INSTITUT GÉOPOLYMÈRE

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

2022 GEOPOLYMERCAMP

14th GP-Camp

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

Saint-Quentin (France)

July 4-6, 2022

State of the Geopolymer R&D 2022

GeopolymerCamp 2022

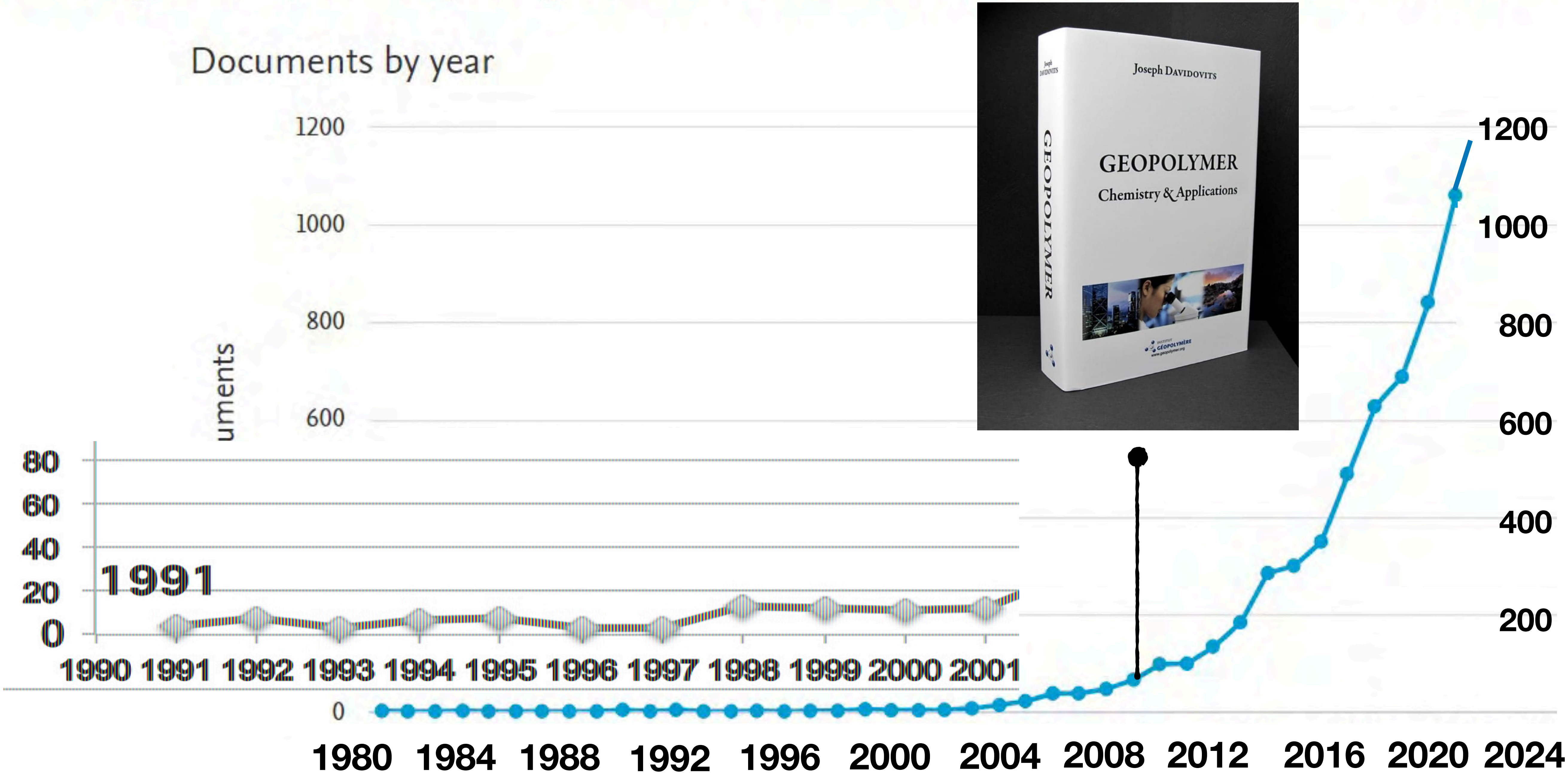
Joseph Davidovits

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 2022

1) **Geopolymer science.**
2) **Global warming**: Sustainable production of electricity with
   a) *Microbial Fuel Cells* and
   b) *Solar Power Technologies*.
3) **Geopolymer and archaeology:** update of research on Easter Island Statues manufacture.

1) Geopolymer science.

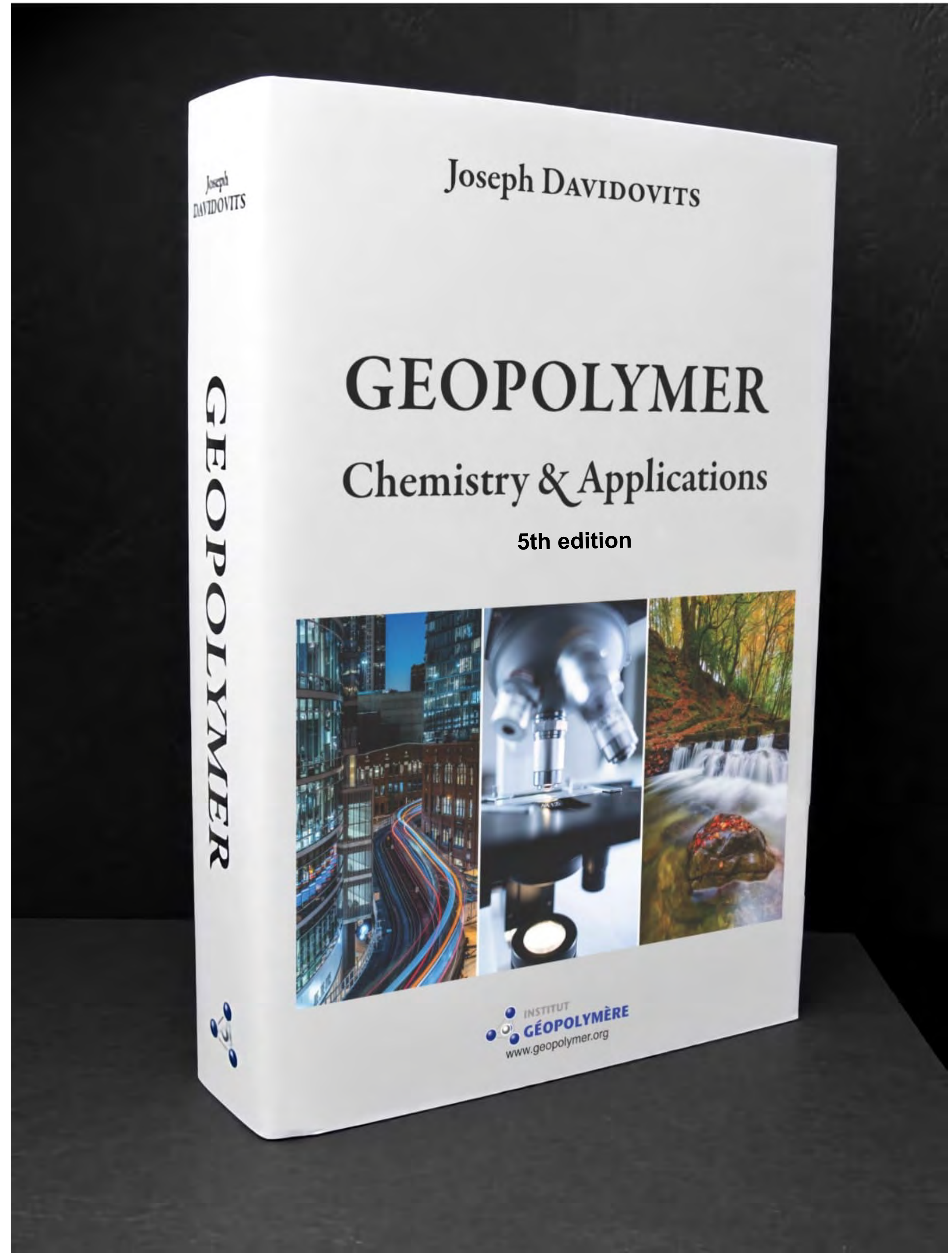
In addition to the numerous updates, this 5th edition adds two new chapters:

- Chap. 11: *Ferro-sialate Geopolymers*
- Chap. 21: *How to quantify and develop geopolymer formulas*.

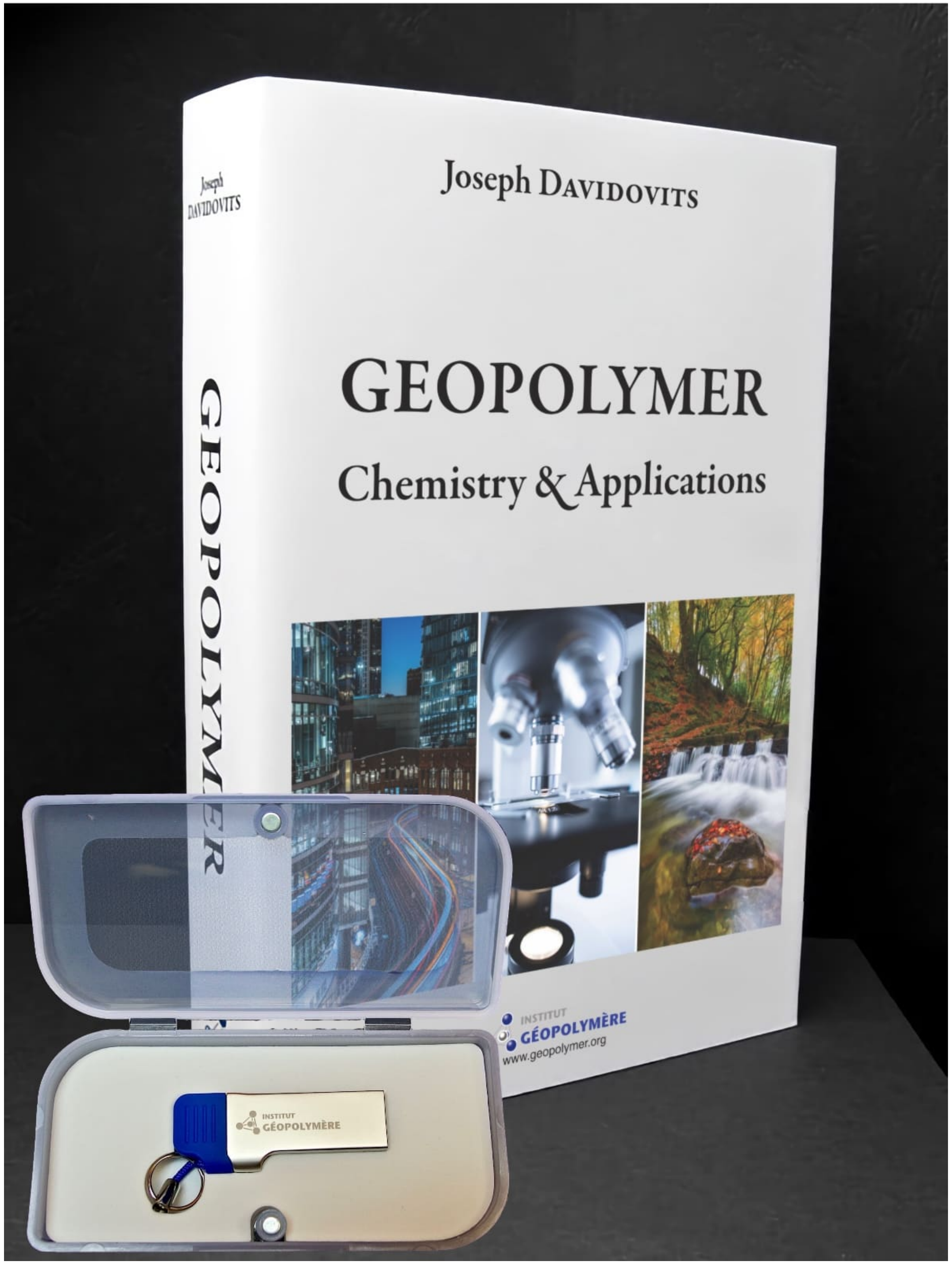
This last new chapter details

- How to select raw materials,
- How to calculate a formula,
- Description of the process method for optimal results,

all in a very pragmatic way.



We have also a new ***Geopolymer Bundle for Newcomers*** which replaces the former one. It includes an experimental part totalizing 3 hours of videos, taken during the Tutorial/Workshop of the Geopolymer Camp.



16 research topics

#1 Polymeric character of geopolymers

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

#3 MK-750-based Ferro-sialate 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.

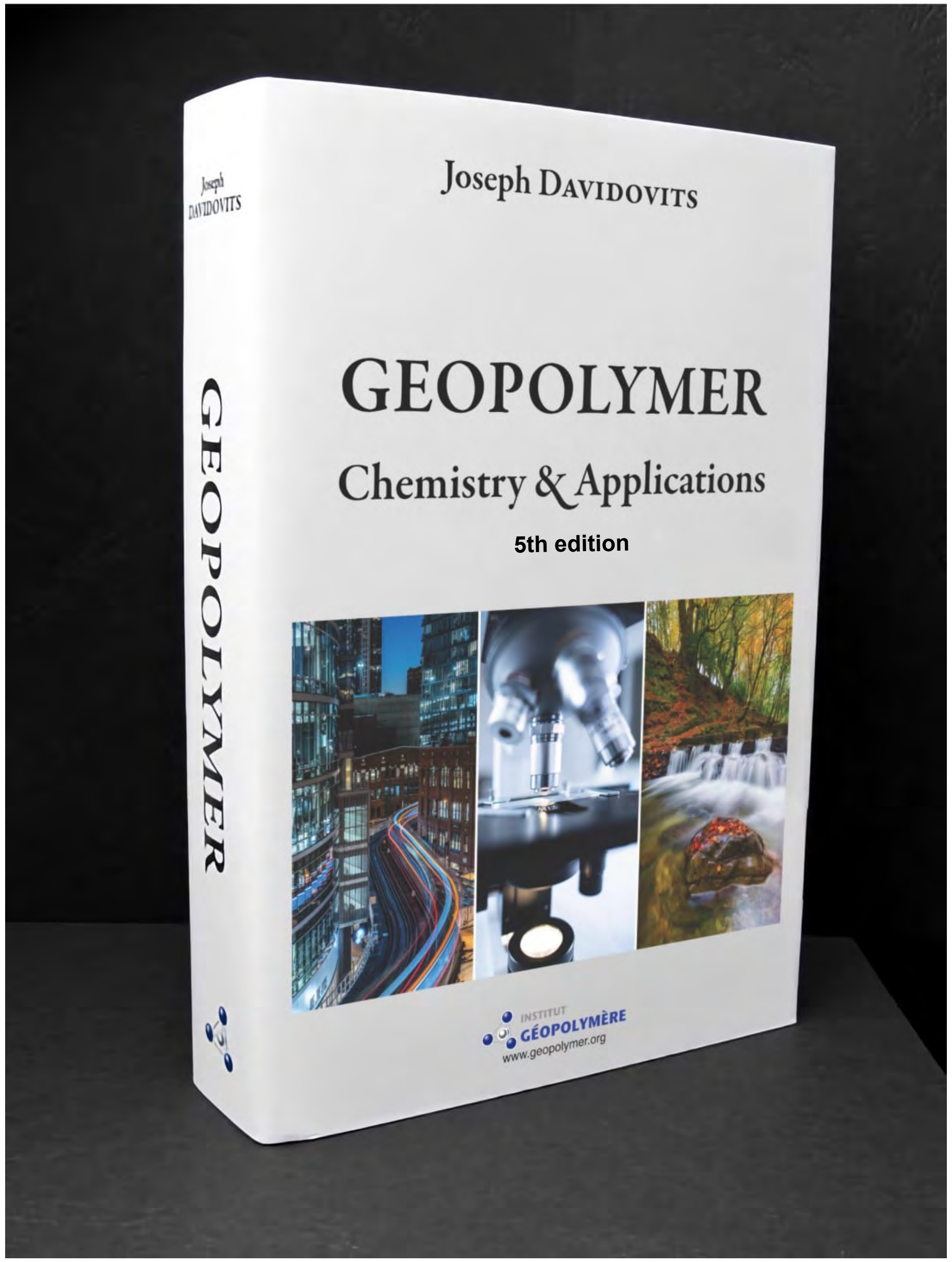
#13 The manufacture of geopolymer cements: No fly ash !

#14 Geopolymer concrete.

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

 # 16 3D printing.

#1 Polymeric character of geopolymers

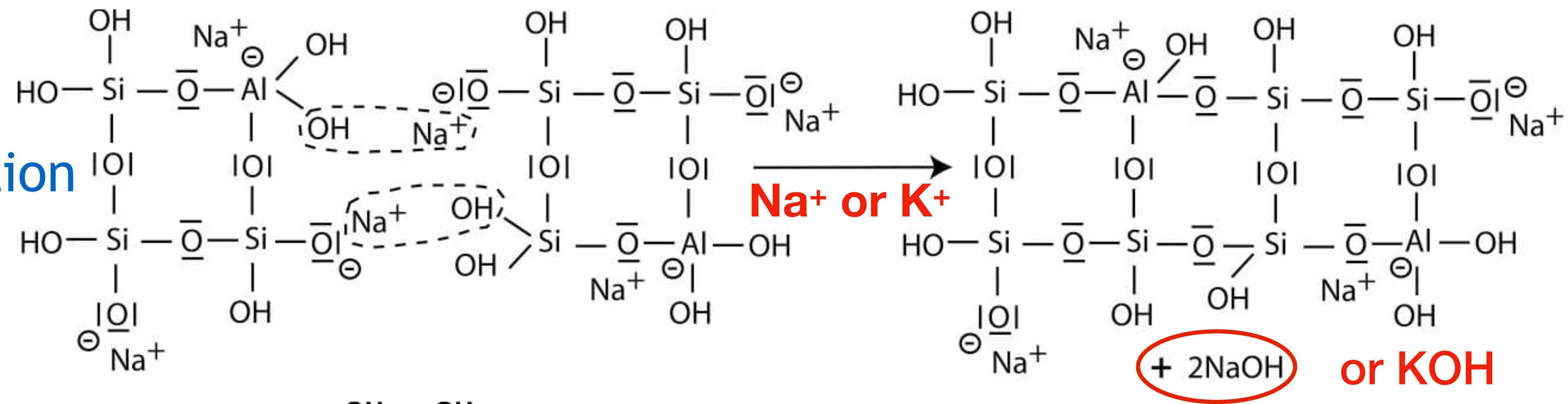


Chapter 2, 7 and 8 + others.

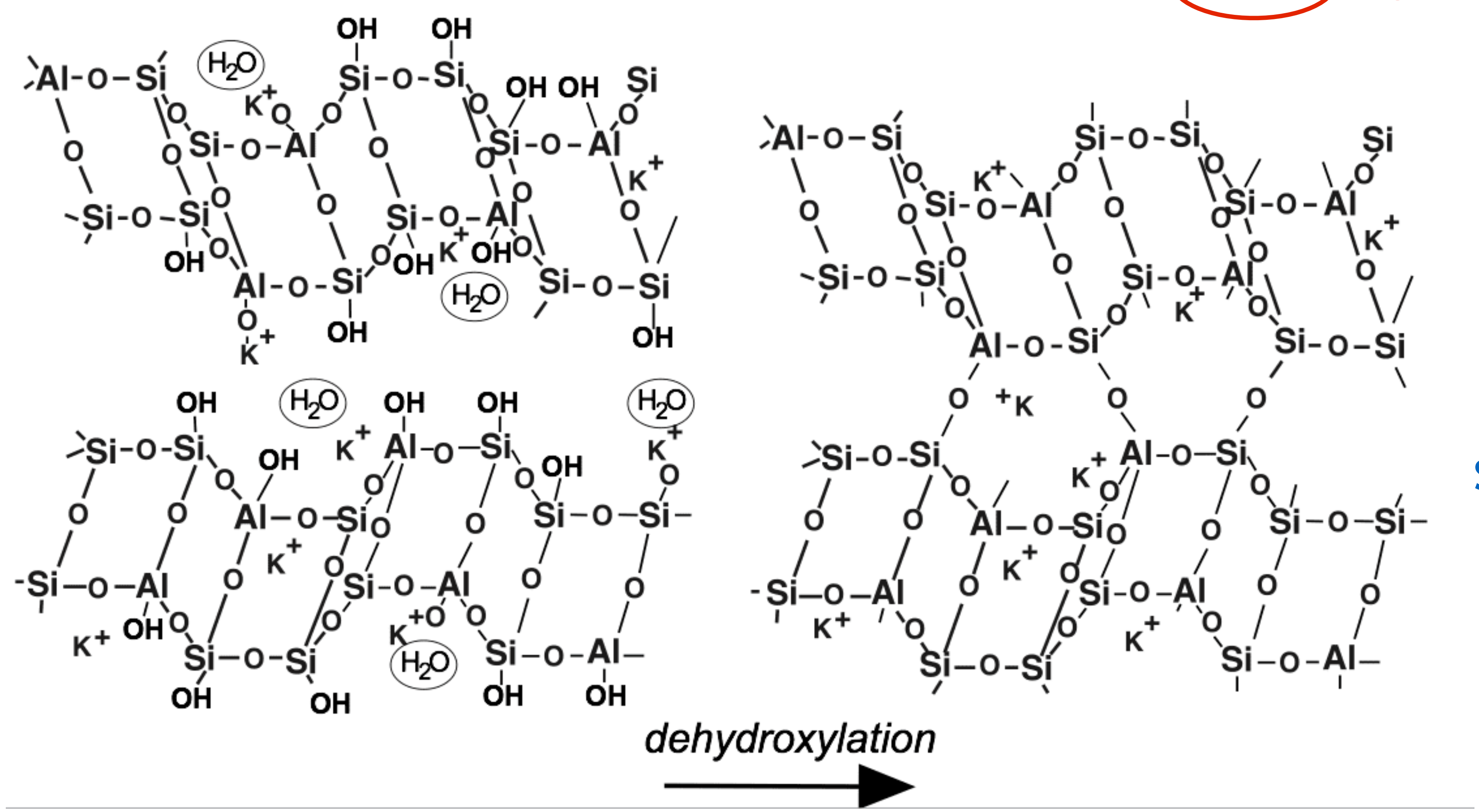
Geopolymerization mechanism

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

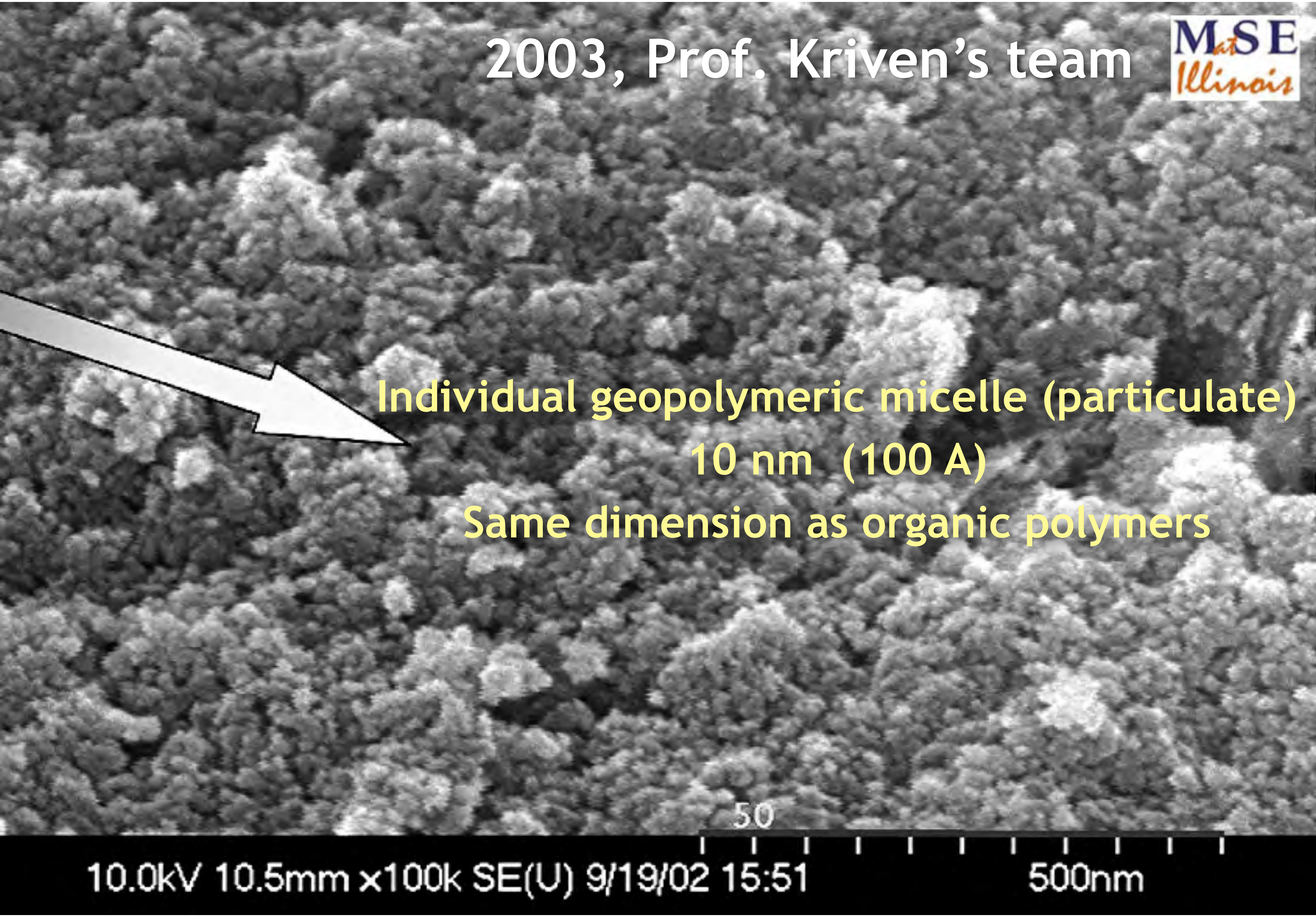
Step 4
polycondensation

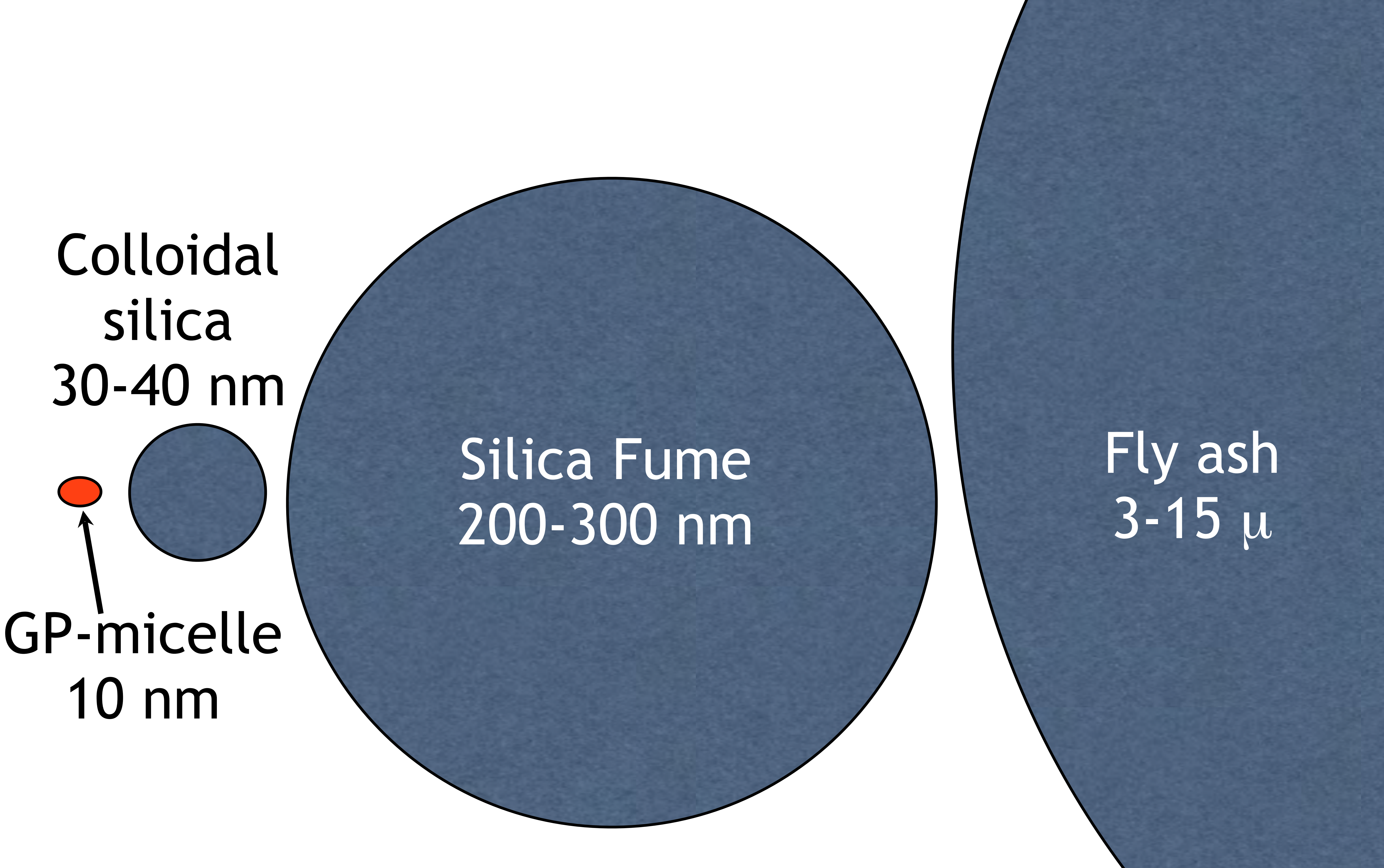


Step 5
reticulation,
networking



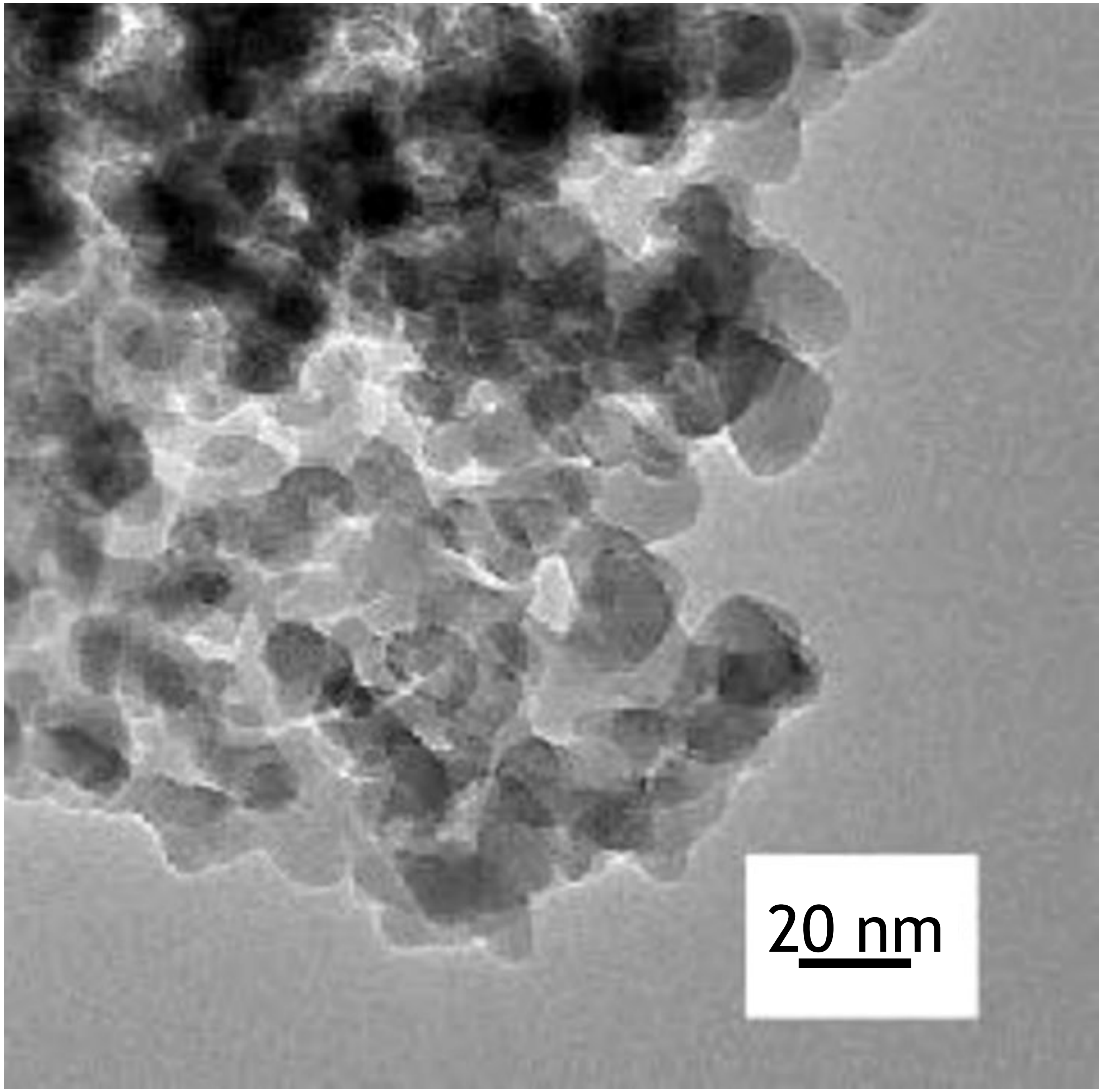
Step 6
geopolymer
solidification


2003, Prof. Kriven's team
MatSE Illinois
Individual geopolymeric micelle (particulate)
10 nm (100 A)
Same dimension as organic polymers
50
10.0kV 10.5mm x100k SE(U) 9/19/02 15:51
500nm



Geopolymer = nano material not
unknown « Gel »

Step 5
reticulation



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

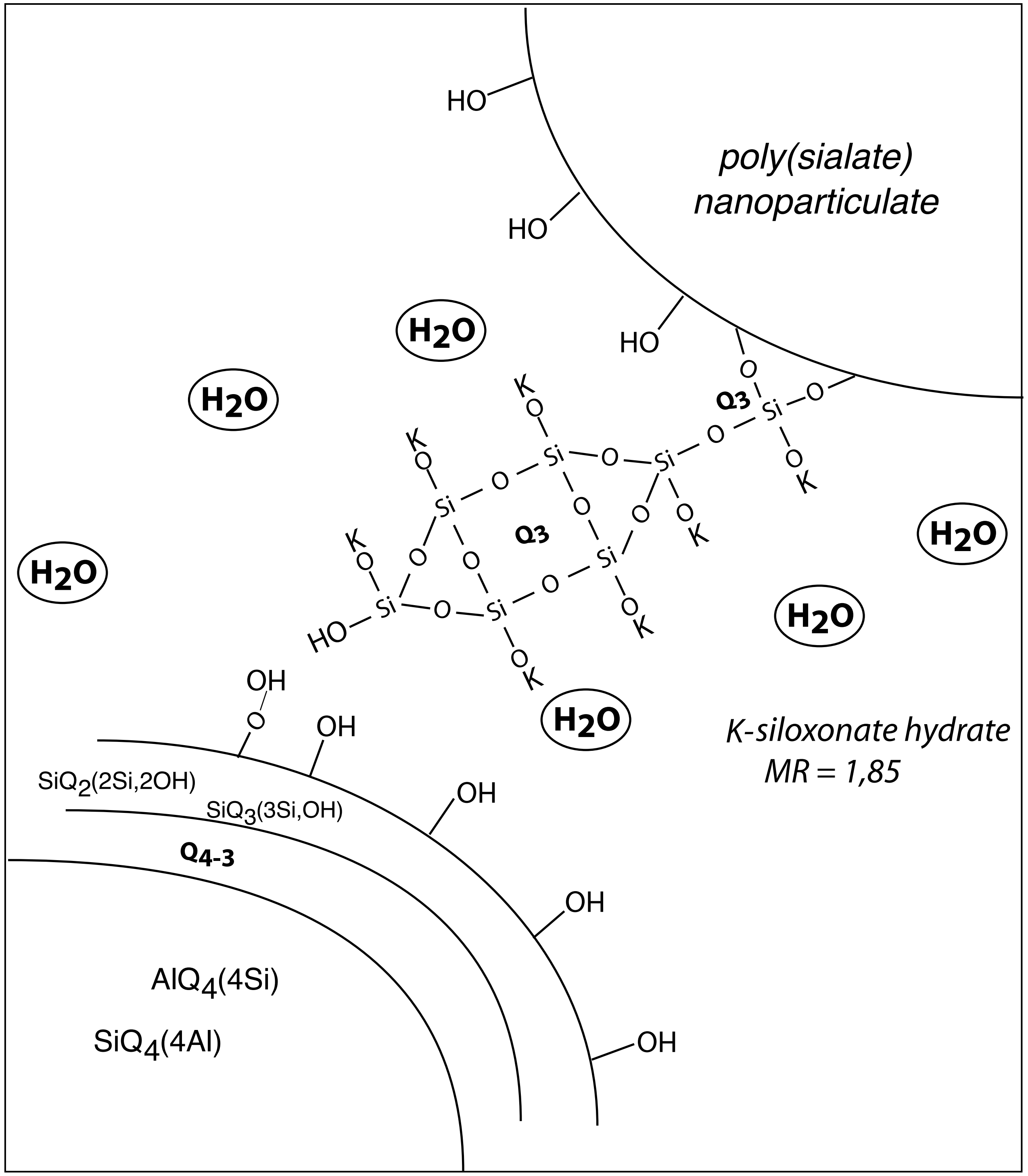
Inter-micellar structure

temperature <200-250°C

silicate molecules

water

-OH on particulate surface



Contents lists available at ScienceDirect

Additive Manufac2021ng

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

ELSEVIER

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.

Contents lists available at ScienceDirect

Additive Manufacturing

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

ELSEVIER

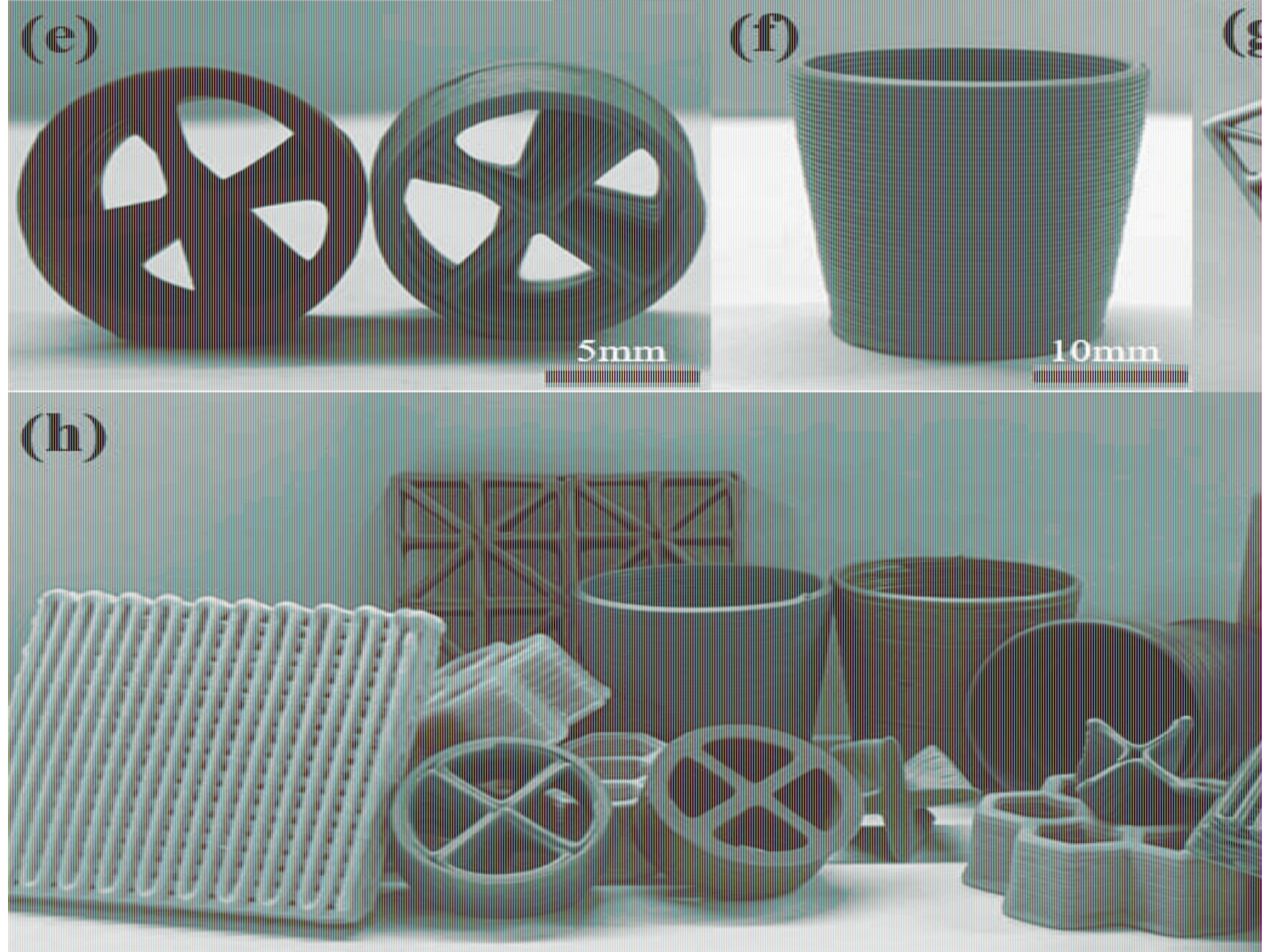
Research Paper

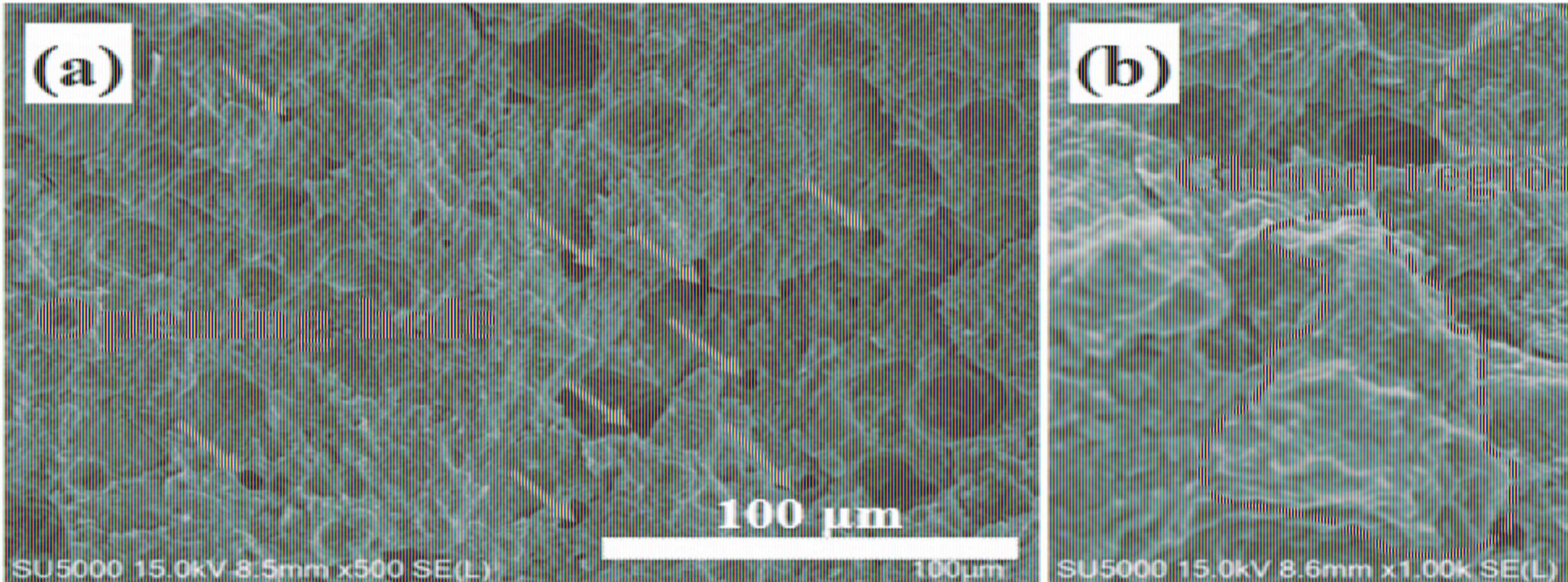
Additive Manufacturing 46 (2021) 102202

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

… We produce high-quality Na-, K-, and Cs-based geopolymer-inks by adding suitable additives, yielding complex patterns, with high spatial resolution, and controllable mechanical properties.

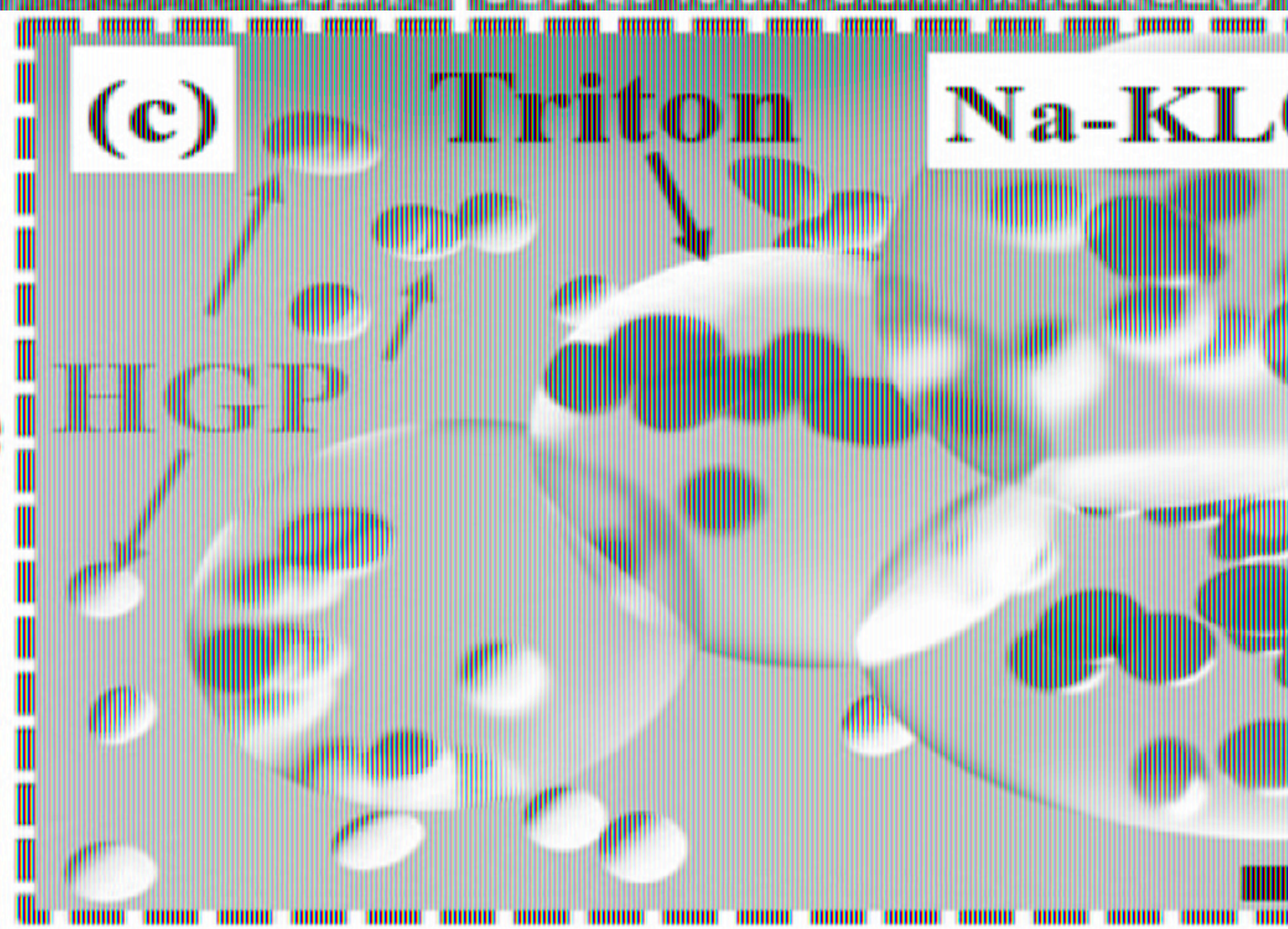
Furthermore, we reveal the mechanism underlying the fracture behaviors of the 3D-printed geopolymers combining compression tests, theoretical models, and FEM analysis. Our results pave the way for designing high-quality geopolymer-based materials, which are critical for industrial applications and sustainable development.

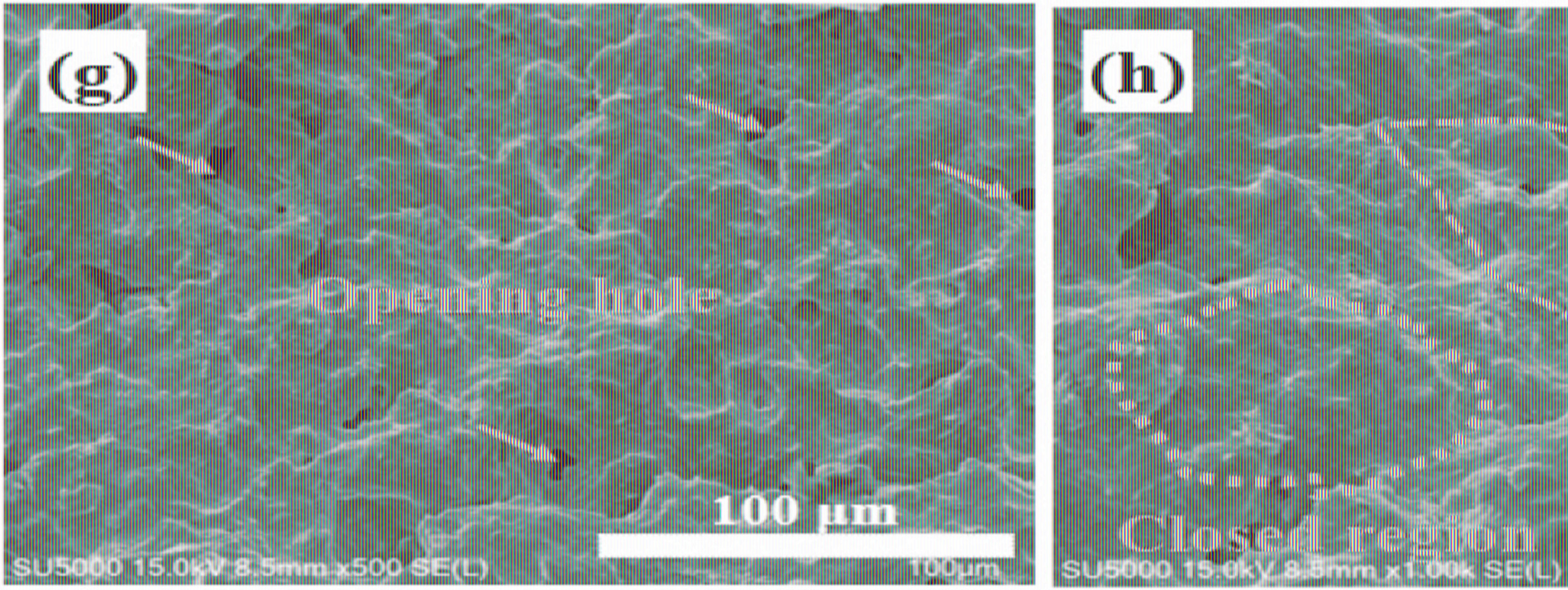

(e)
5mm
(f)
10mm
(g
(h)



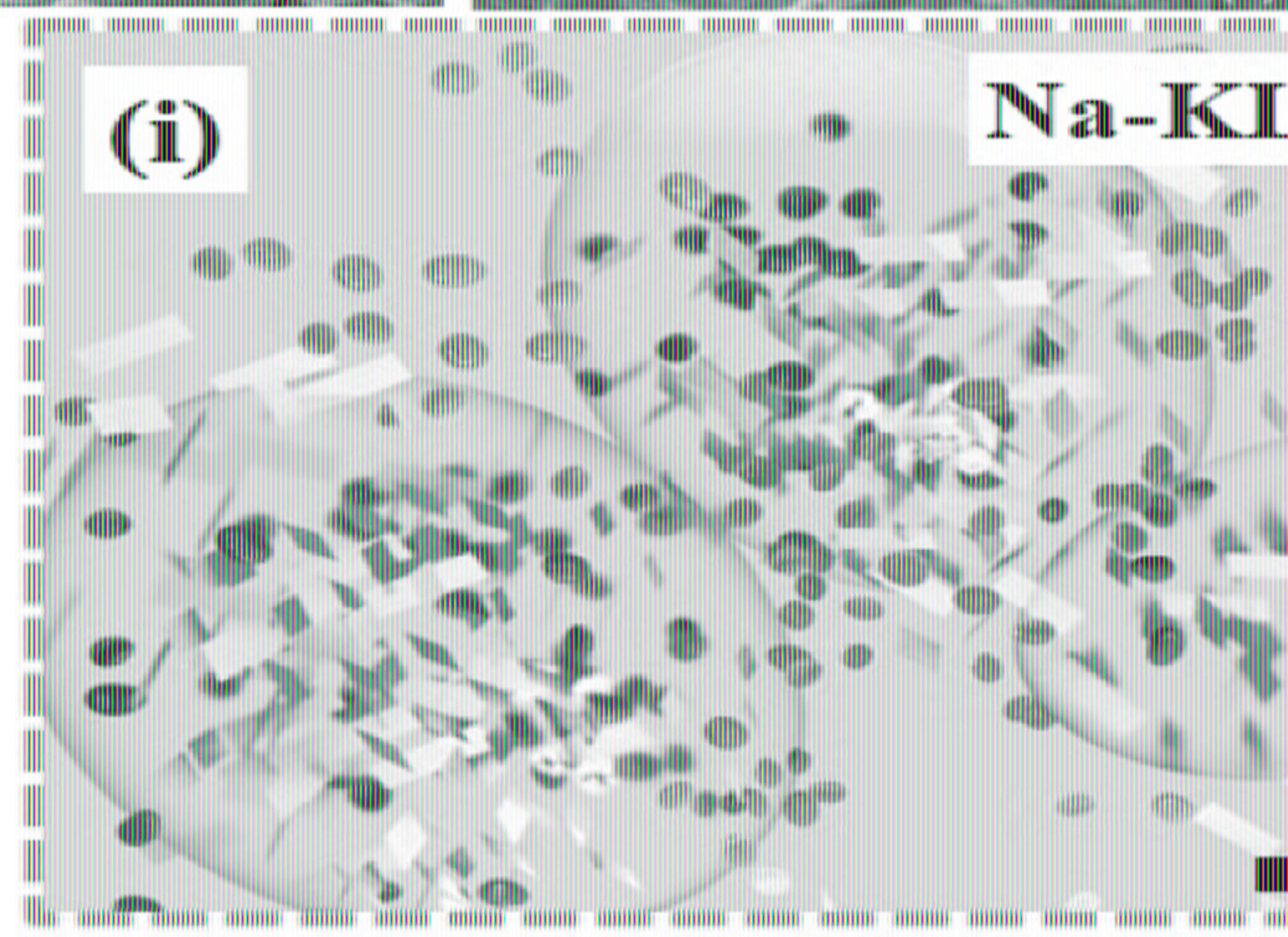
Pure GP-resin with 1.25% additive (Triton), no mineral filler.

The geopolymer micelles (10 nm) are named HGP for Hydrated Geopolymer Particulate.



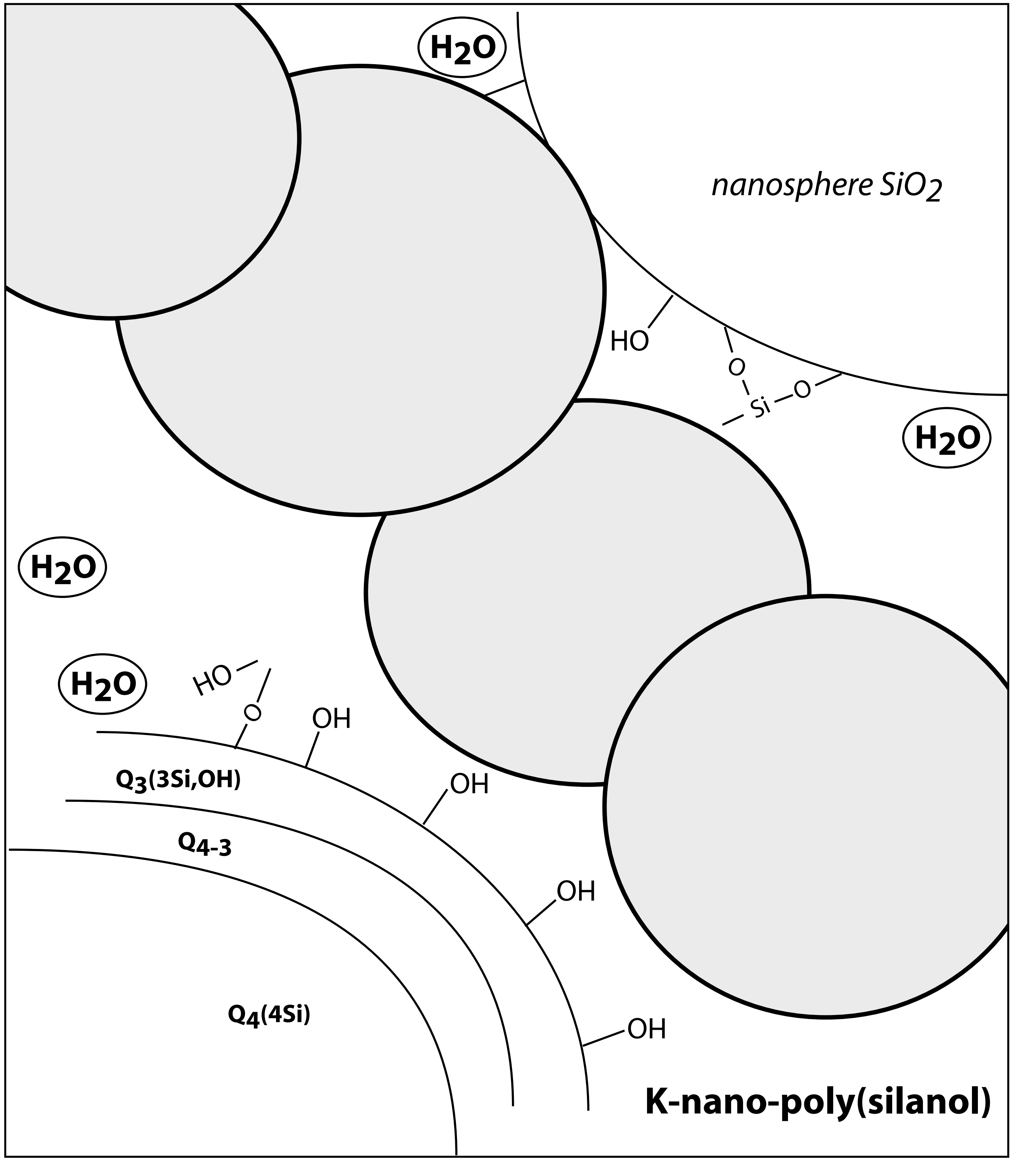


GP-resin with 3.75% additive (Triton), mineral filler 8% kaolin



Inter-micellar structure

with conductive graphite particulates



2)Global warming: Sustainable Production of Electricity

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.

Sustainable Production of Electricity with Geopolymer Technology

(a) *Microbial Fuel Cells*

(b) *Solar Power Energy*

(a) *Microbial Fuel Cells*

Microbial Fuel Cells are one of the most promising technologies for sustainable energy generation from a variety of waste water streams. But capital expenditures have stopped its implementation on a larger scale.

A recent published study, conducted by two German research groups from TH Darmstadt (Technical University) and Dechema Research Institute, Frankfurt a. M., demonstrates that ***Geopolymer-Graphite*** composite anodes result in equal current production when compared to the conventional ***graphite*** anodes.

ACS OMEGA

https://doi.org/10.1021/acsomega.1c03805

2021

Conductive Geopolymers as Low-Cost Electrode M Microbial Fuel Cells

Shifan Zhang, Jürgen Schuster, Hanna Frühauf-Wyllie, Serkan Arat, Sandeep
Markus Stöckl,* Neven Ukrainczyk,* and Eddie Koenders

Cite This: https://doi.org/10.1021/acsomega.1c03805 Read Online

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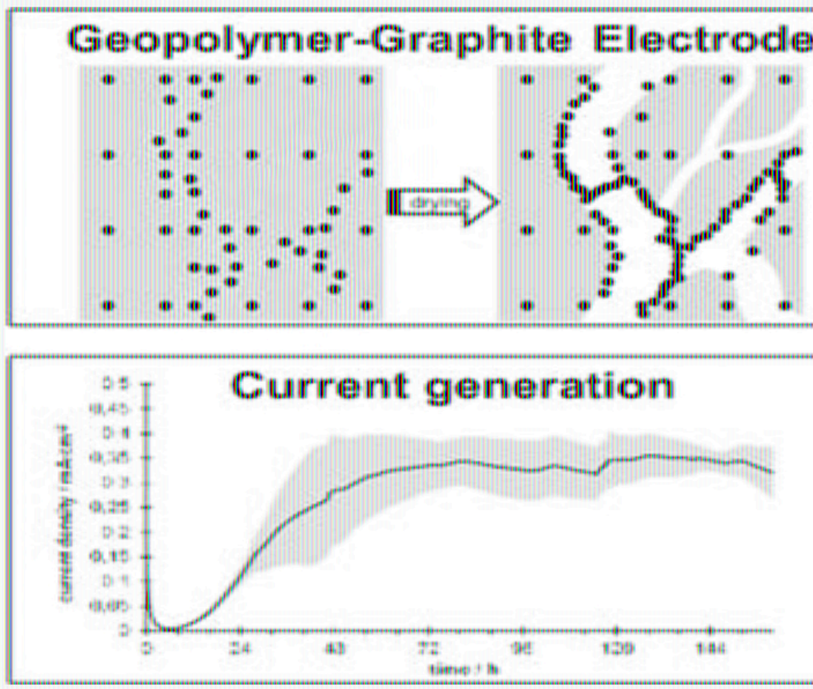
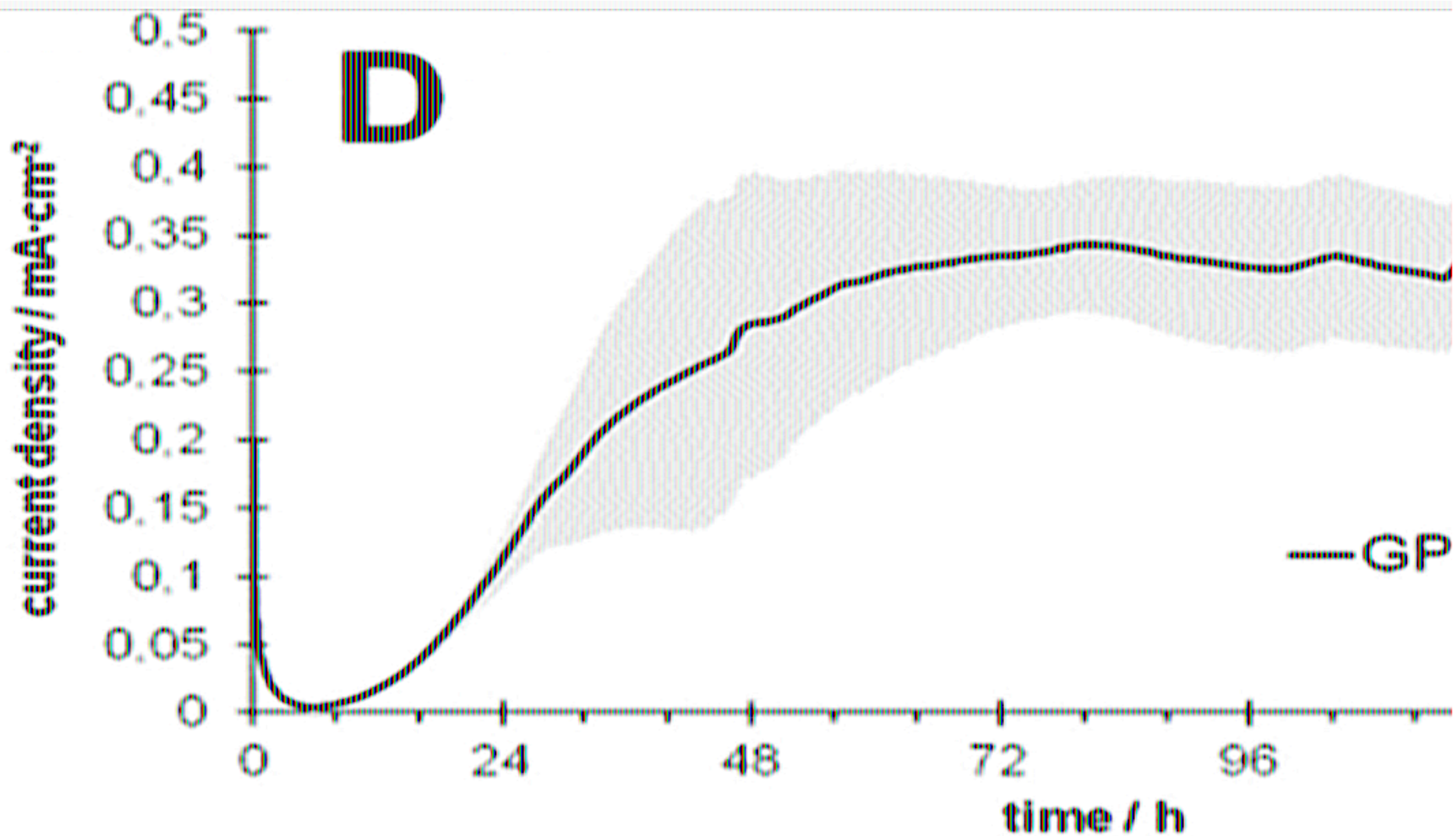
ABSTRACT: Geopolymer (GP) inorganic binders have a superior acid resistance compared to conventional cement (*e.g.*, Portland cement, PC) binders, have better microbial compatibility, and are suitable for introducing electrically conductive additives to improve electron and ion transfer properties. In this study, GP–graphite (GPG) composites and PC–graphite (PCG) composites with a graphite content of 1–10 vol % were prepared and characterized. The electrical conductivity percolation threshold of the GPG and PCG composites was around 7 and 8 vol %, respectively. GPG and PCG composites with a graphite content of 8 to 10 vol % were selected as anode electrodes for the electrochemical analysis in two-chamber polarized microbial fuel cells (MFCs). Graphite electrodes were used as the positive



Geobacter sulfurreducens was used as electroactive bacteria. The geopolymer/graphite composite anode-respiring biofilms resulted in electrical ***current production equal*** to the conventional ***graphite anode***, whereas the Portland/graphite composites showed a very poor performance.

The largest mean value of the measured current densities of a Geopolymer-Carbon composite used as anodes in *Microbial Fuel Cells* was 0.380 mA cm^{-2} i.e. 3.8 A m^{-2}



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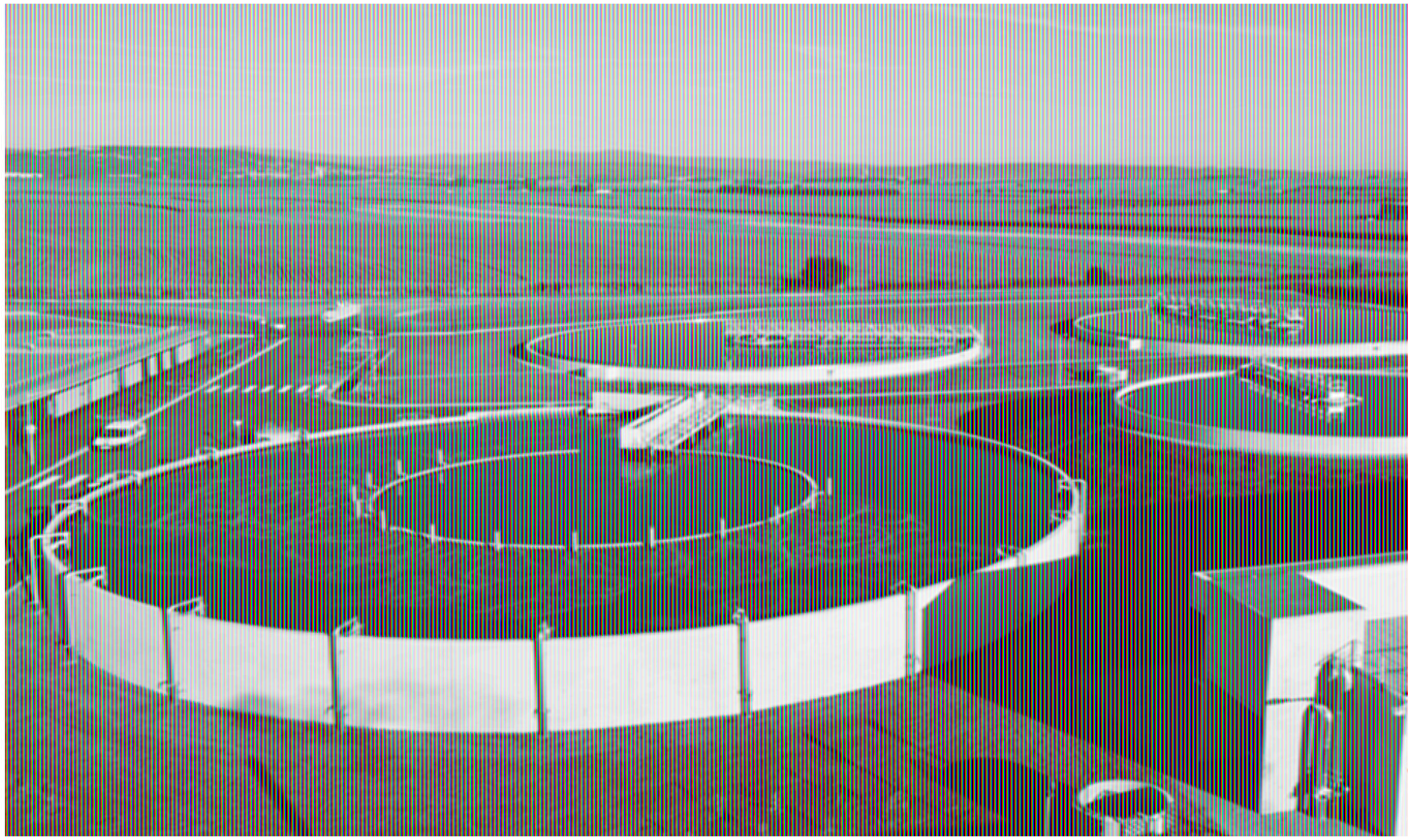
Imagine the following scenario:

…Large-scale factories in the city landscape and immense cylindrical metal structures called ***gazometers***….

…sewage and waste water treatment plant into giant ***Geopolymer Microbial Fuel Cells*** …



… the huge volume, high surface of structural elements such as wastewater/sewage pipes, tanks, and concrete structures,

…. this integration concept would enable a cost-effective solution for high capacity of electrical-power generation in every town or even every village.

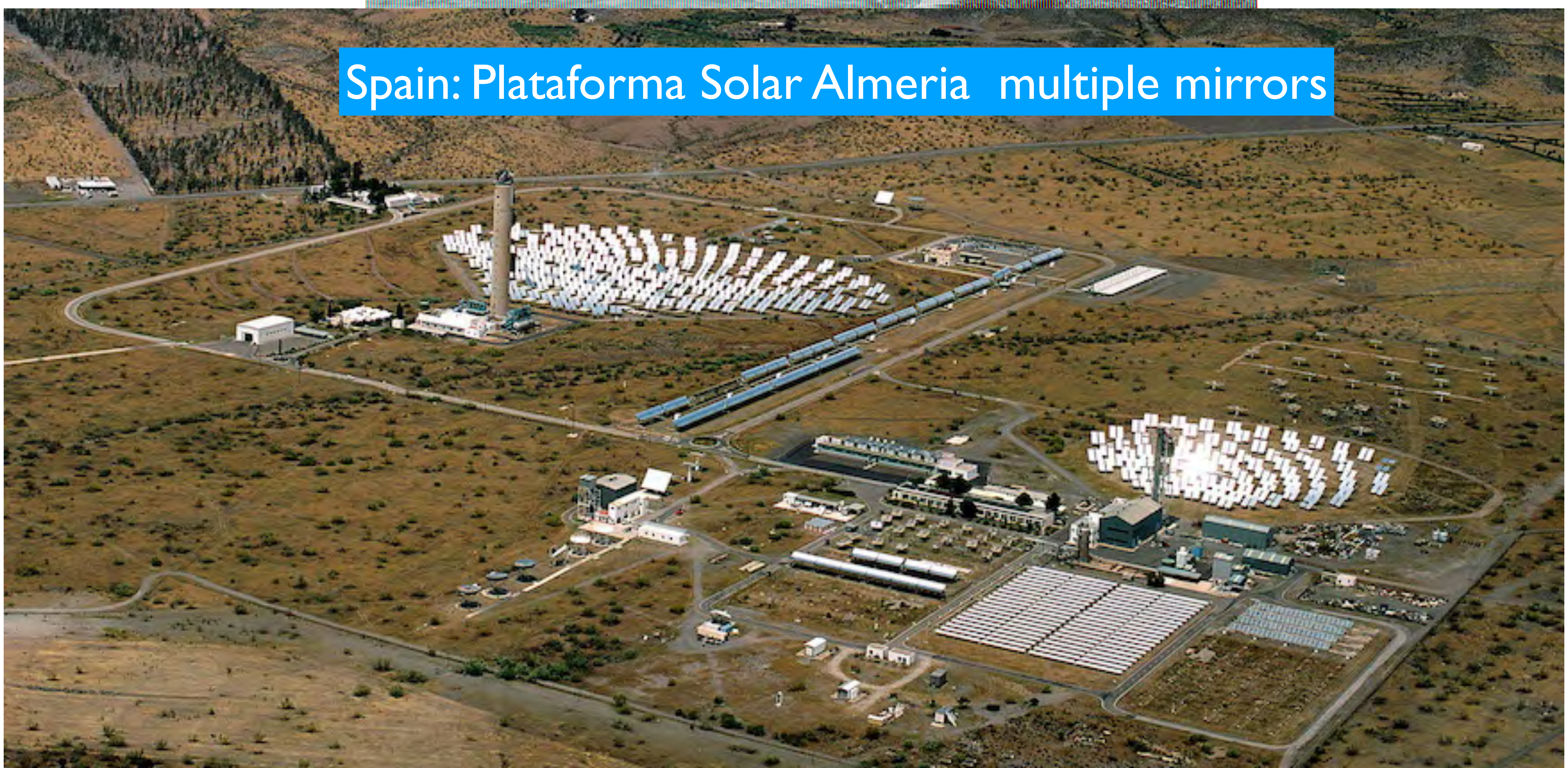
Sustainable Production of Electricity

b) Solar Power Technologies

Solar Furnaces

Southern France: Odeillo

one large mirror



Spain: Plataforma Solar Almeria multiple mirrors

sustainability Sustainability **2022**, *14*, 1937

Article

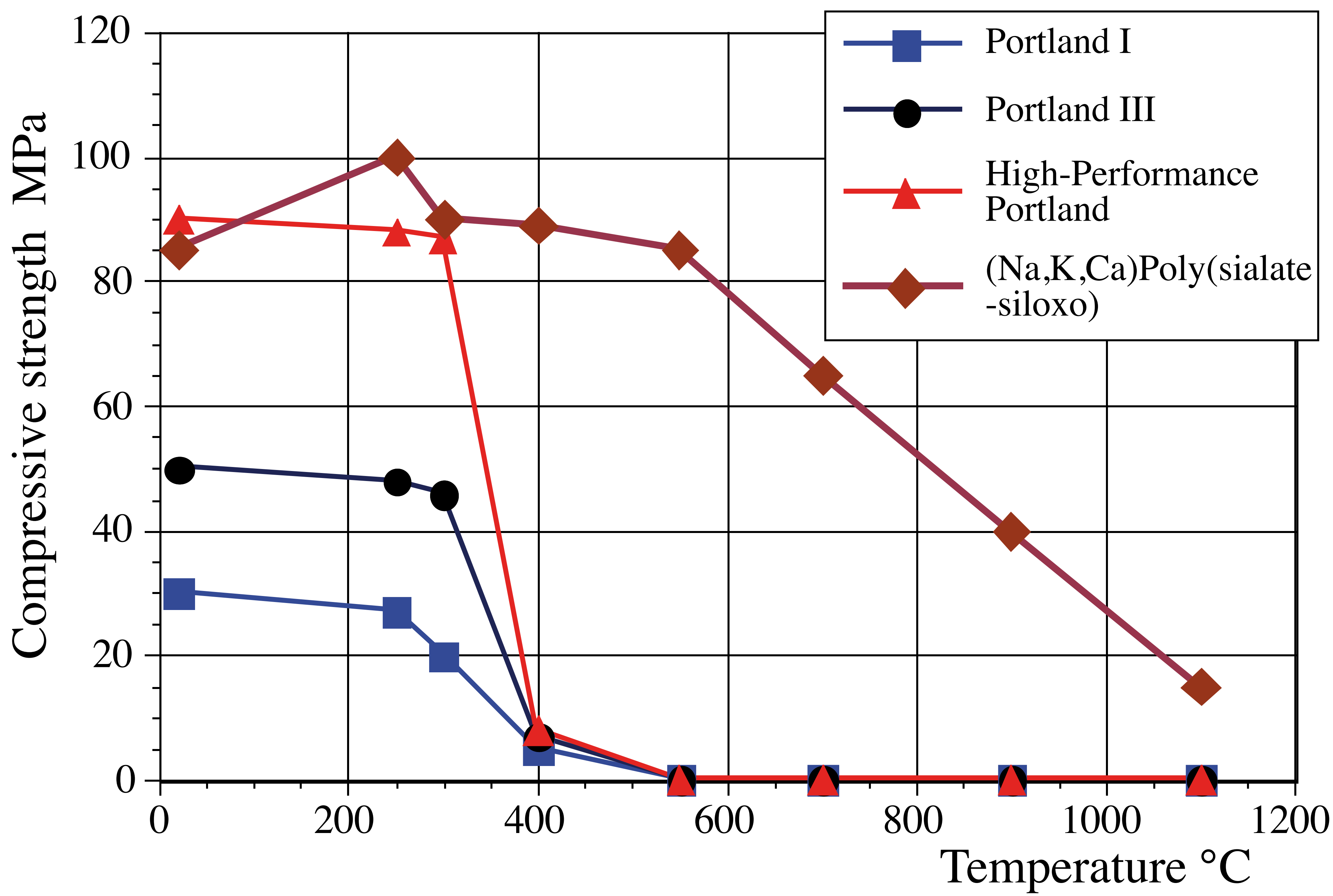
Geopolymer Concrete Performance Study for High-Temperature Thermal Energy Storage (TE

Mohammad Rahjoo [1,*], Guido Goracci [1], Pavel Martauz [2], Esther Rojas [3] and Jorge S. D

Geopolymer Concrete for High-Temperature Thermal Energie Storage (TES) in Solar Power Technologies

Abstract: Solar energy is an energy intermittent source that faces a challenge for its power dispatchability. Hence, concentrating solar power plants employ thermal energy storage (TES) technologies. Ordinary Portland cement (OPC)-based materials are limited to operation temperatures below 400 °C because of thermal degradation processes.

Geopolymer-based concrete is a sound choice due to its thermal energy storage capacity, high thermal diffusivity and capability to work at high temperature regimes, in the 600°C - 700°C range.



3) Geopolymer and archaeology: update of research on Easter Island Statues manufacture.

Distribution limitée
RM/PP/CONSULTANT

Ile de Pâques

Les statues de Rapa Nui
Conservation et restauration

février-mars 1972

par G. Hyvert (Mlle)

1972

Gisèle Hyvert

Nº de série : 2868/RMO.RD/CLP
Paris, mars 1973

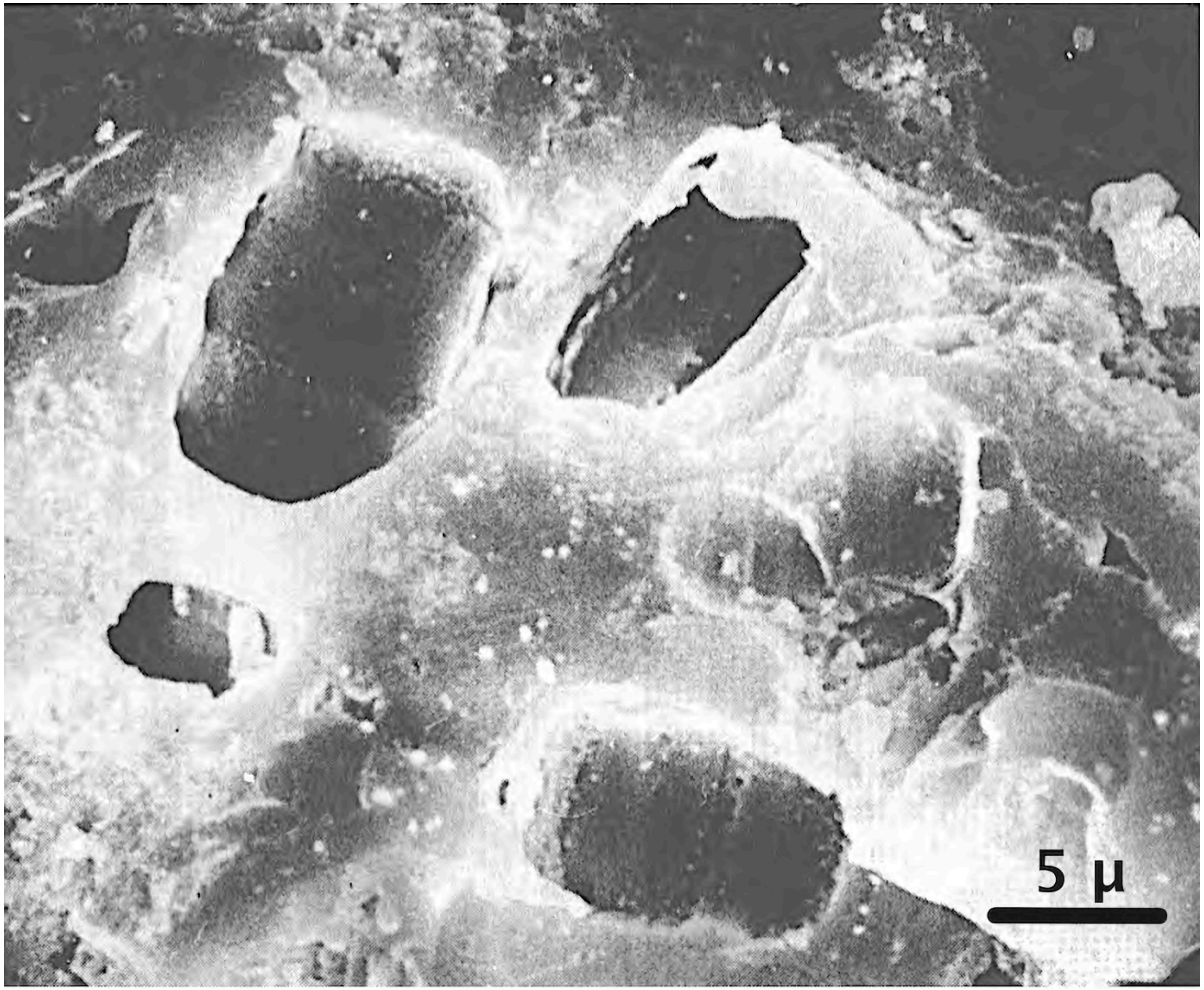
1973

Unesco

Ahu Tongariki

Gisèle Hyvert, UNESCO Rapport 1973.

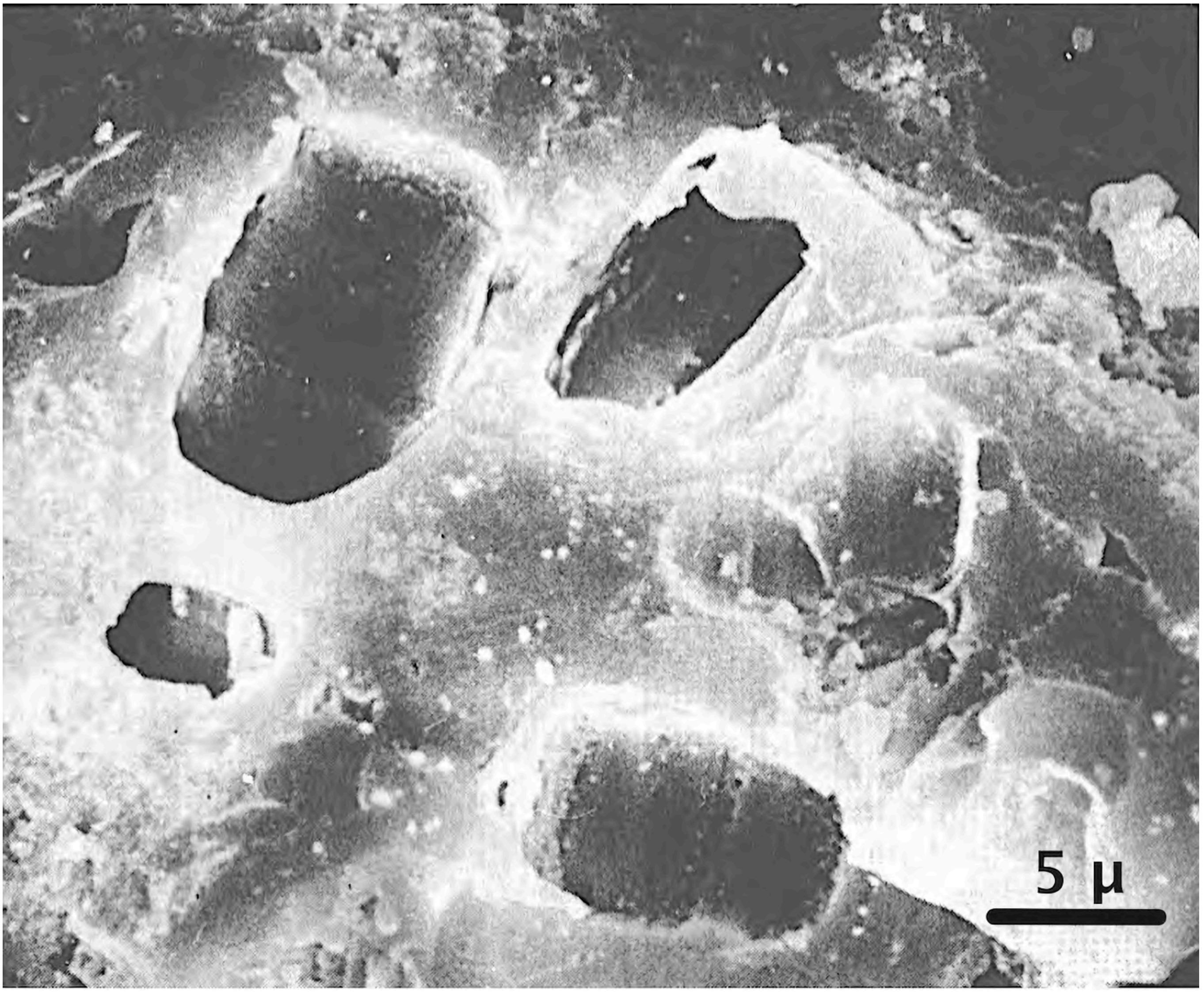
<u>424 d - Ahu Tongariki</u>. (…) At the base of this opal [white] layer, that is inside, below the surface of the rock, (…), there is a particular abundance of small rectangular or diamond shapes, sometimes in the shape of barrels, which appear to be microorganisms or residues of fragments of microorganisms.



barrel-shaped fossilized micro-organisms (bacteria)

Unesco (1973)

".. However, it should be pointed out that these organisms are fossilized, no living microrganisms were found in the samples I examined." (G. Hyvert).



The Moai at Ahu Tongariki are made of volcanic stone. If the stone is natural volcanic stone it cannot contain these fossilized microorganisms located inside of it.

We can only conclude that this stone is artificial, and that the microorganisms were introduced during its manufacture, then that they became fossilized at the time of the hardening of the geopolymeric volcanic stone.

There are several ***scientific clues*** demonstrating this possibility.

I shall present the results of this preliminary research undertaken on several scientific data available, and often misinterpreted, which show the ***artificial nature*** of the Easter Island statues. They also demonstrate the inter-relationship between South-America and Easter Island.

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Joseph Davidovits