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You have £1 billion to spend on research: how are you going to use them?

Introduction

With £1 billion to spend on research, I would investigate the applications of aerogels. While superficially this area of research seems insignificant, if we are able to discover ways to make aerogels more durable and less expensive, then the possibilities of applications would be nearly endless. Not only could it help curb the climate crisis, but it could also help NASA make lighter spacesuits, provide better insulation in buildings, and keep electronics safe from varying weather conditions.

What are aerogels?

Aerogels are solid materials with very low densities[1]. While their properties can vary depending on their components, their densities range from 0.003-0.5g/cm^3[(2)]. For reference, the density of water is 1g/cm^3. They were created in the 1930's by scientist Samuel Stephens Kistler, who believed that an object was a gel due to its structure and not the liquid inside[3]. He attempted to remove the liquid from within jellies via evaporation. However, this caused the structure to collapse into itself. He then hypothesised that one could remove the liquid and replace it with gas, and this would stop it from collapsing. This proved to be successful, and he created the least dense solid known to man.

What are they made of?

Most common types[4]:

- Silica [Fig 1]
- Carbon [Fig 2]
- Metal oxide

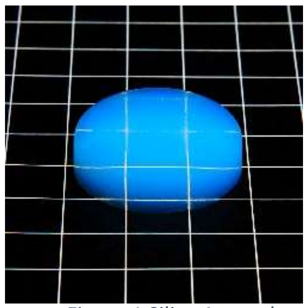

Figure 1 Silica Aerogel (www.buyaerogel.com)

Silica aerogels are most commonly used for insulation, notably used for insulating the Mars Rover[5]. Their insulating abilities stem from their structure. They are about 95% porous, meaning it is difficult to transfer thermal energy between particles[6].

Figure 2 Carbon Aerogel (Spectrum.ieee.org)

Carbon aerogels have brilliant electrical conducting properties. They are currently used in supercapacitors, and investigations are underway to see the possibility of their use to support fuel cells, and as electrodes for redox flow batteries[7].

Metal oxide aerogels are useful catalysts for chemical transformations. They are used to make carbon nanotubes and explosives. In addition to this, some are also magnetic[8].

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[1] (Woods, 2011/2017)
[2] (Igor Mitrofanov, 2017)
[3] (Quinlan, 2010)
[4] (Quinlan, 2010)
[5] (Woods, 2011/2017)
[6] (Woods, 2011/2017)
[7] (Group:, n.d.)
[8] (Quinlan, 2010)

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Key properties

- Low density
- Low mean free path of diffusion (low average distance travelled by molecules between collisions)
- High surface area
- Poor thermal conductors

How are Aerogels made?

For aerogels made of silica[9].

- Silica combined with a solvent to make a gel [Fig 3]
- It is then placed in liquid carbon dioxide
- This is placed in an autoclave and the temperature is raised to the supercritical temperature.
- Then it is vented out.
- This happens multiple times to make sure all the liquid is removed from the gel.

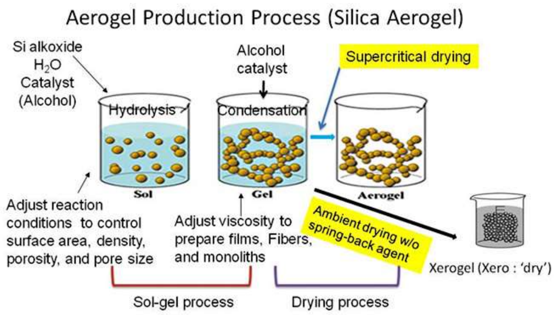

Figure 3 Aerogel Production Process (pamelanorris.wordpress.com)

Discussion

With £1 billion, I would begin my research at gaining a better understanding of aerogels, this would help us make a formula which will lead us to manufacture them with a desired set of properties. Currently, making aerogels is very difficult and "the production process is often non-reproducible"[10]. This research would be key in creating aerogels that have a better structural integrity and more durability to different weather conditions. While silica aerogel is an outstanding material, it is limited by its brittleness. Contemporary methods of increasing the structural integrity include mixing silica with other components, and surface treatments which allow the structure to be able to withstand multiple environmental conditions[11]. With the ability to make more durable aerogels, we would be able to expand the rage of uses in multiple devices.

In the USA 950 trillion British Thermal Units of head are wasted yearly due to poor insulation, the equivalent of wasting 165 million barrels of crude oil[12]. Surely it would be in the best interest of the population to have an insulating system which is more effective and could help the climate crisis. In addition to being remarkable thermal insulators, aerogels are non-toxic, non-flammable, contain no ozone depleting substances, and are recyclable[13]. Theoretically this is the perfect material. They are already being used in Swizerland to insulate historic buildings[14]. However, some aerogels that are mixed with certain components can only be disposed in landfill sites, and others need to go to toxic waste locations, negatively impacting the environment. This is what needs to be focused on, as if we can make a durable, environmentally friendly aerogel, then we are taking steps in the right direction in terms of

[9] (Woods, 2011/2017)
[10] (Norris, 2021)
[11] (Collins, 2019)
[12] (Energy.Gov, 2012)
[13] (Aerogels, n.d.)
[14] (Thomas, 2012)

helping to curb the climate crisis. However, the cost of production of aerogels is about cost is about $1 per cubic centimetre[15], whereas fibreglass, a common insulator, only costs

Furthermore, due to the porous structure, aerogels can act like sponges. This is convenient in cases of oil spills (which will likely occur again), and while it absorbs the oil, the oil remains clean, so would be viable for use. Finally, aerogels can eliminate pollutants in the air, which can help make cleaner and safer air[16].

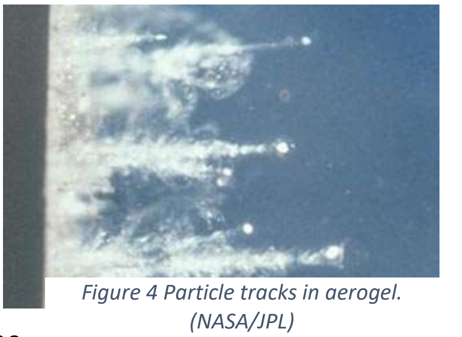
Figure 4 Particle tracks in aerogel. (NASA/JPL)

The next aspect I would wish to address is the cost of aerogel production. The cost is about $1 per cubic centimetre[17]. This creates a level of difficulty in regards of commercial use. Over time the cost of production will decrease as more efficient methods are established, but it still stands that at the moment the cost outweighs the benefits. With my research being focused on finding methods to make the production process reproducible, the cost would be reduced as there would be a higher yield of the desired product. Aerogel has been used to insulate the Mars Rover and to capture space dust in NASA's Stardust mission[18(Fig 4)]. NASA are researching the use of aerogels to insulate space suits, due to their densities being between 0.003-0.5g/cm^3[(19)]. If the cost were greatly reduced, it would result in wider commercial uses, such as insulation, clothing, and more.

<u>Conclusion</u>

I believe that researching aerogel is significant as it is a potential way to tackle climate change and protect the environemnt. Aerogel insulators would reduce the amount of energy wasted, resulting in a diminished use of fossil fuels. Aerogels can also filter the air and remove pollutants, it can keep people warm, and protect eletronics. There are many more applications which will been seen in the future. There are numerous research groups who are working tirelessly to make this pheonominal material even better, then hopefully we will witness their work come to fruition.

[15] (Quinlan, 2010)
[16] (Daily, 2020)
[17] (Quinlan, 2010)
[18] (Perkowitz, 2019)
[19] (Igor Mitrofanov, 2017)

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