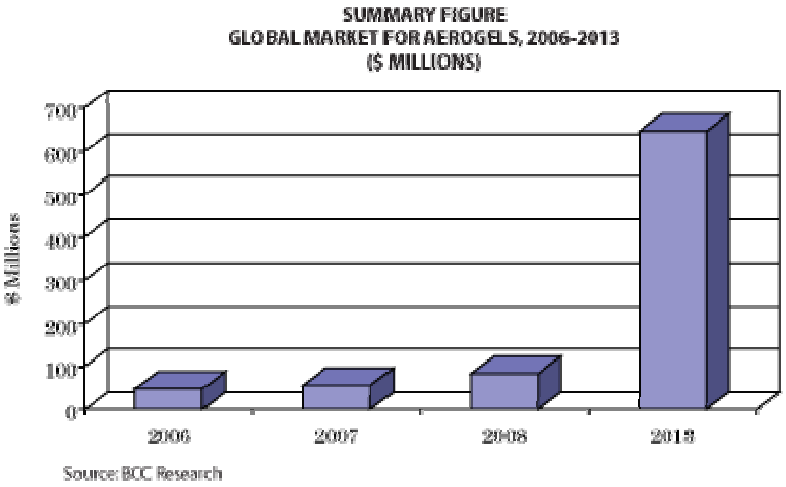
• Arms control experts speculate it is used to transform radiation into pressure in multistage nuclear weapons.

Source: http://en.wikipedia.org/wiki/Aerogel

around it continues.

The Market for Aerogels

With its unique properties of being extremely lightweight, a great thermal insulator and given the vast applications already discovered for this material type, the potential markets for aerogels look promising. According to Electronics.ca research network, the market for aerogels by 2013 is estimated to be $646.3 million with a compound annual growth rate of 50.8%.



Source: http://www.electronics.ca/presscenter/articles/1086/1/Global-Market-for-Aerogels-worth-6463-Million-in-2013/Page1.html

A number of industries have shown active interest in the material and applications have been extend to the automotive, oil and gas, constructions, cryogenics, shipping and other industries.

With new applications being discovered and innovation activity around the development of aerogels still at a high, the production and demand for various types of aerogels will continue to be strong. The current high production costs associated with manufacturing aerogels makes it expensive often costing up to $1000 per ounce. However, this hasn't appeared to have deterred demand and as with most new materials, we can perhaps expect costs to come down later in the life cycle.

Aerogel Insulation Panels

Aerogel insulation panels which can be used in construction are a huge advance in the materials space. With its exceptional ability to insulate and retain temperatures within a space the consequences on greener construction technologies is very significant. The impact of using aerogel panels to insulate builds can be lower energy costs in heating and cooling spaces within and with the search for greener more environmentally friendly materials for construction and the current emphasis on environmental changes, aerogels can be an important part of the future.

Homes with Aerogel Insulation

Image source:
http://solar.gatech.edu

Patent iNSIGHT Pro
Transform Patents to Intelligence

Aerogels – Patent Analysis

Insight Overview

Aerogels may not be a very new discovery but it's one that is gathering momentum more recently in the field of material sciences and one that is still actively being researched with incremental innovation around it happening very actively. Here are a few basic insights into this technology based on patent filings, patent texts, citations and other patent data using the Patent iNSIGHT Pro software.

The Search Strategy

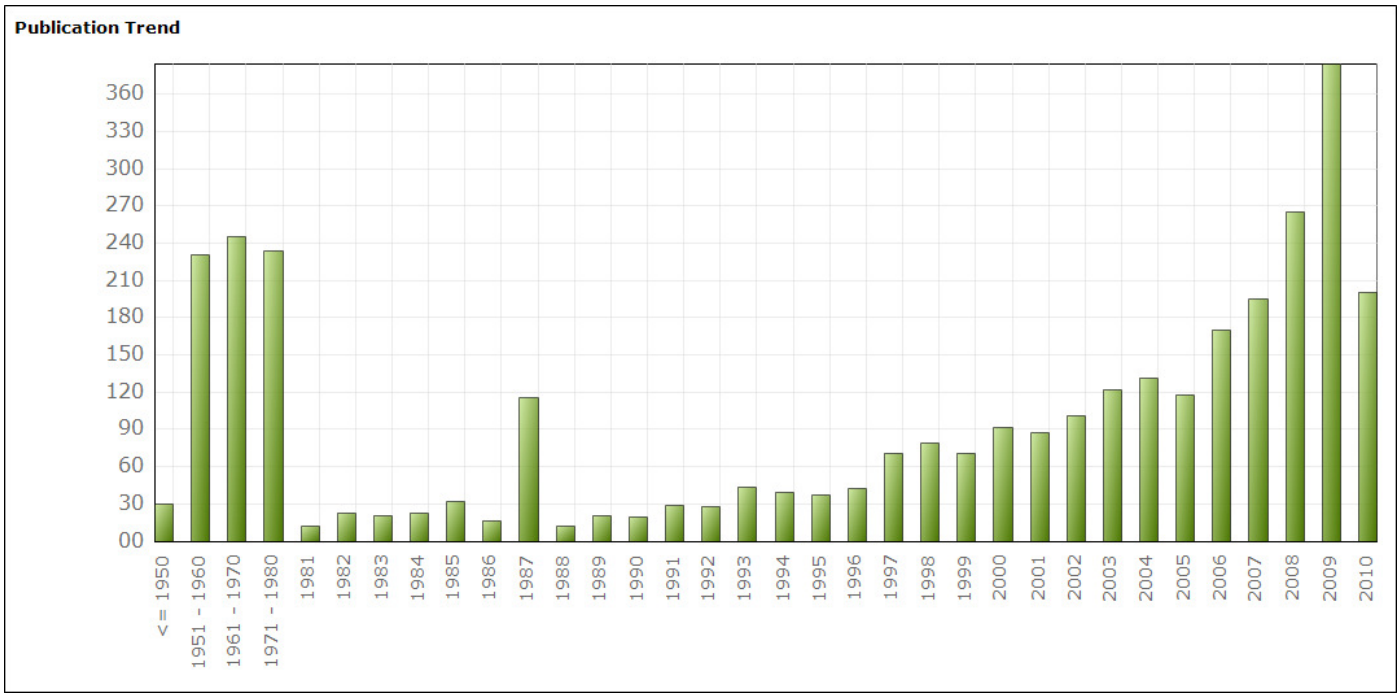
The first step is to create and define a patent set that will serve as the basis of our analysis. Innovations around "Aerogels" have been made primarily in the areas of "Types", "Features" and "Properties". To provide a better insight into the trends within each of these elements, the patent records for aerogels are further classified as per their T3 classifications as listed below:

Using the commercial patent database, PatBase as our data source, we used the following search queries to create our patent set:
(TAC=(AeroGel or aerojell or areogel or aerojel or aerojell or airojell or aero-gel or "aero gel" or airgel or aerogel*)or xerogel* or (seagel* or (agar* and aerogel*)) or (chalcogel* or (chalcogen* and aerogel*))))

The query was directed to search through the full text and a patent set of 3360 records with one publication per family was generated.

Publication Trend

What has been the IP publication trend for Aerogels?



Going by the patent publication trend, the first few decades from the early 1950's right till the late 90's saw consistent activity around the innovation of aerogels with an average of about 20-30 patents published each year. From the year 2000 onwards, the publications started to rise rapidly from about 80 published in 2000 to over 400 last year in 2009. The last 5 years have been the most remarkable clearly displaying just how significant aerogels can be for the future.

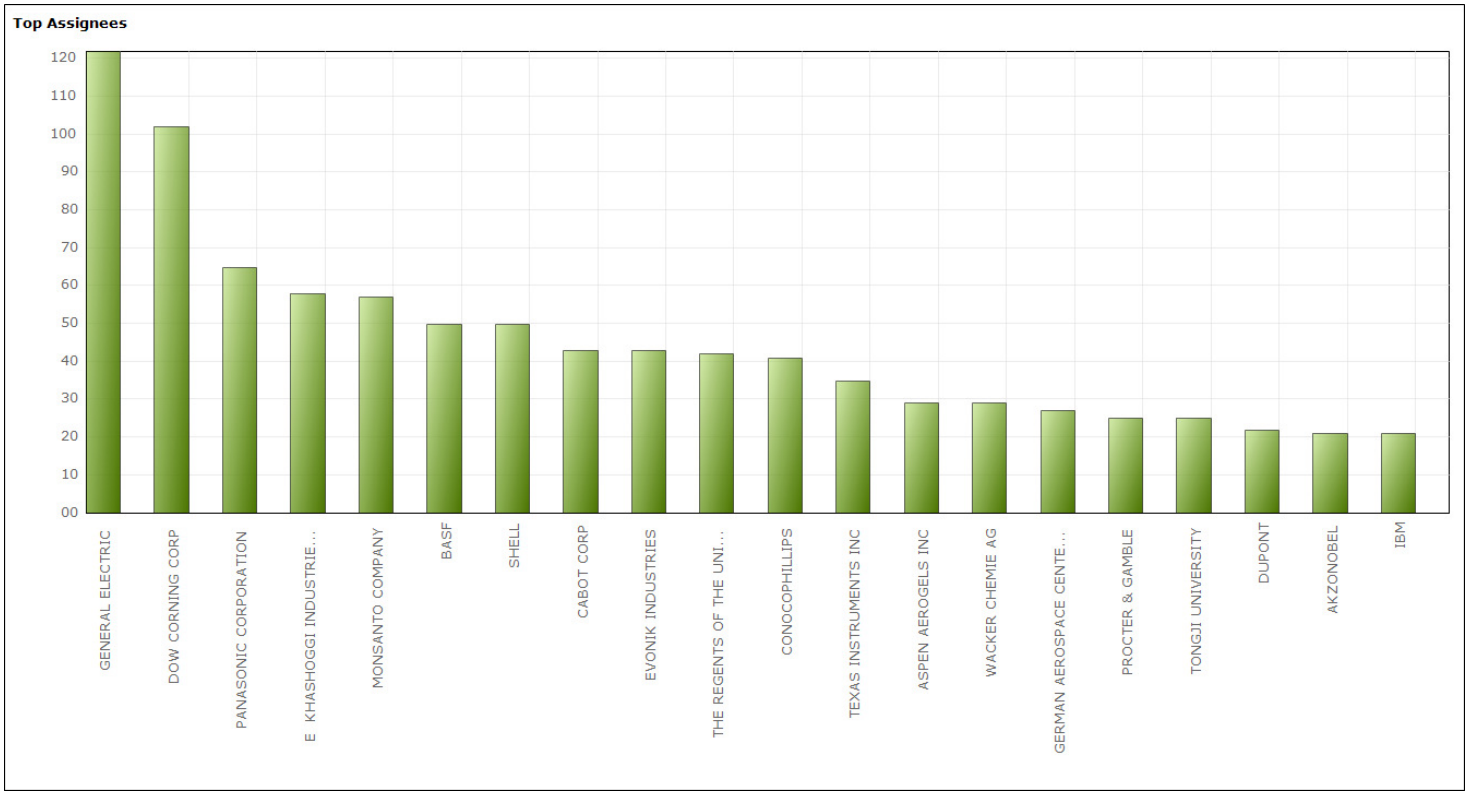
How we did it?

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

Note: For the purpose of this IP publication trend, the classification of the records into the 3 areas for Aerogels was removed so the trend displays IP activity for all filings for Aerogels in general.

Top Assignees

Who have been the top assignees or the key players for Aerogels?



How we did it?

Using the dashboard tool in Patent iNSIGHT Pro the top 20 assignees were listed.

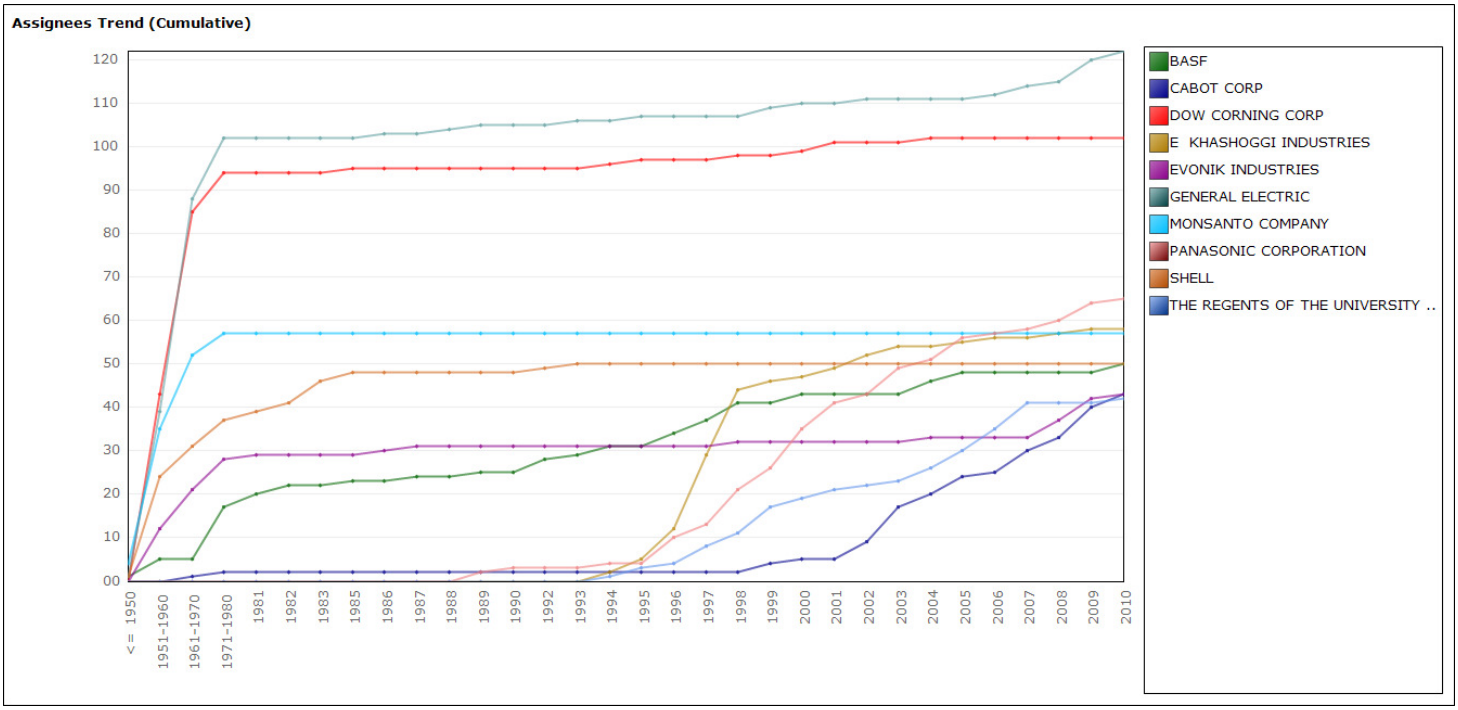
While from marketing or product launches one can assume a certain manufacturer is the number one player for a certain type of technology, it could be misleading. Patent portfolios are a more accurate indicator of how much a business invests in a particular technology such as touch and gives a better picture of who the top assignees in this space are. The top 20 assignees by patents awarded include:

1. General Electric
2. Dow Corning Corp
3. Panasonic Corporation
4. E. Khashoggi Industries
5. Monsanto Company
6. Shell
7. BASF
8. Cabot Corp
9. Evonik Industries
10. ConocoPhillips
11. The Regents of The University Of California
12. Texas Instruments
13. Aspen Aerogels Inc
14. Wacker Chemie AG

15. German Aerospace Center
16. Proctor & Gamble
17. Tongji University
18. Akzonobel
19. DuPont
20. IBM

Click on link below to download the full list of top Assignees:
http://www.patentinsightpro.com/techreports/0610/Top_Assignees.xls

Assignees Trend



Considering cumulative patent filings and publication trends regardless of the T3 classifications, General Electric has the most remarkable figures for IP publications for Aerogels.

To look beyond overall IP holdings related to aerogels however, one needs to look into the three areas of types, features and properties and observe the directions these assignees have pursued with respect to these classifications.

How we did it?

Once the patents were populated in Patent iNSIGHT Pro, the assignee clean-up tools were used

- 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 normalize the assignee names and merge assignees that resulted from a merger or acquisition or name change. ***Please refer Appendix A for more details on merging.***

Properties of materials containing Aerogels

One of the key uses of aerogels is that it is used along with certain other components to manufacture materials having desired properties such as

- Adsorbents
- Dielectric
- Diffusion controllers
- Electric conductors
- Electric insulators
- Ferroelectric
- Piezoelectric
- Semiconductors

Here we have analyzed which type of aerogel and what features of these aerogel when combined together gives us the resulting material with desired above mentioned properties. The various features of aerogels taken into consideration are

- Density
- Environmental resistance
- High compression strength
- High resilience and flexibility
- Thermal conductivity
- Thermal stability

Finally, the different types of aerogels are Alumina Aerogels, Cadmium Selenide, Carbon Aerogels, Carbon Nanotube, Chalcogel or Chalcogenide Aerogels, Chromia- Chromium(III) Oxide, Clay Aerogels, Seagel, Silica Aerogels and Tin Oxide Aerogels.

For this analysis, we created patent buckets for the above mentioned types, features and properties. For creating these buckets we used Patent iNSIGHT Pro's cluster engine. Each patent bucket comprised patents resulting from automatically generated clusters in combination with patents resulting from natural language processing and keyword based searching. Once the buckets were created, we mapped 'types' vs 'features' to identify the various combinations that can lead us to developing materials of the desired properties. The matrices can be seen in the image below:

Feature (Column) / Type (Row)	Thermal Conductivity	Density	Thermal Stability	High Compression Strength	High Resilience and Flexibility	Environmental Resistance
Tin Oxide Aerogels	37	46	13	21	23	2
Silica Aerogels	33	34	14	18	22	
Alumina Aerogels	20	21	2	16	17	1
Seagel	20	20				
Carbon Aerogels	6	18				
Clay Aerogels	13	12				
Carbon Nanotube	5	6				
Chalcogel or Chalcogenide Aerogels	5	1				
Chromia-Chromium(III) Oxide Aerogels	2	2				

Dielectric

Features (Column) / Type (Row)	High Compression Strength	Thermal Stability	Thermal Conductivity	High Resilience and Flexibility	Density	Environmental Resistance
Tin Oxide Aerogels	1	7	6	1	10	1
Silica Aerogels	3	8	7	4	6	
Carbon Aerogels	1	2	1	1	7	
Alumina Aerogels	1					
Carbon Nanotube	1					
Seagel	1					
Chromia-Chromium(III)	1					

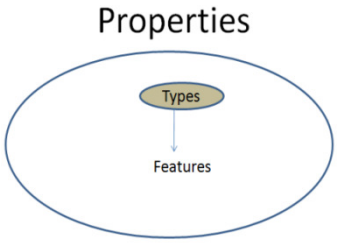
Electric Conductor

Features (Columns) / Types (Rows)	High Resilience and Flexibility	Thermal Conductivity	Density	Thermal Stability	High Compression Strength
Tin Oxide Aerogels	2	7	14	2	2
Silica Aerogels	10	4	8	5	1
Carbon Aerogels		3	9	1	1
Carbon Nanotube	2	5	6		

Electric Insulator

The numbers in the matrices are the number of patents and by clicking on these numbers one can read the patents behind them. This kind of an analysis can help various companies understand to what extent a particular technology has matured and if there is any further scope of innovation. This analysis also helps one to locate whitespace in a technology area. The insights from the analysis can directly influence technology managers' decision to conduct research in poorly patent protected technology areas to eventually become market leaders in that space.

Please click on the icon below to view maps showcasing combinations of types of aerogels and their features and how such categorization can lead us to development of materials of the desired properties.



http://www.patentinsightpro.com/techreports/0610/Aerogel_Properties.pptx

For example from the maps in the presentation one could infer that in order to develop materials with piezo-electric properties, one can use either silica or carbon or tin oxide aerogels having features such as thermal conductivity, density and high resilience and flexibility.

Appendix A: Assignee Normalization

GENERAL ELECTRIC
GENERAL ELECTRIC

DOW CORNING CORP
DOW CORNING CORP

PANASONIC CORPORATION
PANASONIC CORPORATION, ZEON CORP, OTANI NATL DENKI KK

E KHASHOGGI INDUSTRIES
E KHASHOGGI INDUSTRIES

BASF
BASF

EVONIK INDUSTRIES
EVONIK INDUSTRIES, NICOLAY STEPHAN, SEILER MATTHIAS

ASPEN AEROGELS INC
ASPEN AEROGELS INC, GOULD GEORGE, LEE JE KYUN, RHINE WENDELL EUGENE, EMEK NURTEN ESER, MUTHUKUMARAN POONGUNRAN, GOULD GEORGE L, OU DUAN LI, STEPANIAN CHRISTOPHERE JOHN, ZAGHI SHAHROOZ, ABELES JON C, EVANS OWEN R, NEBO JON F, RHINE WENDELL E, TOMICH AARON R

WACKER CHEMIE AG
WACKER CHEMIE AG

CABOT CORP
CABOT CORP, NEW JERSEY INSTITUTE OF TECHNOLOGY

Summary

The discovery of aerogels marks an important moment in the field of material sciences. The extreme light weight properties and thermal properties make it a marvel among new age materials and set it in a unique space as an important innovation for not just the present but the future as well. The patent data shows a very keen interest around aerogels developing over the last few years and continuing to grow at a very rapid pace after a somewhat slower start during the first few decades. A number of applications have been discovered over time with new ones still emerging and the projected market figures for aerogels are evidence of the underlying financial potential for this breakthrough material. Aerogels will be part of our future.

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 180 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.

Gridlogics is headquartered in Pune, India and has a sales presence in Delhi, Mumbai and USA.

For more information:

Visit us at: www.patentinsightpro.com
Or call us at: 1-408-786-5524
Or mail us at: contact@patentinsightpro.com

References

- *http://en.wikipedia.org/wiki/Aerogel*
- *http://www.aerogel.org*
- http://www.aerogem.com/
- *http://www.electronics.ca/presscenter/articles/1086/1/Global-Market-for-Aerogels-worth-6463-Million-in-2013/Page1.html*
- *http://www.marketresearch.com/map/prod/2612999.html*
- http://solar.gatech.edu