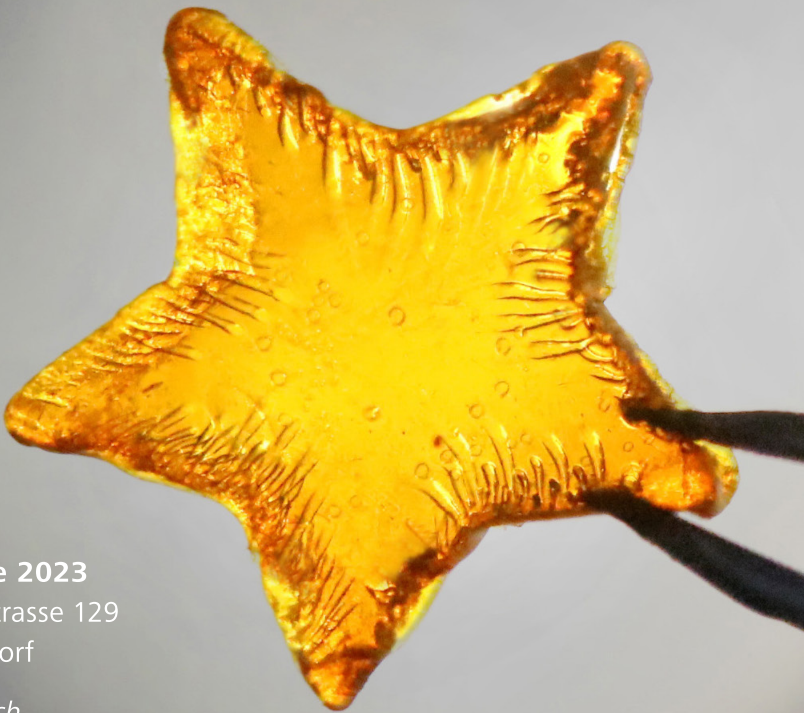
AEROGELS COST ACTION CA18125
environment | medicine | biotech | industry | academia

AEROGEL INDUSTRY-ACADEMIA FORUM
May 31 - June 2, 2023 | ON SITE

Empa
Materials Science and Technology

2nd Aerogel Industry-Academia Forum

Processes, products,
applications & markets



31 May – 2 June 2023
Empa, Überlandstrasse 129
CH-8600 Dübendorf

aia-forum.empa.ch
aerogel@empa.ch

Topic

The aerogel world is undergoing rapid development. On the industry side, new players are entering the market. New aerogel producers, including start-ups but also established materials manufacturers, introduce their products, fight for market share, or aim to develop new applications and markets. In the meantime, traditional manufacturers are also innovating. Silica aerogel remains the important product, but polymer and biopolymer aerogels are becoming available as well. Other companies focus on developing process technologies or aerogel based product development. On the academic side, there has been a veritable explosion of research into understanding traditional aerogel materials and applications, as well as new aerogel materials combinations, new precursors and sustainable raw materials, new aerogel synthesis routes and new potential applications.

Target audience

Representatives from industry (aerogel producers, technology providers, raw material suppliers, formulators, end-users), policy-makers (NGOs, EC-representatives, funding agencies), regulatory entities and academia (aerogel process engineering field, as well as from application-oriented research in the biomedical, toxicological, environmental remediation, catalysis and thermal insulation fields)

Aims

To strengthen and extend your network in the area of aerogel-related materials, technologies and markets.

To introduce your products and services to the aerogel community through talks, posters or booths.

To learn about the hottest and most recent research and developments on aerogels.

To keep yourself updated with the newest information on product standardization, LCA, toxicological evaluation, and about European research funding programs.

To meet to a pool of newcomer and established specialists in the field as well as potential recruits for your institution or company.

COST CA18125 – AERoGELS

AERoGELS explores aerogels for environmental and life sciences applications in a multidisciplinary approach to tackle two of the current main European challenges: circular economy and active ageing. The aim is to advance the state-of-the art on the topic by joining the knowledge and efforts of the experts on cutting- edge aerogel technology, on advanced characterization of materials as well as on biomedical and environmental research. Aerogels will be assessed from a materials performance point of view but also regarding health and environmental implications. AERoGELS disseminates knowledge to society, boosts industry-academia interactions and trains European young researchers on research, innovation and entrepreneurial skills via technical schools, publications and exchanges. Interdisciplinary collaborations will yield innovative and integrated solutions for environment and for life sciences. The long-term scope is to develop aerogel technology to improve welfare and move towards cleaner and smarter production.
https://cost-aerogels.eu/

Aerogel Architecture Award 2023 (3rd edition)

We are delighted to invite you to submit your examples of aerogel use in architecture, construction, refurbishment and monument preservation as built solutions or student projects. We are searching for the top realized projects internationally to showcase the best projects of architects, civil engineers or top project ideas of students from these fields. The best projects selected by our jury will be shortlisted for our Aerogel Architecture Awards ceremony hosted near Zurich at NEST Empa campus, which will give broad recognition to the projects. The projects will be published in relevant international magazines and portals. The award celebrates the best examples with regards to energy efficiency, unconventional solutions, translucent daylighting, high performing buildings solutions with use of superinsulating aerogel materials.
https://www.empa.ch/web/aaa

Wednesday, 31 May 2023

13:30 Registration opens

14:00 Workshop: Aerogels in real life
Aerogel 3D printing
Empa aerogel pilot facility
NEST building demonstrator
Aerogel glass brick
Aerogel product displays

16:30 Welcome reception

Thursday, 1 June 2023

08:00 Registration

08:30 Opening remarks

8:40 Aerogel processing & production (Chair: Shanyu Zhao)
08:40 Irina Smirnova (TUHH)
Continuous production of bioaerogels particles
09:00 Barbara Milow (DLR)
Aerogel Launch Factory – future perspectives
09:20 Sam Cryer & Alyne Lamy (Thermulon)
Cost-effective aerogel-based thermal insulation
09:40 Francisco Ruiz (KEEY Aerogel)
To be announced
10:00 Michal Ganobjak (Empa)
Insulating Translucent Aerogel Glass Brick for Building Envelopes

10:20 Coffee break

10:40 Aerogel applications in high-tech (Chair: Luisa Durães)
10:40 Yunhong Wang (IBIH)
Aerogel from research labs to industry - IBIH's practice and contribution
11:00 Dong Lin (Oregon State U.)
3D Freeze Printing of Aerogel
11:20 Erkey Can (Koç U.)
Aerogels for the Hydrogen Economy: Applications in Fuel Cells and Electrolyzers
11:40 Tingting Wu (Empa)
Polyimide aerogel for thermal management and patch antenna

12:00 Lunch

13:00-13:45 AERoGELS Cost Action
WG4 meeting: Process Engineering, Development and Scale-up for Industrial Applications (open to all)

13:20-14:20 Poster session & Aerogel Architecture Award posters (NEST Foyer)
P1 Christian Scherdel (CAE)
Vacuum glazing with silica aerogel pillars
P2 Wim J. Malfait (Empa)
The questionable accuracy of thermal conductivity data in the aerogel literature: a call to action!
P3 Mattia Turchi (Empa)
Adsorption and surface mobility of CO2 in pores of amorphous silica with different functional groups
P4 Yanfang Wei (Donghua U.)
Superflexible hybrid aerogel-based fabrics enable broadband electromagnetic wave management
P5 Zhiyang Zhao (Nanjing Tech U.)
Multifunctional robust transparent silica aerogels
P6 Stefanie B. Hauser (Empa)
Surfactant-free synthesis of methyl functionalized silica gels with tuneable microstructures
P7 Tingting Wu (Empa)
The effect of polymer concentration and cross-linking density on polyimide aerogels

14:20 Biomedical applications, Safety & Aerogel characterization (Chair: Sandra Galmarini)
14:20 Carlos García González (USC)
Advanced Processing of Aerogels for Drug Delivery
14:40 Sevil Çikrikci (Konya U.)
Alternative Sustainable Materials for SLA and Extrusion Printing: Carrier System Design for Antioxidants
15:00 Veronica Di Battista (BASF)

Assessing the dust released from commercially relevant inorganic aerogel mats: occupational release scenarios simulation and hazard implications

15:20 Connor Hewson (SurfaceMeasurementSystems)
Hysteresis effects in moisture sorption on silica gel materials

15:40 Christian Scherdel (CAE)
Recent developments in structural characterization of aerogels

16:00 Coffee break

16:20 Biopolymer aerogels (Chair: Carlos García González)

16:20 Gustav Nyström (Empa)
Nanocellulose Based Aerogels: Challenges and Opportunities

16:40 Marc Fricke (Aerogel-It)
Decarbonization of industries with green superinsulation

17:00 Zuzanna Sediva (Groam)
To be announced

17:20 Isaac Benito Gonzalez (AeroFybers)
Technological development of biodegradable aerogels in Aerofybers Technologies

17:40 Deeptanshu Sivaraman (Siloxene/Empa)
Hydrophobization of polysaccharide aerogels

18:30 Conference dinner

Friday, 2 June 2023

08:00 Registration

08:40 Markets and applications (Chair: Francisco Ruiz)

08:40 Reso Ibrahim (IDTech)
EV Batteries – the Key to Aerogels Commercial Success

09:00 Jun Shen (Tongji U.)
Several Chinese noteworthy progress in the application of aerogels

09:20 Kamal M. Seeni Meera (DLR)
Challenges in the up-scaling of Resorcinol-Formaldehyde aerogel micro-beads production by jet-cutting

09:40 Stephan Möller & Jayson Zheng (Ultima)
Rapid-Rise Fire Protection of structural Steel: advanced Aerogel Insulation Material and Heat-Flow Simulations

10:00 Luisa Durães (U. Coimbra)
Tailoring silica aerogels for cleaning water: prospects and challenges

10:20 Zeineb Ben Rejeb (U. Toronto)
Ambient-Dried Hybrid Silica Aerogels with Enhanced Mechanical Properties as Efficient Oil Sorbent

10:40 Coffee break

11:00 Round table

12:00 Lunch

12:45-13:30 AERoGELS Cost Action (NEST 022)
Core Group meeting (invitation only)

13:30 Aerogels for buildings (Chair: Jannis Wernery)

13:30 Zahra Mazrouei (Empa)
Silica aerogels for vibration damping and structure-borne sound insulation

13:50 Beat Kämpfen (KZ+partner)
Aerogel as part of a holistic energetical renovation

14:10 Alexander Müller (SUMTEQ) & Sebastian von Stauffenberg (AGITEC)
Sumfoam – first applications of a new class of nanoporous material

14:50 Genevieve Foray (INSA)
In operando 3D microscopy & tomography, a path way to meet the specifications of aerogel applications

15:10 Closing remarks

Aerogel Architecture Award 2023

16:00 Welcome speech
16:15 Presentations of winning projects
17:30 Summary of Jury and announcement of the winners
18:00 NEST tours
19:00 Reception

Continuous drying of bioaerogel particles

I.Smirnova, E. Diecke, D.Arigbe
Hamburg University of Technology, Germany

Abstract

The most cost-intensive step in aerogel production is the supercritical drying, which usually takes place in a time- and energy-consuming batch process. In our group a new concept for continuous drying of bioaerogel particles was developed based on the solid-liquid extraction principle in a counter-current flow. In previous studies, it was shown that a continuous supercritical drying of alginate microparticles in a column is possible [1]. In order to optimize the process, a deeper understanding of the system needs to be developed and the kinetics of the drying step should be studied in details. In particular, crucial for successful and efficient drying is the residence time of the particles in the column, which on the one hand has to be longer than the drying time, and short enough to ensure a high space-time yield on the other hand. Thereby, the residence time is influenced by numerous parameters, e.g. by the process parameters such as pressure, temperature, CO_2 flow rate or particle mass flow. In addition, particle parameters such as density, porosity and particle diameter play a role. To quantify the influence of these parameters and to determine the residence time, the column was equipped with two sighting cells. With the aid of fluorescent particles, which are used as tracers the residence time can be determined experimentally. With this approach, the analysis of various influencing parameters can be carried out and subsequently an optimization of the continuous drying process can proceed. Further, the detailed kinetics of the process can be measured with Raman spectroscopy and the data are applied for the process modelling.

References

[1] Mißfeldt, F., Gurikov, P., Lölsberg, W., Weinrich, D., Lied, F., Fricke, M., & Smirnova, I. (2020). Continuous Supercritical Drying of Aerogel Particles: Proof of Concept. Industrial & Engineering Chemistry Research, 59(24), 11284–11295

Acknowledgments

“Work partly carried out in the frame of the COST-Action "Advanced Engineering of aeroGels for Environment and Life Sciences" (AERoGELS, ref. CA18125) funded by the European Commission.”

Aerogel Launch Factory – future perspectives

Barbara Milow, Pascal Vöpel, Annie Münzberg

German Aerospace Center (DLR), Institute of Materials Research, Department of Aerogels and Aerogel Composites, Cologne, Germany

Abstract

Aerogels have been developed at a high level on a laboratory scale for many years. Nevertheless, only a few aerogel materials have found their way into industrial applications and are produced in sufficient quantities. Another larger number of applications for aerogels has already been identified and material developments are well advanced and almost ready for series production. What is lacking here is the necessary quantities of the materials to move forward. Pilot plant scale production is lacking because facilities of this size are limited and also not available to the community.

With the establishment of the Aerogel Launch Factory we will close the gap.

The concept is that the pilot plants will be set up in the immediate vicinity of the R&D-oriented laboratories for synthesis and characterization. Here, synergies can be exploited.

The presentation will discuss opportunities for collaboration in research, development and technology transfer. Future challenges are identified and the pragmatic approach to using the pilot plants is discussed.

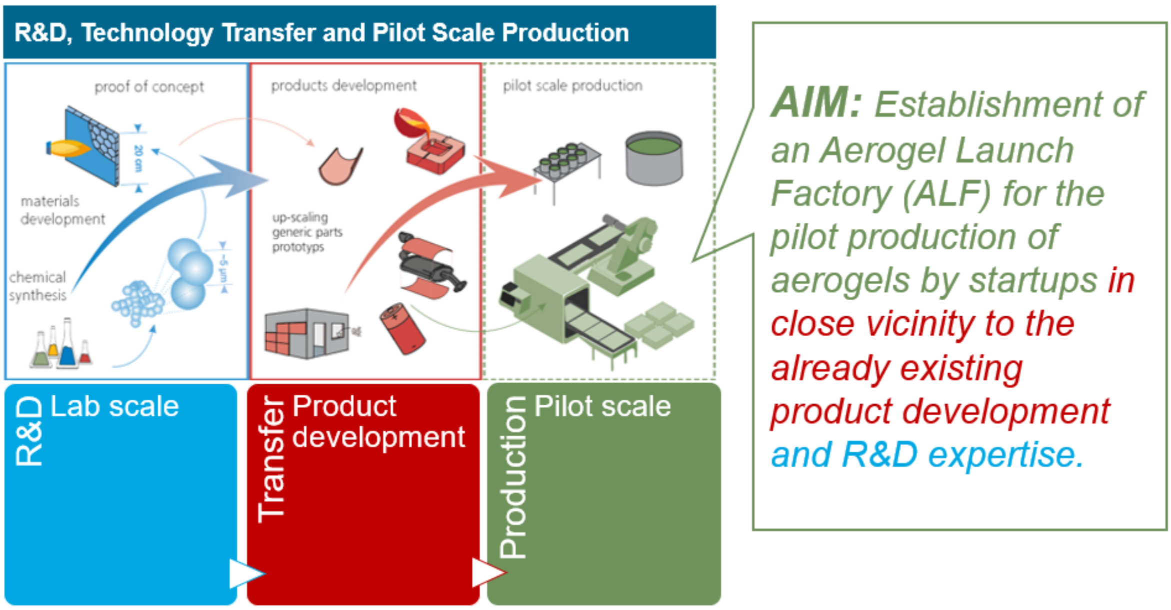


Fig. 1: Opportunities and impact of Aerogel Launch Factory (ALF)

EMPA AIA Submission abstract – Thermulon

Thermulon is a deep-tech start-up based in the North East of England and London working on the continuous production of silica aerogel materials. Created in part in response to the Grenfell Tower tragedy of 2017, Thermulon is developing ways to make homes both energy efficient to meet our climate goals, fire-safe, and affordable.

Additionally, UK Greenhouse gas emissions (GHGs) from buildings are some of the worst in Europe – with 87 MtCO2 equivalent release in 2019 which accounted for 17% of the UKs total GHGs. The UK has legally binding and enforceable emissions reduction targets to hit net-zero by 2050, but little credible plan at the moment.

The UK *can* deliver affordable and sustainable house heating with air-source heat pumps, but 80% of UK homes aren't heat pump ready due to poor insulation (BEIS, 2021). Insulating homes is paramount to reaching net zero and reducing fuel poverty. To do this, building retrofit rates need to increase from 26,000/year to 250,000/year (CfCC, 2020). Current materials failed to insulate the UK's buildings, with 90% of 8m solid wall buildings completely uninsulated (7m; 26% of housing).

Thermulon has developed a cost-effective and easy solution to insulate these houses by developing a novel continuous chemical process to reduce the cost of insulating aerogel. Already operating at large lab scale with promising Thermal Conductivity results, it is undertaking its first commercial trials with partners to integrate into a number of construction products with the aim of scaling it’s continuous production process over the next 18 months as it moves towards a pilot facility.

Insulating Translucent Aerogel Glass Brick for Building Envelopes

Michal Ganobjak[1],*, Wim J. Malfait [1], Janis Just[2], Marcel Käppeli[2], Francisco Mancebo[1], Samuel Brunner[1], Jannis Wernery [1]

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Abstract

Silica aerogels are thermal superinsulation materials that have found increasing application in the building sector in the last ten to fifteen years. While the most common material types are opaque insulating blankets and renders, in its monolithic form silica aerogel can be almost transparent, allowing for composite translucent insulating building system.

Here, we developed and characterized a novel modular, translucent and thermally insulating building component based on silica aerogel granules, the aerogel glass brick. Both thermal and mechanical properties were tested and the former were compared to a 3D simulation of the heat transfer through the brick. The glass brick has a measured thermal conductivity of 53 mW/(m·K), corresponding well to the simulation results of 51 mW/(m·K), and a compressive strength of almost 45 MPa. This makes the glass brick the insulating brick with the highest insulation performance reported in literature or available on the market, and at the same time adds the feature of light transmission.

The aerogel glass brick is suitable when the requirements combine daylighting, glare protection and the need to protect privacy, e.g. offices, libraries, museums; an analysis of the materials costs indicates that the insulating glass brick can be competitive in such applications. The glass brick provides architecture with new design opportunities to increase daylight inside buildings [1]

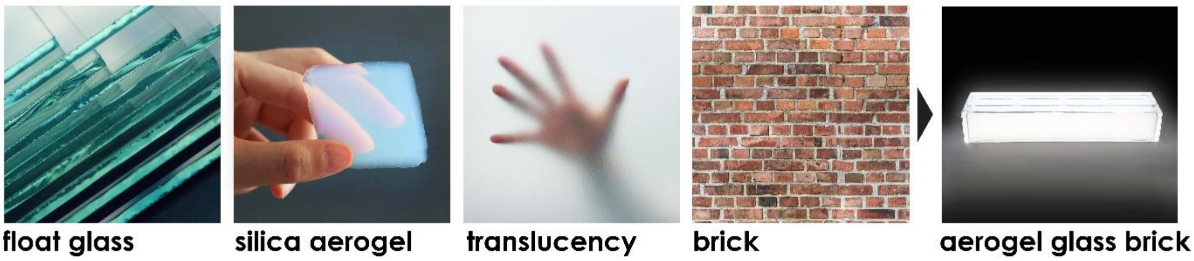

Fig 1. Combining properties of aerogel and glass, translucency and durability into modular, light-transmitting, and thermally insulating element [1]

References

[1] Michal Ganobjak, Wim J. Malfait, Janis Just, Marcel Käppeli, Francisco Mancebo, Samuel Brunner, Jannis Wernery, Get the light & keep the warmth - A highly insulating, translucent aerogel glass brick for building envelopes, Journal of Building Engineering, Volume 64, 2023, 105600, ISSN 2352-7102, https://doi.org/10.1016/j.jobe.2022.105600.

Acknowledgments

This research was supported by Velux Stiftung, project No. 1440 on development of thermal super-insulating translucent glass brick for diffusive daylight. The idea was developed with support of the European Union's Horizon 2020 Research and Innovation program under the Marie Skłodowska-Curie Actions, grant agreement No. 746992.

Aerogel from research labs to industry - IBIH's practice and contribution

Yunhong Wang
1 IBIH Advanced Material Co. Ltd, Hebei, China

Abstract

Aerogel was invented nearly 100 years ago, but for the first 70 years, it was mostly confined to research labs and produced only at small scales. Inspired by the goal to reach global Carbon Neutrality and making our future more sustainable, industry interest in aerogel has skyrocketed over the past 5 years. However, getting aerogel out of research labs into products and scaling up production to make it economically viable, especially for sustainable applications, brings its own set of technological challenges, requiring deep domain expertise and continued investment in R&D. The success of IBIH provides a good example for bringing aerogels from research labs to industry.

IBIH, based in Hebei, China, develops aerogels for a more sustainable, low-carbon future, with a focus on aerogel innovation and manufacturing technologies. IBIH is the market leader in aerogels for EV battery fire protection.

Since its inception, IBIH has chosen the renewable energy market to be its top priority. Researchers at IBIH have comprehensively studied the key pain points of power batteries and the unique advantages of aerogel, and the company joined forces with the leading EV battery manufacturers in China to develop cost-effective, lightweight products for better battery fire-protection, thermal insulation between cells and increased energy density. Thanks to its exceptionally low thermal conductivity and inflammability, aerogels are ideal for this application.

IBIH currently manufactures silica aerogels and EV battery fire protection pads at an annual capacity of more than 100 million pieces, with plans to further increase production capacity and expand its product portfolio. Other products that are being explored in strategic collaborations with EMPA and TUHH include low-cost silica aerogels, organic and bio aerogels.

3D Freeze Printing of Aerogel

Dong Lin[1]

1 Oregon State University, School of Mechanical, Industrial, and Manufacturing Engineering
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Abstract

Aerogels exhibit unique properties such as ultra-low density, high and tunable porosity, large surface area, low thermal conductivity, refractive index, and low dielectric constant, which make them suitable for many applications including energy storage and conversion, catalysis, sensors, and bio-engineering. The vision of tailoring the macrostructure of aerogels for broader applications has stimulated the research on the 3D printing of aerogels. Dr. Lin and his collaborators propose a novel printing methodology, namely 3D freeze printing (3DFP), that combines multi-nozzle inkjet/extrusion printing with freeze casting for 3D printing of aerogels with several key qualities, including continuous, boundary-free, controlled alignment of porosity, and truly 3D structures (e.g., 3D objects with overhang features) [1]. A high-speed X-ray imaging technique has been applied to reveal the process dynamics in the 3DFP process [2]. To date, the 3D printed aerogels have been successfully applied for Radomes for hypersonic vehicles, high-temperature ceramics, acoustic absorption, bone repair, energy storage, thermal insulation, chemical sensor, and chemical absorption.

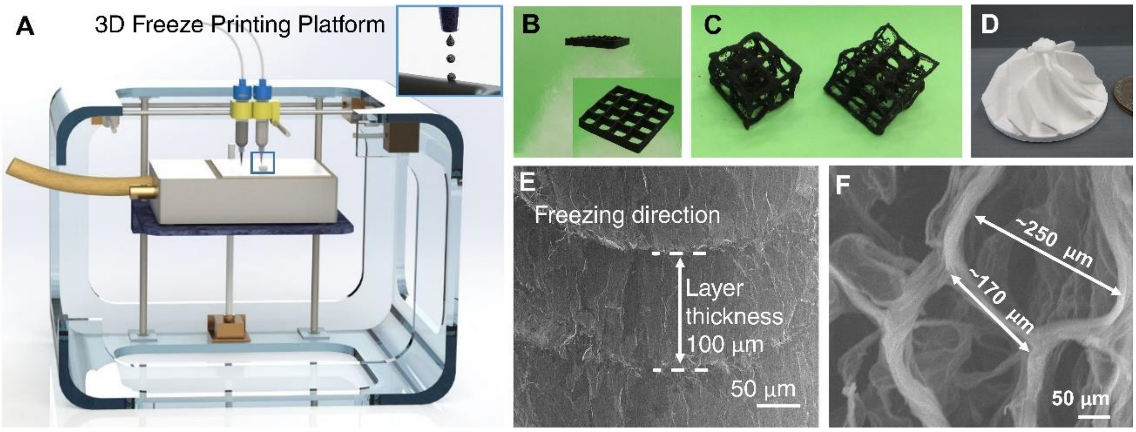

Fig 1. 3D Freeze Printing. (A) Schematic of 3D freeze printing platform. 3D freeze printed (B-C) graphene aerogels and (D) Silica aerogel. (E) Cross-sectional and (F) Surface morphology of printed graphene aerogels.

References

*[1] a)Q. Zhang, F. Zhang, S. P. Medarametla, H. Li, C. Zhou, D. Lin, Small **2016**, 12, 1702; b)P. Yan, E. Brown, Q. Su, J. Li, J. Wang, C. Xu, C. Zhou, D. Lin, Small **2017**, 13, 1701756; c)H. Tetik, K. Zhao, N. Shah, D. Lin, Journal of Manufacturing Processes **2021**, 68, 445; d)X. Song, H. Tetik, T. Jirakittsonthon, P. Parandoush, G. Yang, D. Lee, S. Ryu, S. Lei, M. L. Weiss, D. Lin, Advanced Engineering Materials **2019**, 21, 1800678; e)H. Tetik, J. Orangi, G. Yang, K. Zhao, S. B. Mujib, G. Singh, M. Beidaghi, D. Lin, Advanced Materials **2022**, 34, 2104980.*

*[2] H. Tetik, G. Yang, W. Tan, A. Fong, S. Lei, J. Nelson Weker, D. Lin, Additive Manufacturing **2020**, 36, 101513.*

Aerogels for the Hydrogen Economy: Applications in Fuel Cells and Electrolyzers

C. Erkey[1]

[1] *Department of Chemical and Biological Engineering, Koç University, Istanbul, Turkey*

Abstract

Hydrogen has been attracting increasing interest for energy storage and also as a fuel for decarbonization of many industries. Green hydrogen is obtained by splitting of water in electrolyzers using renewable energy. Hydrogen can also be fed to fuel cells to generate electricity with no green house gas emissions. Development of highly active electrocatalysts for PEM electrolyzers and fuel cells is necessary for widespread utilization of hydrogen. Nanostructured aerogels are a unique and versatile class of materials due to their very low density, high porosity, high surface area, open and interconnected pores. The ability to control their pore and surface properties makes them particularly attractive. Electrically conductive aerogels such as carbon, graphene and metal aerogels have a lot of potential for utilization as electrocatalysts or hosts(supports) to electrocatalytically active species in electrolyzers and fuel cells. It is also possible to utilize metal aerogels directly as electrocatalysts. High surface area and hierarchical pore structure of aerogels provides efficient control over the rates of diffusion of reactants and products and results in excellent dispersion and high accessibility of active sites while high electrical conductivity facilitates rapid electron transfer. The studies carried out in our laboratory and other laboratories on carbon aerogels derived from a wide variety of organic aerogels by pyrolysis and graphene aerogels will be described. Particularly, factors which control the electrochemical activities of aerogel supported Pt nanoparticles, aerogel supported dealloyed Pt nanoparticles and precious metal free aerogels for the oxygen reduction and hydrogen evolution reactions will be discussed. The application of newly emerging metal aerogels in fuel cells and electrolyzers will be presented.

Acknowledgments

In case of work in the frame of AERoGELS Action, please add the following statement: "Work carried out in the frame of the COST-Action "Advanced Engineering of aeroGels for Environment and Life Sciences" (AERoGELS, ref. CA18125) funded by the European Commission."

Title: Polyimide aerogel for thermal management and patch antenna

Tingting Wu[1], Michal Ganobjak[1], Mingxiang Gao[2], Gilberto Siqueira[3], Gustav Nyström[3], Anja K. Skrivervik[2], Wim J. Malfait[1*], Shanyu Zhao[1*]

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2 Microwaves and Antennas Group, École Polytechnique Fédérale de Lausanne, CH-1015, Lausanne, Switzerland;

3 Cellulose & Wood Materials Laboratory, Empa, CH-8600, Dübendorf, Switzerland;

Abstract

Polyimide aerogels exhibit an excellent combination of mechanical strength, high thermal stability (up to 400 °C), low thermal conductivity, and outstanding dielectric properties, implying their potential use as thermal insulators and/or dielectric substrates for batteries, antennas, and radomes. In this study, we presented a 3D assembly process based on the direct ink writing of 'aerogel-in-aerogel' nanocomposites to obtain customized polyimide-silica aerogels. Those aerogels are non-brittle (E=6.7 MPa), exhibit super-insulating thermal conductivity (20.3 mW m^{-1} K^{-1}) and high thermal stability ($T_{5wt\%}$ 447 °C). Additionally, the aerogel composites display excellent low-loss dielectric properties and microwave transmission over all relevant communication frequencies. The high shape-fidelity printing, combined with laser-induced etching of thermally conductive graphene layers or commercial silver paste, enables precise thermal management for portable electronics or maintains an extreme temperature gradient (-40 to +50 °C) across an mm-scale partition. Furthermore, the high electrical conductivity of the laser-induced graphene layer on the low-loss dielectric polyimide substrates allows for precise pattern design of lightweight patch antennas. These ultra-light patch antennas show great potential in aircraft and satellite communications due to their seamless integration of conductive graphene patterns and low-loss dielectric substrates.

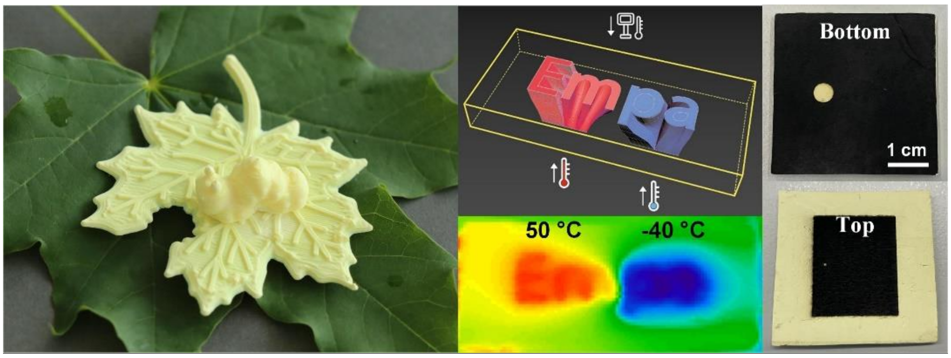

Fig 1. 3D printed polyimide aerogels (left), and their demonstration in thermal management through channeling (middle); laser-induced graphene pattern on polyimide aerogels for patch antennas (right).

References

[1] Z. Kantor, T. Wu, Z. Zeng, S. Gaan, S. Lehner, M. Jovic, A. Bonnin, Z. Pan, Z. Mazrouei-Sebdani, ... W. J. Malfait and S. Zhao, "Heterogeneous silica-polyimide aerogel-in-aerogel nanocomposites." Chemical Engineering Journal, vol. 443, pp.136401, 2022.
[2] T. Wu, M. Ganobjak, G. Siqueira, Z. Zeng, M. Li, E. Filimonova, S. Saghamanesh, A. Bonnin, D. Sivaraman, J. Yip, ... W. J. Malfait and S. Zhao, "3D Printed Polyimide Nanocomposite Aerogels for Electromagnetic Interference Shielding and Thermal Management." Advanced Materials Technologies, pp.2202155, 2023.

Advanced Processing of Aerogels for Drug Delivery

C.A. García-González[1], M. Carracedo-Pérez[1], C. Illanes-Bordomás[1], B. Gonçalves Bernardes[1,2], Th. Duong[1], A. Iglesias-Mejuto[1]

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Email: carlos.garcia@usc.es

Abstract

Aerogels have been recently recognized among the Top-10 emerging technologies by IUPAC Association. Their unique physicochemical properties of aerogels can be exploited for several biomedical applications, including drug delivery, regenerative medicine and biosensors. In terms of production, aerogels can be easily shaped to the intended morphology, scaled-up and have even the possibility of being manufactured under good manufacturing practices (GMP). In this work, recent advances and uses of medicated aerogels are outlined (Fig 1).

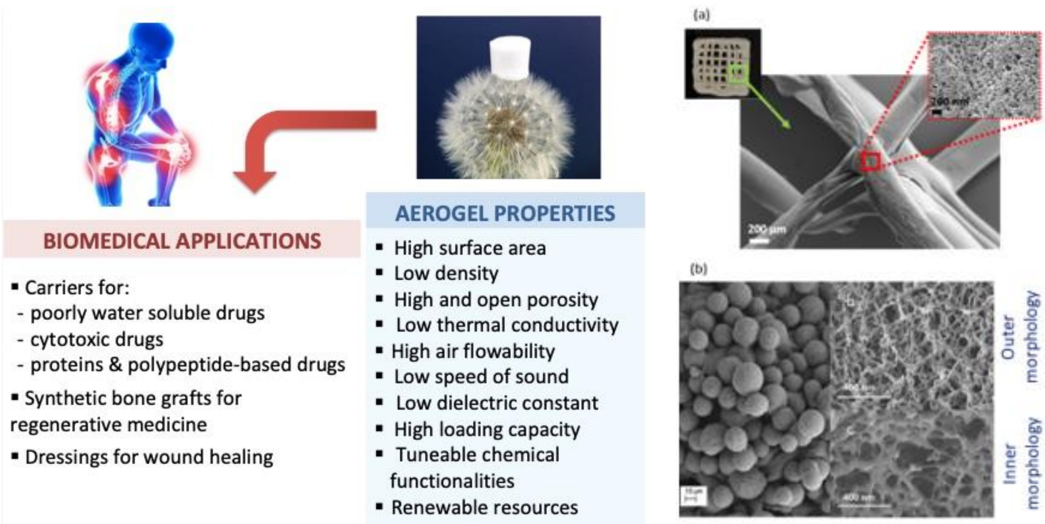

Fig 1. Potential applications of aerogels in drug delivery (left) and examples of medicated aerogels

References

[1] C.A. García-González et al. "Aerogels in drug delivery: From design to application". Journal of Controlled Release, vol. 332, 40-63, 2021.

Acknowledgments

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Alternative Sustainable Materials for SLA and Extrusion Printing: Carrier System Design for Antioxidants

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Abstract

3D printing (3DP) has opened new ways to fabricate complex geometrical structures in different fields, from food to biomedical applications. Unlike conventional methods, 3DP can transform computer-aided models into desired physical objects via layer-by-layer printing. Hydrogels are one of the most suitable classes of ink and photo-curable resin materials in Extrusion-based and Stereolithography (SLA) printing, respectively. SLA printing is based on a photopolymerization reaction for the fabrication of desired geometries. Hydrogels as excellent candidates for drug delivery, wound dressing, encapsulation of phenolic compounds, etc., could be manufactured by solidification of polymer resin upon exposure to UV light in SLA printer [1]. In recent years, the replacement of synthetic materials with nontoxic and sustainable alternatives in gel formulation is also a common issue. Especially, there are still debates about the toxicity of photo-initiators (PIs) used in resin formulations [2]. Regarding this concern, we confirmed the use of riboflavin as a natural PI in poly (ethylene glycol) dimethacrylate (PEGDMA) based light-induced gels to act as carriers for varying kinds of antioxidants (Fig. 1).

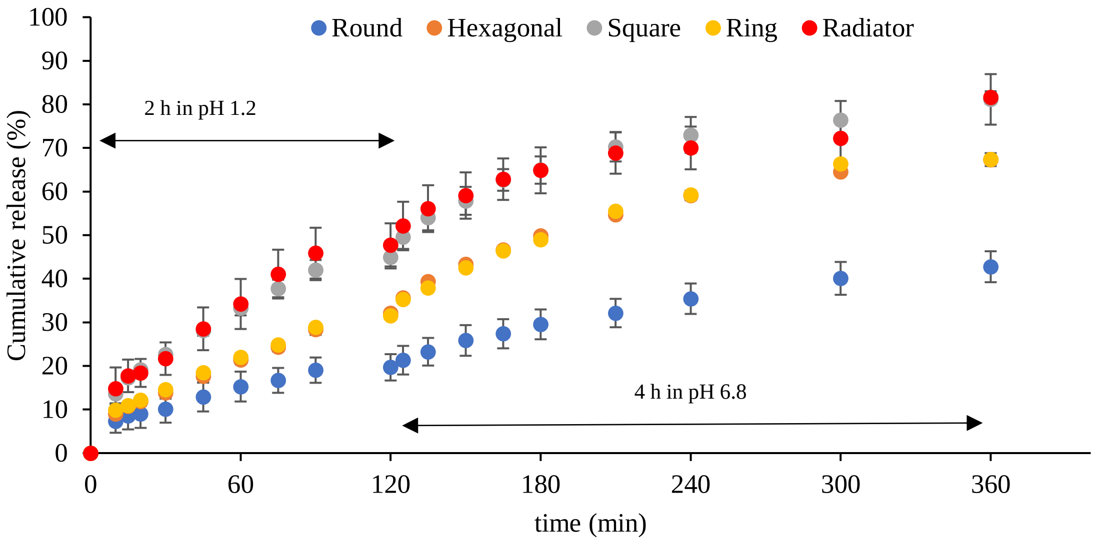

Fig 1. Representative image of model antioxidant release from the hydrogel under simulated gastrointestinal conditions

Secondly, the utilization of natural polymers in extrusion printing also offers a non-toxic, renewable, and biodegradable nature, but still, they might require the use of blends with two or more polymers to enhance their properties like printability, rheological and mechanical features [3]. Considering this purpose, we will give brief information about the printability of alginate/psyllium husk blend and lignocellulosic biomass incorporated ink formulations to be used in extrusion printing for antioxidant delivery applications under different environmental conditions. The mentioned concepts pave the way for future contributions in so many areas, in particular controlled release studies using pH-responsive behavior of the gels.

References

[1] I. Karakurt, A. Aydogdu, S. Cikrikci, J. Orozco, L. Lin, "Stereolithography (SLA) 3D printing of ascorbic acid loaded hydrogels: A controlled release study." Int. J. Pharm., 2020, 584, 119428
[2] A. Aydogdu Emir, S. Cikrikci Erunsal, "Impact of oleuropein on LCD-based stereolithography-assisted fabrication of 3D printed PEGDMA hydrogels." Eur. Poly. J., 2022, 180, 111592
[3] E. Bahcegul, G. Bahcegul and N. Ozkan, "3D printing of crude lignocellulosic biomass extracts containing hemicellulose and lignin." Industrial Crops and Products, 2022, 186, 115234.

Assessing the dust released from commercially relevant inorganic aerogel mats: occupational release scenarios simulation and hazard implications

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Abstract

Because of aerogel mats novelty in the global market, very little is known about worker exposure scenarios to aerosolized particulate matter. Due to their encapsulated use[1], these materials don't pose a threat to actual consumers. Instead, mat installation by professionals, during which different mechanical treatments are applied, can release aerosols in the respirable range, hence potential risks for inhalation exposure need to be assessed.[2]

We simulated occupational exposure in three realistic working scenarios for four Aerogel Mats, commercially relevant insulators, with different structural modifications, expected to enhance their performance. These mats are compared with two conventional stone wool insulators for Safe and Sustainable by Design (SSbD) purposes. Conventional insulation materials such as stone wool show a thermal conductivity between 30-40 $mWm^{-1}k^{-1}$, whereas inorganic aerogel mats can go lower than 20 $mWm^{-1}k^{-1}$, hence more than 2-fold improvement.[3]

Release tests included cutting using an insulation knife, and a circular saw, both relevant for the construction process, and sanding, to mimic a tear-down scenario. The aerogel dust collected from each experiment was used to address possible hazard implications by using two in chimico assays established from the GRACIOUS IATAs[4], 1) surface reactivity on human blood serum using the Ferric reducing ability of serum (FRAS) assay,[5] and 2) particle's dissolution kinetic under lung simulant conditions, to understand particle fate upon inhalation. [6-8]

We know that benefits provided by aerogel mats in terms of energy saving are of primary importance and align with the European Green Deal[9] and the sustainable development goals (SDGs)[10], therefore, special attention should be made during their design to balance safety and functionality.

We aim to provide guidance in the selection of criteria to be considered at the design phase of the product and, in the selection of assessment methods easily accessible to companies and start-ups for a safe and economically feasible business.

Fig 1. Cutting using a circular saw and sanding, inside a particle-free chamber. Aerosol release monitored in parallel by Optical particle sizer (OPS), Condensation particle counter (CPC) and Electrical low pressure impactor (ELPI)

References

1. Ibrahim M, Sayegh H, Bianco L et al. Hygrothermal performance of novel internal and external super-insulating systems: In-situ experimental study and 1D/2D numerical modeling. Applied Thermal Engineering 2019;1501306-1327.
2. Singh D, Marrocco A, Wohlleben W et al. Release of particulate matter from nano-enabled building materials (NEBMs) across their lifecycle: Potential occupational health and safety implications. Journal of Hazardous Materials 2022;422126771.
3. Baetens R, Jelle BP, Gustavsen A. Aerogel insulation for building applications: A state-of-the-art review. Energy and Buildings 2011;43(4):761-769.
4. Traas L, Vanhauten R. GRACIOUS framework blueprint, can be found under https://doi.org/10.5281/zenodo.5497615. 1.0 eds.2021.
5. Gandon A, Werle K, Neubauer N et al. Journal of Physics: Conference Series, 2017, pp 012033.
6. Keller JG, Wiemann M, Groeters S et al. Aerogels are not regulated as nanomaterials, but can be assessed by tiered testing and grouping strategies for nanomaterials. Nanoscale Advances 2021.
7. Keller JG, Graham UM, Koltermann-Jülly J et al. Predicting dissolution and transformation of inhaled nanoparticles in the lung using abiotic flow cells: The case of barium sulfate. Scientific Reports 2020;10(1):458.
8. Koltermann-Jülly J, Keller JG, Vennemann A et al. Abiotic dissolution rates of 24 (nano)forms of 6 substances compared to macrophage-assisted dissolution and in vivo pulmonary clearance_ Grouping by biodissolution and transformation. NanoImpact 2018;1229-41.
9. EU. The European green deal. COM (2019) 640 final. eds.2019.
10. Nations U. Sustainable development goals (SDG), it can be found under https://sdgs.un.org/goals. eds.2015.

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Hysteresis effects in moisture sorption on silica gel materials

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Abstract

Sorption isotherms describe the amount of vapour adsorbed or desorbed at different equilibrium concentrations (partial pressures) in the gas phase. Generally, one can distinguish between the adsorption isotherm (when the partial pressure is increased) and the desorption isotherm (when the partial pressure is decreased). In some cases, adsorption and desorption isotherm don't coincide. The difference between them is called hysteresis or hysteresis gap.

Hysteresis effects in vapour sorption on solid materials can have different causes. There are different mechanisms responsible for fundamental hysteresis effects and those most relevant to moisture sorption on silica gel materials will be discussed.

Moisture content strongly influence the quality of a wide variety of products, like food and pharmaceuticals which can be analysed using the Dynamic Vapor Sorption (DVS). A shelf-life model can be employed to test different product/packaging combinations with minimal time-consuming storage tests. This poster describes water adsorption and desorption on a solid. Mathematically, these processes could be described by the steady-state characteristics, i.e. a sorption isotherm, and the respective kinetic behaviour. The sorption isotherm describes the relationship between the water content in a solid at equilibrium and the relative humidity in the surrounding headspace which is different for every solid [1].

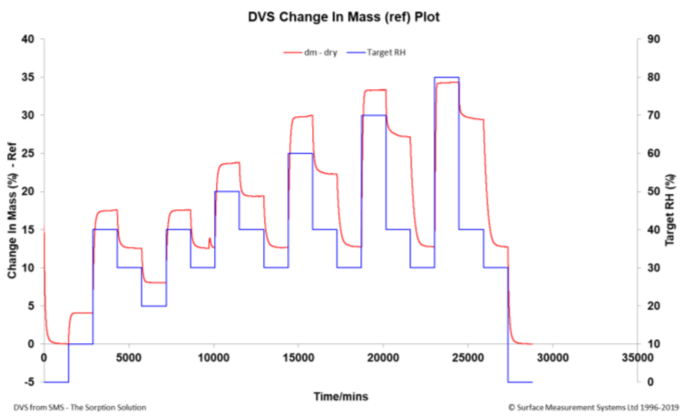

Fig 1. Water uptake on samples using the DVS

The RH profile contains different segments, with a change in the relative humidity from 0% to 80% measured as shown in Figure 1. Different step heights in RH are used to characterise the kinetics. The measured data is divided into 18 subsets, one for each new relative humidity condition applied. The 18 subsets are then regrouped into 6 parts, each containing 3 subsets. Only the relative humidity of the first subset of each group is different and varies between 10% and 80% relative humidity. The second subset of each group has always a relative humidity of 40%, the third subset of each group has always a relative humidity of 30%. Using the data, the equilibrium water content $w_{i,iso}$, and the reaction rate constant k are calculated and fitted using a model.

The DVS system has been used as a tool to show that the desorption kinetics of water on silica gel depends not only on the current RH, but also on the RH in the process, because of hysteresis effects. These results can also help by the design of more efficient packaging concepts for the preservation of a wide range of materials. It shows that more silica gel is needed to protect against drying compared to moisturizing the product because of the slower desorption kinetics of silica gel.

References

[1] A. Pöllmann, M. Reinelt and H. Briesen, "Investigation of the kinetics of hysteresis effects in silica gel, Materials, 2022, 15(17), 6031.

Acknowledgments

The work presented in this abstract was performed by Alexander Pöllmann, Matthias Reinelt and Heiko Briesen from TUM School of Life Science Weihenstephan and Fraunhofer Institute for Process Engineering and Packaging IVV. The experiments were performed at Surface Measurement Systems using the DVS instrument and permission has been granted to present their findings in this abstract. We would like to thank them for their hard work and cooperation.

Recent developments in structural characterization of aerogels

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Abstract

Reliable measurements of structural features of highly porous materials like aerogels are crucial for materials development. The knowledge of specific surface area, particle size, pore size and pore volume enables correlations and predictions of physical properties (e.g. thermal, electrical, mechanical).

To date, the most commonly used method for the determination of structural properties of aerogels is nitrogen adsorption. The reason therefore is its broad availability, user-friendly lab instruments and well-established standards e.g. for the specific surface area with BET (Brunauer-Emett-Teller) [1] or pore size distributions. However, Schlumberger et al. [2] showed that nitrogen adsorption (77 K) may overestimate the BET surface areas of silicas and other oxides in the order of > 20 % compared to Argon adsorption (87 K). Furthermore, length change of up to 50vol% of highly porous materials during adsorption can lead to misinterpretation of pore size distributions [3] as long as the isotherm data is not corrected.

As a complementary technique for structural characterization, small angle X-ray scattering (SAXS) draws more and more attention in porous materials development. Therefore standards for the determination of particle sizes (ISO 17867) and specific surface area (ISO 20804) are already published and further SAXS-standards are under development. The reliable determination of specific surface areas on silica model materials was published in Schlumberger et al. with good agreement of specific surface areas derived from Ar-adsorption (87 K) and SAXS (Fig 1) whereas N2-adsorption deviates from these two methods [2].

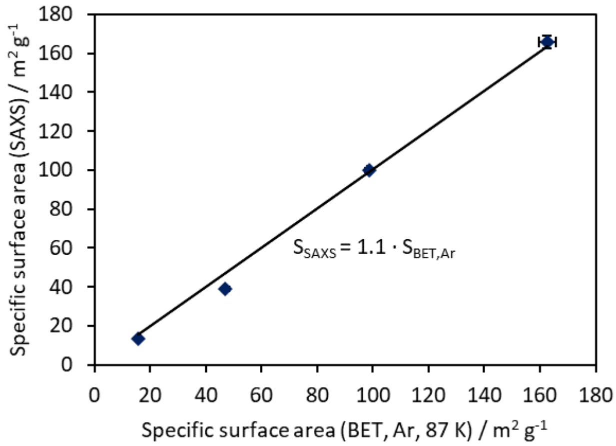

Fig 1. Specific surface areas of silica model materials derived from SAXS and Ar-adsorption [2].

References

[1] S. Brunauer, P.H. Emmett, E. Teller, J. Am. Chem. Soc. 60(2) (1938) 309-319.
[2] C. Schlumberger, C. Scherdel et al., Microporous Mesoporous Mater. 329 (2022).
[3] G. Reichenauer, G.W. Scherer, Colloids Surf. A, 187 (2001) 41-50.

Nanocellulose Based Aerogels: Challenges and Opportunities

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Abstract

Nanocellulose is a highly promising renewable biological colloid that can be used in a wide range of potentially sustainable materials. One way to optimize material functionality is through control of the assembly of nanocellulose during material fabrication, which may result in materials with high specific strengths and tunable optical and thermal properties.[1] Aerogels and foams are materials where nanocellulose has been considered promising due to its e.g. high aspect ratio, network forming ability and variable surface chemistry. This has inspired research and technological developments for both classical aerogel applications such as thermal insulation, but also emerging applications within for instance biomedicine and electromagnetic shielding. In this talk, I will provide a brief overview of the nanocellulose aerogel field using some of our research,[2-5] as well as that of other groups, as examples while critically assessing the main challenges that are limiting technological implementation, but also show some of the unique opportunities that this material class may offer within the aerogel space.

References

[1] K. De France, Z. Zeng, T. Wu, and G. Nyström. Functional Materials from Nanocellulose: Utilizing Structure-Property Relationships in Bottom-Up Fabrication. Advanced Materials, 33, 2000657 (2021).
[2] Z. Zeng, C. Wang, G. Siqueira, D. Han, A. Huch, S. Abdolhosseinzadeh, J. Heier, F. Nüesch, C. Zhang and G. Nyström. Nanocellulose-MXene Biomimetic Aerogels with Orientation-Tunable Electromagnetic Interference Shielding Performance. Advanced Science, 7:2000979 (2020).
[3] Z. Zeng, E. Mavrona, D. Sacré, N. Kummer, J. Cao, L. Müller, E. Hack, P. Zolliker, and G. Nyström. Terahertz Birefringent Biomimetic Aerogels based on Cellulose Nanofibers and Conductive Nanomaterials. ACS Nano, 15, 7451-7462 (2021).
[4] C. Antonini, T. Wu, T. Zimmermann, A. Kherbeche, M.-J. Thoraval, G. Nyström and T. Geiger. Ultra-Porous Nanocellulose Foams: A Facile and Scalable Fabrication Approach. Nanomaterials, 9:1142 (2019)
[5] T. Wu, Z. Zeng, G. Siqueira, K. De France, D. Sivaraman, C. Schreiner, R. Figi, Q. Zhang and G. Nyström. Dual-porous cellulose nanofibril aerogels via modular drying and cross-linking. Nanoscale, 12:7383-7394 (2020)

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Decarbonization of industries with green superinsulation

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Abstract

Resource and energy efficiency, carbon footprint reduction as well as product end-of-life solutions have become urgent sustainability challenges contemporary businesses face. This translates into a growing demand for new clean tech materials and solutions, which aerogel-it addresses with its aerogel materials for numerous applications. Novel bioaerogels based on natural raw materials such as lignin as well as robust polymer aerogels based on the proven SLENTITE® technology achieve outstanding performance in fields as varied as high-performance insulation or load and release of active substances. Recently, lignin bioaerogels have gained public interest since aerogel-it was able to convert lignin as an abundant side stream of the pulp and paper industry to a valuable high-performance insulation material for various industries where it combines energy efficiency and CO_2 reduction in-use with an inherently low CO_2 footprint compared to synthetic materials. aerogel-it is in the process of acquiring investment and setting up commercial production of the new aerogel materials.

Technological development of biodegradable aerogels in Aerofybers Technologies

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Abstract

The research interest in (nano)cellulose-based foams and aerogels is recent but rapidly growing. The combination of performance, tunable porous architecture and sustainability makes them of interest for a wide range of applications including e.g. biomedical scaffolds, thermal insulation and agronomic applications due to their biocompatibility, biodegradability and compostability [1], [2].

In this way, Aerofybers Technologies S.L. is a recent start-up company (2022) whose aim is to provide a sustainable alternative to conventional porous materials, in line with circular economy principles and the SDGs boosted by the EU. Our aerogels are based on biopolymers (mainly cellulose, although other alternatives such as agarose or alginate can be used) and can be coated by our patented method using alternative biopolymers such as PLA or PHB which confer the aerogels improved mechanical performance (up to 10-fold) and water-resistance (>100º contact angle), while maintaining their biodegradable character. Moreover, the coating methodology enables the incorporation of both hydrophilic and lipophilic bioactives [3] which can be specially relevant in agronomic or biomedical applications. The biodegradability of the newly developed porous materials is assessed to meet the requirements according to the standard ISO 20200.

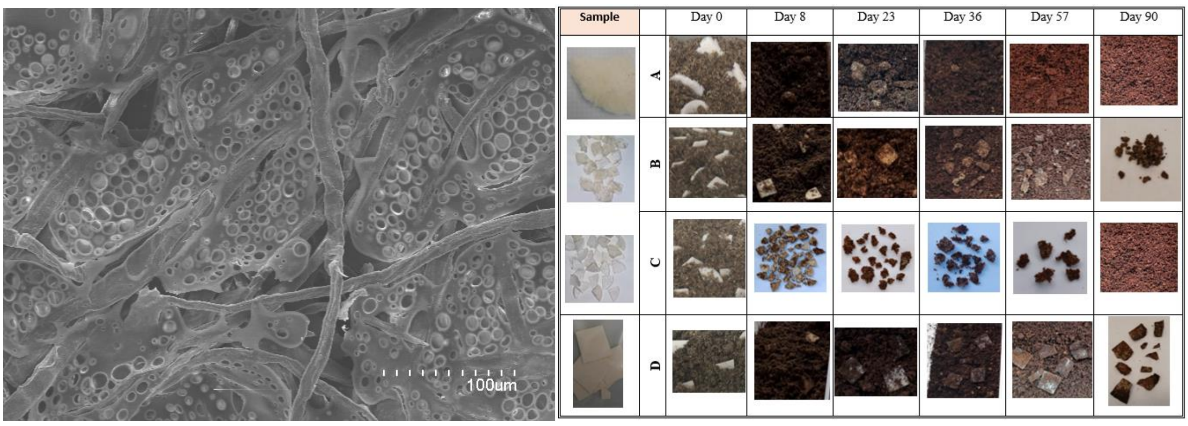

Fig 1. Microstructure (left) observed by SEM and biodegradability (right) of the coated aerogels.

References

[1] N. Lavoine and L. Bergström, "Nanocellulose-based foams and aerogels: Processing, properties, and applications," *J. Mater. Chem. A*, vol. 5, no. 31, pp. 16105–16117, 2017.

[2] T. Budtova, "Cellulose II aerogels: A review," *Cellulose*, vol. 26, no. 1, pp. 81–121, 2019.

[3] I. Benito-González, A. López-Rubio, P. Galarza-Jiménez, and M. Martínez-Sanz, "Multifunctional cellulosic aerogels from Posidonia oceanica waste biomass with antioxidant properties for meat preservation," *Int. J. Biol. Macromol.*, vol. 185, pp. 654–663, 2021.

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Hydrophobization of cellulose aerogels

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Abstract

The current aerogel market is dominated by silica aerogels, but have drawbacks in terms of fragility, cost and sustainability. Cellulose aerogels provide a lower-cost, biocompatible and biodegradable alternative for various applications, including building insulation, but their application potential is limited by the extreme sensitivity to liquid water and water vapor. With this study, we present a drop-in modular chemical hydrophobization technique for cellulose aerogels. Acid chlorides modify the surface hydroxyl groups of cellulose nanofibril (CNF) aerogels to create long-chain esters (C_6, C_{12}, C_{18}), in a simple post-gelation, pre-drying step. FTIR and solid-state NMR confirm grafting, with estimated ester contents of 19, 21 and 23 wt. %, corresponding to 0.42, 0.29 and 0.22 surface groups per D-glucose unit, for C_6, C_{12} and C_{18} respectively. The hydrophobized aerogels maintain their typical optical transparency (~72% transmittance at 600 nm). The water contact angle (WCA) increases from 0-20 to 125°, with a 3.5 times reduction in water vapor uptake and a 90% reduction in humidity induced shrinkage. The surface modification has no direct effect on thermal conductivity, beyond a small decrease that is consistent with known effects of densification. They also maintain their low thermal conductivity after prolonged treatment at high humidity conditions, unlike unmodified aerogels. Preliminary proof-of-concept studies on chitosan and alginate aerogels show that the hydrophobization protocol can be easily extended to other polysaccharide aerogels. The ability to easily protect biopolymer aerogels from degradation by water and humidity is a crucial stepping-stone towards commercially viable and sustainable aerogel insulation products.

Acknowledgments

In case of work in the frame of AERoGELS Action, please add the following statement: "Work carried out in the frame of the COST-Action "Advanced Engineering of aeroGels for Environment and Life Sciences" (AERoGELS, ref. CA18125) funded by the European Commission."

EV Batteries – the Key to Aerogels Commercial Success

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Abstract

Aerogels are not a new discovery, however the road to commercialization has been littered with past failings and seemingly insurmountable challenges. In 2023, the industry stands on the cusp of receiving greater commercial success led by new innovations, manufacturing maturity, and market drivers. The main market driver is the booming automotive EV battery demand, which is showing no signs of slowing down. IDTechEx forecasts the global automotive EV battery demand to exceed 2,600GWh by 2028[1], providing a huge addressable market.

Based in Cambridge, IDTechEx conduct technical market intelligence on a range of emerging technologies since 1999 and has provided the premier market research into the aerogel field.

This presentation will give an overview on the following:

- The current commercial status of the aerogel industry
- Key aerogel players
- Applications of aerogels in electric vehicle battery packs
- Global market outlook

References

[1] https://www.idtechex.com/en/research-report/electric-vehicles-land-sea-and-air-2022-2042/867

Several Chinese noteworthy progress in the application of aerogels

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Abstract

Aerogels are nanoporous materials which were initially prepared by Kistler in 1931. In recent years, aerogels are attracting more and more people because of the unprecedented global pressure of the problems of energy and environment. As the materials with the lowest thermal conductivity, aerogels are ideal materials for thermal insulations which can save energy, and incur to reduce carbon emissions. As the materials with high porosity and specific surface area, aerogels are ideal materials to adsorb poisonous molecules or ions in the air and water, which can be applied in environment protection. In this presentation, some noteworthy recent progress of preparation and application of aerogels in China are introduced, especially the low cost routings for mass scale production, nanostructure control of the materials, different composite techniques, typical applications, are introduced, such as high effective thermal insulations, environmental protection, catalysis, adsorbents, energy storage and conversion, sensors, biomedicine, safety and health, etc. The interactions of aerogels with electromagnetic wave, acoustic wave, intense laser and high-speed moving particles are also introduced.

References

[1] J. Shen, X. X. Zhang, "Recent progress and applications of aerogels in China," Journal of Sol-Gel Science and Technolog, https://doi.org/10.1007/s10971-021-05639-2, Oct. 2021.
[2] Z. Zhang, X. D. Wang, Y. Wu, W. B. Zou, X. L. Wu, J. Shen, "Aerogels and their applications – a short review," J. Chin. Ceram. Soc., 46(10), 1426-1446, 2018.

Challenges in the Up-scaling of Resorcinol-Formaldehyde Aerogel Micro-beads Production by Jet-Cutting Method

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Abstract

Carbon aerogels (CAs) are excellent materials with high surface area and unique microstructures consisting nano-particles and nano-pores. CAs find potential applications in catalysis, chromatography, energy, adsorbents, desalination, etc. In recent times, researchers focused on the development of CAs in the form of micro-spheres and/or micro-beads due to the reduction in process time and equipment costs for various applications. Carbon micro-beads are produced from coal or petroleum pitch by carbonizing at 350-500 °C to achieve mesophase spheres in pitch. The carbonization is quenched before an extensive growth and aggregation of the spheres and separated as solids from soluble pitch by extraction with a solvent. Carbon aerogel micro-beads of 1 μm to 3 mm are also fabricated by using an inverse emulsion gelation of resorcinol-formaldehyde (RF) solution at elevated temperatures followed by freeze drying or super-critical drying and subsequent carbonization. The freeze drying or super-critical drying techniques consume large amount of solvents, energy and time for the large scale production.

Fig. 1. Overview of the RF and Carbon Aerogel Micro-beads Production.

Herein, we report the development of RF aerogel micro-beads through dropping method. The shaping of RF sol solution into a micro-beads is quite challenging because of its low apparent viscosity (~ 0.5 Pa.s) and faster sol-gel transition. Hence, we aimed to improve the viscosity of the RF sol solution using a sustainable polysaccharide based thickener to achieve suitable viscosity (1 - 10 Pa.s) in-order to shape them into a micro-beads. The pre-gelled RF sol solution with various concentrations of thickener is dropped into an acid bath to form micro-beads followed by curing, washing and ambient pressure drying and carbonization. The ambient

pressure drying of the micro-beads is one of the greatest advantages of the process in-terms of low-cost. The overview of the RF and Carbon aerogel micro-beads production at the laboratory and large scale is depicted in Fig. 1. However, large scale production of RF aerogel micro-beads by Jet-Cutting method poses several challenges *viz.*, handling of enormous amounts of RF sol and acid bath, process parameter optimization, waste disposal, etc. Hence, we adopted low to high viscous alginate solution (0.5 - 3wt.%) with a viscosity ranging from 0.08 to 10 Pa.s, as a model system to optimize the Jet-Cutting parameters. The diameter of the beads (d_{bead}) can be described in eq. 1.

$$d_{bead} = \sqrt[3]{\frac{3}{2} D^2 \left(\frac{u_{fluid}}{n.Z} - d_{wire}\right)} \quad - - - - - - - - (1)$$

Where, D - diameter of the nozzle, u_{fluid} - fluid velocity, n - number of cutting wires, Z - number of cutting tool rotation, d_{wire} - *diameter* of the wire,

The operation of Jet-Cutter for the production of micro-beads with low-viscous fluid is no means of complicated. However, the fluid velocity, diameter of the nozzle and number of cutting tool rotation need to be understood. In the next step, large scale production of the RF micro-beads using Jet-Cutting method will be optimized and demonstrated.

References

[1] N. Liu, S. Zhang, R. Fu, M. S. Dresselhaus, G. Dresselhaus, "Carbon aerogel spheres prepared via alcohol supercritical drying," Carbon, vol. 44, no. 12, pp. 2430-2436, Oct. 2006.

[2] S. Chandrasekaran, P. G. Campbell, T. F. Baumann, M. A. Worsley, "Carbon aerogel evolution: Allotrope, graphene-inspired, and 3D-printed aerogels," J. Mater. Res., Vol. 32, No. 22, Nov. 2017

[3] S. T. Mayer, F-M. Kong, R. W. Pekala, J. L. Kaschmitter, "Organic aerogel microspheres and fabrication method therefore, " US patent 5508341, Apr. 1996.

[4] Seeni Meera Kamal Mohamed and Barbara Milow, "Herstellung von monodispersen Aerogelpartikeln," DP 10 2021 100 898.0, 2020 & PCT Anmeldung, 2022.

[5] T. Anklam, "Synthesis and characterization of resorcinol-formaldehyde (RF) and carbon aerogel micro-beads by dropping method," Master's Thesis, University of Cologne, Feb. 2021.

[6] U. Prüße, F. Bruske, J. Breford, K-D. Vorlop, "Improvement of the jet cutting method for the preparation of spherical particles from viscous polymer solutions," Chem. Eng. Technol. Vol. 21, no. 2, pp. 153-157, Feb. 1998.

[7] U. Prüße, B. Fox, M. Kirchhoff, F. Bruske, J. Breford, K-D. Vorlop, "New process (jet cutting method) for the production of spherical beads from highly viscous polymer solutions," Chem. Eng. Technol., vol. 21, no. 1, pp. 29-33, Jan. 1998.

Acknowledgments

This work is carried out within the framework of the project, **'FFAE' (Fokusanwendungen Fahrzeugstruktur Antriebsstrang Energiemanagement) under AP3420** funded by the **Programme Direction: Transport – DLR**. We wish to thank the support of Ms. Rebekka Probst (DLR) for SEM images and Mr. Benjamin Ignatzi (DLR) for the laboratory support.

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Fokusanwendungen Fahrzeugstruktur Antriebsstrang Energiemanagement

Rapid-Rise Fire Protection of structural Steel: advanced Aerogel Insulation Material and Heat-Flow Simulations

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Abstract

Armacell is the global leader in providing innovative, technical insulation solutions and components to conserve energy and make a difference around the world. Utilizing its innovative and patented technologies Armacell recently extended its portfolio with ArmaGel HTF, a significant addition to Passive Fire Protection of structural steel and pipework in rapid-rise fire scenarios. Its unique performance was proven in a series of rapid-rise fire tests according to the UL 1709[1] standard conducted at UL Labs, Rosenheim, Germany. Being able to withstand a furnace temperature of 1093°C without loss of integrity and protecting the underlying steelwork for more than 120 min. before it reaches the critical temperature of 538°C clearly demonstrated its capabilities in multiple combinations of steel massivities, with Hp/A ranging from 74,8 to 274,9 m^{-1}, and insulation thicknesses of 30 to 100 mm. We will present interpolated heat-flow simulations of selected Hp/A and insulation thickness combinations using COMSOL[2] software (fig. 1).

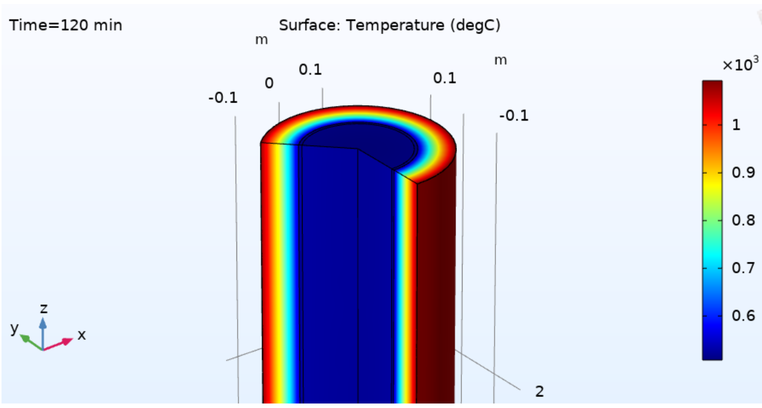

Figure 1. Heat-flow simulation using COMSOL Multiphysics.

References

[1] UL 1709, Standard for Safety Rapid Rise Fire Tests of Protection Materials for Structural Steel, 6th edition, August 8, 2022.
[2] COMSOL Multiphysics GmbH, COMSOL Multiphysics® Simulation Software, V 6.1.

Tailoring silica aerogels for cleaning water: prospects and challenges

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Abstract

Aerogels are known for their extremely high porosity, from 85 to 98 vol% of mesopores, which is a key feature to intensify surface-dependent processes like adsorption [1-4]. Wastewater treatment and drinking water cleaning by high-surface area adsorbents is seen as a simple and efficient advanced technique when the pollutants persist after conventional treatments or are in very low concentrations. In the case of silica aerogels, there are additional advantages as negligible toxicity and tailorable surface chemistry for more effectiveness. In this work, selected case studies of design of organically modified silica aerogels for capture of different types of pollutants in water will allow to highlight the high versatility and suitability of these materials for this application. Moreover, their limitations and challenges for technology transfer to effective application in the industrial context will be analyzed. As shown in Figure 1, the number of publications devoted to the study of silica aerogels for remediation of water systems is gradually increasing, mainly due to environmental emergency, high versatility and reuse option [1-4].

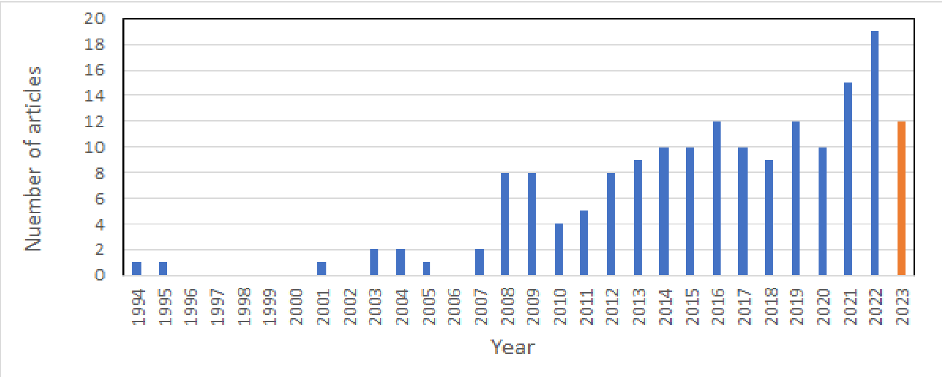

Fig 1. Number of articles per year obtained with the following search criteria in Web of Science: (TI=(aerogel) AND TI=(silica*)) AND (TS=(*water*) OR TS=(aqueous) OR TS=(aqua*)) AND (TI=(clean*) OR TI=(remediation) OR TI=(recover*) OR TI=(removal) OR TI=(pollutant*) OR TI=(treatment*) OR TI=(*sorption) OR TI=(environment*)) (TI= Title; TS= Topic; date of search: 02-05-2023).*

References

[1] F. Akhter et al., Environ Sci Pollution Res vol. 30, pp. 11226–11245, 2023.
[2] A.S. Jatoi et al., J Porous Mater vol. 28, pp. 1919-1933, 2021.
[3] R. Ganasamoorthy et al., J Cleaner Production vol. 329, 129713, 2021.
[4] P. Fraco et al., Molecules vol. 26, 4440, 2021.

Acknowledgments

Work *supported by the* COST-Action "Advanced Engineering of aeroGels for Environment and Life Sciences" (AERoGELS, ref. CA18125) funded by the European Commission. This work was also supported by the European Regional Development Fund, through COMPETE 2020, combined with Portuguese National Funds, through Fundação para a Ciência e Tecnologia, I.P. [POCI-01-0145-FEDER-006910; UID/EQU/00102/2020; UIDB/00313/2020; UIDP/00313/2020].

Ambient-Dried Hybrid Silica Aerogels with Enhanced Mechanical Properties as Efficient Oil Sorbent

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Abstract

Due to their 3D interconnected porous structure, low density, large specific surface area, and tunable surface chemistry, silica aerogels (SAs) can be excellent adsorbents for wastewater remediation applications. However, such practical applications of SAs are restricted by their brittleness and their weak mechanical properties, as well as the high costs associated with their synthesis. In this study, we report the development of new ambient-dried, stretchable, and compressible bridged SAs with fine-tuned physicochemical, structural, morphological, and thermal features, as well as adjustable surface wettability. The aerogels' synthesis was achieved by integrating different flexible organic molecular spacers within the silica network through a thiol-ene click chemistry strategy. The obtained SAs exhibit light weight, adjustable thermal conductivity, remarkable flexibility, and high hydrophobicity. In fact, due to the presence of various tailorable flexible molecular bridges and a large number of methyl groups in the silica network, our rationally designed SAs have demonstrated high compressibility and mechanical resilience, allowing them to withstand many fatigue cycles at a compressive strain up to 90% without any fracture. Moreover, our engineered SAs exhibit excellent hydrophobic-oleophilic properties, offering efficient oil-water separation with large oil sorption capacity, fast oil sorption rate, and exceptional regeneration and reuse abilities. The observed properties and performances of our synthesized SAs make them excellent candidates for large scale oil spill recovery applications.

Key words: Flexible aerogels, silica aerogels, molecular bridging, hydrophobic, water remediation

An investigation into the use of silica aerogels to reduce building vibration

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Abstract

Using silica aerogels means obtaining a low-density, highly mesoporous (<50 nm) material. The market for aerogels is driven primarily by thermal insulation, but they may also be useful for acoustic insulation. In most acoustic research on aerogels, airborne sound absorption is studied, but their potential for dampening or isolating structure-borne sound and vibration has not been explored [1, 2]. Here, the vibroacoustic properties of a bed of silica aerogel granules were determined and the performance contrasted with that of recycled rubber. The resonance frequency, dynamic stiffness, and transmissibility were determined by forcing vibrations of a mass-spring-damper system. The particle sizes and structural properties were examined by nitrogen sorption analysis and sieving, before and after vibration testing. The results indicate a strong potential of aerogel-based materials for vibration isolation performance with very low dynamic stiffness and very low resonance frequencies. Therefore, they showed better performance in comparison with rubber granules, and similar in comparison with the highly engineered polyurethane foams, but over a much wider range of static loads. To conclude, high-performance vibration isolation provides a real opportunity for silica aerogel to move beyond its established thermal insulation market. However, this potential needs further research to be unlocked.

References

[1] Z. Mazrouei-Sebdani, H. Begum, S. Schoenwald, K. V. Horoshenkov, W. J. Malfait, "A review on silica aerogel-based materials for acoustic applications," Journal of Non-Crystalline Solids, vol. 562, pp. 120770, Jun. 2021.

[2] Z. Mazrouei-Sebdani, M. Naeimirad, S. Peterek, H. Begum, S. Galmarini, F. Pursche, E. Baskin, S. Zhao, T. Gries, W.J. Malfait, "Multiple assembly strategies for silica aerogel-fiber combinations–a review," Materials & Design, vol. 223, pp. 111228, Nov. 2022.

Acknowledgments

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Aerogel as part of a holistic energetical renovation

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Abstract

Aerogel is a wonderful material to respect historic monuments. But it helps to sustain the qualities of buldings of the last century as well. The catholic parochial center of the Holy Spirit in Zurich-Hoengg was built in 1973, just before the first oil crisis. Fifty years later a profound energetical renovation was necessary. For many years, the responsible persons have been conscious about the challenges of climate change and have realized already in 1999 a photovoltaic installation on the roof of the church. As shown in the scheme a successful energetical improvement needs a lot of different parts and components working together. Not only the building envelope has to be improved, but also the technical systems have to be replaced and shifted to the renewable energies.

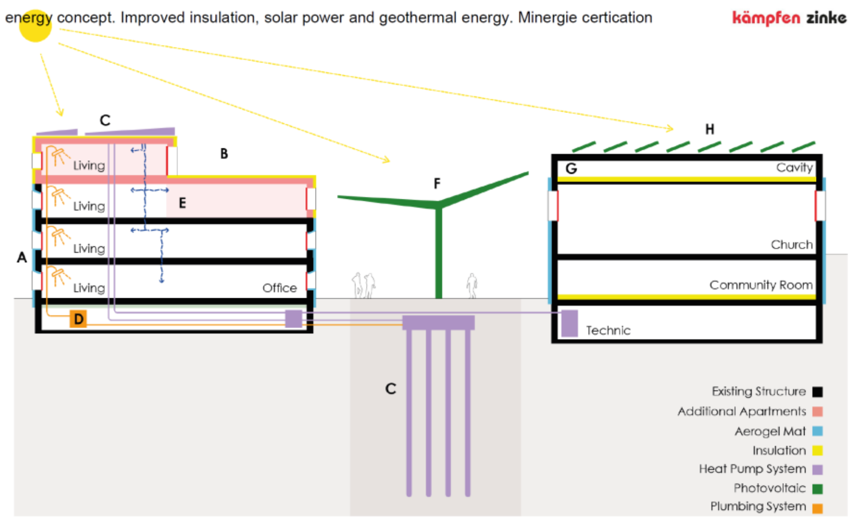

Fig 1. Optional First figure that explains it all

By using the thin aerogel material, energy losses can be minimized and at the same time the architectural expression can be respected. For instance, the roof finishings had not to be adapted and the windows had not to be reduced. Different other measures were taken, so replacing the fossile heating system by a heat pump, supported by solar collectors on the roof. The most important argument is that, if ever possible, buildings have to be restored, transformed or even enlarged instead of demolished and replaced by new ones. The check of the consumed grey energy speaks always in favour of energetical transformation.

References

Energetical renovation Pfarreizentrum Heilig Geist, Zürich-Hoengg 1917 – 1921.
Architects: Kämpfen Zinke + Partner, Zürich. www.kaempfen.com

Sumfoam – first applications of a new class of nanoporous material

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Abstract

As part of a cooperation between SUMTEQ GmbH and AGITEC AG, sustainable projects in the field of building insulation are being implemented. With the new material class Sumfoam - the first scalable nanoporous polymer foam - the manufacturer SUMTEQ offers products with exceptional thermal insulation properties. The foam granulate is ground into different particle sizes from 4 mm down to fractions < 3 mm or compressed into molded parts depending on the field of application, enabling energy-saving insulation with lambda values of < 25 mW/mK in bulk or even below 20 mW/mK as a panel.

The focus of the collaboration is currently on blow-in insulation, as retrofit insulation of double-skin masonry walls, and on high-performance insulation panels.

This presentation will provide insights into the latest developments in the field of building insulation and how Sumfoam and AGITEC can jointly contribute to a sustainable future.

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Fig 1. Sumfoam granulate

Challenges in the Up-scaling of Resorcinol-Formaldehyde Aerogel Micro-beads Production by Jet-Cutting Method

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Abstract

Carbon aerogels (CAs) are excellent materials with high surface area and unique microstructures consisting nano-particles and nano-pores. CAs find potential applications in catalysis, chromatography, energy, adsorbents, desalination, etc. In recent times, researchers focused on the development of CAs in the form of micro-spheres and/or micro-beads due to the reduction in process time and equipment costs for various applications. Carbon micro-beads are produced from coal or petroleum pitch by carbonizing at 350-500 °C to achieve mesophase spheres in pitch. The carbonization is quenched before an extensive growth and aggregation of the spheres and separated as solids from soluble pitch by extraction with a solvent. Carbon aerogel micro-beads of 1 μm to 3 mm are also fabricated by using an inverse emulsion gelation of resorcinol-formaldehyde (RF) solution at elevated temperatures followed by freeze drying or super-critical drying and subsequent carbonization. The freeze drying or super-critical drying techniques consume large amount of solvents, energy and time for the large scale production.

Fig. 1. Overview of the RF and Carbon Aerogel Micro-beads Production.

Herein, we report the development of RF aerogel micro-beads through dropping method. The shaping of RF sol solution into a micro-beads is quite challenging because of its low apparent viscosity (~ 0.5 Pa.s) and faster sol-gel transition. Hence, we aimed to improve the viscosity of the RF sol solution using a sustainable polysaccharide based thickener to achieve suitable viscosity (1 - 10 Pa.s) in-order to shape them into a micro-beads. The pre-gelled RF sol solution with various concentrations of thickener is dropped into an acid bath to form micro-beads followed by curing, washing and ambient pressure drying and carbonization. The ambient

pressure drying of the micro-beads is one of the greatest advantages of the process in-terms of low-cost. The overview of the RF and Carbon aerogel micro-beads production at the laboratory and large scale is depicted in Fig. 1. However, large scale production of RF aerogel micro-beads by Jet-Cutting method poses several challenges *viz.*, handling of enormous amounts of RF sol and acid bath, process parameter optimization, waste disposal, etc. Hence, we adopted low to high viscous alginate solution (0.5 - 3wt.%) with a viscosity ranging from 0.08 to 10 Pa.s, as a model system to optimize the Jet-Cutting parameters. The diameter of the beads (d_{bead}) can be described in eq. 1.

$$\boldsymbol{d_{bead}} = \sqrt[3]{\frac{\boldsymbol{3}}{\boldsymbol{2}}\,\boldsymbol{D^2}\left(\frac{\boldsymbol{u_{fluid}}}{\boldsymbol{n.Z}} - \boldsymbol{d_{wire}}\right)} \quad - - - - - - - - (\boldsymbol{1})$$

Where, D - diameter of the nozzle, u_{fluid} - fluid velocity, n - number of cutting wires, Z - number of cutting tool rotation, d_{wire} - *diameter* of the wire,

The operation of Jet-Cutter for the production of micro-beads with low-viscous fluid is no means of complicated. However, the fluid velocity, diameter of the nozzle and number of cutting tool rotation need to be understood. In the next step, large scale production of the RF micro-beads using Jet-Cutting method will be optimized and demonstrated.

References

[1] N. Liu, S. Zhang, R. Fu, M. S. Dresselhaus, G. Dresselhaus, "Carbon aerogel spheres prepared via alcohol supercritical drying," Carbon, vol. 44, no. 12, pp. 2430-2436, Oct. 2006.

[2] S. Chandrasekaran, P. G. Campbell, T. F. Baumann, M. A. Worsley, "Carbon aerogel evolution: Allotrope, graphene-inspired, and 3D-printed aerogels," J. Mater. Res., Vol. 32, No. 22, Nov. 2017

[3] S. T. Mayer, F-M. Kong, R. W. Pekala, J. L. Kaschmitter, "Organic aerogel microspheres and fabrication method therefore, " US patent 5508341, Apr. 1996.

[4] Seeni Meera Kamal Mohamed and Barbara Milow, "Herstellung von monodispersen Aerogelpartikeln," DP 10 2021 100 898.0, 2020 & PCT Anmeldung, 2022.

[5] T. Anklam, "Synthesis and characterization of resorcinol-formaldehyde (RF) and carbon aerogel micro-beads by dropping method," Master's Thesis, University of Cologne, Feb. 2021.

[6] U. Prüße, F. Bruske, J. Breford, K-D. Vorlop, "Improvement of the jet cutting method for the preparation of spherical particles from viscous polymer solutions," Chem. Eng. Technol. Vol. 21, no. 2, pp. 153-157, Feb. 1998.

[7] U. Prüße, B. Fox, M. Kirchhoff, F. Bruske, J. Breford, K-D. Vorlop, "New process (jet cutting method) for the production of spherical beads from highly viscous polymer solutions," Chem. Eng. Technol., vol. 21, no. 1, pp. 29-33, Jan. 1998.

Acknowledgments

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Vacuum glazing with silica aerogel pillars

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Abstract

To provide a novel approach to evacuated window systems, highly transparent supports are required to keep the two glass panes of the window at distance (2 to 3 cm). One option for these supports are silica aerogels. The requirement profile for the supports are:

- optical transparency (visible spectrum): > 0.50 at a thickness of 2 cm (image quality, not translucency)
- mechanical stiffness: can withstand 1 MPa (1 bar) external uniaxial load at compressive strain < 5%
- thermal conductivity (ambient conditions): < 0.035 W/(m·K)

The synthesis of the aerogels was performed with TEOS as precursor by applying a 2-step process and subsequent supercritical drying with CO_2. By variation of synthesis parameters, a silica aerogel with a Young's modulus of 24.6 MPa, a visual transmission of 0.67 and a thermal conductivity of 0.0206 W/(m·K) was developed. These silica aerogels do not crack up to an external load of 1 MPa, at which they show a compressive strain less than 5% thus fulfilling the previously defined requirement profile. These silica aerogels were used in vacuum glazing where the window panes are only partially supported by the aerogel pillars (< 50%). Simulations predict U_g-values down to 0.5 $Wm^{-2}K^{-1}$ for the window element, which is comparable or even lower than for current triple glazing.

Fig 1. Demonstrator of vacuum glazing with transparent silica aerogel pillars.

The questionable accuracy of thermal conductivity data in the aerogel literature: a call to action!

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Abstract

Aerogels are an exciting class of materials with record-breaking properties including, in some cases, ultra-low thermal conductivities. The last decade has seen a veritable explosion in aerogel research and industry R&D, and aerogels can now be synthesized from a variety of materials for a rapidly expanding range of applications. However, both from the research side, and certainly from a market perspective, thermal insulation remains the dominant application. Unfortunately, continued progress in this area is severely hampered by the proliferation of incorrect thermal conductivity data, with values that often are far outside of what is possible within the physical limitations. The loss of credibility of thermal conductivity data in the scientific literature makes it very difficult to compare the performance of different types of aerogels and other superinsulators, which may set back further scientific progress and hinder the technology transfer to industry and society. Here, we compile over 330 thermal conductivity results on silica, other inorganic, biopolymer and synthetic polymer aerogels from 55 research papers to highlight the extent of the problem. Thermal conductivity data outside of what is physically possible are common, even in high profile journals and from the world's best universities. Almost all implausible data are derived from transient methods. Guidelines on how to acquire more accurate thermal conductivity data are provided. This paper is a call to authors, reviewers, editors and readers to exercise caution and skepticism when they report, publish or interpret thermal conductivity data.

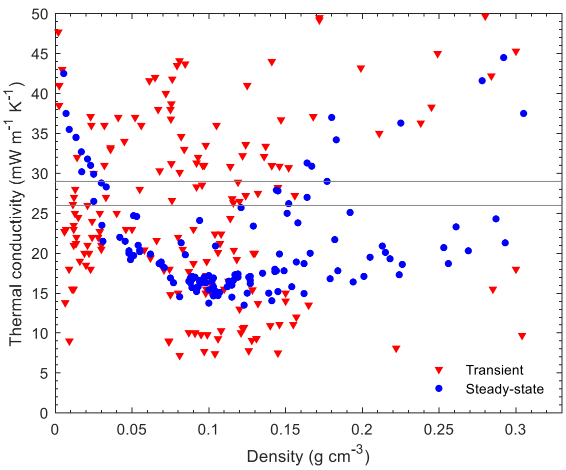

Figure 1. Thermal conductivity of biopolymer, synthetic polymer, silica and other inorganic aerogels, and their hybrids (Table S1 for data sources). Horizontal lines denote the thermal conductivity of standing air and conventional insulation (26 and 29 mW m^{-1} K^{-1}). Data grouped by measurement technique.

Title: Adsorption and surface mobility of CO_2 in pores of amorphous silica with different surface functional groups – tailoring of a sorbent to the application

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Abstract

Recent rapid climate change related to anthropogenic carbon dioxide (CO_2) emissions imposes a great challenge on humankind. An energetic transformation toward low-emission electricity sources may significantly reduce the CO_2 emission; however, a complete and immediate transition from fossil fuels burning for electricity generation is not possible. Similarly, ceasing the dispersed emissions, including in agriculture and mining sectors, is implausible even in the long term. Carbon capture from flue gases and directly from the air via adsorption could address both of these problems.

Silica aerogels are highly-porous (up to 99%) amorphous materials characterized by pore size distribution typically in the 2-50 nm range. These characteristics result in a very low density (lower than 0.5 g/cm^3) and a very high specific surface area (typically in the order of 1000 m^2/g). The high porosity and specific surface area make aerogels suitable adsorbents for gas separation and carbon capture. Additionally, the surface of the pores can be functionalized with different groups, modifying the surface properties of the adsorbent, thus, adsorption selectivity. Hydroxyl (-OH) and ethoxyl ($-OCH_2-CH_3$) are among the most common surface groups found on silica substrates synthesized from the tetraethyl orthosilicate precursor. Particular emphasis is placed on the effect of the amorphous surface features. Recently, we have demonstrated by Molecular Dynamics (MD) simulations the differences between the adsorption of CO_2 in crystalline (Fig 1a) and amorphous (Fig 1b) silica nanopores [1]. In contrast to crystals, amorphous surfaces are characterized by a disordered structure that dictates adsorption behavior at the surface. As a result, the adsorption patterns of the gas at the amorphous pore surfaces are irregular and difficult to characterize. From an application point of view, the heterogeneous features of the amorphous nanosurfaces (e.g., roughness, functional groups, hydroxyl groups, oxygen vacancies) locally enhance CO_2 adsorption. A recent work [2] showed the potential of hydrophilic (high-density of -OH groups) and hydrophobic (high density of $-OCH_2-CH_3$) membranes for fluid separation.

We will discuss the possible pathways of experimental validation of sorption models and extensions of the models for further functionalization of the adsorbent, allowing tailoring of the sorbent to the application and process boundary conditions (e.g., grafting of trimethylsilyl groups for enhanced hydrophobization, thus decreasing water cosorption or grafting of amino groups for enhanced selectivity towards CO_2).

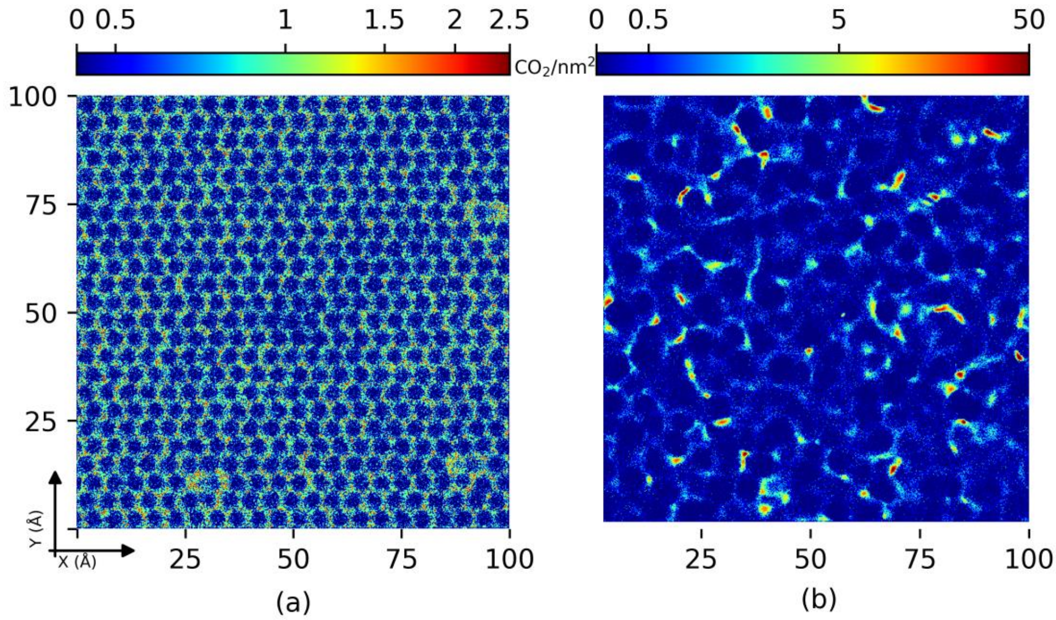

Fig 1. CO_2 density maps: regular patterns at the crystalline surface (a), irregular patterns at the amorphous surface (b)

References

[1] M. Turchi, S. Galmarini, and I. Lunati, "Amorphous matters: surface defects in nanopores enhance CO2 adsorption" to be submitted (2023).
[2] E. Loccufier, J. Geltmeyer, L. Daelemans, D. R. D'hooge, K. De Buysser, K. De Clerck "Silica nanofibrous membranes for the separation of heterogeneous azeotropes" Advanced Functional Materials vol. 28 no. 44, p.p. 1804138, 2018.

Superflexible hybrid aerogel-based fabrics enable broadband electromagnetic wave management

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Abstract

Broadband electromagnetic wave (EMW) management aerogels have received extensive attention in the safety and thermal management fields, but the mismatch in terms of their mechanical flexibility and functionality has limited their application. This work reports an ultralightweight (8.7 $mg{\cdot}cm^{-3}$), superflexible, hyperelastic ($\geqslant$ 95% strain), and superhydrophobic (contact angle: 157°) wearable hybrid aerogel-based fabric that offers both electromagnetic interference (EMI) shielding and thermal insulation functions. A nanotape-enabled multi-crosslinked hybridization strategy, in which freeze-drying-initiated hydrophobic -Si-O-Si- nanotape welds weak bacterial nanocellulose-silver nanowire interfaces perfectly, gives the fabric outstanding mechanical properties. Optimized synergy gain engineering between the metal and the semiconductor (antimony tin oxide nanoparticles) produces significant enhancements in the electrical conductivity (502.46 $S\ m^{-1}$), the EMI shielding effectiveness (SE, 100 dB), and the thermal insulation performance (ultralow thermal conductivity of 0.025 $W\ m^{-1}\ K^{-1}$) of the fabric. The hybrid aerogel-based fabric is fabricated into broadband EMW management clothing, which has excellent prospects for safety and thermal management applications.

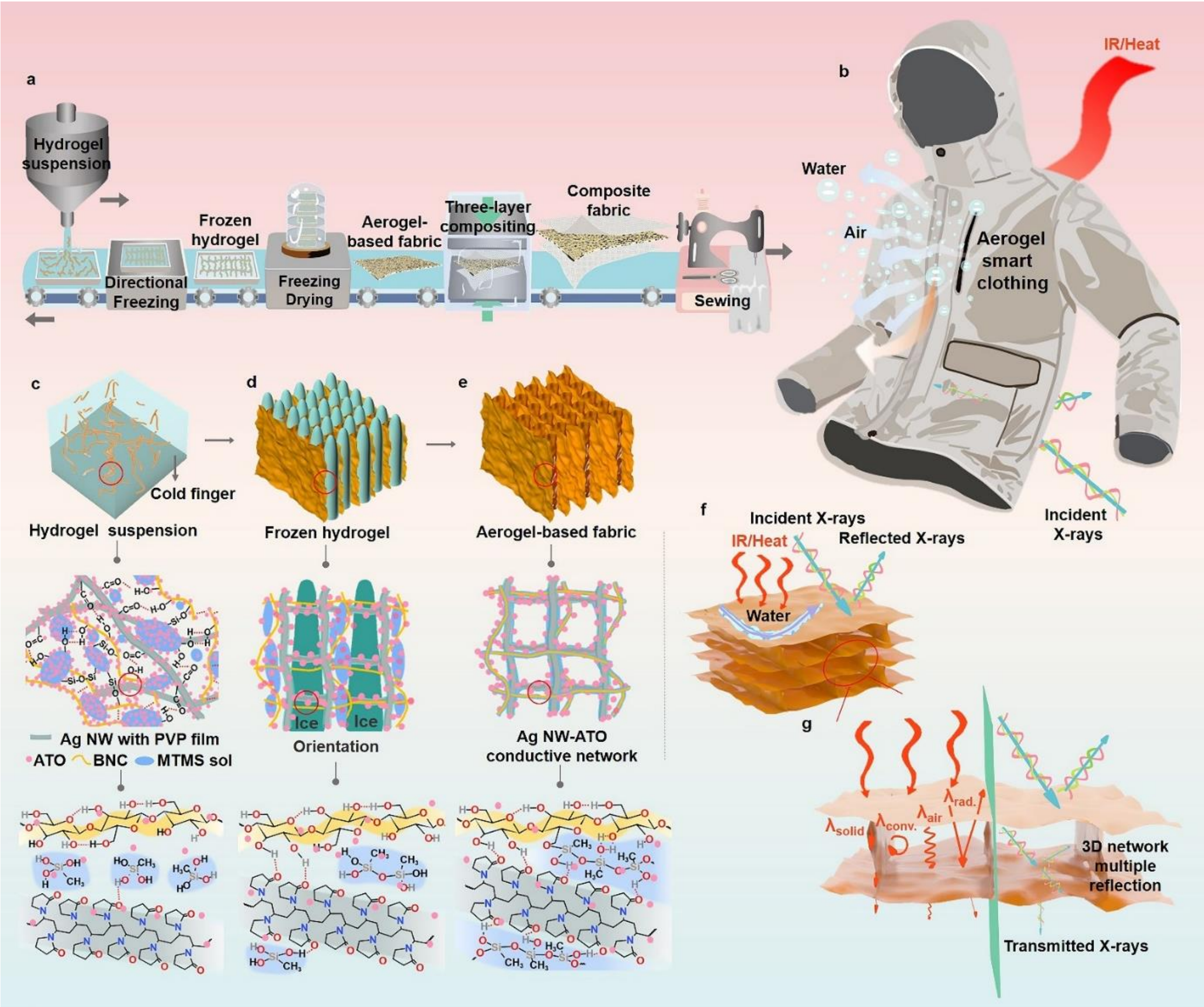

Fig. 1. Illustration of the fabrication of BNC (methyltrimethoxysilane; MTMS)-Ag NW-ATO hybrid aerogel-based fabrics and the associated broadband EMW management clothing.

Multifunctional Robust Transparent Silica Aerogels

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**Corresponding author: xdshen@njtech.edu.cn*

Abstract

Realization of optically transparent, mechanically robust and flexible aerogels has been a longstanding challenge, which limits their practical applications in energy-saving devices, such as thermally insulating films for enhancing energy efficiency of windows. The poor transparency precluded even hypothetical consideration of the possibility of birefringent aerogels. In this study, a highly transparent silica aerogel with outstanding robust performance and hydrophobicity was synthesized through the optimization of the surfactant-induced mesoporous structure by avoiding the macroscopic phase separation. The highest optical transmittance is comparable to commercial glass. It was even served in extreme environments from -196°C to 1000°C, and still exhibited amazing thermal, mechanical and durability properties. This surfactant-induced approach provides a novel way to realize optically transparent, thermally superinsulating and mechanically robust multifunctional aerogels.

Fig 1. Transparent silicon aerogel in the sunlight

References

[1] K. Kanamori, et al, 2007, Adv. Mater., 19(12), 1589-1593.
[2] Zhao Z, et al, 2021, ACS Appl. Mater. Interfaces, 13(18), 21286-21298.

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Surfactant-free synthesis of methyl functionalized silica gels with tuneable microstructures

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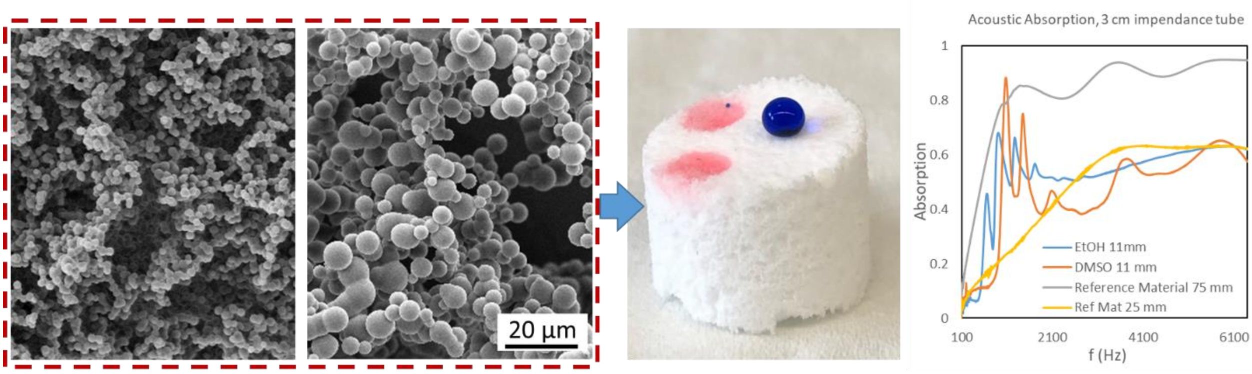
Abstract

Highly porous silica gels can be synthesized through the sol-gel processes and their microstructures (pore/particle sizes) are tuneable from several nanometers to hundred micrometers. However, such variable structures cannot be achieved by one general approach.[1,2] Recently, a surfactant-assisted protocol was reported[3], who provided a feasible route for varying the silica gel structures by using di- and tri- functional alkoxysilanes co-precursors. However, this method requires a long aging period to guarantee a good gel formation and the use of large amounts of surfactants and the gelation trigger urea, which needs to be removed after gel formation by intensive solvent exchanges. [4] Herein, we use a surfactant-free protocol to achieve similar structures and properties and reduce the processing time from 7-10 to 2 days.[5]The pore and particle structure are controlled by the proportions of the di- and tri- functional alkoxysilanes and their gelation solvents. The gel structures were found to be strongly influenced by the solvents with different Hansen solubility parameters[6], the average pore sizes can be varied from 20 nm to 10 µm, and the surface area could be tuned from over 500 $m^2 g^{-1}$ to below 0.5 $m^2 g^{-1}$, while all samples maintain a similar high porosity and low envelope density. All the samples show comparable water repellency with contact angle close to 150°, which is efficient for oil absorption in water.



Identical density, various pore & particle structures **Oil-water separation & acoustic absorption**

The gels with large particle sizes (6 µm) present superior acoustic properties, especially in the low frequency ranges, and the change in the pore size affects such sound absorption frequency ranges and effectiveness. The work provides a simple and scalable method to achieve various pore structures from one single sol-gel formulation. A fundamental understanding of pore structure formation as a function of solvent system was systematically studied. The materials with specific pores show high potential for various applications in oil-water separation and acoustic absorption.

References

[1] Michel Andre Aegerter, Nicholas Leventis, Matthias M. Koebel, "Aerogels Handbook", *Springer Verlag* (2011), ISBN: 978-1-4419-7477-8

[2] A. Venkateswara Rao, Sharad D. Bhagat, Hiroshi Hirashima, G.M. Pajonk, "Synthesis of flexible silica aerogels using methyltrimethoxysilane (MTMS) precursor", *Journal of Colloid and Interface Science*, vol. 300, no. 1, pp. 279-285, (2006). https://doi.org/10.1016/j.jcis.2006.03.044.

[3] Kanamori, K., Aizawa, M., Nakanishi, K. and Hanada, T. "New Transparent Methylsilsesquioxane Aerogels and Xerogels with Improved Mechanical Properties". *Advanced Materials*, 19: 1589-1593, (2007). https://doi.org/10.1002/adma.200602457

[4] Gen Hayase, Kazuyoshi Kanamori, Kazuki Nakanishia, "New flexible aerogels and xerogels derived from methyltrimethoxysilane/dimethyldimethoxysilane co-precursors", *J. Mater. Chem.* ,vol: 21, no: 43 pp: 17077-17079, (2011). https://doi.org/10.1039/C1JM13664J

[5] Gen Hayase, "Surfactant-Free Aqueous Fabrication of Macroporous Silicone Monoliths for Flexible Thermal Insulation", *Bulletin of the Chemical Society of Japan*, vol: 94 no: 9, pp. 2210-2215, 2021. https://doi.org/10.1246/bcsj.20210189

[6] Zhu, Z., Snellings, G. M. B. F., Koebel, M. M., & Malfait, W. J. "Superinsulating polyisocyanate based aerogels: a targeted search for the optimum solvent system". *ACS Applied Materials and Interfaces*, *9*(21), 18222-18230, (2017). https://doi.org/10.1021/acsami.7b03344

Title: The effect of polymer concentration and cross-linking density on polyimide aerogels

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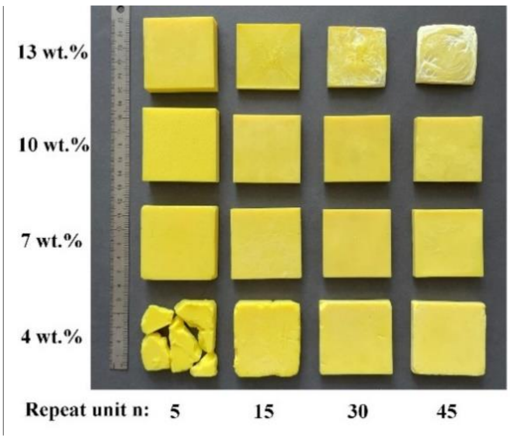
Abstract

Polyimide aerogels have been widely investigated because of their excellent mechanical strength, high thermal stability, low thermal conductivity, and outstanding dielectric properties. Generally, polyimide aerogels are synthesized through firstly the polycondensation of dianhydride and diamine into poly (amic acid) oligomers, which are then cross-linked by cross-linkers and chemically imidized into polyimide. The repeat unit of oligomers directly determines the cross-linkers used, resulting in variable chemical network densities, meanwhile, the polymer concentration will influence the solid networks in the final aerogels after the removal of solvents. So far, there is no detailed study of their effects on polyimide aerogels. Therefore, we have designed and investigated 16 compositions of polyimide aerogels from BPDA and ODA, with different repeat units (5, 15, 30, 45) and polymer concentrations (4, 7, 10, 13 wt.%) (Fig. 1 left). A clear influential trend of repeating unit and polymer concentration on the properties of polyimide aerogels was discovered. Increasing polymer concentration could promote shorter gelation time and enhance the mechanical performance of aerogels, but also lead to higher volumetric shrinkage upon supercritical drying and higher final density. The shorter oligomer chain length, which means higher cross-linking density, helped to resist shrinkages, resulting in lower density. In addition, the thermal conductivity's dependence on density exhibited a typical U-shaped curve for porous materials with the specified density range (0.08-0.10 g/cm^3) for optimal thermal conductivity (21-23 mW/(m·K)) (Fig. 1 right). This fundamental study, based on general (density, shrinkage, gelation time, and porosity), mechanical, and microstructure characteristics of polyimide aerogels with diverse formulations, could instruct the future design of polyimide aerogels for targeted properties and applications.



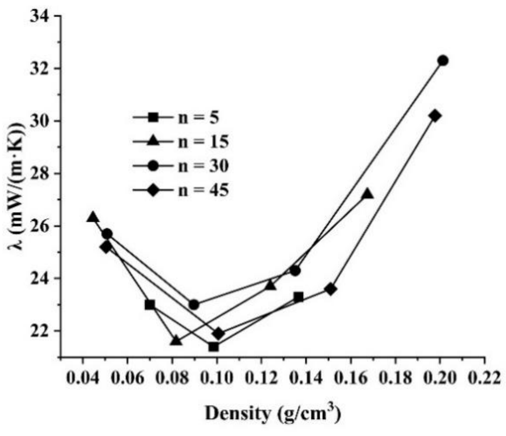


Fig 1. Overview appearance of synthesized polyimide aerogels with different polymer concentrations and repeat units (left); and the dependence of thermal conductivity on aerogel density for different repeat units n (right).