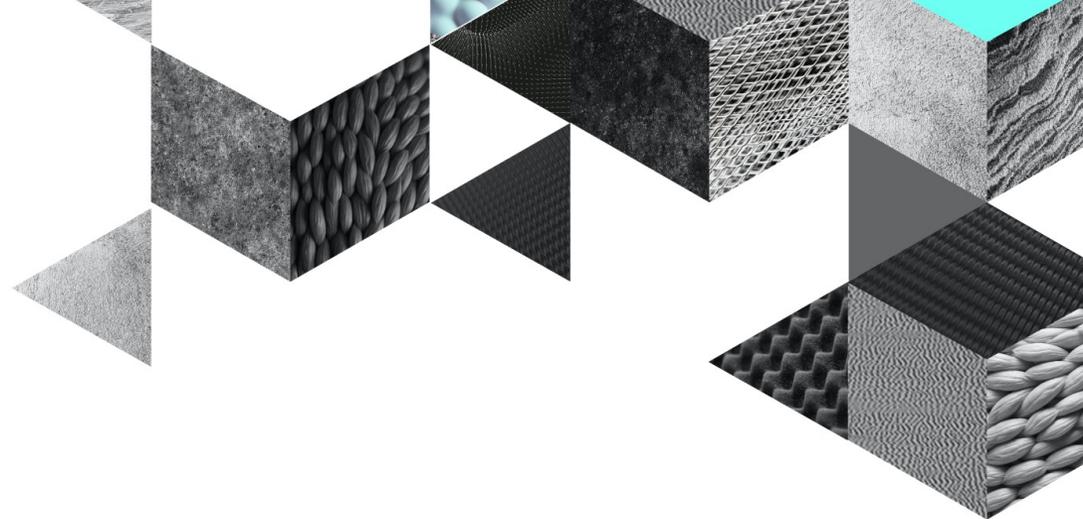
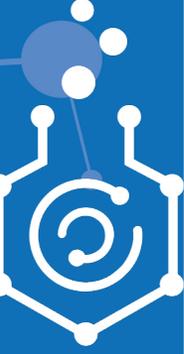


ПАНЕЛЬНАЯ ДИСКУССИЯ

РАЗРАБОТКА КРОВООСТАНАВЛИВАЮЩИХ МАТЕРИАЛОВ НА ОСНОВЕ АЭРОГЕЛЕЙ, РХТУ ИМ МЕНДЕЛЕЕВА

ПАВЕЛ ЦЫГАНКОВ





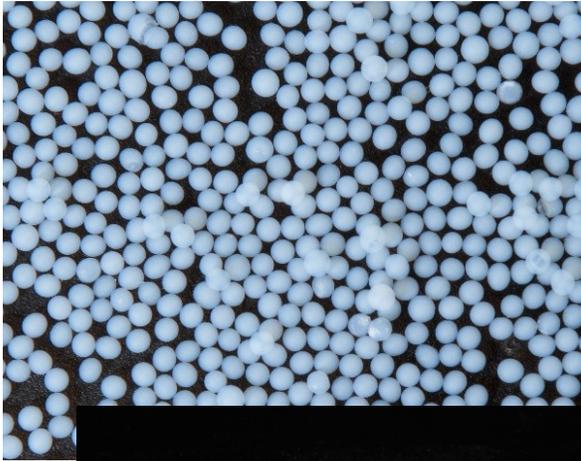
Aerogels from laboratory to industry

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

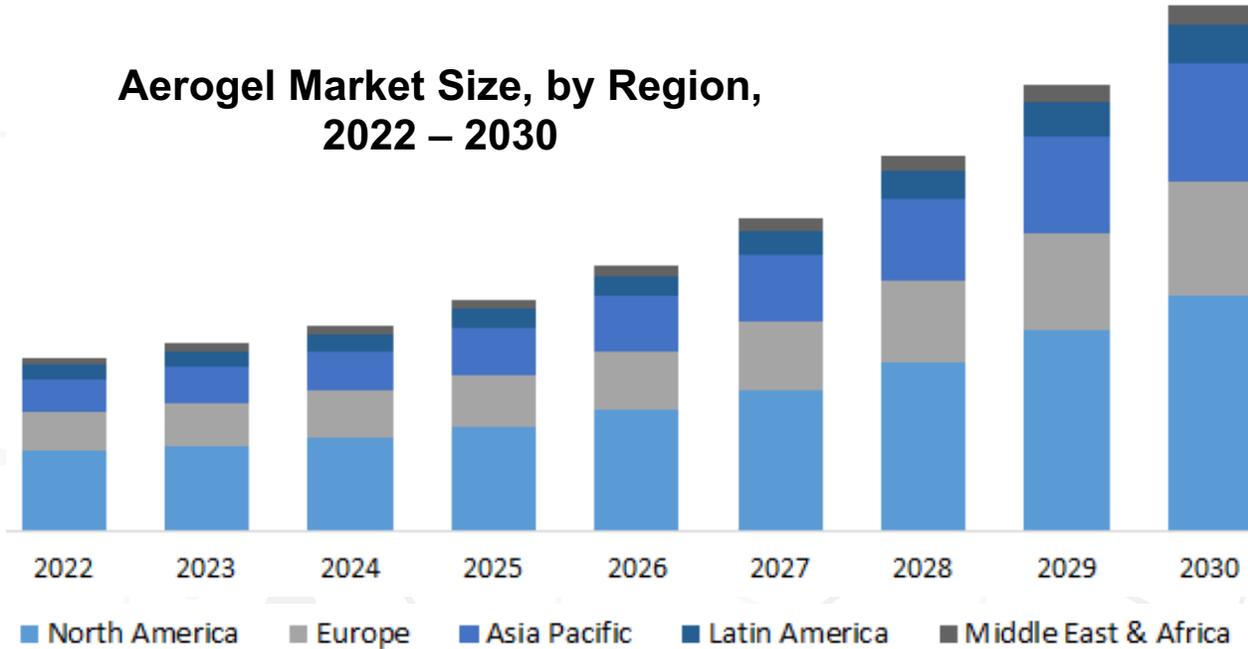
Different shapes and sizes



Aerogel market

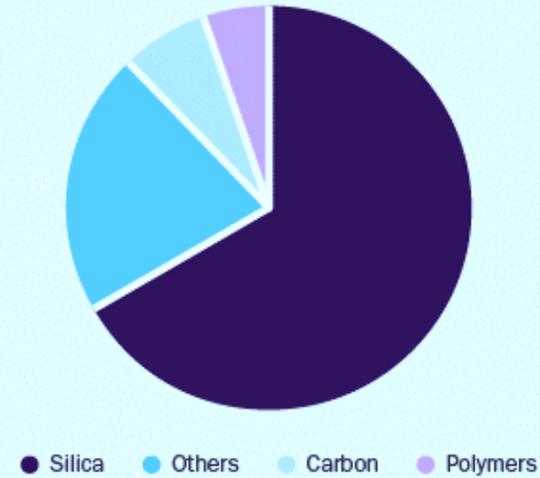


Aerogel Market Size, by Region, 2022 – 2030



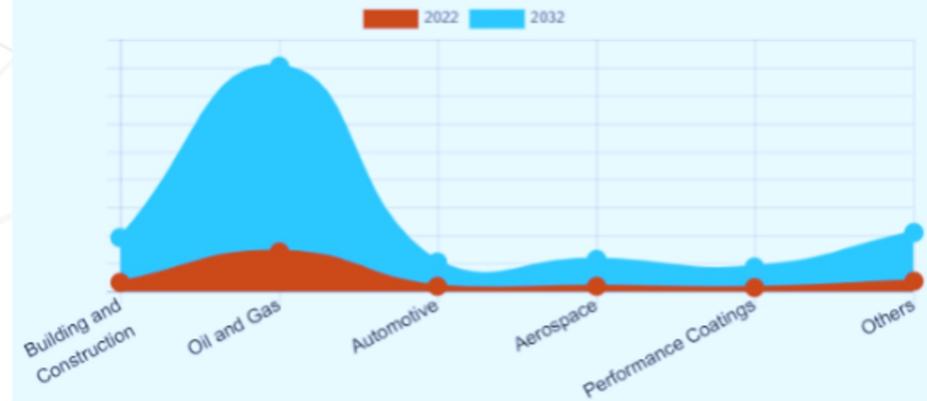
Global Aerogel Market

share, by product, 2022 (%)



AEROGEL MARKET

BY END USE INDUSTRY



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

<https://www.polarismarketresearch.com/industry-analysis/aerogel-market>
<https://www.grandviewresearch.com/industry-analysis/aerogel-market>
<https://www.alliedmarketresearch.com/aerogel-market>

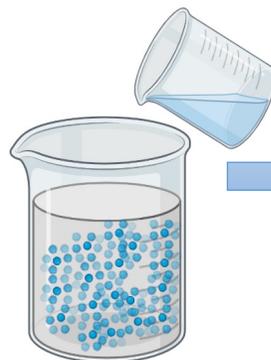
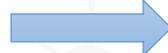
Preparation of aerogels



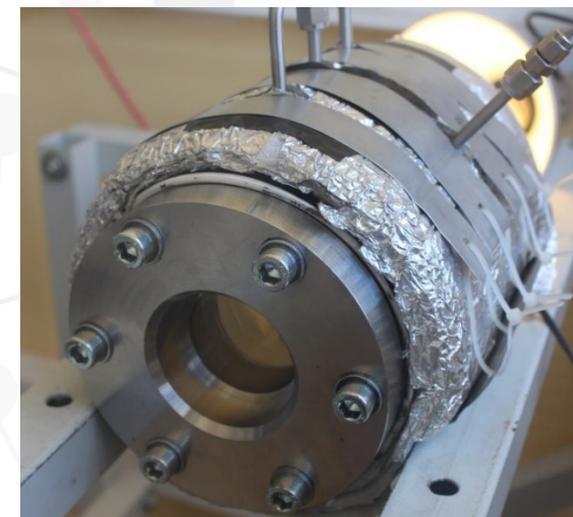
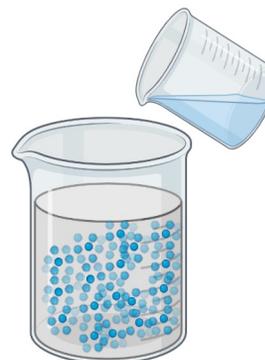
Sol



Gelation

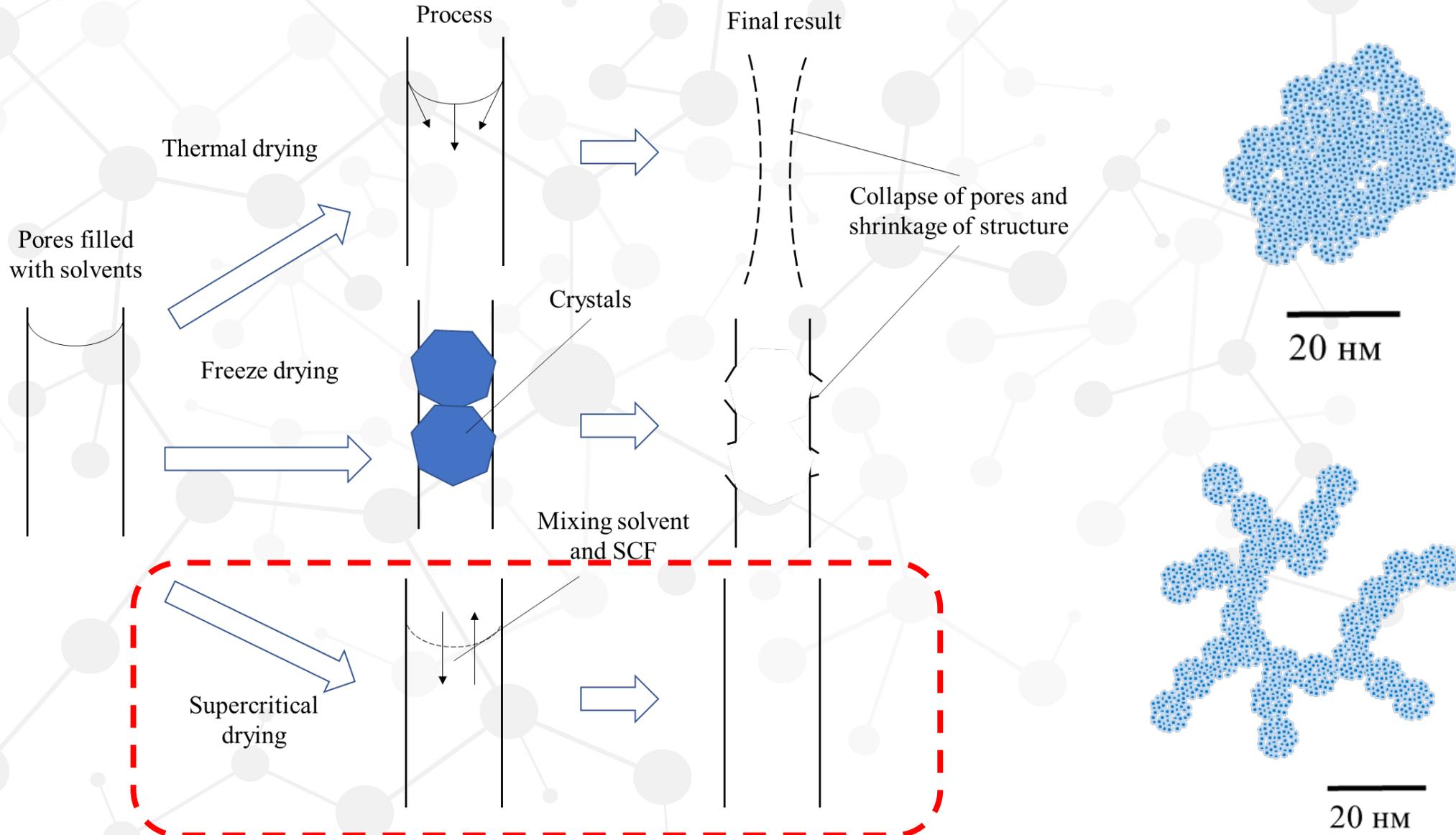


Preparing for
drying

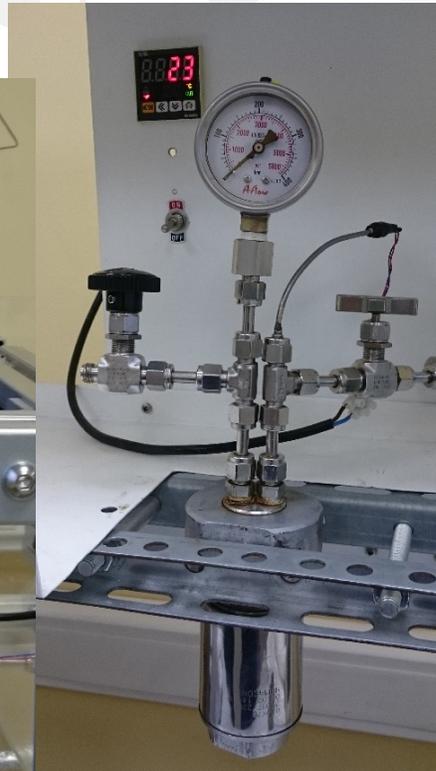
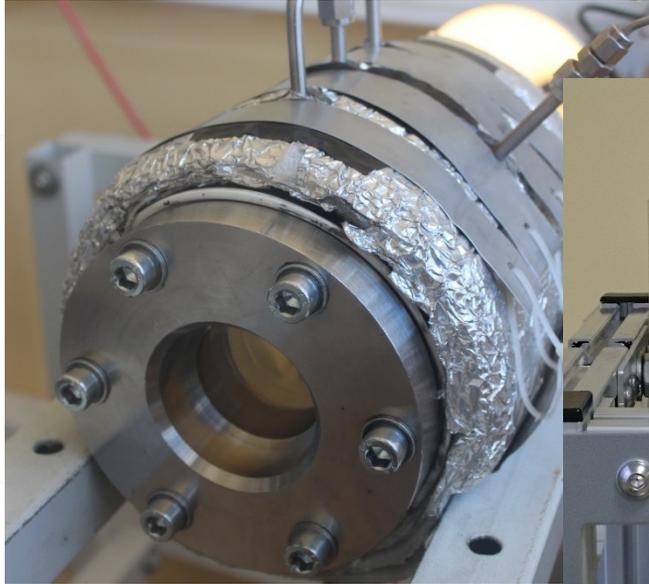


Drying

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 бар
- paddle mixer

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

Aerogels for superinsulation



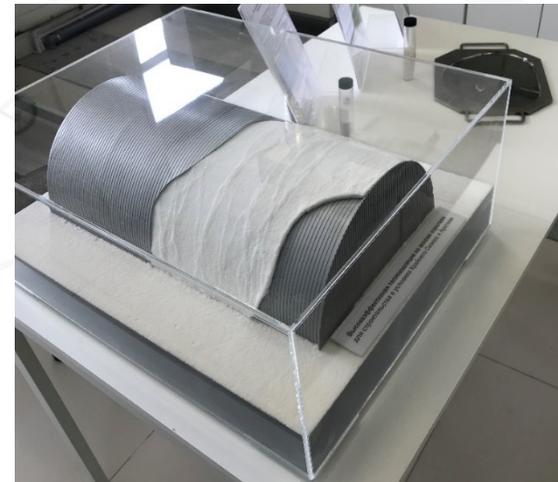
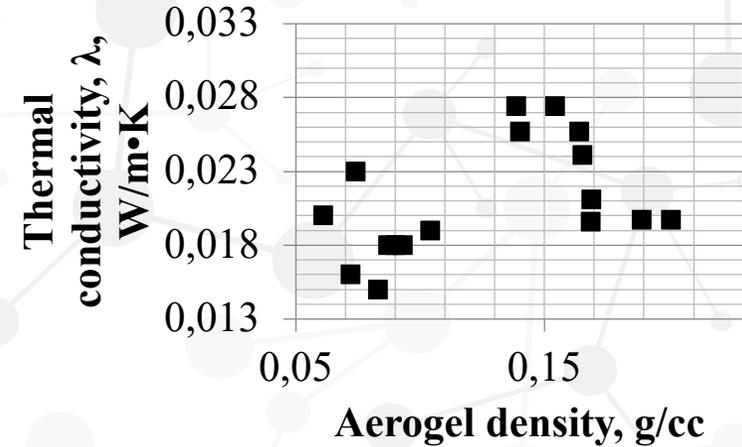
Thermal conductivity of different materials

| Material | λ , W/(m·K) |
|------------------|---------------------|
| Glass wool | 0,034-0,045 |
| Polystyrene foam | 0,029-0,055 |
| Air | 0,025 |
| Aerogel | 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



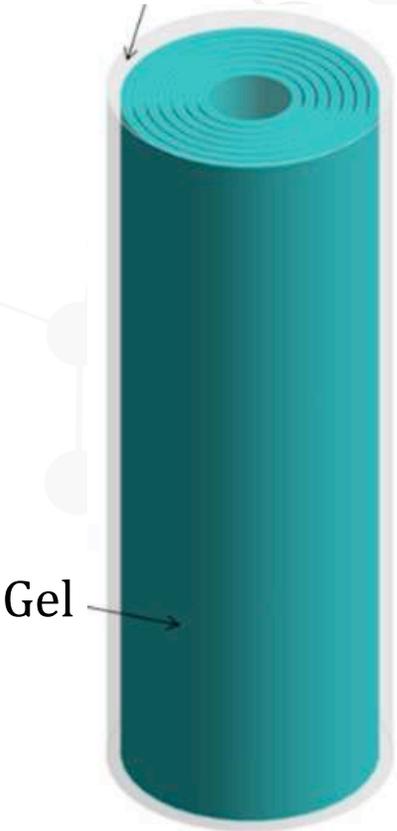
Building prototype for the Far North

Aerogel blankets

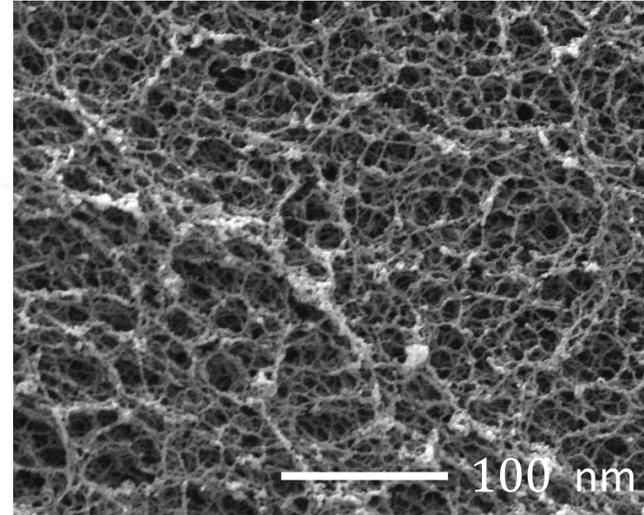


Product appearance

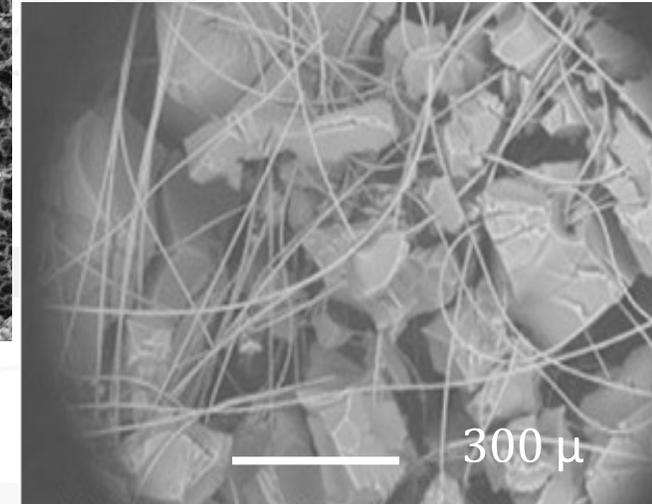
Free volume of the vessel



Aerogel structure



Fiber reinforced aerogel

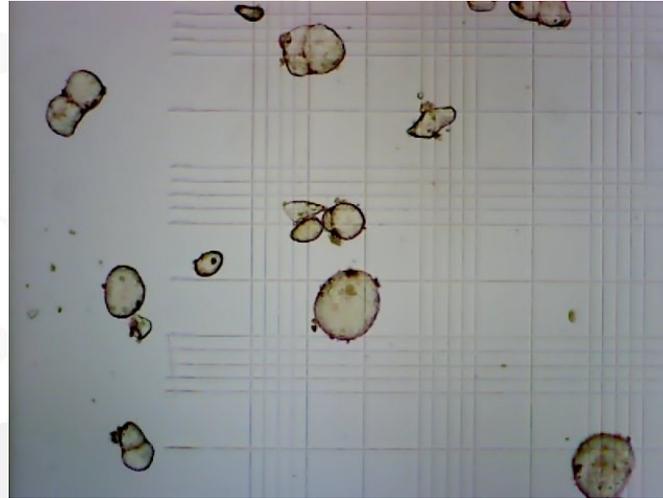
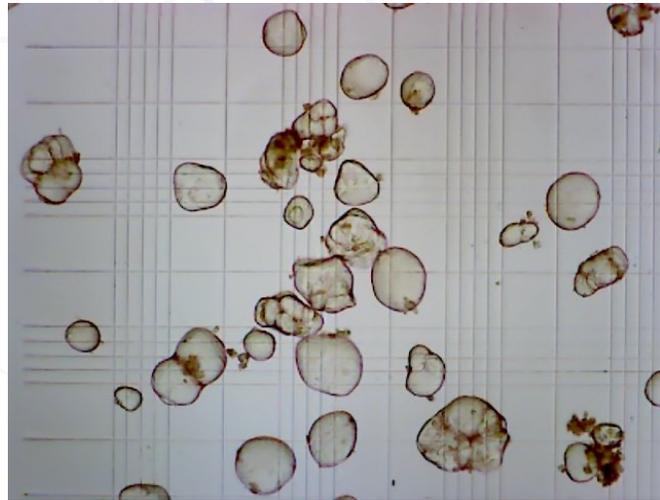


Thermal
conductivity < 15
 $\text{mW}/(\text{m}\cdot\text{K})$

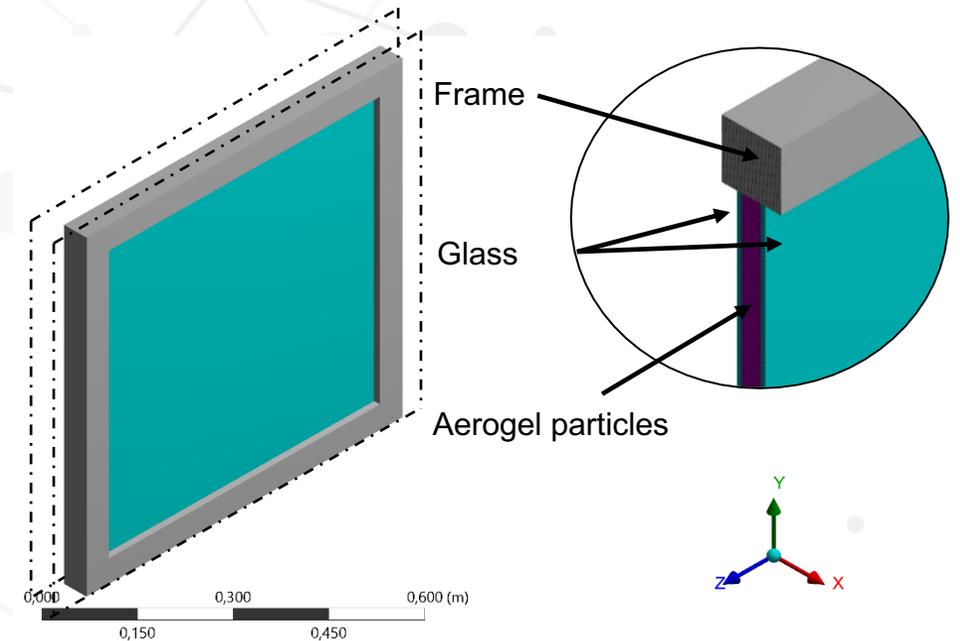
Aerogel particles for superinsulation



Aerogel particles



Prototype of translucent heat-insulating panel



Aerogel particles properties:

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

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

Production development



**Pre-design
development**



Design

Automation



Funding

Technical assistance

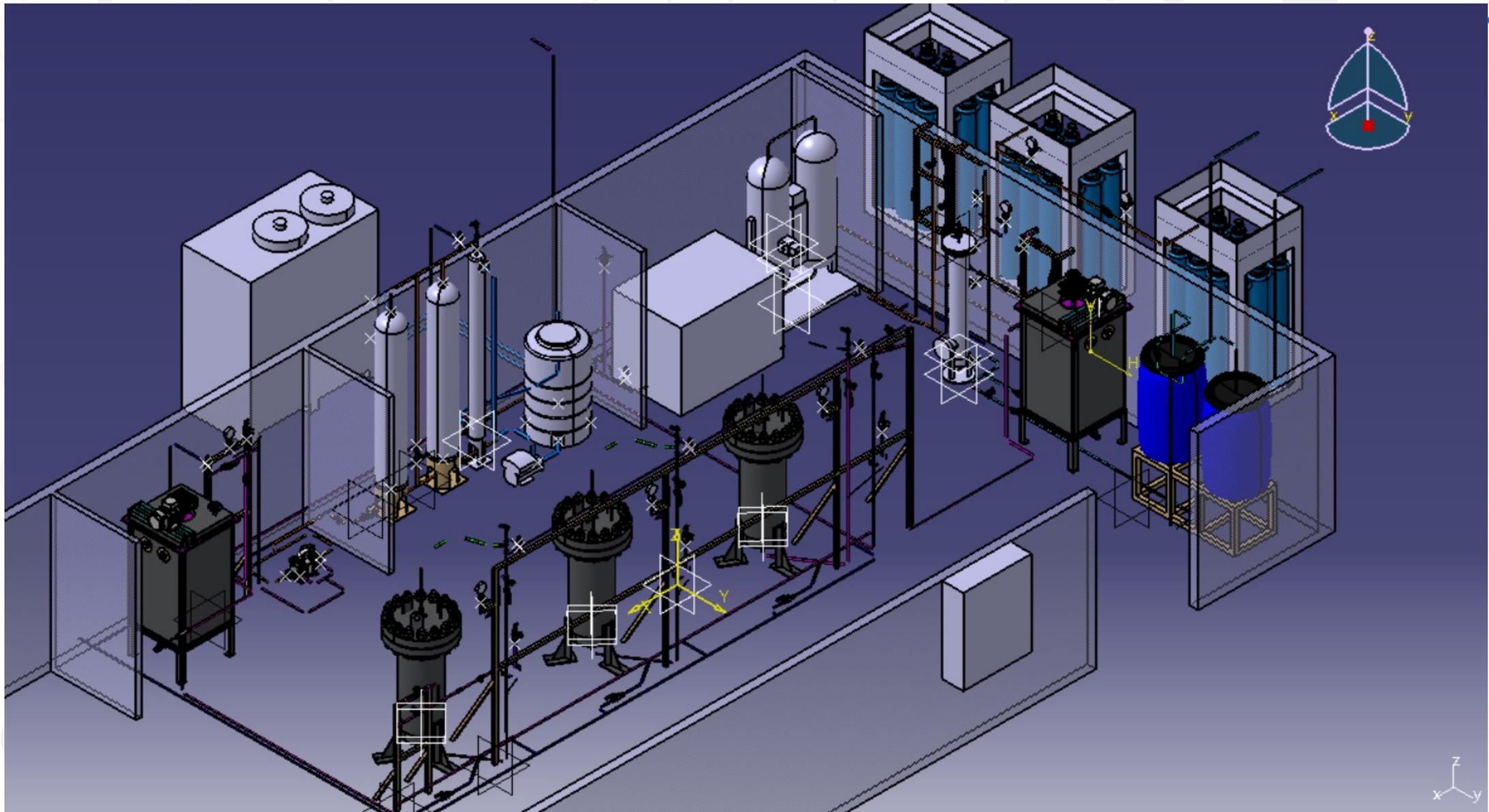


**Technical
supervision**

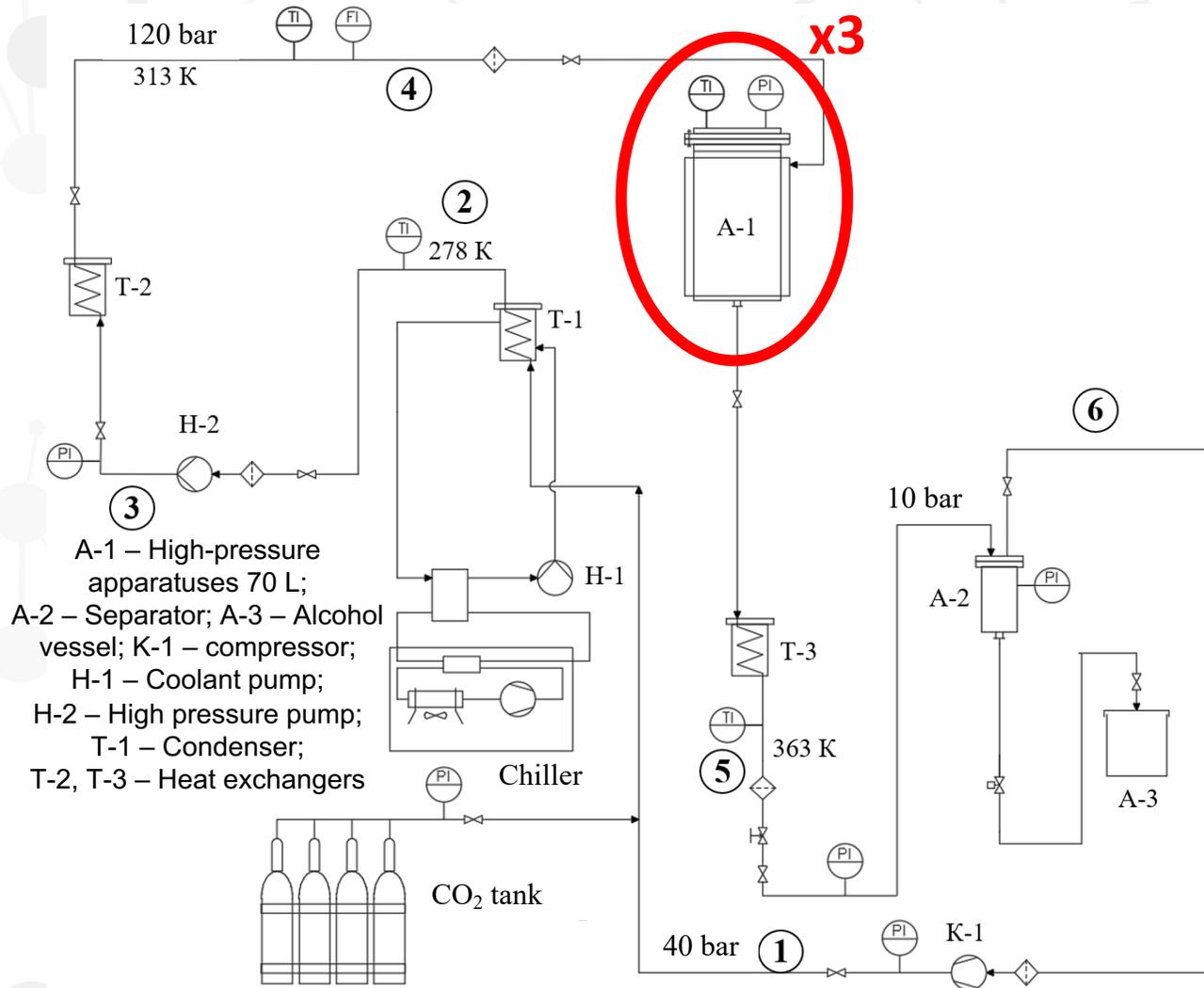
Supercritical drying equipment design



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
 Carbon dioxide flowrate
 150 kg/h
 Capacity up to 10 000 m²
 per year



High-pressure apparatuses 70 L

General view of supercritical drying equipment



High pressure apparatuses

General view of supercritical drying equipment



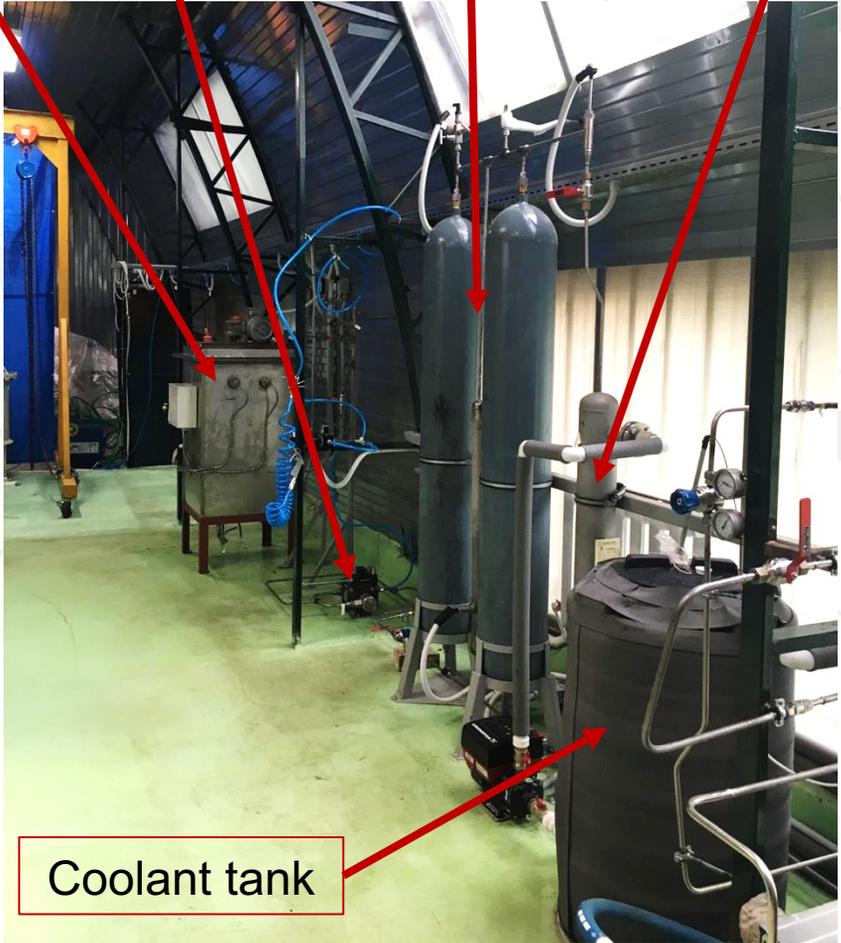
High pressure apparatuses

Heater

High pressure pump

Buffer CO₂ tank

Condenser



Coolant tank

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

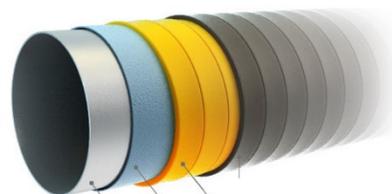
Cryogenic and refrigeration equipment

- Low temperature freezer for pharma

Pozis Inc.

Pipes for various purposes

PLC Peterpipe



Current challenges and prospects



- price of raw materials is increasing
- alcohol recovery

- Development of a new superinsulation production – 1 million m²/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.



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

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



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.

* Lovskaya D., Menshutina N., Mochalova M., Nosov A., Grebenyuk A. Chitosan-based aerogel particles as highly effective local hemostatic agents. Production process and in vivo evaluations // *Polymers*, 2020, V.12, Issue 9

Thank you for attention!

We invite you to cooperation!

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+7 967 268 97 39
tsygankov.p.i@muctr.ru**

РОССИЙСКИЙ
ХИМИКО-ТЕХНОЛОГИЧЕСКИЙ
УНИВЕРСИТЕТ
ИМ. Д. И. МЕНДЕЛЕЕВА

