Silica Aerogels

A multifunctional building material

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ZEB The Research Centre on Zero Emission Buildings

Outline

- **ZEB-WP1**:Nanotechnology & Construction
- Silica aerogels
  - *Superinsulation*
  - *Advanced glazing*
- Aerogel-like materials
- Perspective

FME-ZEB: *Zero Emission Buildings*

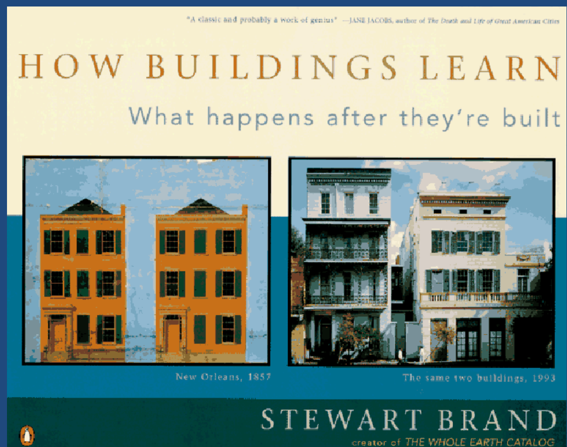
A national research centre that will develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings with **zero greenhouse gas emissions** related to their production, operation, and demolition.

www.zeb.no

ZEB – Research activities

ZEB will focus its work in five areas that interact and influence each other:

- WP-1: Advanced materials technologies
- WP-2: Climate-adapted low-energy envelope technologies
- WP-3: Energy supply systems and services
- WP-4: Use, operation, and implementation
- WP-5: Concepts and strategies



WP1: advanced materials and technologies

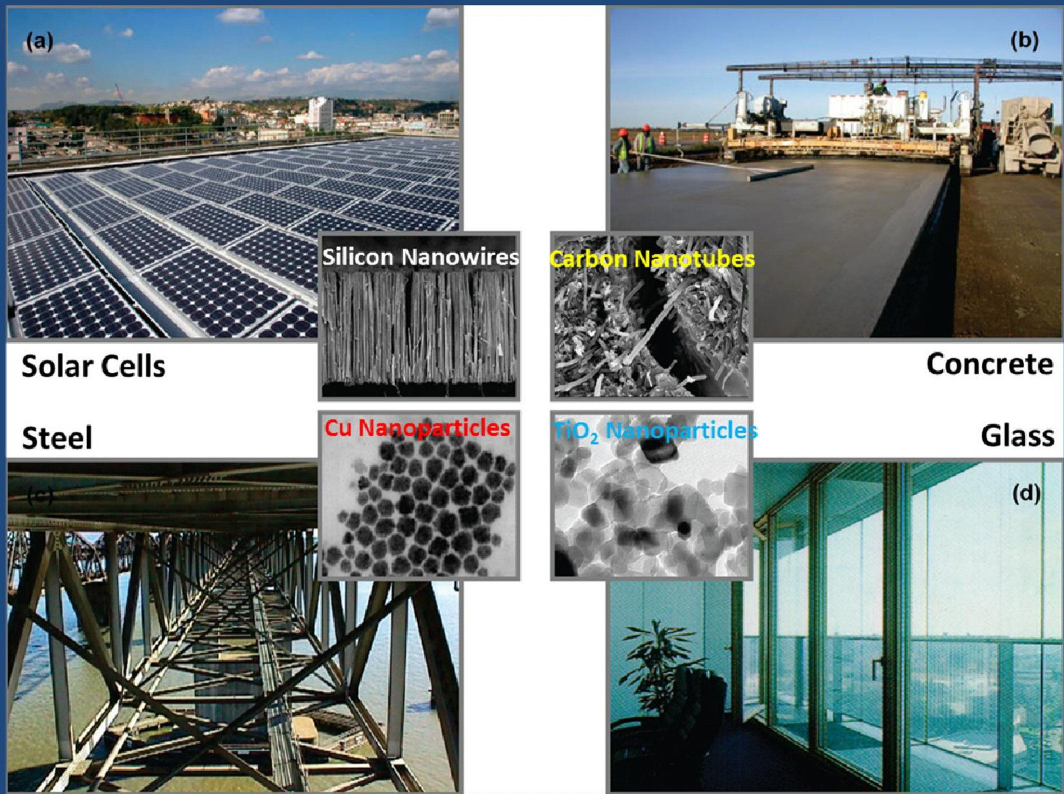
Developing new and innovative materials and solutions, as well as improving the current state-of-the-art technologies.

1. **Nano insulation materials (NIM) –** *aerogels, hollow nanostructures*
2. **Advanced glazing materials and technologies –** *nanoelectrochromics*
3. **Advanced coating materials –** *antireflection coatings*
4. **Building integrated photovoltaic panels –** *advanced façade technology*
5. **Phase changing materials (PCM) –** *advanced façade technology*

Nanotechnology and construction

Nanotechnology is an enabling technology that allows us to develop materials with improved or totally new properties. Nanomaterials are widely used in construction, e.g.:

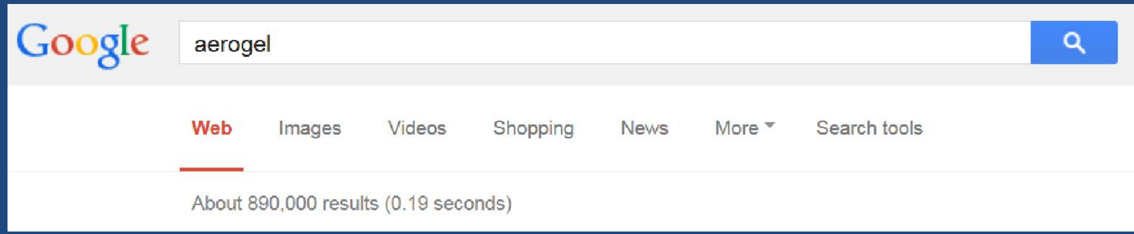
- in concrete
- in steel
- in glass
- in coating
- in photovoltaic
- …



J. Lee, et al. *ACS Nano* **2010**, *4*, 3580

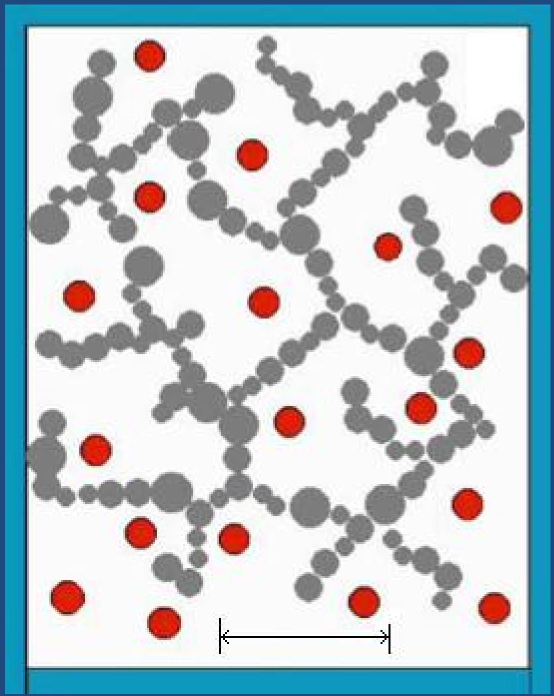
Silica Aerogels

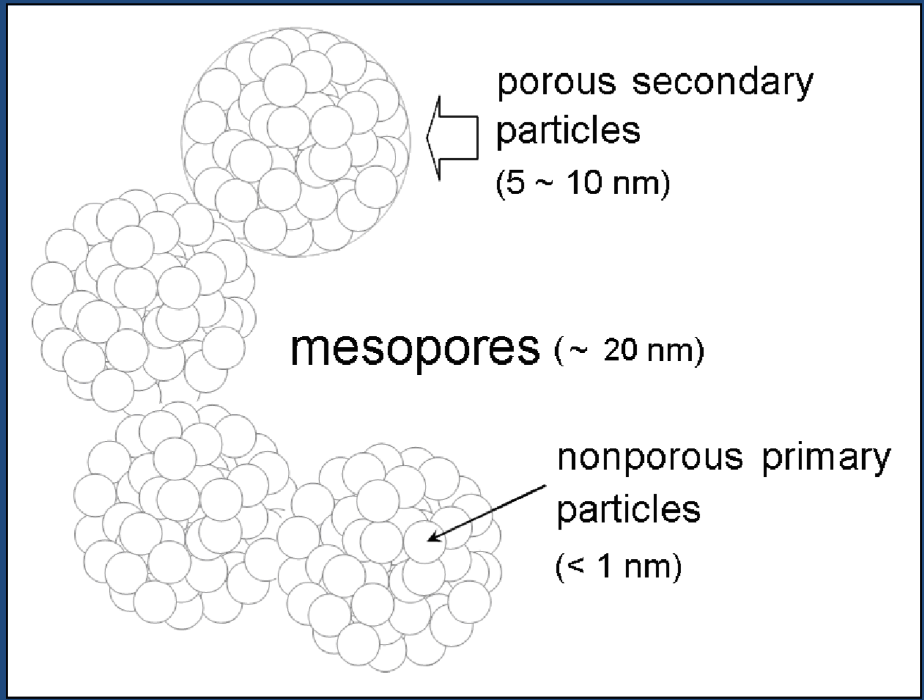
Silica aerogels



the best insulating solid

Nanoporous structure





The pore sizes of air pockets in aerogels are about 20 nm, which is smaller than the mean free path of air molecules under STP conditions (~ 68 nm). As a result, there is virtually no gas phase conduction in the material. Solid phase conduction will occur only along the silica-chain matrix (a few nm in diameter), which is significantly reduced due to the size effect.

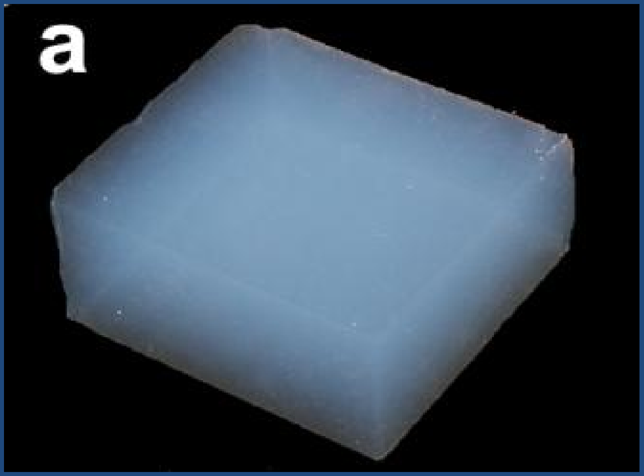
Thermal conductivity of aerogel is typically 10–20 mW/mK.

Properties

Density	Porosity	Mean pore size	Thermal conductivity	Strength	
				Tensile	Compressive
~ 0.1 g/cm^3	~ 95 %	~ 20 nm	~ 13 mW/mK [a] ~ 20 mW/mK [b]	~ 10 kPa	~ 1 MPa

[a] *monolithic aerogels*

[b] *aerogel granules*



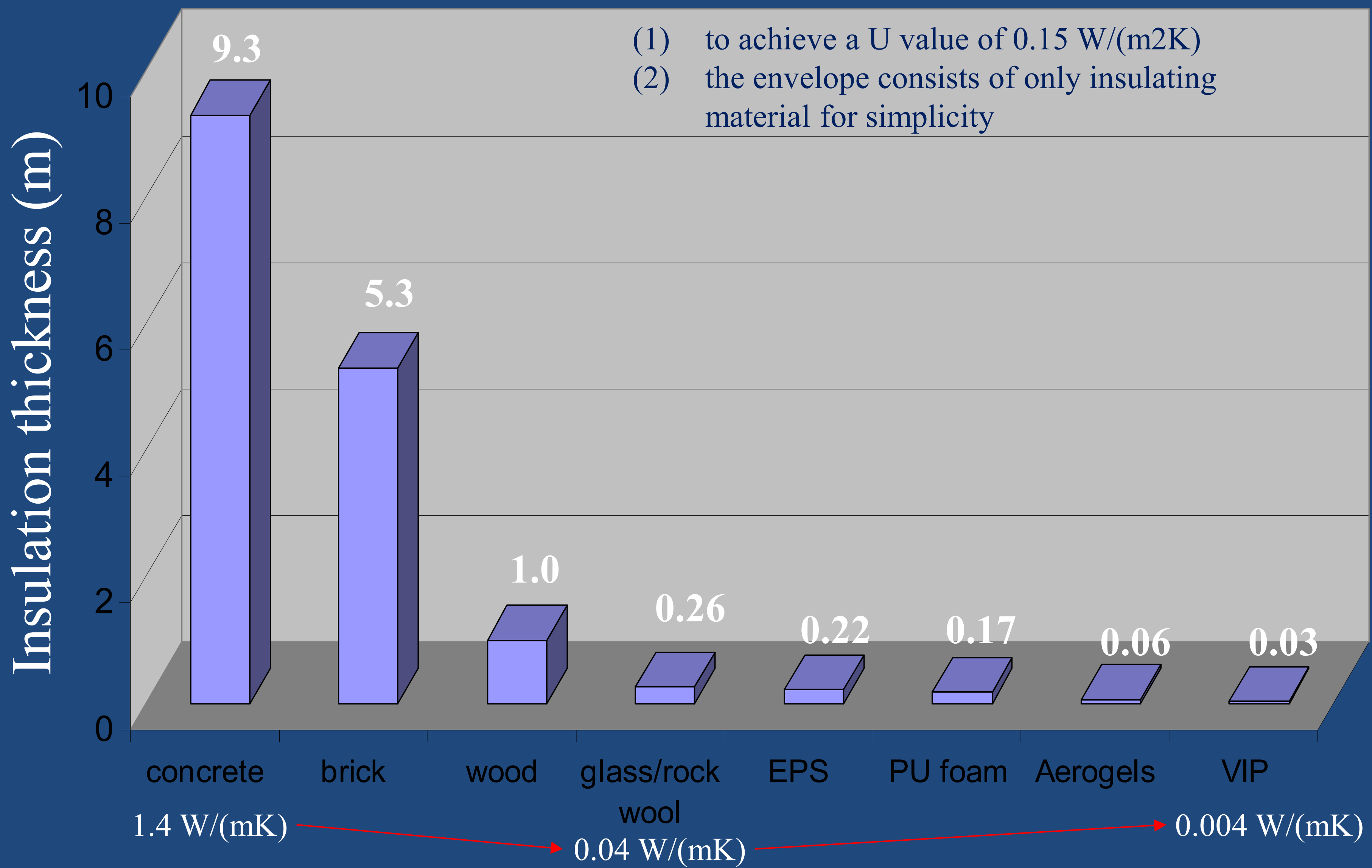
Silica aerogels: *R&D*

- Exploring the application of silica aerogels
- Improving the performance of silica aerogels
- Developing new aerogel materials

Silica aerogels as building materials

(1) superinsulation

Thinner insulation, better performance



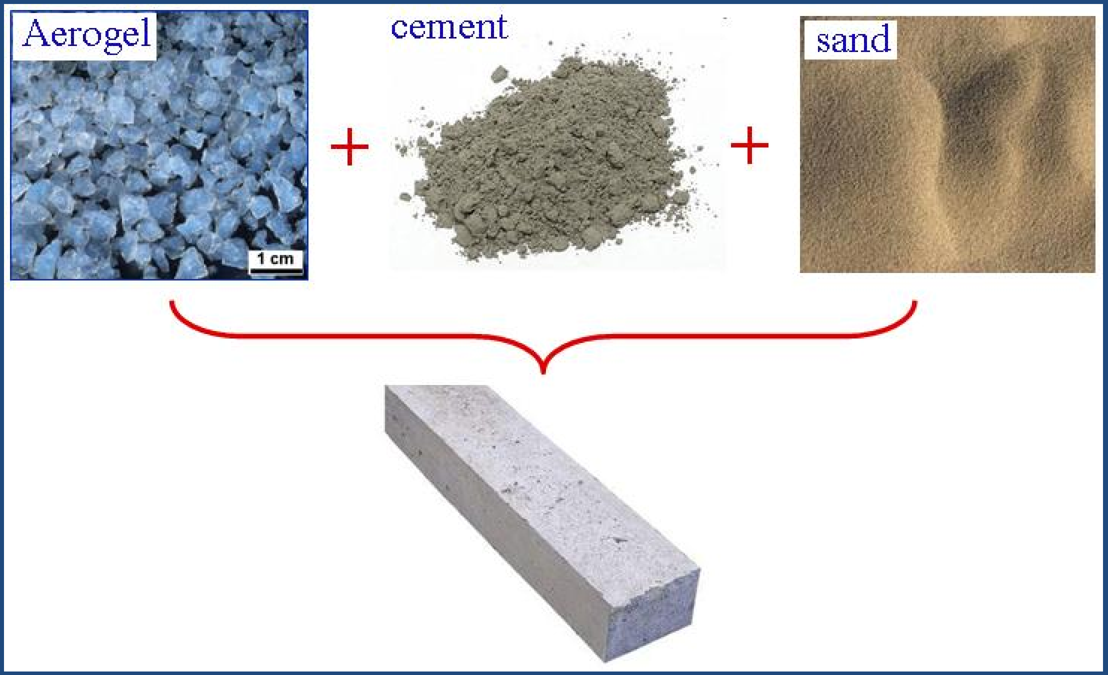
Improving the workability of silica aerogels

Fiber reinforced blanket

Aerogel render/plaster

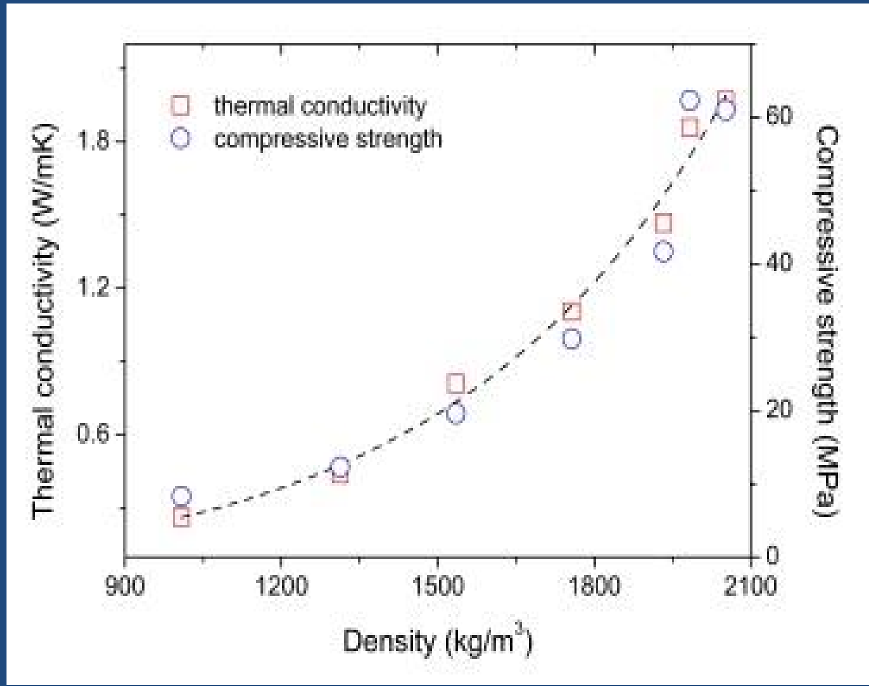
AIC – *aerogel incorporated concrete*

- Aerogel has a typical thermal conductivity of 0.010-0.018 W/mK, compared to ~ 1 W/mK for normal concrete.
- The combination of aerogel and cement (and other materials) may lead to new lightweight thermal insulating concrete.



T. Gao, et al., *Construction and Building Materials,* 52 (2014) 130–136

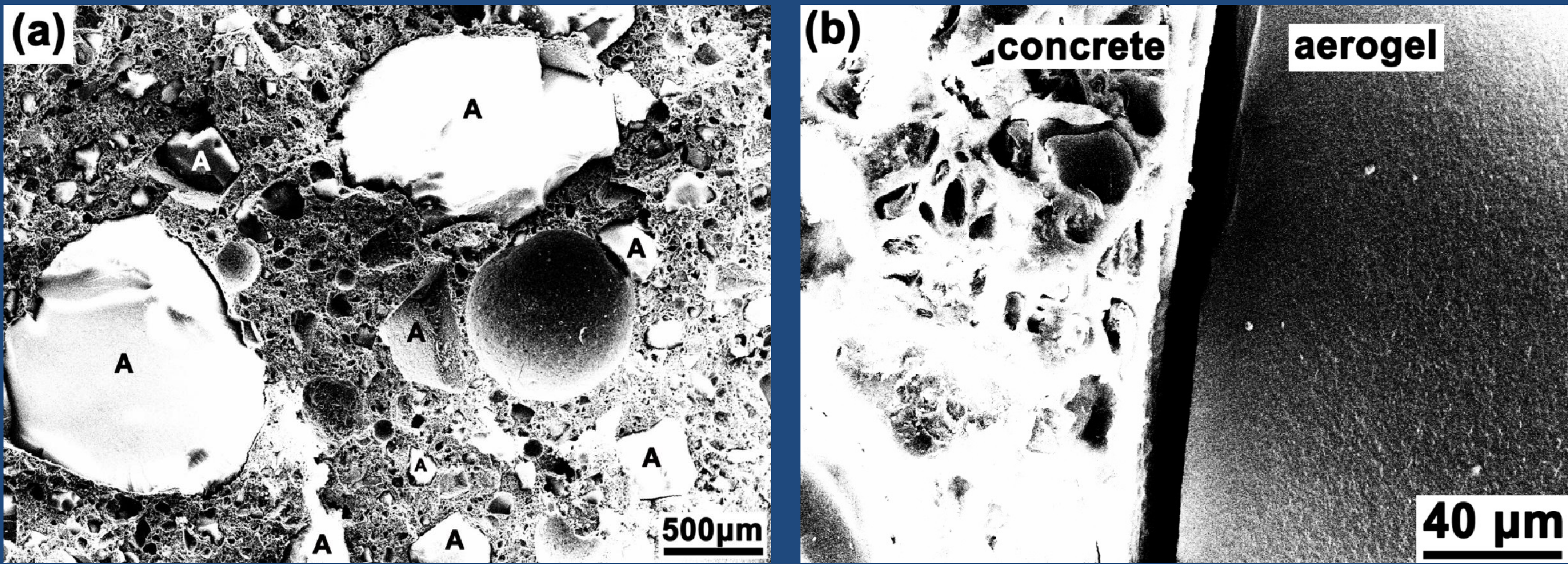
AIC – *aerogel incorporated concrete*



at an aerogel content of 60 vol.%:

- The density of AIC is about 1 g/cm3
- The thermal conductivity of AIC is about 0.26 W/mK
- The compressive strength of AIC is about 8.3 MPa
- *The properties of AIC can be changed by varying the aerogel content.*

AIC – *aerogel incorporated concrete*



SEM images of AIC sample. A denotes aerogel particles.

Improving the stability of aerogels, especially the surface!

Silica aerogels as building materials

(2) advanced glazing

Window glazing

Advantages

- indoor-outdoor interaction
- healthy indoor environment

Disadvantages

- poor thermal control
- poor visual control

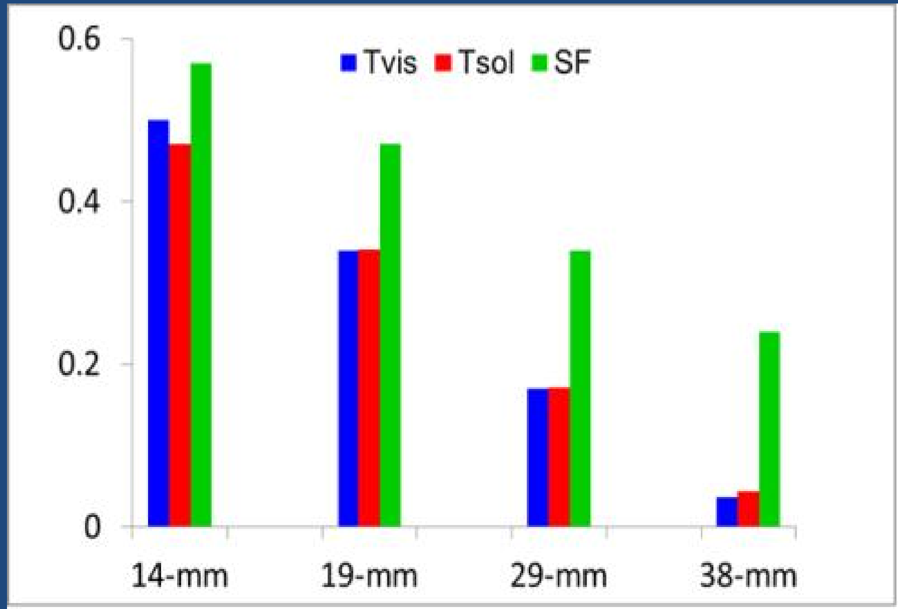
Aerogel glazing – *commercialization*

Aerogel glazing – *specular vs. diffuse*

Comparison between specular clear glass glazing (left) and diffuse AGUs (right)

T. Gao, et al., *Applied Energy,* (2014) submitted

Aerogel glazing – *controlled properties*



U value (W/m2K)

AGU-14: **1.19**

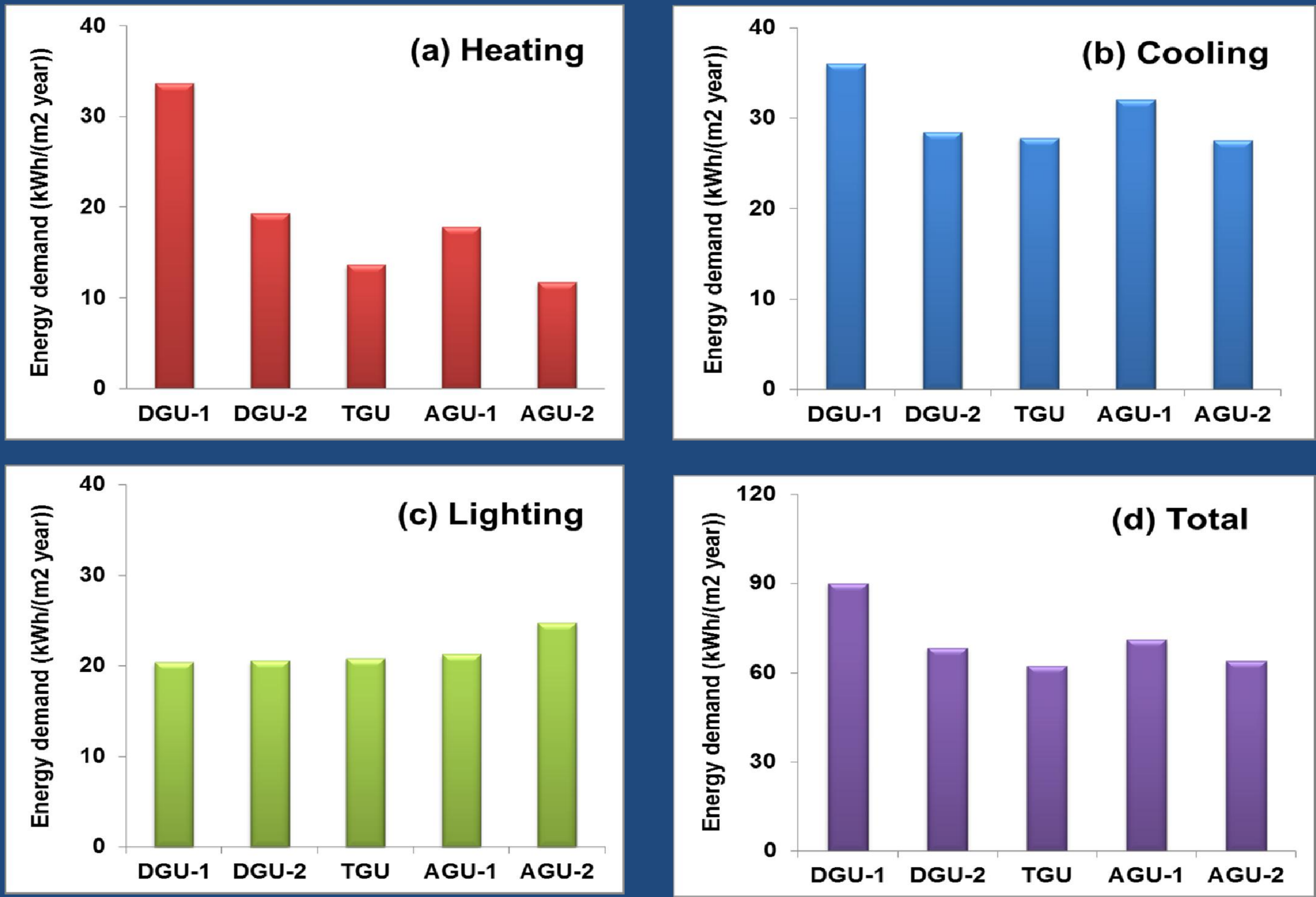
AGU-19: **0.87**

AGU-29: **0.62**

AGU-38: **0.47**

T. Gao, et al., *Applied Energy, 128* (2014) 27–34

Aerogel glazing – *energy savings*



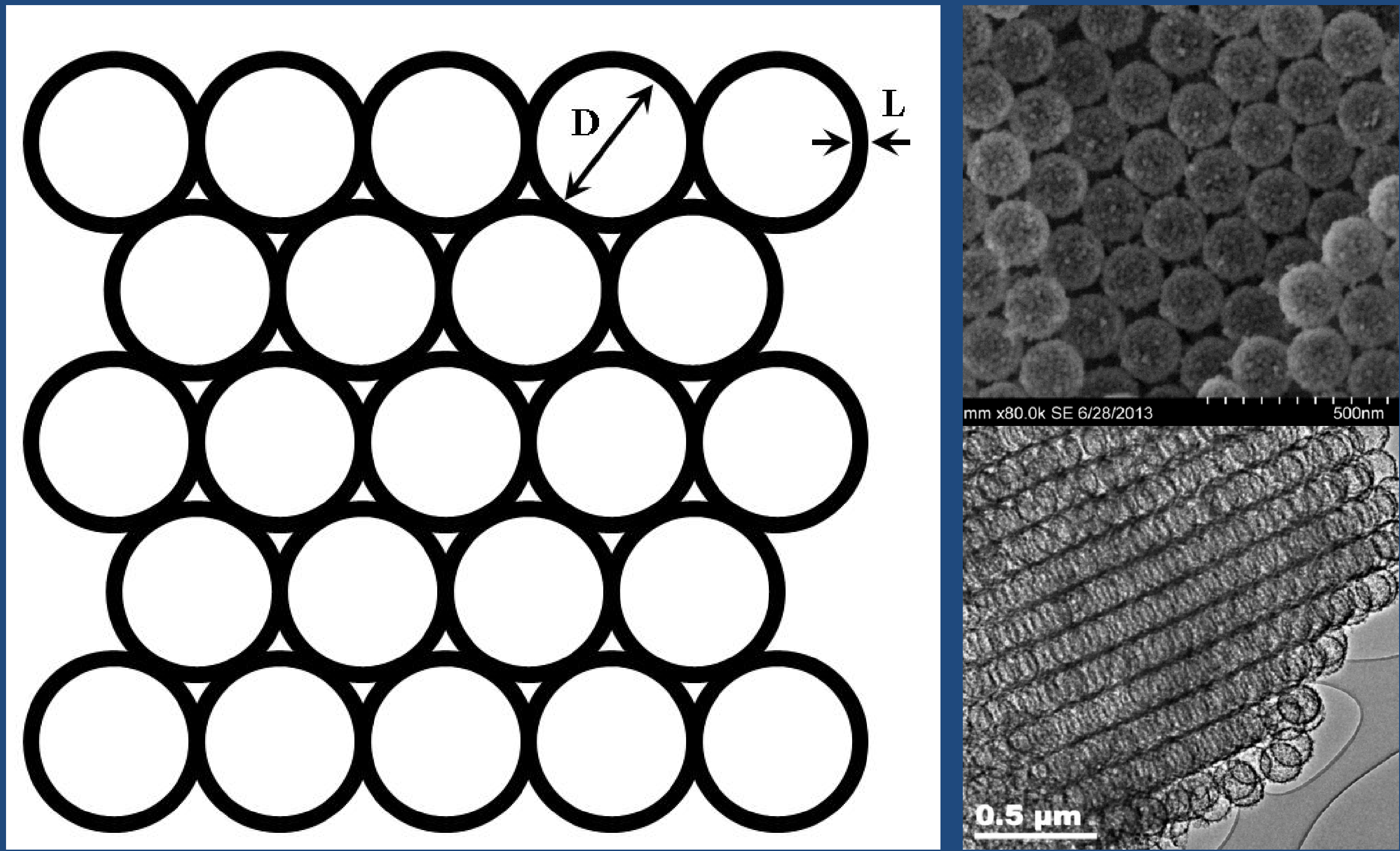
Aerogel glazing – *R&D potentials*

- **Health, safety, and environmental (HSE) issues**
- **Cost**
- **Property control of aerogel granules**
- **Stability and durability of silica aerogels and AGUs**

T. Ihara, et al., *Energy and Buildings,* (2014) submitted

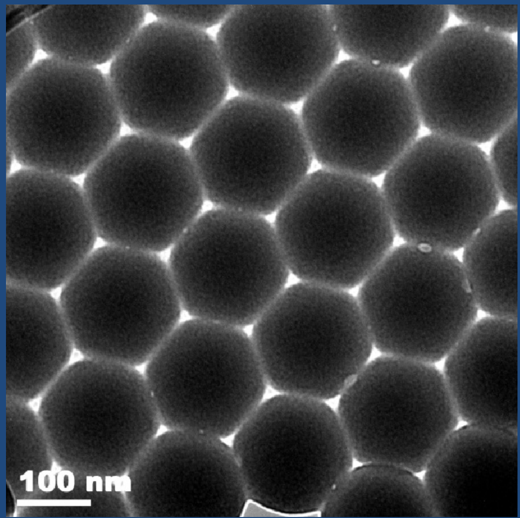
Aerogel-like Materials

(1) Hollow silica nanospheres (HSNSs)



T. Gao, et al., *ACS Applied Materials & Interface, 5* (2013) 761–767

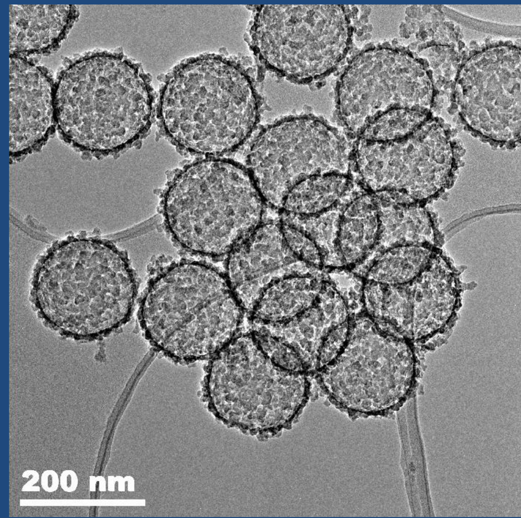
HSNSs – *template-assisted synthesis*



Polystyrene nanoparticles

coated with SiO_2

remove PS cores



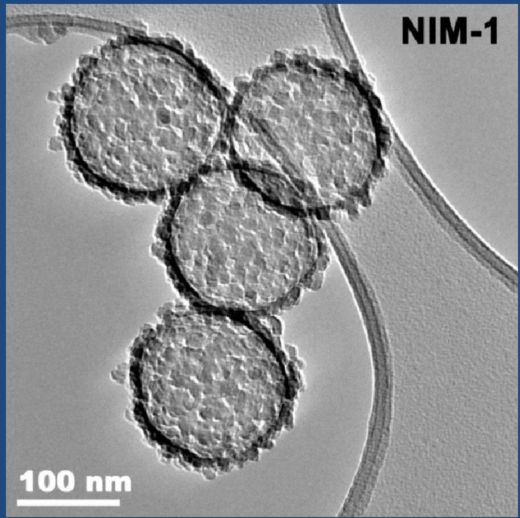
Hollow SiO_2 nanospheres

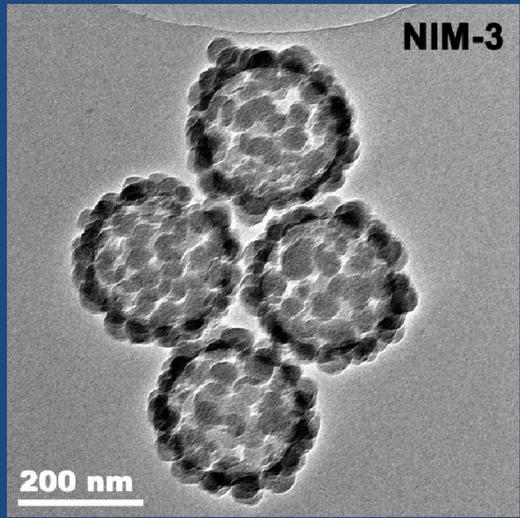
Advantage: very good size (diameter and layer thickness) control

Disadvantage: the polystyrene template

Improvement: other template materials with modified surfaces

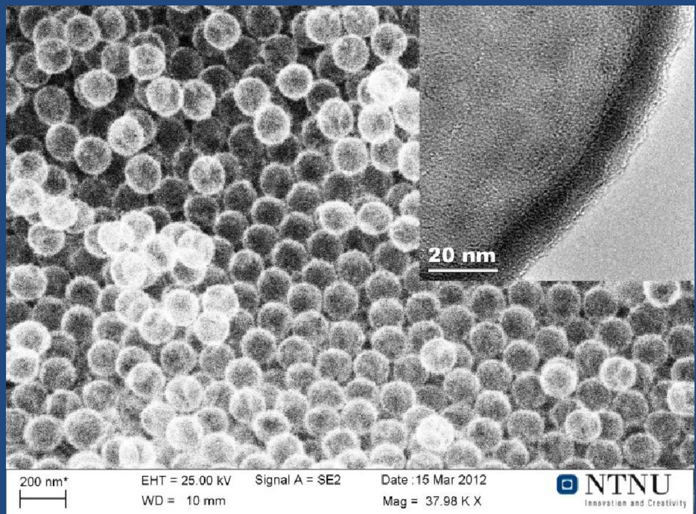
Dimension:

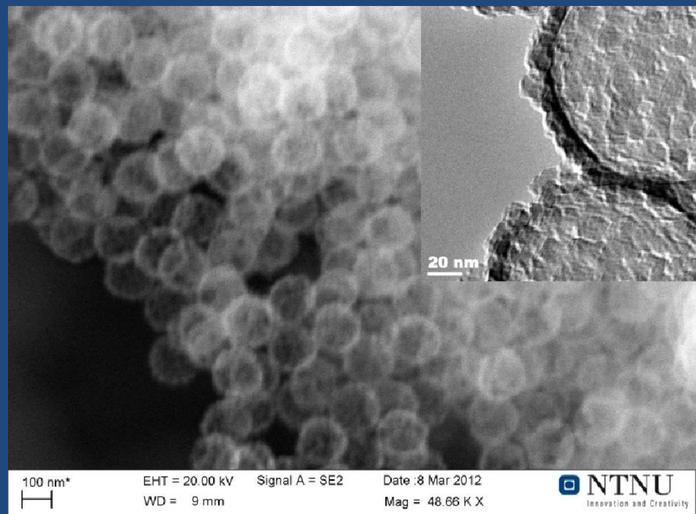




By controlling the size and the surface of PS template spheres, the dimension and the properties of hollow silica nanospheres can thus be adjusted.

Surface roughness:





HSNSs – *thermal property*

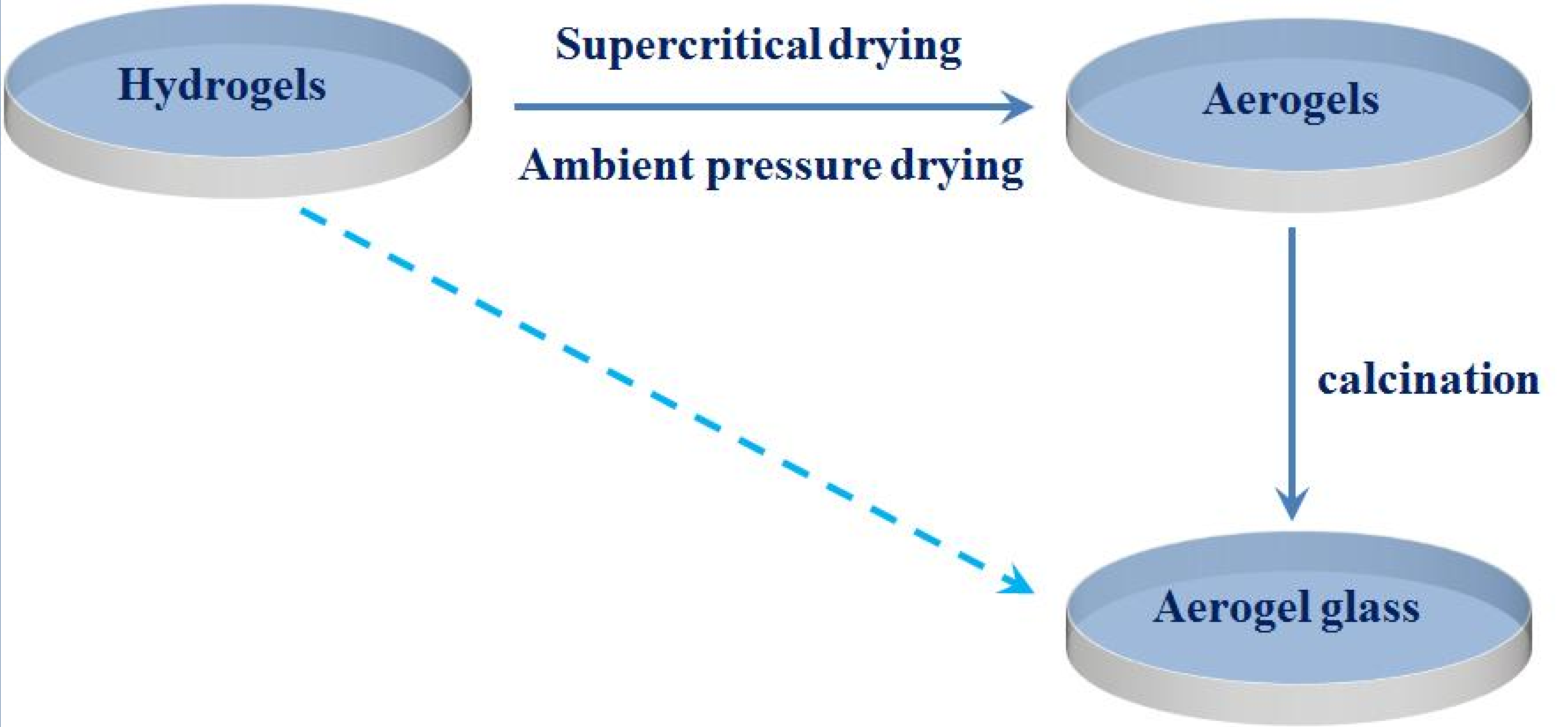
	Inner diameter (nm)*	Layer thickness (nm)*	Thermal conductivity (W/mK)*
Solid SiO_2	300	-	0.089
NIM_5-1	250	50	0.067
NIM_6	50–300	10	0.045
NIM_3	200	25	0.024
NIM_1	150	15	0.020
Aerogel	-	-	0.015

* *Uncertainty also varies with the measured values*

(2) Aerogel glass materials

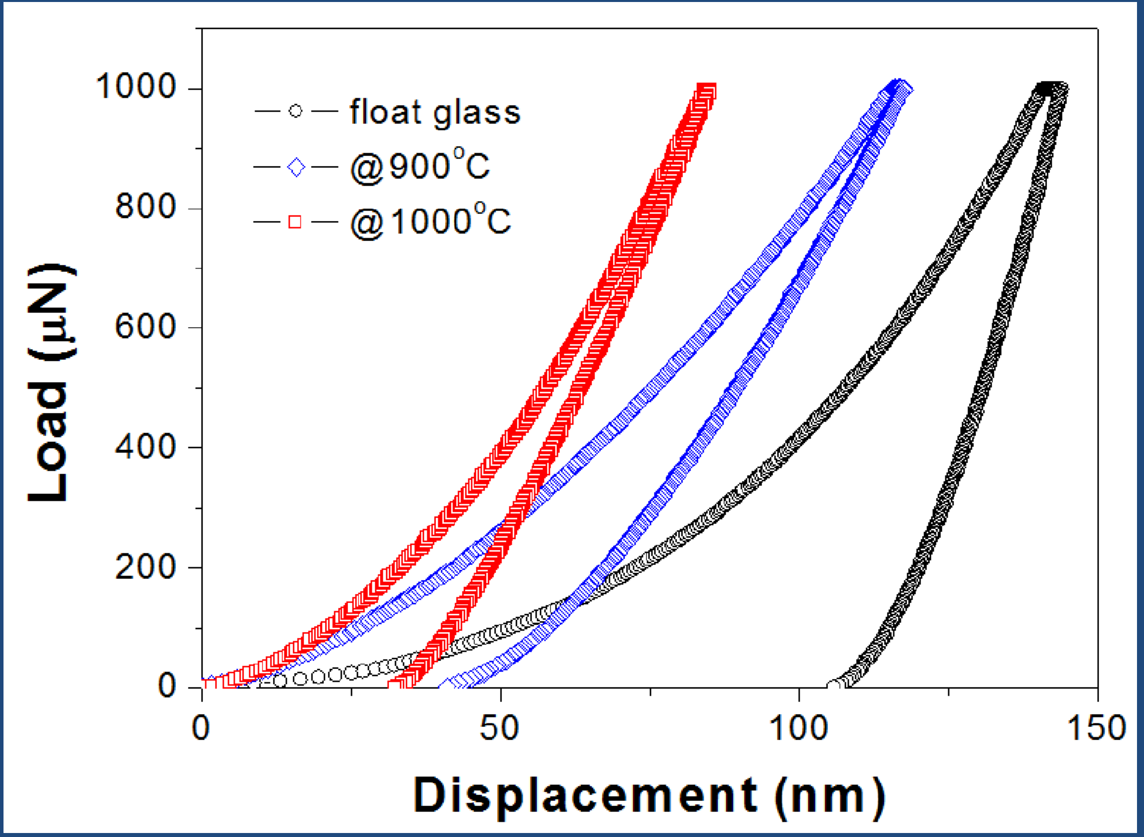
- Lightweight
- Thermally insulating
- Transparent
- Mechanically strong

Challenge: *gel → glass transformation*



1. The process economics
2. The target application – window glazings

Challenge: *gel → glass transformation*



	E_r / GPa	H / GPa
Float glass	50.7	1.64
GT-900	39.1	4.78
GT-1000	68.4	9.51

Melting of silica at 900 ~ 1000°C

Aerogel glass materials - *properties*

	ρ (g/cm^3)	T_{vis} (%) at 500 nm	k (W/(mK))	E_r (GPa)
Float glass	2.5	92.0	1.0	50.77
Aerogel glass	1.8	95.4	0.18	6 – 60

T. Gao, et al., *Applied Physics A, 117 (2014) 799–808*

Perspective

- We are in great search for alternate building materials. This can effectively be achieved through the emerging field of nanotechnology.
- There is wide scope of research for the application of nanotechnology in the building industry.
- The main limitation is the high manufacture cost of nanomaterials, also the concerns with the environmental impact.

Congratulations to NTNU Nanolab!