Aerogels
Fundamentals and Potentials of the „Wonder Material“

Materials Cologne / 25.03.2022

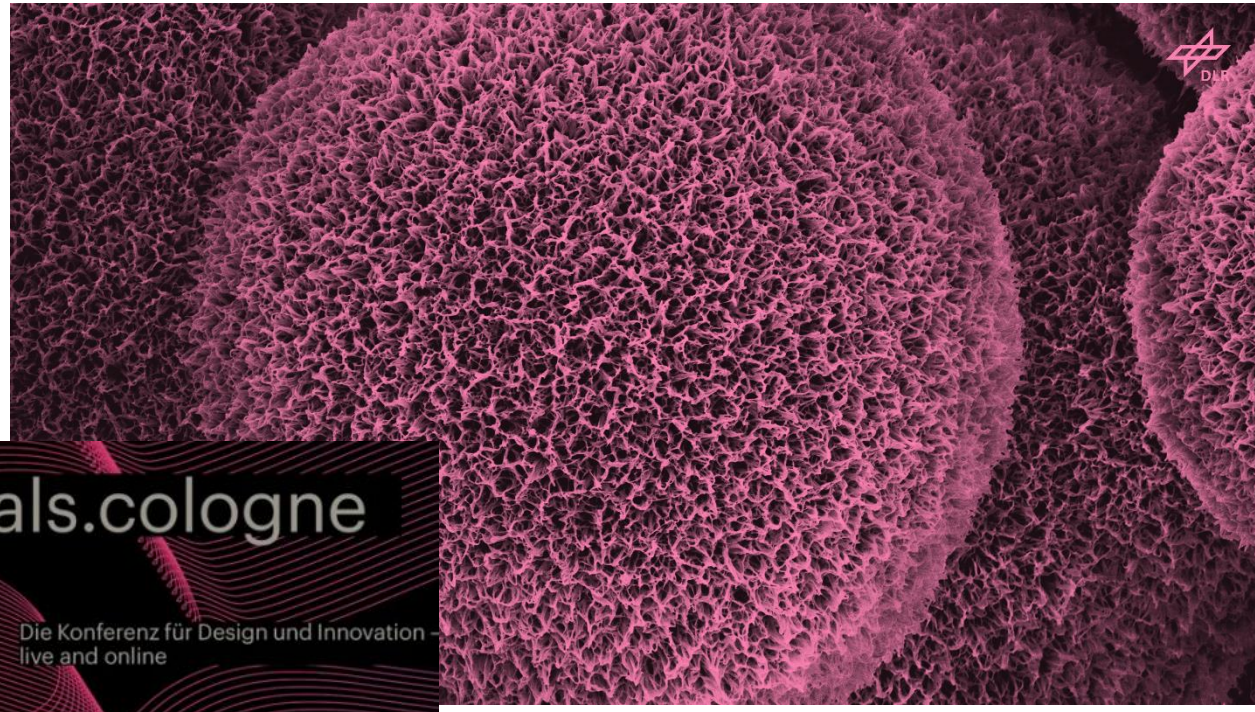
DLR

Agenda

1. Introduction

2. What are Aerogels?

3. Application examples

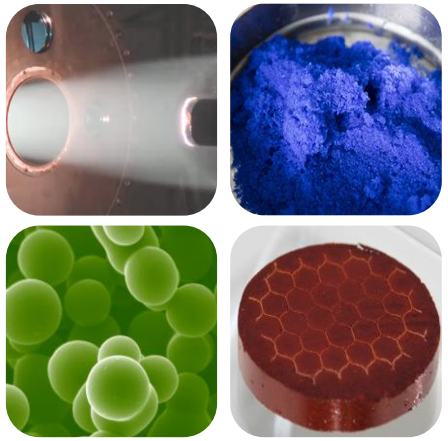


1. Introduction
Speaker

German Aerospace Center (DLR)
Institute for Materials Research

Prof. Dr. Barbara Milow

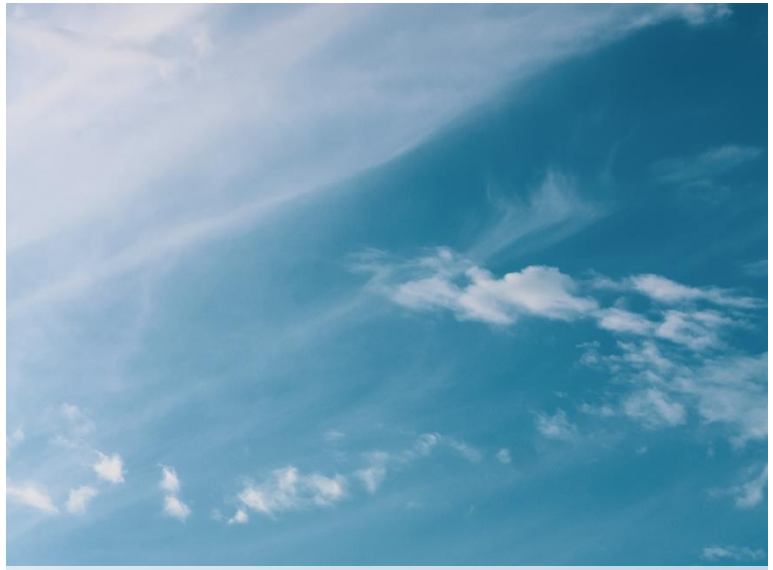
Head of Department
Aerogels and Aerogel Composites



ZAT
ein Helmholtz-Innovation-Lab

2. What are Aerogels?
Definition

Aerogel



derived from the Greek:
ἀήρ *(aḗr)* for „**Air**“

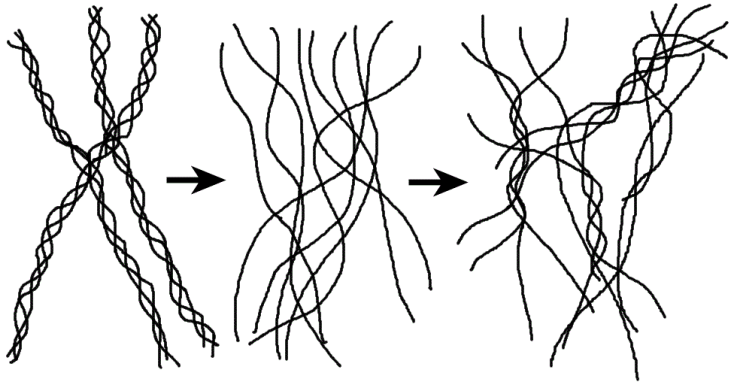
(shortform) „gelling/gelatine“;
derived from the Latin gelatus for
„**frozen**, **solidified**“

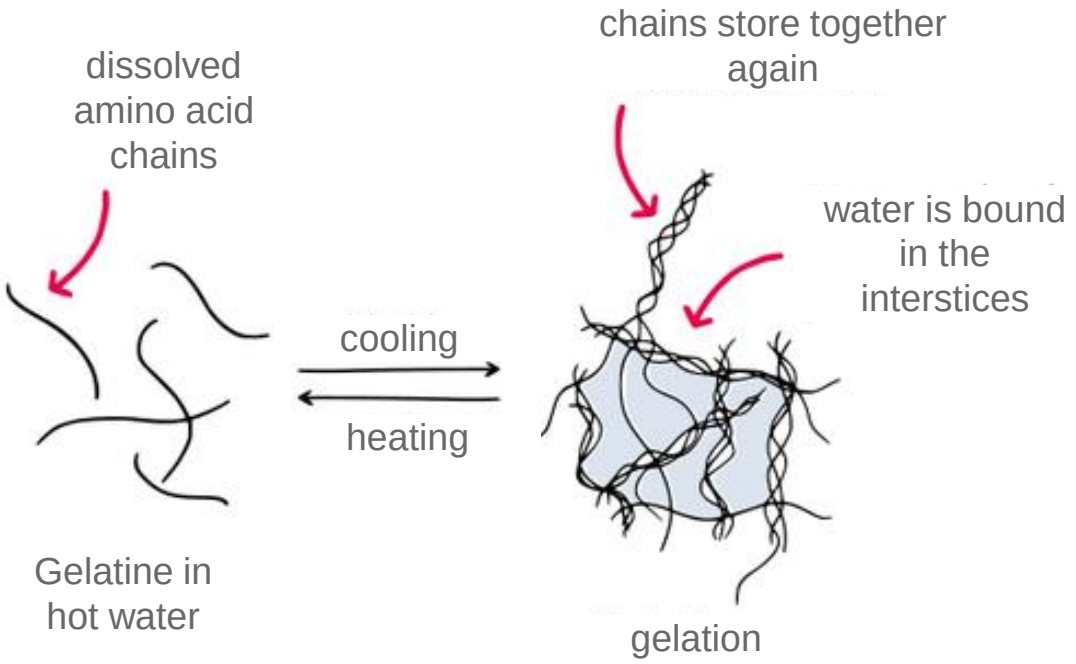
2. What are Aerogels?

Popular gels…

2. What are Aerogels?

Popular gels…



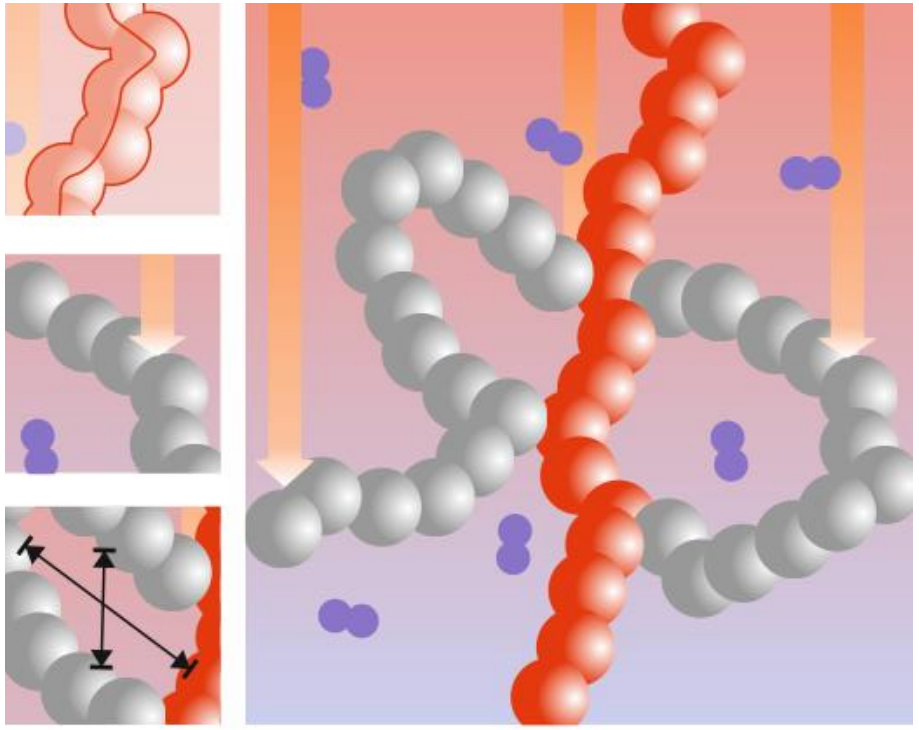


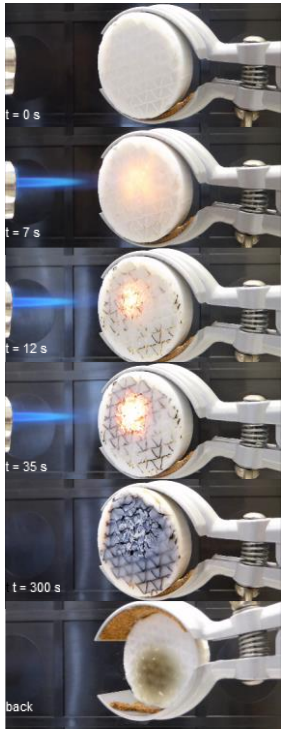
Glucose syrup; sugar; gelatin; dextrose; fruit juice from fruit juice concentrate: apple, strawberry, raspberry, orange, lemon, pineapple; acidifier: citric acid; fruit and plant concentrates; safflower, spirulina, apple, elderberry, orange, currant, kiwi, lemon, chokeberry, mango, passion fruit, grape; flavor; elderberry extract; glazing agents: beeswax white and yellow, carnauba wax.

https://onlineshop.haribo.com/goldbaeren
https://www.studieinsuess.de/suesse-wissenschaft/geliermittel-im-vergleich-gelatine-vs-agar-agar/
http://daten.didaktikchemie.uni-bayreuth.de/umat/gele/gele.html

2. What are Aerogels?
Unique properties

- Solid material with **enormous porosity**
  - Up to > 99 %
- **Low specific weight**
- Excellent **low thermal conductivity**
  - Up to 0.010 W/(K·m)
- Heat transport by diffusion prevented
- Heat radiation through turbidity minimized
- Heat conduction via the solid body extremely low





USP Aerogel

Best requirement for the application in the construction industry!

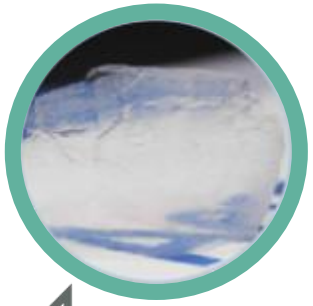
2. What are Aerogels?
Range and properties of Aerogels

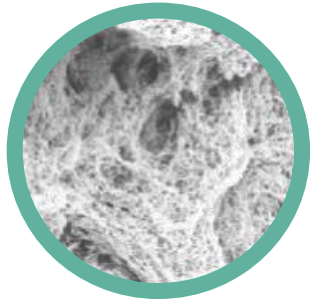
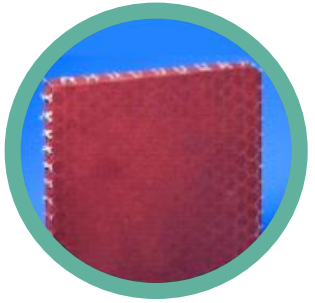
Organic Aerogels
- temperature resistant up to approx. 250 - 300°C
- compatible with common resin systems (comparable to honeycomb structures)

Carbon Aerogels
- absorptivity of toxic gases
- electrically conductive
- potential electrode material

Biopolymeric Aerogels
- biogenic raw materials („Wood“: Cellulose + Lignin, „Crabs“: Chitin)
- biodegradable

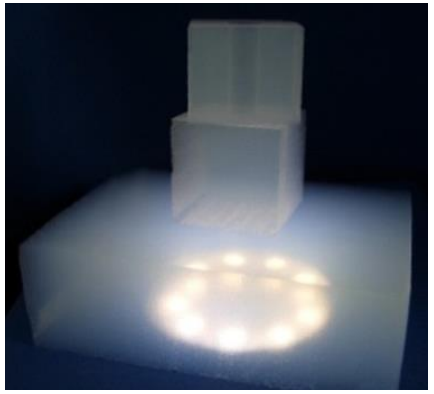
Inorganic Aerogels
- high temperature stable (1200°C)
- translucent
- high compatibility with aggregates/reinforcing fabric



2. What are Aerogels?

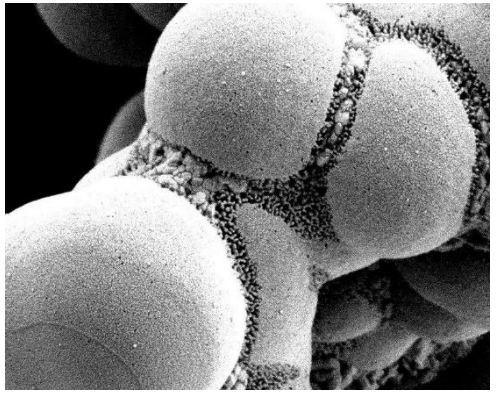
Aerogels



Inorganic Aerogels

Organic Aerogels

Biopolymeric Aerogels



Carbon Aerogels

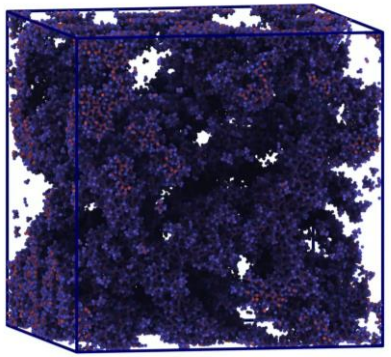
Aerogel Composites

Fibre Reinforced Aerogel Composites

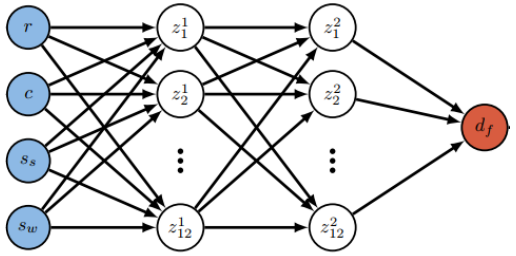
3D-nano-fibre Reinforced Polymer Composites

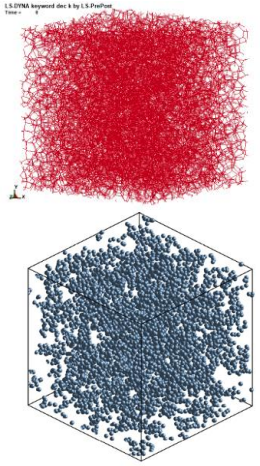
Granular Aerogel Composites

Modelling and simulation



Molecular dynamics simulations

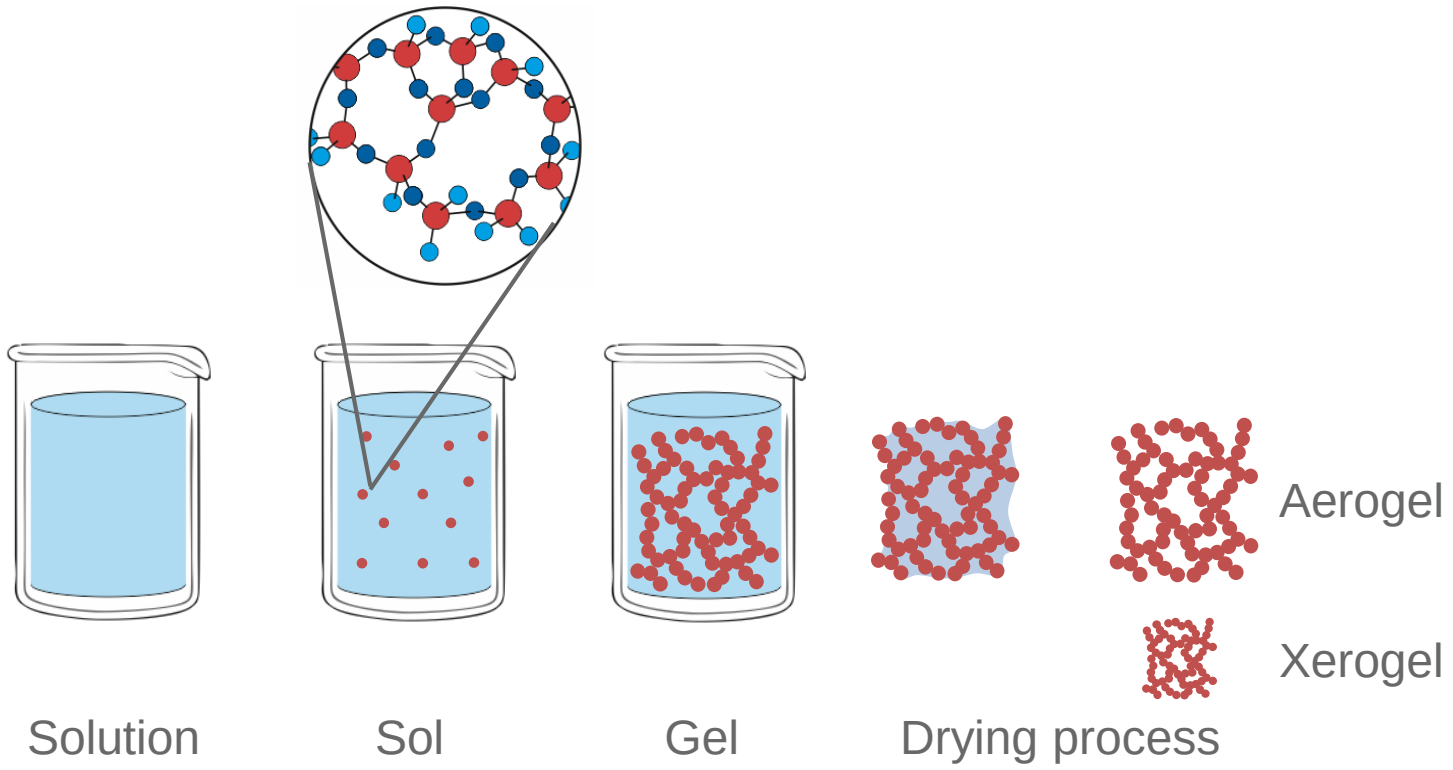


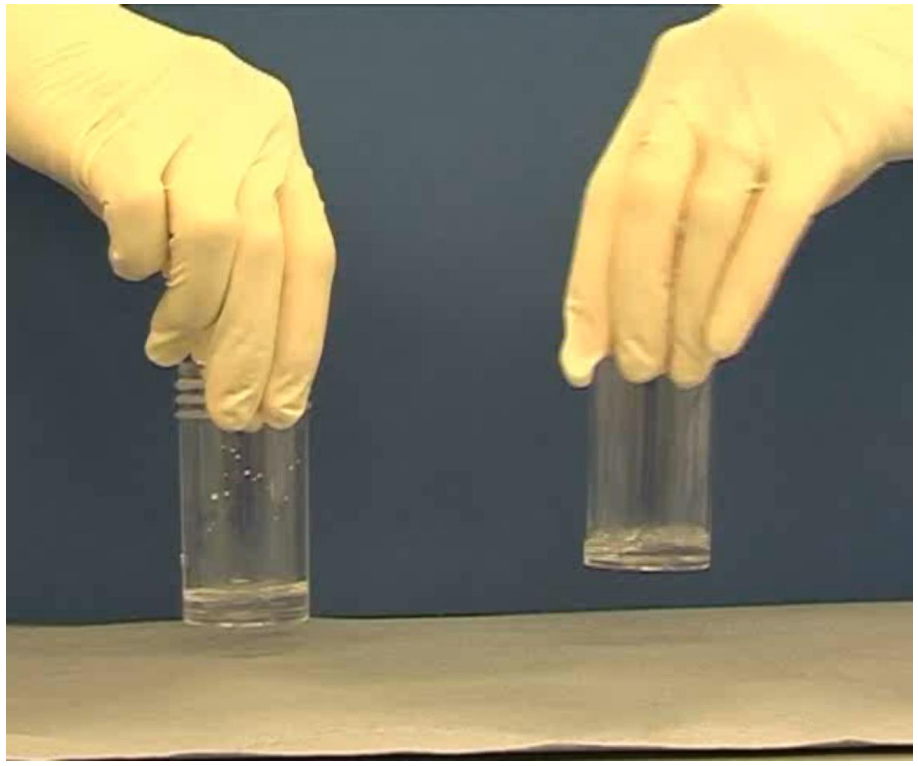


„machine learning“ supported Modelling and simulation

2. What are Aerogels?

Synthesis-Strategy… a little chemistry is a must…





3. Application examples

Transfer of technology: Versatile use of Aerogels

Aviation
Cabin insulation, engine shielding, acoustic insulation, electric flying

Automotive transport
E-mobility, battery technology, insulation of passenger cells, efficiency enhancement of exhaust tract, lightweight construction

Rail transport
Lightweight construction for wagons, acoustic insulation, fire safety

Shipping
Cryogenic tanks for LNG, cabin insulation (thermal and acoustic) for passenger ships, transport boxes for fresh goods (fish, vegetables, etc.)

Aerospace
High-performance ablators for re-entry (recycling of components)

House construction
New construction, renovation of old buildings, CO2 savings, space-efficient insulation, gaining living space, sustainable insulation from renewable raw materials, fire resistance

Other technical applications
Insulation for oil and gas pipelines, insulation for chemical installations, medical technology, food technology, aerogel core sand additive for foundries.

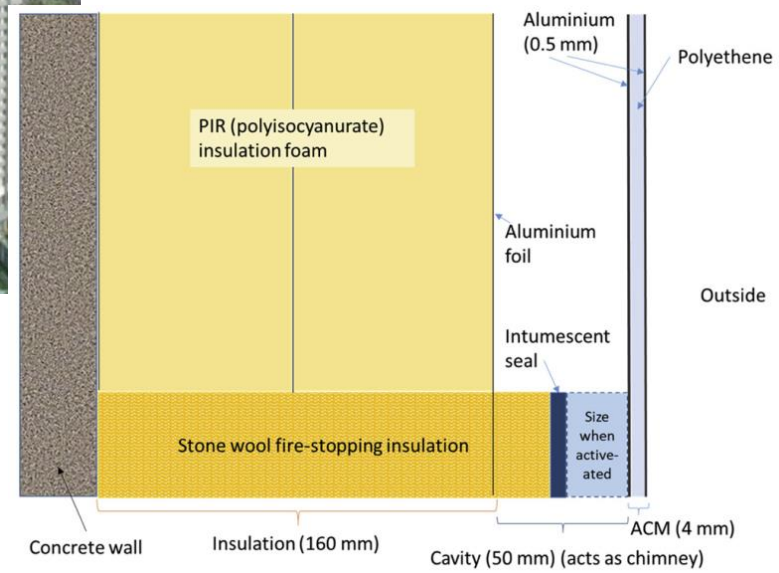
3. Application examples
Insulating: Example Grenfell Tower London

Background:

Retrofitting/renovation of the building was planned, but still …

- Rigid PVC for thermally insulated windows
- Double aluminum-laminated polyisocyanurate (PIR) as thermal insulation on concrete wall (ventilated) with only thermal stability of up to 400°C

Chimney effect leads to **rapid fire spreading**



USP Aerogel

Aerogels are high temperature resistant!
=> New insulating materials regarding **fire protection** highly interesting!

https://twitter.com/i_aliarif/status/874840353836236800
Sean T. McKenna et al. Journal of Hazardous Materials, 2019, 115-123.

3. Application examples
Conventional building material

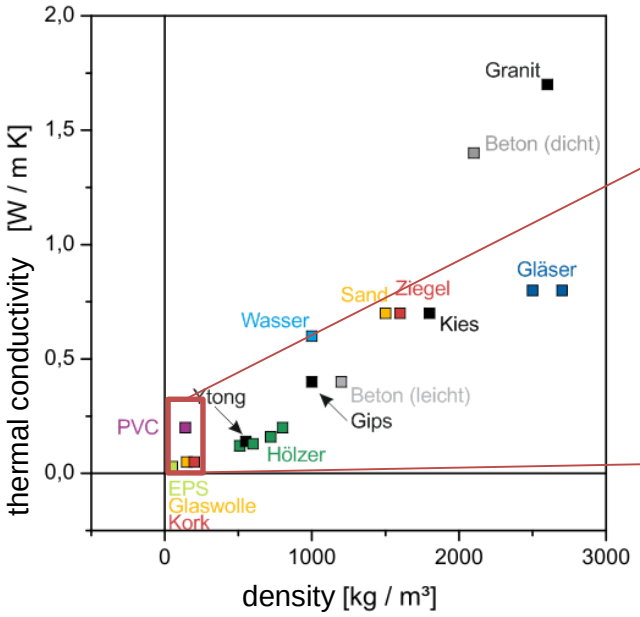
„Traditional“ field of application of Aerogels:

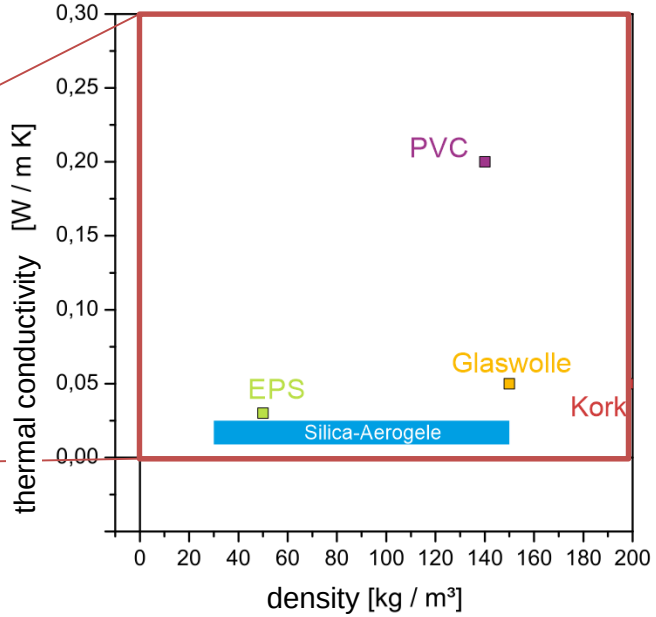
- **(High-performance) insulating**
- **Excellent insulating properties**

  << 0.020 W/(K·m)

Aerogels as …

- … filling of hollow bodies
- … aggregates
- … high-performance insulating molded bodies





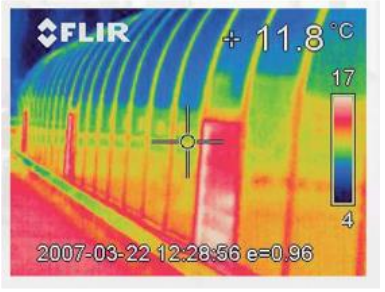
https://www.schweizer-fn.de/stoff/wleit_isolierung/wleit_isolierung.php

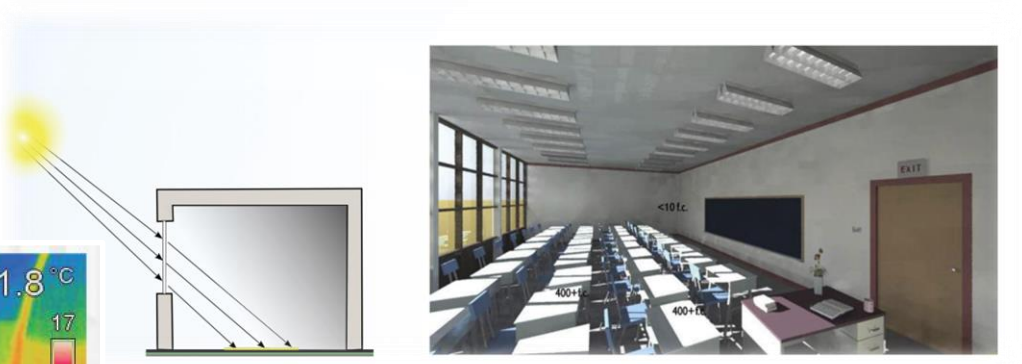
3. Application examples
Filling of hollow bodies

- still **without basic light transmission**
  - 16 mm multiwall sheet: 59%
  - + Aerogel filling: 57%
- light scattering due to Aerogel granules
- **additional insulating effect**
  - 16 mm multiwall sheet:

    1.82 W/(K·m²) → 1.31 W/(K·m²)
  - 25 mm multiwall sheet:

    1.50 W/(K·m²) → 0.89 W/(K·m²)





USP Aerogel

„2 in 1“: optimal **room illumination** with **additional insulating properties**

3. Application examples
Filling of hollow bodies

- Monolithic Aerogel as **window filling**
- **Increased insulating capacity** due to monolithic shape in comparison to granules
- **Transparency** remains (mostly) intact due to reduced light refraction
- Technically more complex than granules
- U-value app. 0.22 W/(K·m²)

Matthias Koebel, Arnaud Rigacci, Patrick Achard, Aerogel-based thermal superinsulation: an overview J Sol-Gel Sci Technol (2012) 63:315–339.
Jensen KI, Kristiansen FH, Schultz JM (2005) Highly insulating and light transmitting aerogel glazing for super-insulating windows : HILI+(European project ENK6-CT-2002-00648), Public final report.
U. Berardi, The development of a monolithic aerogel glazed window for an energy retrofitting project , Applied Energy 154 (2015) 603–615.
J.M. Schultz, et al., Super insulating aerogel glazing, Solar Energy Materials and Solar Cells 89, 2-3 (2005) 275–285.

3. Application examples

Aerogel as aggregate in high-performance insulating plaster

- Thermal conductivities up to **factor 1** better than conventional insulating plasters
- Comprehensive substrate treatment sometimes necessary

Multi layer structure:

1. Plaster base pre-treatment
2. Insulating plaster (app. 8 mm per working cycle)
3. Surface consolidation
4. Reinforcement
5. Finishing plaster
6. Paint

USP Aerogel

Insulating properties of „Aerogel plaster“ **much better than** conventional plasters

https://www.hasit.de/media/importer_assets/122440.pdf

https://mamview.fixit-holding.com/CIP/mediadelivery/rendition/100_123729/Brosch%C3%BCre-V2:-HASIT-Fixit-222-%22Aerogel-Hochleistungsd%C3%A4mmputz%22-HASIT-Fixit-Aerogel-Hochleistungs-D%C3%A4mmputzsystem-de

3. Application examples

Aerogel particles as aggregate in paints and lacquers

- Thermal conductivity

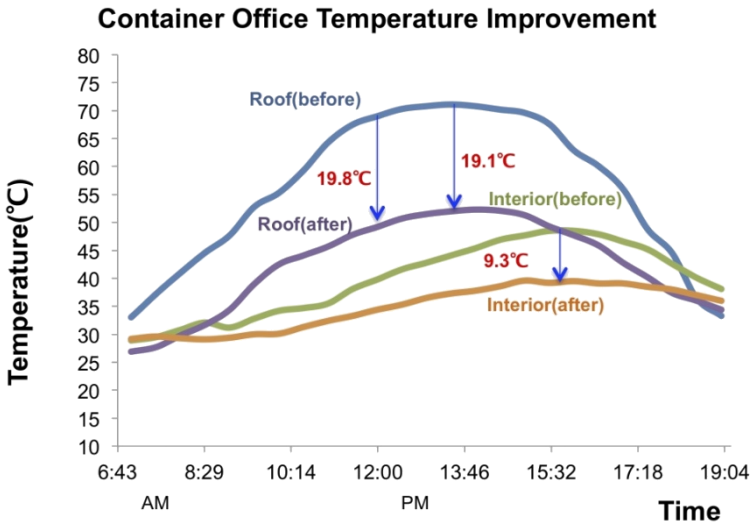
λ **= 0.04 – 0.045 W/(K·m)**

Before

After

- Easy application due to spreading and squeegeeing

app. 12.50 €/L



https://rovashield.com/solutions-architectural/

3. Application examples
Aerogel as aggregate in concrete

- Compressive strength enables practical use
- Graded wall construction possible
  - **Base course:**

    50 % Aerogel

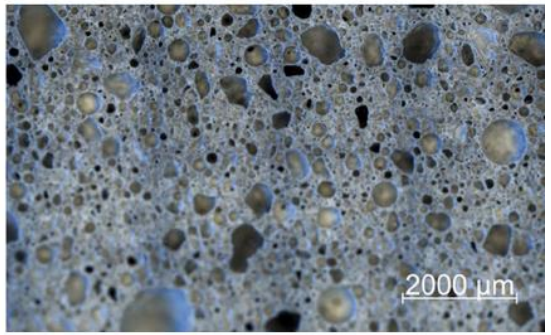
    Pressure resistant: 19.5-25.5 MPa

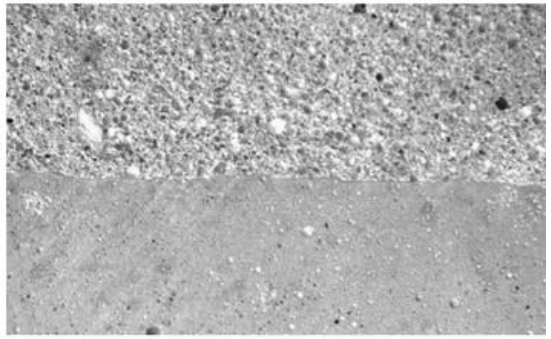
    Thermal conductivity: λ = 0.260 W/(K·m)
  - **Insulating layer:**

    70 % Aerogel

    Pressure resistant : ca. 2 MPa

    Thermal conductivity: λ = 0.090 W/(K·m)





USP Aerogel

- Ideal for **lightweight construction**
- Employment of additional (traditional) insulating material **obsolete**
- **Sustainable, resource-efficient** construction method

M. Schnellenbach-Held, T. Welsch, S. Fickler, B. Milow, L. Ratke: Entwicklung von Hochleistungsaerogelbeton, BETON- UND STAHLBETONBAU, 111 (9), 555-563, SEP 2016

3. Application examples
Aerogels as fibre composite

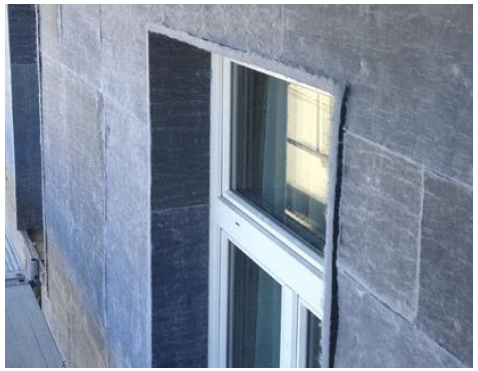
Infiltrated fiberboards with **Aerogel (-“Granules“)**

- Easy to shape
- Mechanically flexible
- Adaptable on irregular walls

- ***Spaceloft*** *(ca.115 €/m²)*
  Thermal conductivity: λ = 0.015 W/(K·m)

- ***Thermal Wrap*** *(ca.120 €/m²)*
  Thermal conductivity: λ = 0.023 W/(K·m)

- ***HeckAero***
  Thermal conductivity: λ = 0.019 W/(K·m)



Thank you!

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