View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by International Institute for Science, Technology and Education (IISTE): E-Journals

Chemical and Process Engineering Research
ISSN 2224-7467 (Paper) ISSN 2225-0913 (Online)
Vol.9, 2013
www.iiste.org

AEROGEL – A Promising Building Material for Sustainable Buildings

Anjali Acharya[1*] Deepa Joshi [2] Vasudha A Gokhale [3]

1. Institute for Excellence in Higher Education Bhopal M.P. India
2. Institute for Excellence in Higher Education Bhopal M.P. India.
3. B.N. College of Architecture,Pune,India.

anjaliacharya2007@rediffmail.com

Abstract

The sustainable buildings can be defined as efficient buildings from the point of view of maintenance and operation costs, and of which value increases in time, through positive impact on the natural and social environment. The aim of rendering buildings sustainable can be achieved only by the production of new advanced materials, and by using them, especially at the glass surfaces, for more resistant envelopes at different external actions which may increase considerably the durability period of a building and may increase the energy efficiency through a high level thermal insulation. This paper, aims to explore the possibility of the use of Aerogels as a building material with reference to its chemical, physical characteristics and performance. The paper presents also an analytical application demonstrates that it is supposed to be an expensive method initially but is more advantageous, considering the low costs afterwards, mainly, because of reduced energy consumption. It talks about chemical adaptation of Aerogels for optical applications, chemical adaptation of Aerogels to thermal insulation and its various applications in Building Industry.

Keywords: aerogel, sustainable building,, thermal insulation, life cycle costs

1. Introduction

Aerogels are coherent, porous solids made by the formation of a colloidal gel followed by removal of the liquid from within the pores of the gel. They are usually of very low density, can he made in large pieces (monolithic structure), and can also be transparent. Aerogels had little practical value until 1974, when Cantin et al. reported on the use of silica aerogels as detectors in Cerenkov radiation. All materials that can be synthesized as wet gels by the sol-gel process can be dried by the supercritical method to obtain aerogels. New properties based upon the very open texture of these materials make them outstanding for some applications. Iinorganic gels, that is to say mostly oxides, independent solid colloidal particles (i.e., nano-particles with a size below a micrometer) are often formed, in a first step of the process. Each colloidal particle has a more or less densely cross linked internal structure. It is usually easy to maintain such particles in a dispersed state in the solvent, in which case a colloidal suspension also termed a sol is obtained. In th e second step, these colloidal particles can be made to link with each other, while they are still in the solvent, so as to build a three-dimensional open grid, termed a gel . The transformation of a sol to a gel constitutes the gelation process, and the gels which are obtained are then termed colloidal gels. On the other hand, it is also quite possible to directly

form some gels from rather linear polymer formed occurrence of individual particles. When this occurs, the gels are termed polymeric gels.

1.1 Historical Background

Aerogel was created by Steven Kistler in 1931 and it has become a material of interest to scientists in recent decades due to its light weight. Aerogel is a synthetic porous ultra light material derived from a gel, in which the liquid component of the gel has been replaced with a gas. It is an advanced material which holds 15 entries in the Guinness Book of Records for properties such as lowest density solid and best insulator. It is a silica-based substance, consisting of a loose dendritic network of the atom silicon.

1.2 Production of Aerogels: Preparation : Aerogels can be prepared by using Alumina, Chromium, Tin oxide and Carbon. But apart from these materials used for making of aerogel, silica based aerogel is preparation is easier and reliable.

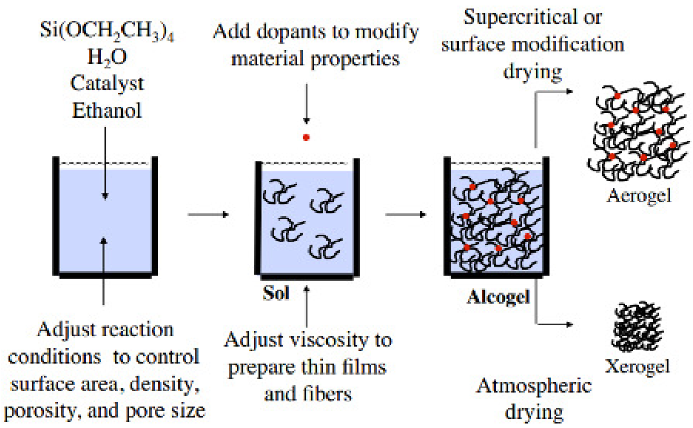

Figure. 1. Aerogel preparation method

4 to 30 times more water is added to Tetraethylorthosilicate (TEOS) in the presence of ethanol it leads to the further chemical reaction

Si (OCH2CH3) 4 (liq.) + 2(H2O) (liq.) → SiO2 (solid) + 4(HOCH2CH3) (liq.)

Final product density is mainly depends on the concentration of silicon alkoxide monomers in the solution. After gelification, the gel is left undisturbed in the solvent for 48 hours to complete the reaction. Once reaction will complete the alcogel product will form. Inorganic aerogels can be prepared via sol-gel processing, a technique which requires alcoxides or metal salts in alcoholic or aqueous solutions. The alcogel is then submitted to supercritical drying. The final products formed in this reaction are:

- Aerogel
- Xerogel

After mixing, a dispersion of colloidal particles is generated (hydrolysis and condensation polymerisation) which form a three-dimensional network (gelation). The particle size depends on the catalyst and varies between nanometer and micrometer scale. After the gelation process the enclosed pore liquid has to be carefully removed to preserve the nanostructure of the aerogel

2. Cellulosic aerogels

Aerogels, materials with extreme porosity and very low bulk density, can be made using the so called 'Critical Point Drying'- technique.In a recent study aerogels were prepared from cellulose, xylan, lignin, their mixtures and from spruce wood. The procedure was:

- Dissolution of the lignocellulose material in an ionic liquid.
- Creating a hydrogel by precipitating the dissolved polymeric material with aqueous ethanol.
- Exchanging the aqueous precipitant to pure ethanol.
- Exchanging ethanol to liquid carbon dioxide.
- Increasing the temperature to above the Tc of carbon dioxide .
- Releasing the pressure slowly to obtaing the aerogel material.

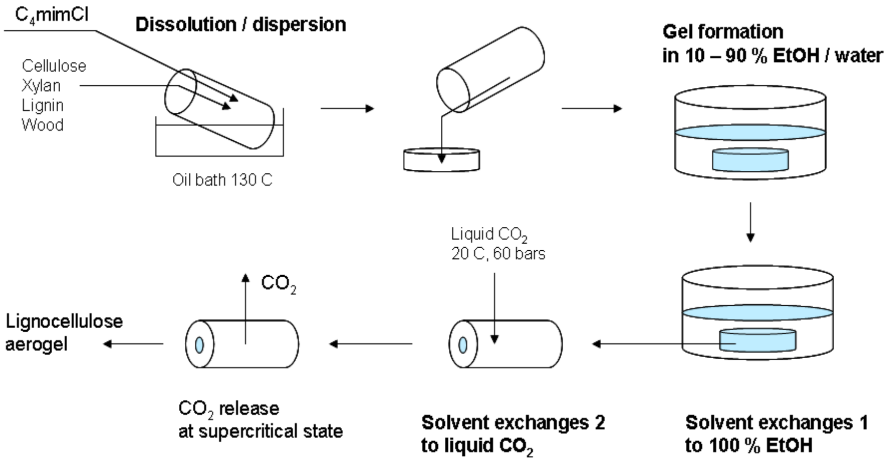

Figure 2. lignocelulose Aerogel.

2.1 Carbon aerogels:

- Carbon aerogels provide high specific surface areas combined with a fully tunable three-dimensional structure.
- They have tunable performance for specific applications by the addition of dopants that can enhance the electrical, thermal, and mechanical properties of the composite material.
- They are excellent thermal insulators because their gaseous components greatly reduces heat transfer by conduction, convection, and radiation.
- They improve electric double-layer super capacitors—very low impedance compared to conventional supe rcapacitors, yet can absorb or produce very high peak currents.

3 Potential Applications

- Energy storage in batteries and super capacitors are an ideal use of carbon aerogels. Tunable porosities can be used to minimize diffusion resistance while maintaining constant surface area.
- Hydrogen generated from water by solar energy, and electric energy from sustainable sources, are anticipated fuels of the future. These technologies incorporate CAs as functional nano materials.
- CAs as nano catalysts can assist in electro-catalysis as electrode materials and by providing catalyst support in proton-exchange-membrane fuel cells.
- CAs offer considerable potential to significantly improve desalination efficiency through a technique known as capacitive deionization. This can increase the world's fresh water supply through capacitive desalination of sea water and brackish water.
- CAs are extremely "black" in the infrared, making them efficient in solar-energy collectors.

4. Properties of Aerogel : They possesses following properties:

- Low thermal conductivity
- Hardness
- Heat resistance
- Transparency
- Elasticity
- Insulation

- Durability
- Flexibility

The aerogels made from pure cellulose, cellulose-lignin or -xylane mixtures or from spruce wood had open pore structures and were brittle. The aerogels had bulk densities as low as 25 g / litre and BET areas up to 500 m2/ g. The preparation of Lignocellulosic Aerogels from Ionic Liquid Solutions, Carbohydrate Polymers.

5. Chemical Adaptation of Aerogels for Optical Applications

Silica aerogels are extremely porous materials which can be made transparent. Optical applications depend on their homogeneity. A second type of application is that silica aerogels can entrap all kinds of molecules or dopants with special fluorescent properties. A third group of applications combines both properties of transparency and thermal insulation and was described in the previous section. Aerogels in Cherenkov Counters: Low-refractive-index silica aerogel constitutes a convenient medium for the Cherenkov counters, which are used for electrically charged particle identification in high-energy physics experiments. This is, also, tied to a major problem of cosmology, which requires the identification of anti-matter and matter particles in the cosmic rays. The principle of Cherenkov counters rests on the fact that electrically charged elementary particles, which travel across the radiator medium with a velocity “v” higher than the velocity of light “c” in this medium, they emit a light. An analysis of this light can therefore be used to derive the velocity of a particle and hence its nature.

5.1 Luminescent Arogels : Photoluminescent materials based on silica aerogels can be made by encapsulation of various photoluminescent dopants during the gelation process.

Electrical Applications

- Batteries
- Capacitor Electrodes
- Dielectric Materials
- Piezoelectric Materials

Aerogels as Additives or Encapsulation Medium

Chemical Applications

Aerogel particles can be used as filler of other materials, to provide them with some hardness, resistance to wear, or some thickening characteristics. Aerogels can be used as carriers of diverse components, for instance pigments. In pharmacy and agriculture, where many applications require a progressive release of active agents, aerogel particles can operate as nanovessels to carry substances as diverse as fungicides, herbicides, pesticides.

Silica Aerogels for Nuclear Waste Storage

Silica aerogels are chemically very stable with time on stream and possess a very large porous volume per cm3. They can easily be converted into vitreous silica after a low temperature (at about 1000 °C) and short heat treatment.

Mechanical Applications

A distinctive characteristic of silica aerogels is that they are extremely light, brittle materials, yet sufficiently strong to be handled. Their compressive strength, tensile strength, and elastic modulus are very low, and they largely depend on the network connectedness and aerogel density. Indeed, as previously mentioned, a gel can however be aged in alkoxide solutions to chemically stiffen its network, especially the necks between colloidal particles. Aerogels for Inertial Confinement Fusion (ICF) Borate, organic, and carbon aerogels were used for some time in inertial confinement fusion experiments

(ICF) as target microspheres containing the fuel.193 These aerogels were stable to radiation and could be wetted by deuterium and tritium.

Application of Aerogels in Catalysis

Sol-gels have characteristics which make them good materials for applications in catalysis,. Catalytic reactions can be of the redox or of the acid-base type.

6. Use of Aerogel for Sustainable Building Construction.

Roof : Aerogel insulation can insulate roof cavities or be used to reduce thermal bridging in roof rafters. It can be used for highly insulated homes that are sealed from the outside, both over masonry and under shingles and it has high insulatin value. In ood frame homes, thin strips of aerogel can be applied

to studs to prevent what's called thermal bridging, where heat escapes through the walls' framing.
Aspen provides this chart for for the R-value-philes (Spaceloft being Aspen's brand name for their building insulation aerogel):

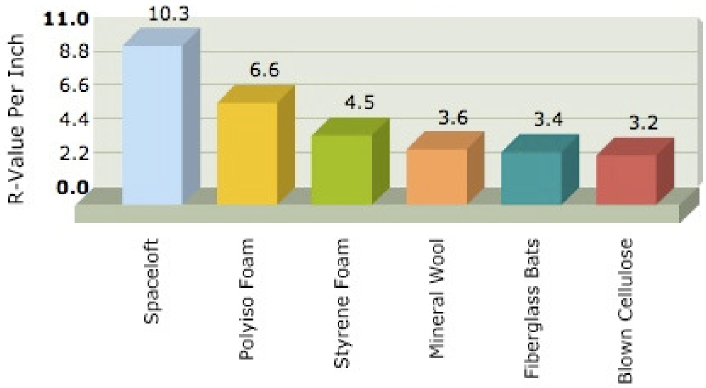

Figure 3. R-value of Aerogel.

Framing : In a typical building, the framing (25% of the building envelope) is un-insulated, resulting in heat loss through the studs. The insulation stops this "thermal bridging" and improves thermal performance up to 40% in steel studs and up to 15% in wood studs.

The development of the super insulating glazing would lead to significant energy savings in both existing and new residential and commercial buildings. The light transmittance and U-value of aerogel-glazed windows, ~40% and 0.85 W/m2K, respectively, present new opportunities for the use of day lighting in buildings and the architectural design of building façades. In addition to glazing, aerogels have also been used in solar collector covers.

Floor : Aerogel insulation's thermal efficiency, good compression strength, and thin profile make it attractive as an under floor insulating layer where height is an issue. It installs fast in under floor applications without disrupting door fittings, while providing substantial energy savings. Aerogel insulation is a fast, cost-effective solution for basement renovations, easy to install, improves thermal comfort, and does not disrupt door fittings because it is so thin. It installs quickly and can improve the thermal comfort of a house. If used with radiant floors it saves energy and enables a fast heating cycle.

Aerogel as a Super-insulator: Aerogel is a transparent material with interesting optical properties, such as high light and solar transmittance but, differently from the normally used transparent materials such as glass, it has also very good thermal insulation properties; it is in fact used as transparent wall in solar collectors and in office buildings. Aerogel is available as panes and as granules. Glazing systems with monolithic aerogel are not yet used in mass production , but during the year 2005 many types of translucent granular aerogel appeared on the market for day lighting systems . The different systems found in the Literature polycarbonate panels, structural panels, insulated glasses) are able to offer excellent thermal performance, high quality of the diffused light, a good solar heat gain and good sound insulation characteristics. One of the most important examples of aerogel uses to date is the application of silica aerogels as super insulation. An inch-thick pane of a low-density silica aerogel is as effective of an insulator as a stack of 30 panes of window glass, and thanks in part to this impressive insulating ability, the electronics on the twin Mars Exploration Rovers have managed to survive the extreme thermal cycling experienced on Mars (from -140°C to 20°C) well beyond design lifetime. Aspen Aerogels has even recently commercialized a family of super-insulating blankets based on silica aerogel for terrestrial use. One major advantage to silica aerogel as a terrestrial thermal insulation is the enhanced energy efficiency it can bring to industrial plants. Energy-intensive refineries, for example, predominantly use mineral wool as an insulating medium. Silica aerogel materials are now poised to displace mineral wool as a superior insulation in the next decade, resulting in greater efficiency that translates into reduced emissions in what amounts to 15% of all industrial CO_2 emissions in the United States. Furthermore, unlike polyurethane and polystyrene insulations, no chlorofluorocarbon (CFC) blowing agents are required to manufacture aerogel insulation.

7. Highly energy-efficient windows:

In addition to the low thermal conductivity of silica aerogel, a high solar energy and daylight transmittance is achieved. In fact, by using the passive solar energy through windows, it is possible to reduce the annual energy consumption for space-heating in cold climates, such as in the northern European Countries or in highlands. Double-pane windows, sealed sandwiches of glass with rarefied gas like Ar or Kr trapped inside, are a way to address this problem, however lose their insulating ability over the course of about 10 years. It has been proposed that silica aerogel, which is usually transparent, could be a revolutionary window insulation material. Unfortunately, due to nanostructural variations in the aerogel's substructure, silica aerogels Rayleigh scatter the short wavelengths of visible light, which makes them appear blue. For practical commercial applications in windows, this effect would need to be significantly reduced, and in order to do so, a better understanding of the origins of these nano-structural variations and how to control them must be established.

8.Conclusion:

The unique properties of aerogels offer many new applications in buildings. The extraordinary low thermal insulation and optical transparency of aerogels allow its applications in window panes and solar collector covers. Due to their low thermal conductivity and acoustic property for noise abatement, aerogels could be used in buildings, as well as for adsorption and catalysis in indoor air purification, photocatalysis in environmental clean-up, non-combustibility (inorganic aerogels) in fire retardation boards in kitchens. Aerogel materials may also be applied to a building's walls, attics, grounds and appliances. The unusual properties of aerogels open the way to a new range of opportunities for their application in buildings. Their main benefits include excellent insulating properties provide energy and cost savings due to reduced loss of heated or conditioned indoor air, healthier indoor environment due to removal of airborne contaminants, heat- and sound-retarding properties due to the non-combustibility and acoustic properties of the aerogel. Above all they are user-friendly, recyclable and reusable.

References:

ASPEN. www.aerogel.com (25 September 2011, date last accessed).

Baetens R, Jelle BP, Gustavsen A. Aerogel insulation for building applications: a state-of-the-art review. Energy Build 2011;43:761-9. doi:10.1016/j.enbuild.2010.12.012.

CIBSE Guide F: Energy Efficiency in Buildings, (2004). Chartered Institution of Building Services Engineers London.

Fesmire JE, Sass JP, . Aerogel insulation applications for liquid hydrogen launch vehicle tanks. Cryogenics 2008;48:223-31. doi:10.1016/j.cryogenics.2008.03.014.

Fesmire JE, . Aerogel insulation systems for space launch applications. Cryogenics 2006;46:111-7. doi:10.1016/j.cryogenics.2005.11.007.

Hrubesh LW, Poco JF . Thin aerogel films for optical, thermal, acoustic and electronic applications. J Non-Cryst Solids 1995;188:46-53. doi:10.1016/0022-3093(95)00028-3.

Hrubesh LW, . Aerogel applications. J Non-Cryst Solids 1998;225:335-42. doi:10.1016/S0022-3093(98)00135-5.

Jones SM, . Aerogel: space exploration applications. J Sol-Gel Sci Technol (2006);40:351-7. doi:10.1007/s10971-006-7762-7.

LBL. eetd.lbl.gov/ecs/aerogels/sa-physical.html (25 September 2011, date last accessed).

Moreno-Castilla C, Maldonado-Hodar FJ, . Carbon aerogels for catalysis applications: an overview. Carbon 2005;43:455-65. doi:10.1016/j.carbon.2004.10.022.

Pierre AC, Pajonk GM, . Chemistry of aerogels and their applications. Chem Rev 2002;102:4243-65. doi:10.1021/cr0101306.

Schmidt M, Schwertfeger F, . Applications for silica aerogel products. J Non-Crystal Solids 1998;225:364-8. doi:10.1016/S0022-3093(98)00054-4.

This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE's homepage: http://www.iiste.org

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There's no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a **fast** manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar