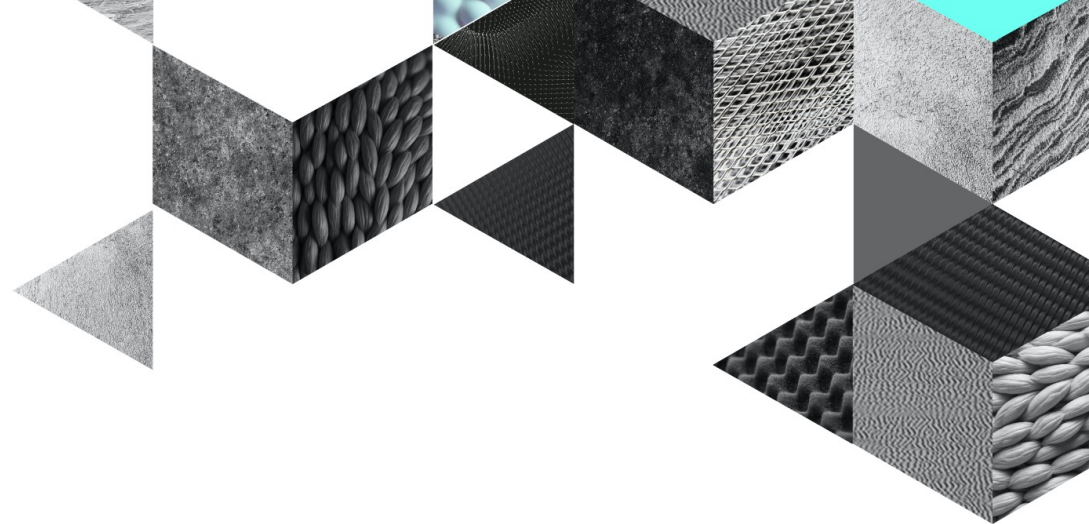


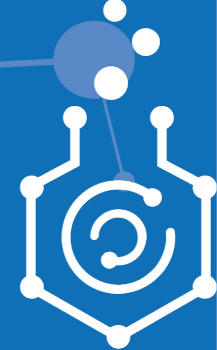
## ПАНЕЛЬНАЯ ДИСКУССИЯ

# РАЗРАБОТКА КРОВООСТАНАВЛИВАЮЩИХ МАТЕРИАЛОВ НА ОСНОВЕ АЭРОГЕЛЕЙ, РХТУ ИМ МЕНДЕЛЕЕВА

ПАВЕЛ ЦЫГАНКОВ







# Aerogels from laboratory to industry

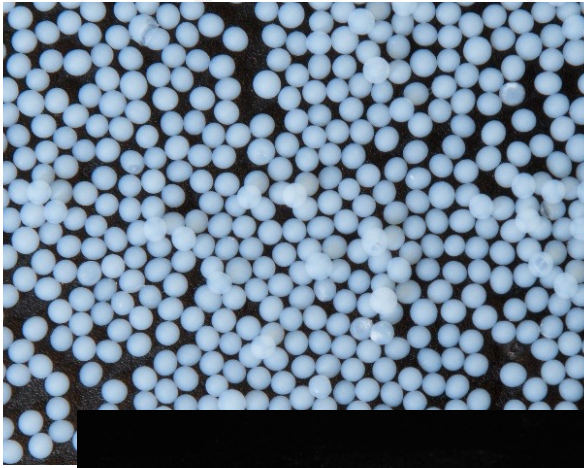
PhD Pavel Tsygankov  
Senior Researcher

D. Mendeleev University of Chemical  
Technology of Russia

April 10, 2024



# Properties of aerogels



## Types of aerogels:

Organic aerogels

Inorganic aerogels

Hybrid aerogels

**Large surface areas and pore volume:**

$$S = 200 - 2000 \text{ m}^2/\text{g}$$

$$V_{\text{pore}} = 3 - 10 \text{ cm}^3/\text{g}$$

**Low-density:**

$$\rho = 0.003 - 0.35 \text{ g/cm}^3$$

**High porosity:**

85 – 99 %

**Pore diameter :**

4 - 20 nm

**Different shapes and sizes**

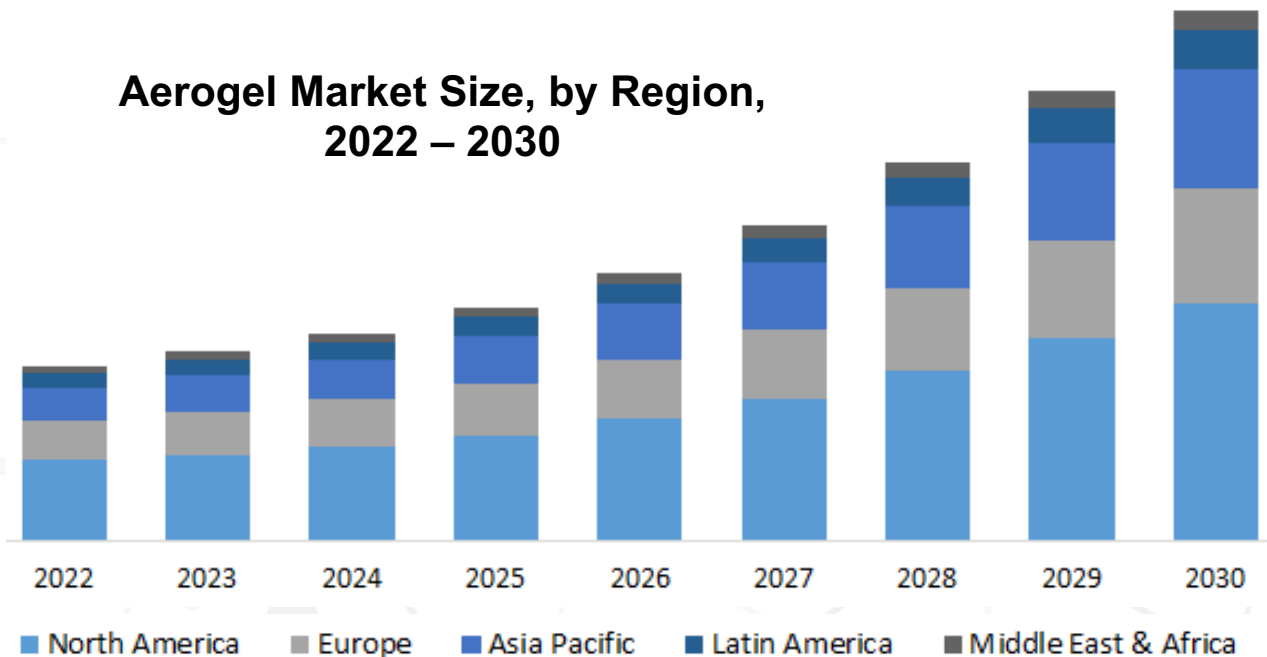




# Aerogel market

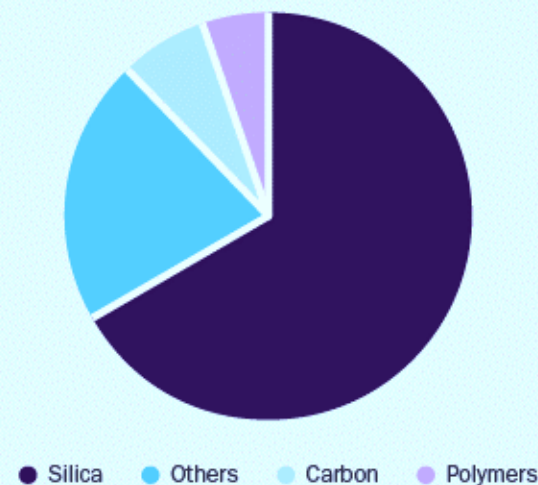


**Aerogel Market Size, by Region,  
2022 – 2030**



**Global Aerogel Market**

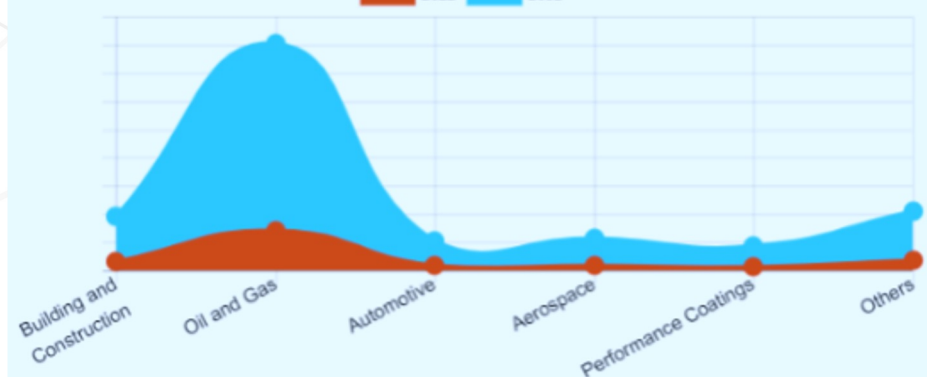
share, by product, 2022 (%)



**AEROGEL MARKET**

BY END USE INDUSTRY

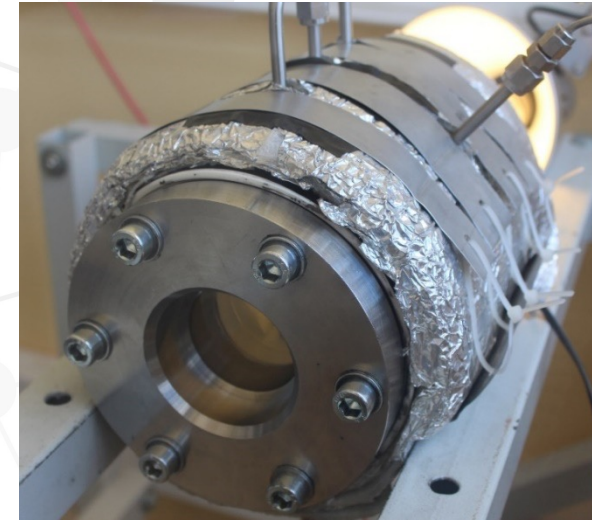
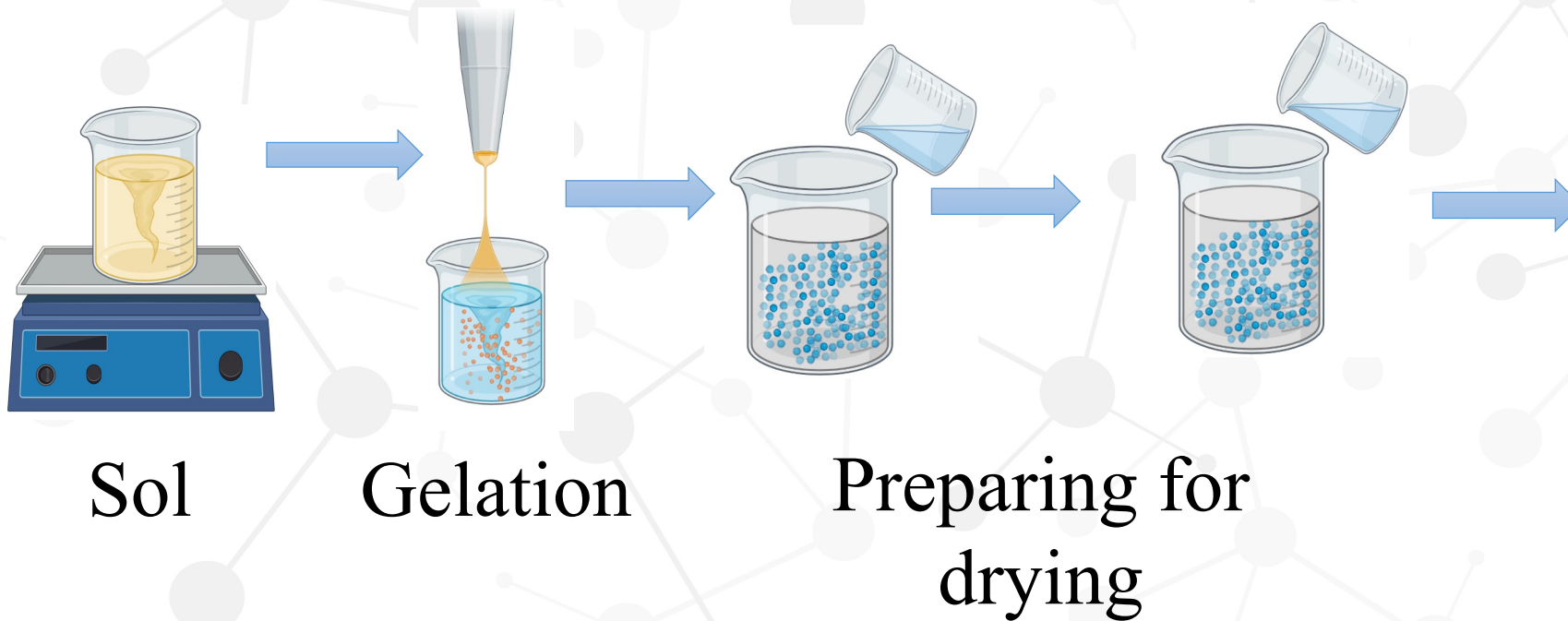
2022 2032



Oil and Gas segment was the highest revenue contributor in the market



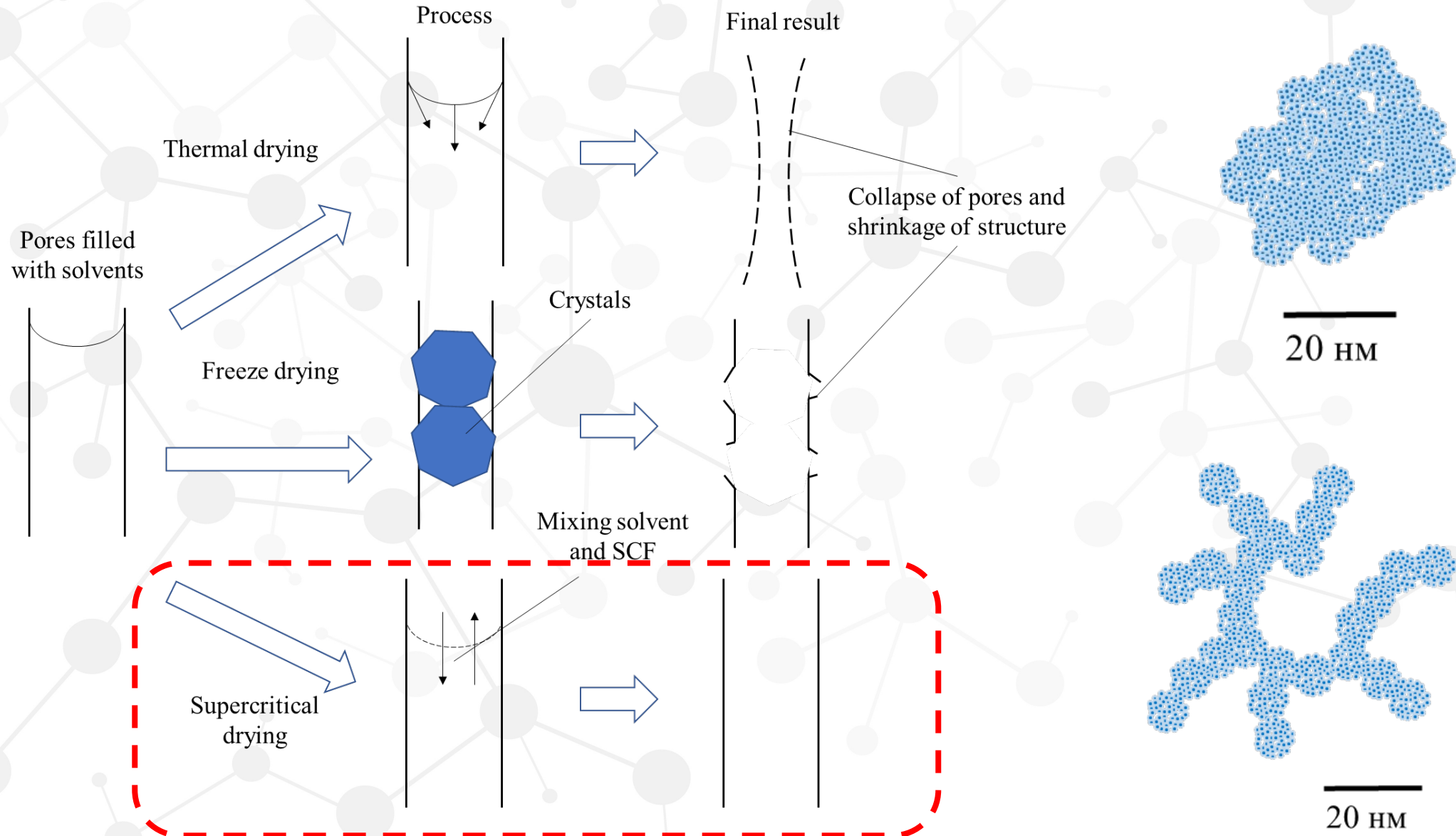
# Preparation of aerogels



Drying

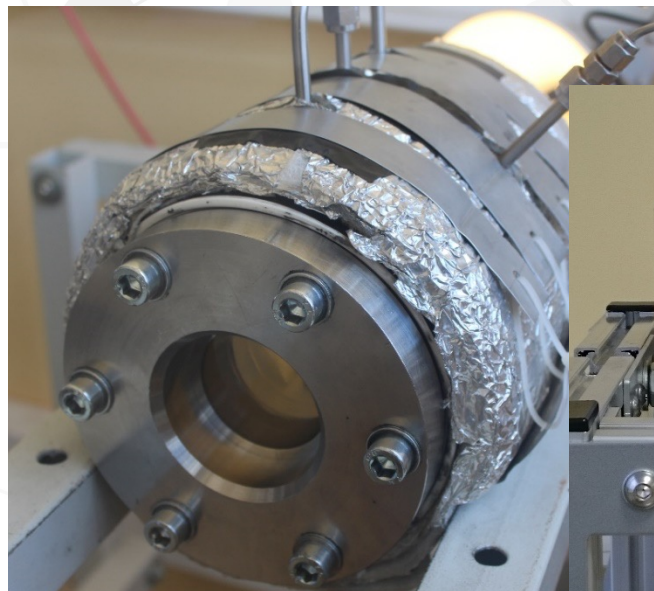


# Drying techniques





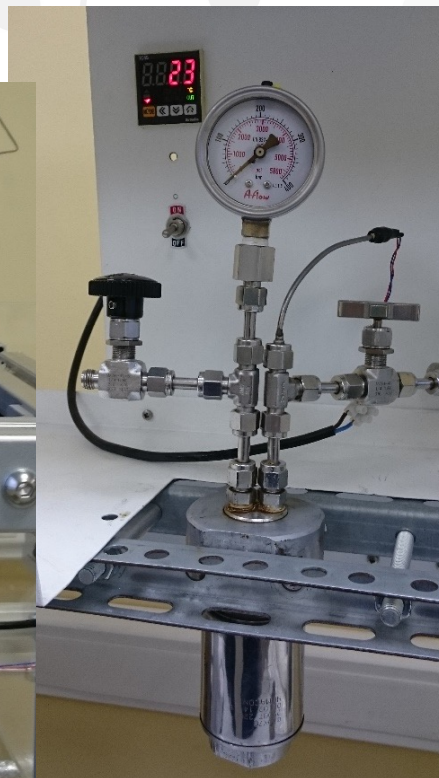
# Lab scale high pressure equipment for supercritical process



- volume – 250 ml
- temperature up to 100 °C
- max. pressure: 300 bar



- volume – 2 L
- temperature up to 80 °C
- max. pressure: 200 bar



- volume – 65 ml
- temperature up to 120 °C
- max. pressure: 350 bar



- volume – 300 ml
- temperature up to 500 °C
- max. pressure: 300 bar
- paddle mixer

- drying
- extraction
- micronization
- impregnation
- adsorption
- foaming
- high temperature processes



# Aerogels for superinsulation



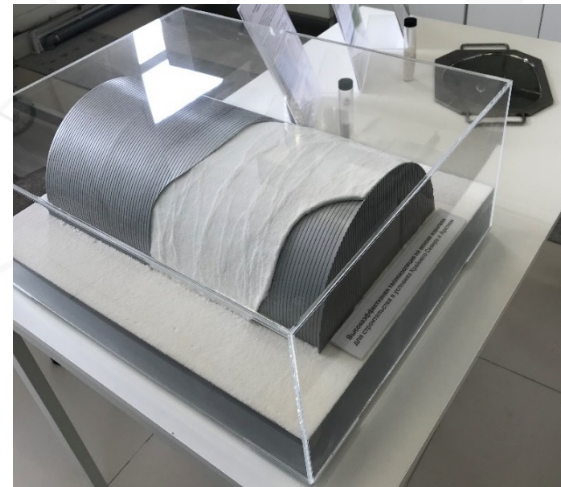
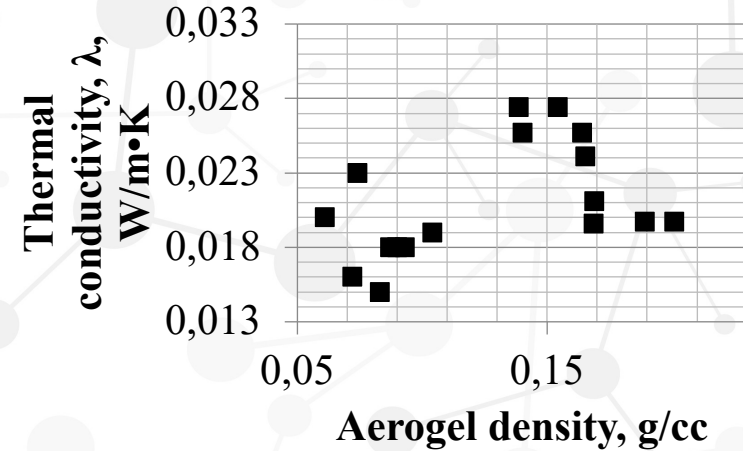
Thermal conductivity of different materials

Material	$\lambda$ , W/(m·K)
Glass wool	0,034-0,045
Polystyrene foam	0,029-0,055
Air	0,025
<b>Aerogel</b>	0,014-0,020

## Application:

- Oil and gas transport and refining industry (Superinsulation of pipes)
- Chemical industry (insulation of cryogenic plants)
- aerospace industry (low-density superinsulation of fuel tanks, other units of aircraft and rocket launchers)
- construction in the Far North and the Arctic

Thermal conductivity of aerogel at different density



Building prototype for the Far North



# Aerogel blankets



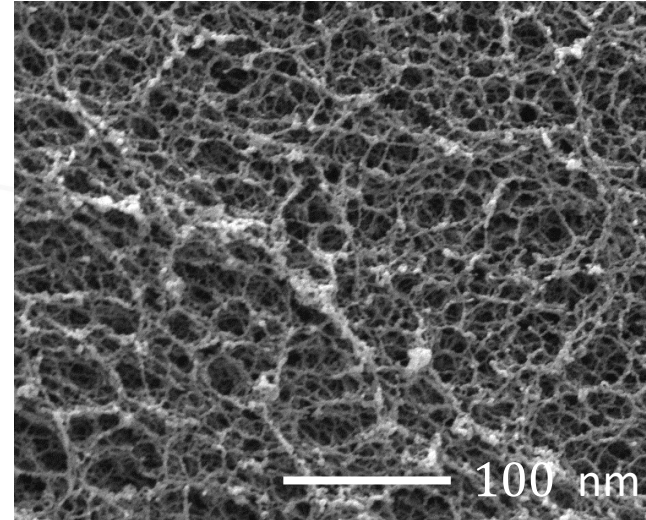
Product appearance

Free volume of  
the vessel

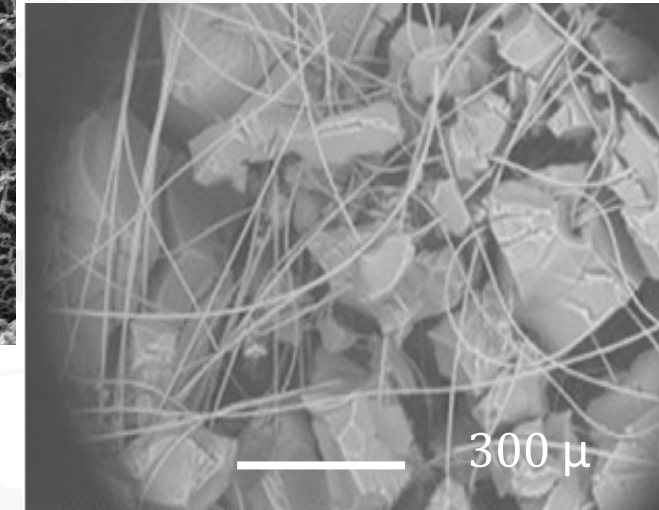
Gel



Aerogel structure



Fiber reinforced aerogel



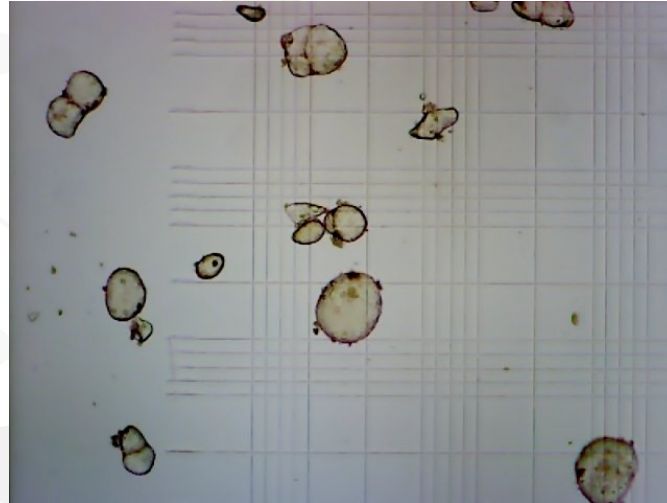
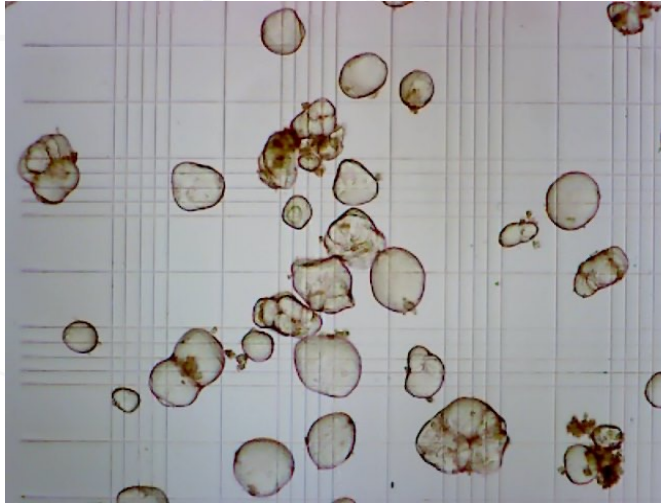
Thermal  
conductivity  $< 15$   
 $\text{mW}/(\text{m}\cdot\text{K})$



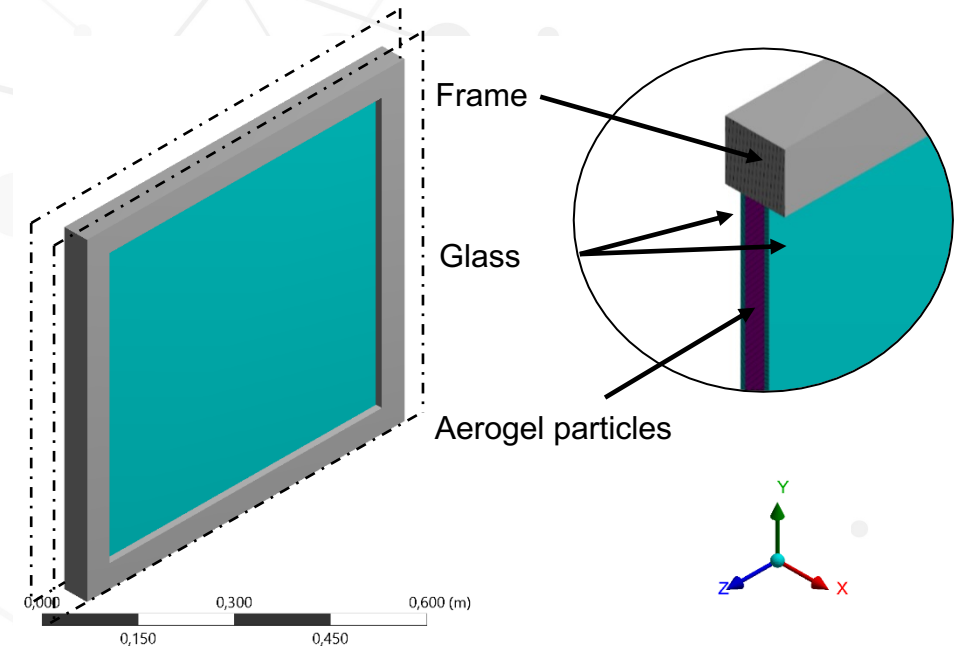
# Aerogel particles for superinsulation



## Aerogel particles



## Prototype of translucent heat-insulating panel



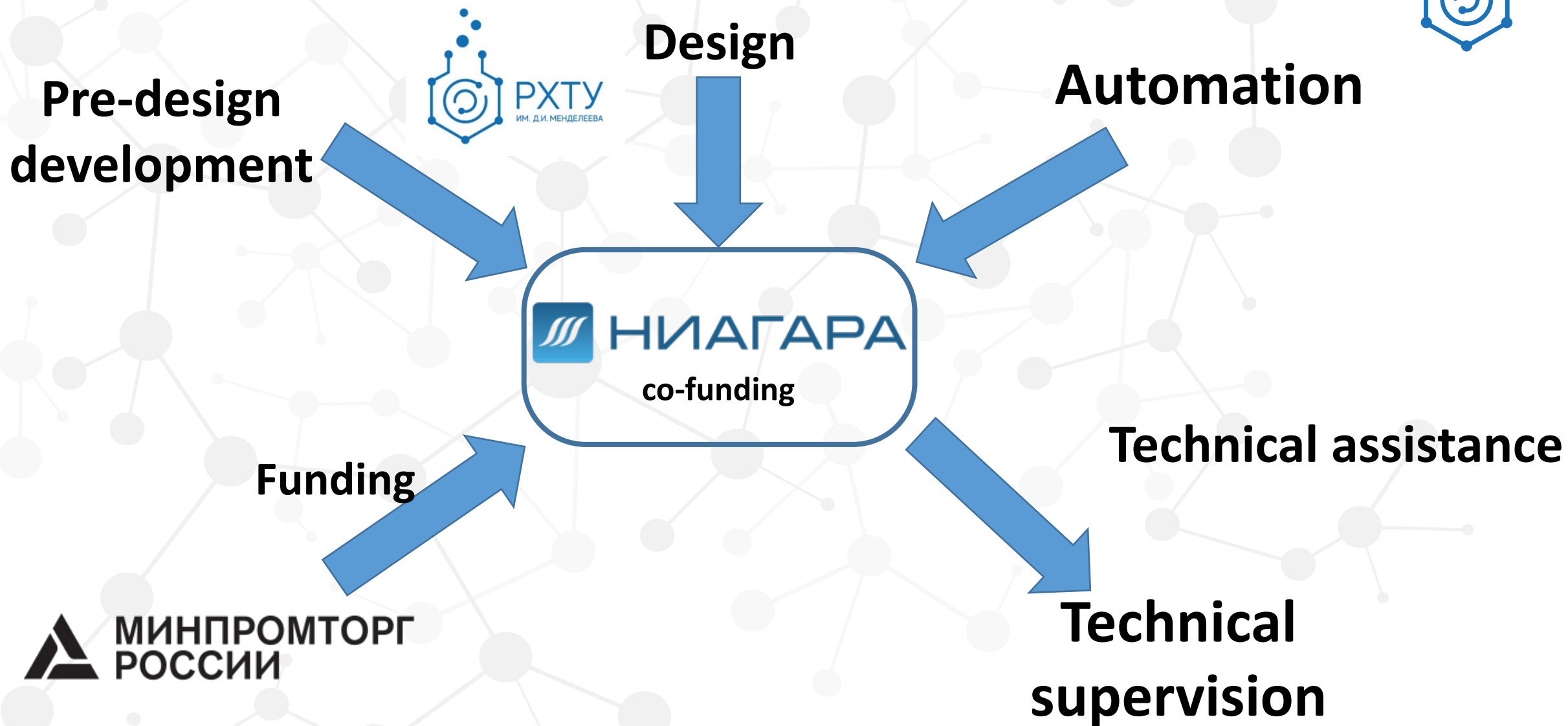
## Aerogel particles properties:

- Diameter: 100 – 500  $\mu\text{m}$
- Bulk density: 0,04 - 0,1 g/cc
- Bulk thermal conductivity: 20 – 25 mW/(m·K)

**Thermal conductivity**  
 **$\approx 5 \text{ mW}/(\text{m}\cdot\text{K})$**



# Production development

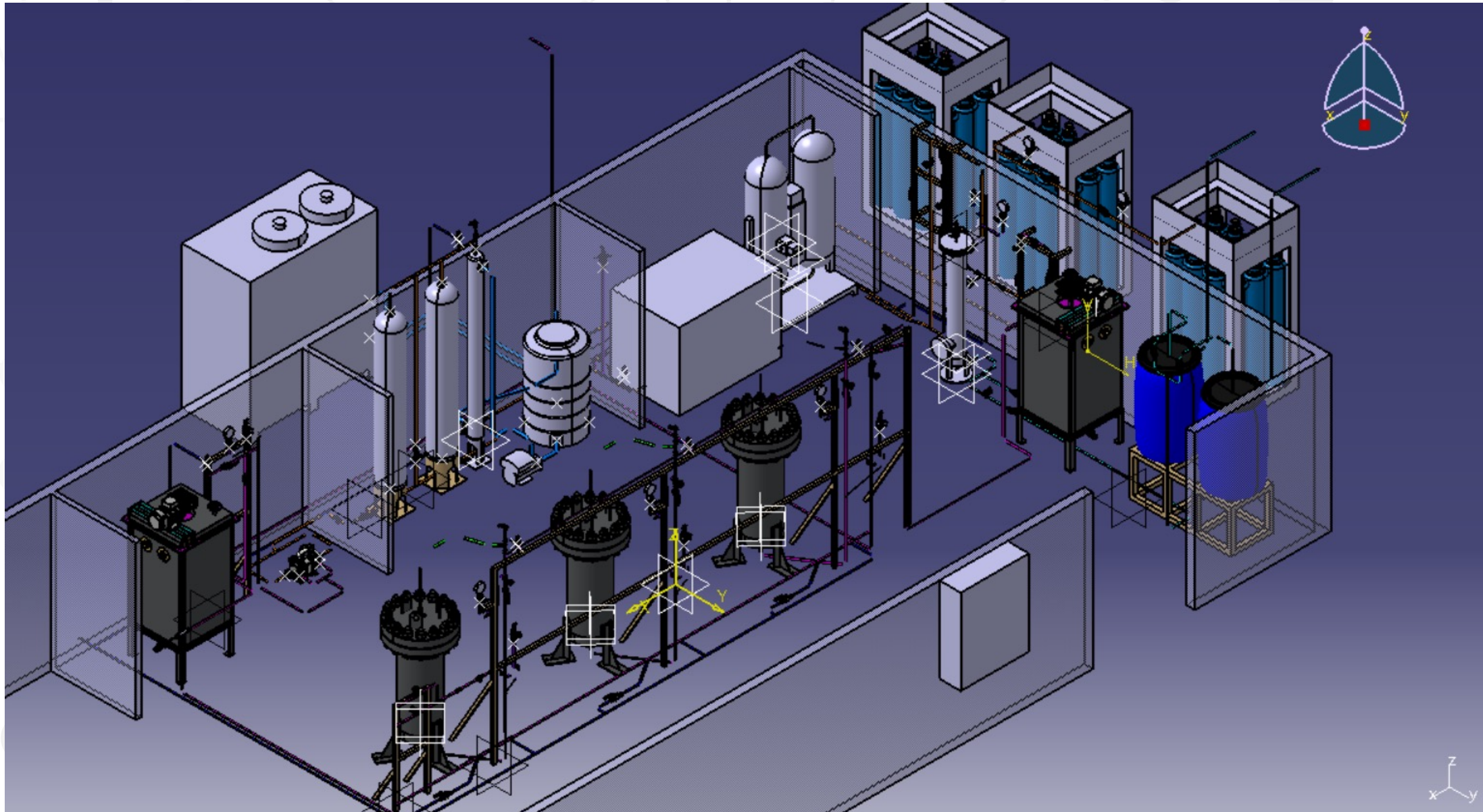




# Supercritical drying equipment design

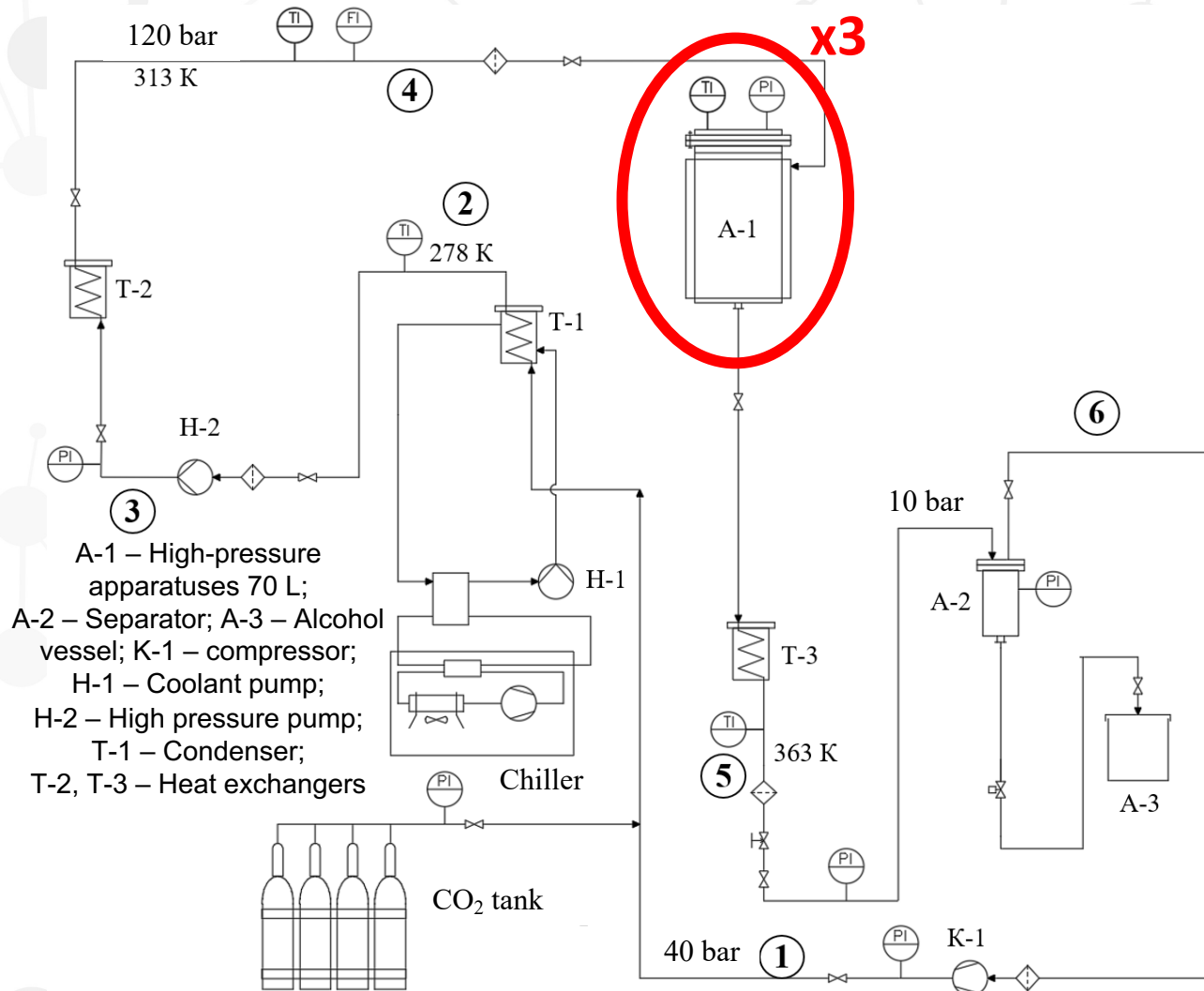


ChemCad





# Pilot plant for aerogel-based material production



A-1 – High-pressure apparatuses 70 L;  
A-2 – Separator; A-3 – Alcohol vessel;  
K-1 – compressor;  
H-1 – Coolant pump;  
H-2 – High pressure pump;  
T-1 – Condenser;  
T-2, T-3 – Heat exchangers

**Parameters:**  
Product form – blankets  
Carbone dioxide flowrate  
150 kg/h  
Capacity up to 10 000 m<sup>2</sup>  
per year



High-pressure apparatuses 70 L

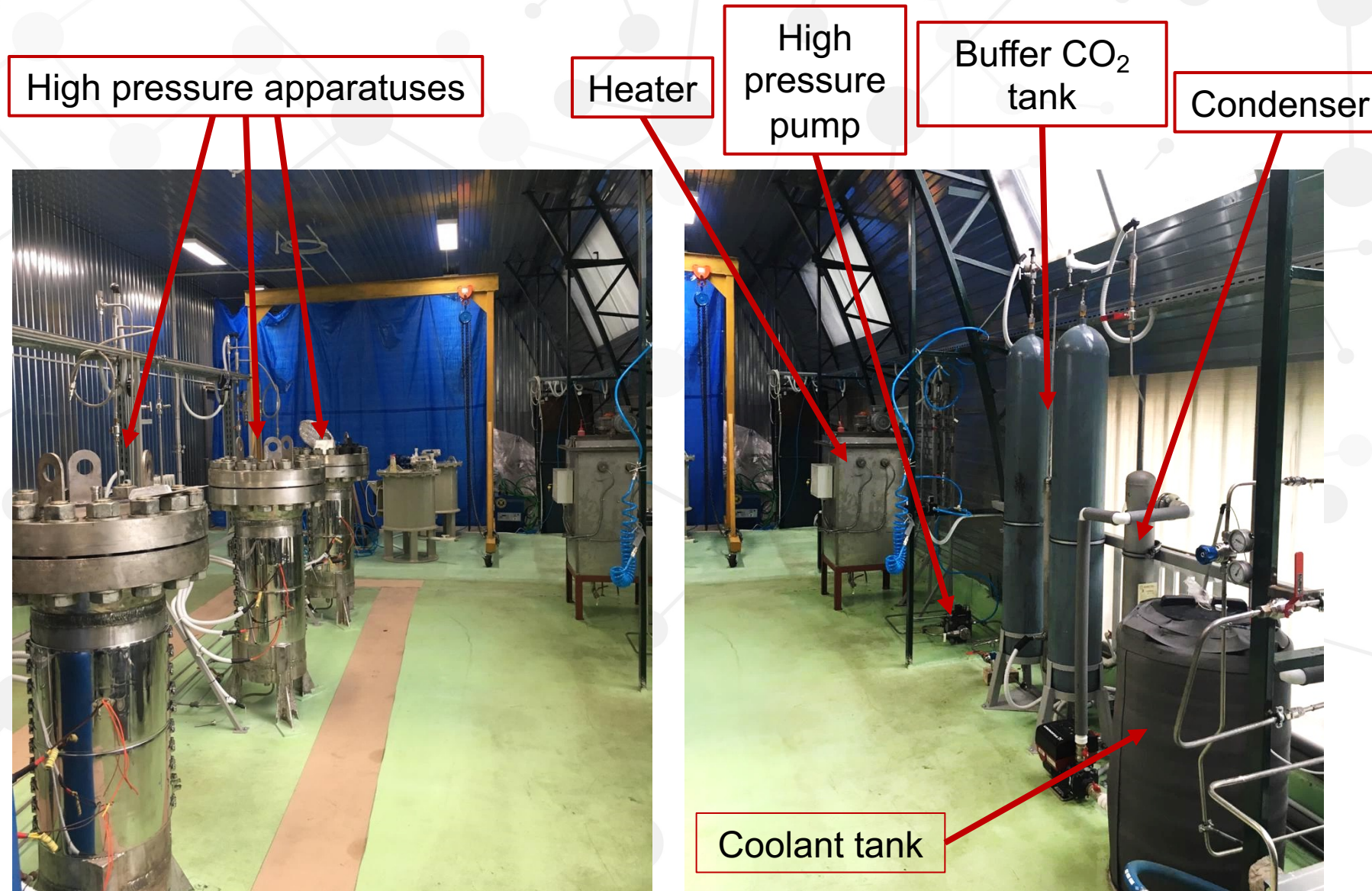


# General view of supercritical drying equipment





# General view of supercritical drying equipment





# Aerogel based superinsulation demands in Russia



## **Aerospace industry**

- Superinsulation of aircraft fuselage, key rocket assemblies, oxidizer tanks

**JSC «Kompozit», Khrunichev State Research and Production Space Center**



## **Fuel and Gas: production, transportation and storage**

- Body insulation of deep oil wells

## **LLC TMC-Truboprovodservice**

- LNG storage tanks superinsulation (new trend of accessible and cheap storage of small volume)

## **LLC TopGas, PLC Novatech**



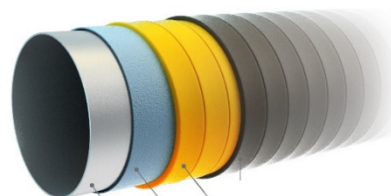
## **Cryogenic and refrigeration equipment**

- Low temperature freezer for pharma

**Pozis Inc.**

## **Pipes for various purposes**

**PLC Peterpipe**





# Current challenges and prospects

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- price of raw materials is increasing
- alcohol recovery

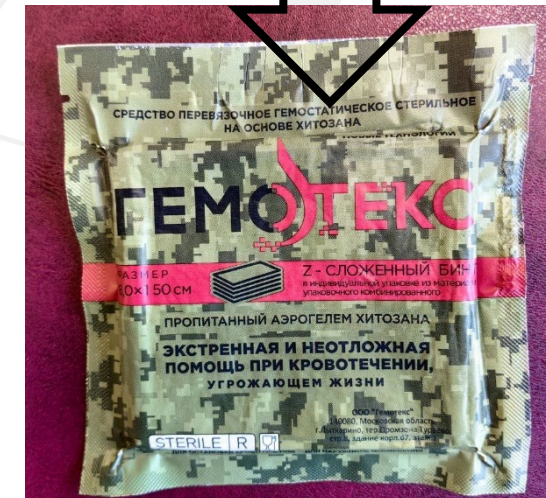
- Development of a new superinsulation production – 1 million m<sup>2</sup>/year
- **Expansion of the range of materials:**
  - aerogels for medical applications (218 government decree)
  - sorbents
  - etc.



# Aerogels for medical applications



Hemostatic agent in the form of a bandage



For the first time, hemostatic efficacy of chitosan-based aerogel particles was studied *in vivo* on a model of damage of a large vessel in the deep wound. Pigs were used as test animals.



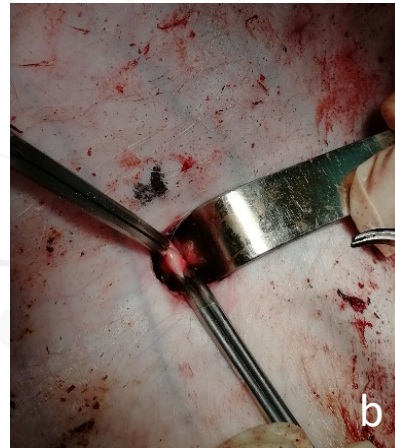
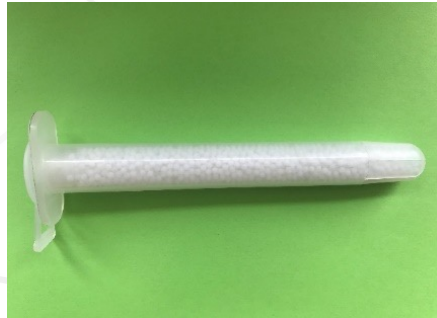
Damaging of the femoral artery by a vascular medical nibbler with a diameter of 6 mm

Development is protected by a patent  
RU 2709462 C1  
"Wound healing and hemostatic agent based on chitosan and a method for its production"

Stopping massive bleeding within  
**3 minutes**



Aerogel particles in pure form and as part of an applicator ("filled syringe")



Stages of modeling the damaging of the large vessel (pig's femoral artery): (a) modeling of the wound channel—a soft tissue wound made by stylet trocar; (b) the allocation of the femoral artery in the wound.



The image shows a large, multi-story building made of orange-brown bricks. It has many windows, some of which are curved. The sky is blue with some white clouds. The building is the Russian Chemical Technology University named after D.I. Mendeleev.

**Thank you for attention!**

**We invite you to cooperation!**

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РОССИЙСКИЙ  
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УНИВЕРСИТЕТ  
ИМ. Д. И. МЕНДЕЛЕЕВА

