An Analysis on Synthesizing Techniques of Aerogel and its Applications

Akshat Mohite[1] Akhilesh Desai[2]

[1,2]*Dept. of Mechanical Engineering, A.P. Shah Institute of technology, Maharashtra, India*

Abstract- *In this paper the current techniques for synthesizing aerogel and its applications are reviewed in which the fillers are supercritical CO2. In this paper we have tried to provide the synthesizing techniques with a computational overview. Aerogel which is also called as frozen smoke was first created by Samuel Stephan kister in 1931. It is a material which is produced by extracting liquid components of a gel through the process of supercritical drying whose process and significance is mentioned in this paper. The application of aerogel along with its properties are mentioned below in a tabular form systematically arranged. This paper also reveals the use of aerogel as a sensors. Aerogel can be positively used as a sensors due to its high surface active sites and high porous density. The aerogel nearly consist of 99.8% of air as a constituent which allows it to become one of the lightest solid on this planet. This technology was used by NASA to trap dust particles in space it was observed that the particles vaporizes on impact with solid and pass through gases. NASA also used this technology for thermal insulation of mars rover not only this but this light weight solid can be used in wetsuits, fire-fighter suits, rockets and much more. Because of its unique structure it almost entirely counteracts the three methods of heat transfer: convection, conduction and radiation. Aerogel was in earlier days quite hard to synthesize, but it was achieved by replacing supercritical alcohol with supercritical carbon dioxide. These changes reduced the time spent on drying the aerogels and also reduced the hazardous and flammable nature of their production. From earth to space this frozen smoke technology has undoubtedly have a place in our future. The below paper gives us the idea of how the above technology can be used by achieving its maximum efficiency.*

Keywords- **Aerogel, silica aerogel, Synthesis, aerogel applications.**

1. Introduction

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 [1,2] Silica aerogels have drawn a lot of interest in the technological field because of their low bulk density (up to 95% of their volume is air), hydrophobicity, low thermal conductivity, high surface area. Aerogels are synthesized from molecular precursors by sol-gel processing. however, recently developed methods allow removal of the liquid at atmospheric pressure after chemical modification of the inner surface of the gels, leaving only a porous silica network filled with air.

Therefore, by considering the surprising properties of aerogels, the present review addresses synthesis of silica aerogels by the sol-gel method, as well as drying techniques and applications in current industrial development and scientific research. Aerogel is currently manufactured synthetically. It is a porus and ultra- light material derived from a gel in which the liquid part of the gel has been replaced by gas[1]. The result of replacing the liquid part of the gel with gas results in a extremely low density[3] solid with low thermal conductivity. Aerogels are currently produced by supercritical drying process. This allows the liquid to be slowly dried off without causing the solid matrix in the gel to collapse from capillary action. The first aerogels were produced from silica gels[4]. In last few years of extensive research aerogel has promising applications in chemical absorber, imaging device, optics, light guides, aerogel blankets, matchers for transducers, thermal protection for navy divers[5]. In this document various aspects of aerogel synthesis are viewed along with their commercial and industrial applications specifically as super capacitor electrodes.

2. Aerogel Synthesis-

The synthesis of Aerogel can be divided in 3 parts

1. Gel preparation –The silica gel is obtained by sol–gel process. The sol is prepared by a silica source solution and by addition of catalyst, gelation is occurred. The gels are usually classified according to the dispersion medium used, e.g., hydrogel or aquagel, alcogel and aerogel (for water, alcohol, and air, respectively).

2. Aging of the gel - The gel prepared in the first step is aged in its mother solution. This aging process strengthens the gel, so that shrinkage during the drying step is kept to a minimum.[5,6]

3. Drying of the gel - In this step, the gel should be freed of the pore liquid. To prevent the collapse of the gel structure drying is made to take place under special conditions.[6,7]

All methods of aerogel production involve these three general steps. Additional procedures can also be undertaken in order to influence the final product structure. There are, currently, a variety of methods for silica aerogel synthesis which will be reviewed and discussed in the following sections. In 1931, to develop the first aerogels, Kistler used a process known as supercritical drying which avoids a direct phase change.

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 initial aqueous pore liquid for a CO2-miscible liquid such as ethanol or acetone, 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 exchanges the initial liquid from the gel with carbon dioxide, without allowing the gel structure to collapse or lose volume[7].

3. chemistry of sol- gel process-

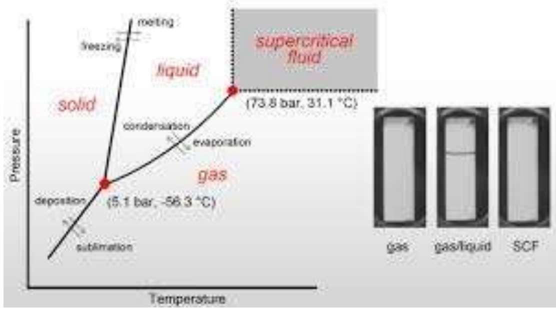
It is a process of producing solid material from small molecules. there are several methods which are able to influence the two major processes i.e the hydrolysis and condensation reactions (sol-gel process) they also include the activity of metal alkoxide, the water/alkoxide ratio ,solution ph , tempeature and nature of solvent .

particularily speaking about this process, a "sol" which is a collidial solution is formed which gradually evolves towards the formation of gel-like diphasic system containing both liquid and solid phase. But in order to procure the final result it is important to separate the phases, this separation of phases is done either by accelerating with help of centrifugation or by simple process of sedimentation which the substance does it by itself.

4. Supercritical Drying:-

This process is widely referred to as critical point drying. To eliminate the capillary forces, gels are dried at critical points. We could observe a concave menisci which evaporation continues, compressive forces build around the perimeter of the pores and it contracts. Eventually the surface tension cause the collapse of the gel body. This method is considered as most important step of aerogel production since it enables preservation of three-dimensional pore structure and also leads to unique structure properties of aerogel which are high porosity, low density and large surface area. Presented. Moreover, the current challenges and some perspectives for the development of high-performance aerogel-based sensors are summarized.

Listed below are some major uses of aerogel as a sensors:



Hence the method of drying of the aerogel is referred as "supercritical drying".

5. Aerogel Properties and Application-

Aerogels have some unique properties which makes them attractive in science and technology, as given in Table 1. Due to these unique properties, aerogels are used for various applications as mentioned in Table 2, and some recent applications are as briefly discussed below.

5.1. Applications:

Property	**Value**
Apparent density	0.03-0.35 g/cm^3
Internal surface area	600-1000m^2/g
Percentage of solid	0.13-0.15%
Mean pore dia.	~20nm
Primary particle diameter.	2-5nm
Refractive index	1.0-1.08
Coeff. Of thermal expansion.	2.0-4.0 x 10^6
Dielectric constant	~1.1
Sound velocity	100m/s

6. Aerogel as sensors-

Field of study	Applications
Chemistry	(i)Catalyst (ii)Adsorbents (iii)Nano Vessels (iv)Extracting agents
electronics	(i)Sensors (ii)Insulators
insulation	(i)Thermal (ii)Acoustics
agriculture	(i)Carrier materials
fillers	(i)Paints (ii)Varnishes (iii)Functional liquids
kinetic energy absorbers	(i)Shock absorption (ii)Tank baffle

Aerogels are unique solid-state materials composed of interconnected 3D solid networks and a large number of air-filled pores. They extend the structural characteristics as well as physicochemical properties of nanoscale building blocks to macroscale, and integrate typical characteristics of aerogels, such as high porosity, large surface area, and low density, with specific properties of the various constituents. These features endow aerogels with high sensitivity, high selectivity, and fast response and recovery for sensing materials in sensors such as gas sensors, biosensors and strain and pressure sensors, among others. Considerable research efforts in recent years have been devoted to the development of aerogel-based sensors and encouraging accomplishments have been achieved. Herein, ground breaking advances in the preparation, classification, and physicochemical properties of aerogel and their sensing applications are :-

6.1 Aerogel as Catalysts-

The high surface area of aerogels leads to many applications, such as a chemical absorber for cleaning up spills. This feature also gives it a great potential as a catalyst or a catalyst carrier[10]. Aerogels aid in heterogeneous catalysis, when the reactants are either in gas or liquid phase. They are characterized by very high surface area per unit mass, high porosity which makes them a very attractive option for catalysis. Some of the reactions catalysed by aerogels are listed below:

1. Synthesis of nitrile from hydrocarbons using nitric oxide (NO). Isobutene can be converted into meth acrylonitrile by reacting it with NO on zinc oxide aerogel.
2. Synthesis of methanol from CO using copper zirconia aerogel[11].

6.2 Aerogel as a thermal insulator:

Apart from high porosity and low-density one of the most fascinating properties of aerogels is their very low thermal conductivity. Aerogels possess a very small thermal conductivity, ~1–10% that of a solid, additionally, they consist of very small particles linked in a 3-dimensional network with many “dead-ends”. Therefore, thermal transport through the solid portion of an aerogel occurs through a very tortuous path and is not particularly effective. The space not occupied by solids in an aerogel is normally filled with air (or another gas) unless the material is sealed under vacuum. These gases can also transport thermal energy through the aerogel. The pores of aerogel are open and allow the passage of gas (albeit with difficulty) through the material.

6.3 In Housing, Refrigerators, Skylights, and Windows.-

Silica aerogels can be synthesized using *low cost precursors at ambient* pressure which makes aerogels suitable for commercialization. Aerogels transmit heat only one hundredth as well as normal density glass. The first residential use of aerogels is as an insulator in the Georgia Institute of Technology’s Solar Decathlon House, where it is used as an insulator in the semi transparent roof. Aerogels are a more efficient, low- density form of insulation than the polyurethane foam currently used to insulate refrigerators, refrigerated vehicles, and containers. Foams are blown into refrigerator walls by chlorofluorocarbon (CFC) propellants, the chemical that is the chief cause of the depletion of the earth’s stratospheric ozone layer. replacing chlorofluorocarbon-propelled refrigerant foams with aerogels could help eliminate this problem.

6.4. In Clothing, Apparel, and Blankets-

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 and flexible material. The mechanical and thermal properties of the product may be varied based upon the choice of reinforcing fibers, the aerogel matrix, and pacification additives included in the composite. Aspen Aerogels Inc. of Marlborough, Massachusetts has produced a Space loft product, an inexpensive and flexible blanket that incorporates a thin layer of aerogel embedded directly into the fabric. Another type of aerogels is organic, which is made of carbon and hydrogen atoms.

6.5. Can be used as a supercapacitor –

A hybrid approach is beneficial to simultaneously exploit the characteristics of capacitive and transition materials to increase the energy density and power density of supercapacitors. In order to achieve optimal electrochemical performance, by means of a facile hydrothermal co-synthesis, we synthesize a three-dimensional porous aerogel consisting of MoS2 nanosheets and reduced graphene oxide (rGO) with a controllable composition and morphological structure. The MoS2/rGO porous aerogel hybrids working as electrode material for supercapacitors, can efficiently enhance surface charge transport, provide more chemical reaction sites, shorten the migration path for electrons and ions, and facilitate the electrolyte diffusion. This techniques may be useful for the future.

7. Conclusion-

In this review an overview of research in aerogel composite and insights to the factor that will ultimately control their properties In the interest of brevity this is not a comprehensive review. In particular, this review does not attempt to review the patent literature because due to the proprietary nature of patents, it is difficult to get complete information. If we see current basis Aerogel is a great topic with major of research is application oriented, patents are vital section of this research area, the omission of patents is notable. Here we observed different techniques for the production and applications of Aerogel so as we may achieve the maximum efficiency. Aerogel Is the future of the space travel due to its low density property. In the future during space colonization Aerogel can be one of the most used material and hence we need more research on this topic so we don't fall short of information.

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