INSTITUT GÉOPOLYMÈRE

UNIVERSITÉ de Picardie Jules Verne

CAMPUS universitaire de Saint-Quentin

PÔLE TECHNOLOGIQUE

2024 GEOPOLYMERCAMP

16th GP-Camp

LTI PÔLE TECHNOLOGIQUE SAINT-QUENTIN

UNIVERSITÉ de Picardie Jules Verne

MAG Matériaux Avancés en Géopolymère

Saint-Quentin (France)

July 8-10, 2024

GEOPOLYMER CAMP 2024

State of the Geopolymer R&D 2024

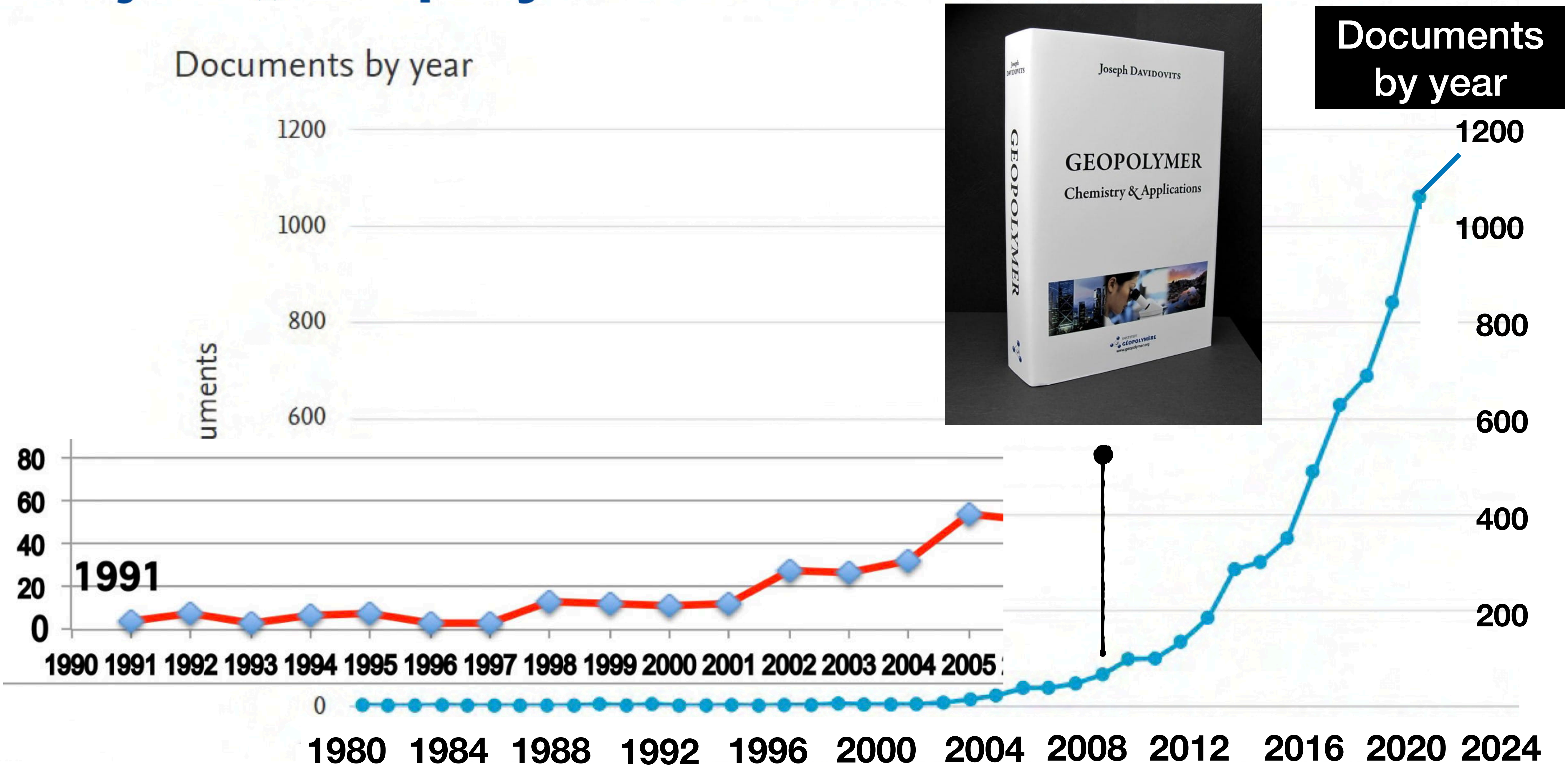
Joseph Davidovits

Geopolymer research 1988

1st Geopolymer conference

Geopolymer research 2018

Subject „Geopolymer“ in Scientific Publications



Literature Search: Statistical data of SCOPUS database

Geopolymer science.

From primary to quaternary structures

1975-1976: mineral polymer

1978-1979: geopolymer

2 systems:

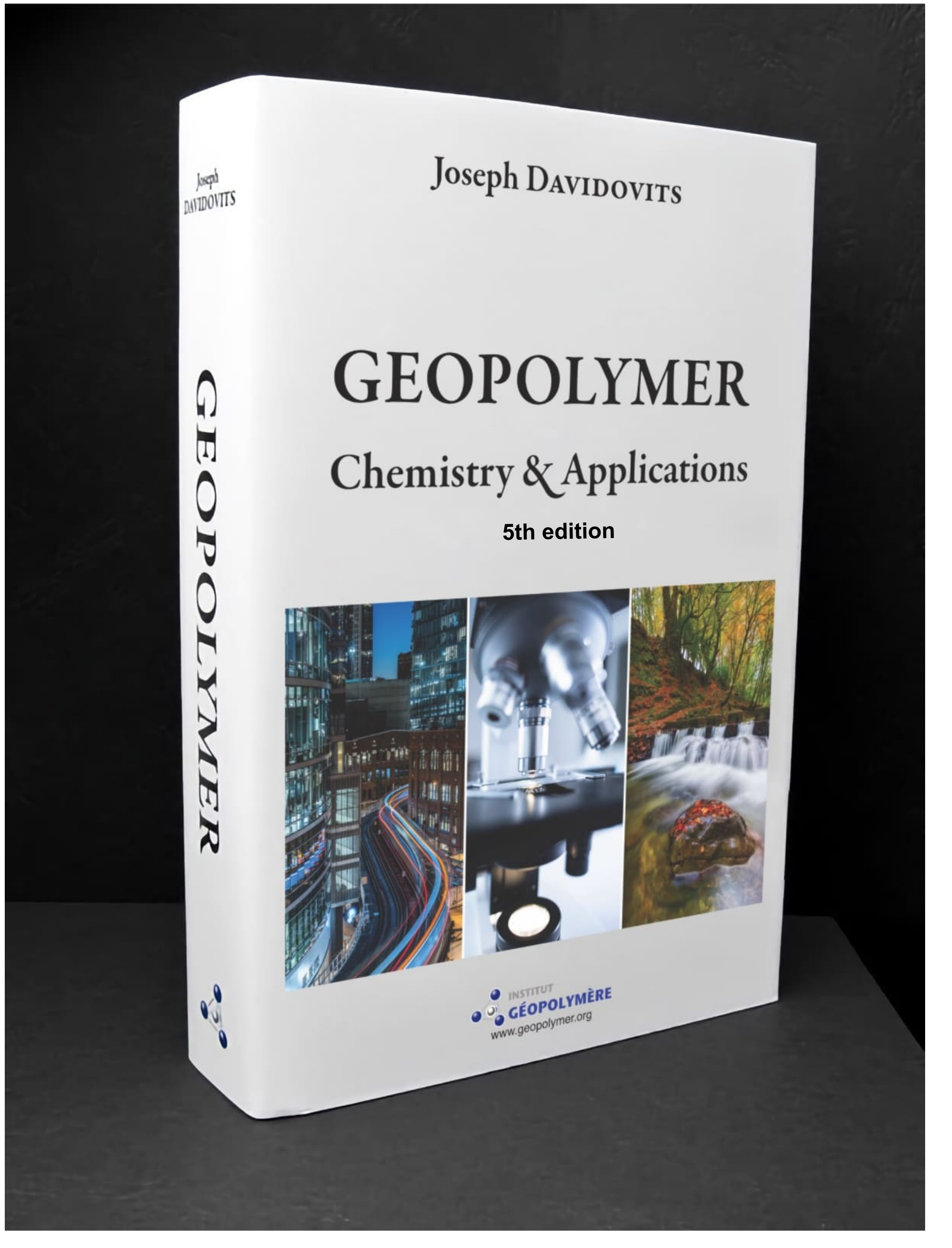
- poly(sialate)-alkaline-based GP

Na-based and K-based

- alumoxy-acid-based GP

phosphoric-based

and organic-based



a) Poly(sialate)-based Geopolymerization

a) Poly(sialate)-based Geopolymerization

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

From primary to quaternary structures

Alkalination *and* Depolymerization of silicates:

primary structure

Gel formation of oligo-sialates:

secondary structure

Polycondensation:

tertiary structure

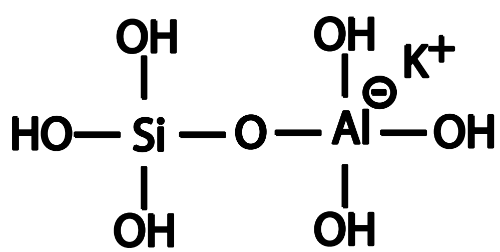
Reticulation, networking + GP solidification:

quaternary structure

From primary to quaternary structures

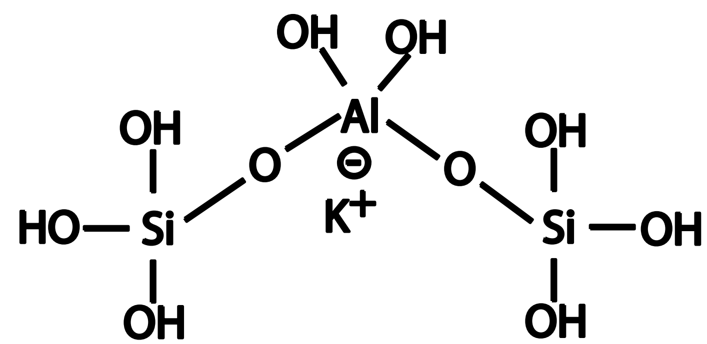
Alkalination *and* Depolymerization of silicates:

primary structure



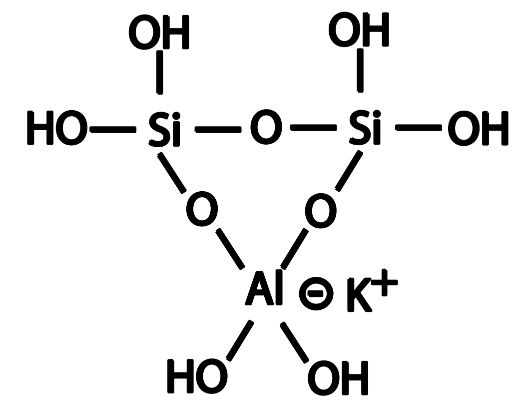
ortho-sialate

1



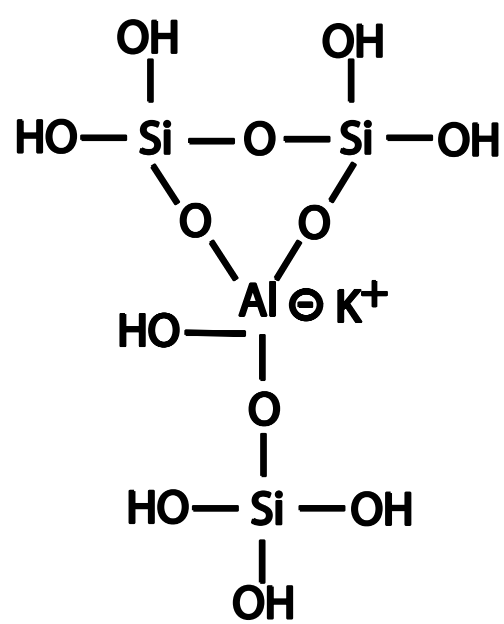
ortho(sialate-siloxo)

2



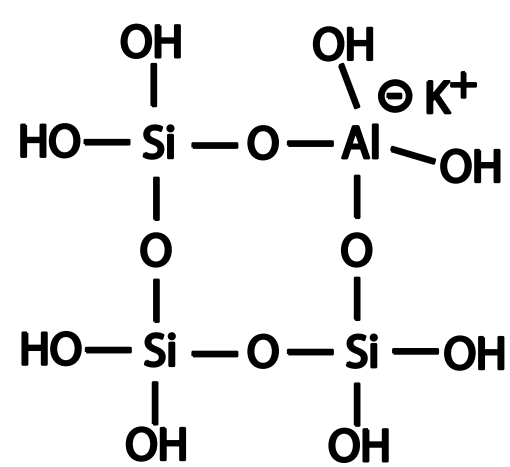
ortho(sialate-siloxo)

3



ortho(sialate-disiloxo)

4

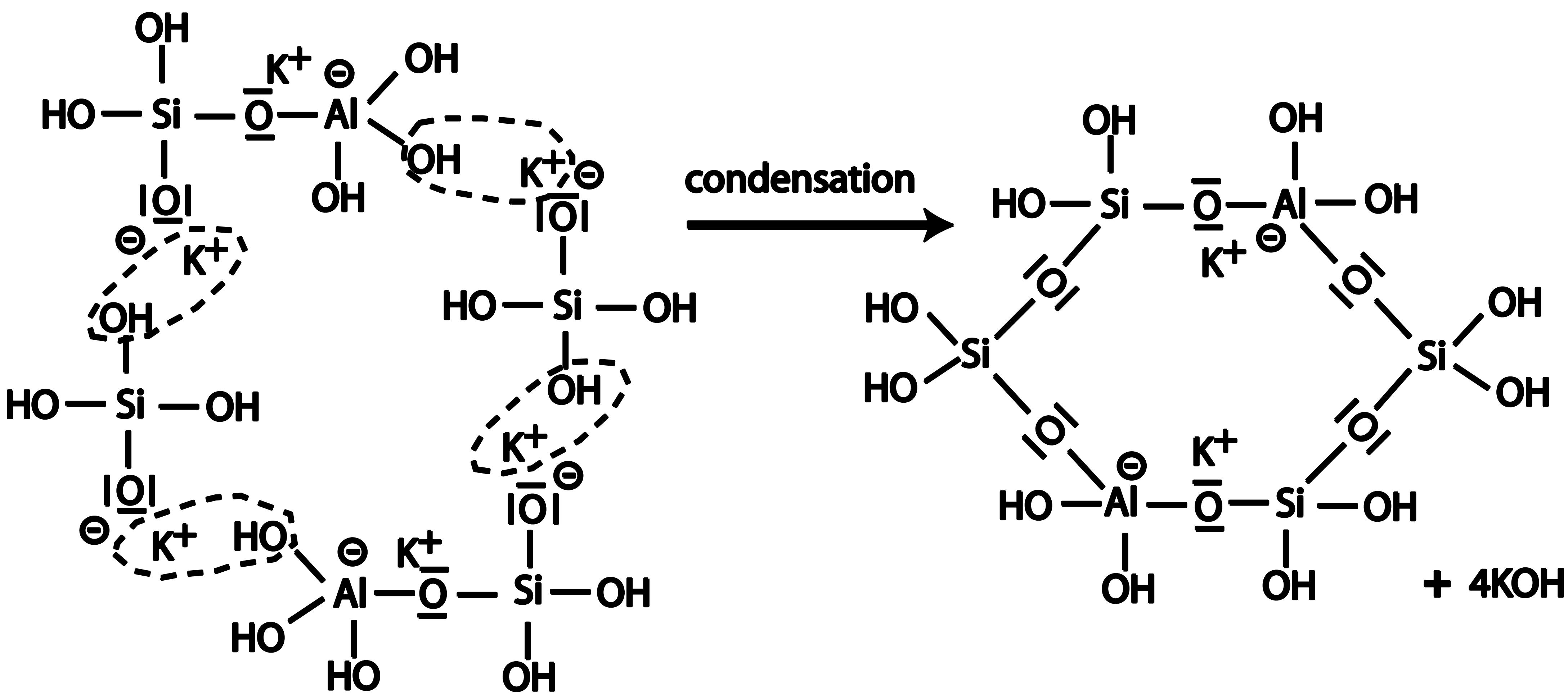


ortho(sialate-disiloxo)

5

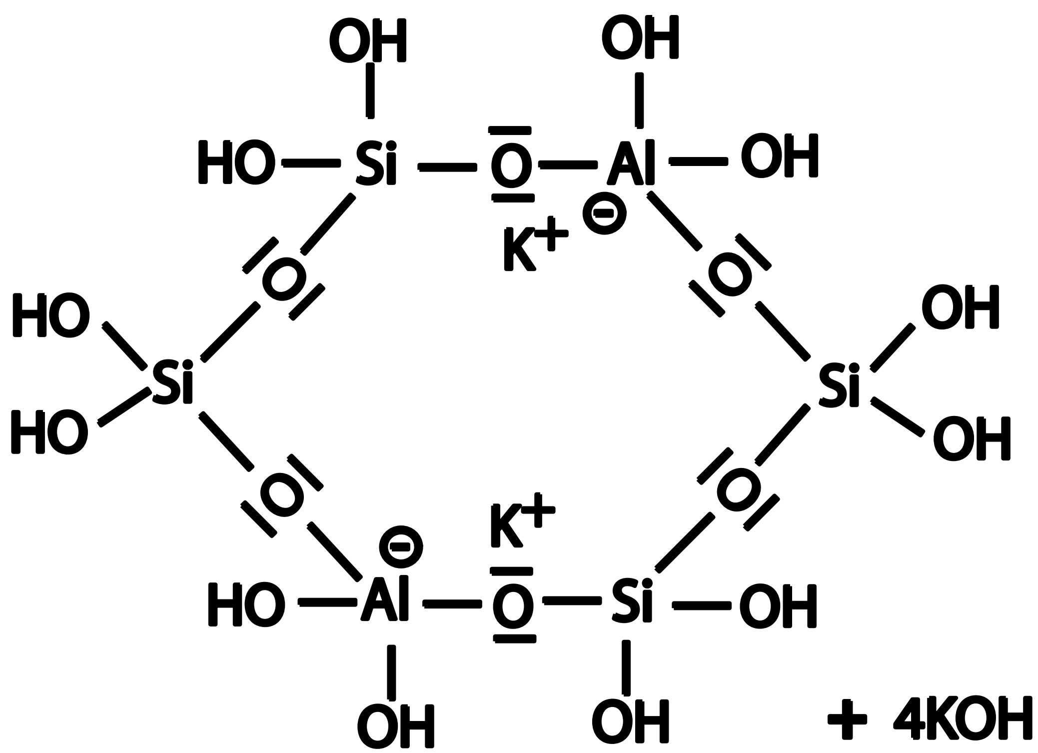
Gel formation of K-oligo(sialate-siloxo)

secondary structure



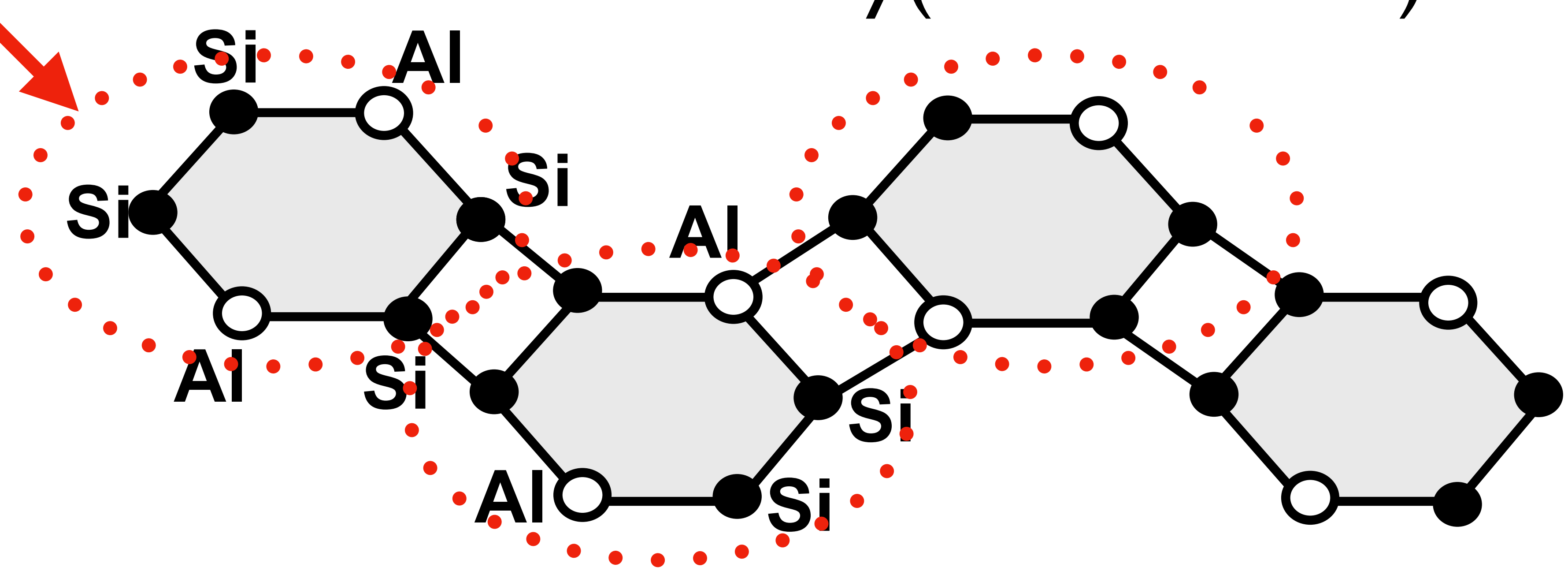
Polycondensation of K-poly(sialate-siloxo)

tertiary structure



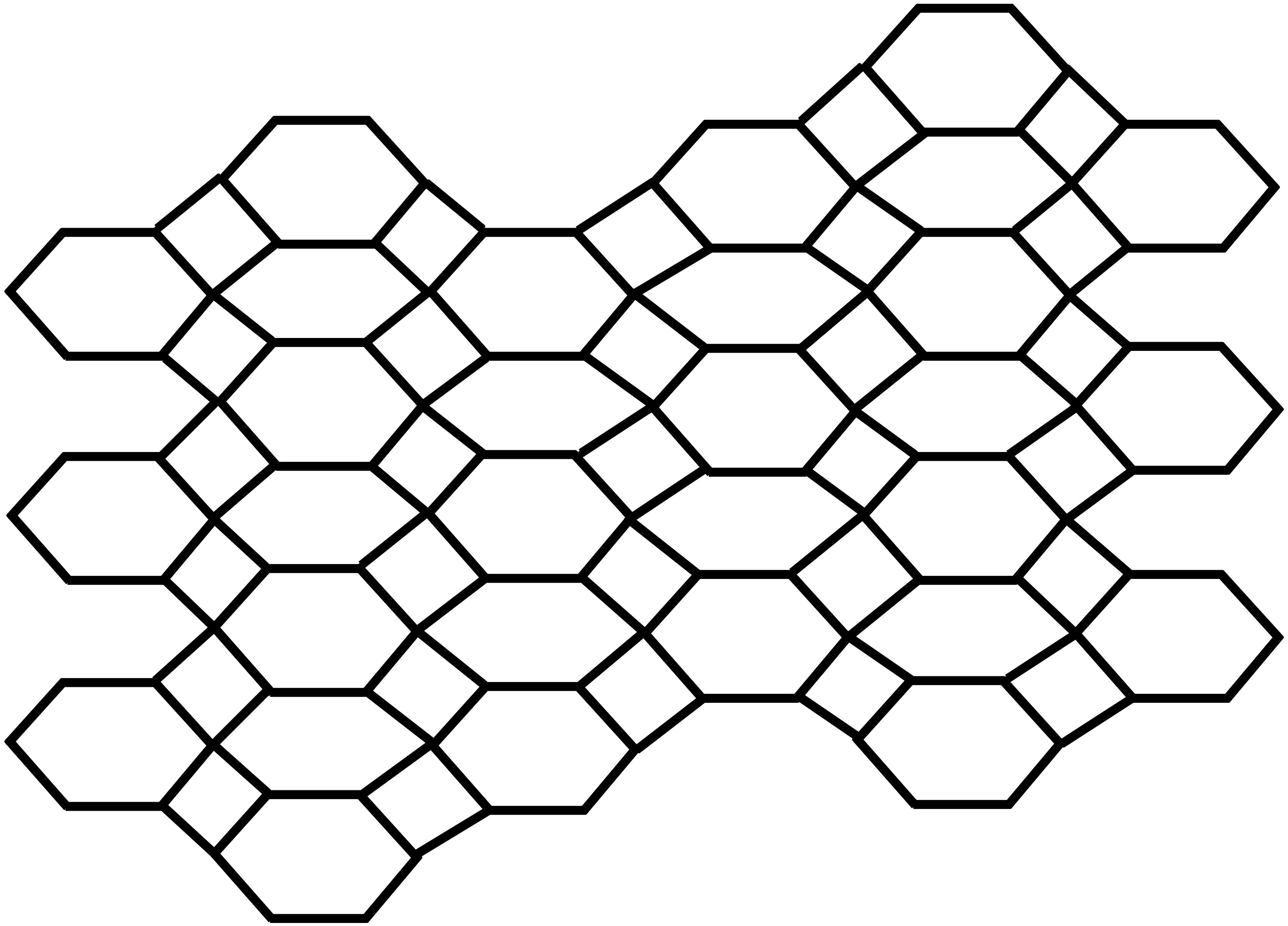
K-oligo(sialate-siloxo)

K-Poly(sialate-siloxo)



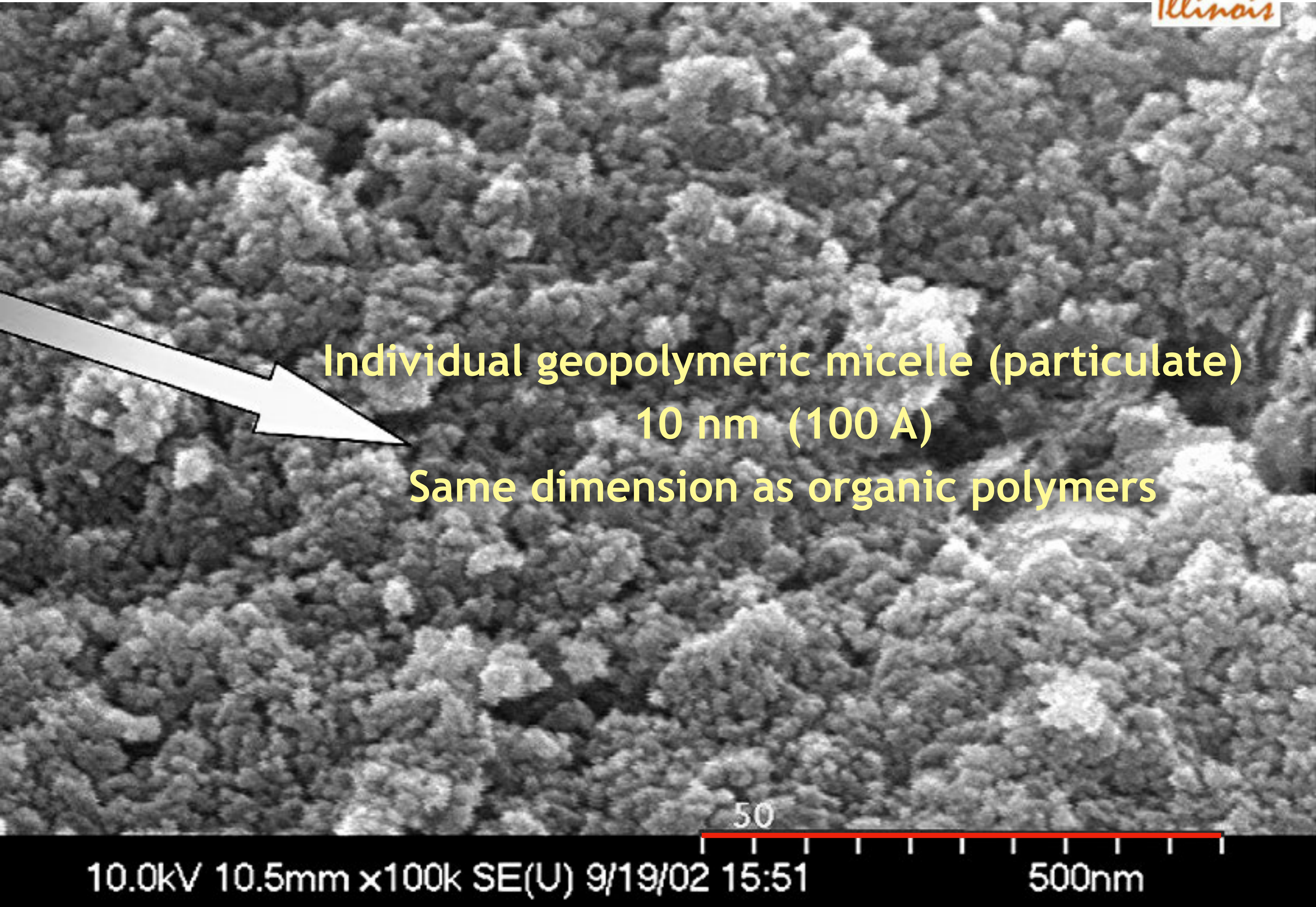
Reticulation, networking of K-poly(sialate-siloxo)

quaternary structure



Leucite framework KSi_2AlO_6

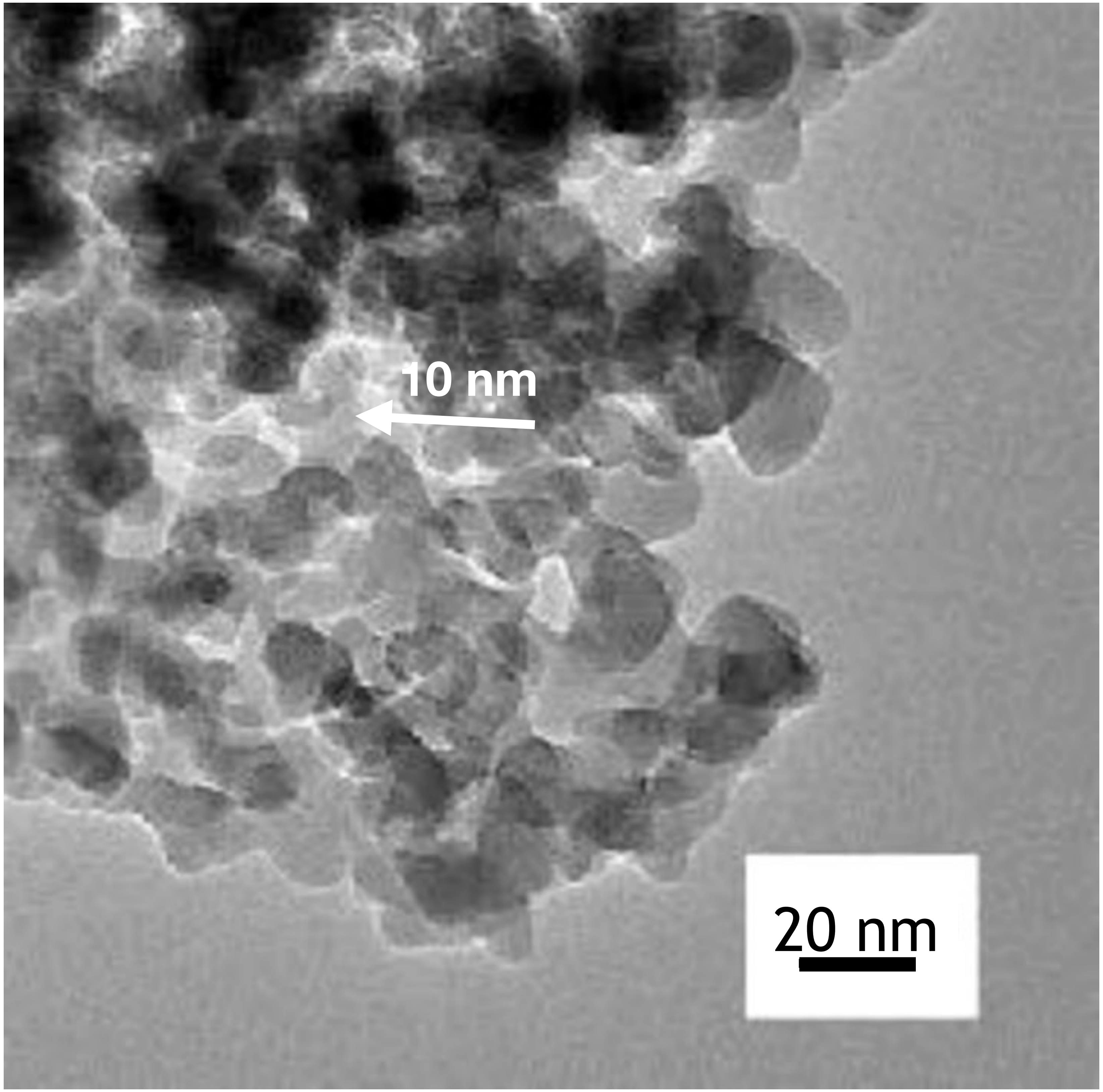
2003, Prof. Kriven's team *University of Illinois, USA*



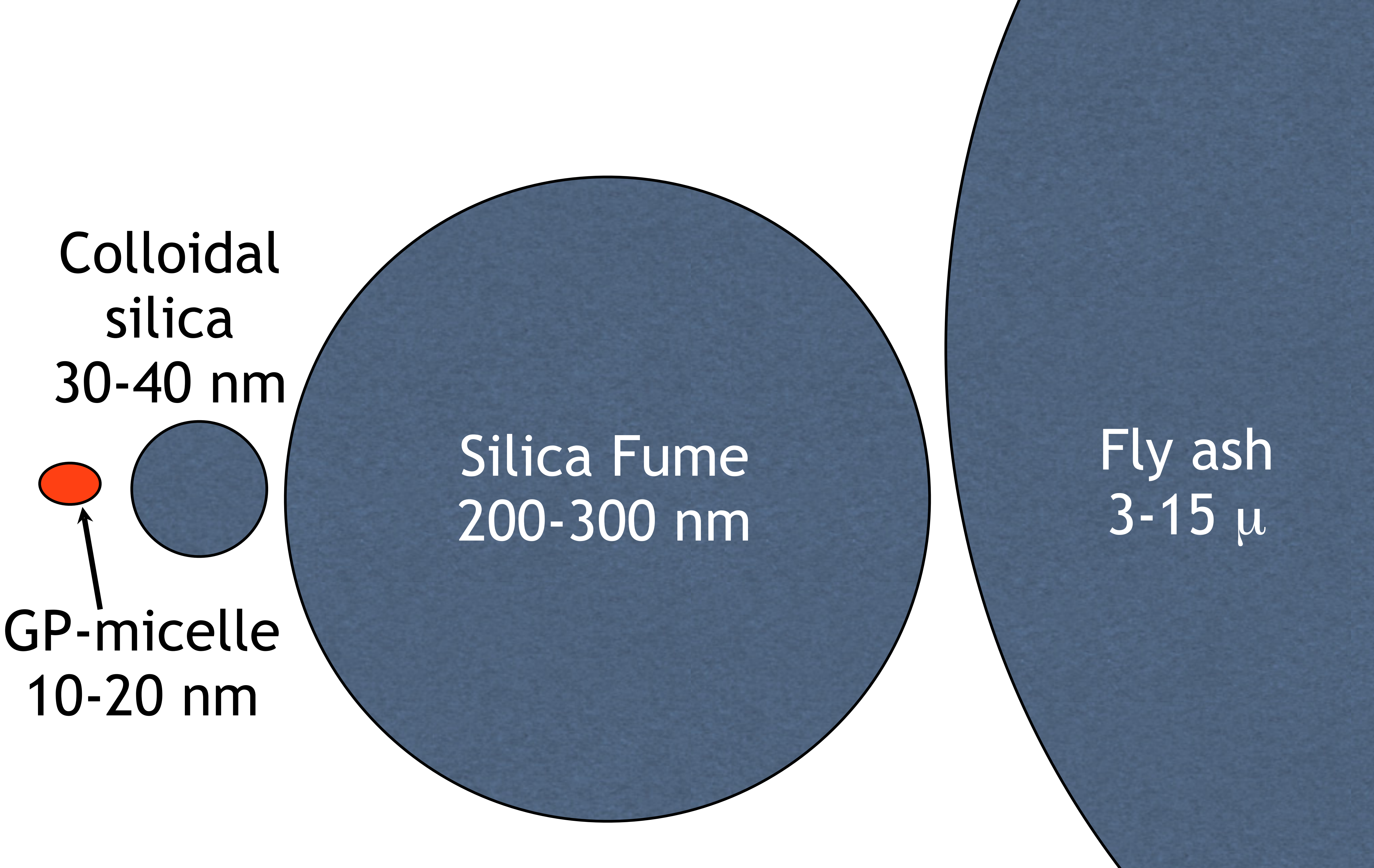
Step 5

reticulation

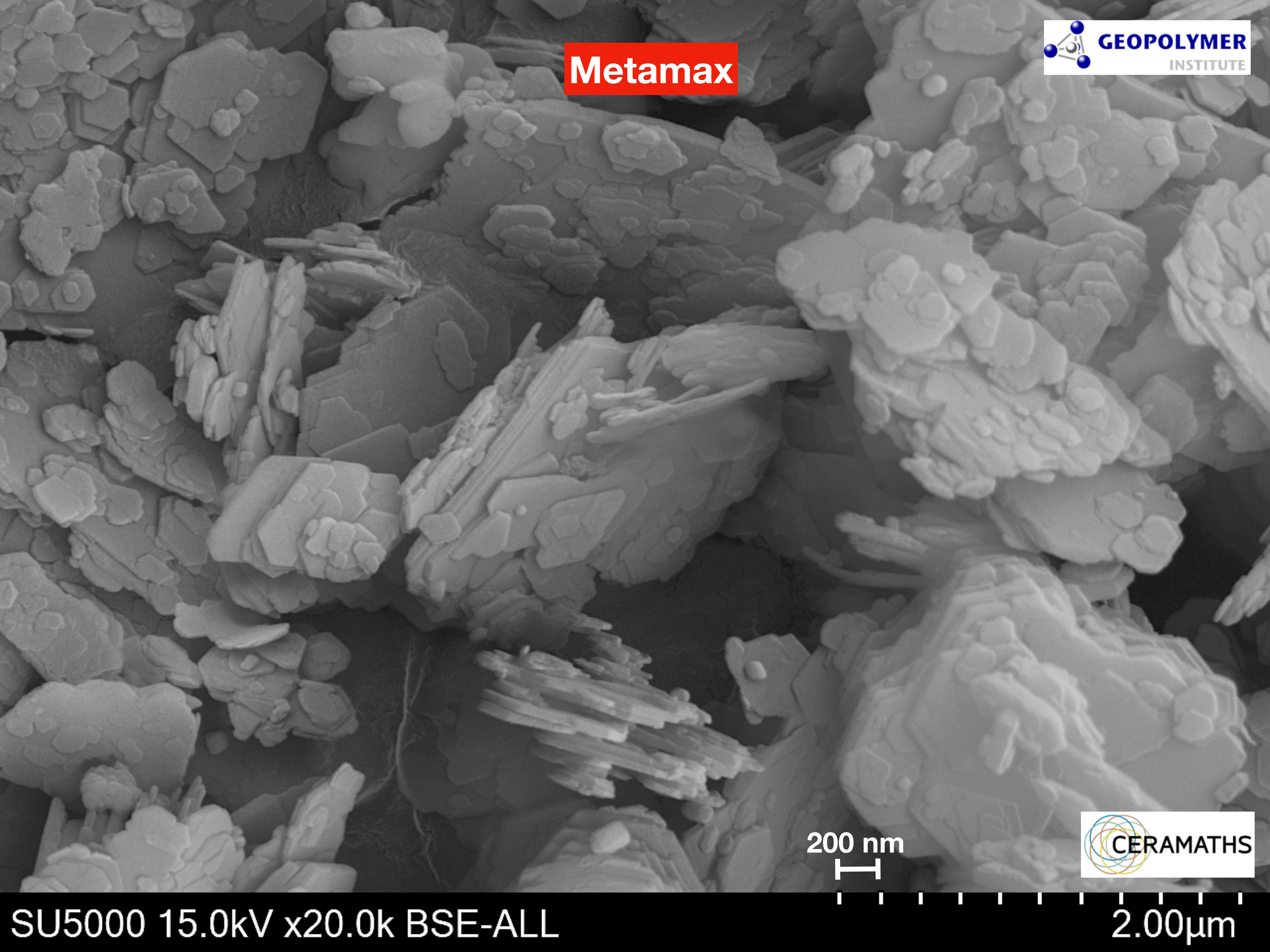
quaternary structure



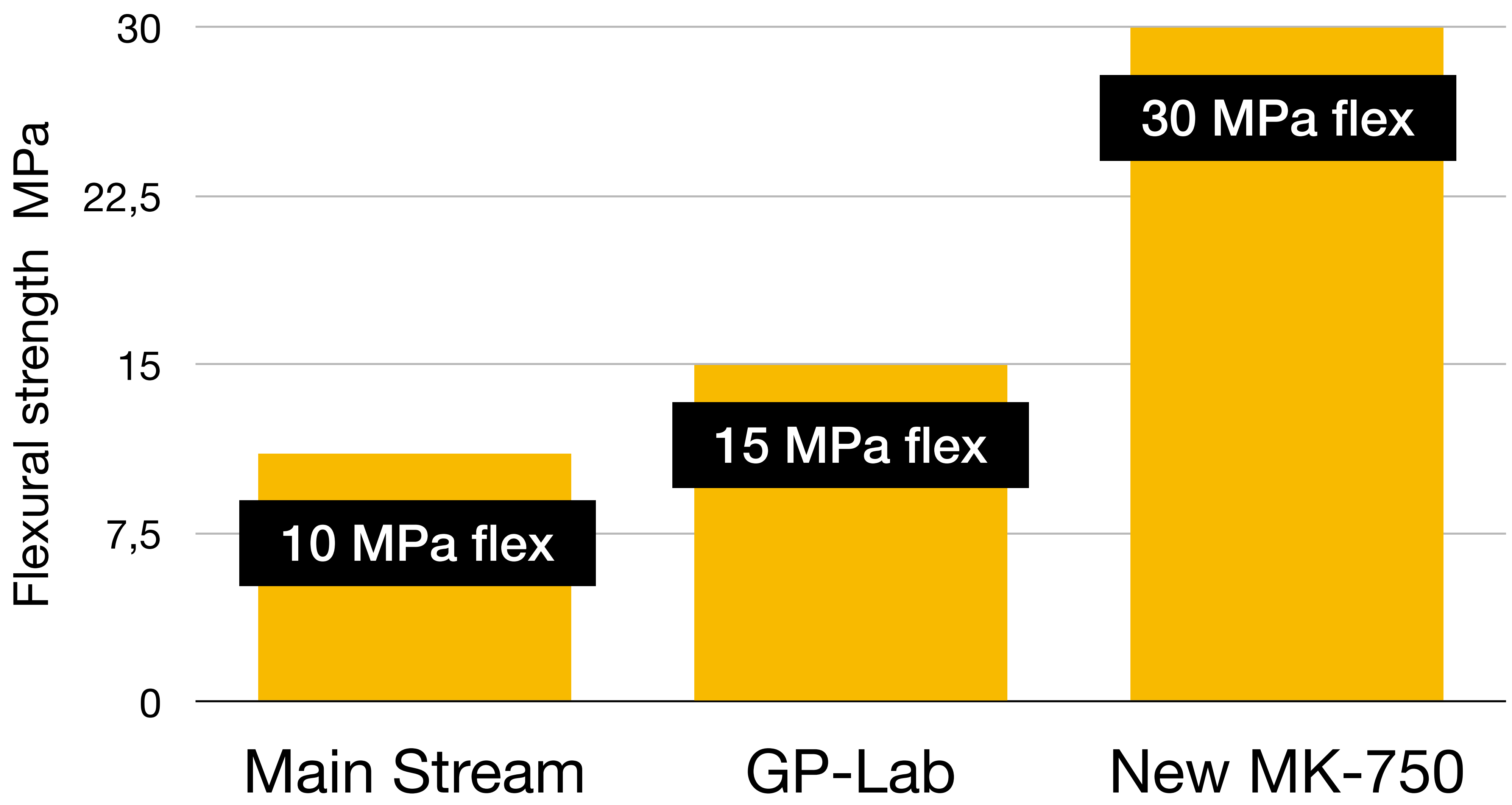
2012 Prof. Dong-Kyun (Don) Seo's team
School of Molecular Sciences, Arizona State University, Tempe, USA



Poly(sialate) Geopolymer = nano material
not unknown « Gel » or « Hydrate »


Metamax
GEOPOLYMER
INSTITUTE
200 nm
CERAMATHS
SU5000 15.0kV x20.0k BSE-ALL
2.00µm

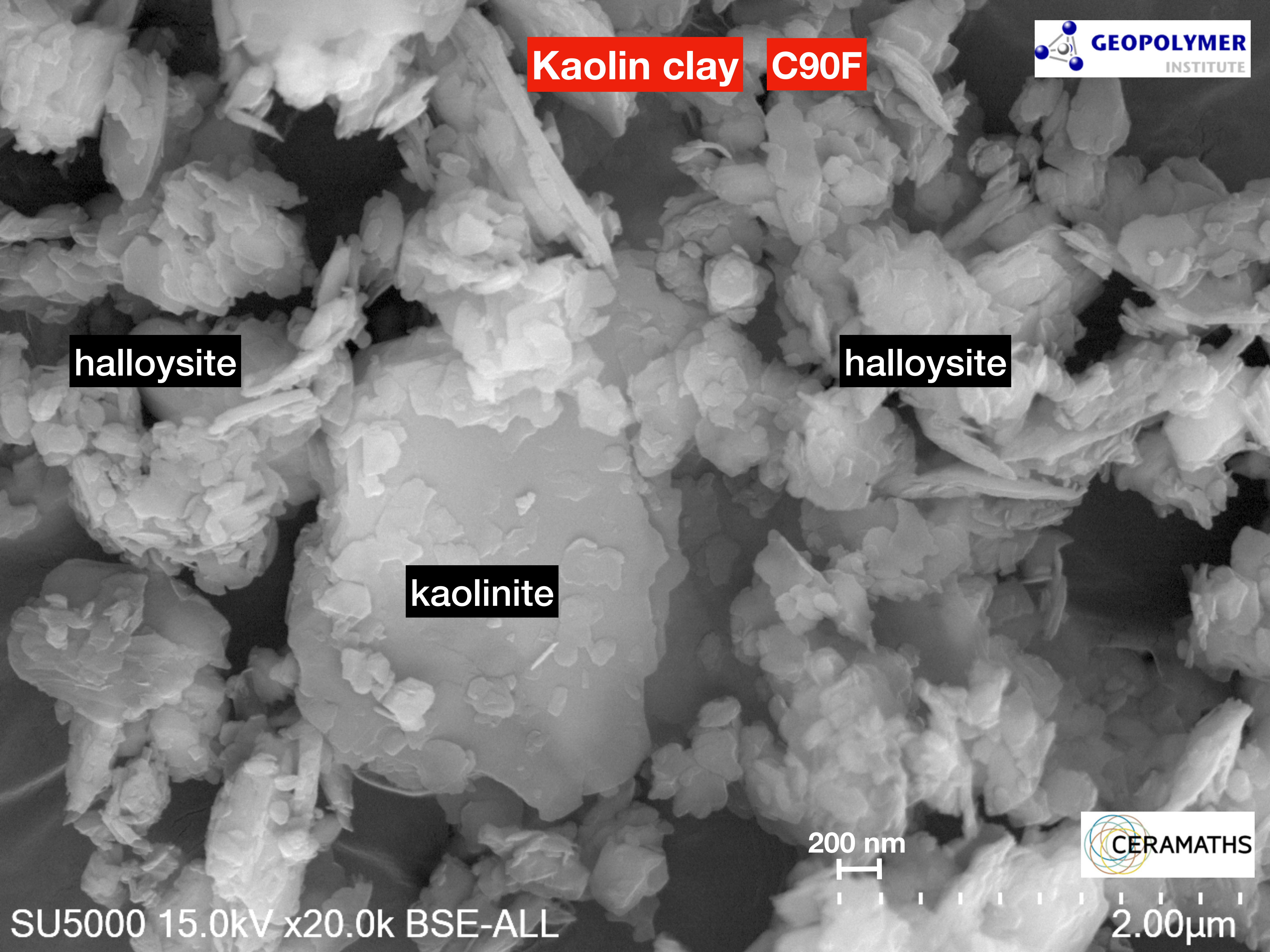
High-strength MK



Flexural strength 25-30 MPa

Compressive strength 180 MPa

with mineral filler: feldspar


Kaolin clay
C90F
GEOPOLYMER
INSTITUTE
halloysite
halloysite
kaolinite
200 nm
CERAMATHS
SU5000 15.0kV x20.0k BSE-ALL
2.00µm

minerals

2019

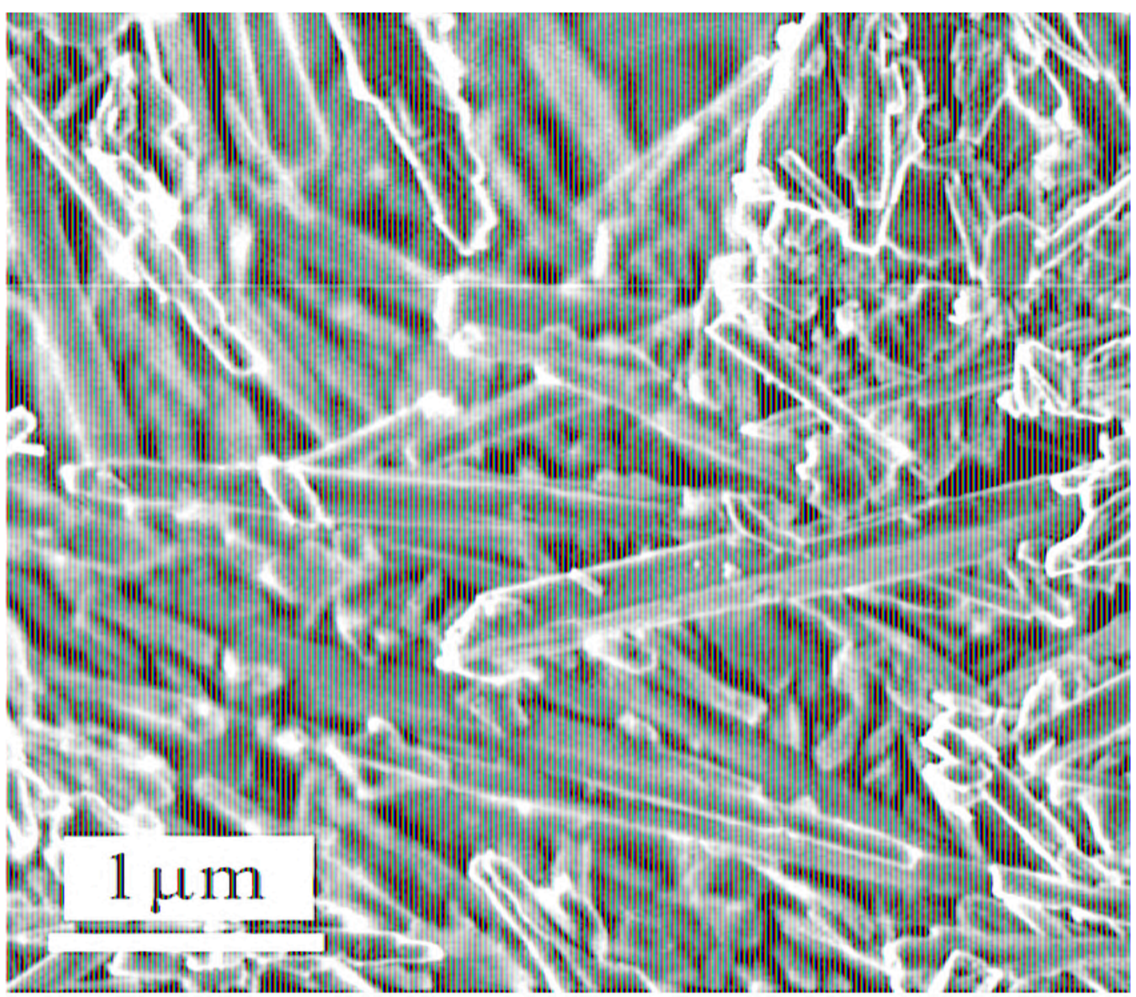
MDPI

Article *Minerals* **2019**, *9*, 670; doi:10.3390/min9110670

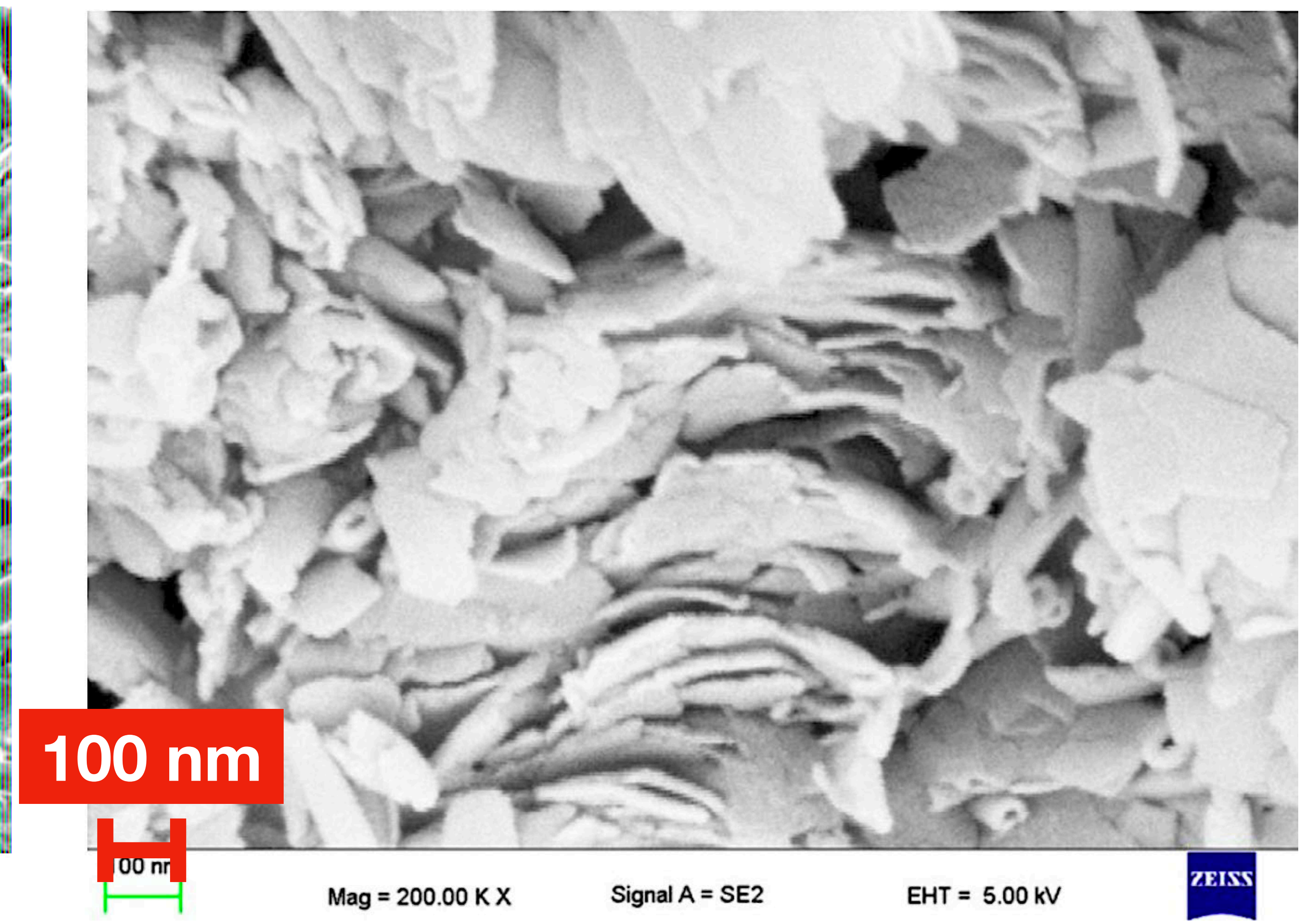
Characterization of Diatomaceous Earth and Halloysite Resources of Poland

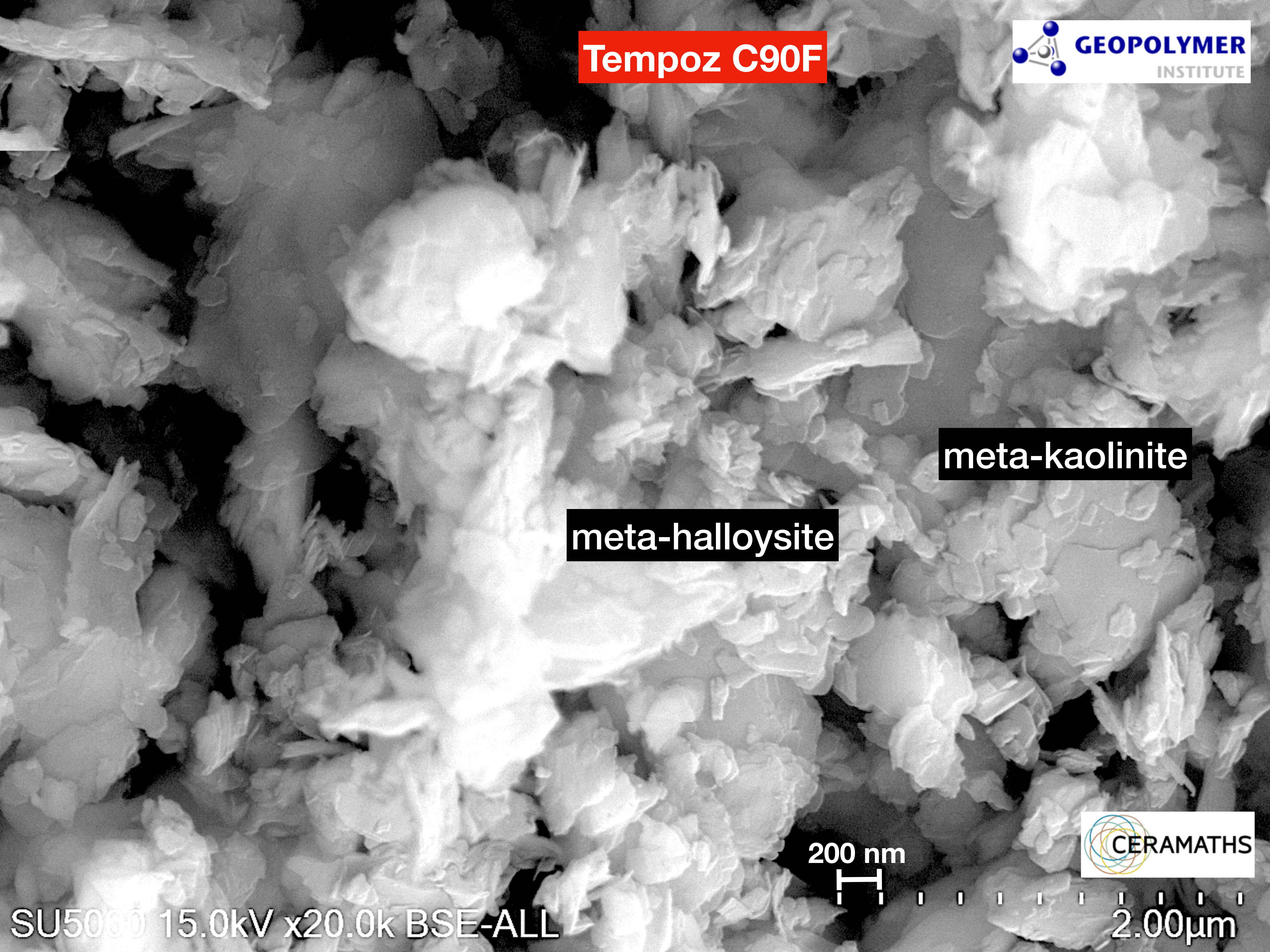
Marcin Lutyn´ski , Piotr Sakiewicz and Sylwia Lutynska, Silesian University of Technology, Gliwice, Poland.

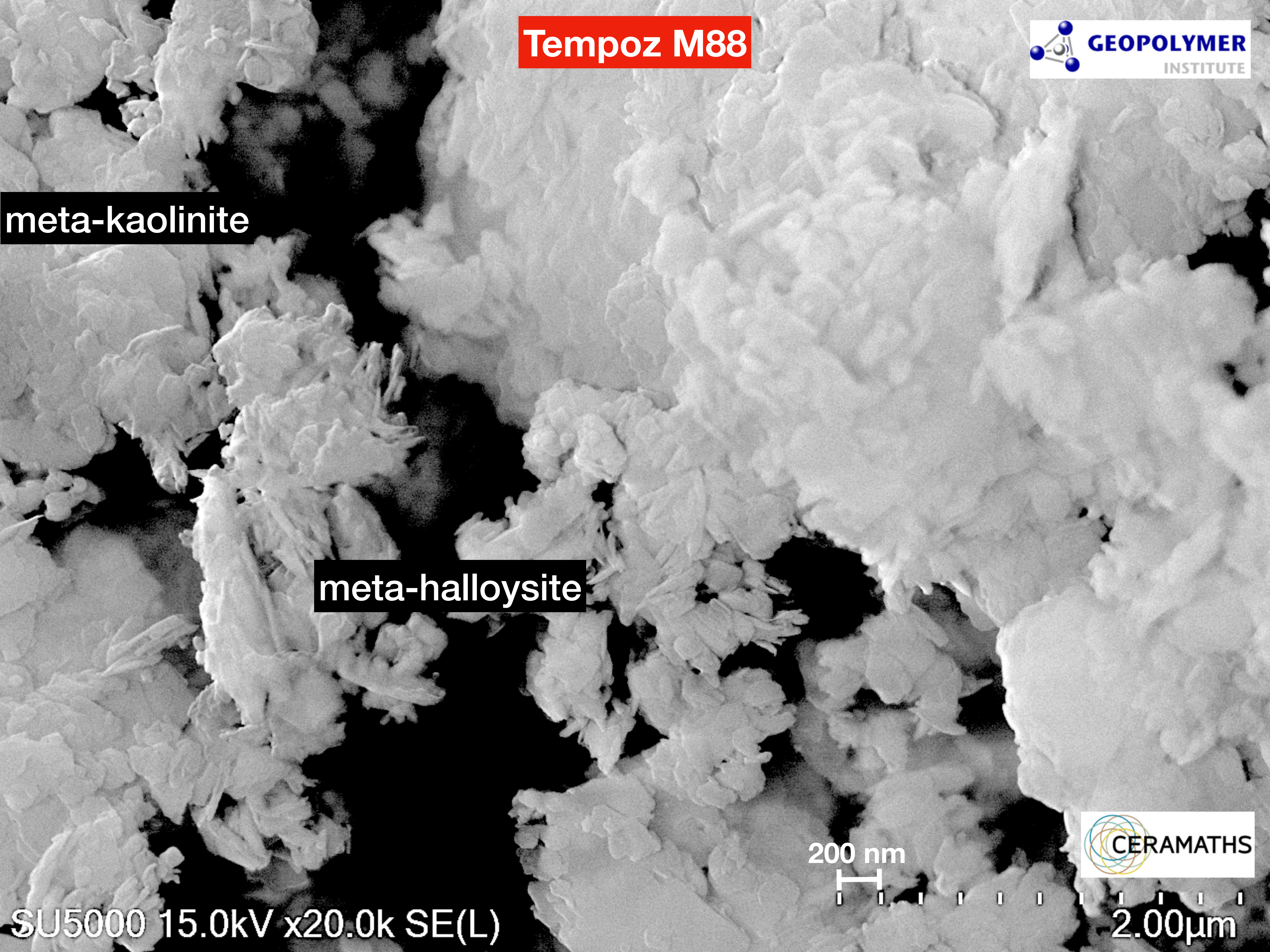
Halloysite nanotubes



Halloysite nanoplates

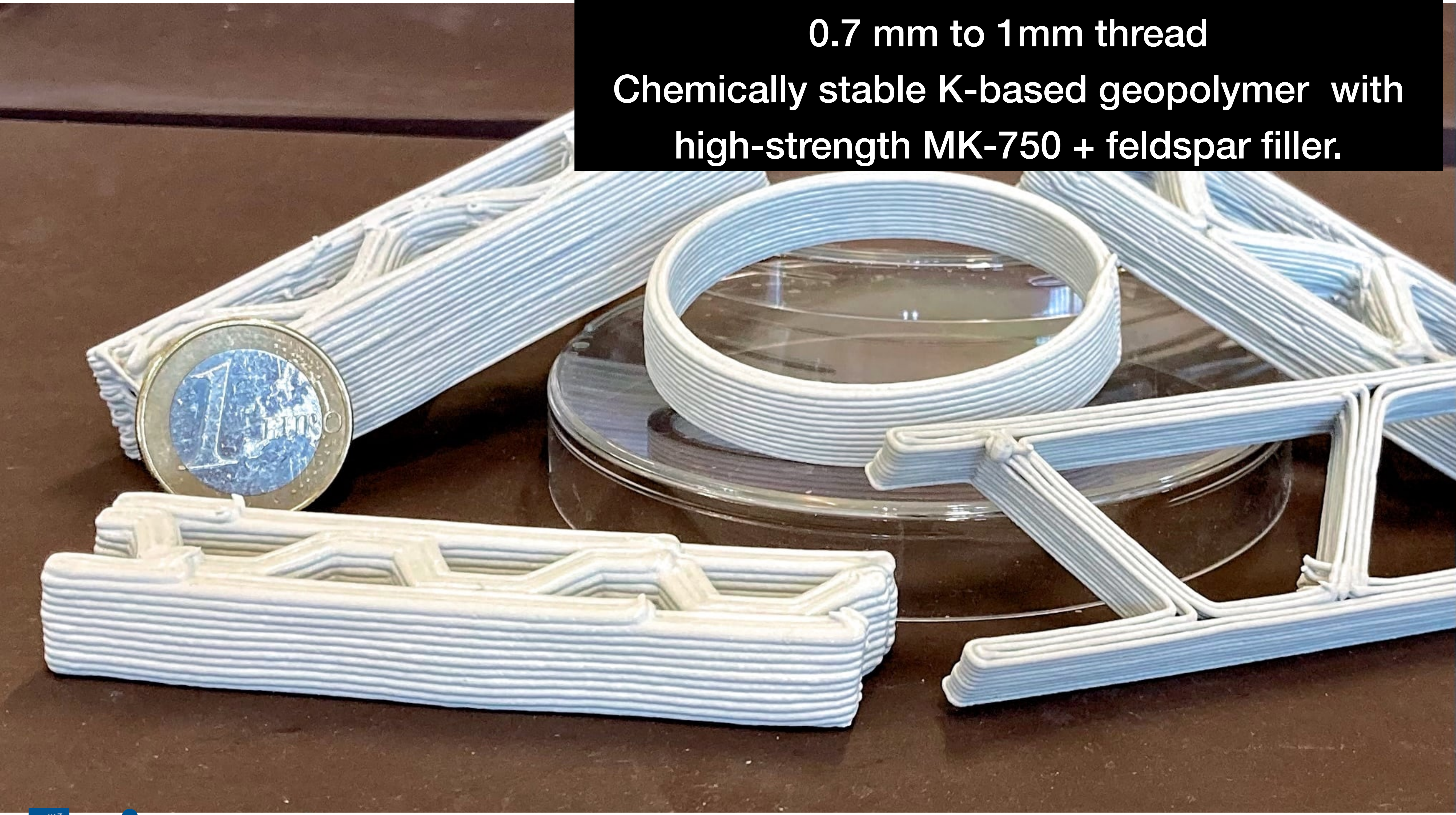



Tempoz C90F
GEOPOLYMER
INSTITUTE
meta-kaolinite
meta-halloysite
CERAMATHS
200 nm
SU5000 15.0kV x20.0k BSE-ALL
2.00µm


Tempoz M88
GEOPOLYMER INSTITUTE
meta-kaolinite
meta-halloysite
200 nm
CERAMATHS
SU5000 15.0kV x20.0k SE(L)
2.00µm

3D printing ceramic-type geopolymer

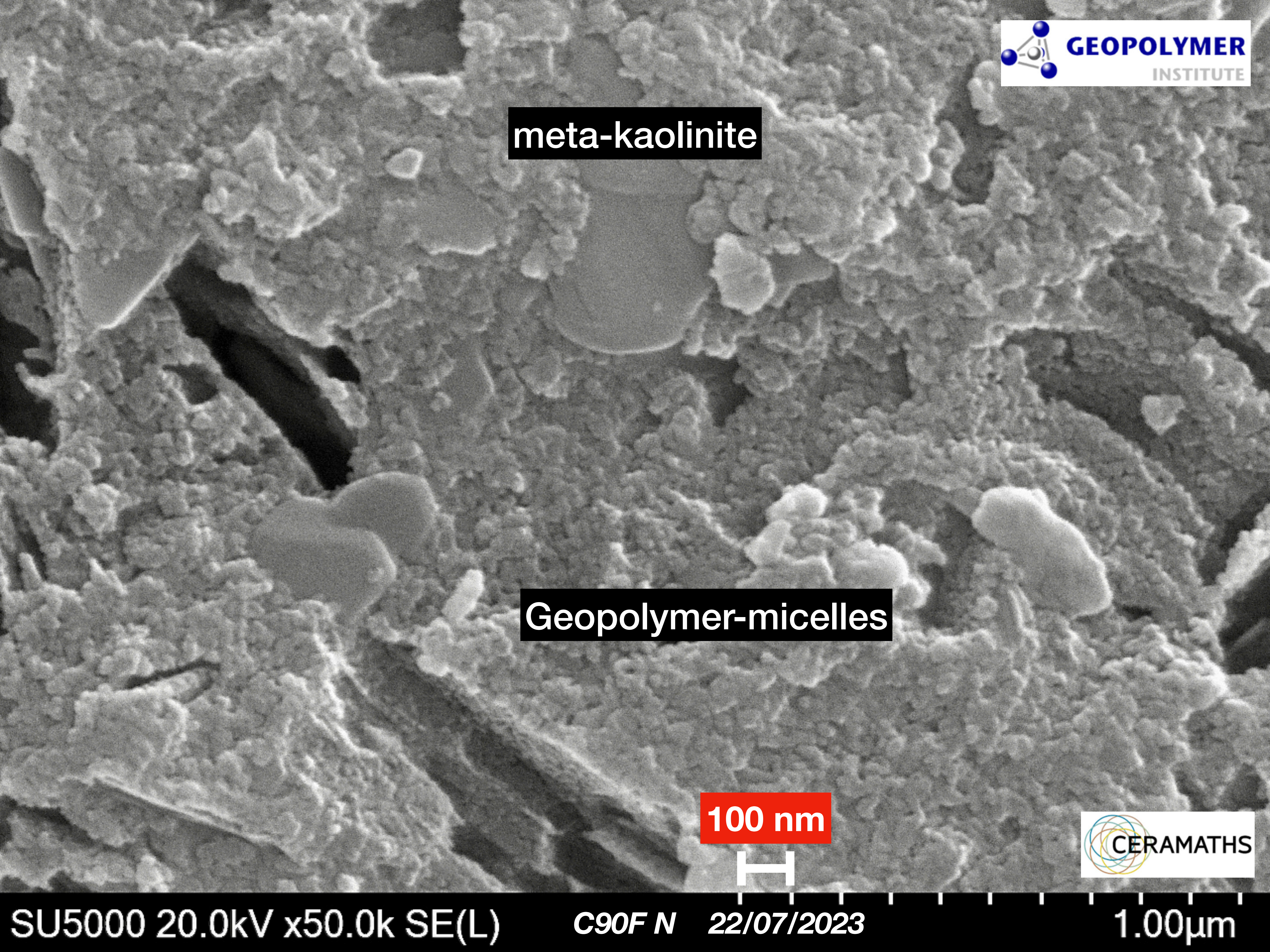
High-Strength 3D-Printed Geopolymer Ceramic
0.7 mm to 1mm thread
Chemically stable K-based geopolymer with high-strength MK-750 + feldspar filler.

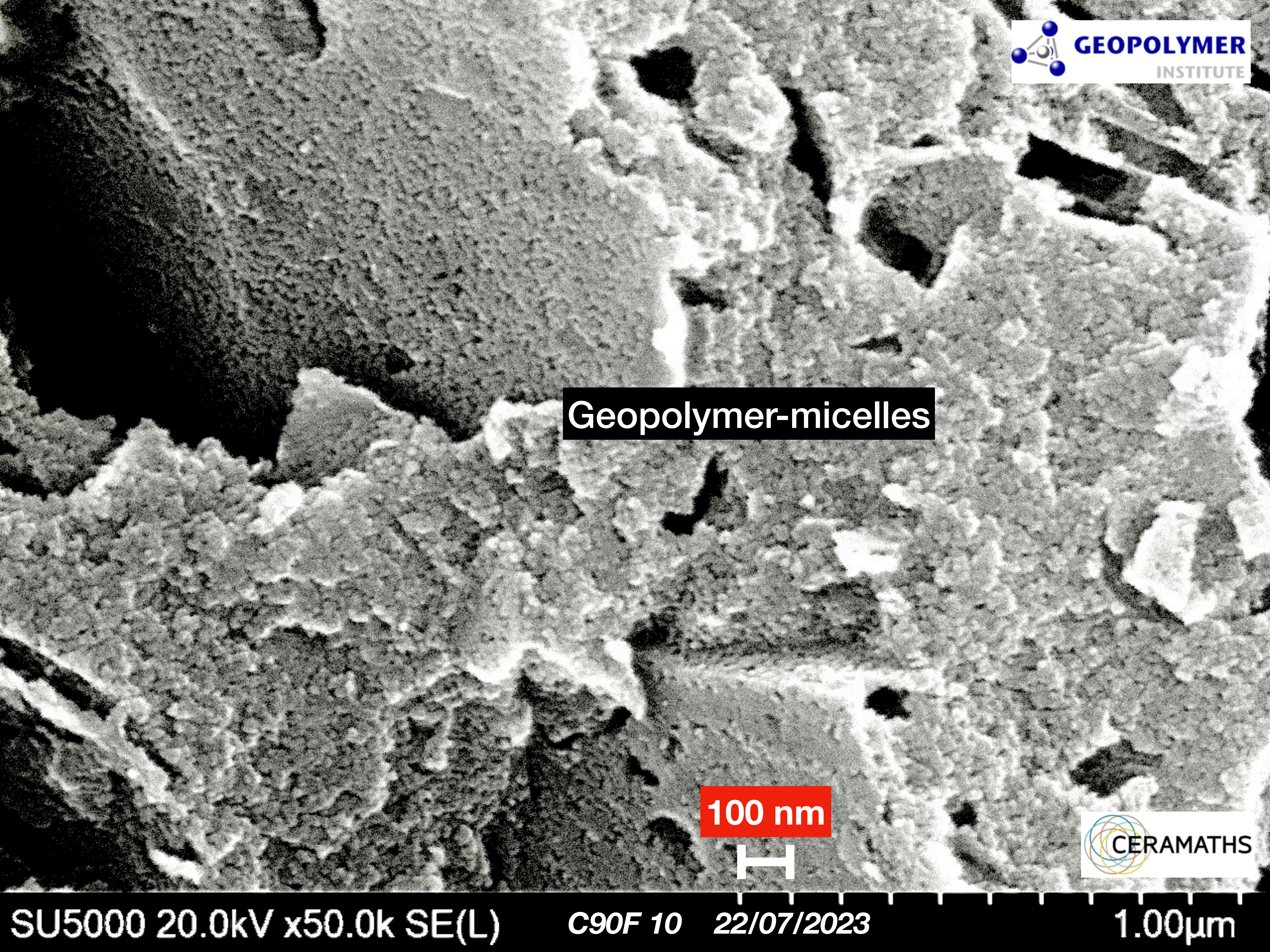


MAG Matériaux Avancés en Géopolymère

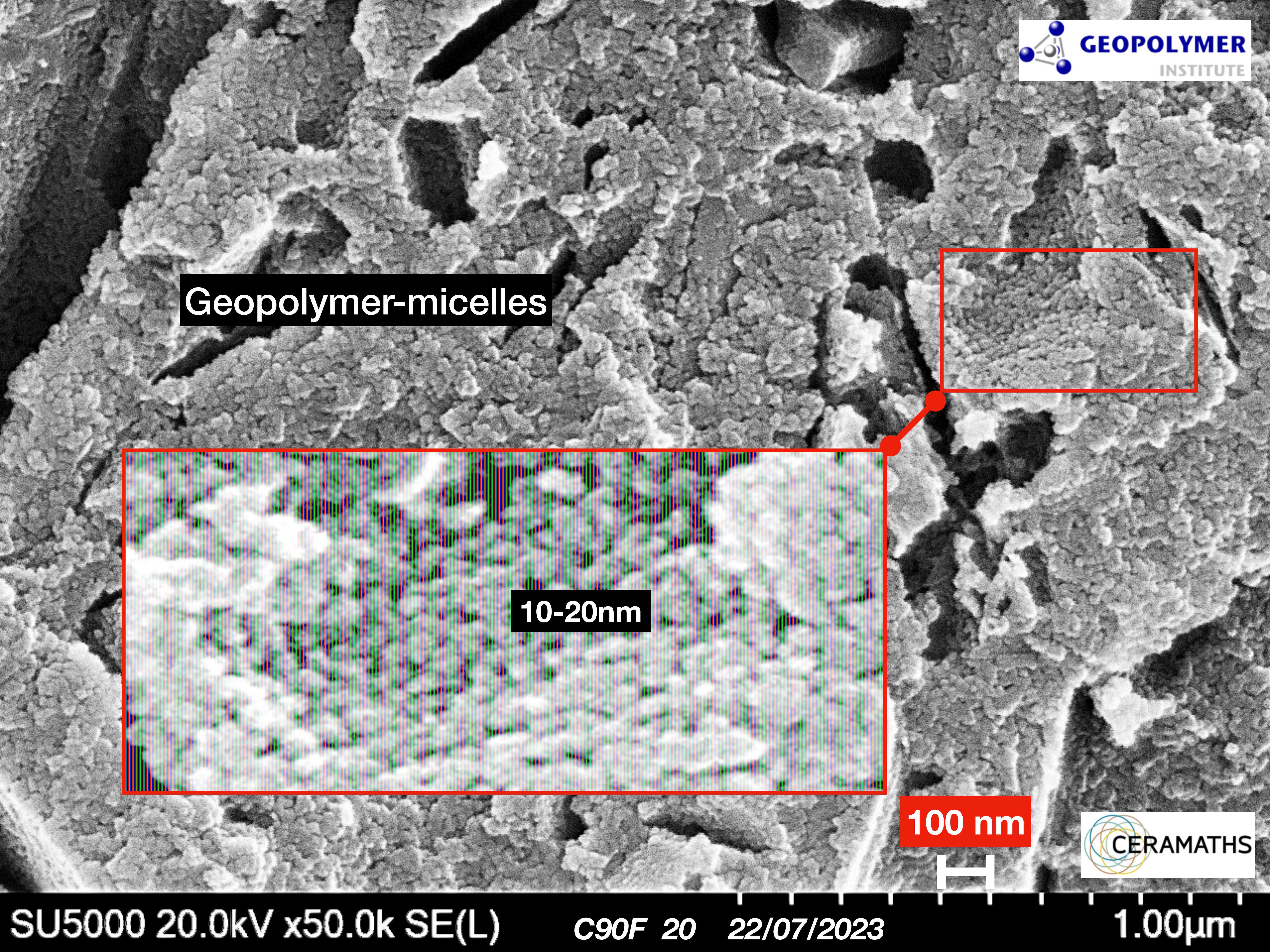
2023 GeopolymerCamp

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


GEOPOLYMER
INSTITUTE
meta-kaolinite
Geopolymer-micelles
100 nm
CERAMATHS
SU5000 20.0kV x50.0k SE(L)
C90F N
22/07/2023
1.00µm



Geopolymer-micelles
100 nm
SU5000 20.0kV x50.0k SE(L)
C90F 10
22/07/2023
1.00µm


GEOPOLYMER
INSTITUTE
Geopolymer-micelles
10-20nm
100 nm
CERAMATHS
SU5000 20.0kV x50.0k SE(L)
C90F 20 22/07/2023
1.00µm

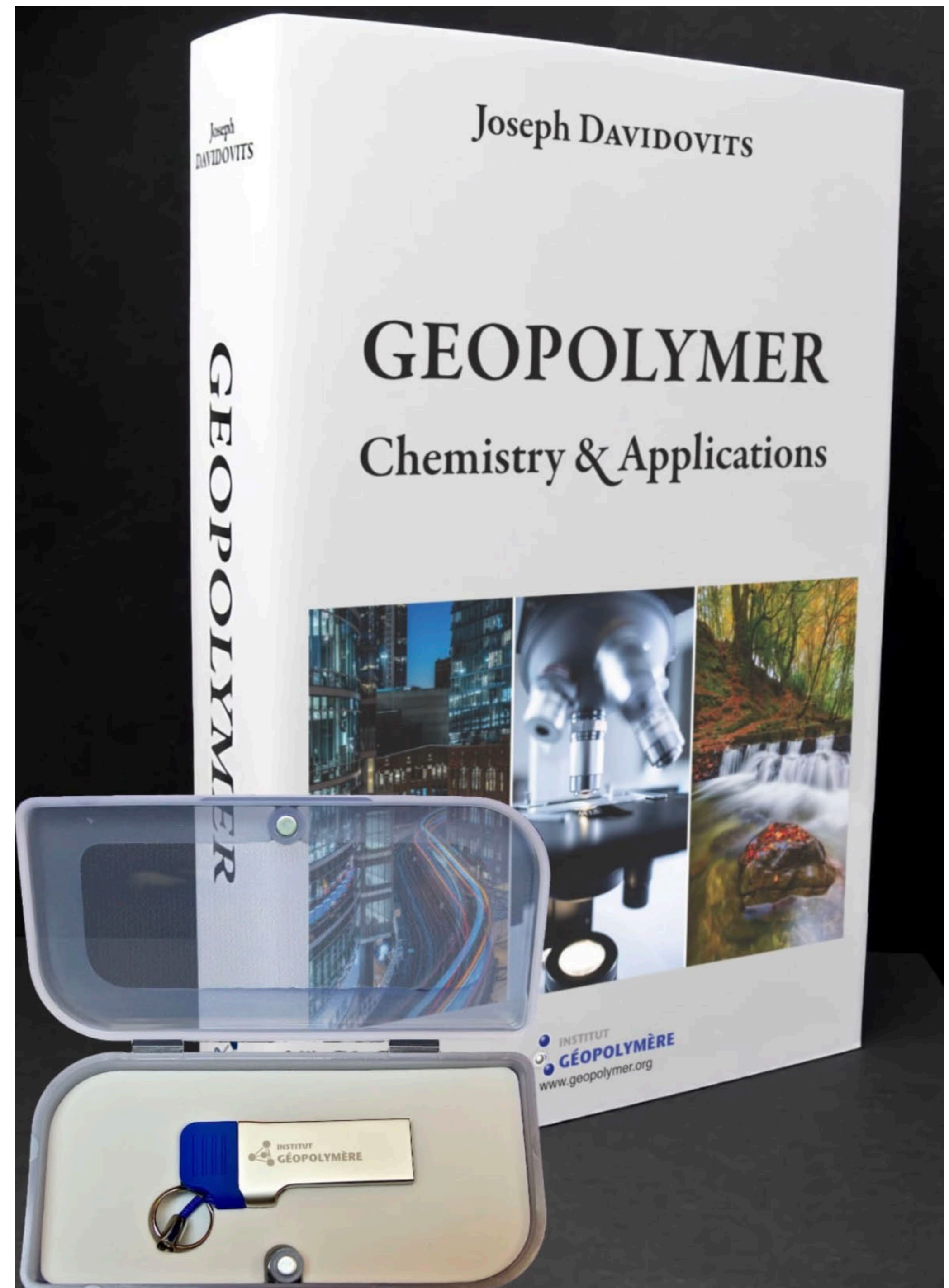
The conclusion of this study is that we have demonstrated that the quaternary structure of metakaolin-based geopolymer is a well-defined 3D polymeric network in the form of individual particles called *geopolymer micelles*, with overall dimensions in the range of 10 to 20 nm.

The quaternary structure of the nano-sized K-based geopolymer micelle retains the same shape when heated up to 1000°C. Its microstructure also remains X-ray amorphous. At higher temperatures it crystallizes into the mineral leucite with a melting point above 1400°C.

This explains its unique structural properties, for example:

- excellent thermal shock resistance at high or very low temperatures,
- resistance to very high vacuum,
- making it the ideal material for lunar, space and extraterrestrial applications.

Cement scientists who promote the misconception that the result of geopolymerization is a NASH or KASH type hydrate are mistaken. Alkali activated materials are not geopolymers.

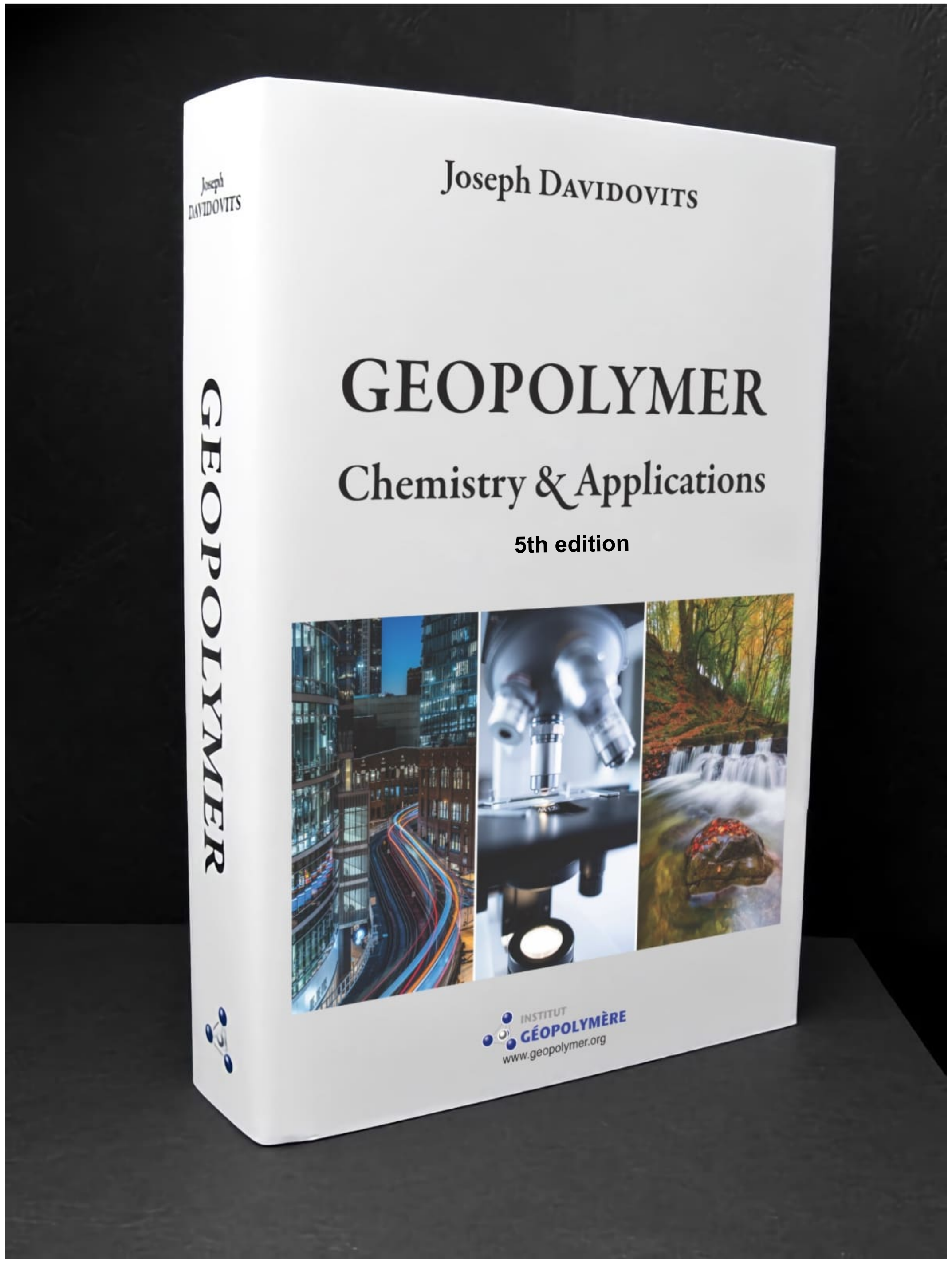


They can purchase the *Geopolymer Bundle* book and learn how to produce true Geopolymers.

b) Alumoxy-based Geopolymerization Al-O-X

phosphoric acid-based

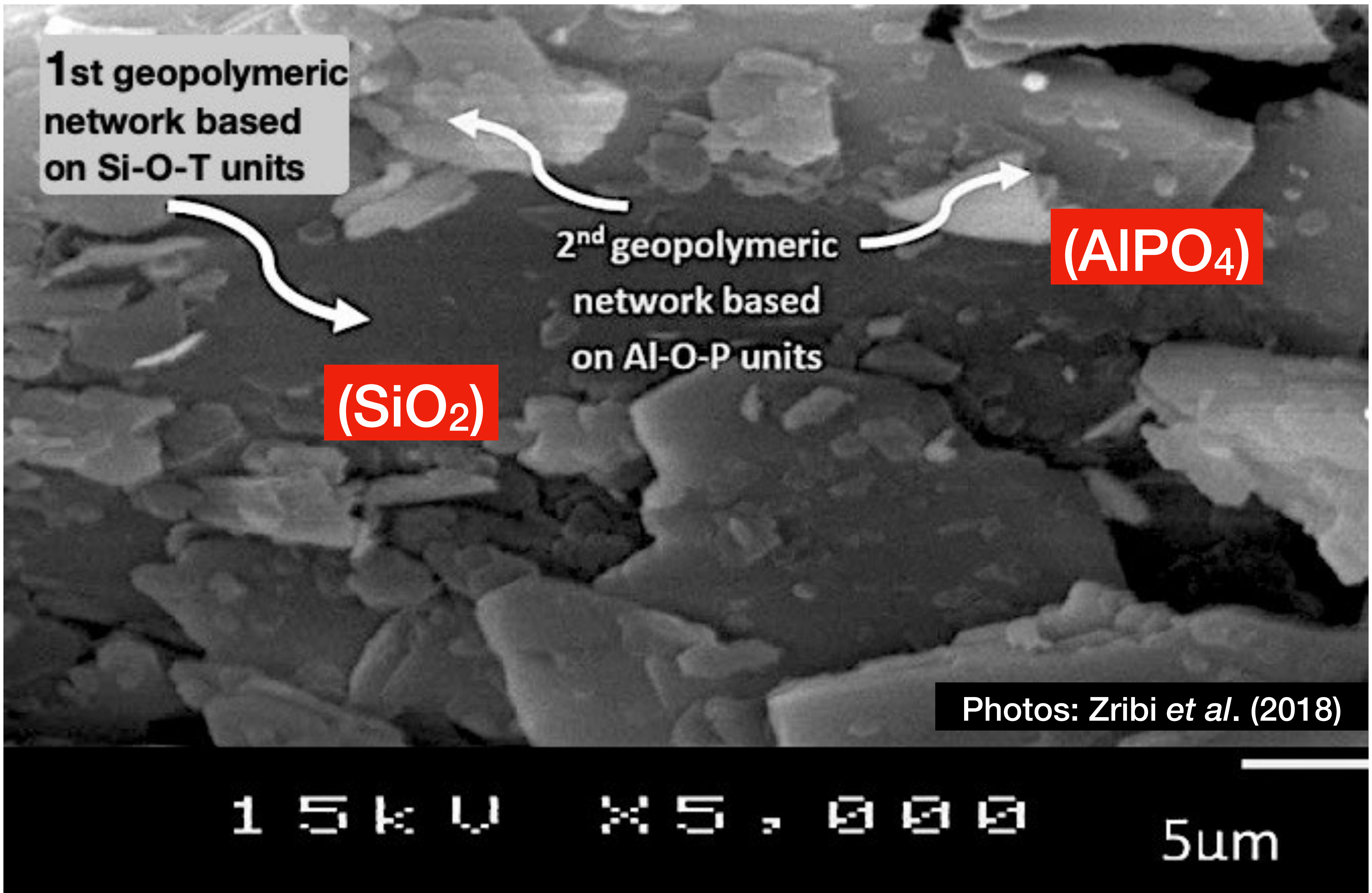
organic acids-based



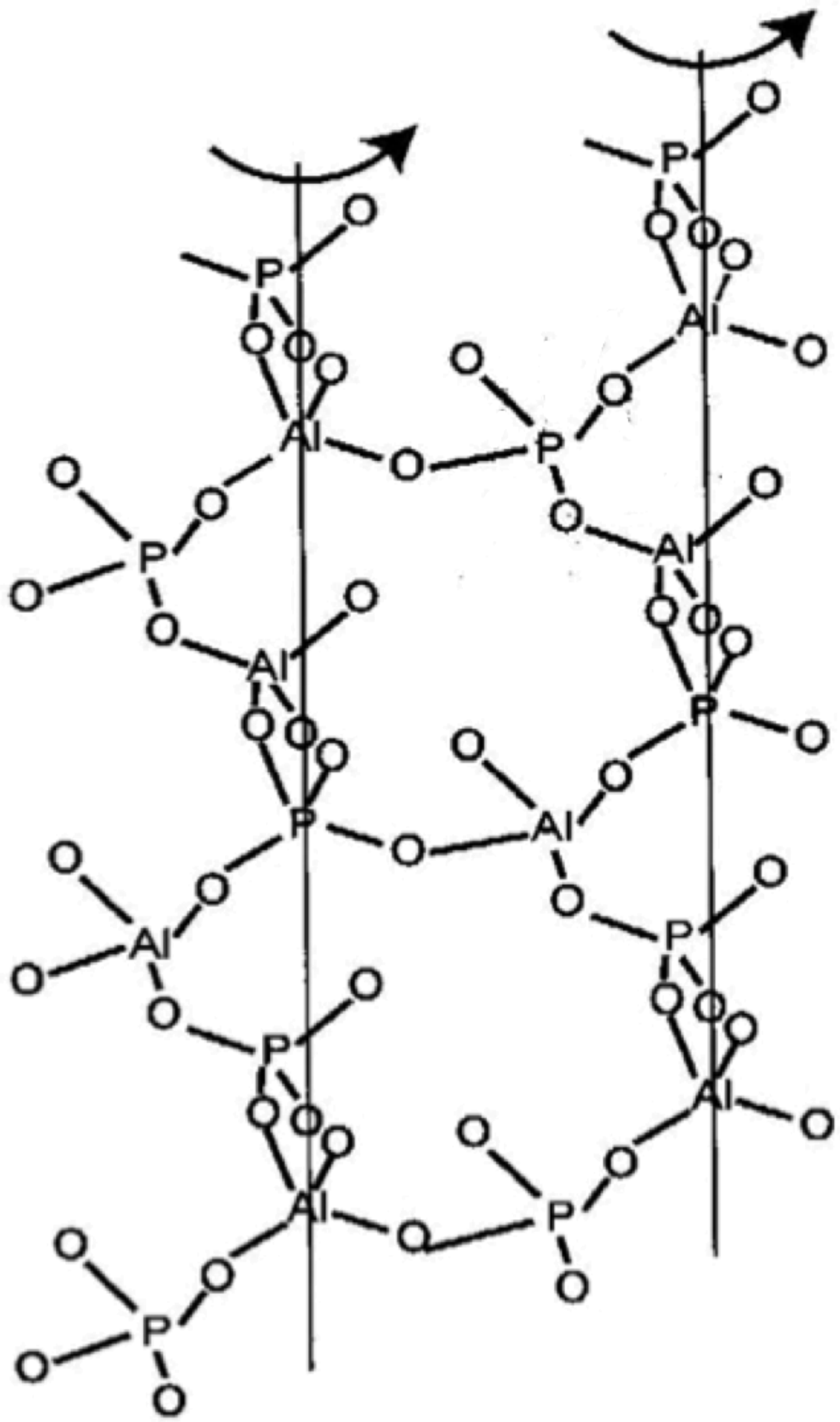
Chapter 14
Phosphate based-GP

Alumoxy-based Geopolymerization Al-O-X
Phosphoric acid + MK-750

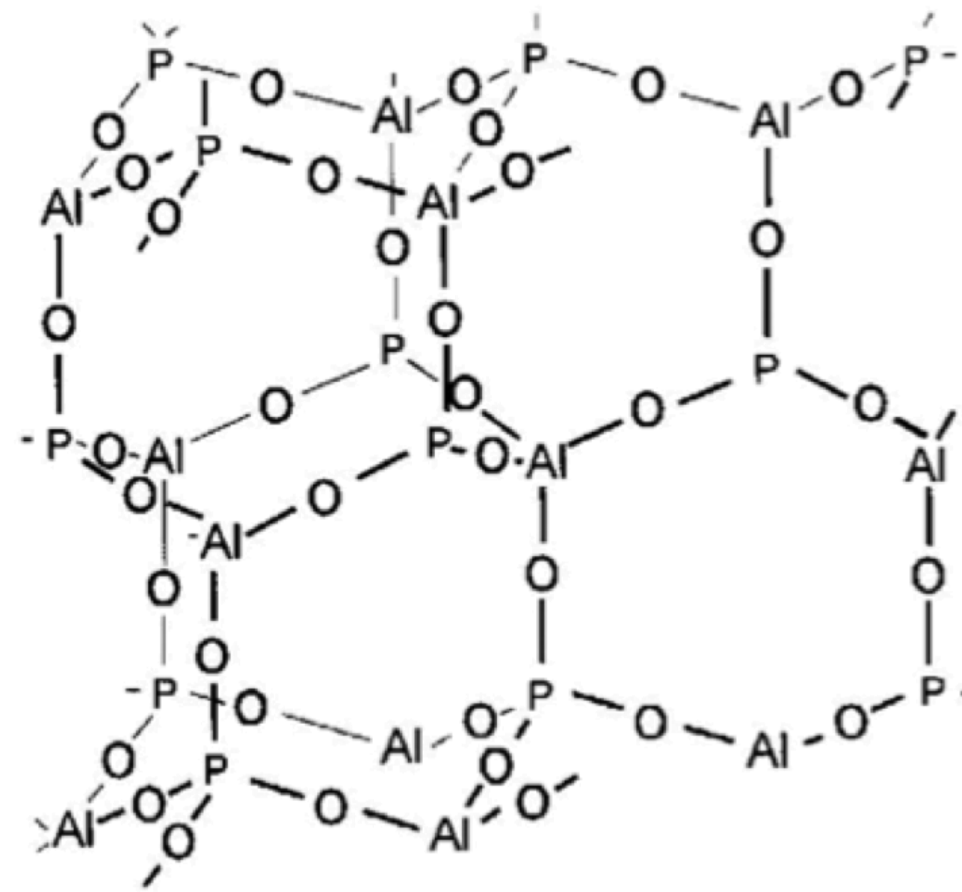
$$H_3PO_4 + Si_2O_5AlO_2 \longrightarrow (SiO_2)_n + (AlPO_4)_n$$



Polymeric structures of AlPO4-Geopolymers



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



$AlPO_4$-tridymite/cristobalite

$AlPO_4$-berlinite (isostructural to quartz)

Alumoxy-based Geopolymerization Al-O-X organic acids-based

We believe we have now found the principles of the *alumoxy-based geopolymerization Al-O-X*.

They are no longer alkaline-based (Na,K)Si-O-Al (Na,K)-sialate. It was not easy because we had to take a new approach.

But thanks to the perseverance of my son, Ralph Davidovits, we succeeded.

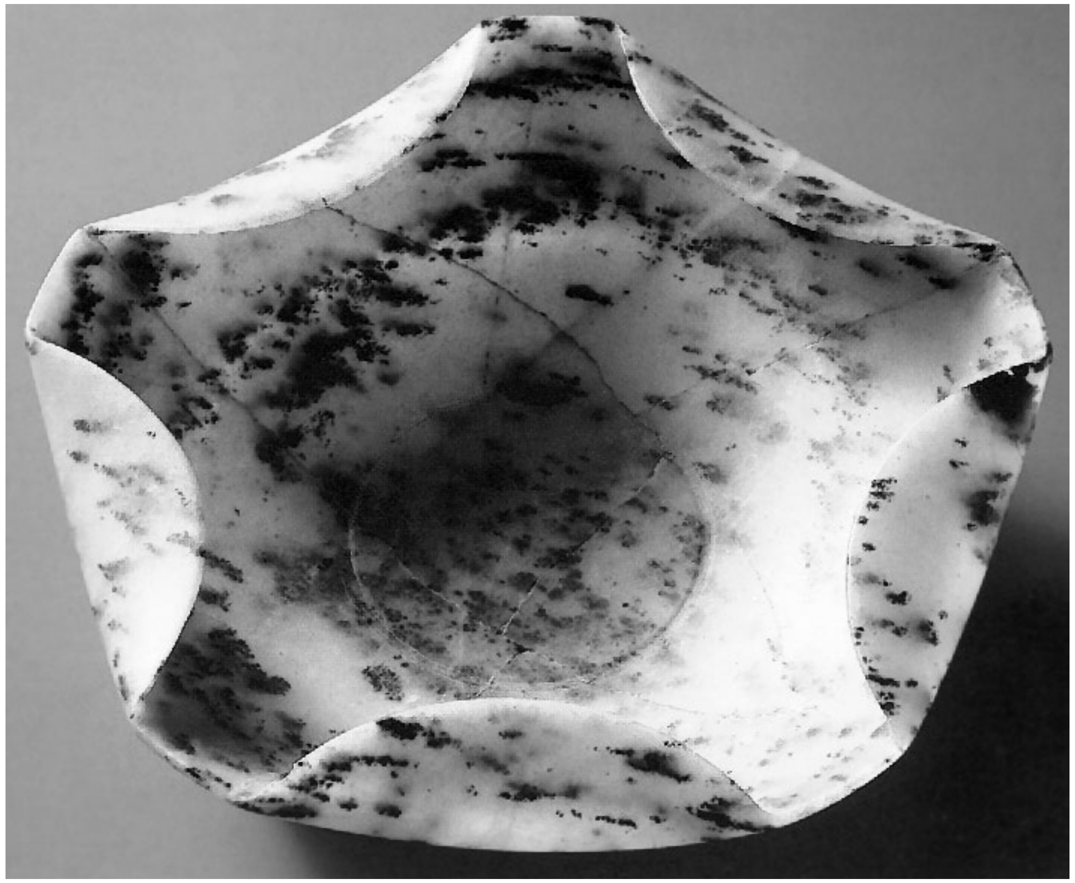
One of our breakthroughs is the ability to replicate famous ancient artifacts such as the ancient hard stone vases from the early dynasties (2500 BC) in Egypt.

Alumoxy-based Geopolymerization Al-O-X organic acids-based

These vases are thought to have been made from geological hard stones. An impossible carving task indeed.

We believe that these ancient artefacts were made using artificial stones.

I have always maintained that these vases were made of a moldable stone paste, similar to clay and ceramics.



Berkeley, Phoebe Hearst M. (USA)

Boston, Museum of Fine Arts (USA)

Alumoxy-based Geopolymerization
organic acids-based

Indeed they were made using a method very similar to that developed at Tiwanaku/Pumapunku in Bolivia, South America for the andesite volcanic monuments.

See the articles and videos at the Geopolymer Institute web-site, at :

www.geopolymer.org/archaeology/

Book : "*Ancient Geopolymers in South America and Easter Island*" is planned for Nov. 2024, by Springer-Nature.

State of the Geopolymer R&D 2024

GEOPOLYMER CAMP 2024

Joseph Davidovits