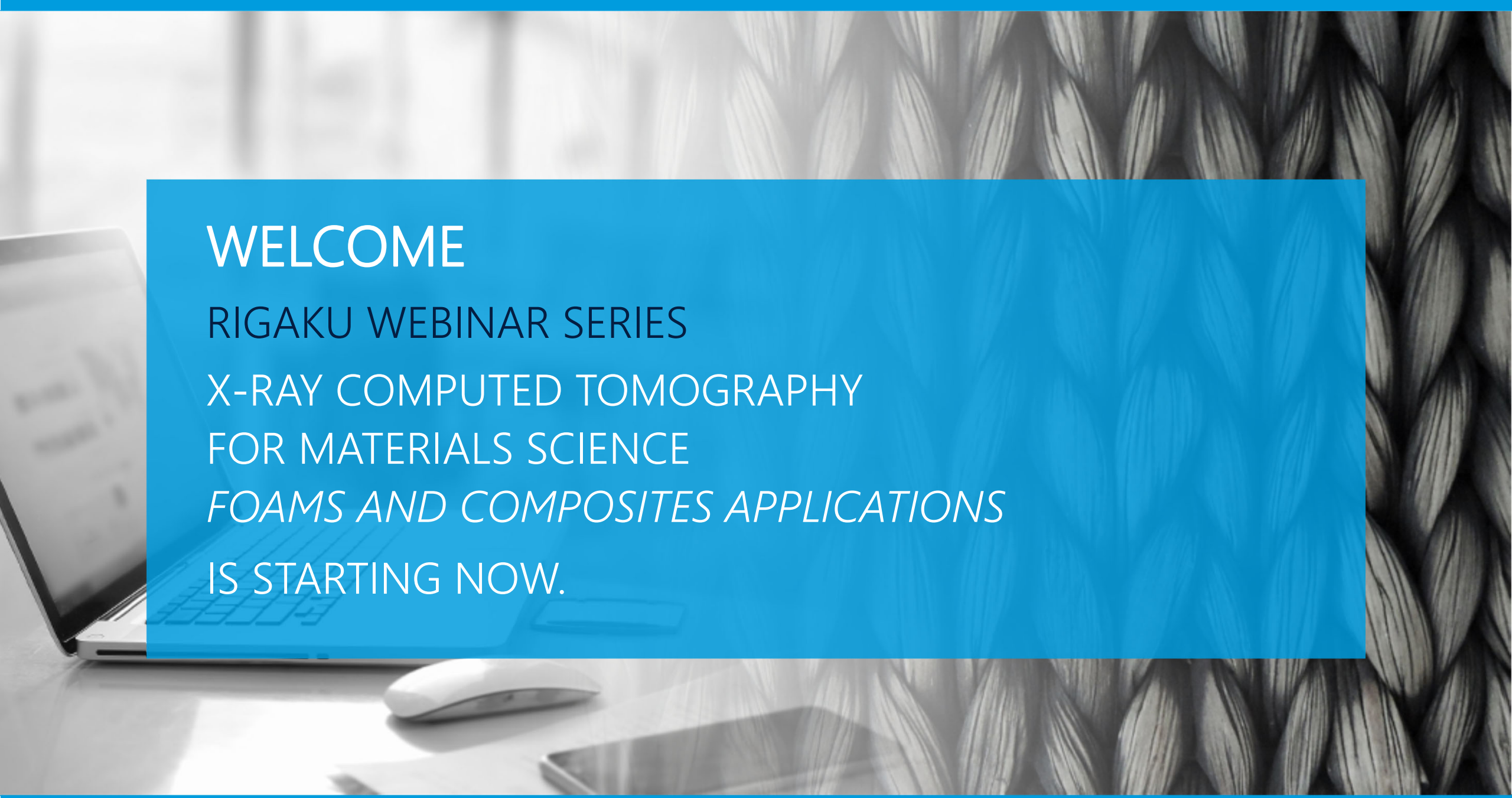


WELCOME

RIGAKU WEBINAR SERIES

X-RAY COMPUTED TOMOGRAPHY FOR MATERIALS SCIENCE

FOAMS AND COMPOSITES APPLICATIONS

IS STARTING NOW.

Presenter: Aya Takase

Senior Scientist
Rigaku Americas Corporation

Host: Tom McNulty

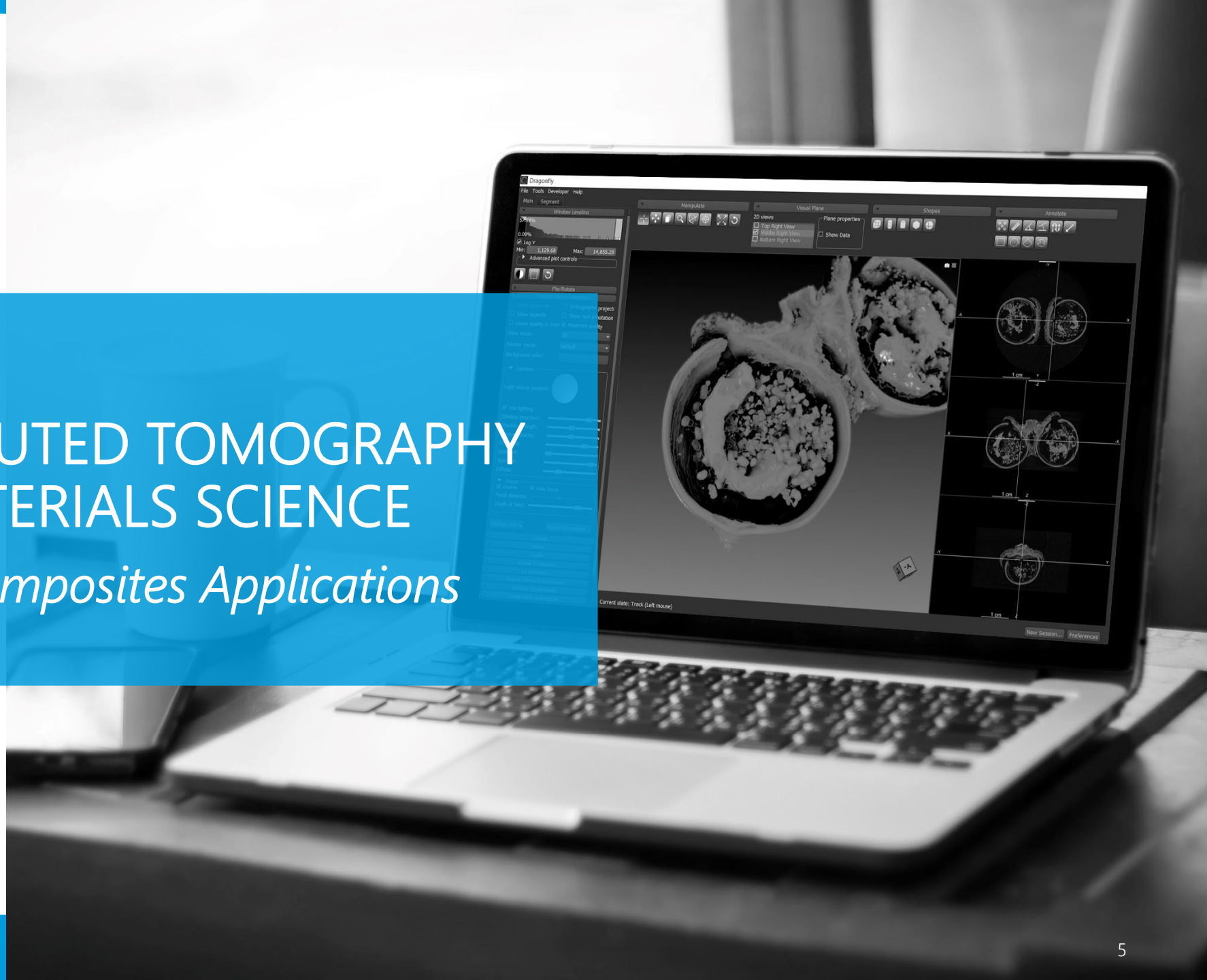
Senior Vice President
Rigaku Americas Corporation

You can send us questions during the presentation.
They will be addressed at the end of the presentation.

A recording of this webinar will be available.
You will receive an email with a link to it tomorrow.

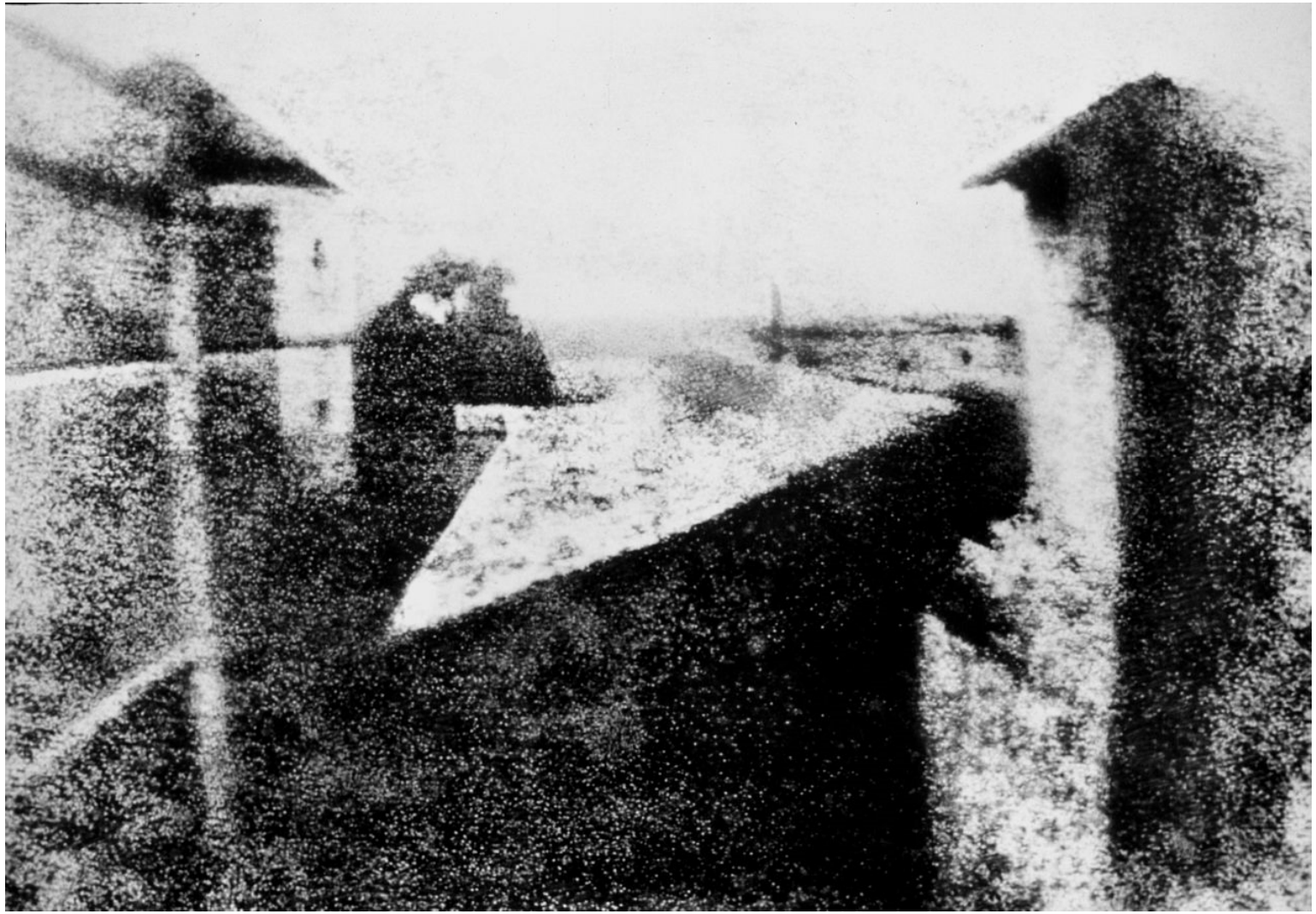
X-RAY COMPUTED TOMOGRAPHY FOR MATERIALS SCIENCE

Foams and Composites Applications

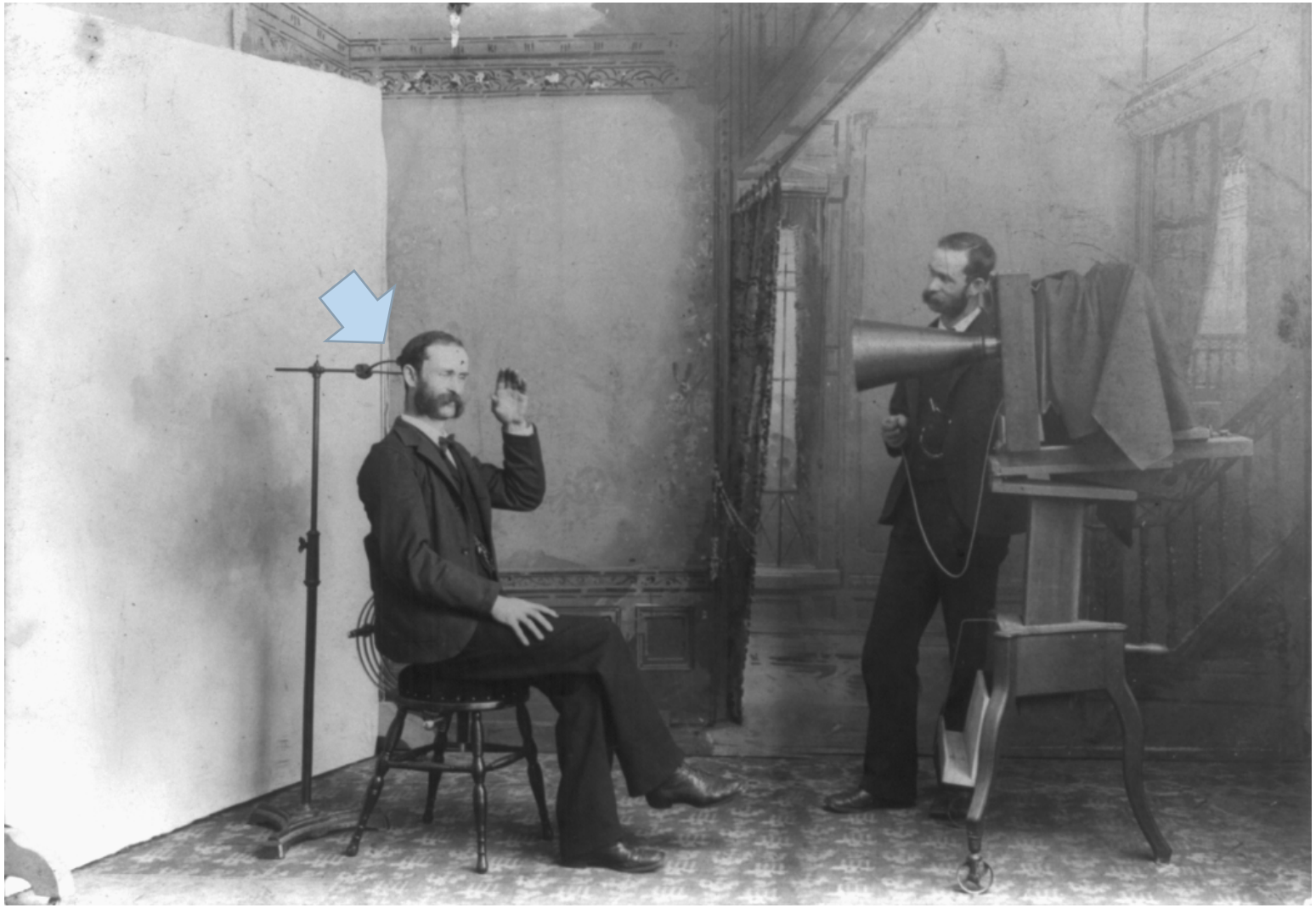


1826

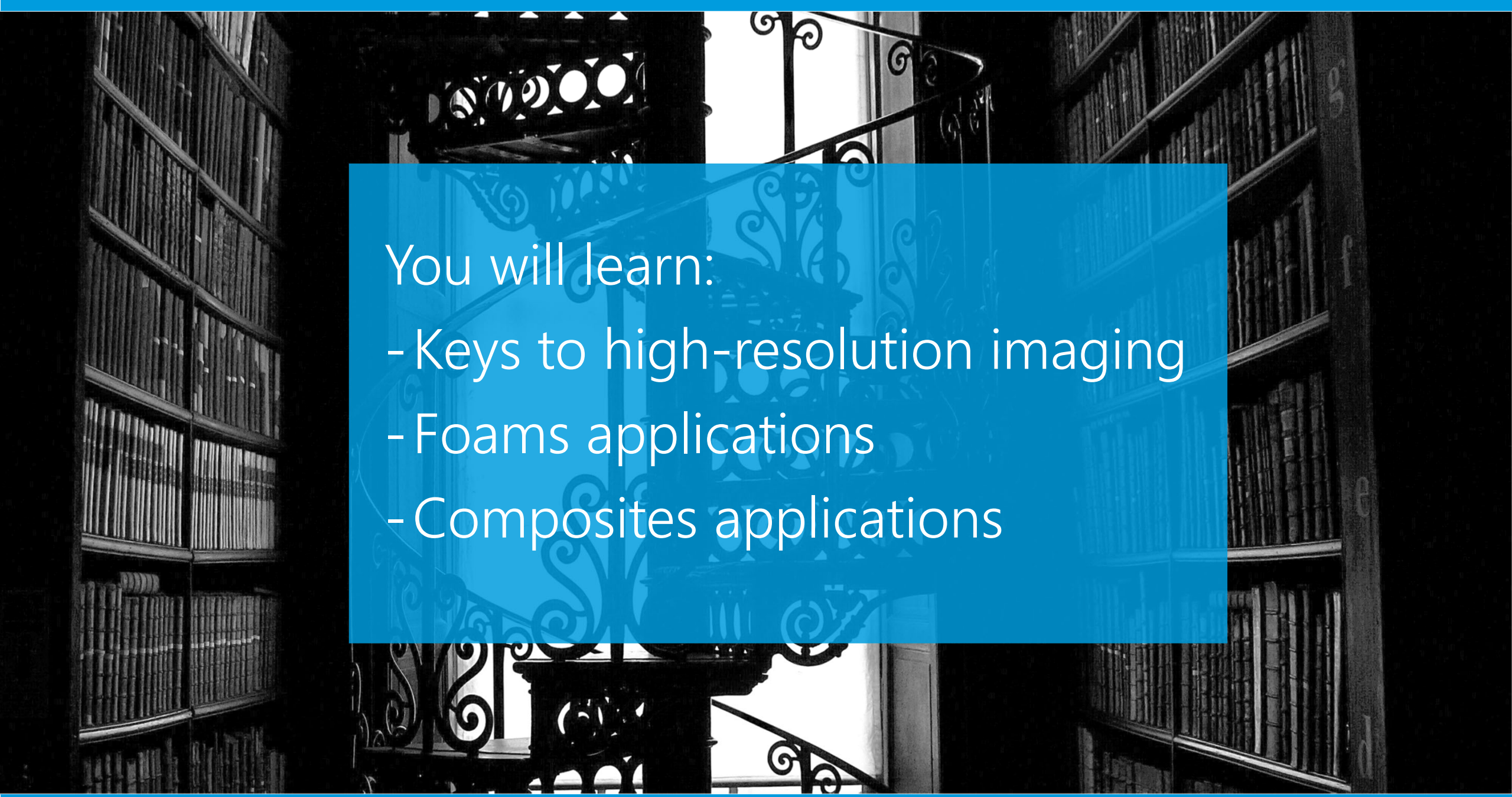
1827



Wikimedia Commons: “View from the Window at Le Gras” Joseph Nicéphore Niépce



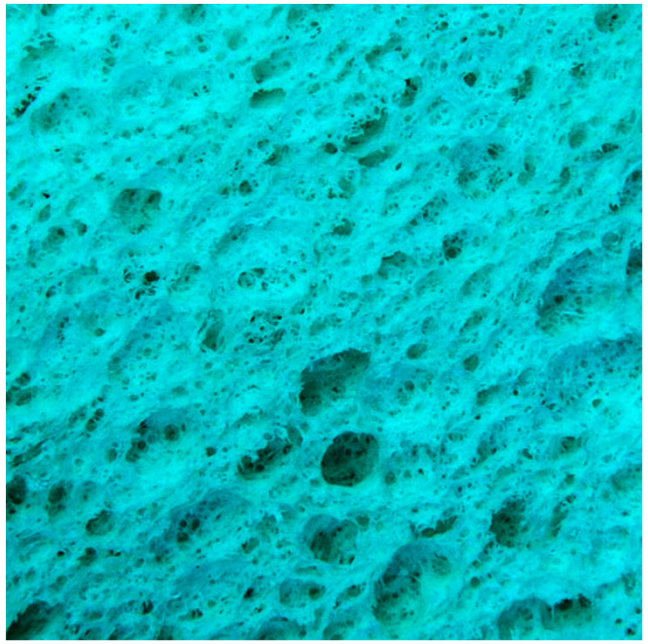
Library of Congress Prints and Photographs Division - digital ID cph.3a20638



You will learn:

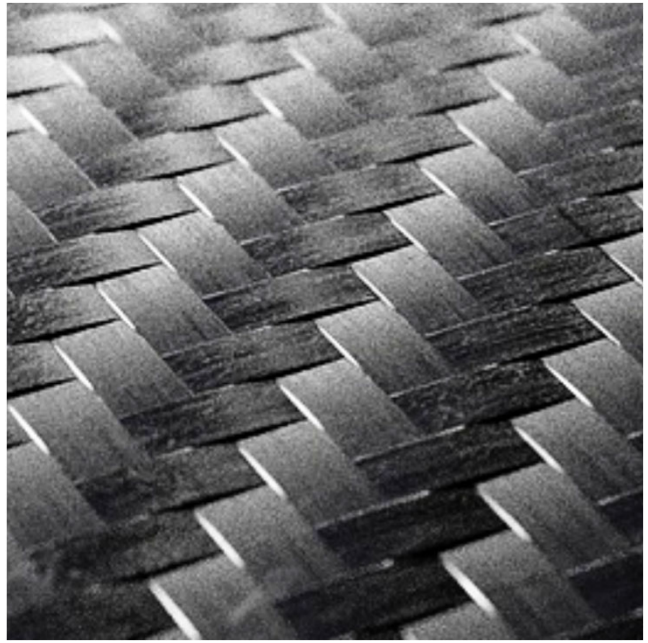
- Keys to high-resolution imaging
- Foams applications
- Composites applications

WHY HIGH RESOLUTION?



Foam cell size
~ microns – millimeters

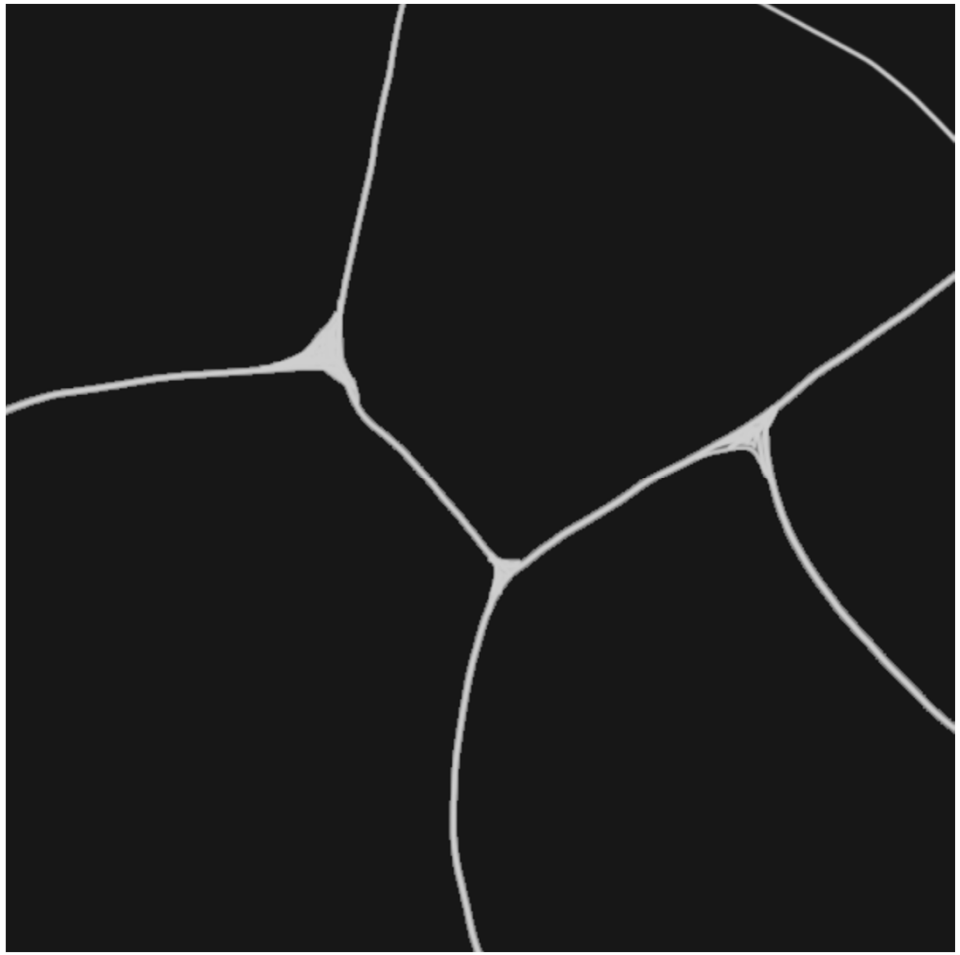
Fiber diameter
~ 5 – 30 microns

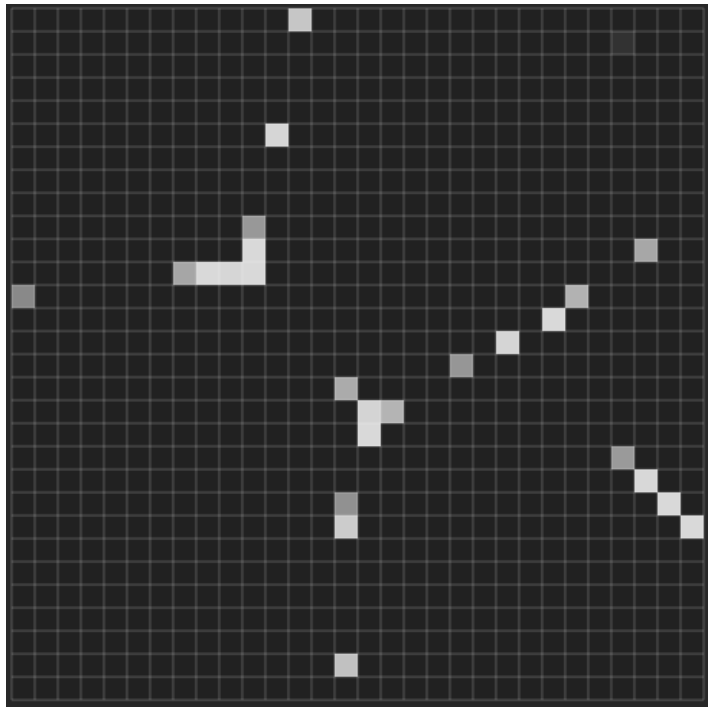


Optimize X-ray energy

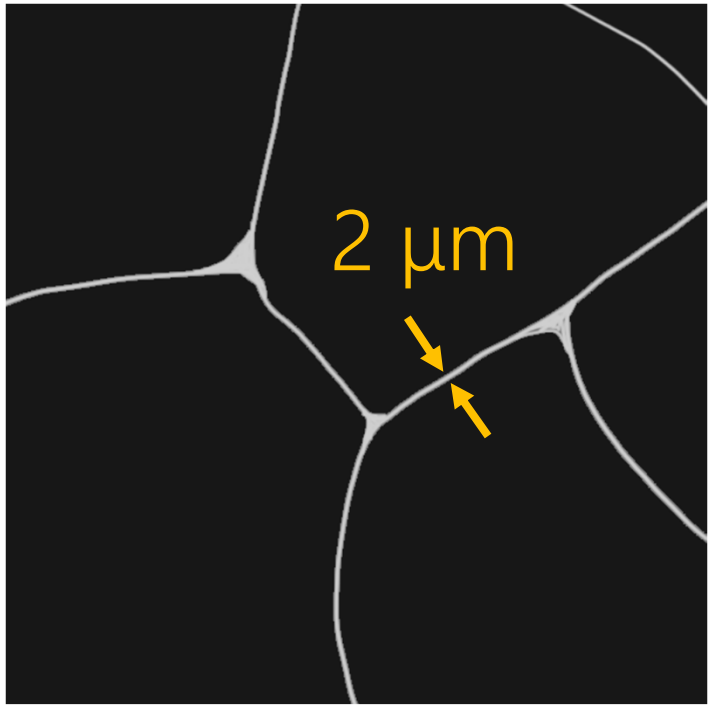
Optimize resolution

WHAT RESOLUTION IS HIGH ENOUGH?





Large voxel

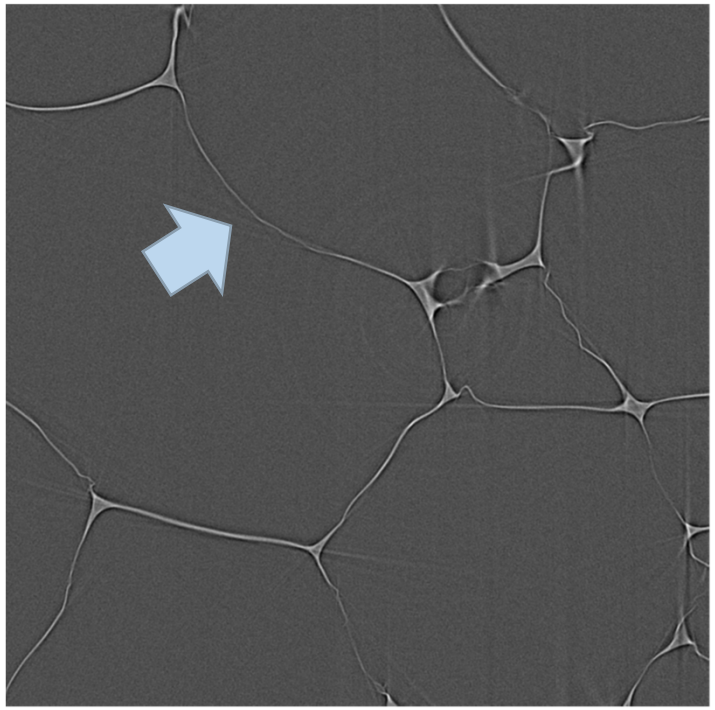


Small voxel

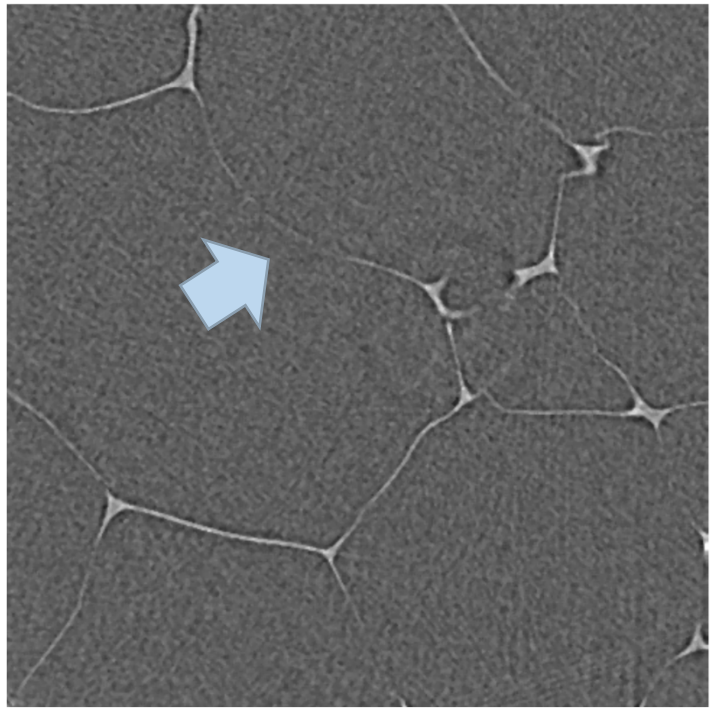
t = 2 µm

Voxel < 1 µm

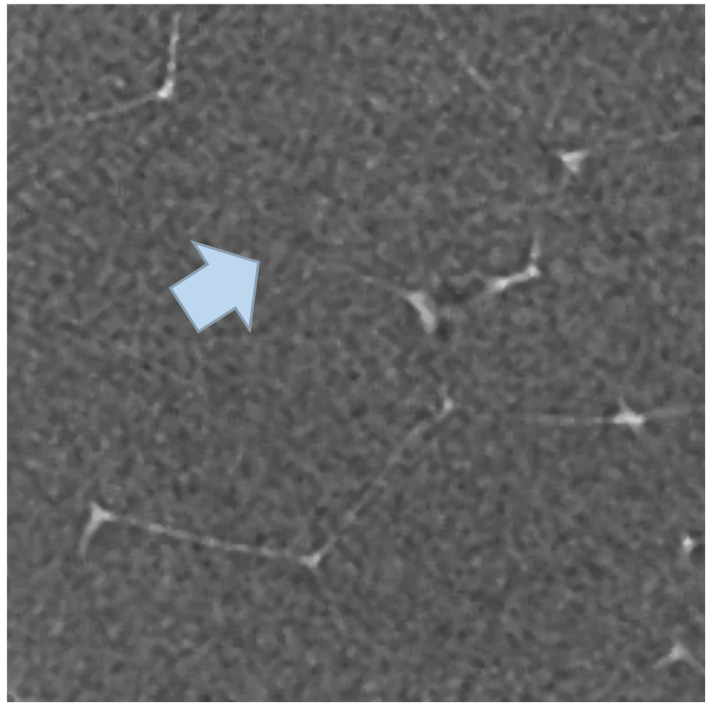
0.26 µm

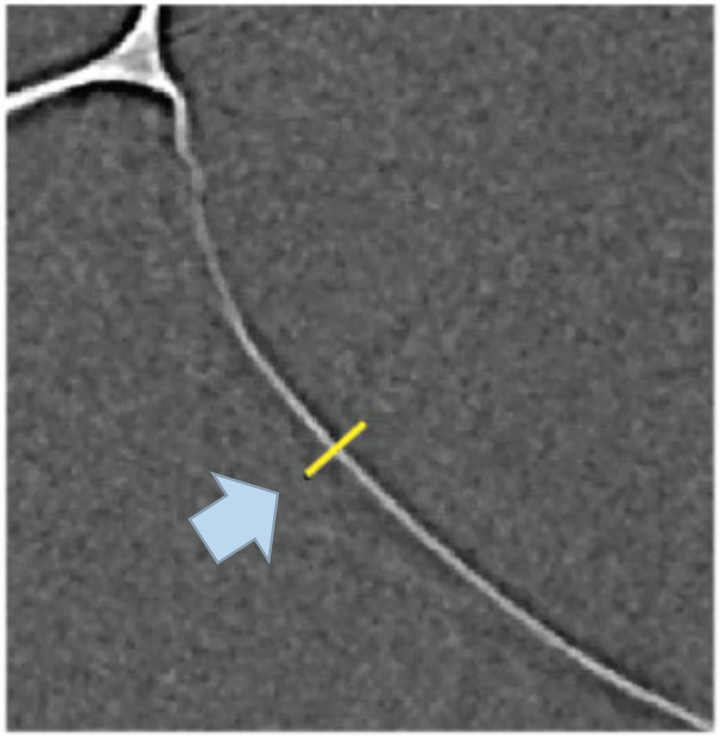


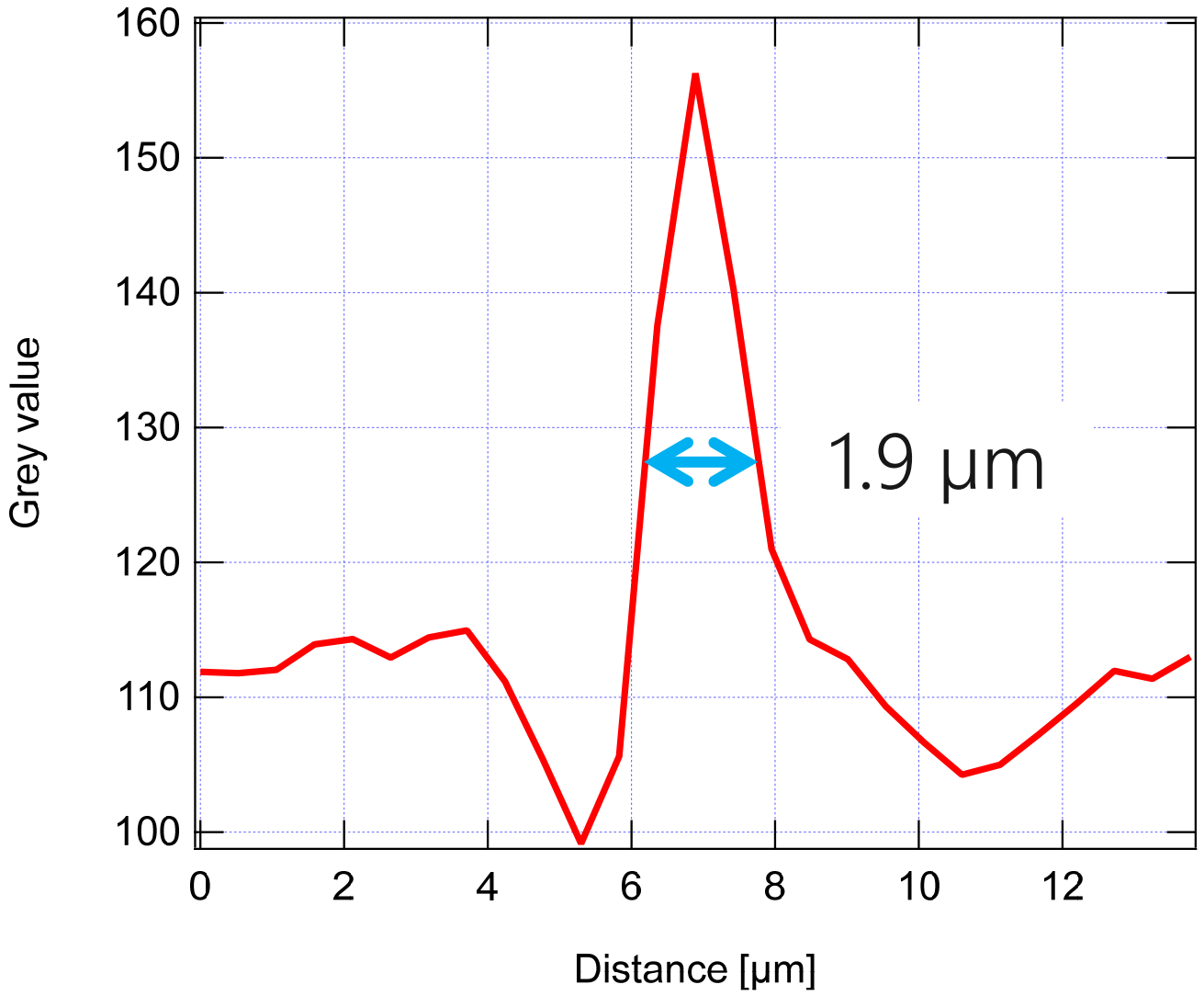
1.06 µm



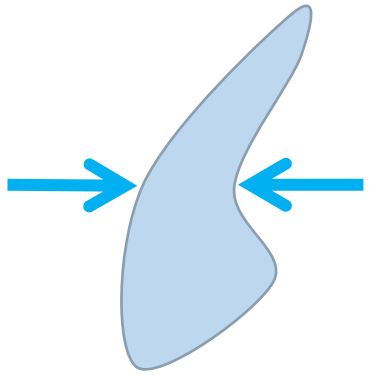
2.12 µm





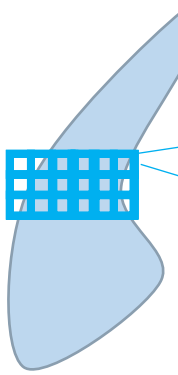

160
150
140
130
120
110
100
Grey value
0
2
4
6
8
10
12
Distance [µm]
1.9 µm

Feature size



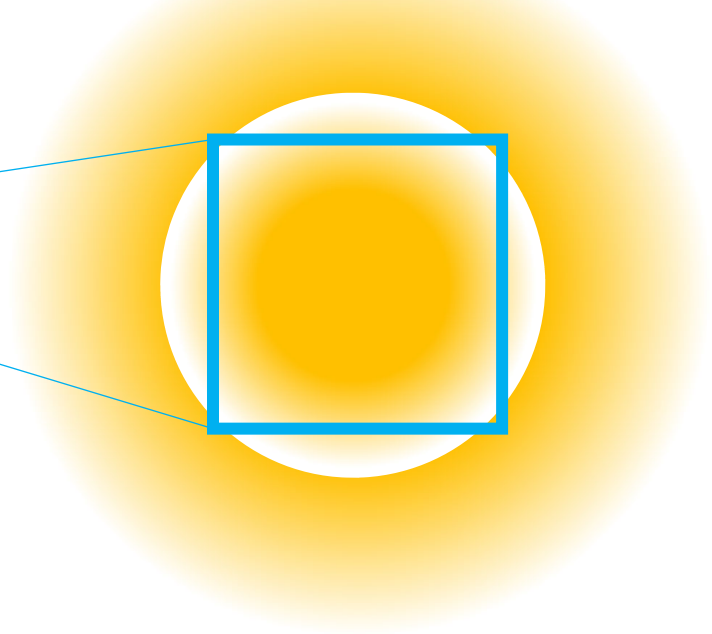
5 µm

Voxel size



0.5 ~ 2.5 µm

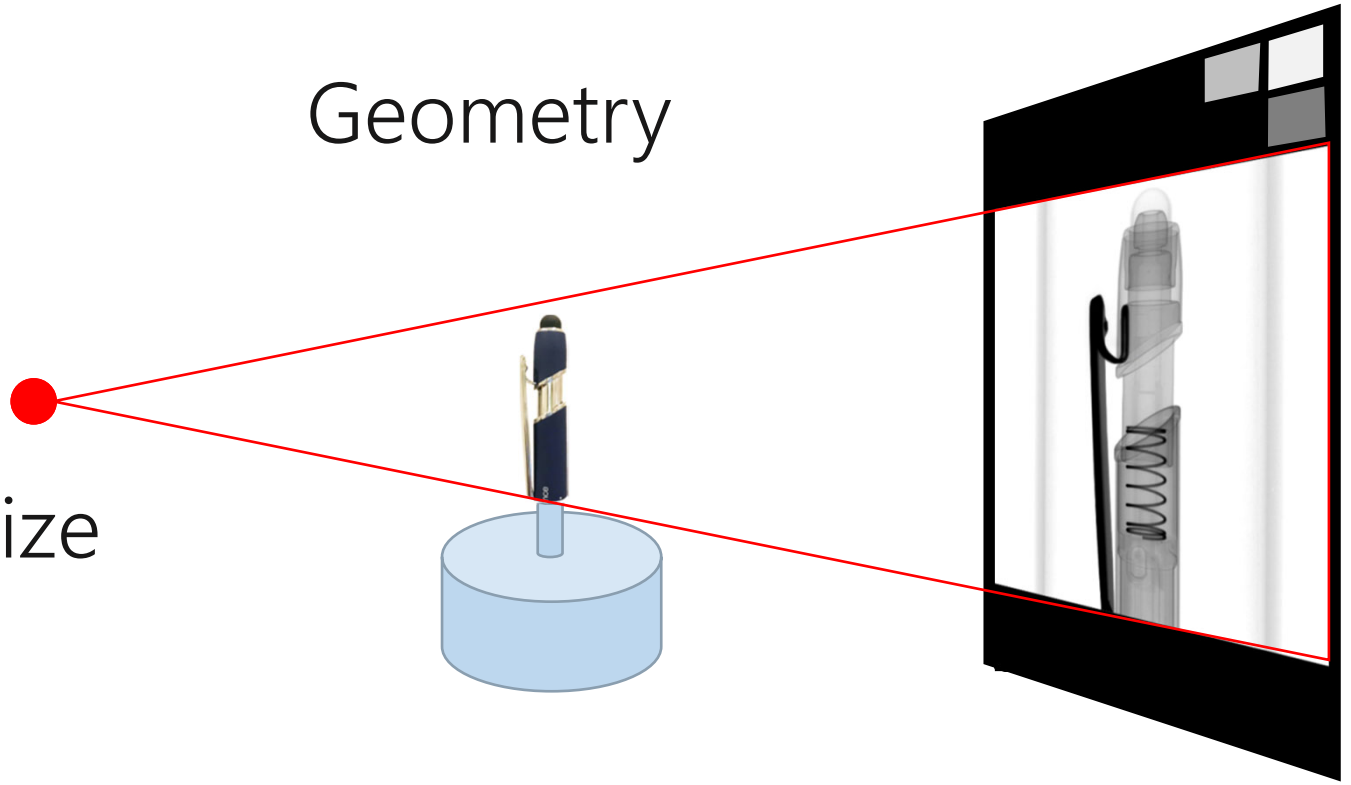
Resolution function



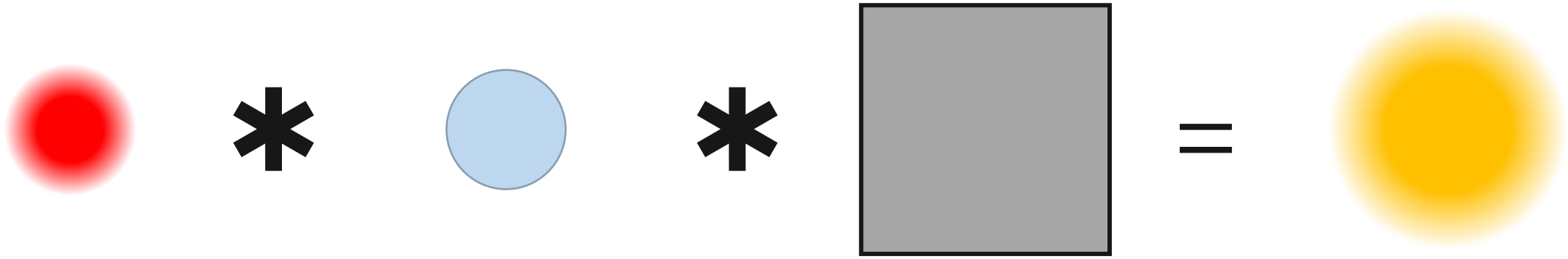
WHAT DETERMINES RESOLUTION FUNCTION?

Pixel size

Geometry



Focus size

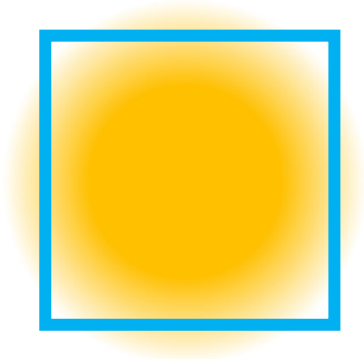


Focus size
Drifting

Defocus etc.

Pixel size

Resolution
function



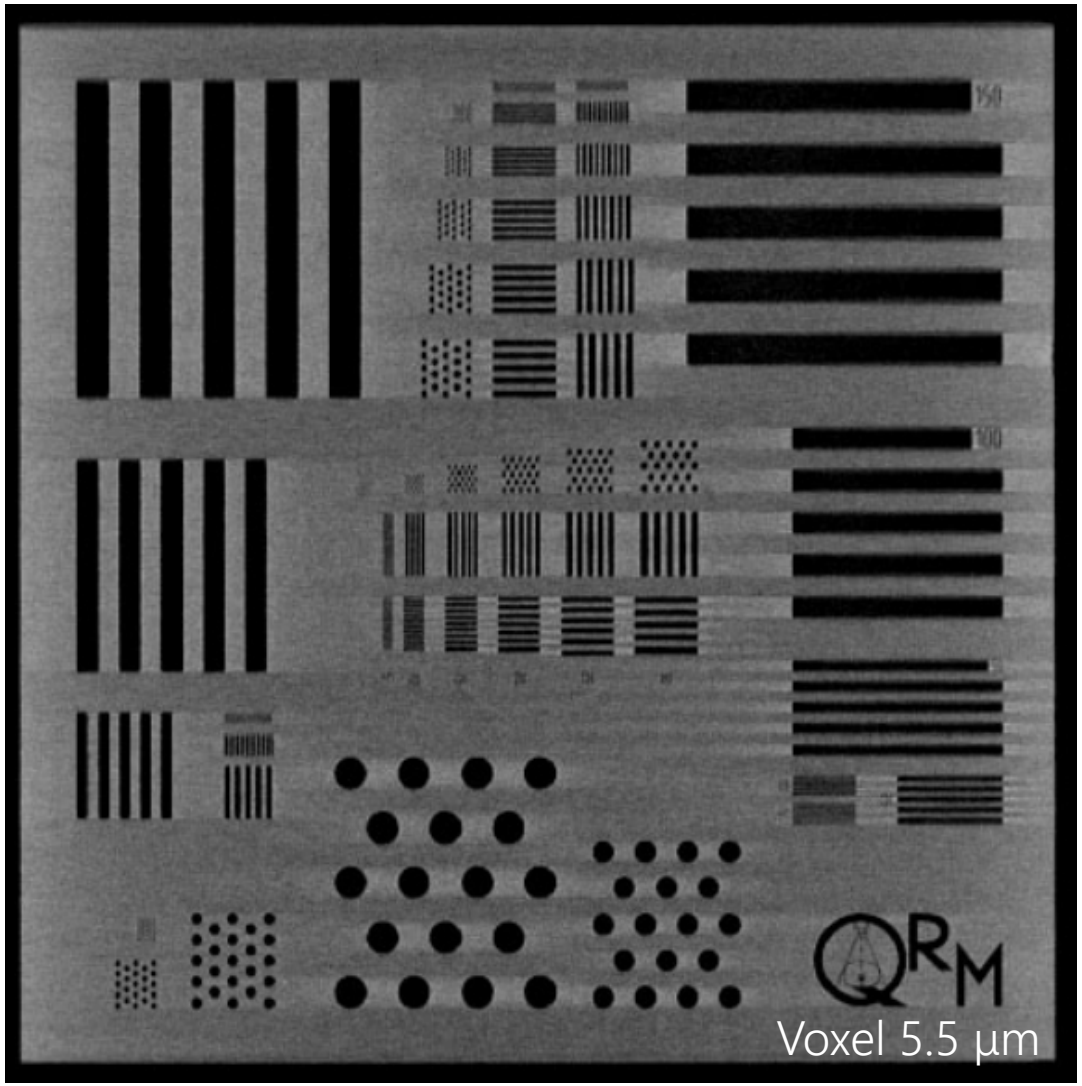
Spatial resolution

HOW DO YOU TEST RESOLUTION?

5 – 150 µm

QRM Micro-CT BarPattern Phantom

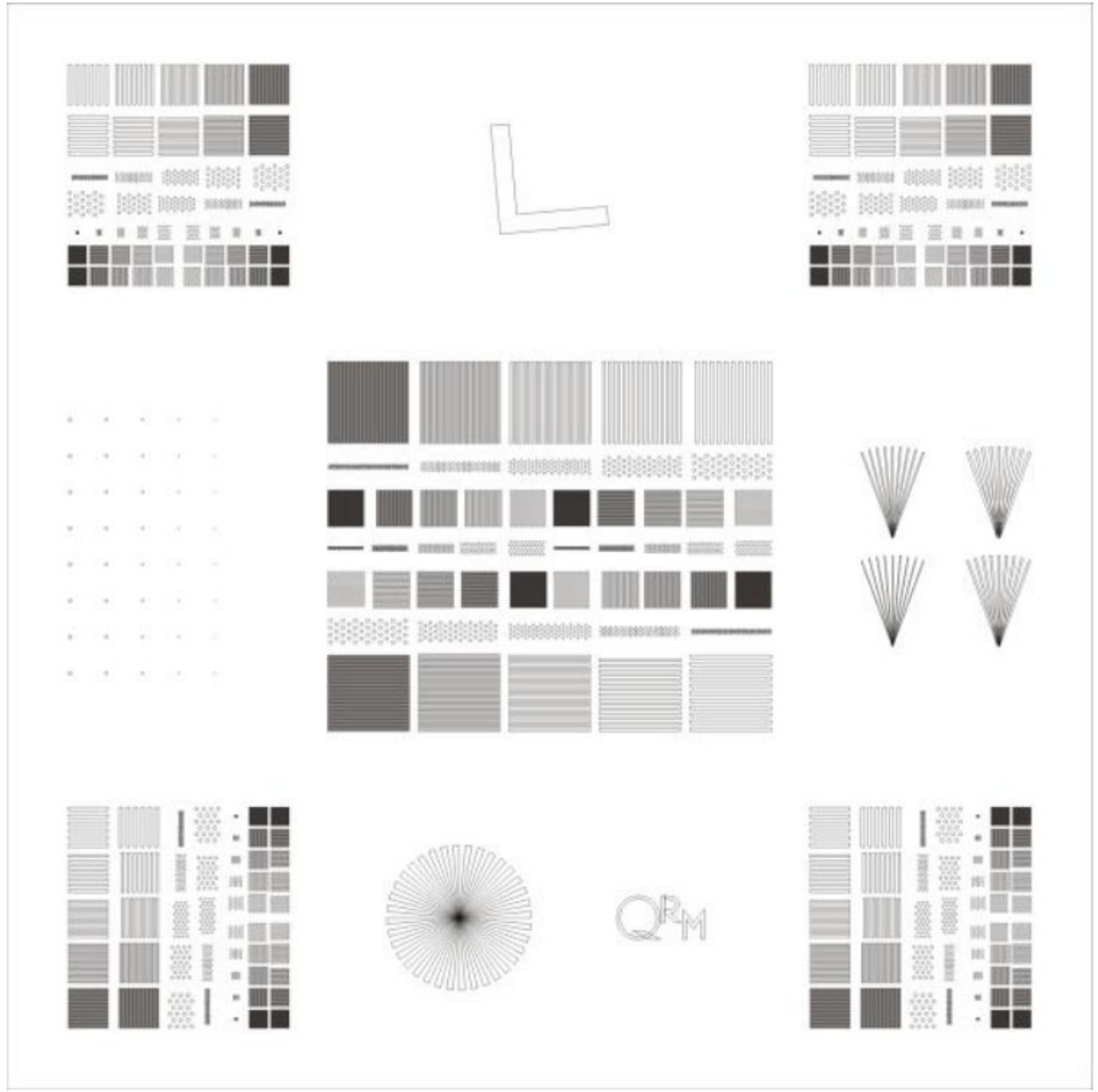
www.qrm.de

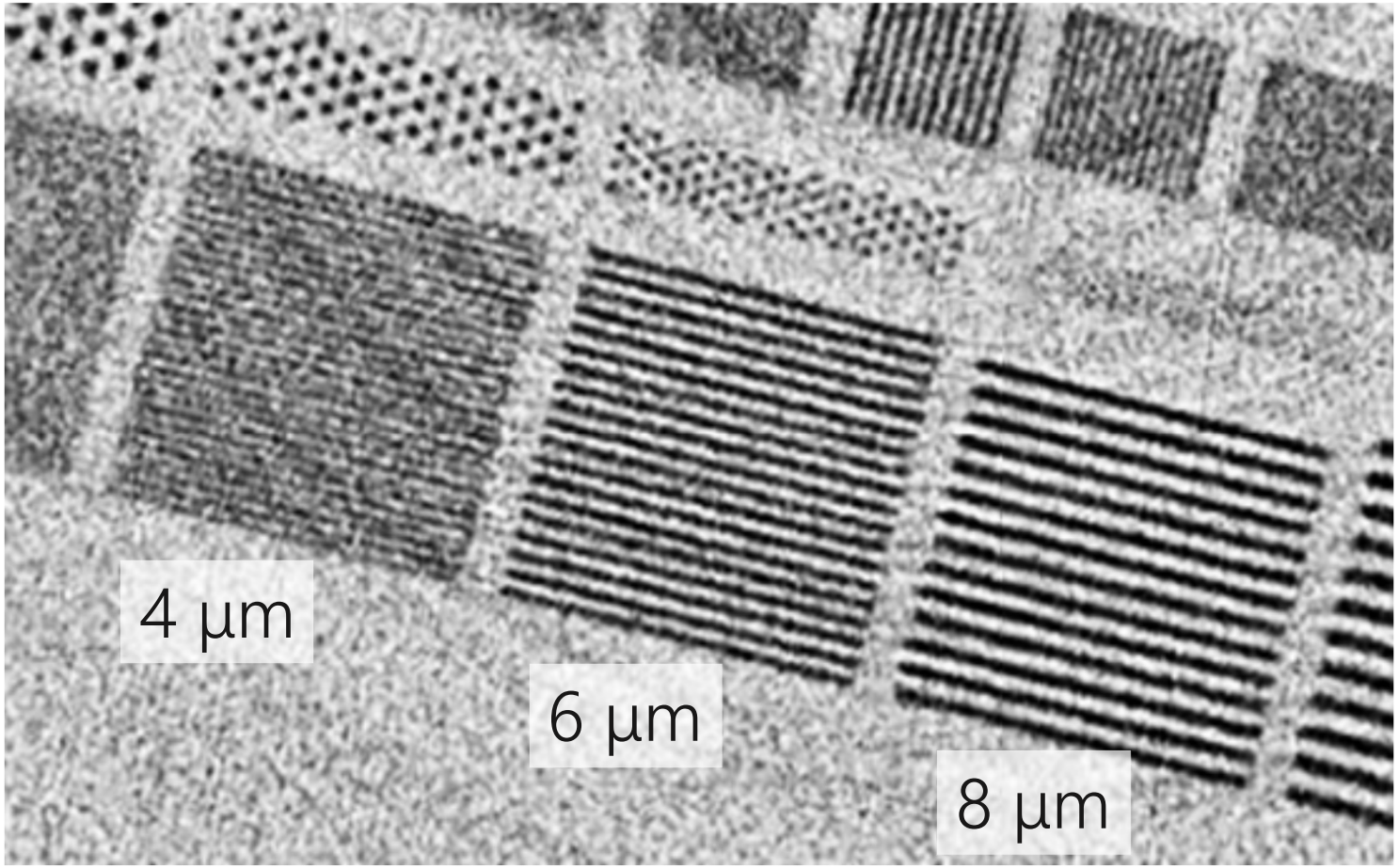


1 – 10 µm

QRM Micro-CT BarPattern NANO

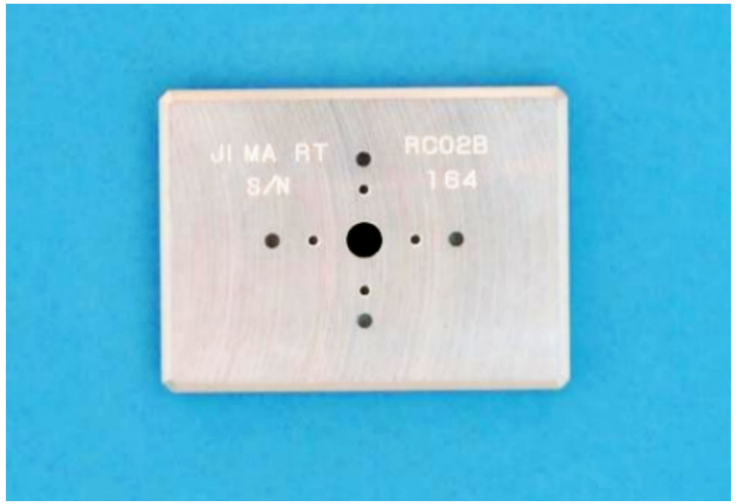
www.qrm.de



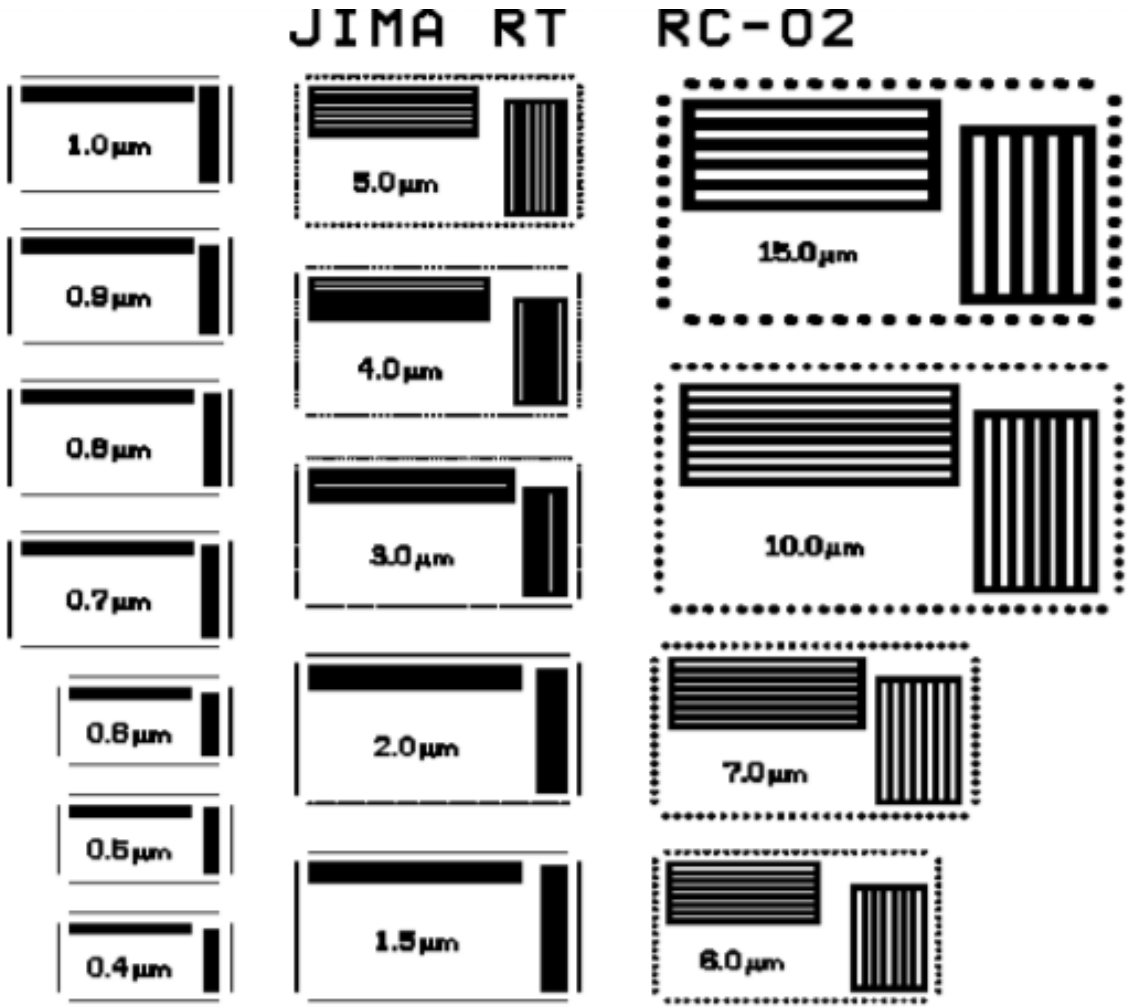


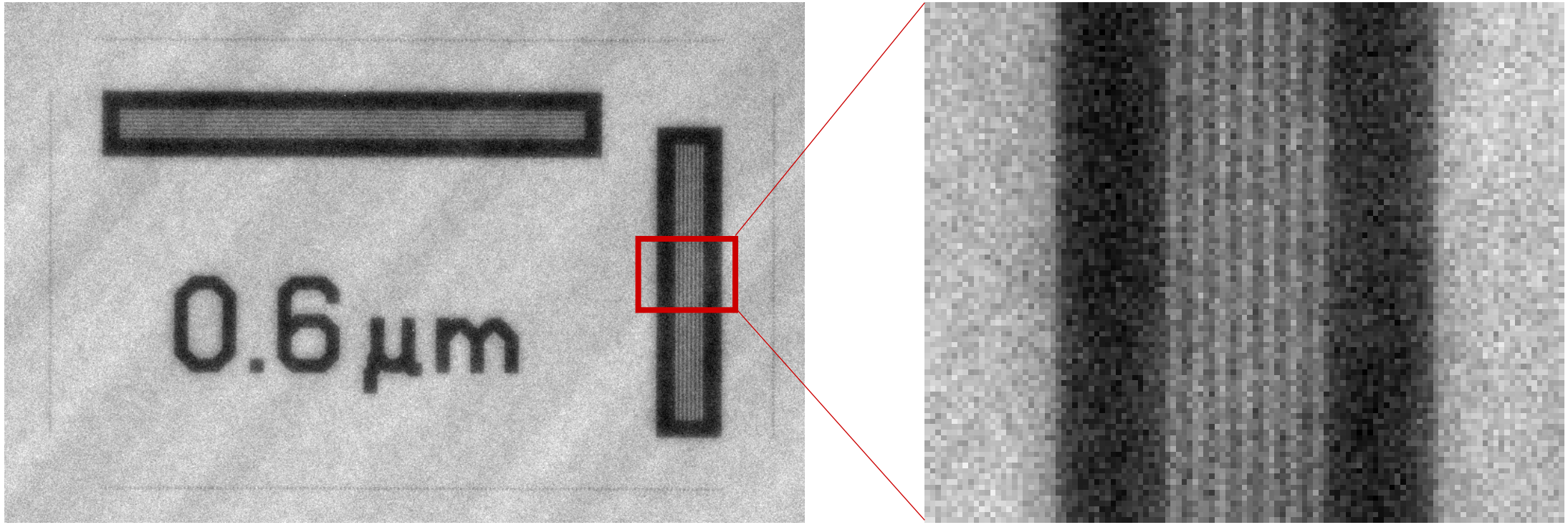
Voxel size 2.2 µm

0.1 – 15 µm (2D)



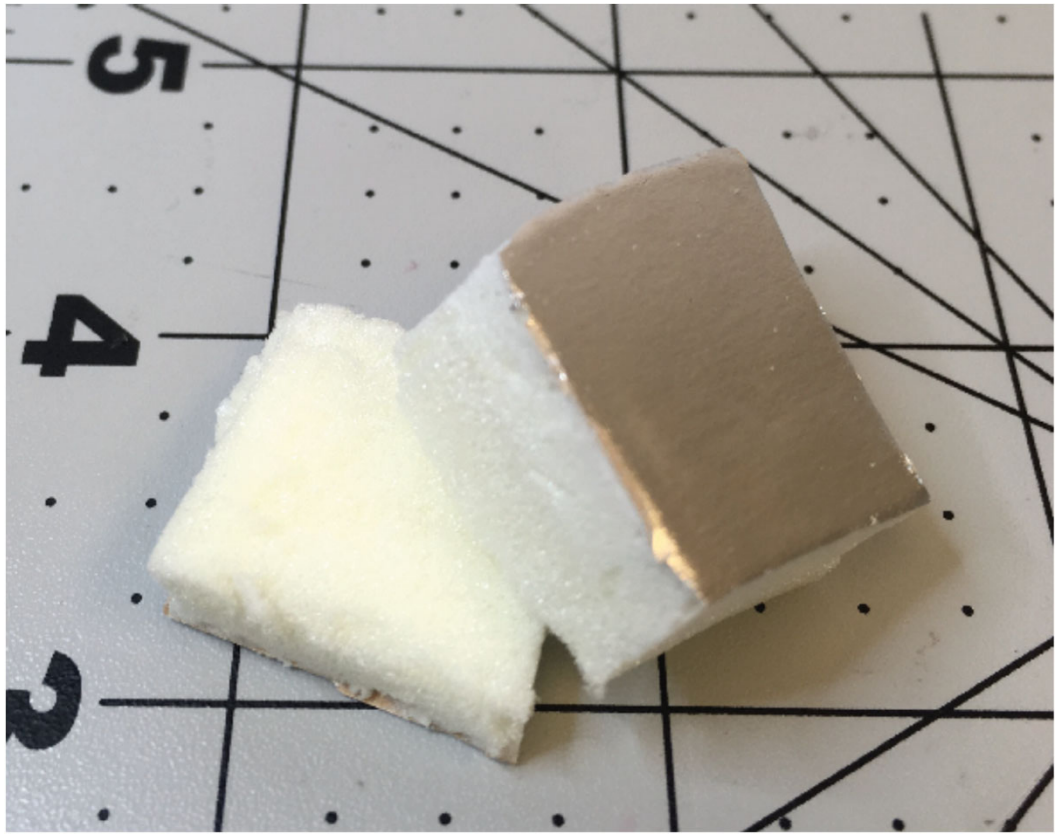
JIMA RT RC-02B
www.jima.jp



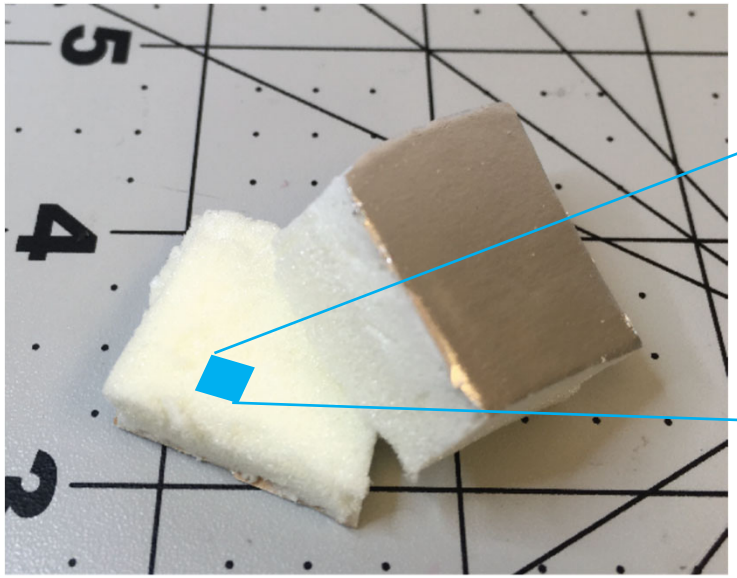


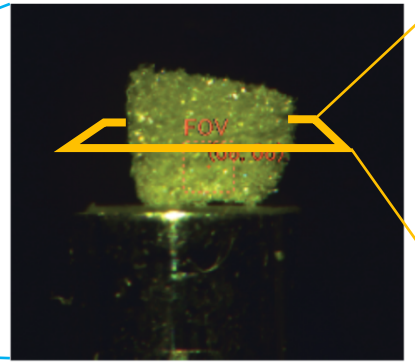
Voxel/pixel size 0.27 µm

HOW DOES THIS AFFECT ANALYSIS RESULTS?

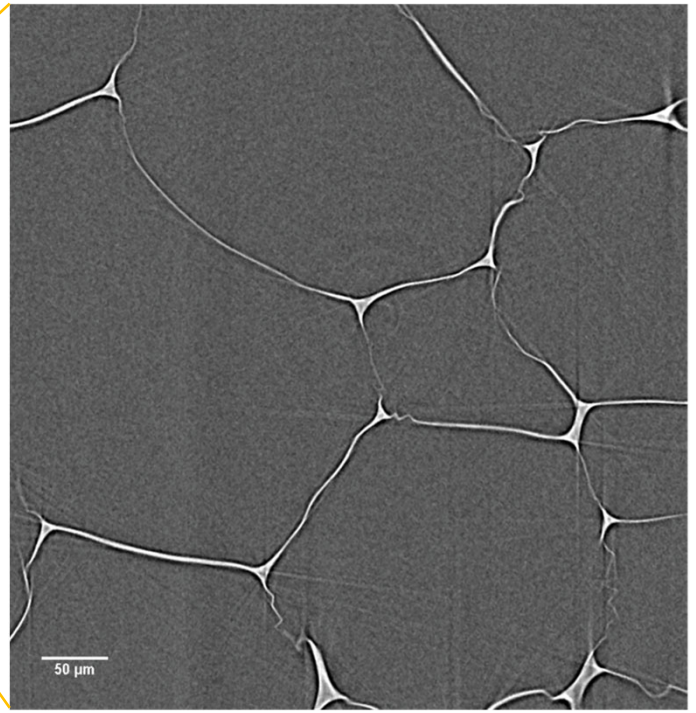


Porosity ?

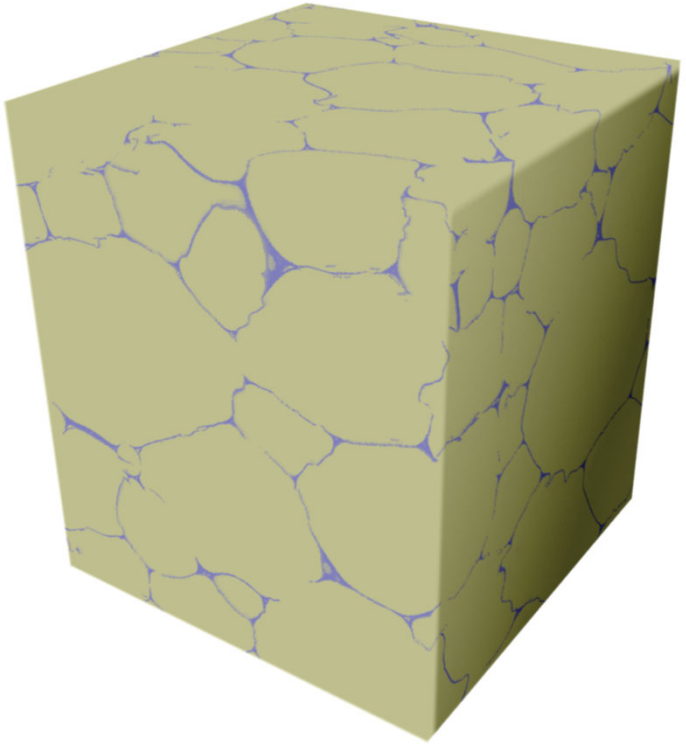




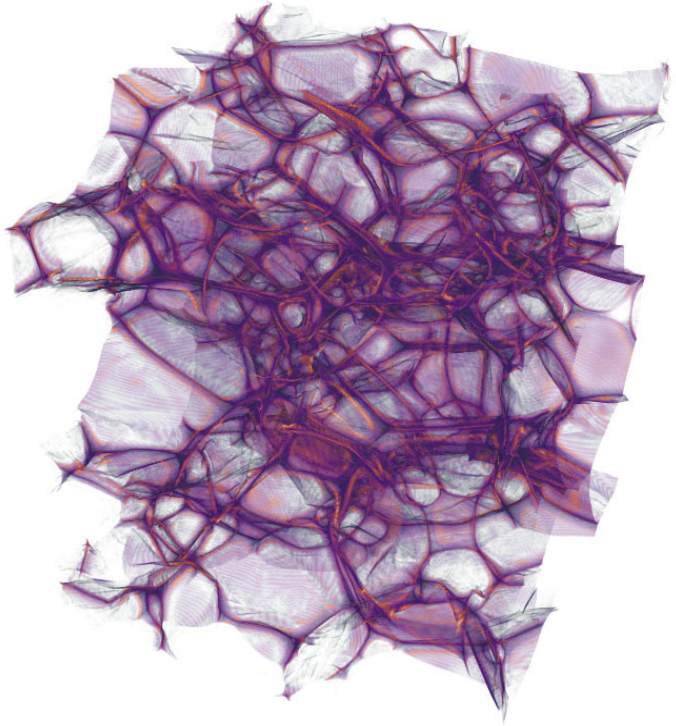
FOV ~ 0.7 mm cube



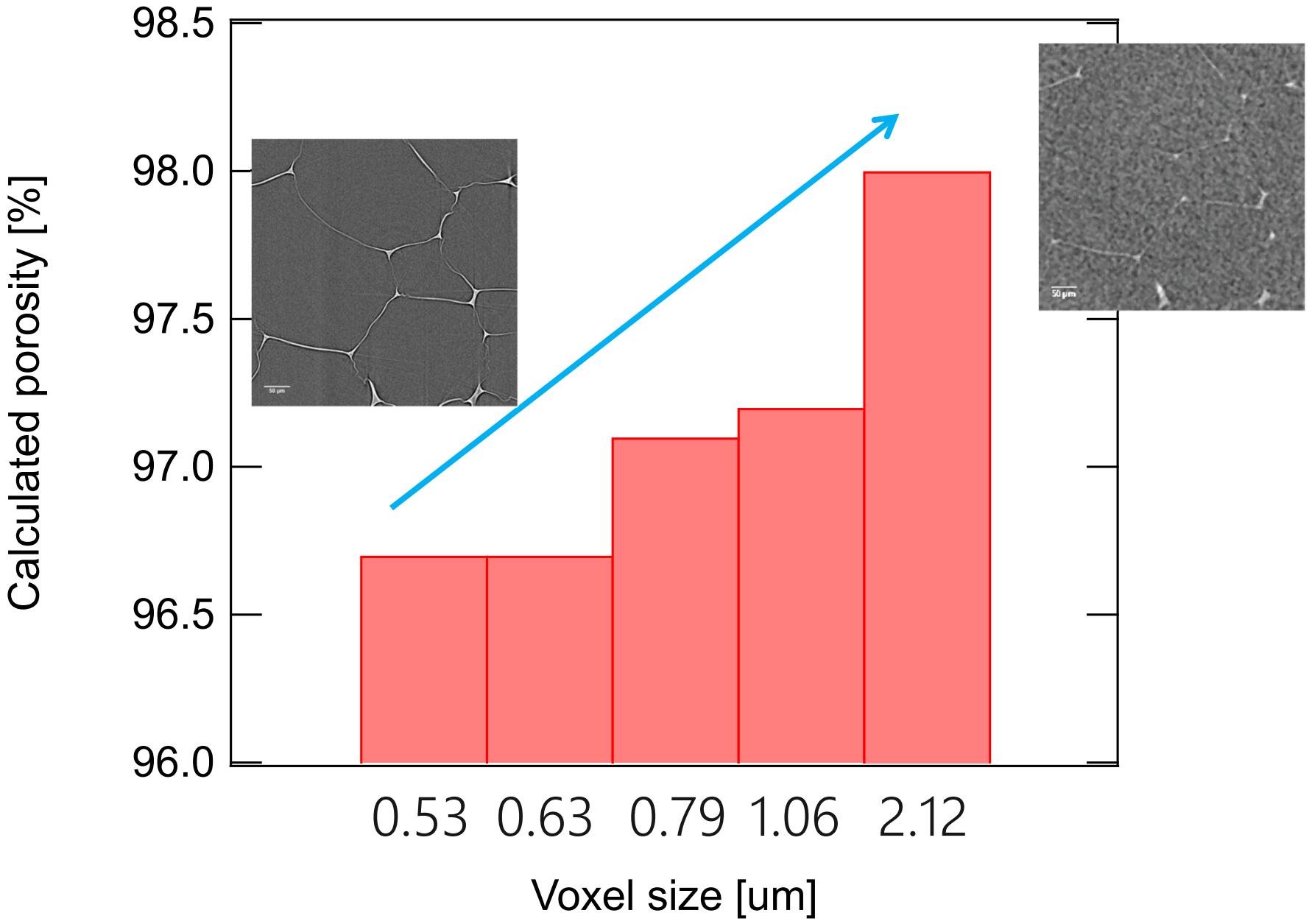
Pores/cells



Polymer



Porosity = 96.7 vol%


98.5
98.0
97.5
97.0
96.5
96.0
Calculated porosity [%]
0.53
0.63
0.79
1.06
2.12
Voxel size [um]

HOW DO YOU ACHIEVE HIGH RESOLUTION?

KEYS TO HR IMAGING

- Use high magnification factor
- Use parallel beam geometry

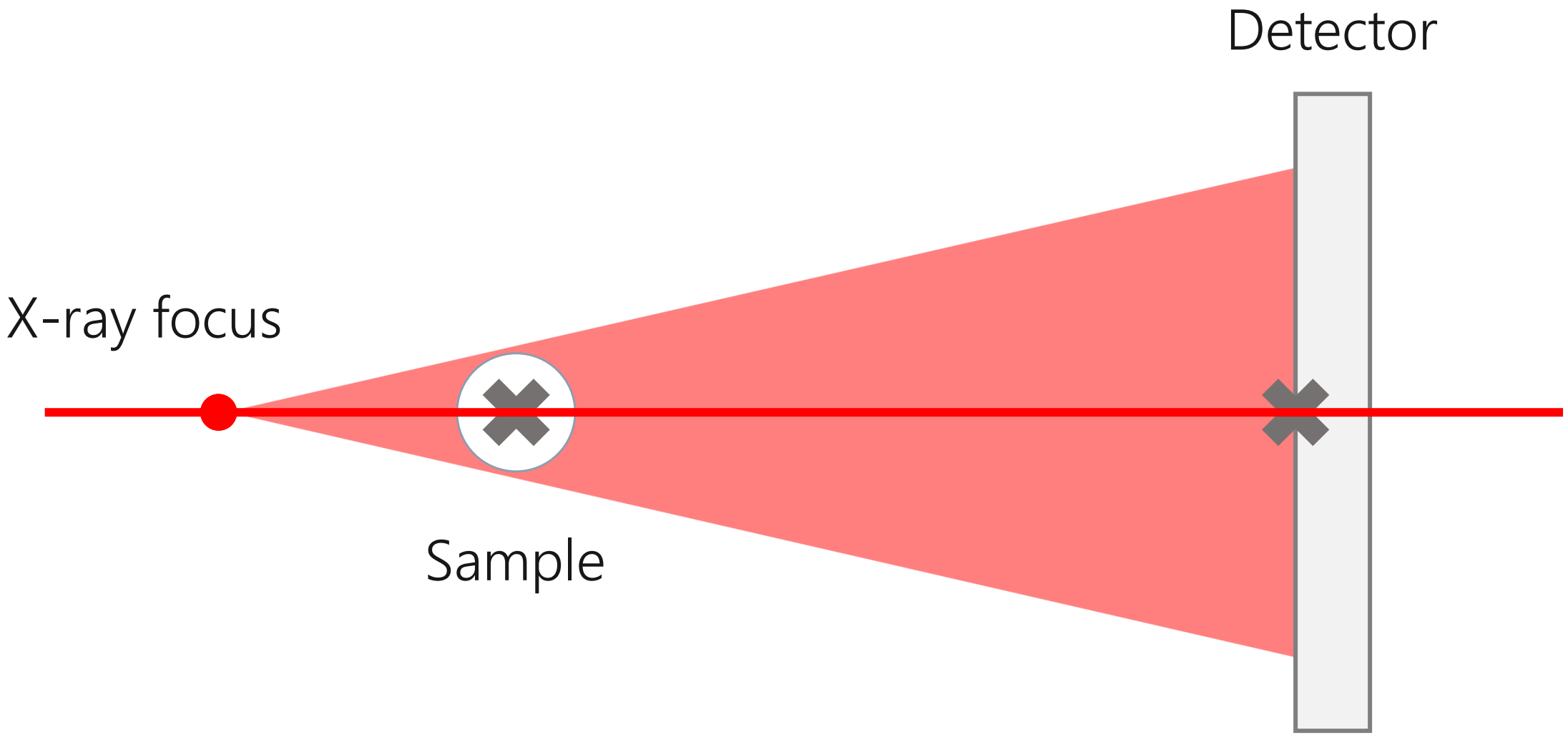
MORE KEYS TO HR IMAGING

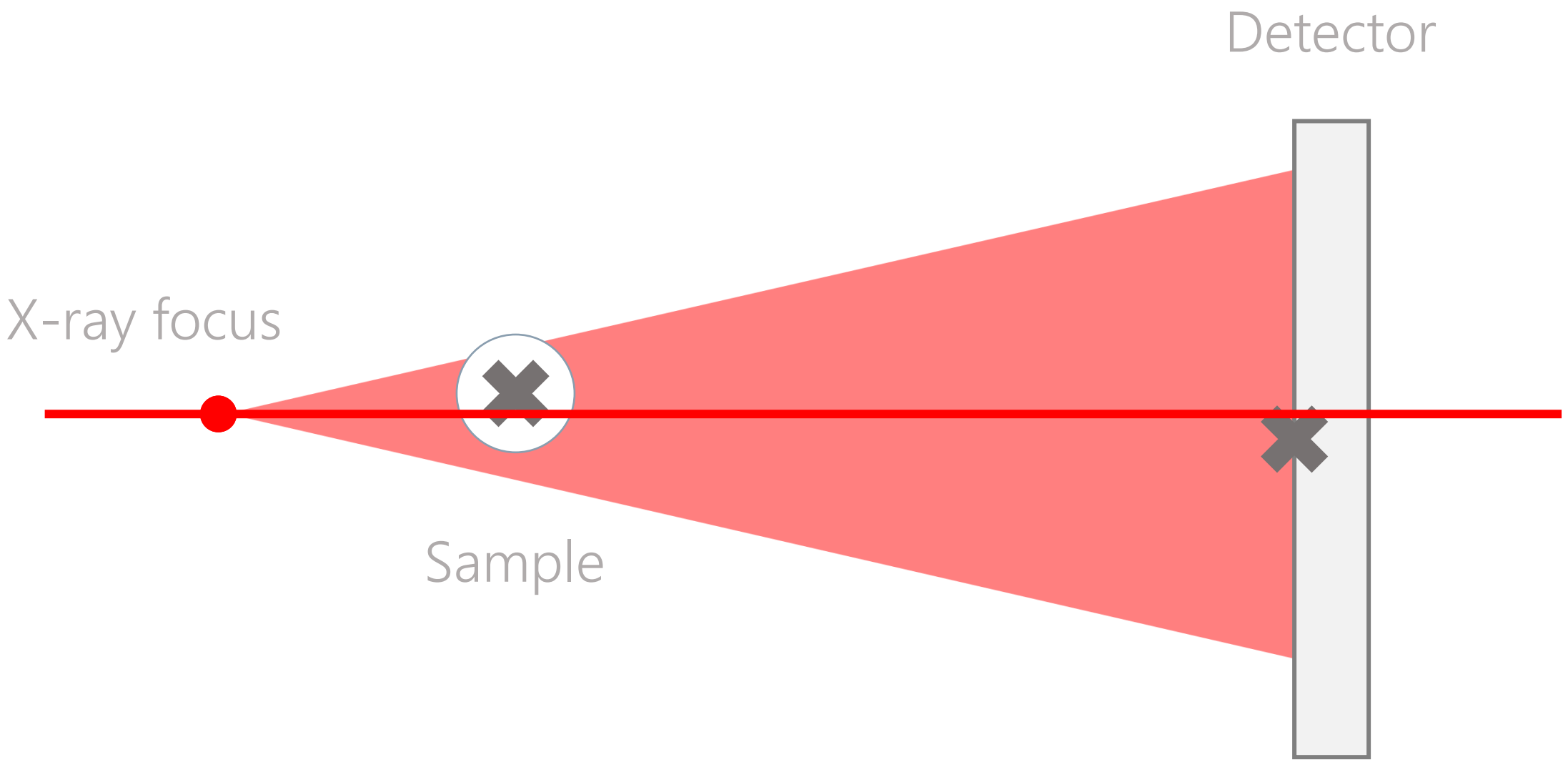
- Correct focus
- Eliminate sample movement
- Eliminate sample deformation
- Run a fast scan

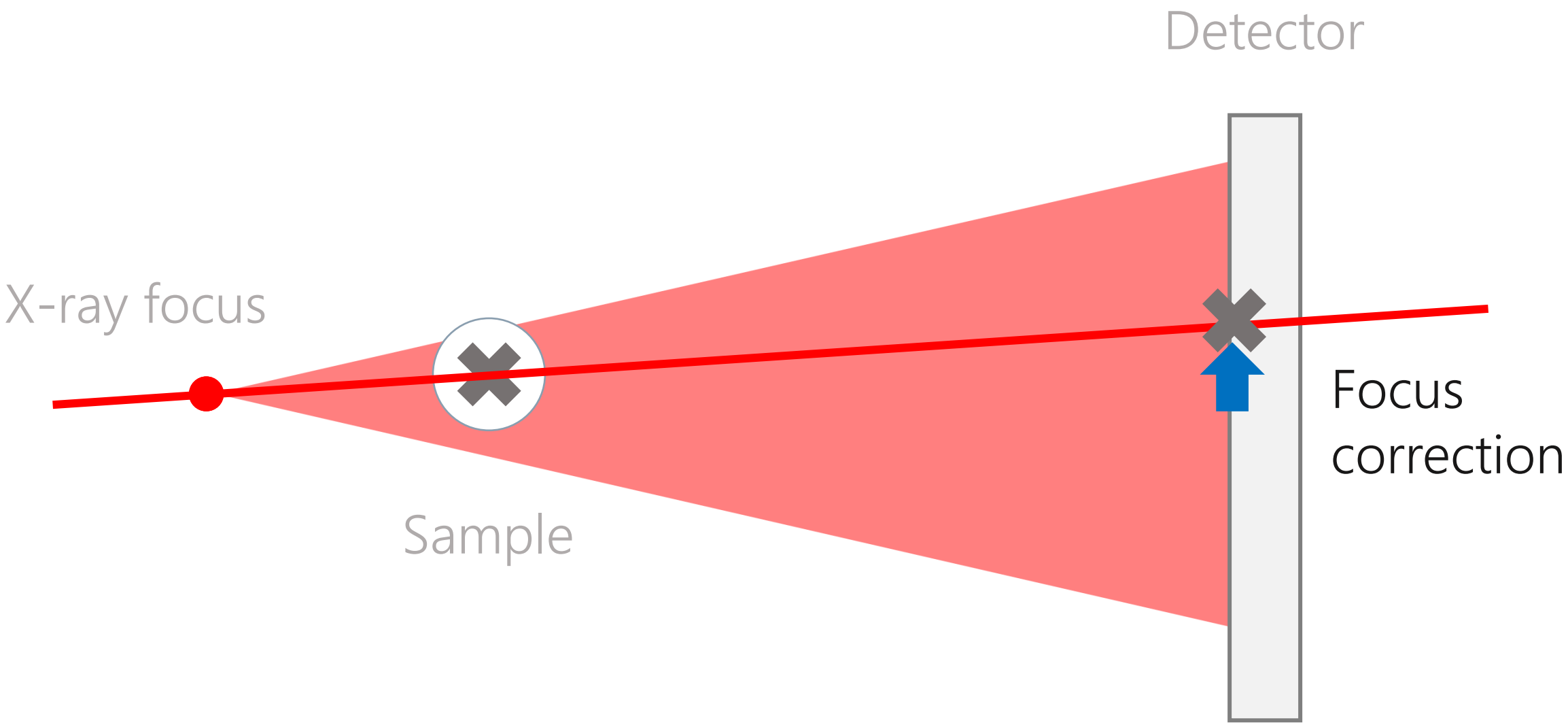
MORE KEYS TO HR IMAGING

- Correct focus
- Eliminate sample movement
- Eliminate sample deformation
- Run a fast scan

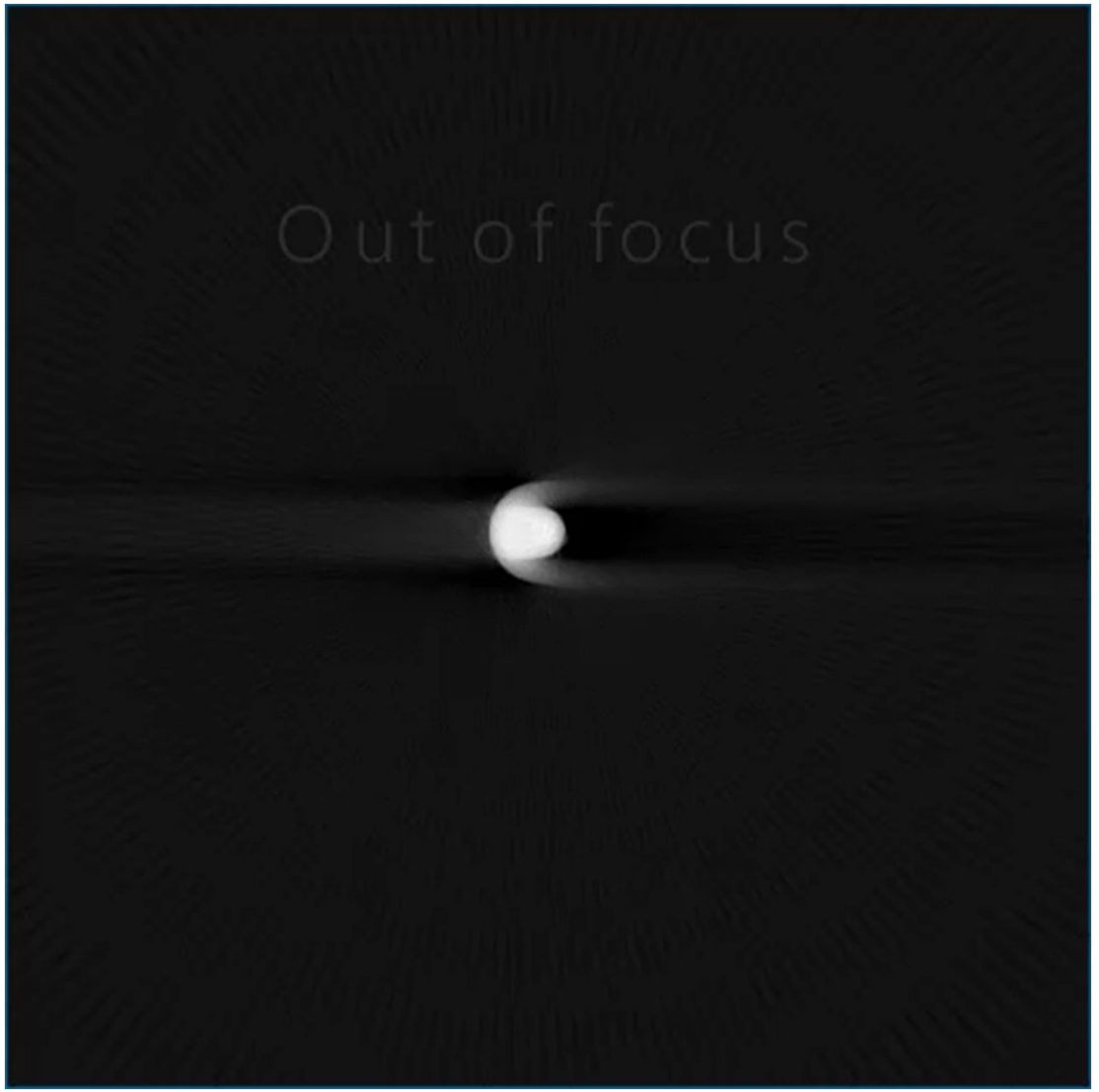
WHAT IS FOCUS CORRECTION?

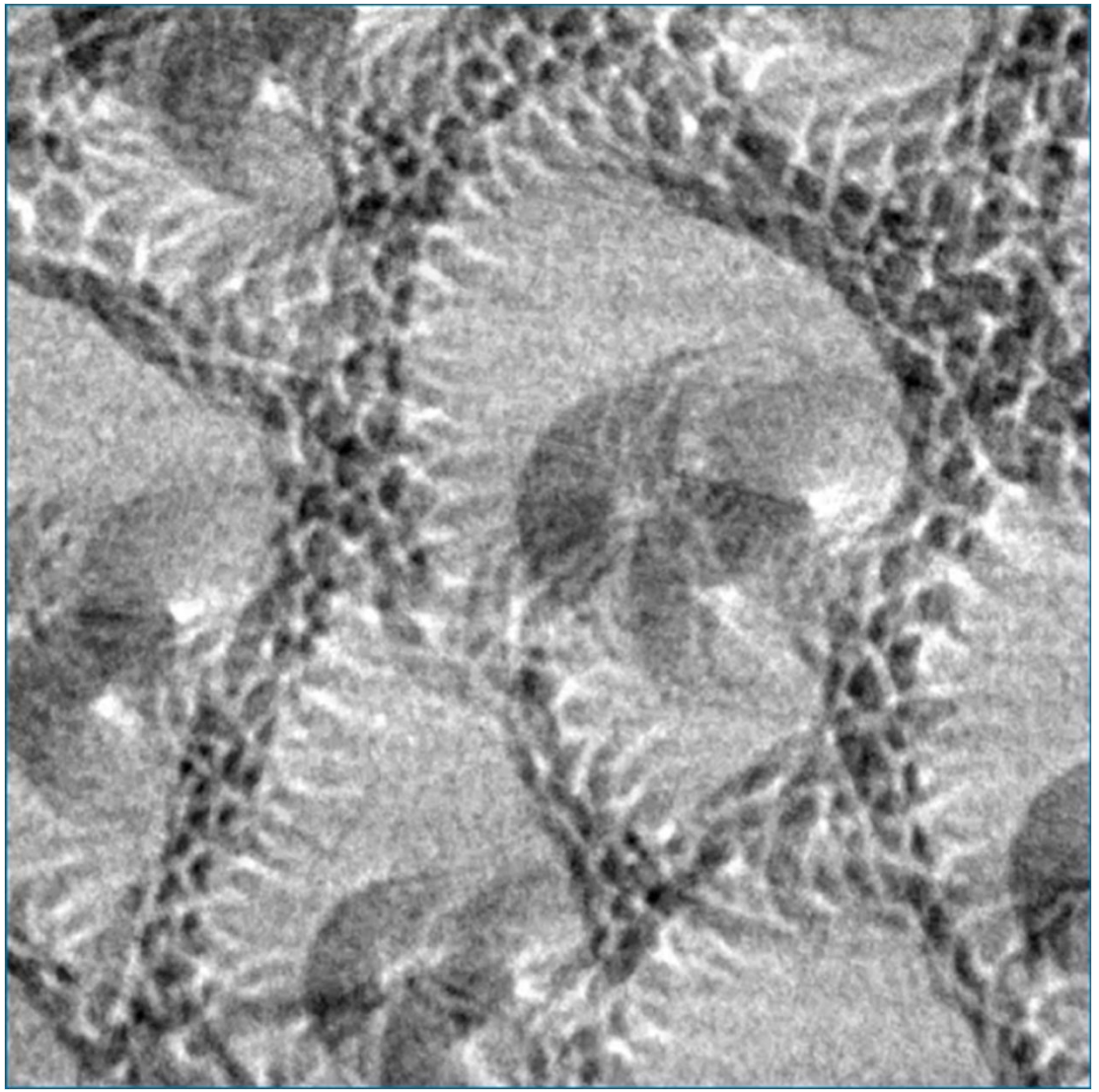

Detector
X-ray focus
Sample


Detector
X-ray focus
Sample


Detector
X-ray focus
Sample
Focus
correction

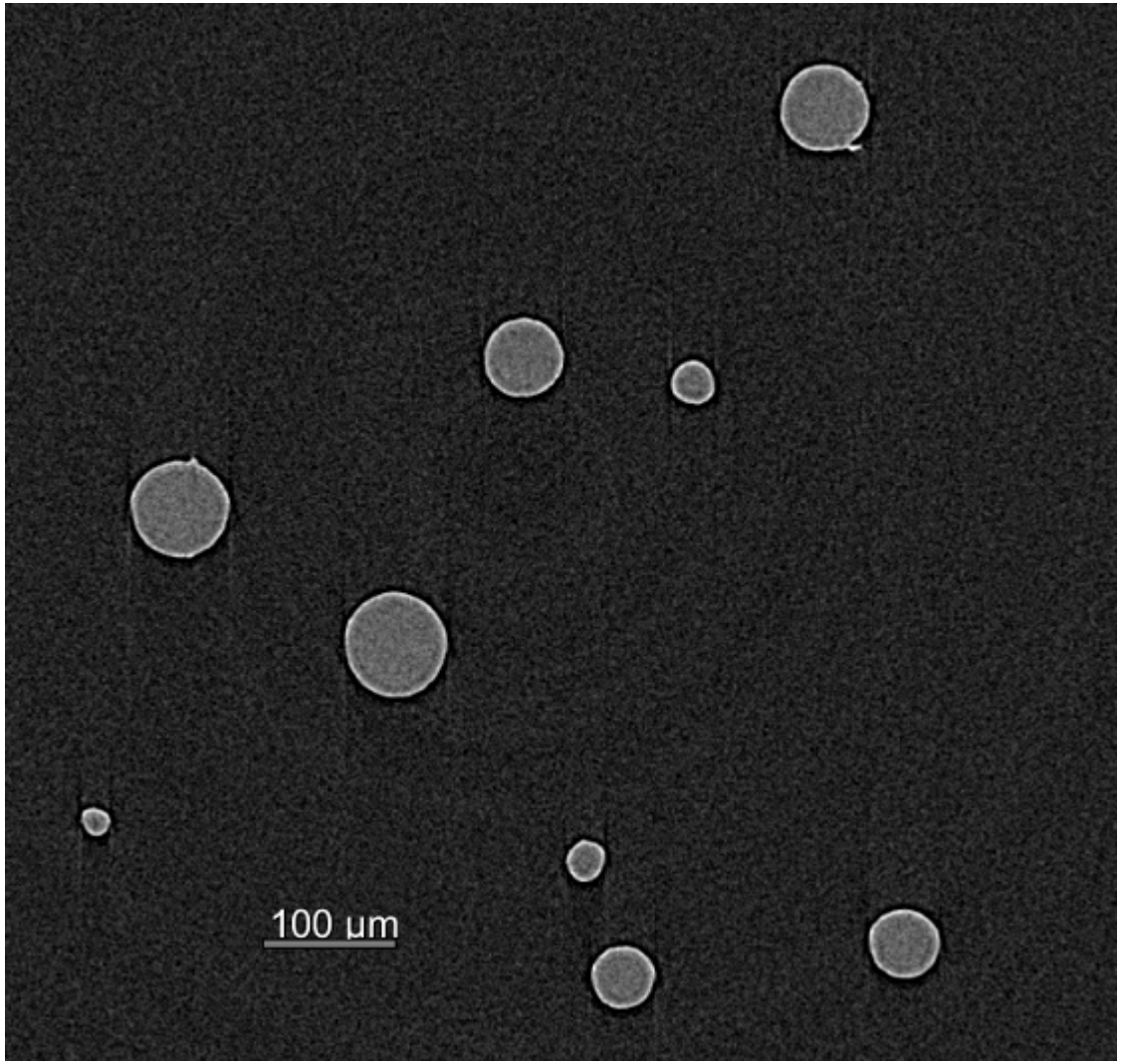
HOW DO YOU CORRECT FOCUS?

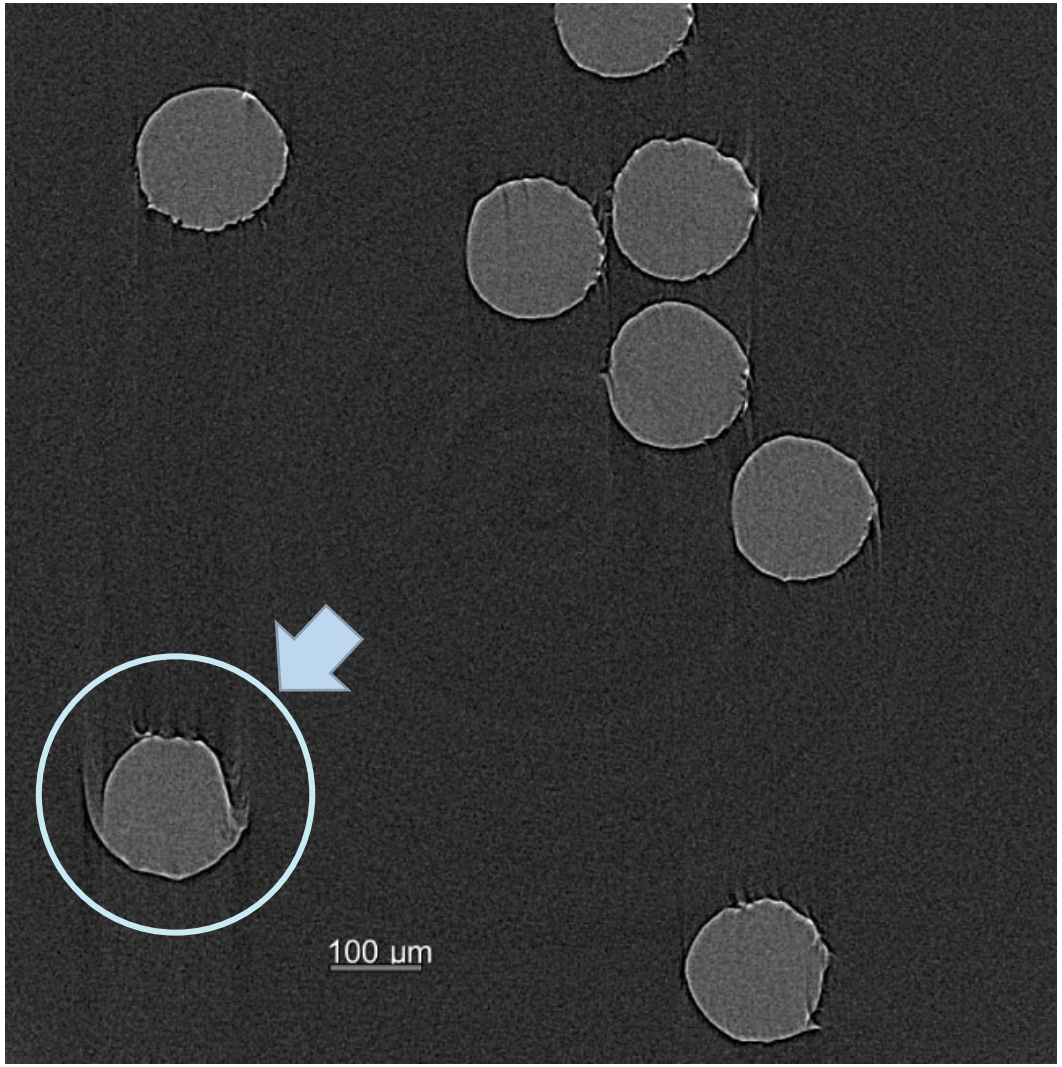

Out of focus

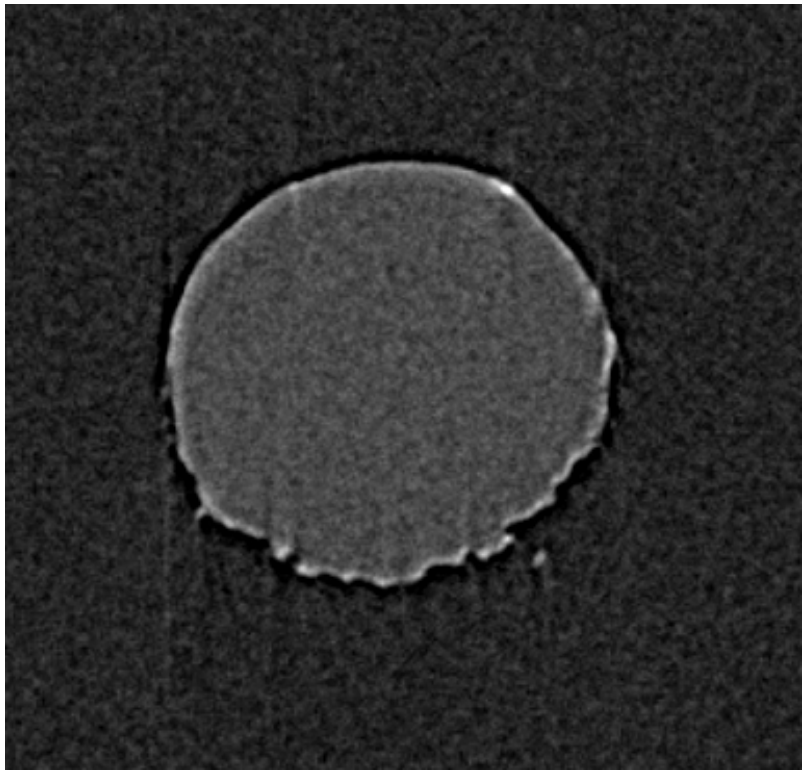


MORE KEYS TO HR IMAGING

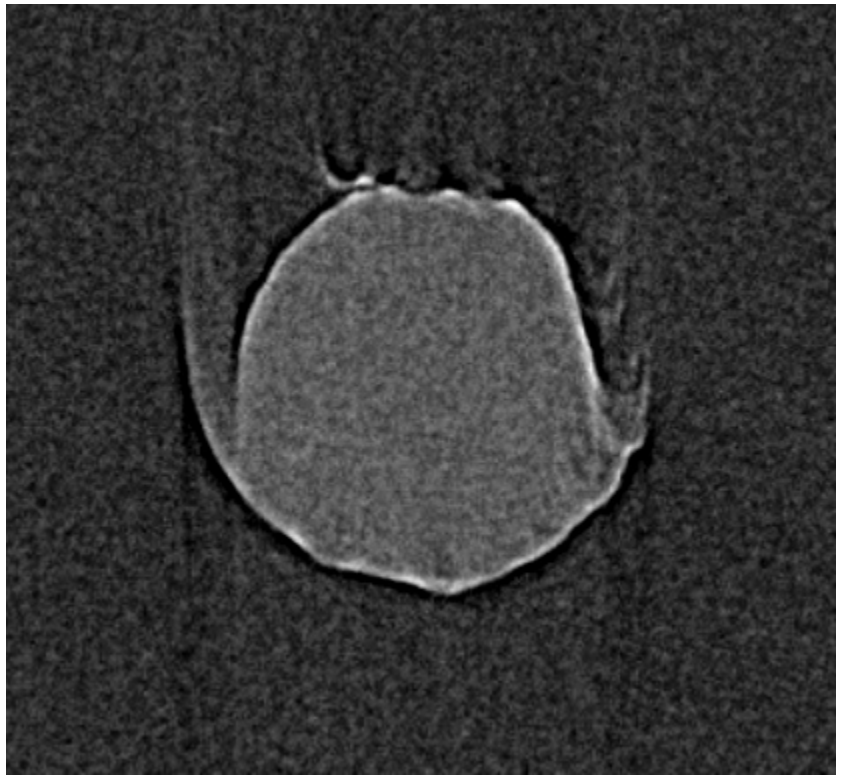
- Correct focus
- Eliminate sample movement
- Eliminate sample deformation
- Run a fast scan


100 µm


100 µm



Still sample

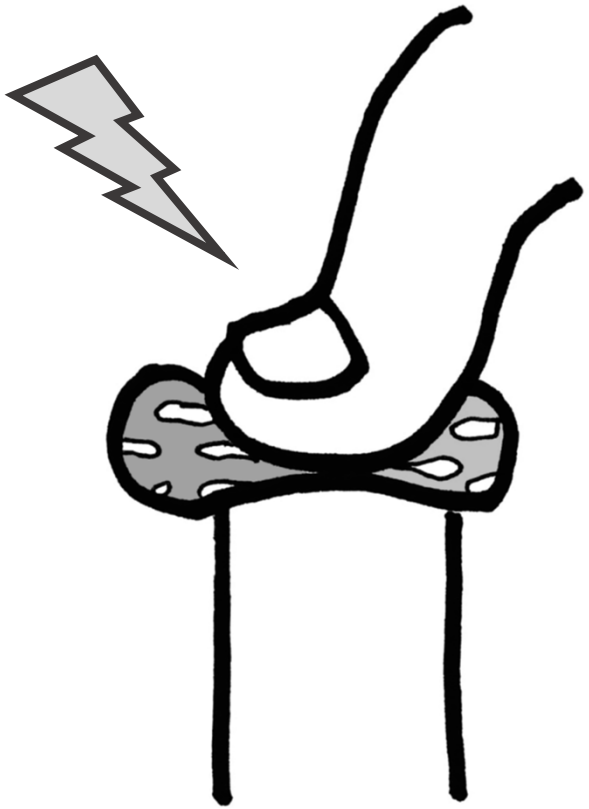


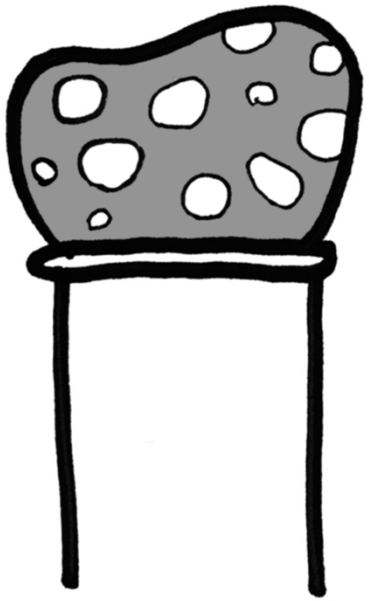
Moving sample

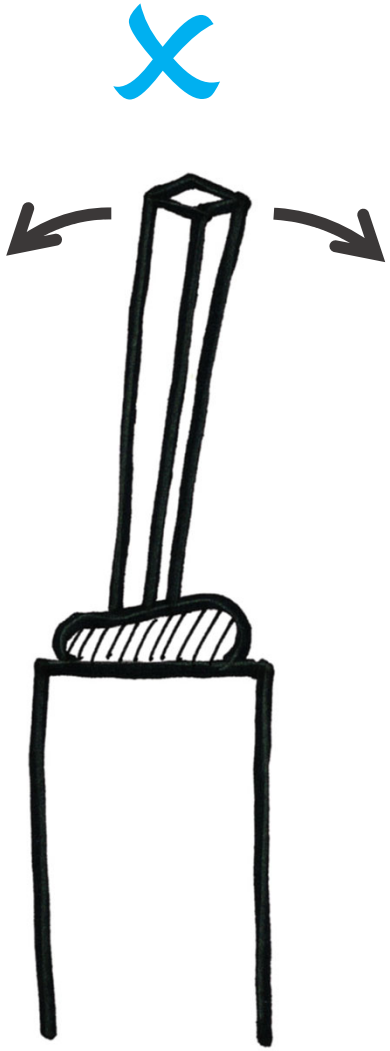
HOW DO YOU PREVENT THIS?

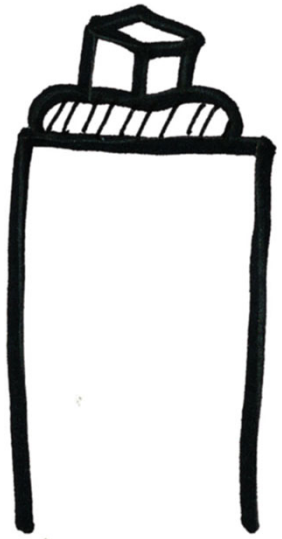
Secure the sample

- UV resin
- Epoxy
- Utility wax
- Carbon tape
- Double-sided tape

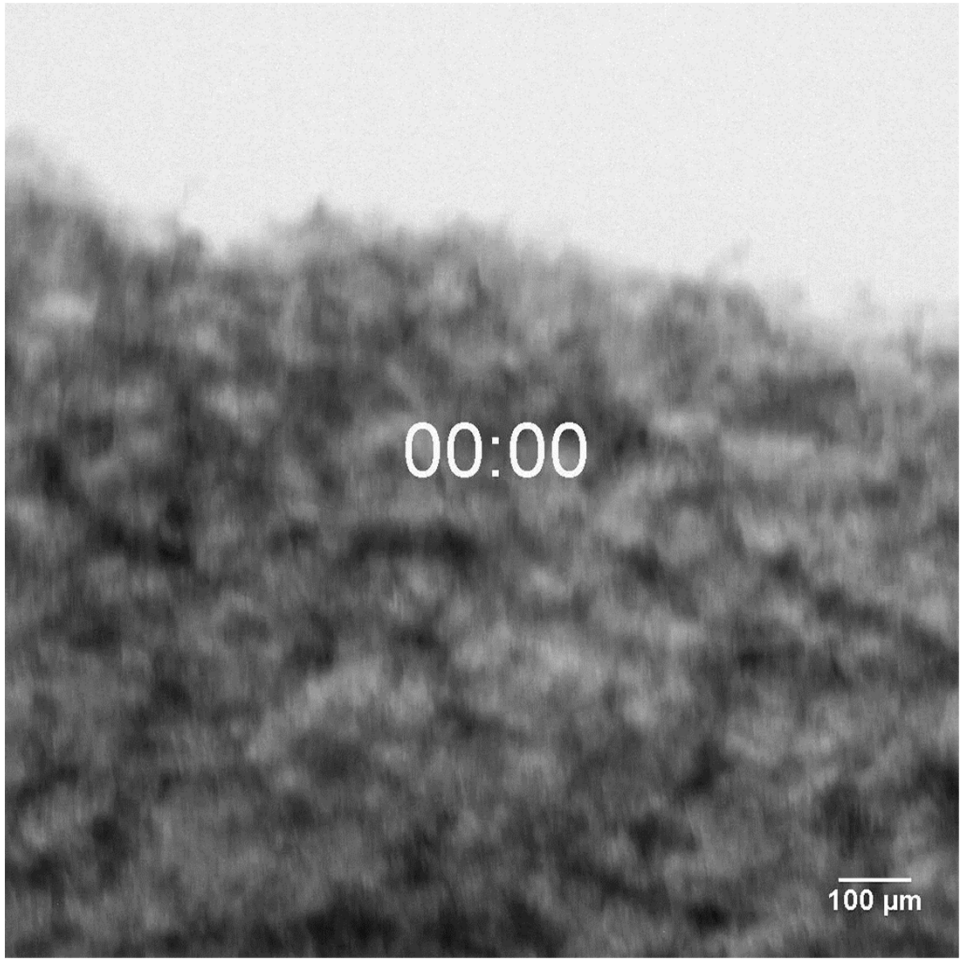




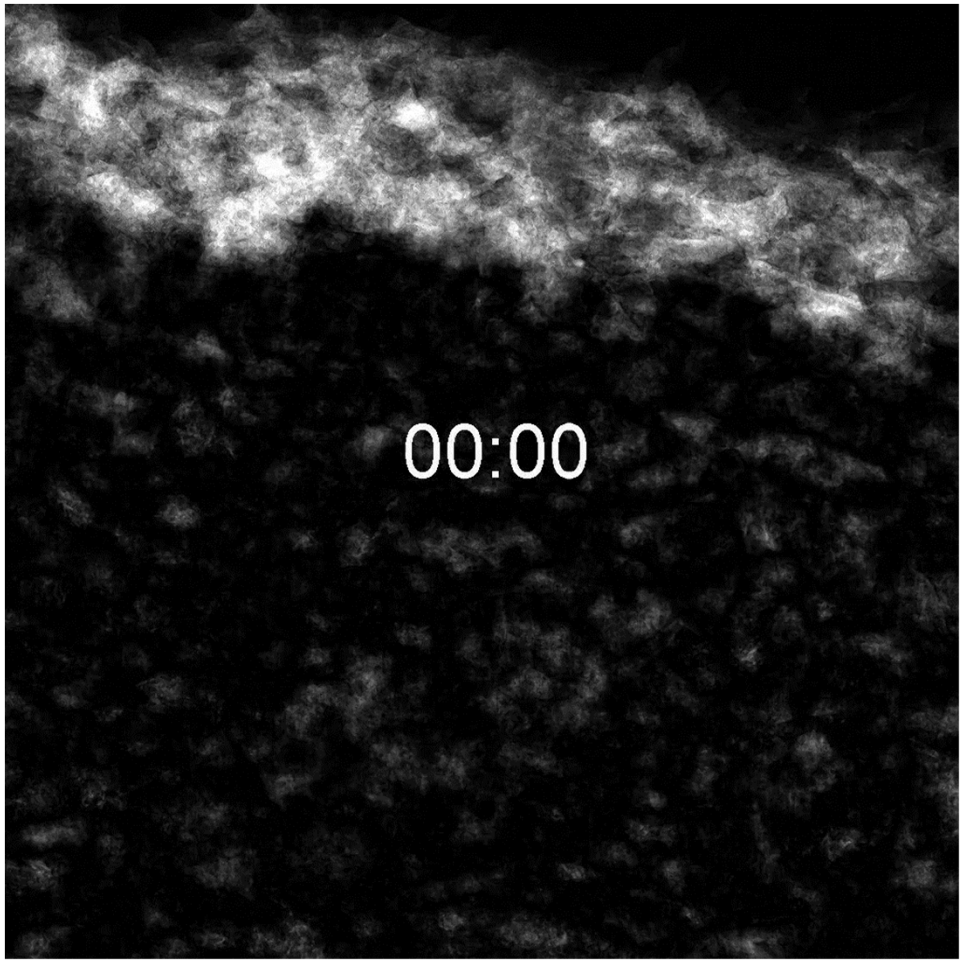




Wait long enough



Current image – Last image

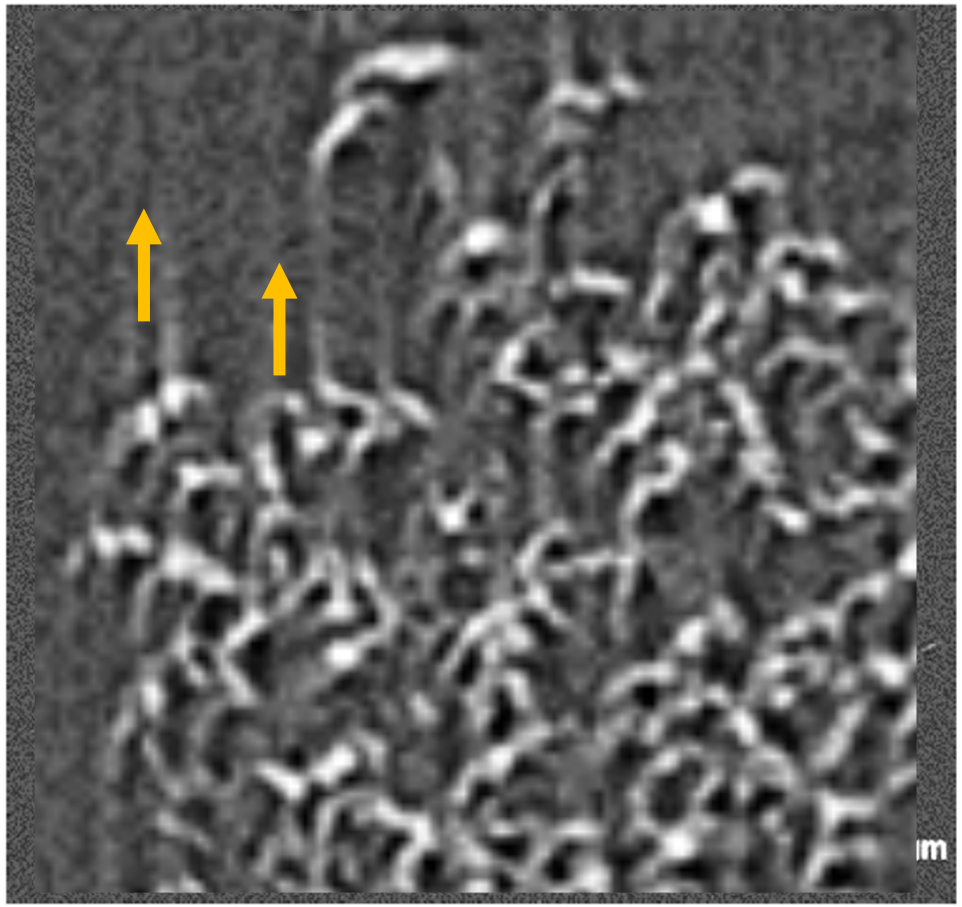


What if the sample is unstable?

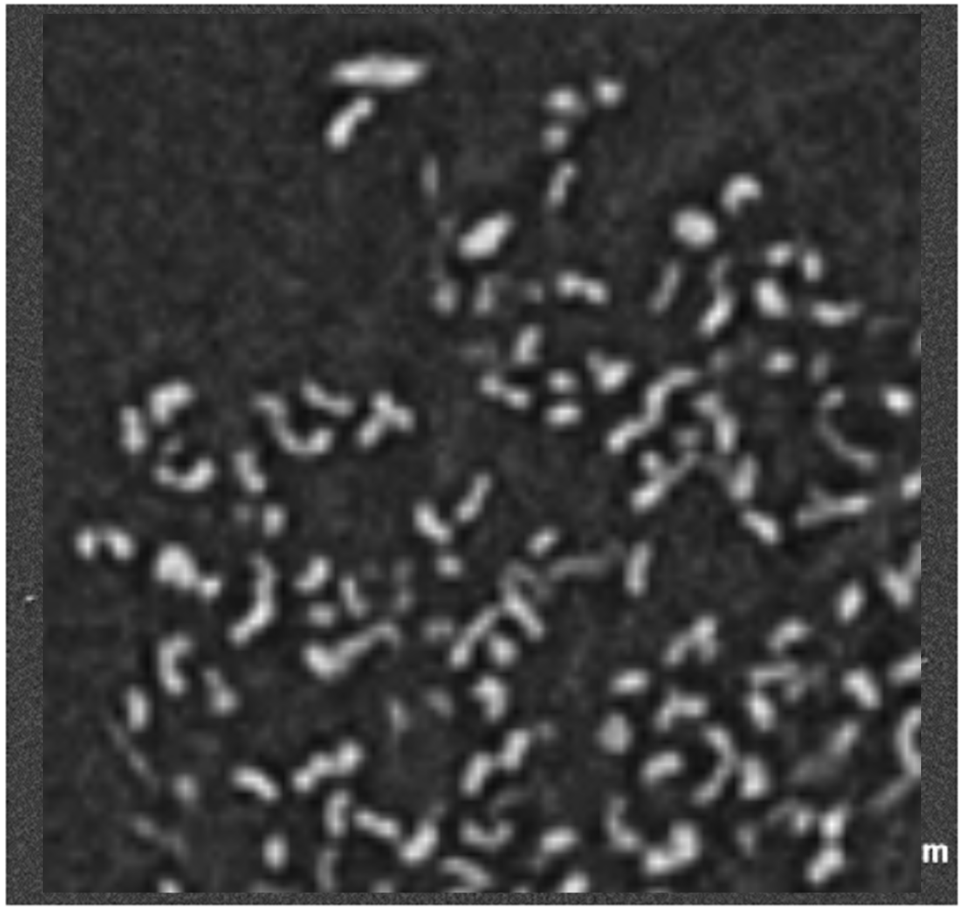
MORE KEYS TO HR IMAGING

- Correct focus
- Eliminate sample movement
- Eliminate sample deformation
- Run a fast scan

Unwoven fabric



129 min



12 min

KEYS TO HR IMAGING

- Use high magnification factor
- Use parallel beam geometry

MORE KEYS TO HR IMAGING

- Correct focus
- Eliminate sample movement
- Eliminate sample deformation
- Run a fast scan

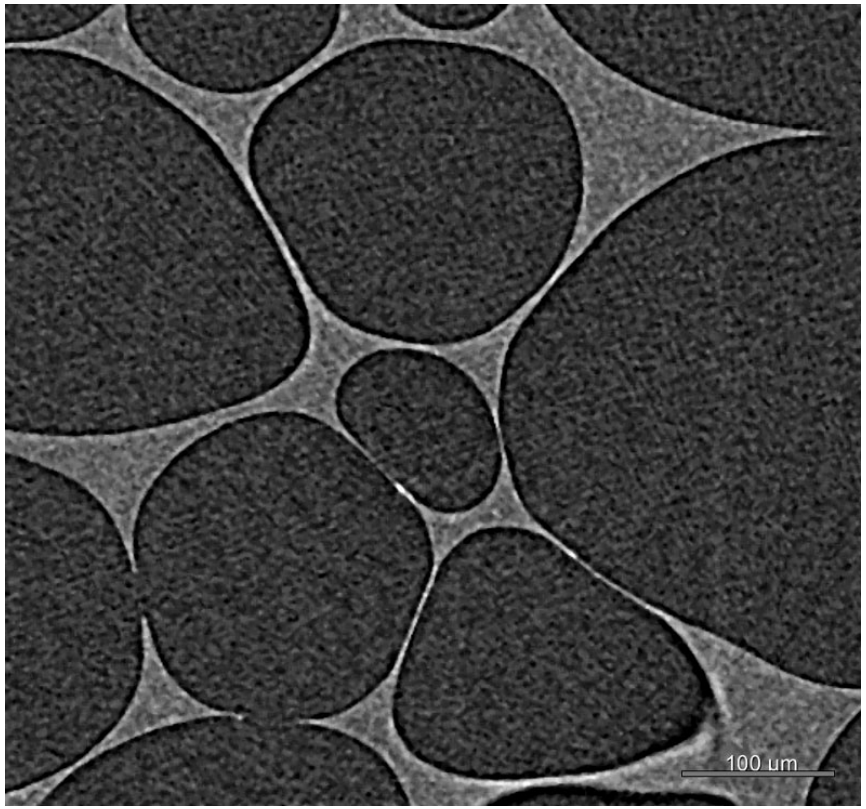
WHAT CAN WE DO WITH CT FOR FOAMS?

FOAM APPLICATIONS

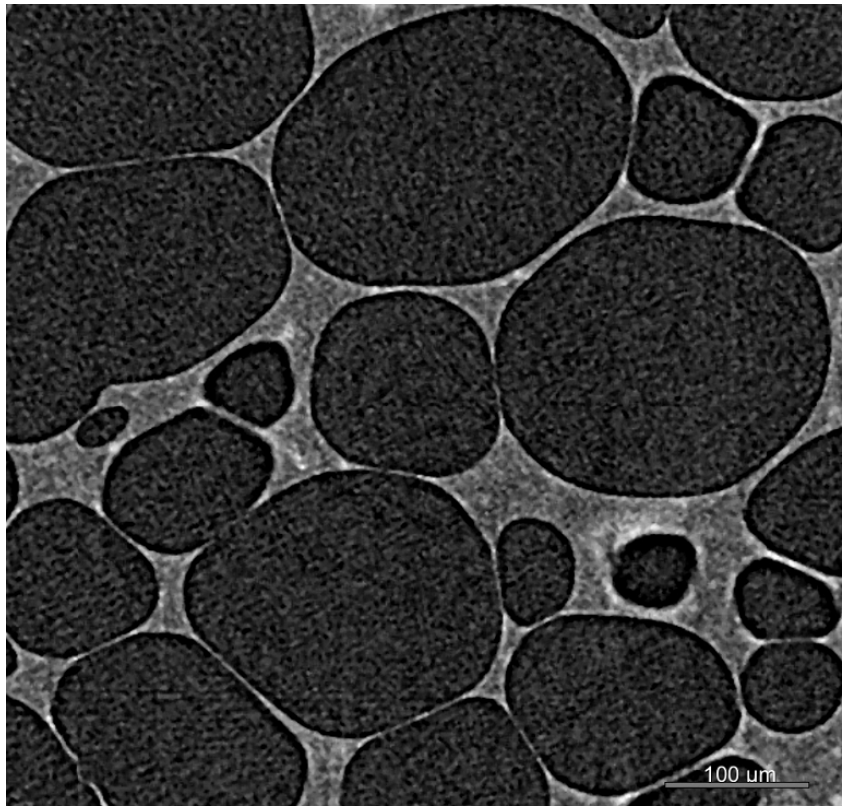
- Porosity
- Filler distribution
- Cell size/shape distribution
- Cell wall thickness
- Cell morphology visualization

LET’S COMPARE EAR PLUGS

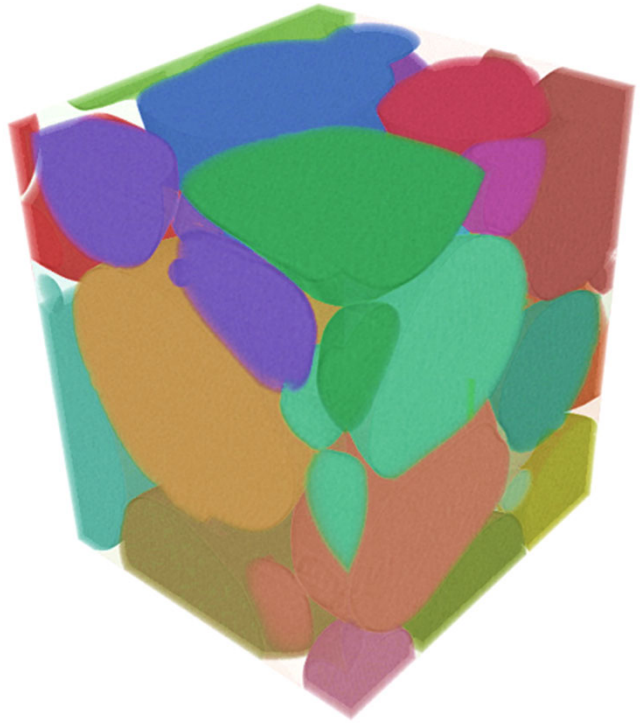
Store brand A



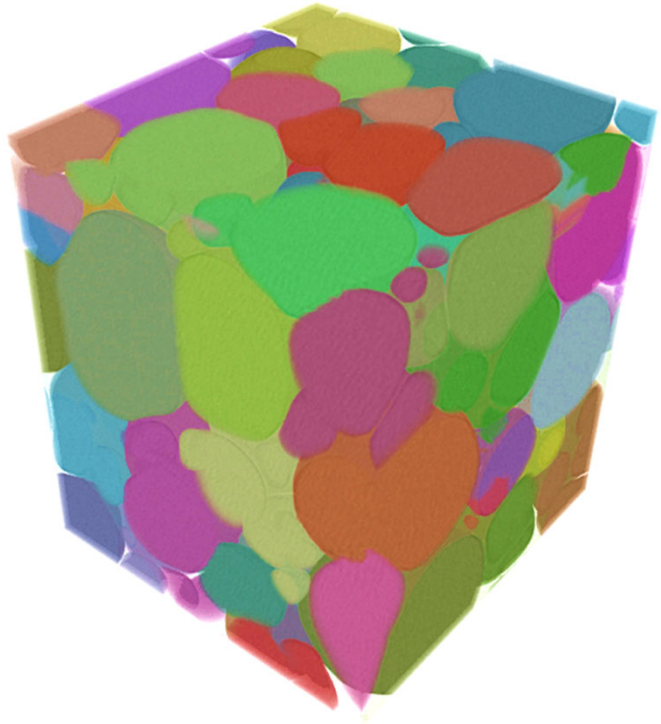
Store brand B



Store brand A



Store brand B



Cell volume

Mean = 3.1 x 10^6 µm^3

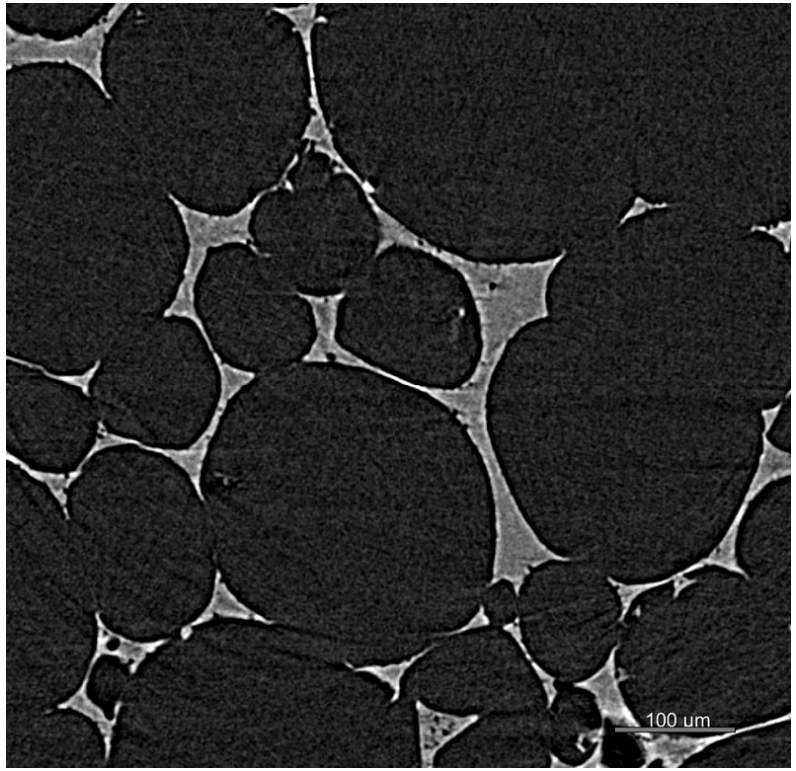
Mean = 1.1 x 10^6 µm^3

ARE ALL MAKEUP SPONGES THE SAME?

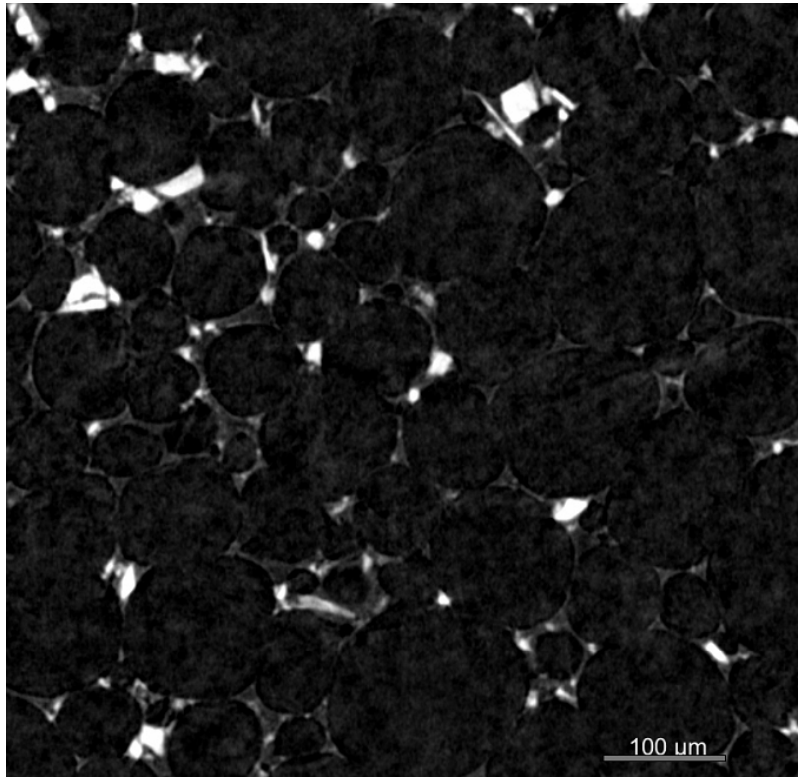
GLAMOUR March 10, 2016

"Your Ultimate Guide to Makeup Sponges"

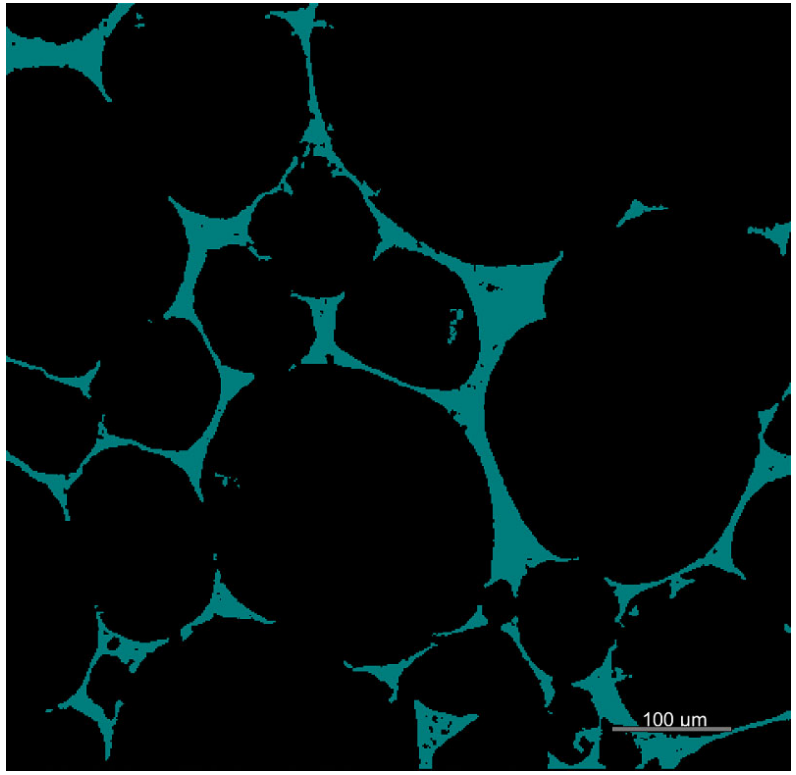
Premium brand $20



Store brand $5

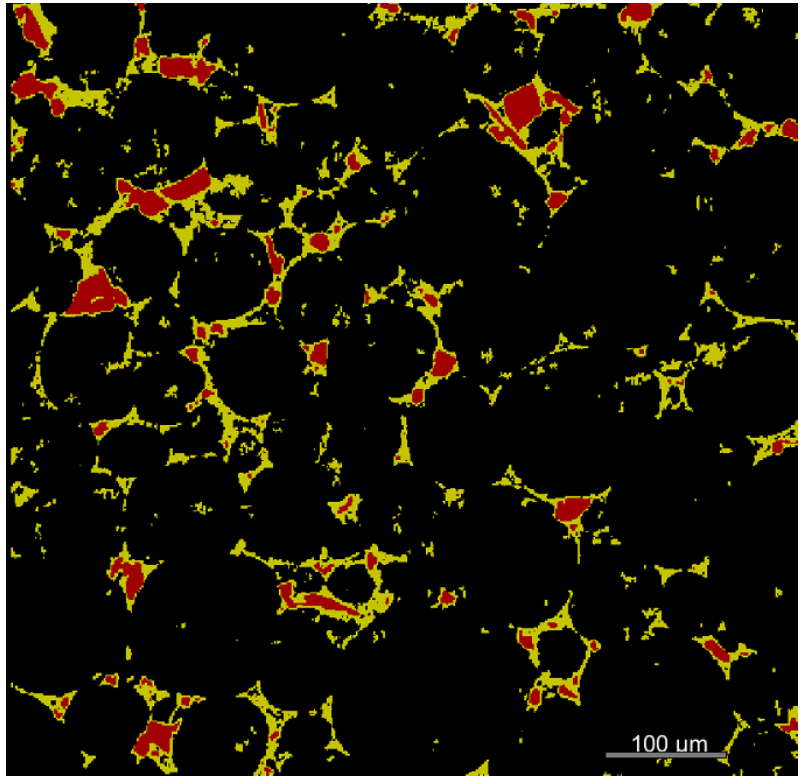


Premium brand $20



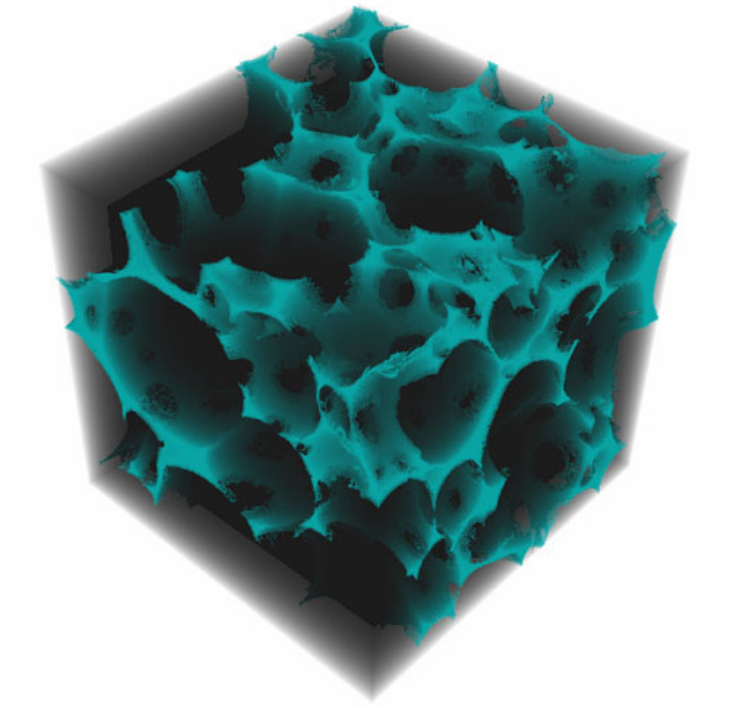
Polymer / cells

Store brand $5



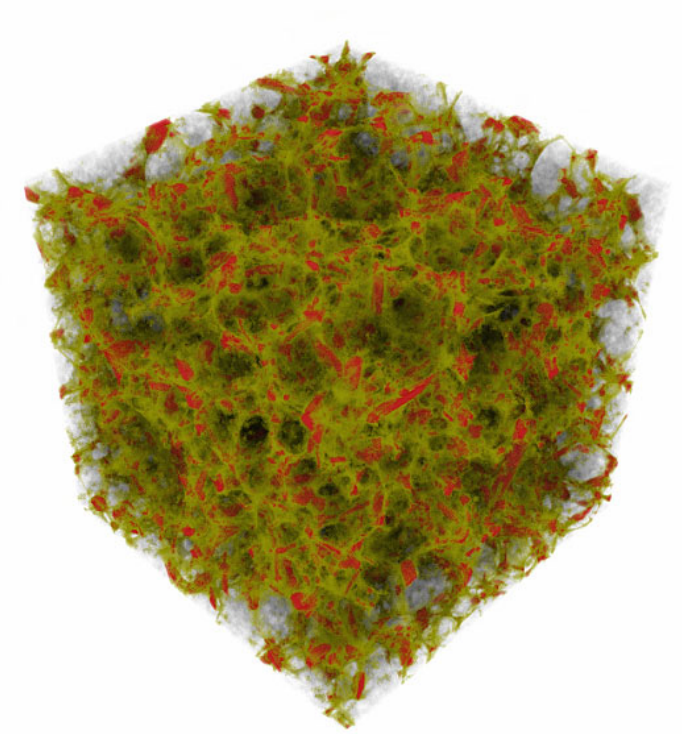
Polymer / filler / cells

Premium brand $20



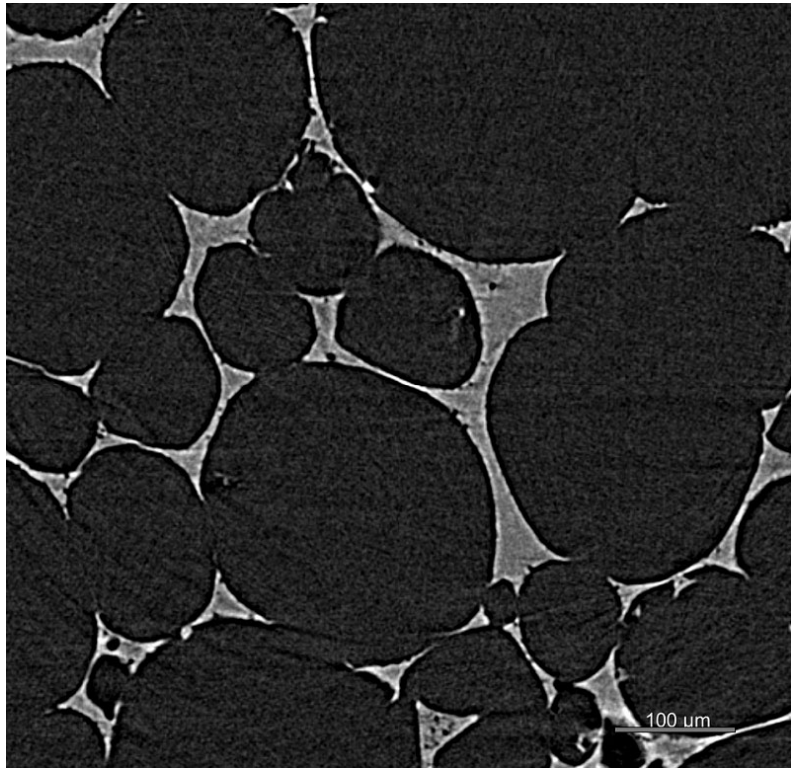
Polymer = 9.3 vol%

Store brand $5

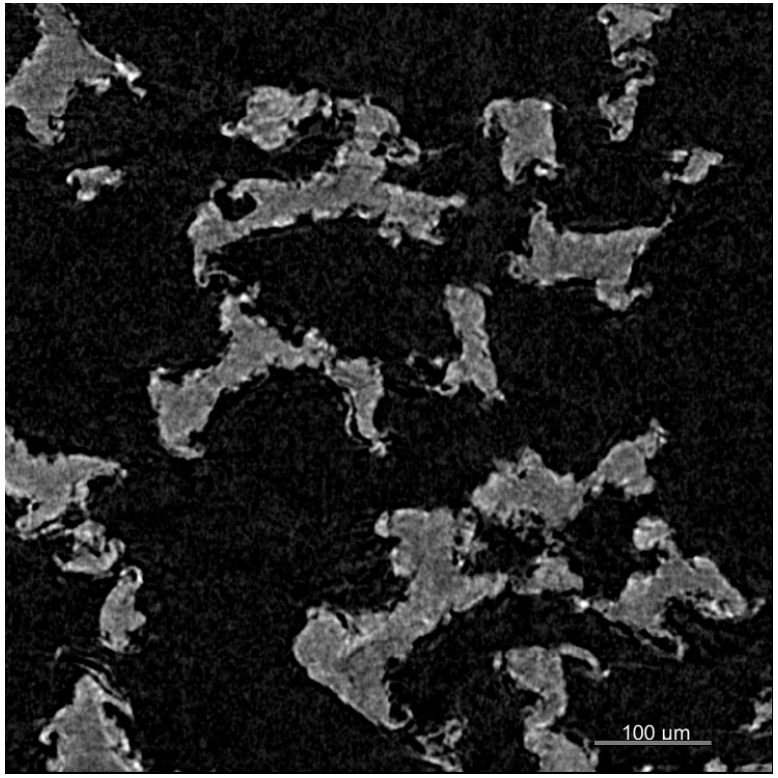


Polymer = 9.0 vol%
Filler = 3.3 vol%

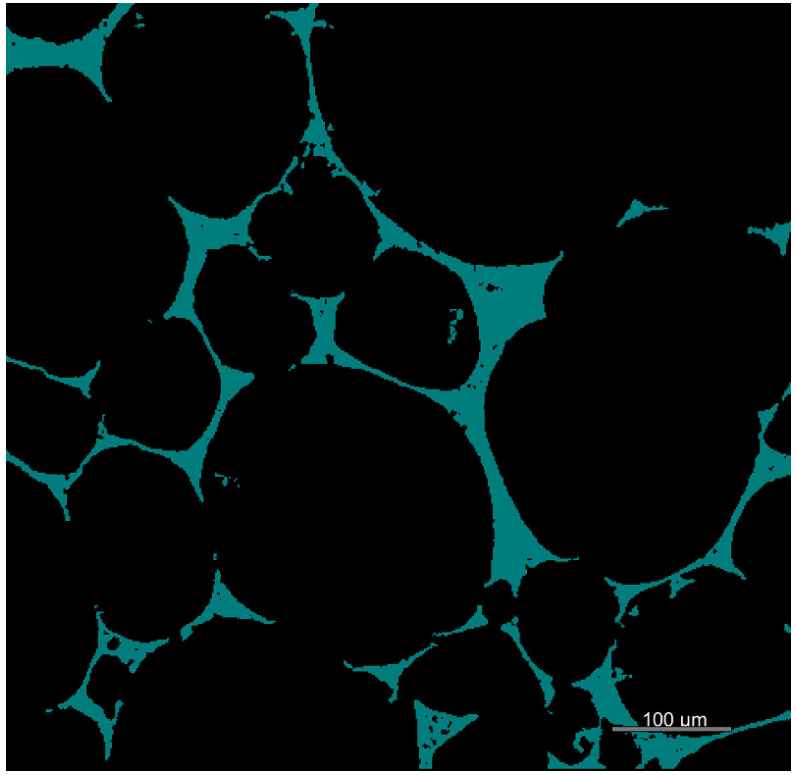
Brand new



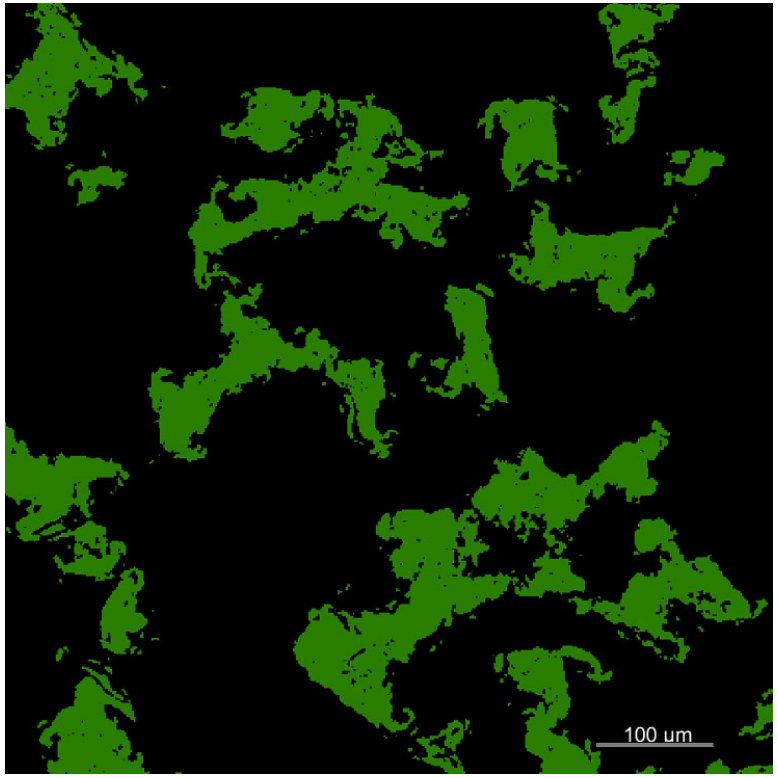
7-month old



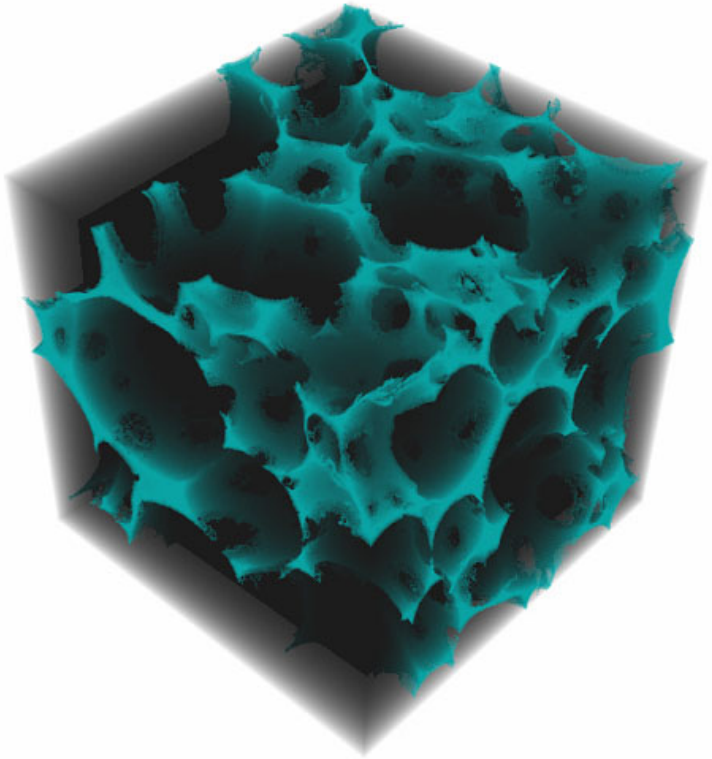
Brand new



7-month old

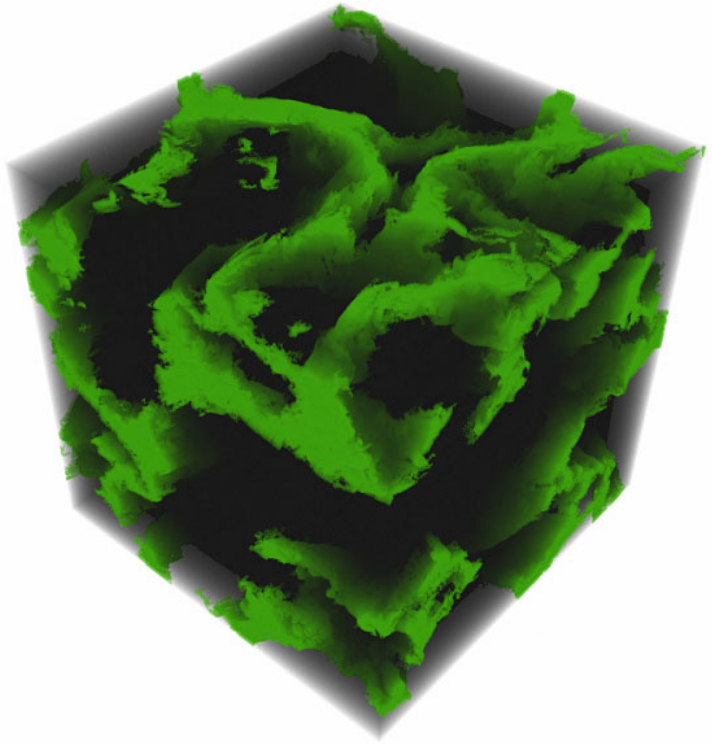


Brand new



Porosity = 90.7 vol%

7-month old

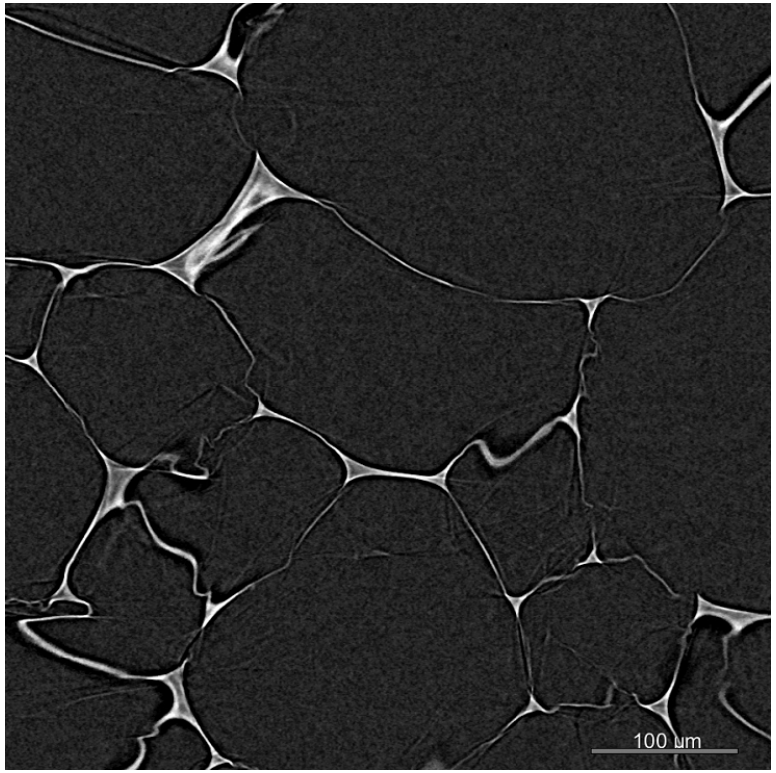


Porosity = 84.4 vol%

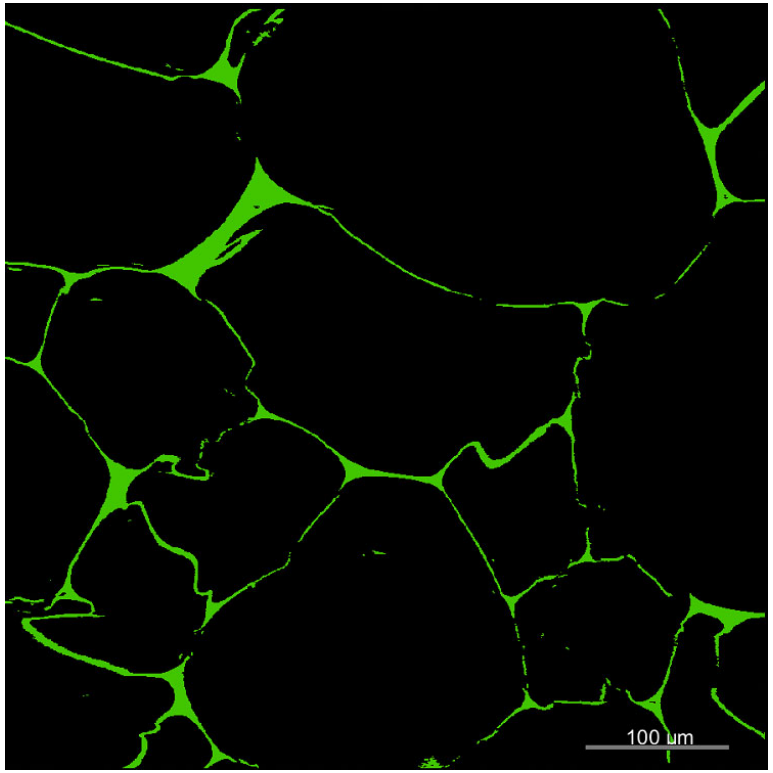

PLAFEN

CAN YOU ANALYZE CELL WALL THICKNESS?

Insulator

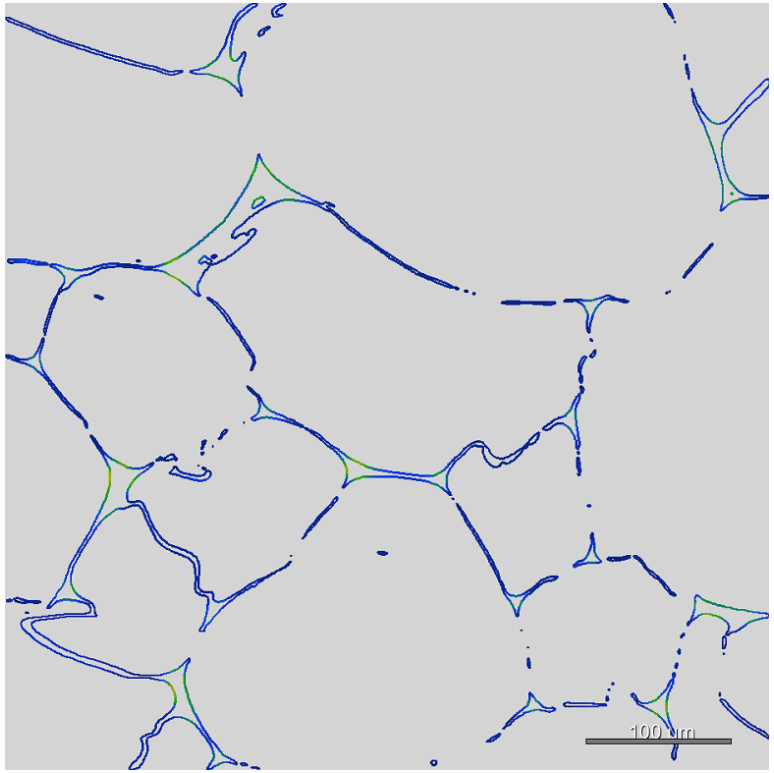


Insulator

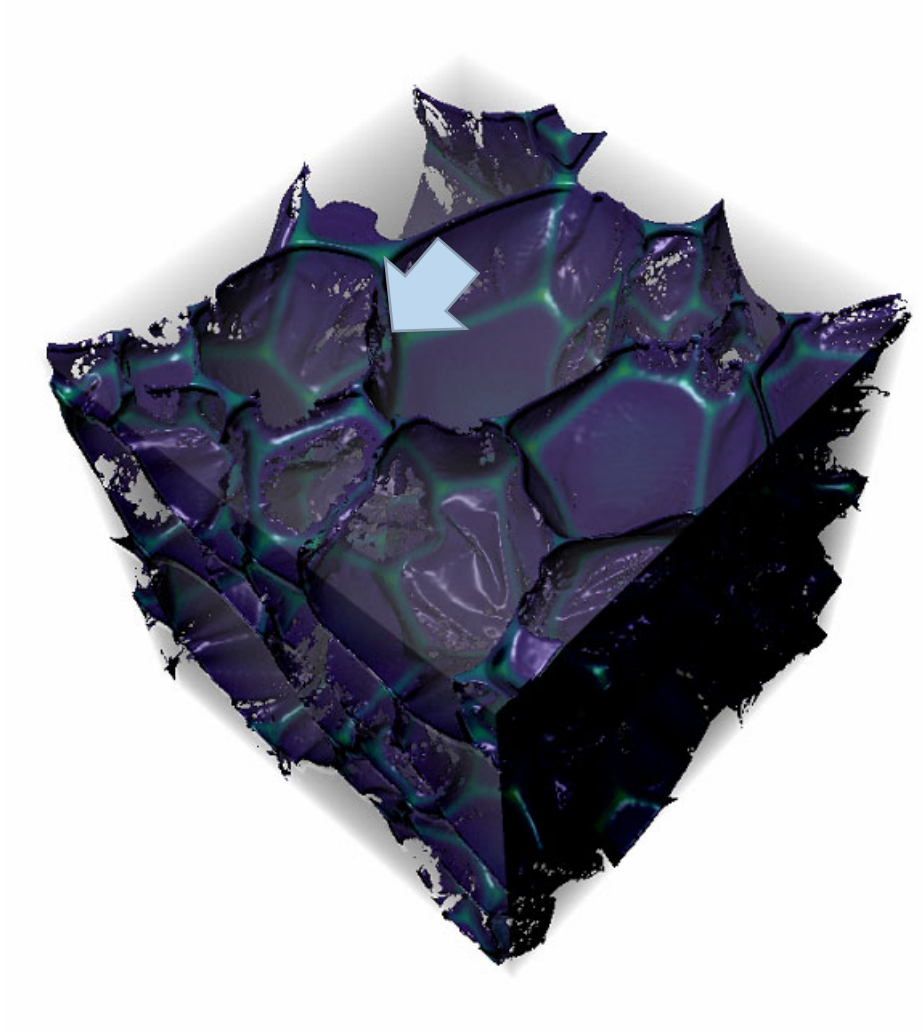


Porosity 96.7 vol%

Insulator



Wall thickness



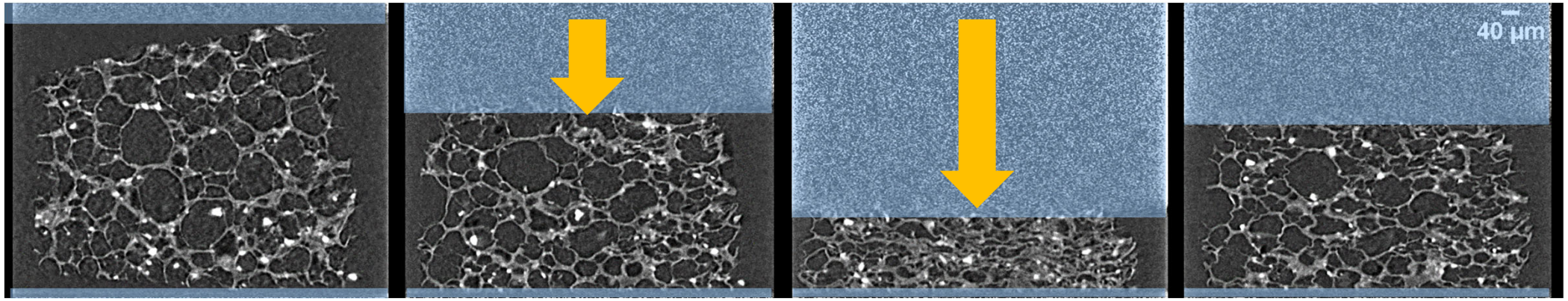
Wall thickness
Mean 4.6 µm
Max. 23.3 µm

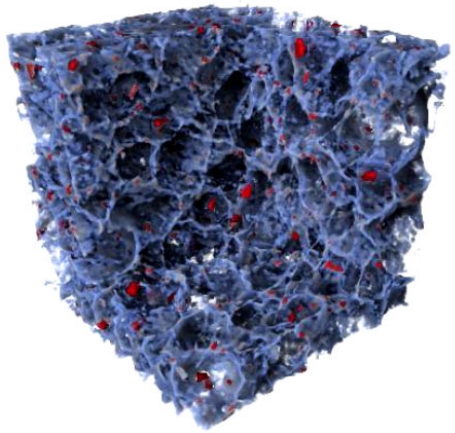
Thin

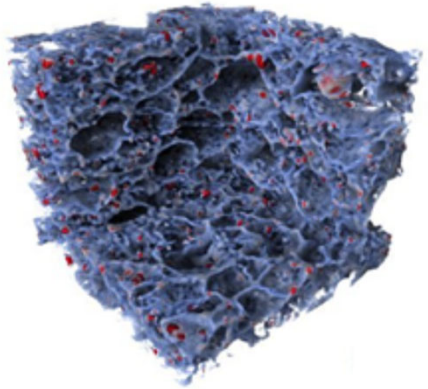
Thick

CAN YOU COMPRESS FOAMS?

Cross section 7MPa 14MPa 0MPa

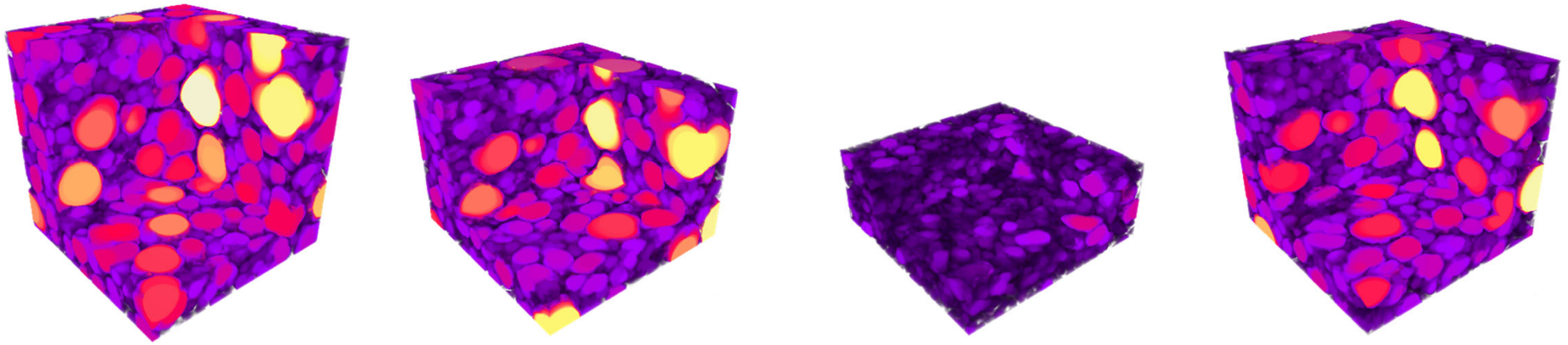






3D

7MPa 14MPa 0MPa



0μm 100μm

Cell size

FOAM APPLICATIONS

- Porosity
- Filler distribution
- Cell size/shape distribution
- Cell wall thickness
- Cell morphology visualization

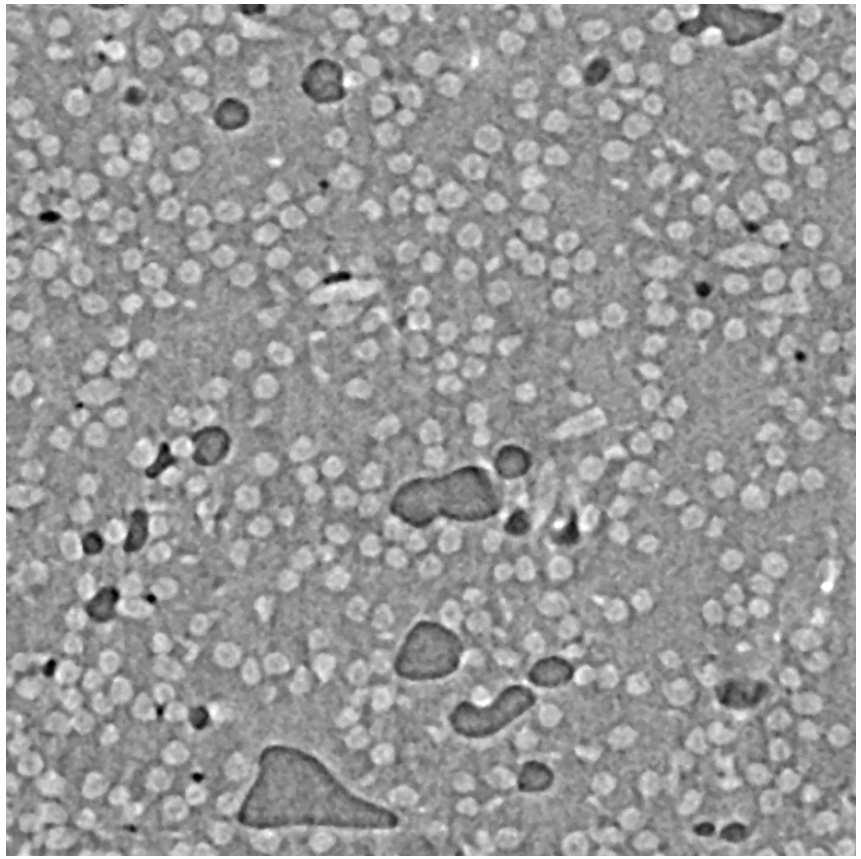
WHAT CAN WE DO WITH CT FOR COMPOSITES?

COMPOSITE APPLICATIONS

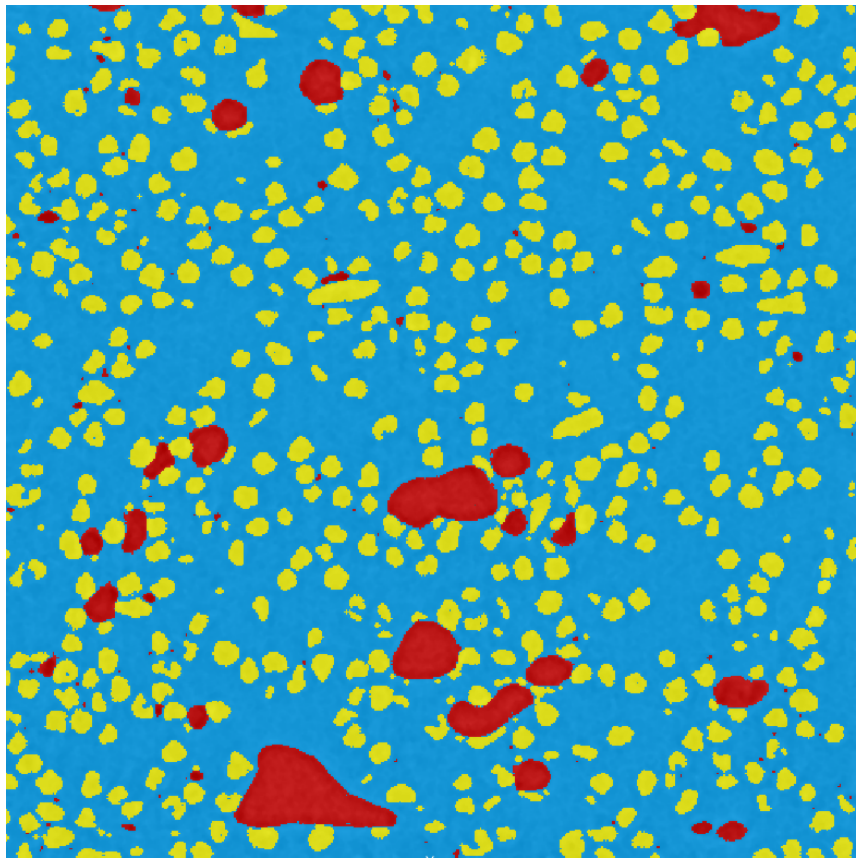
- Volume fraction
- Fiber/filler distribution
- Fiber orientation
- Voids distribution
- Crack visualization

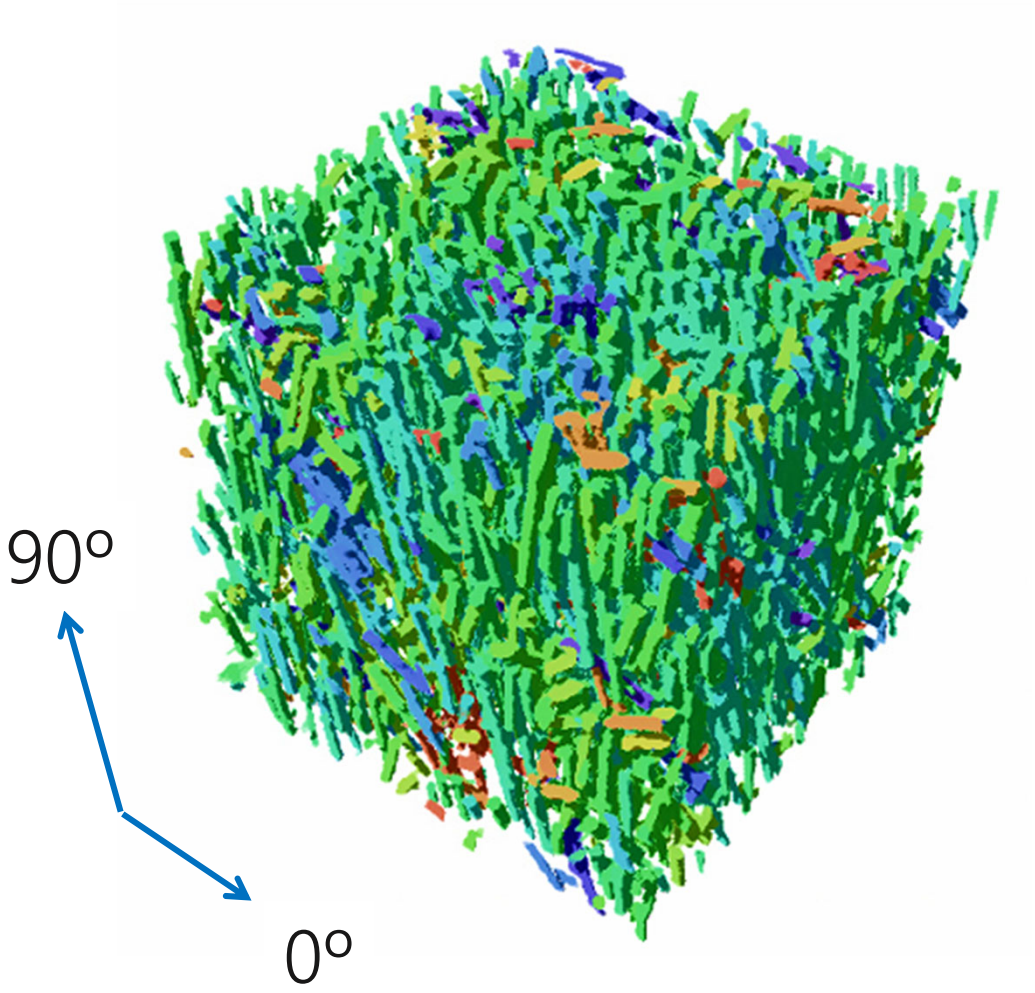
LET’S LOOK AT CARBON FIBERS

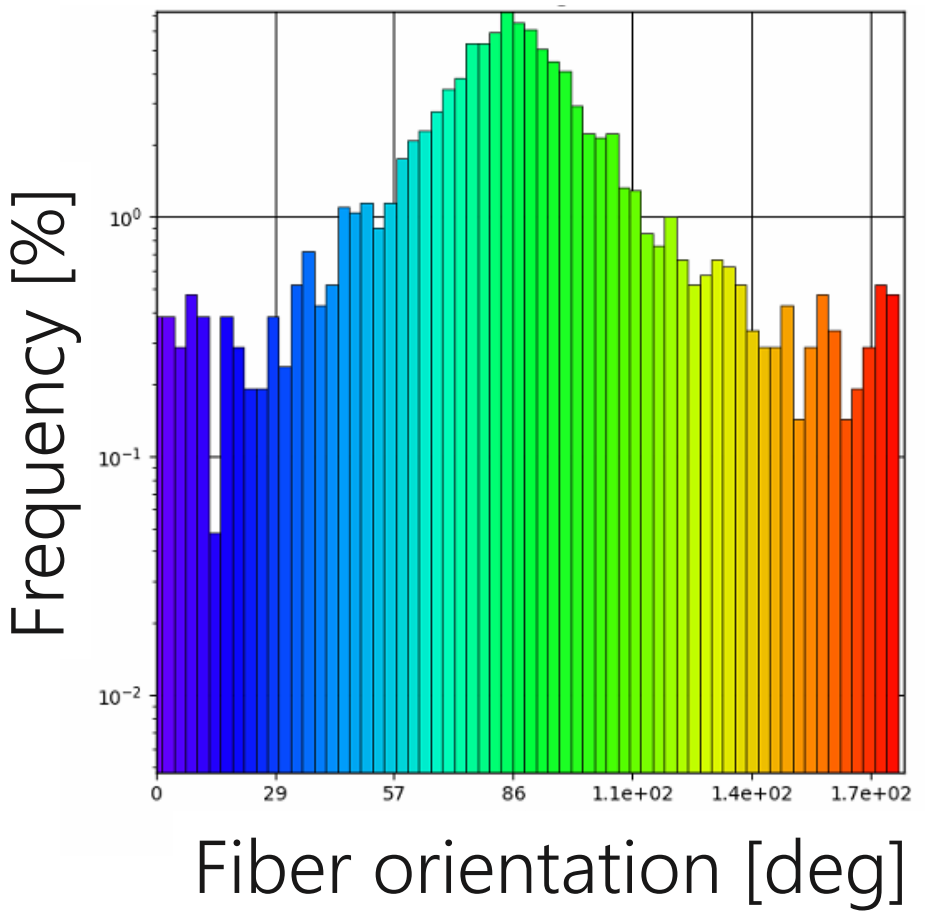
CFRP

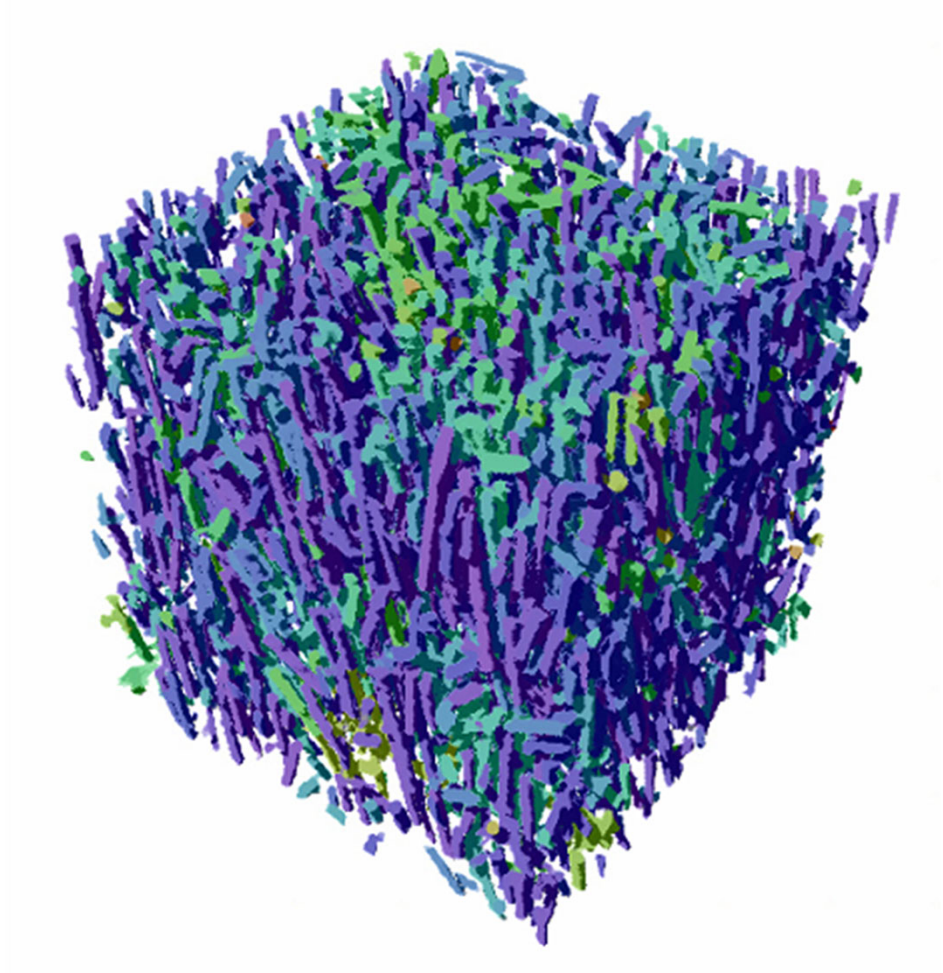


CFRP

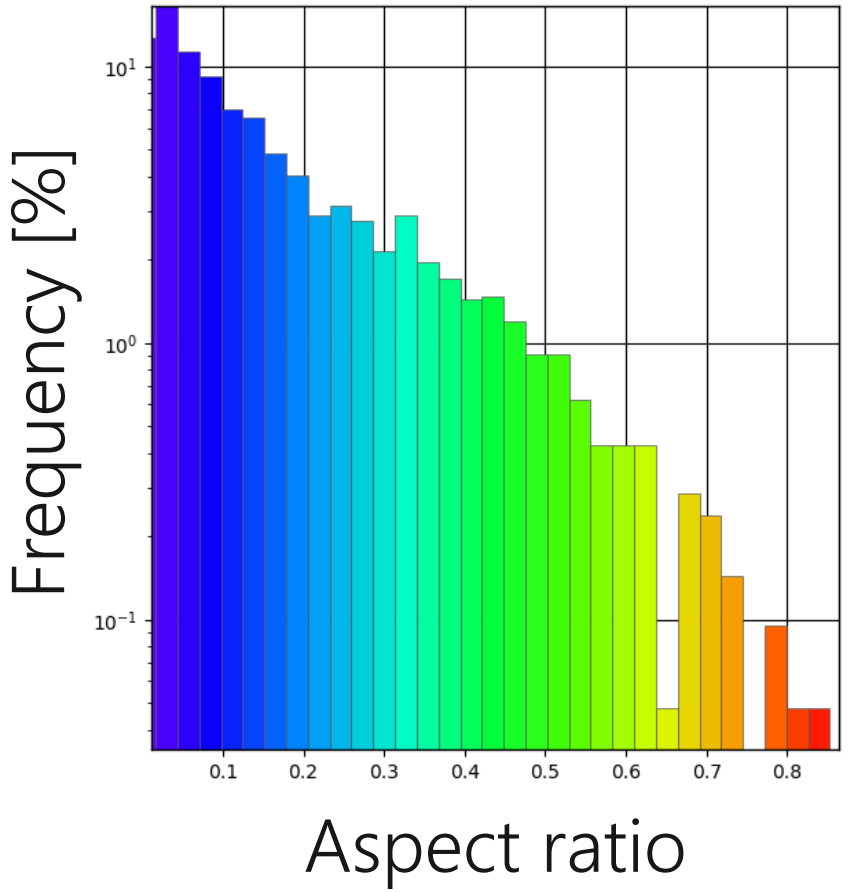


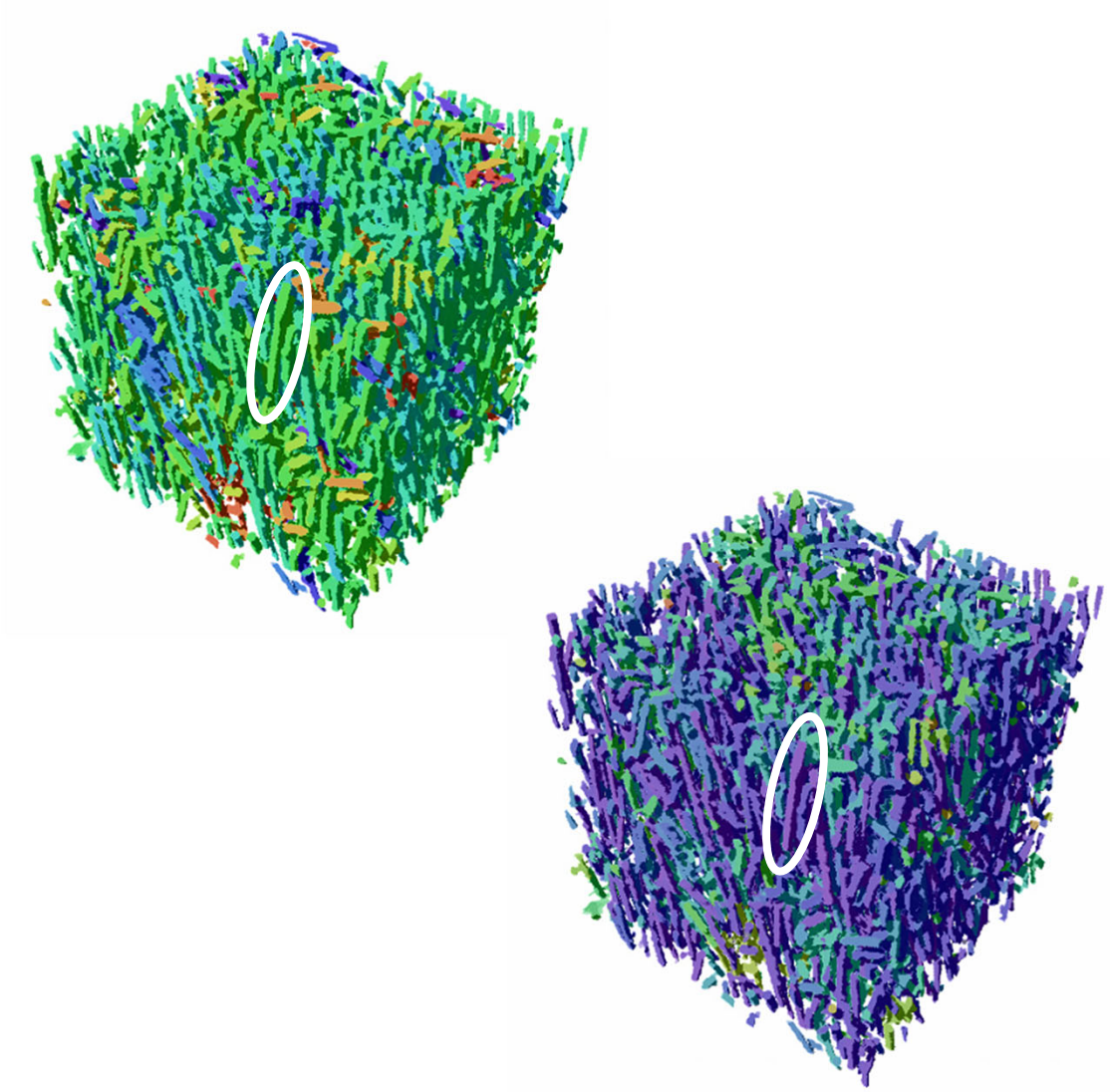

90°
0°

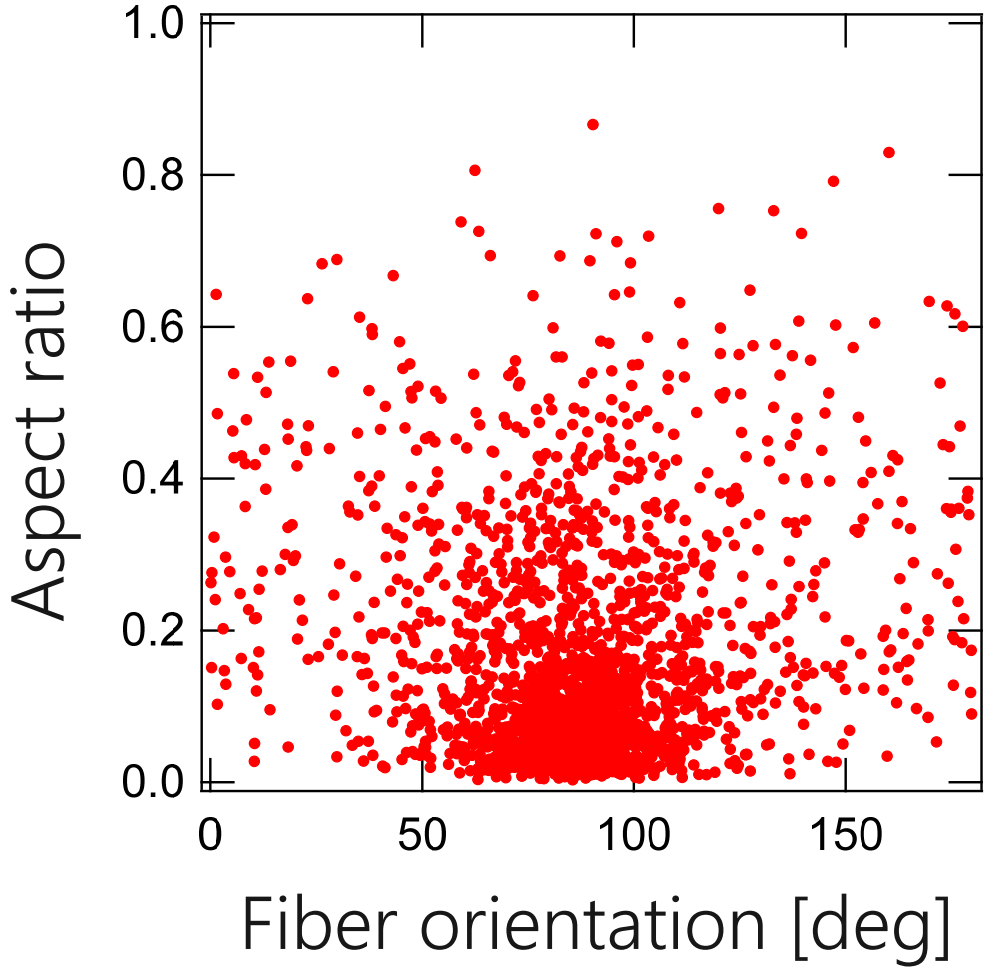

Frequency [%]
10^{0}
10^{-1}
10^{-2}
0
29
57
86
1.1e+02
1.4e+02
1.7e+02
Fiber orientation [deg]



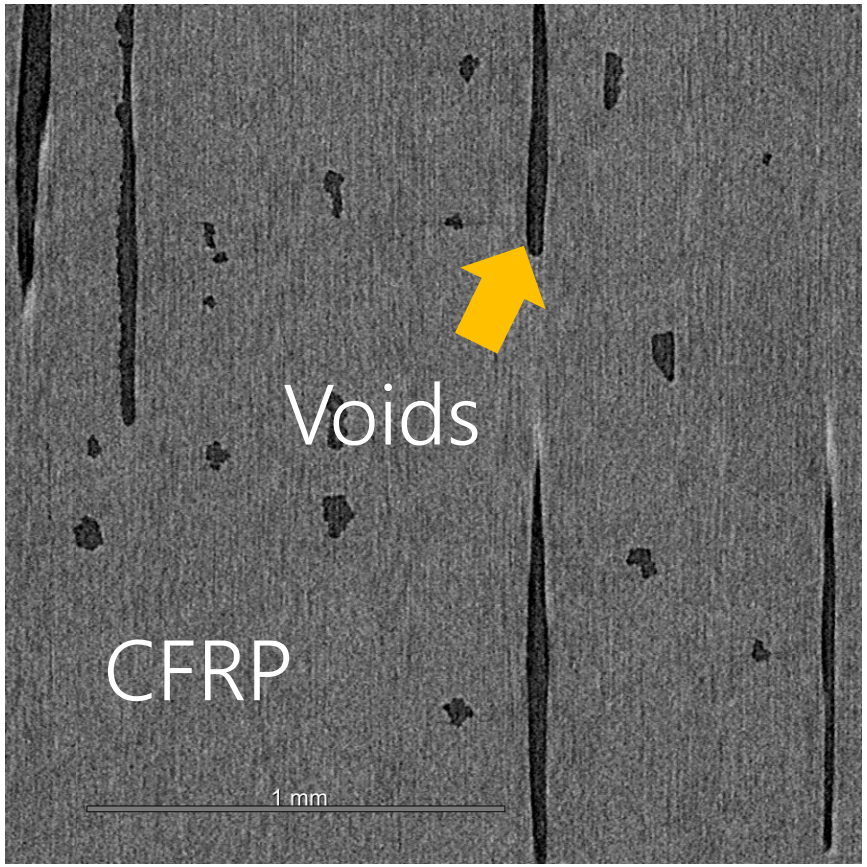
Long  Short

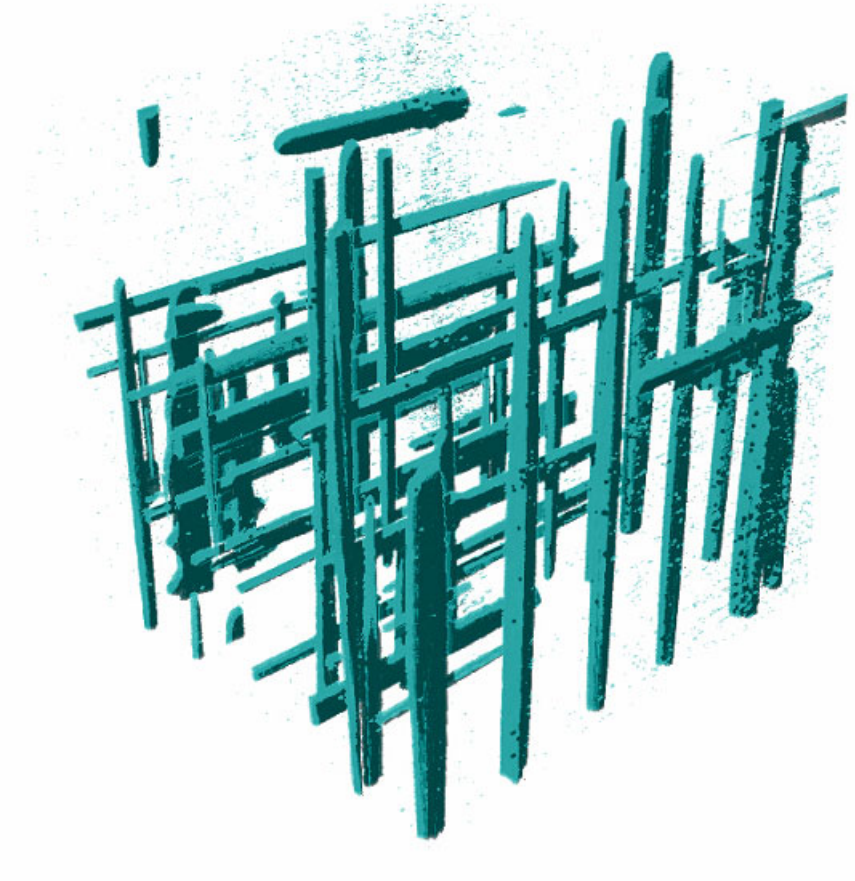


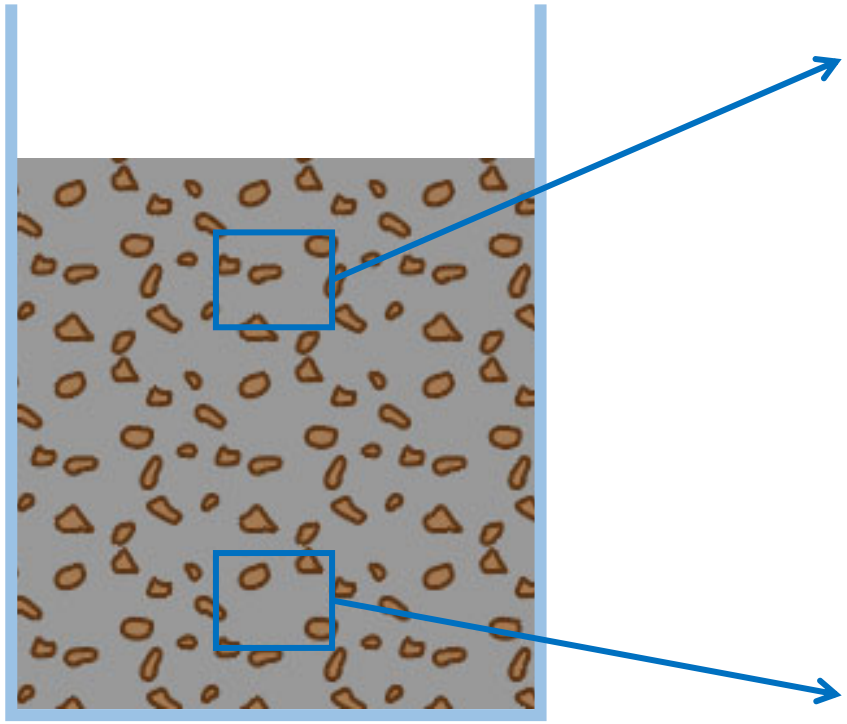


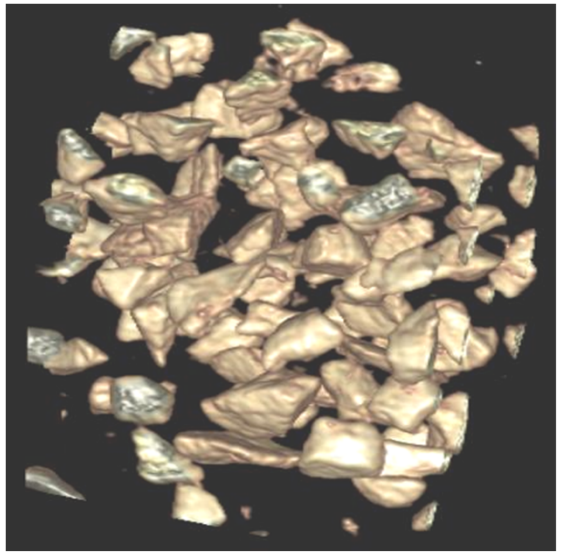

Aspect ratio
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
Fiber orientation [deg]

Voids in CFRP

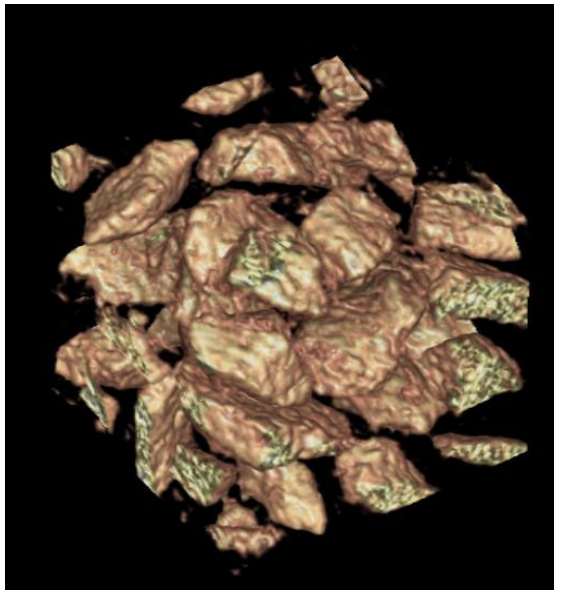






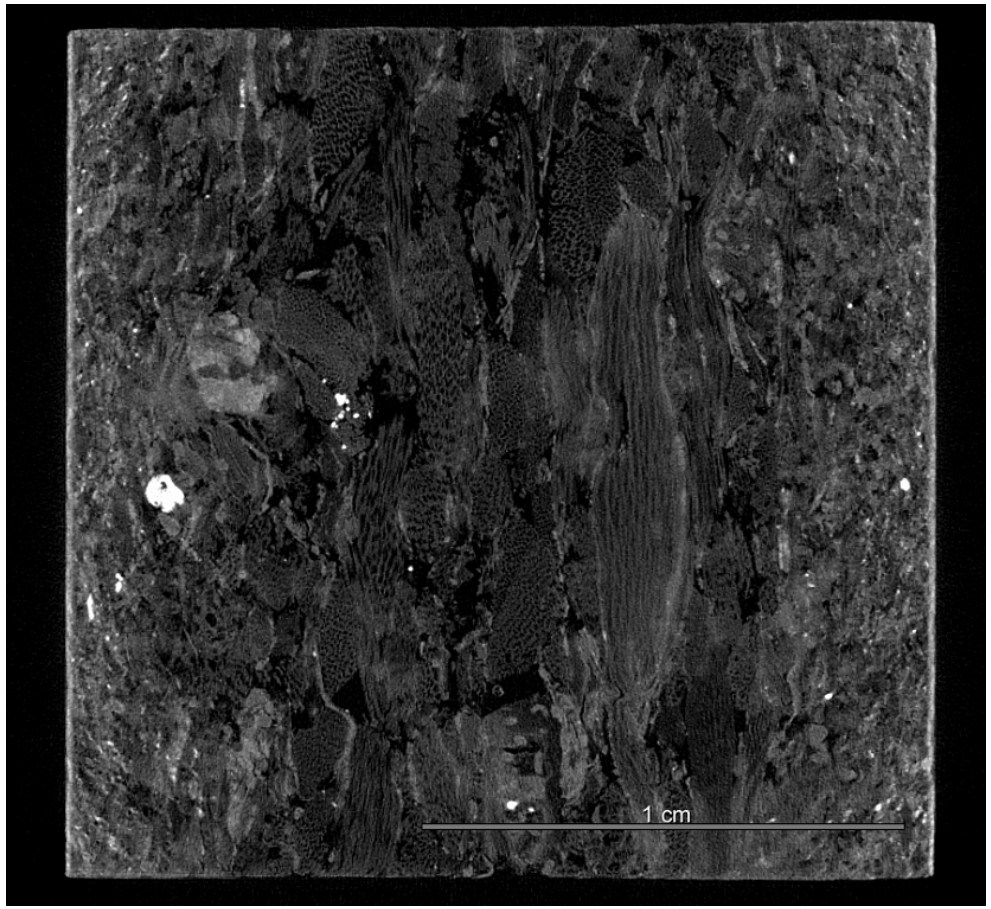


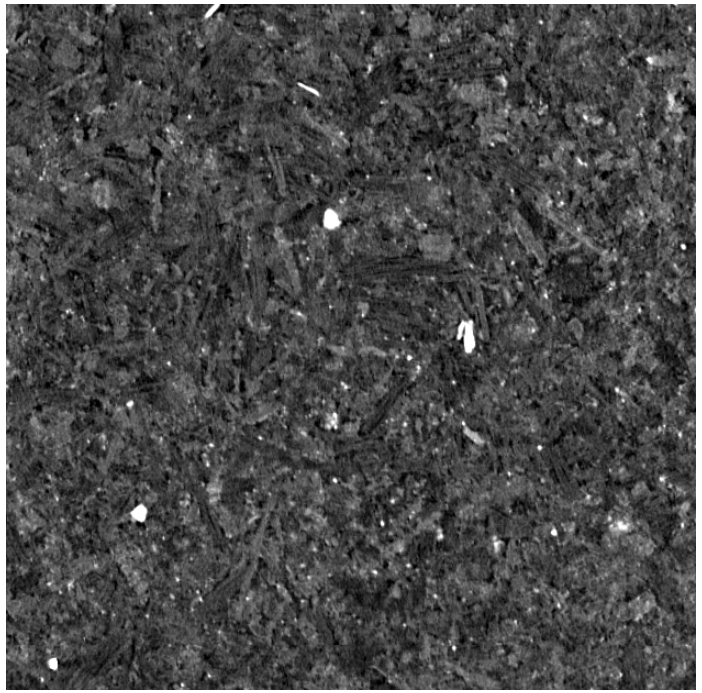
Filler 12 vol%



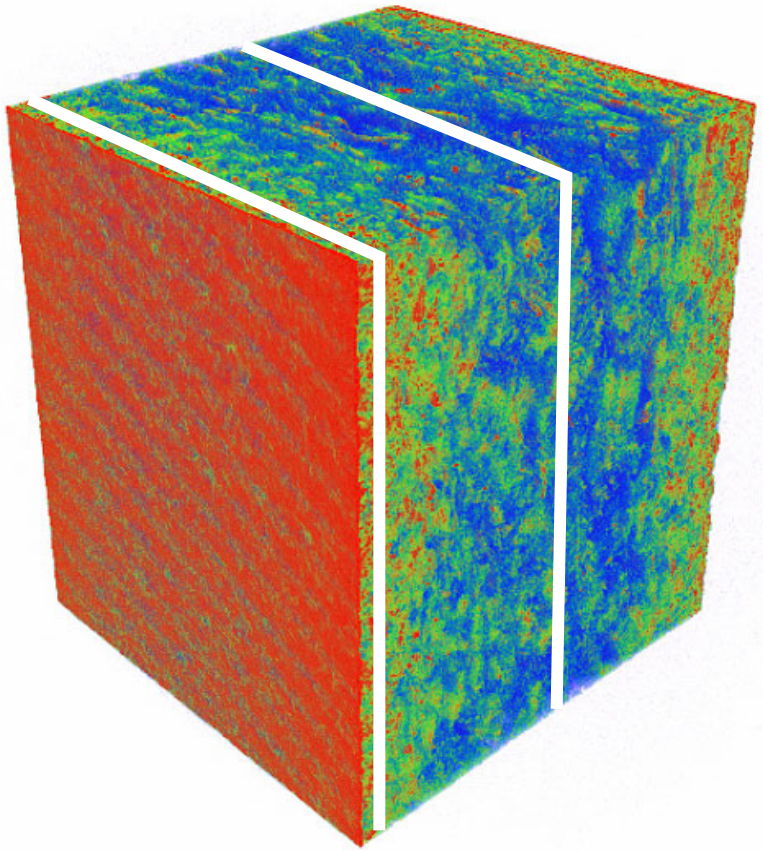
Filler 35 vol%

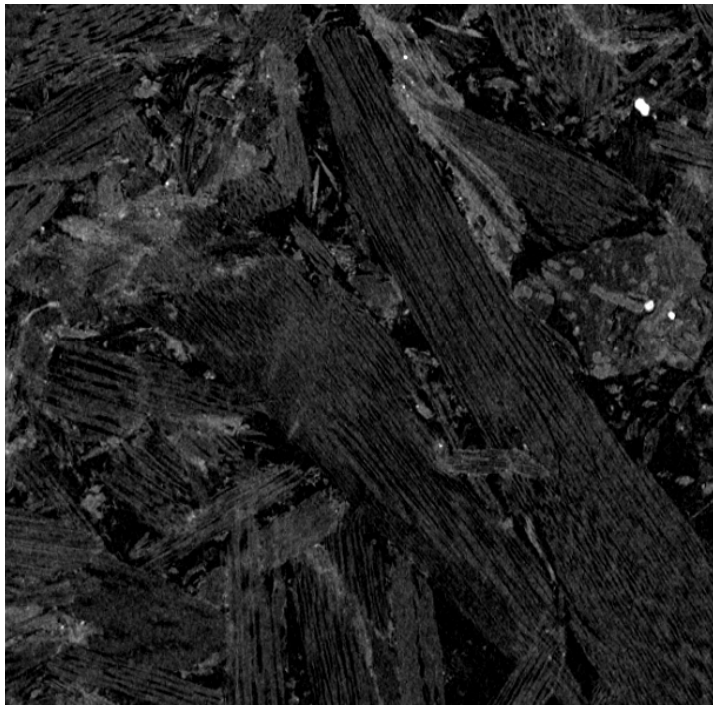
Wood composites





Solid 98.7 vol%

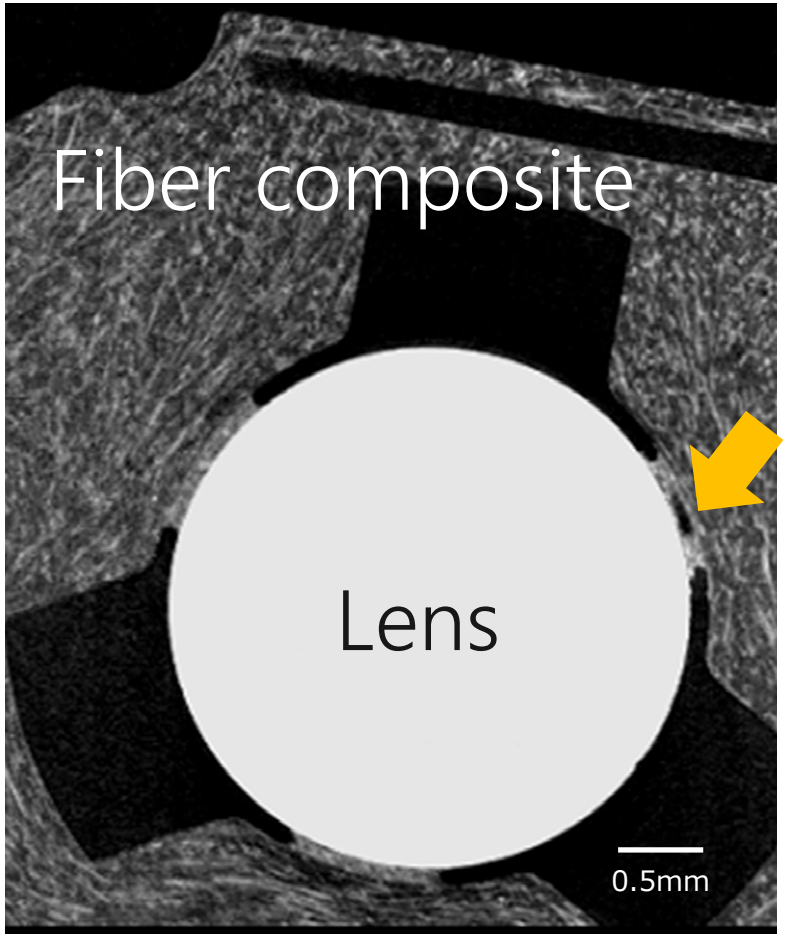


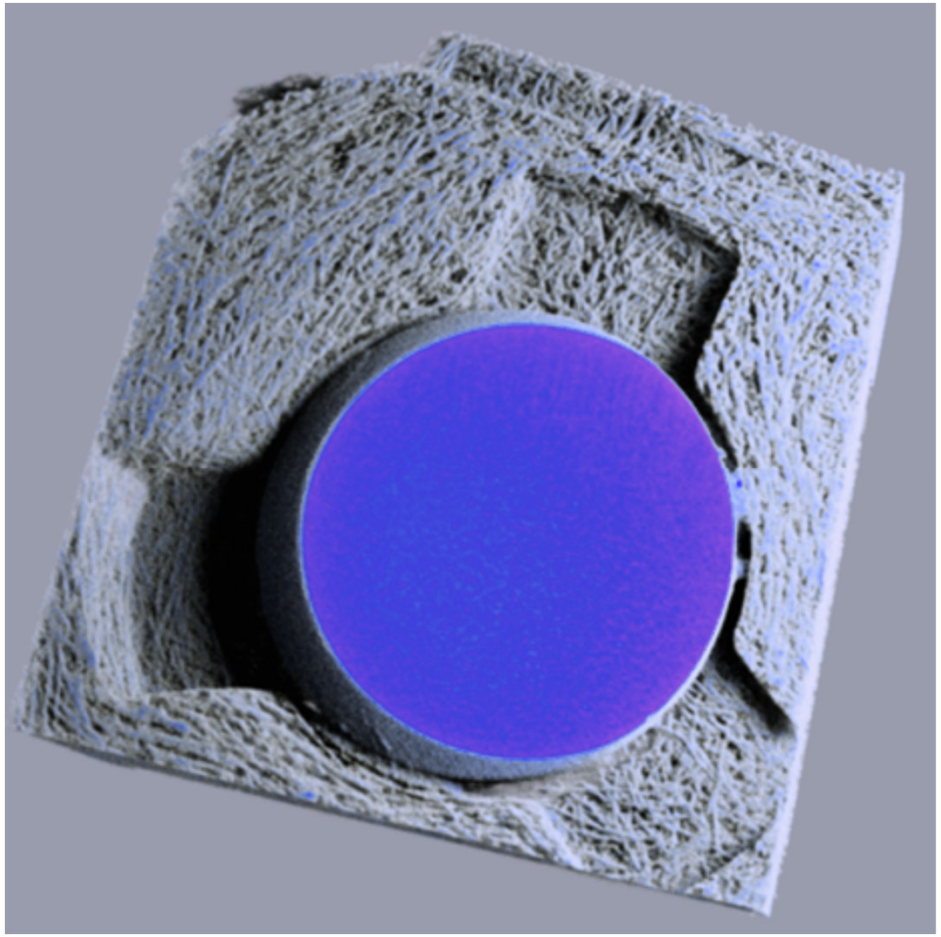


Solid 80.9 vol%

CAN YOU SEE DAMAGES/CRACKS?

Smartphone camera lens





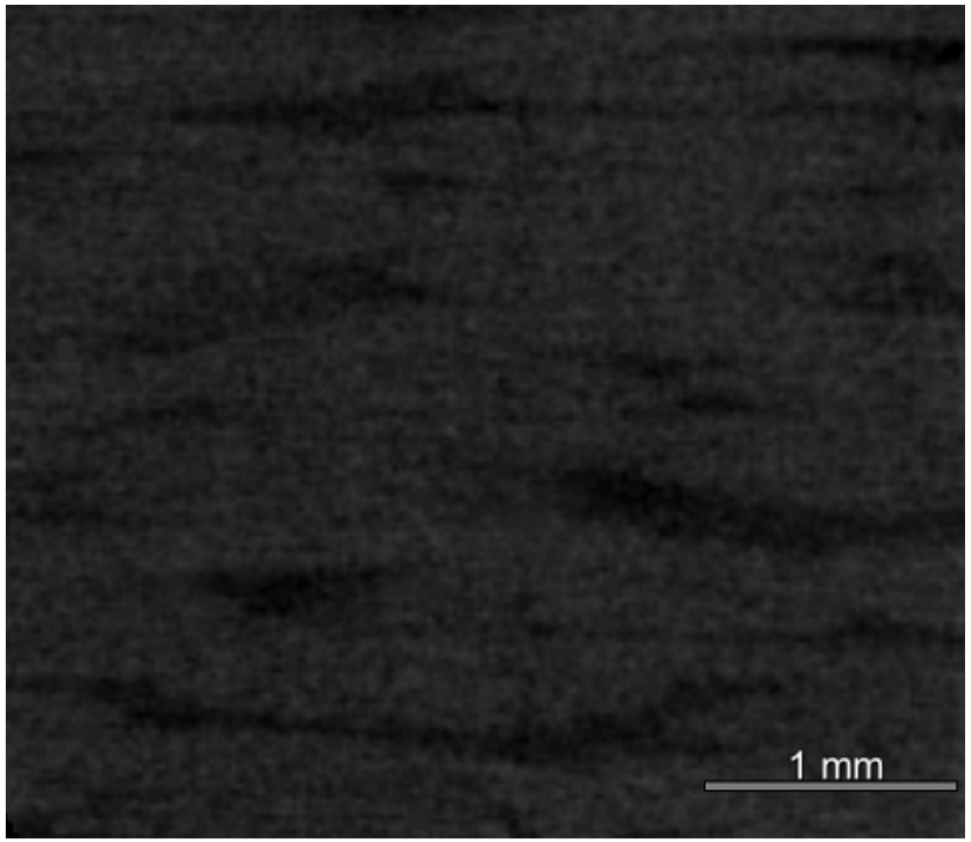
WHAT ABOUT SMALL CRACKS?

Contrasting agent recipe

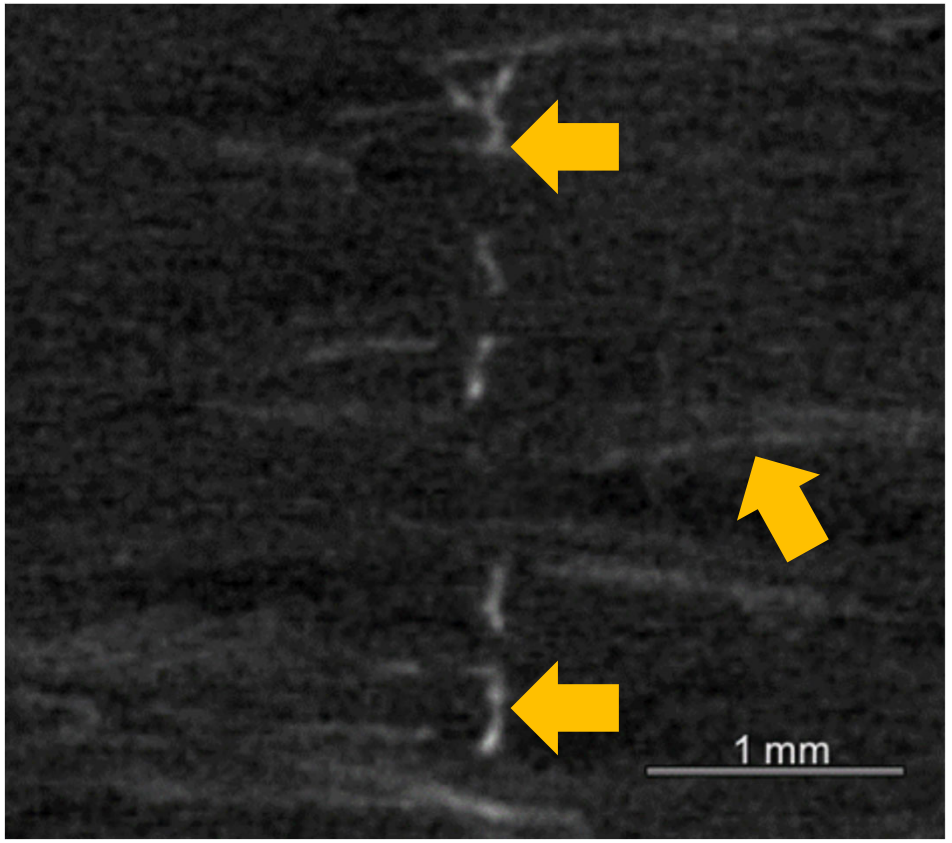
250 g zinc iodide
80 ml distilled water
80 ml isopropyl alcohol
1 ml Kodak Photo-Flo

Soak for 1 - 2 days

Cracks in CFRP



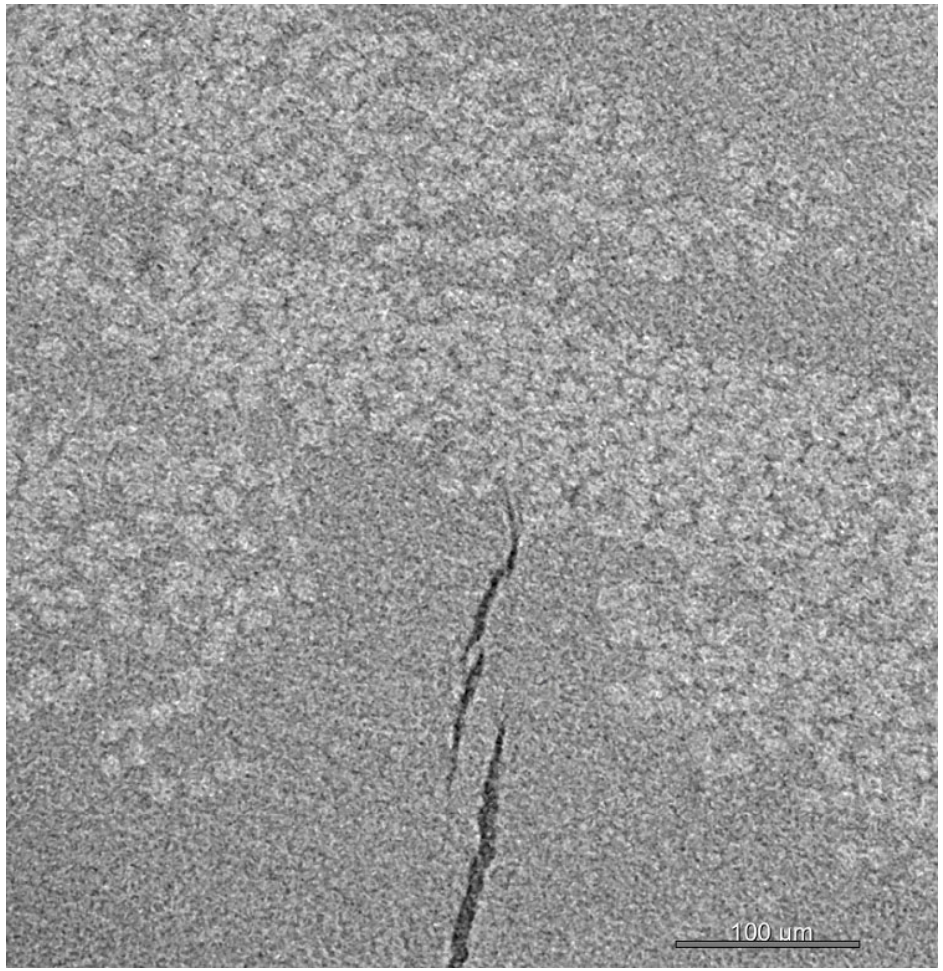
w/o contrast agent



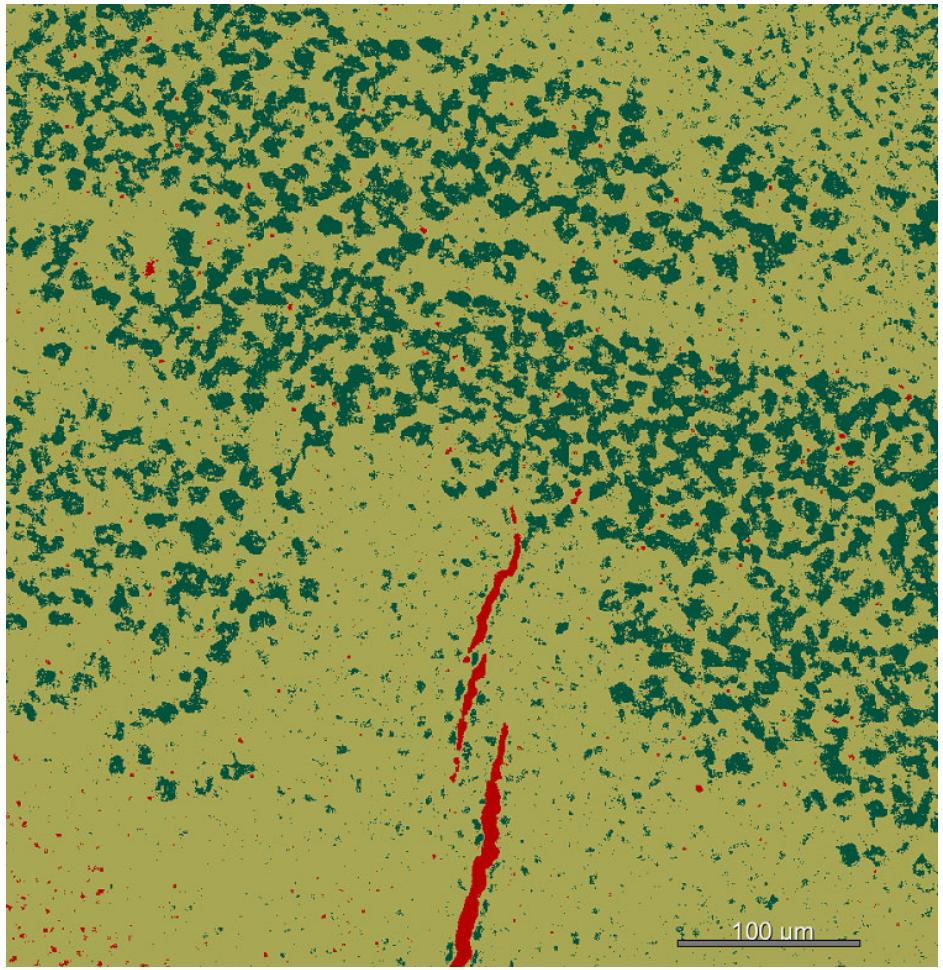
with contrast agent

WHERE ARE THE CRACKS?

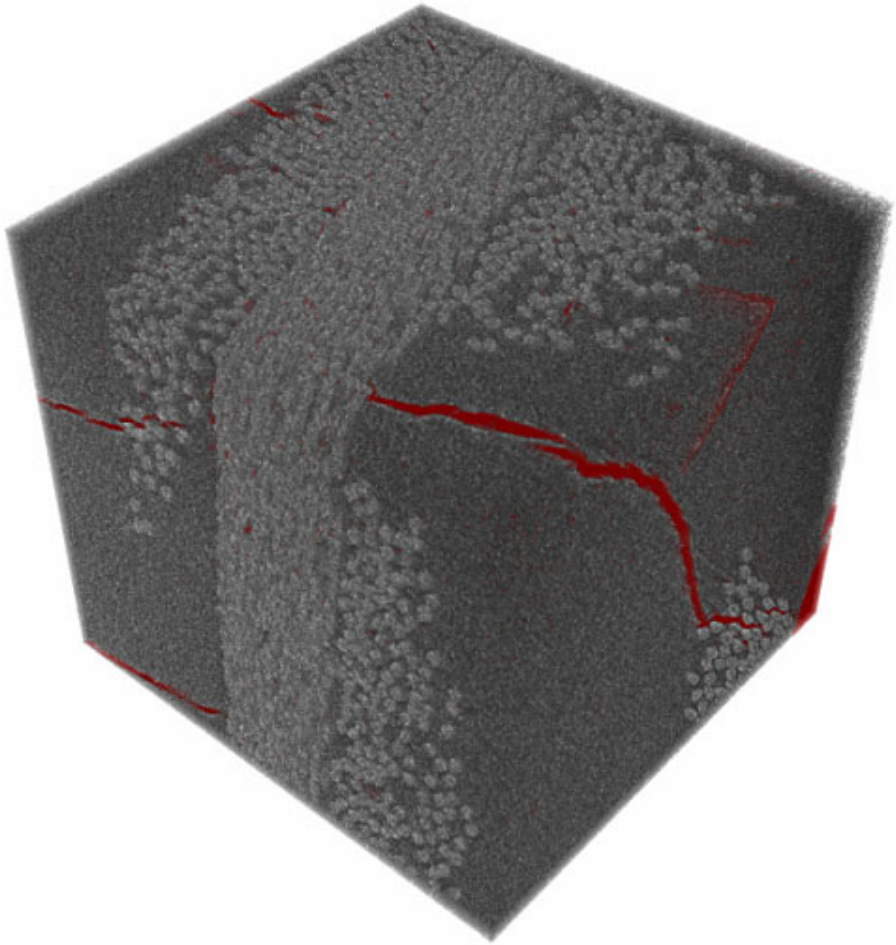
SiC fibers in SiC matrix @ Mo 17 keV



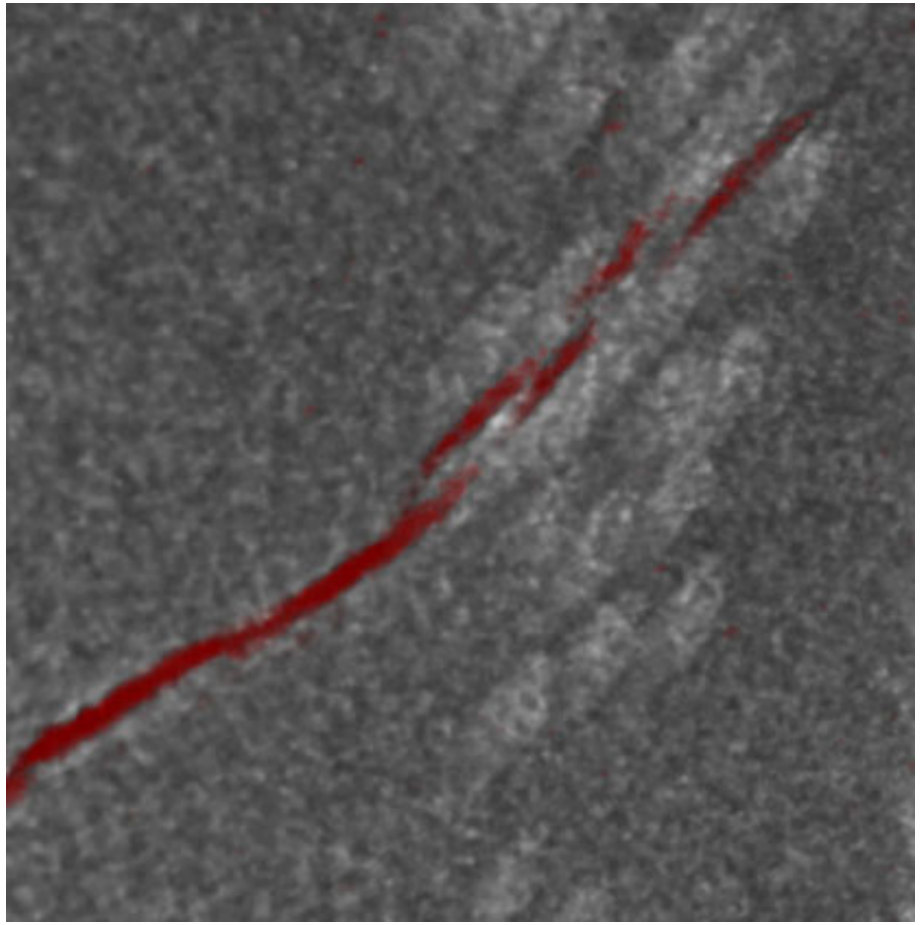
SiC fibers in SiC matrix



SiC fibers in SiC matrix

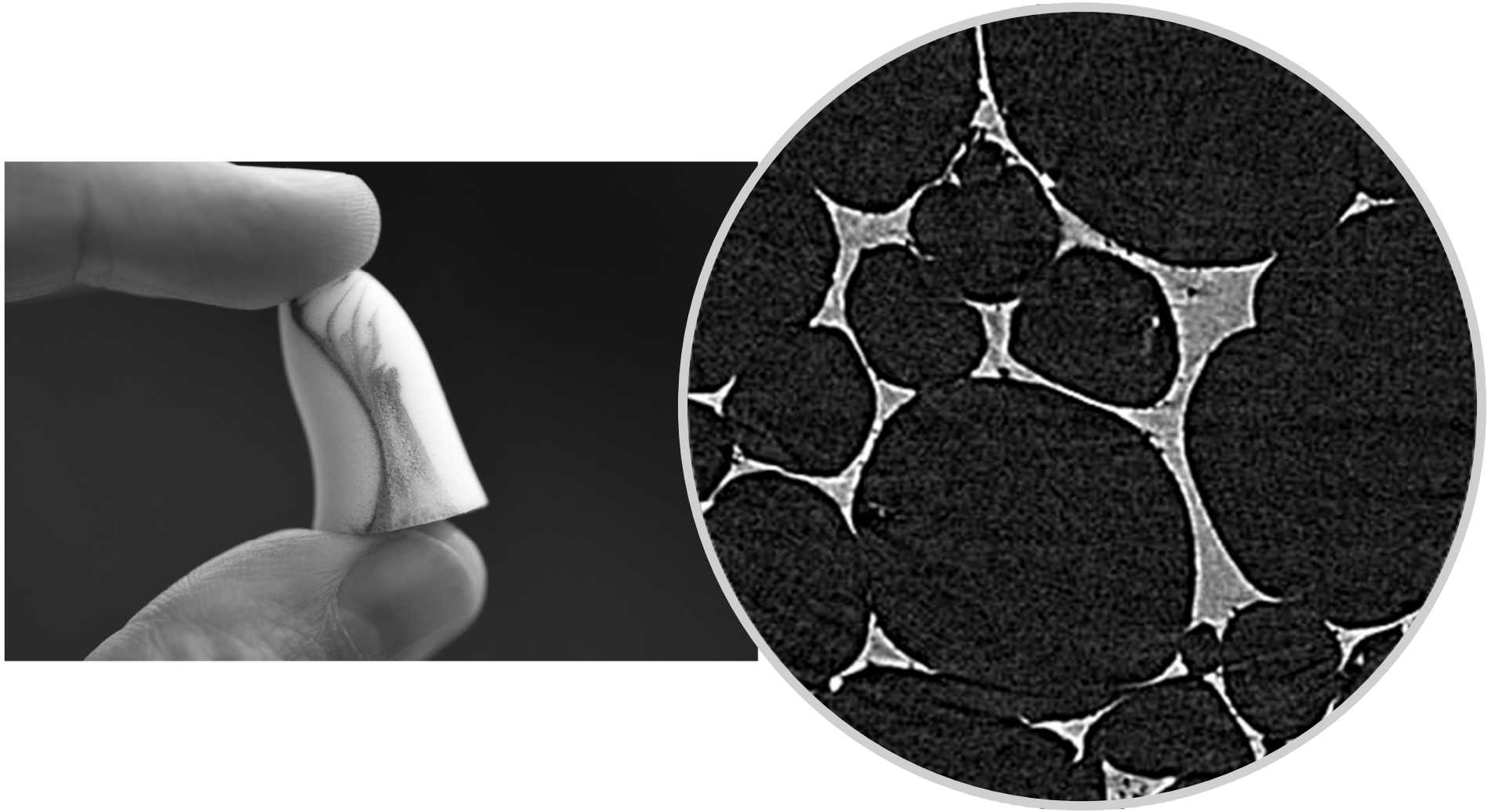


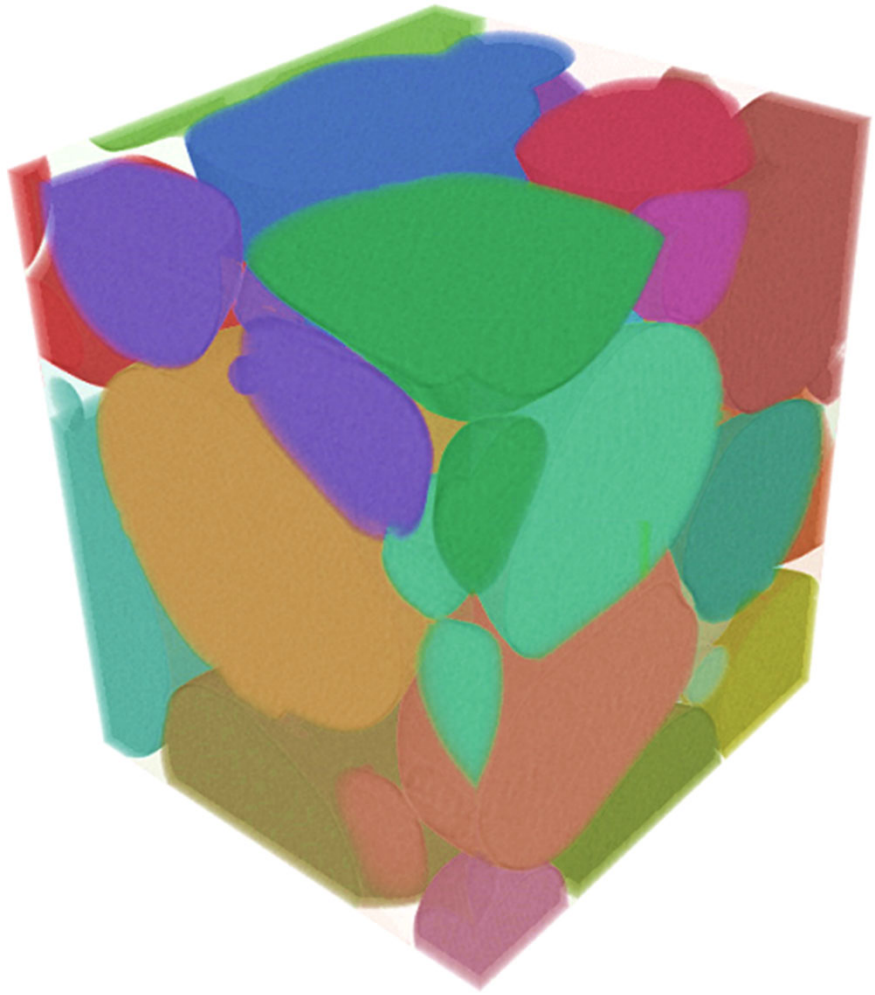
SiC fibers in SiC matrix



COMPOSITE APPLICATIONS

- Volume fraction
- Fiber/filler distribution
- Fiber orientation
- Voids distribution
- Crack visualization





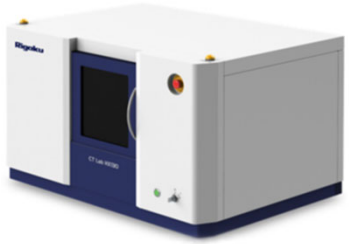
You just learned:

- Keys to high-resolution imaging
- Foams applications
- Composites applications

ALL IMAGES WERE COLLECTED ON…

nano3DX

CT Lab HX



CT Lab GX

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www.rigaku.com/en/webinars/x-ray_ct_introduction

Rigaku webinar

X-ray Microscopy Seminar & Workshop

April 1st Wednesday

University of Delaware, Newark, DE

Q & A SESSION

Aya Takase

Tom McNulty

We'll follow up with your questions.

Recording will be available tomorrow.

Send your ideas to aya.takase@rigaku.com