INSTITUT GÉOPOLYMÈRE

UNIVERSITÉ de Picardie Jules Verne — CAMPUS universitaire de Saint-Quentin — PÔLE TECHNOLOGIQUE

2023 GEOPOLYMERCAMP

15th GP-Camp

LTI PÔLE TECHNOLOGIQUE SAINT-QUENTIN — UNIVERSITÉ de Picardie Jules Verne — MAG Matériaux Avancés en Géopolymère

Saint-Quentin (France)

July 10-12, 2023

2023
GEOPOLYMERCAMP

State of the Geopolymer R&D 2023

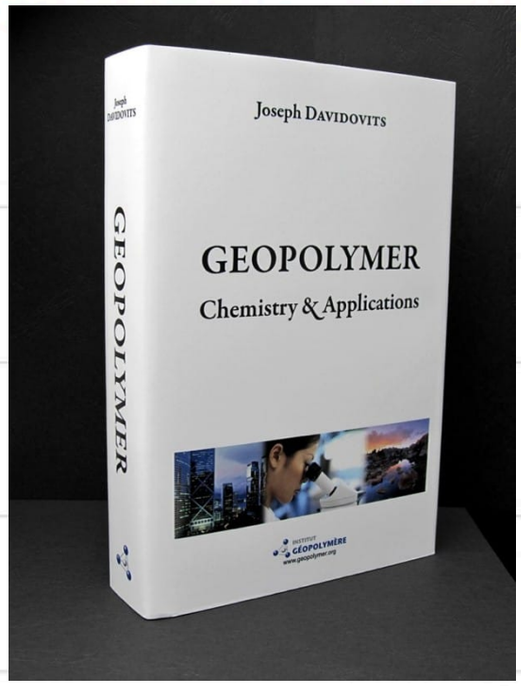
Joseph Davidovits

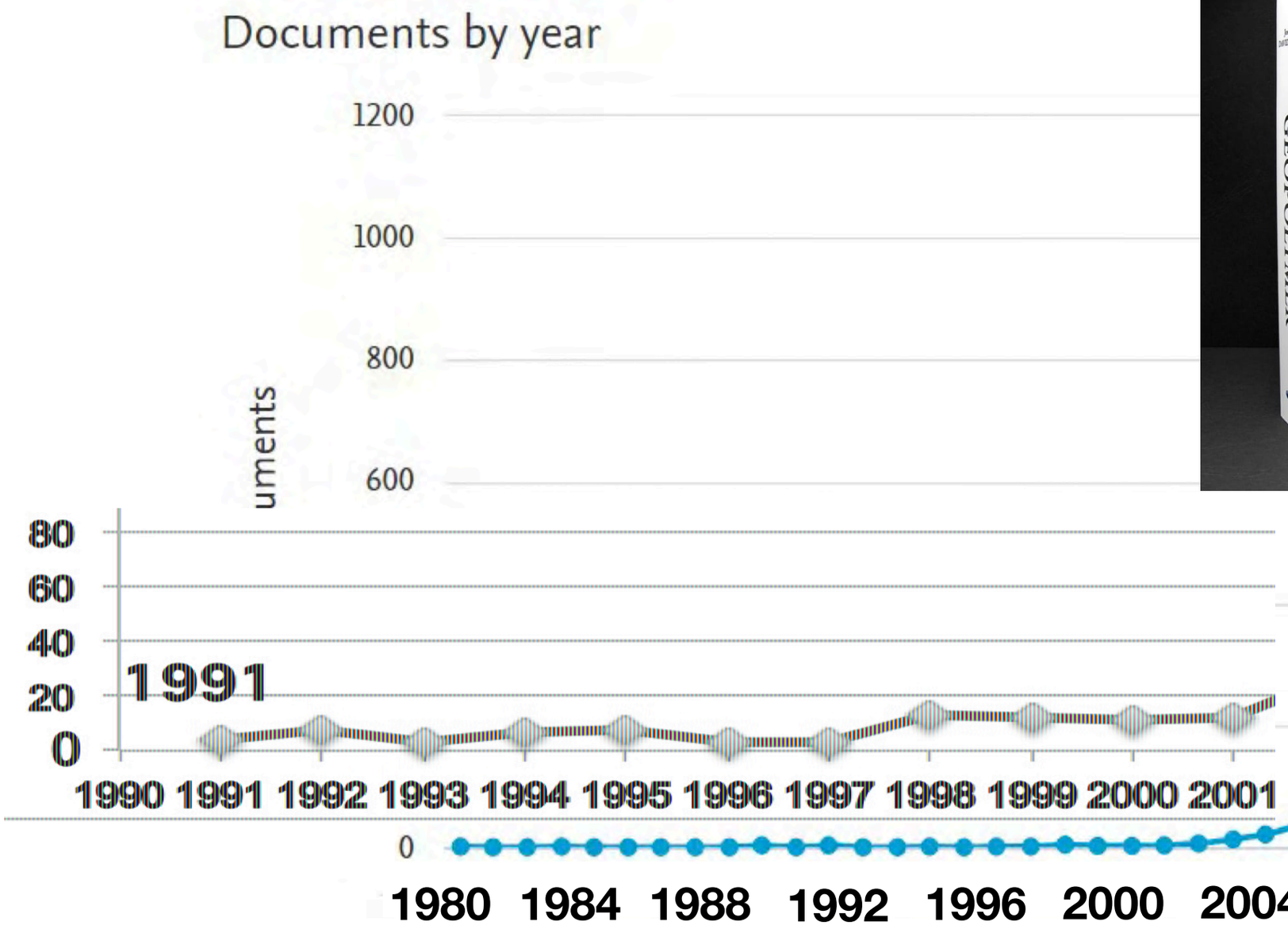
Geopolymer research 1988

1st Geopolymer conference

Geopolymer research 2018

Subject „Geopolymer“ in Scientific Publications





Literature Search: Statistical data of SCOPUS database

State of the Geopolymer R&D 2023

1) **Geopolymer science.**

2) **Global warming**: management of water resources; floodings and infrastructures (roads, pavements repair).

3) **Additive manufacturing / 3D printing.**

State of the Geopolymer R&D 2023

1) Geopolymer science.

16 research topics

#1 Polymeric character of geopolymers

#2 Poly(siloxonate), soluble silicate (water-glass)

#3 Metakaolin MK-750 geopolymer

#4 Calcium-based geopolymer

#5 Rock-based geopolymer

#6 Silica-based geopolymer

#7 Fly ash-based geopolymer

#8 Phosphate-based geopolymer

16 research topics

#9 Organic-mineral geopolymer.

#10 Long-term durability (archaeology).

#11 Geopolymer-fiber composites.

#12 Geopolymer in ceramic processing.

#13 The manufacture of geopolymer cements: No fly ash !

#14 Geopolymer concrete.

#15 Material for Radioactive waste, Particules and gaz pollution.

 # 16 3D printing; additive manufacturing.

#1 Polymeric character of geopolymers

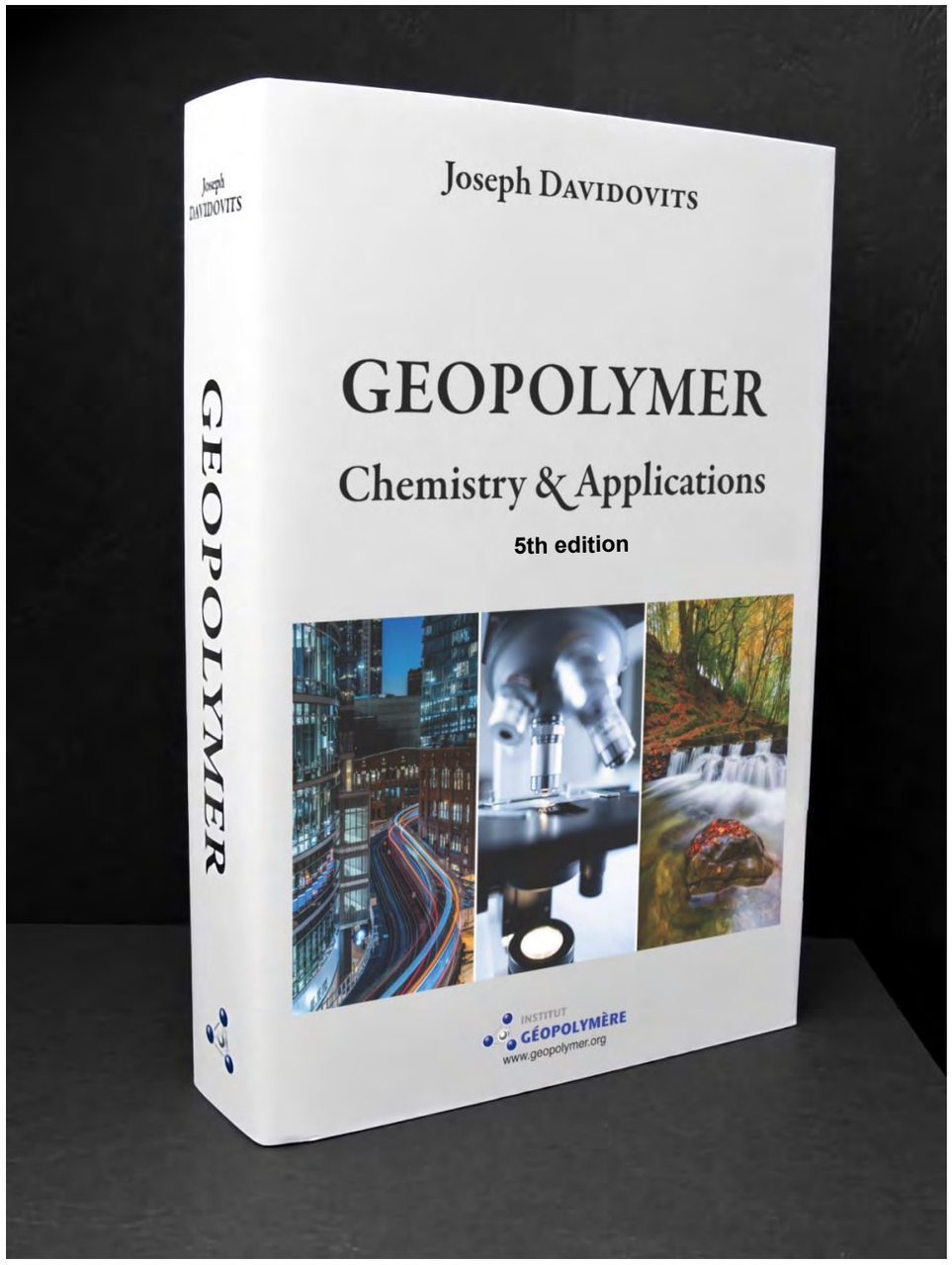
1975-1976: mineral polymer

1978-1979: geopolymer

2 systems:

- alkali-based GP

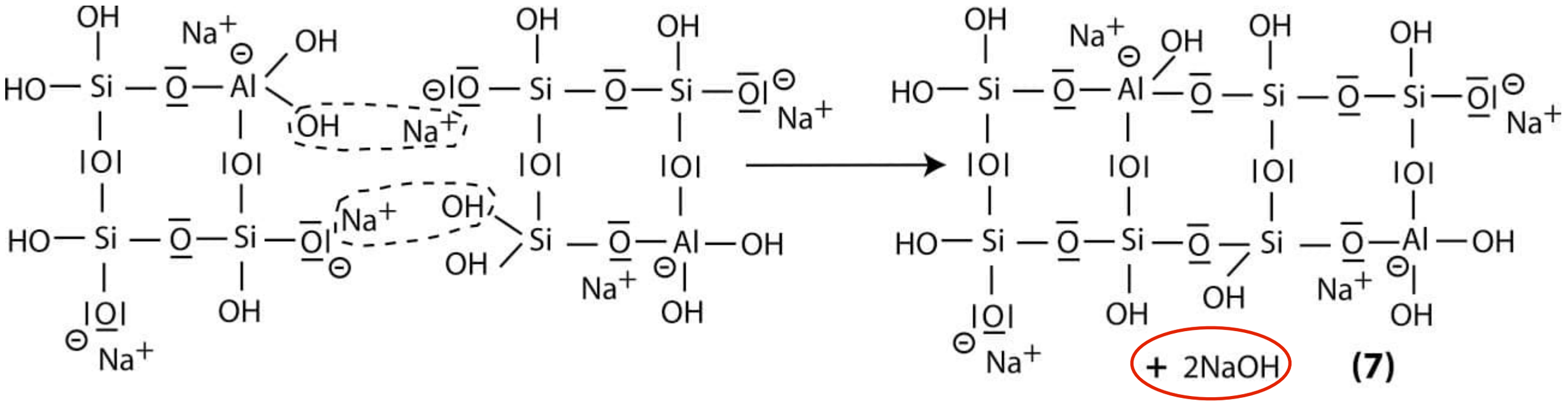
- phosphoric acid-based GP



Alkali-based Geopolymerization

1. Alkalination ~~*alkali-activation*~~
2. Depolymerization of silicates
3. Gel formation of oligo-sialates
4. Polycondensation
5. Reticulation, networking
6. Geopolymer solidification

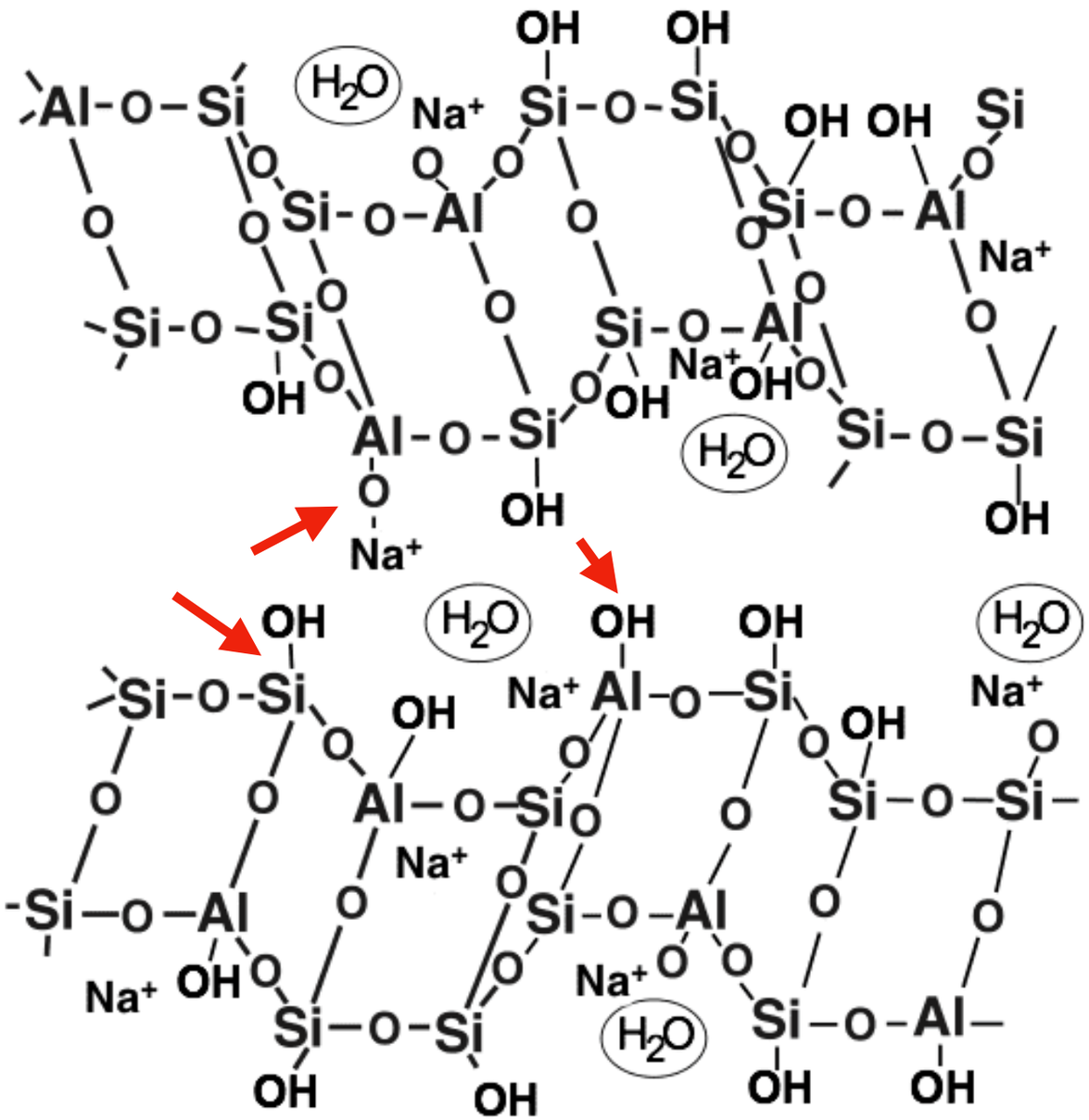
Step 4: polycondensation



Na^+ or K^+

or KOH

Step 5: reticulation, networking



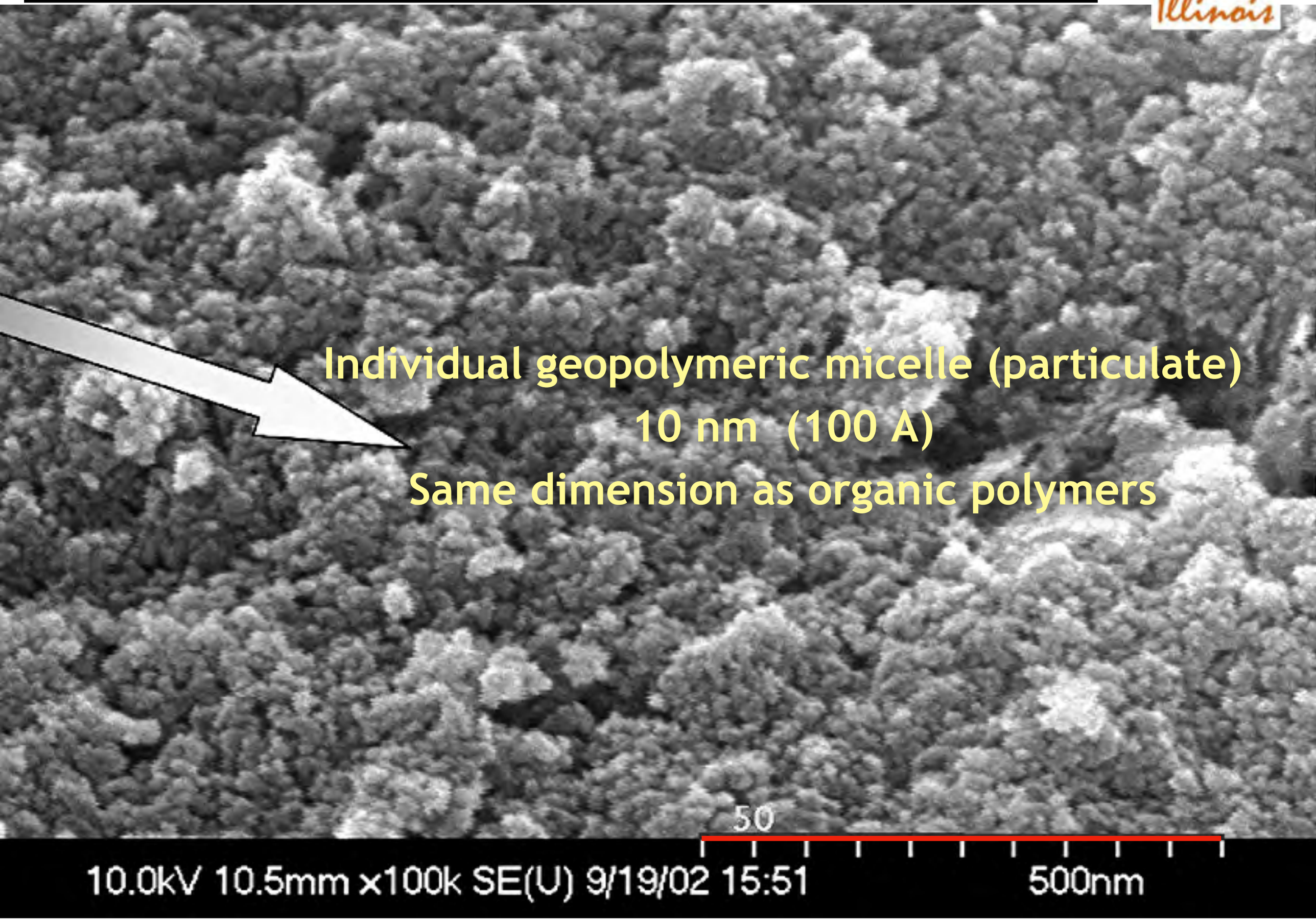
Step 5: reticulation, networking

Step 6: geopolymer solidification

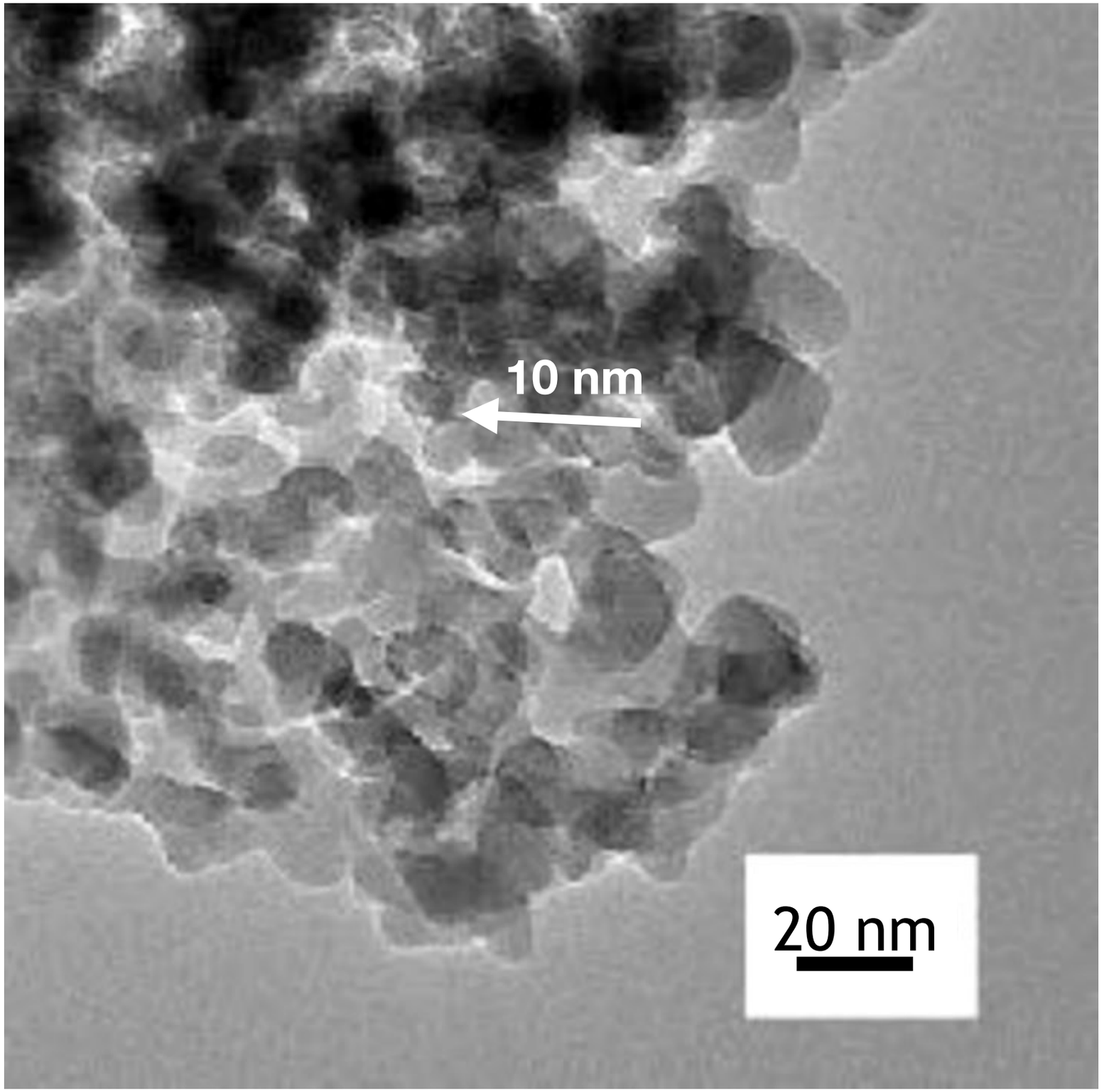
dehydroxylation

2003, Prof. Kriven's team *University of Illinois, USA*

MSE at Illinois



Step 5
reticulation



2012 Prof. Dong-Kyun (Don) Seo's team
School of Molecular Sciences, Arizona State University, Tempe, USA

Colloidal
silica
30-40 nm

GP-micelle
10 nm

Silica Fume
200-300 nm

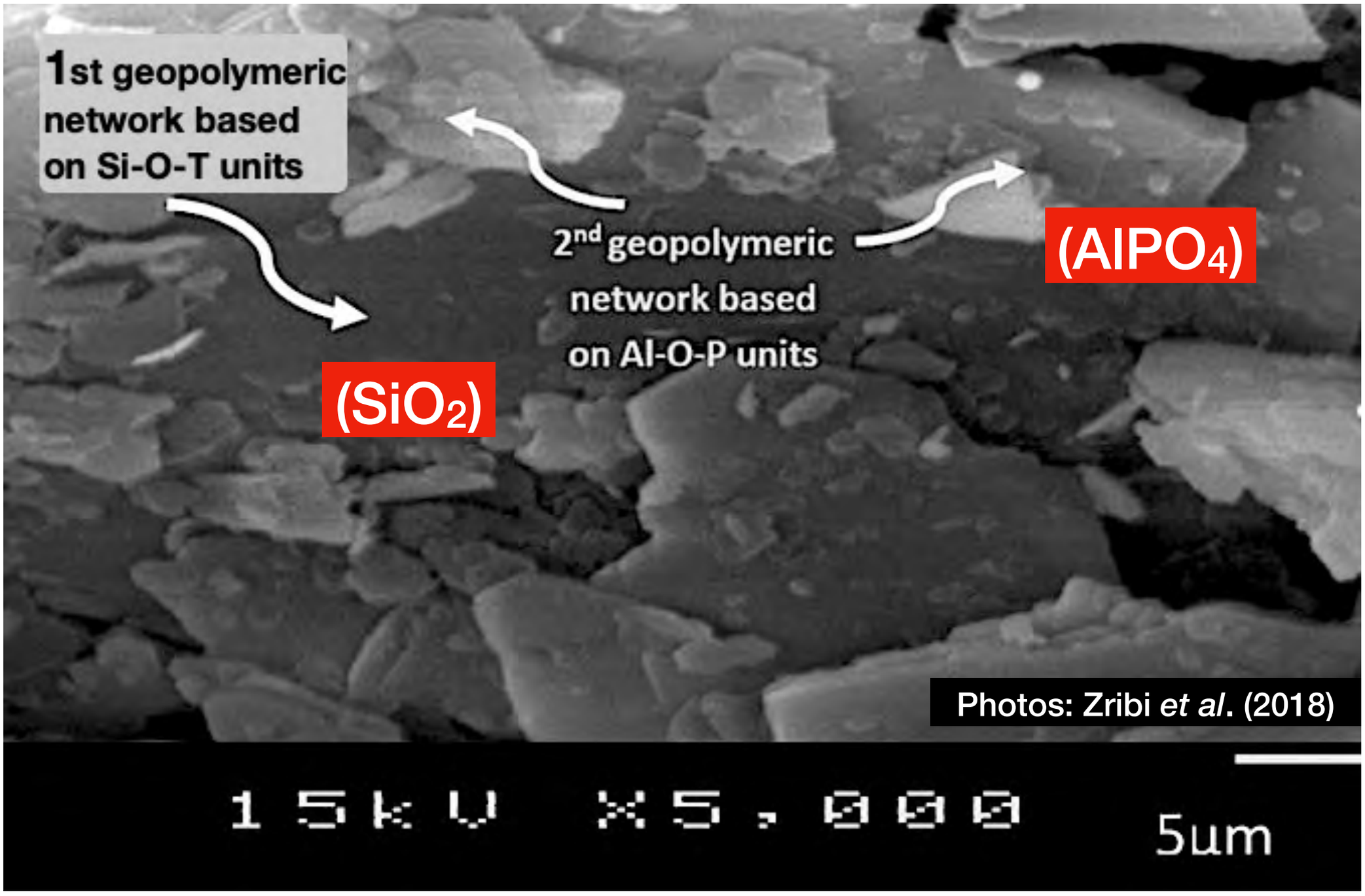
Fly ash
3-15 μ

Geopolymer = nano material not
unknown « Gel »

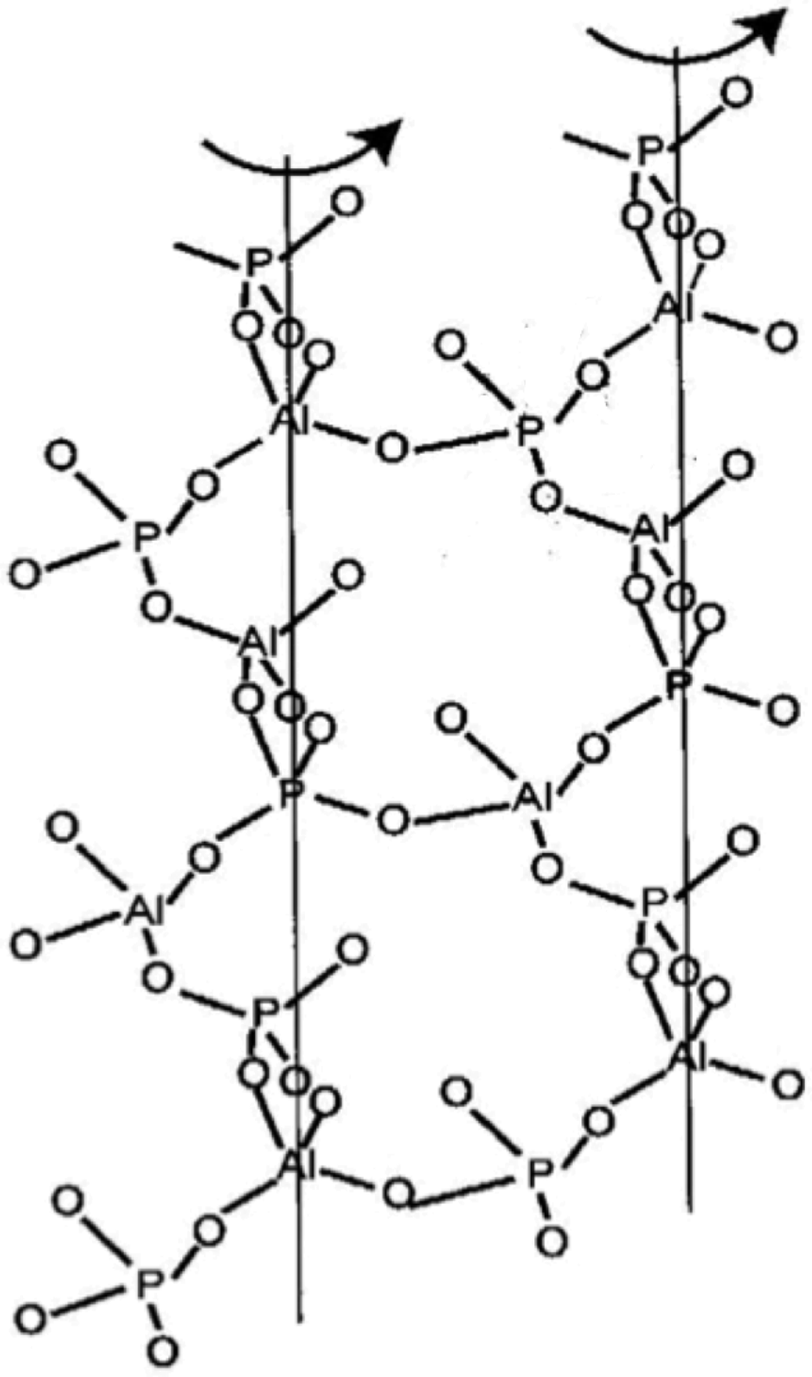
Acid-based Geopolymerization

Phosphoric acid + MK-750

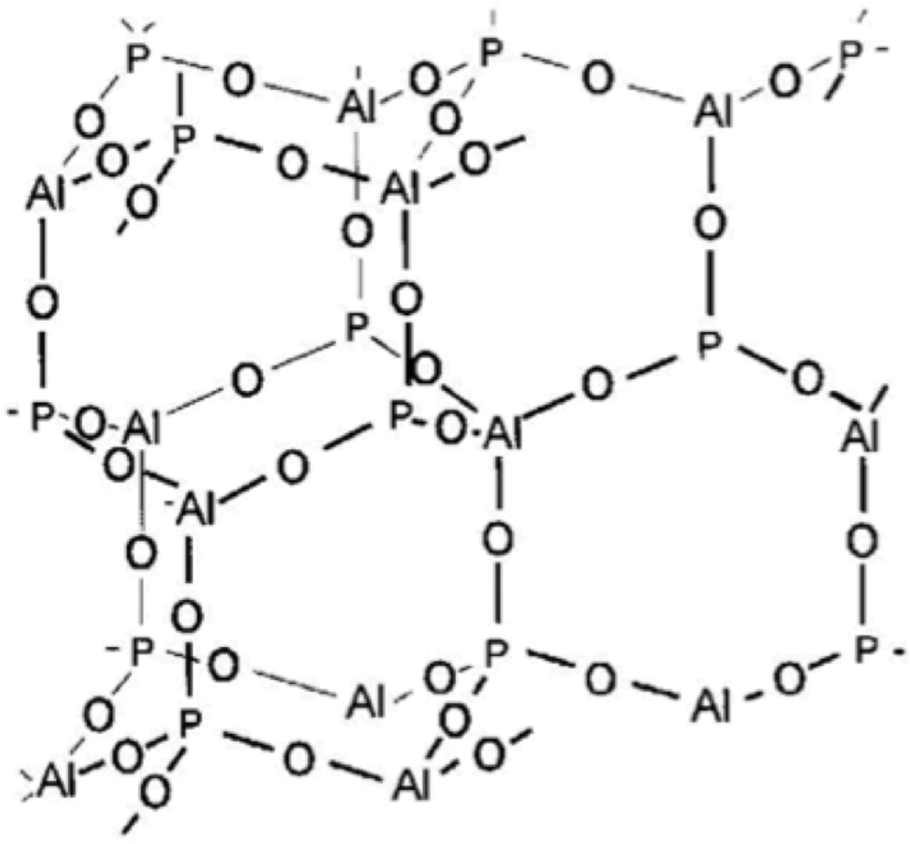
$$H_3PO_4 + Si_2O_5AlO_2 \longrightarrow (SiO_2)_n + (AlPO_4)_n$$



Polymeric structures of $AlPO_4$-Geopolymers



⇒ Cross-linked (P-O-Al-O)n
poly(alumino-phospho) chains



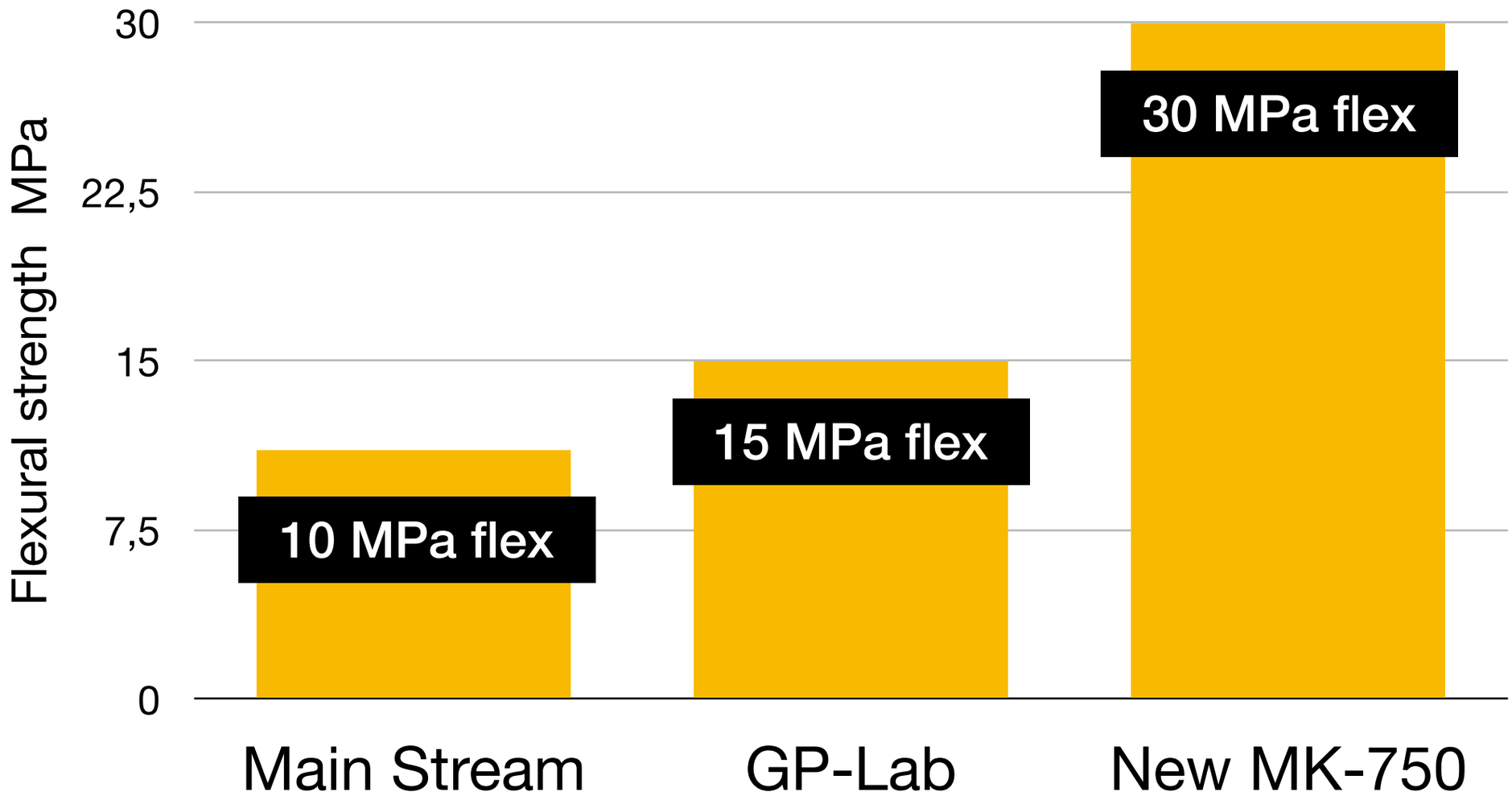
$AlPO_4$-tridymite/cristobalite

$AlPO_4$-berlinite (isostructural to quartz)

#3 Metakaolin MK-750 alkali-based geopolymer

High-strength MK

High-strength MK



Flexural strength 30 MPa

Compressive strength 180 MPa

State of the Geopolymer R&D 2023

2)Global warming:

- Management of water resources;

- Floodings and infrastructures:

(roads, pavements repair).

A continent is on fire.

Photo credit: AP/Euronews (31/12/2019).

A continent is on fire. Both Australia and California have never experienced such an inferno. More and more citizens blame the climate change, CO_2 emissions responsible for this, essentially from the burning of coal in the power plants.

I) Management of Water Resources;

The Ganges, the “mother river”, as the Hindus call it, is a lifeline, a source of economic prosperity as much as of religious veneration.

Over the 2,500 kilometers of their course, these waters would be able to heal those who immerse themselves in them and to free them from the cycle of reincarnations.

The Ganges irrigates 30% of Indian territory, washes and feeds 450 million people, or 40% of the Indians.

But today the Ganges is on the brink, closer than ever to suffocation, contaminated by three billion liters of wastewater per day, representing a pollution rate 3,000 times higher than the recommendations of the World Organization of health.

Environ Monit Assess (2023) 195:693
https://doi.org/10.1007/s10661-023-11303-9
Environmental Monitoring and Assessm

A comprehensive review on sustainable clay geopolymers for wastewater treatment: circ and future outlook

Ali Maged · Hadeer Abd El-Fattah · Rasha M. Kamel · Sherif Kharbish · Ahmed M. Elgarahy

Suez University and Port Said University , Egypt.

Recently, the awareness of the environmental sustainability for wastewater treatment has increased rapidly in quest of meeting the enormous global water demand coupled with the inherent depletion of water resources and the development of modern society.

Heavy metals, herbicides, dyes, pesticides, pharmaceuticals, and organic (aromatic) compounds are among the contaminants of rivers and lakes. ….

The presence of pharmaceutical substances in water adversely impacts human health and living ecosystems because they may lead to antibiotic tolerant bacteria and genetic resistance factors in the marine ecosystem. …

Due to the spreading of the COVID-19 pandemic, most antiparasitics, antiprotozoals, antibiotics, glucocorticoids, and antivirals were consumed in large quantities in this virus treatment.

The concentration of antiviral agent drugs increased by more than 70% in urban wastewater during the pandemic compared with their concentration before the pandemic.

The only practical approaches are new sustainable materials and products, green production techniques, and precise life cycle management….

In this regard, ***Clays-Based Geopolymers*** have emerged as affordable, durable, and eco-benevolent materials for water and wastewater clean-up.

2) Flooding and Infrastructures.

Roads,

Pavements

Repair.

THE ECONOMIC TIMES
English Edition | Today's Paper

24 July 2022

Mumbai roads will be potl in two yrs, will use Geopol technique: Maha CM Shi

ANI | 24 Jul 2022, 08:46 AM IST

Maharashtra Chief Minister Eknath Shinde stressed on the problems that the citizens are facing due to potholes on the streets in Mumbai on July 23. The CM further informed that the government will be filling these potholes using the Geopolymer technique.

"Today I held a meeting which was attended by Mumbai Municipal Commissioner and other representatives. It has been discussed that potholes will be filled using the Geopolymer technique. Instructions have been given to fill potholes immediately," the CM said.

3) Geopolymer for Additive Manufacturing 3D-Printing

- ceramic-type

- cement / concrete

3D printing ceramic-type geopolymer

Dipartimento di
Ingegneria Industriale

Direct and indirect 3D printing with geopolymers

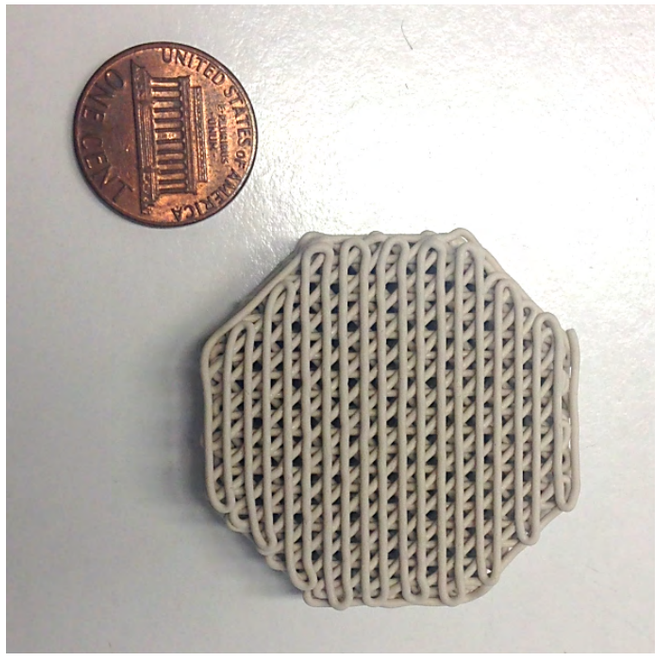
G. Franchin[1], H. Elsayed[1], P. Scanferla[1], A. De Marzi[1], F. Gobbin[1], L. Zeffiro[1], A. Conte[1], A. Italiano[2], P. Colombo[1,3]

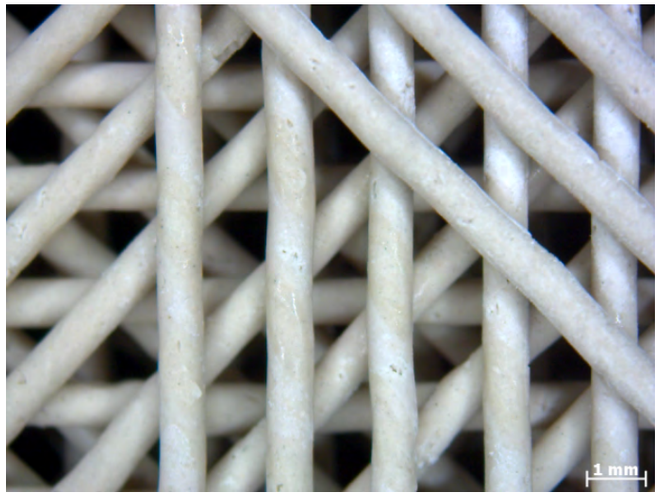
[1] Industrial Engineering Dept., University of Padova, Italy
[2] Desamanera, Borsea (RO), Italy
[3] Dept. of Material Science and Engineering, The Pennsylvania State University, PA, USA

2016
GEOPOLYMERCAMP

Results

Increased complexity





Proposed application:
filters

Contents lists available at ScienceDirect

Additive Manufacturing

journal homepage: www.elsevier.com/locate/addma

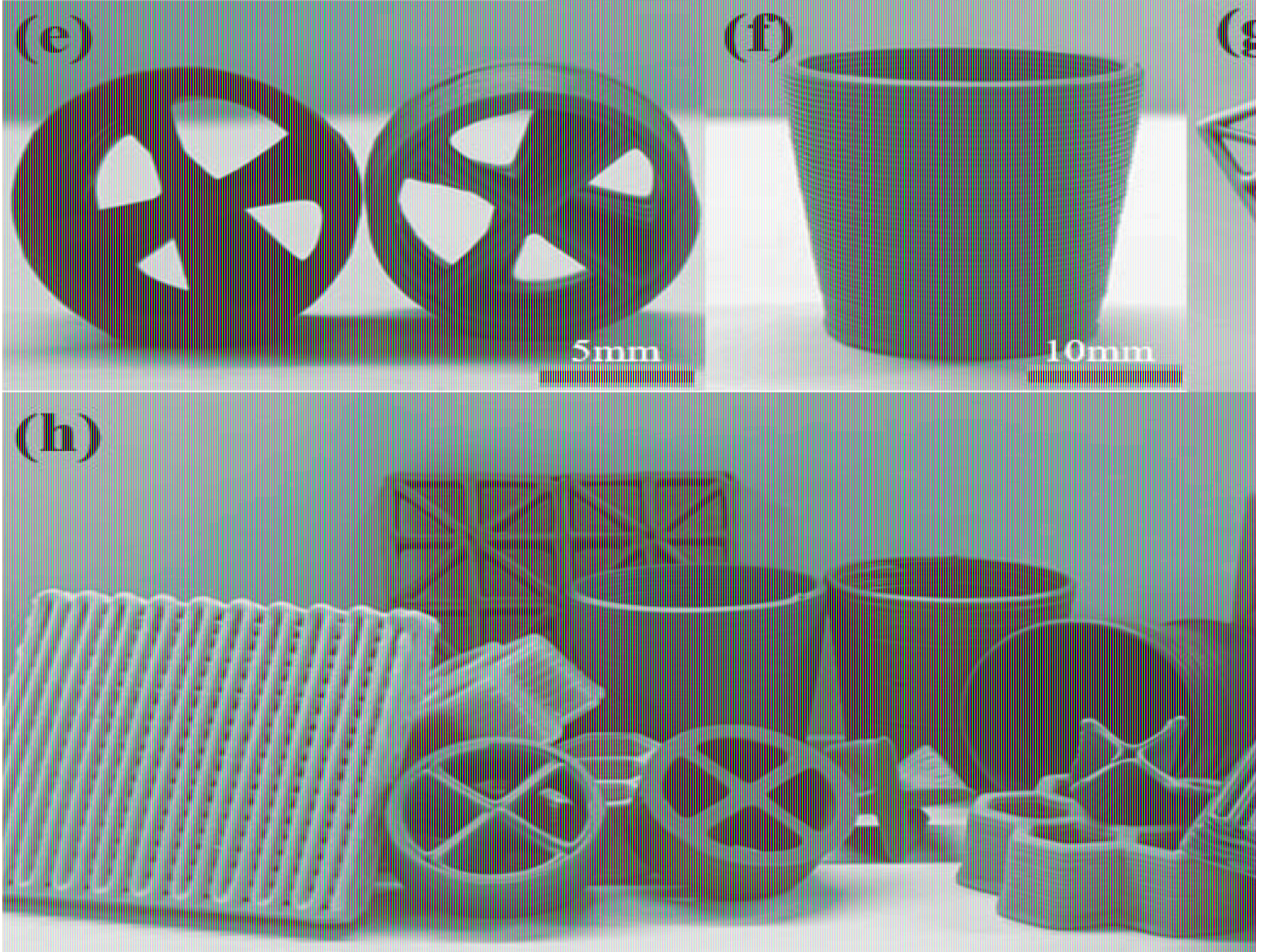
Additive Manufacturing 46 (2021) 102202

Direct ink writing of geopolymer with high spatial resolution and tunable mechanical properties

Siqi Ma, Shuai Fu, Shengjian Zhao, Peigang He, Guoru Ma Meirong Wang, Dechang Jia, Yu Zhou, Harbin Institute of Technology, China.

ABSTRACT: Direct ink writing (DIW) of geopolymers with desirable patterns, compositions, and properties holds great promise for sustainable concrete, porous adsorbent, and high-temperature ceramic.

However, precisely constructing geopolymers by DIW is subject to the low viscosity of geopolymer inks and the limited choice of alkali metal ions.

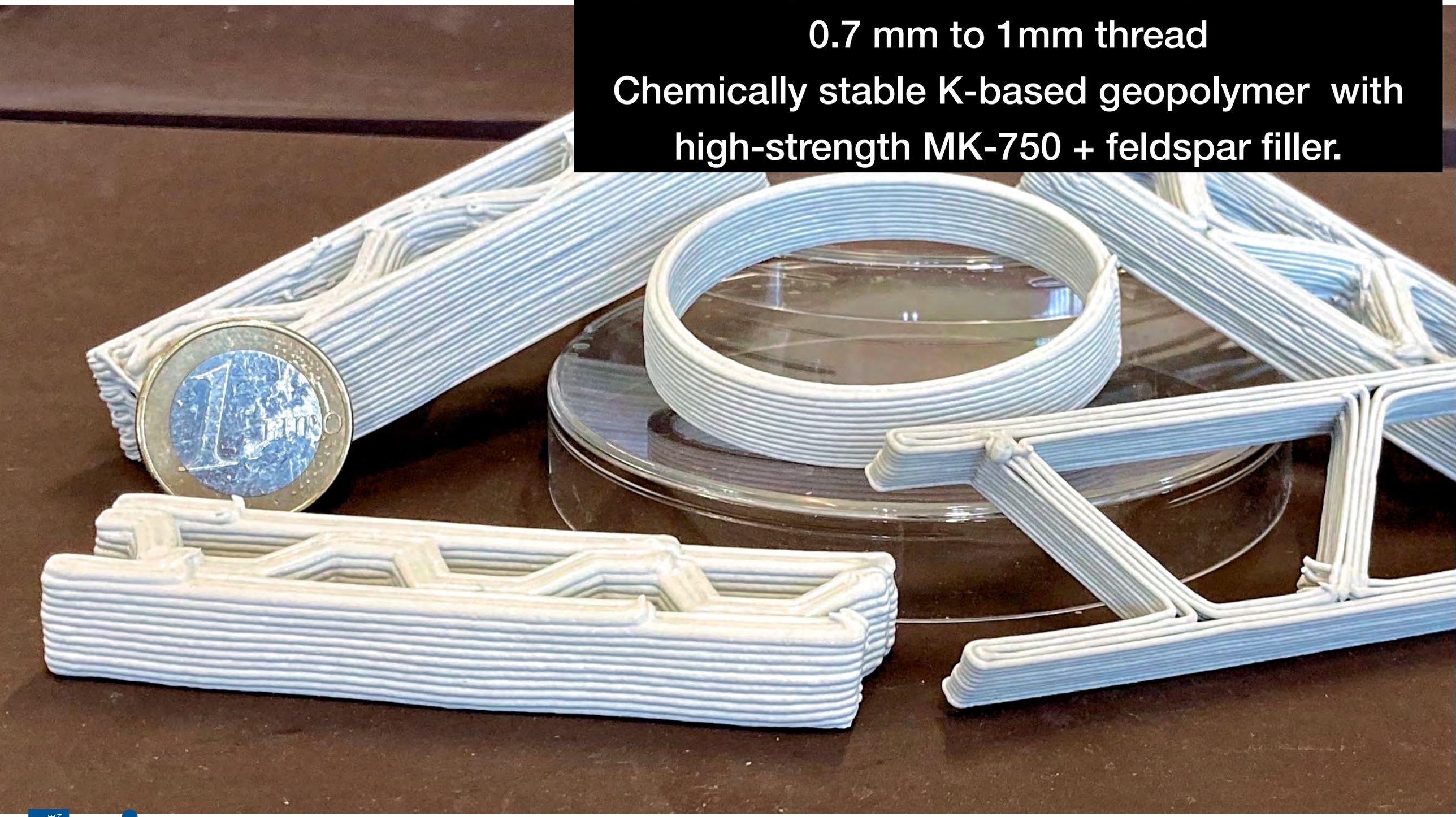

(e)
(f)
5mm
10mm
(h)

3D printing ceramic-type geopolymer

High-Strength 3D-Printed Geopolymer Ceramic

0.7 mm to 1mm thread

Chemically stable K-based geopolymer with high-strength MK-750 + feldspar filler.



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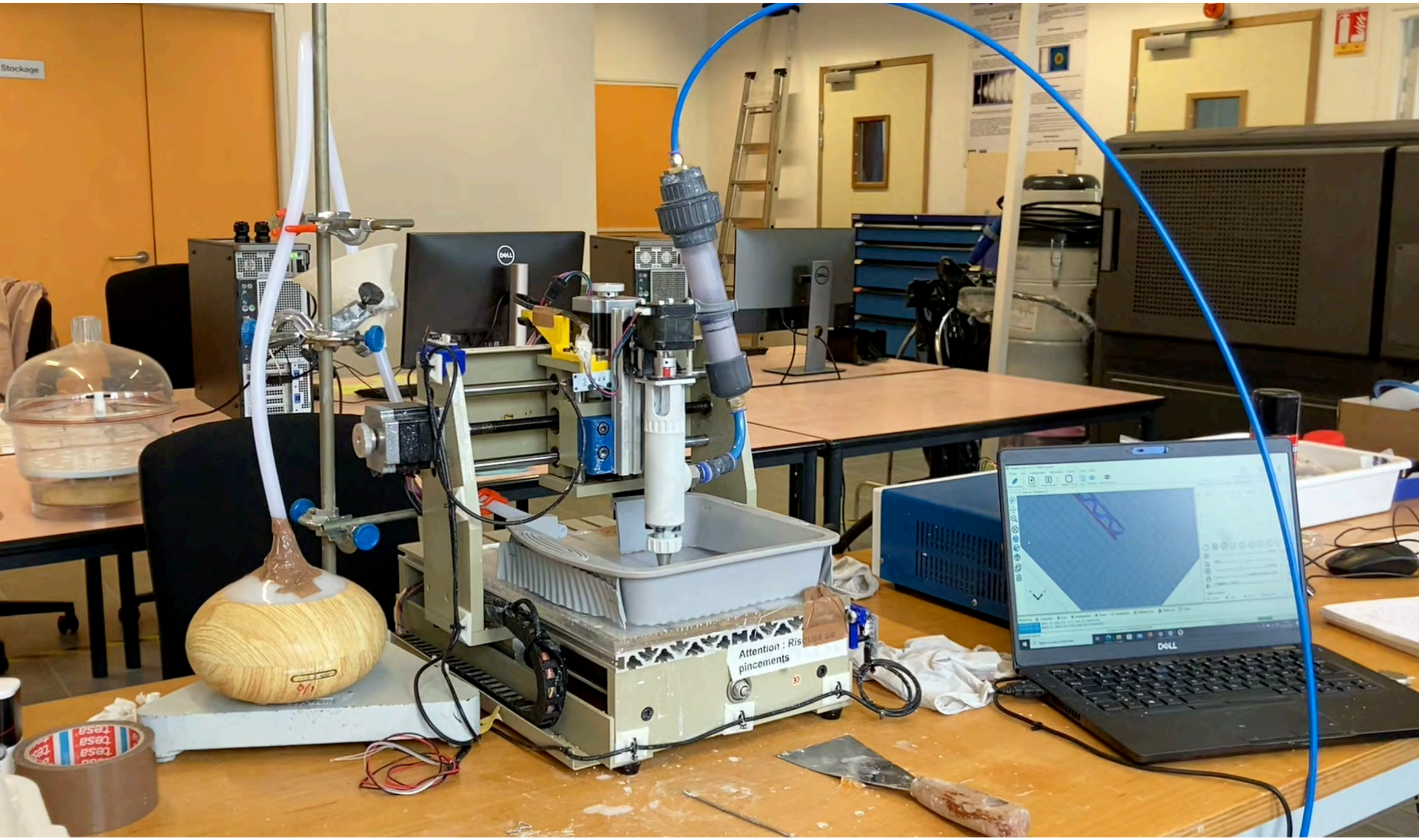


3D printing cement / concrete geopolymer

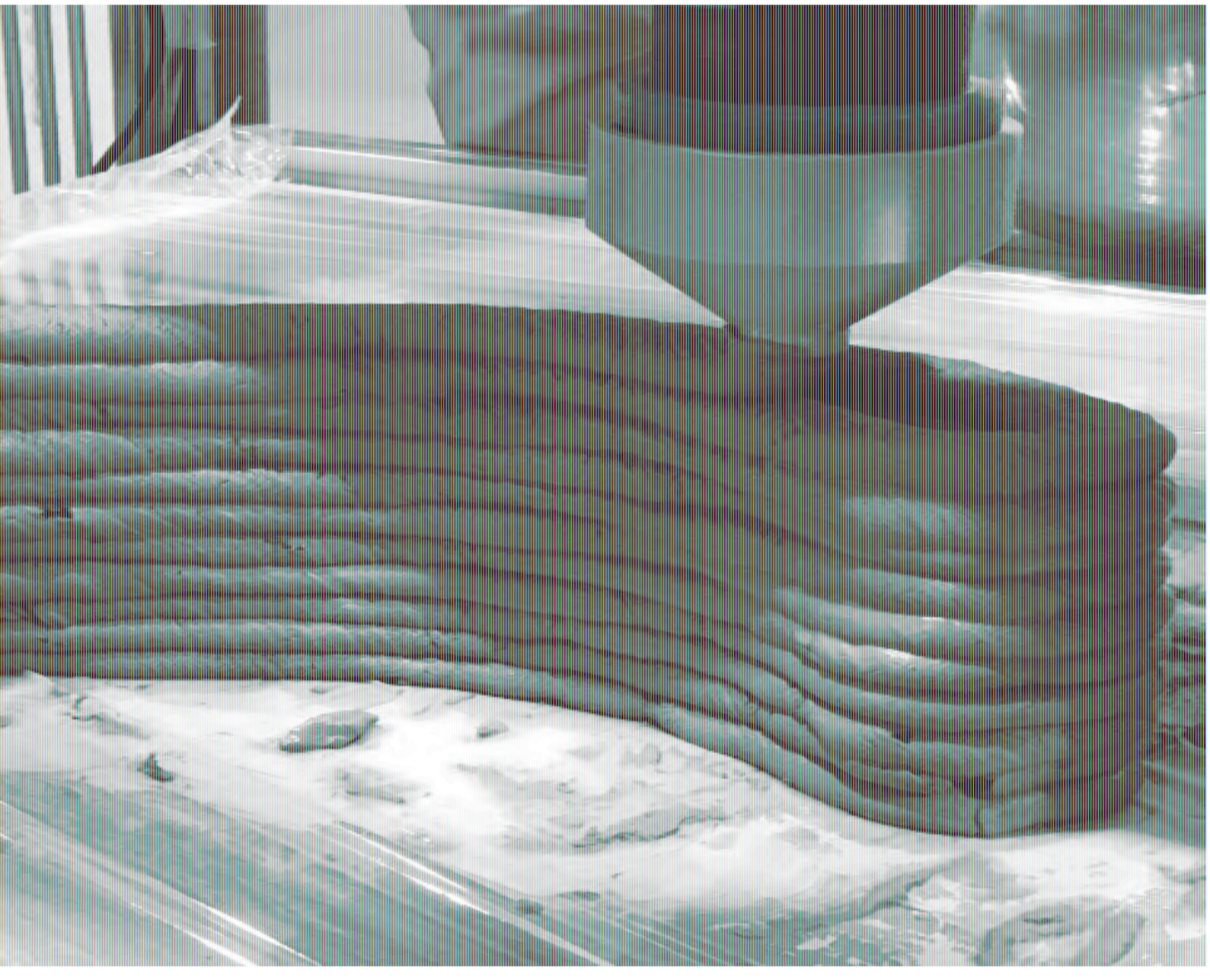
NANYANG TECHNOLOGICAL UNIVERSITY

2016 GEOPOLYMERCAMP

Biranchi Panda
PhD Research student
Singapore Centre for 3D printing

2016

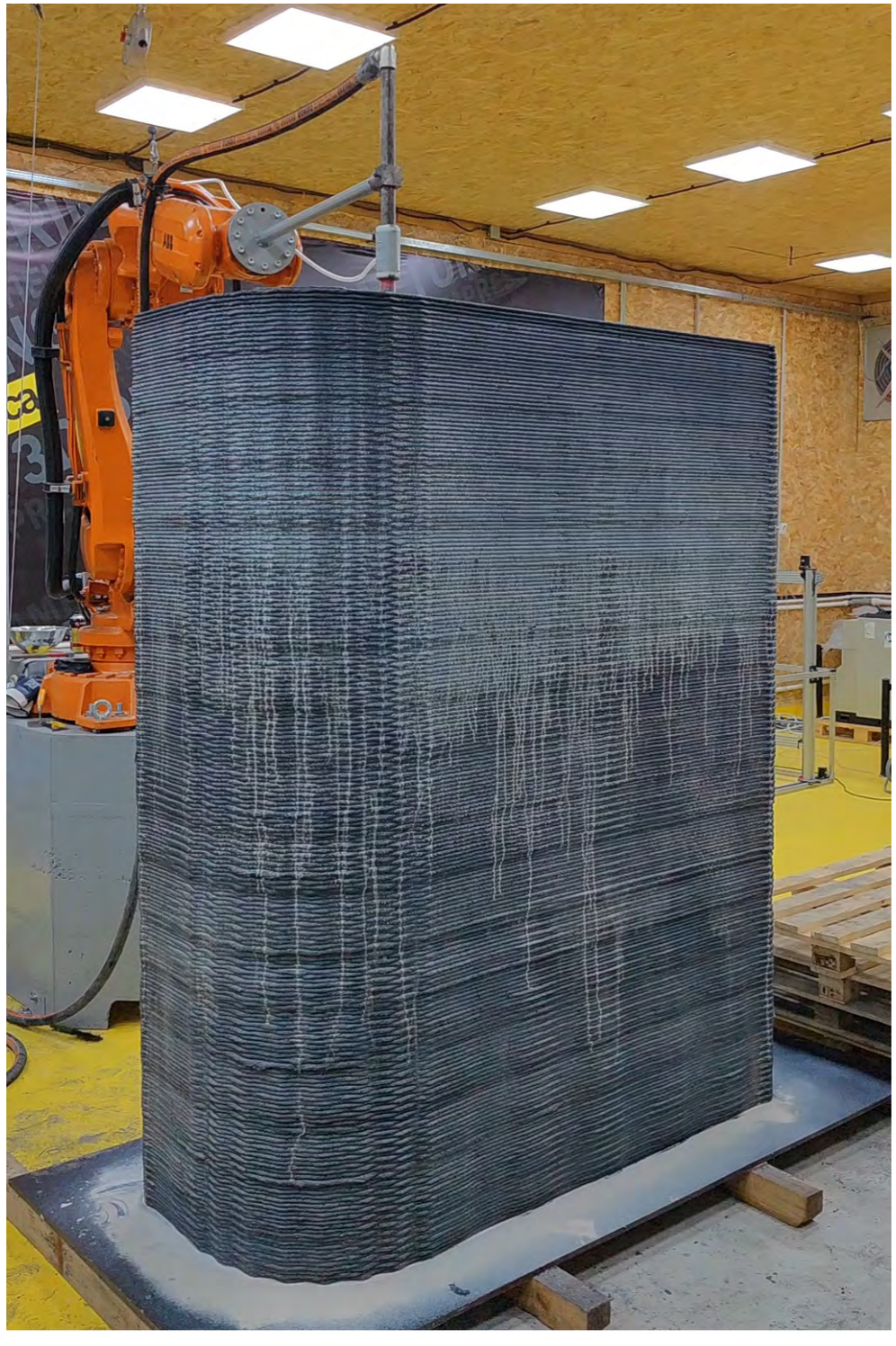
GeopolymerCamp



3D Printing Process

RENCA

2022 GeopolymerCamp



4 hours 50 minutes
non-stop 3D printing

renca.org

2023

GEOPOLYMERCAMP

GEOPOLY
INTERNAT

Las Vegas, USA

www.gpi.earth

energies

December 2022

Review

An Overview for Modern Energy-Efficient Soluti and Martian Habitats Made Based on Geopolymn and 3D Printing Technology

Kinga Korniejenko, Kinga Pławecka and Barbara Kozub

Faculty of Material Engineering and Physics, Cracow University of Technology, Cracow, Poland

… NASA and the European Space Agency (ESA) announced that they wanted to ensure habitats on the Moon or Mars before 2040. The first manned mission after Apollo 17, Artemis III, is scheduled to take place by 2024 to help implement sustainable lunar exploration.

Human in-space missions (the Moon, Mars, etc.) will require the capability to build structures on site using the local (planet) resources. Nowadays, one of the ***most promising materials for that purpose are geopolymer composites…***

The other critical point for in-space application is proper technology. In this case, the ***most promising solutions seem to be 3D printing technologies.***