A Review on Aerogel An Introduction

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Abstract – *Aerogel is a solid with extremely low density and low thermal conductivity. Nicknames include frozen smoke, solid smoke, solid air, or blue smoke owing to its translucent nature and the way light scatters in the material. It look like expanded polystyrene to the touch. It can be made from a variety of chemical compounds. by extracting the liquid component of a gel through supercritical drying Aerogel is produced. This liquid can be slowly dried off without changing the solid matrix in the gel, as would happen with conventional evaporation. The first aerogels were produced from silica gels.. Aerogel does not have a designated material with set chemical formula but the term is used to group all the material with a certain geometric structure. Aerogel has become a material of interest to scientists in recent decades due to its unique physical properties that give it the potential to improve technologies in a variety of fields. In particular, aerogels offer the lowest densities and the lowest thermal conductivities of any known solid. Since then, many other types of aerogels have been created, including carbon-based and clay-based aerogels. Silica-based aerogels are the simplest and most widely studied type of aerogel, with new uses and applications arising ever. The goal was to create a reliable, non-toxic method, using inexpensive materials*

Key Words: Aerogel, Material, silylating agents, Airglass, Alcogel

1.INTRODUCTION

In 1931, 'Steven Kistler' made a bet with a colleague that he could prove a wet gel contained a solid matrix the same size and shape of the gel. To do this he began with a gel and extracted the liquid, leaving a low-density solid behind. Using an autoclave to drive the liquid past its critical point he was able to conquer the obstacle of surface tension which would otherwise rip apart the internal solid structure of the gel. His successful wager produced the first silica-based aerogel. For half a century this curious material went relatively unnoticed, due to the notorious difficulties and safety issues involved in its creation .

In the early years, fabricating aerogels meant sending alcohol to volatile pressures and temperatures in order for it to reach its supercritical point and allow for the supercritical-extraction of the gel. Then, in the 1980's, interest was renewed when a French scientist, attempting to improve the fabrication process for the French government, developed a process which used less-toxic materials. He switched out methyl alcohol and Tetra Methyl Ortho Silicate (TMOS) for the safer pairing of ethyl alcohol and Tetra Ethyl Ortho Silicate (TEOS). The next breakthrough came in the early 1990's when liquid carbon dioxide replaced the ethyl alcohol involved in the gel before the sample was taken through the supercritical process. This allowed scientists to bypass the dangerous pressures and temperatures needed to send the pure ethanol past its supercritical point. Liquid carbon dioxide has the relatively mundane requirements of 305 K and 1050 psi to be brought to its supercritical point.

To obtain hydrophobic low density and low thermal conductivity aerogels for thermal insulation and liquid marble formation purpose, various sol-gel parameters, processing parameters namely washing, shaking, various solvents, silylating agents and drying method were varied along with doping the gel with $TiO2$ powder.

Aerogel is a typical nano-porous thermal insulation material with open-cell structure. Due to the excellent properties, aerogel is widely applicable in industry fields such as astronautics, thermal insulation and so on. However, the extremely low porosity and complicated structure make it a challenge to accurately predict the effective thermal conductivity and enhance the insulation performance. The experimental measurements of the aerogel thermal conductivity under different pressure and temperature. Most of the present researches adopted some regular structure to represent the aerogel structure, which can simplify the heat transfer analysis of materials, but also contain artificial parameters and ignore the stochastic characteristic of aerogel material. In the aspect of numerical study, used the macroscopic numerical method to obtain the thermal conductivity, whereas using traditional numerical methods is hard to solve the micro-scale heat transfer problem. the open-cell micro-porous random structure of aerogel was reconstructed basing on the solid-phase growth principle, which has no artificial parameters and guarantees the stochastic characteristic of aerogel material. Then the lattice Boltzmann method was adopted to predict the aerogel effective thermal conductivity.

The increase of building energy consumptions driven by the higher expectations for indoor comfort, together with concerns for the rise in GHG emissions, are pushing the research and design interest toward energy saving in buildings. The development of new insulating materials is among the most promising options. The aerogels are considered one of the most promising family of materials for insulating purposes, given their high thermal insulation. They are dried gels with such a high porosity that they have lower thermal conductivity than air. Moreover, they are nontoxic, low flammable, lightweight, and air permeable. The synthesis of these materials was discovered in the early 1930s and since that time, several products have been developed, mainly using silica as a raw material. The production process of silica aerogel aims to build sufficiently rigid materials with the same porous texture as that of the wet sol-gel stage. The aging of the gel and its drying are the two most risky phases of the production of aerogels, and are responsible of their high cost. The solid microstructure of the aerogels has been described as "beads on a string" or "pearls on a necklace" referring to the roughly spherical particles connected by small necks or thin strands. This structure is much less stiff than that of an open-cell foam (up to 30 to 50 times lower). After cost, the main limitation that is preventing aerogels from becoming more widely used in the building sector is hence their high fragility. Their fragility has hence suggested the use of aerogels in protected compartments. Given their good light optical properties, aerogels have been considered for building fenestration systems since the 1980s. Products with aerogel in the interspace between the window panes have shown to provide high thermal resistance and light transmittance.

Two types of aerogel exist, the monolithic and the granular aerogels. Monolithic silica aerogels have higher solar transmittance than granular ones; for example, 10 mm monolith translucent silica aerogel windows have shown a solar transmittance up to 0.8, whereas the maximum solar transmittance of granular silica aerogel windows is around 0.5. However, cracks often occur when manufacturing large pieces of monolithic aerogels, so glazing systems with monolithic aerogel have not yet been used beyond research prototypes . A monolithic aerogel window with vacuum glazing and a 13.5 mm thick aerogel panel was developed within the EU project HILIT; this project proved the possibility to realize windows with a thermal conductivity of 0.66 W/m2K and a light transmissibility above 0.8. Since then, Airglass AB, the firm that provided the aerogel in the HILIT project, has continued refining the production process of monolithic panels.

1.1 WHAT IS AEROGEL?

Aerogel means an extremely light and porous semi-solid materials. Silica based aerogels are among the lightest ones , can be less than four times as dense dry air , and some are nearly transparent , its nick name is ''solid smoke'' or ''frozen smoke.''

Because of aerogels unique structure, its use as insulator. the super insulating air pockets with the aerogels structure almost entirely counterect the three methods of heat transfer .

PROPERTIES OF AEROGEL

- Low density - UV Infrared
- It has 90 – 99.9 % porosity.
- Large sound absorption - low sound velocity :Damping > 50 dB, vl ≈ 100 m/s
- Low thermal conductivity: 0.005 - 0.1 W/mK
- It can be Transparent or opaque or can be coloured.
- Variable refractive index (1.001 to 2.1)
- No reaction with metallic melts up to 950°C (Silica and some other oxide aerogels)
- Hydrophobic by polymeric residues (-CH3)

ACTUAL PHOTOGRAPH OF AEROGEL

Fig 1. Actual Aerogel

1.2 PRODUCTION PROCESS.

Aerogels begin life as a silica (SiO2) gel. Though aerogels have also been created with alumina, chromia, tin oxide, carbon and other materials, silica versions are the easiest and most reliable to produce. The silica gels are about 99% liquid by weight, but contain matrices that give the liquid surface tension. In a silica gel these molecular networks are made up of silica dendrites.

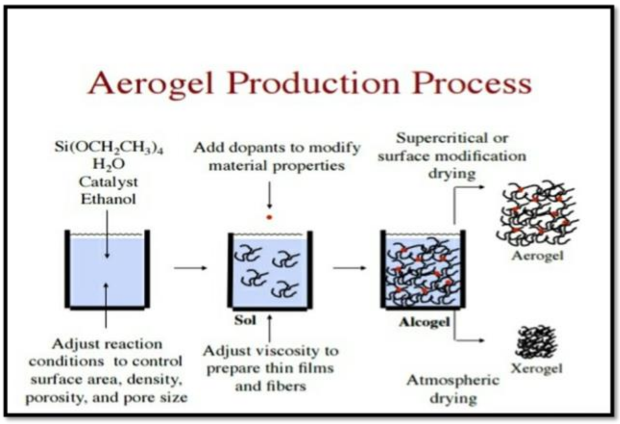
The first step in making aerogels is to create what is called a "wet gel." Currently, the best way to create the wet gels is to begin with a silicon-alkolyde precursor, such as TEOS, which was used for this project. The chemical makeup of TEOS is Si(OCH2CH3)4, which, when added to water, achieves the chemical reaction.

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

eq. The amount of water indicated in eq is only enough to exactly balance the reaction. In practice, anywhere from 4 to 30 times more water should be used to increase the strength of the gels . This chemical reaction is generally accomplished in ethanol.

Acid or base catalysts are added to this reaction in order to decrease gelation time from several days to around an hour. Base catalysts were used in this project due to their tendency to create clearer aerogels. Base-catalyzed aerogels also retain more of their volume throughout processing than do their acid-catalyzed counterparts.

The current precursors are largely alkoxides M(OR)n which are compounds consisting of a metal M and an alkoxide group OR. With silicon precursors the R designating the alkyl group is often a methyl CH3 group or an ethyl C2H5 group. The reason silica-based aerogels have been studied much more than any other type is because silicon atoms carry a reduced partial positive charge δ+. In Si(OEt)4 δ+ is about 0.32 .



APPLICATIONS OF AEROGEL

1. Use of carbon black in aerogel-like composite material with heat insulating properties .
2. Functional starch based carbon aerogels used for energy applications .
3. Phenolic Aerogel used in improvement of Polyester Blanket Thermal Insulators properties .
4. Aerogel is used in everything from makeup and paint to napalm.

ADVANTAGES & LIMITATIONS

- **Advantages**

1. Aerogel is the best overall type of insulation.
2. Fibreglass is cheap.
3. Mineral wool is effective, but not fire resistant cellulose is fire resistant and ecofriendly, but hard to apply.
4. Polyurethane is a good insulation product.
5. Because of their high thermal resistance, insulation products based on aerogels (e.g. insulation blankets or granules) achieve a relatively high level of thermal insulation with a limited insulation thickness. This makes it possible to save interior space (on walls or floors).
6. Insulation blankets based on aerogels can be easily cut to shape and are flexible enough to be fitted around complicated details. Their main advantage compared to vacuum insulation panels (VIP) (which have a thermal conductivity in the same order of magnitude) is their reduced sensitivity to mechanical damage.
7. Aerogels are water repellent and vapour open.

- **LIMITATIONS**

1. Aerogel production cost is high and hence it is can not be affordable for small scale production.
2. Aerogel is soft and lightweight so has poor mechanical properties.
3. Aerogel is prepared from Chemicals so it may affect Health during production.
4. Aerogel is very soft material so large pieces cannot be lifted at corners.
5. Silica aerogel is destroyed by contact with liquids.

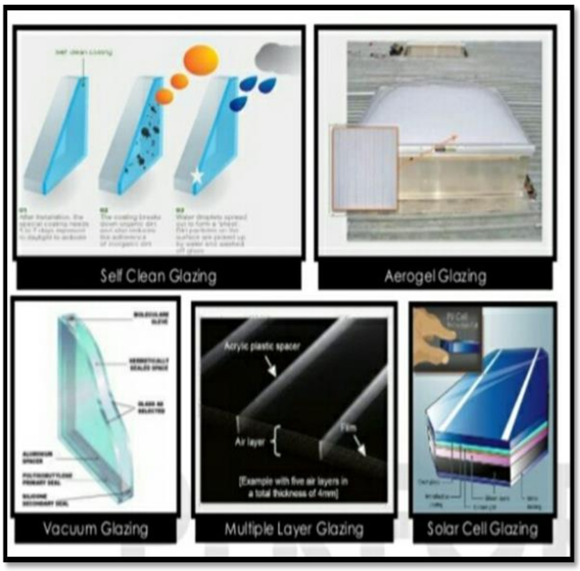


Fig.2 Product made by aerogel

3. CONCLUSIONS

Thus, from the above paper Aerogel is a material can be used to replace commonly used solid materials. A semi-solid Aerogel is currently used in Aerospace application to reduced the heat transfer rate and simultaneously reduced heat loss .

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