WELCOME

RIGAKU WEBINAR SERIES

X-RAY COMPUTED TOMOGRAPHY FOR MATERIALS & LIFE SCIENCE

4D AND IN-SITU APPLICATIONS

IS STARTING NOW.

Presenter: Aya Takase

Director of X-ray Imaging
Rigaku Americas Corporation

Host: Tom Concolino

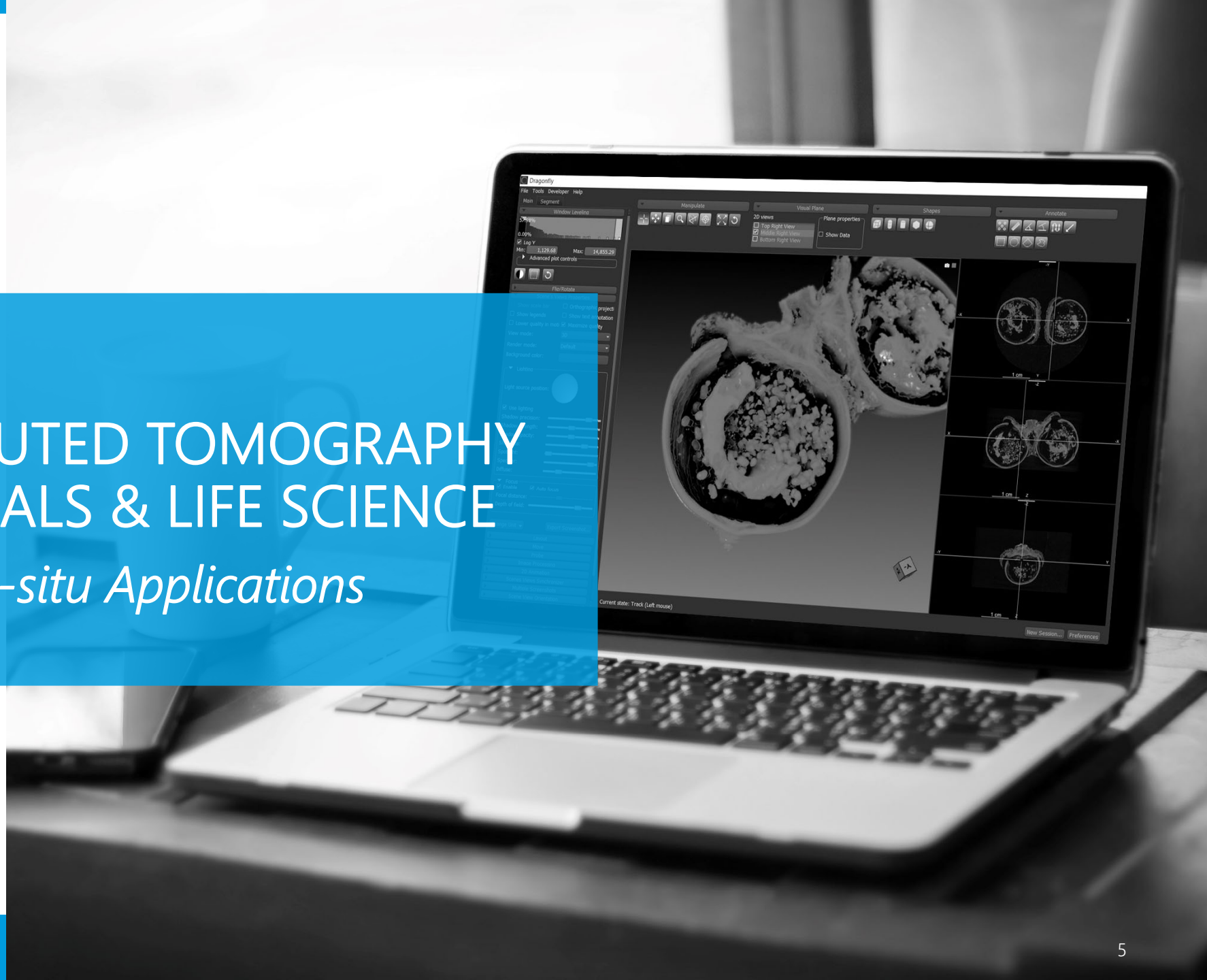
Southeast Regional Account Manager
Rigaku Americas Corporation

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 & LIFE SCIENCE

4D and In-situ Applications




ENCAP


60
5
55
10
50
15
45
20
1/5

You will learn:

- Keys to 4D & *in-situ* CT
- How to plan experiments
- 4D & *in-situ* applications

WHAT IS 4DCT?

4DCT = 3D + time

Time resolved CT measurements

WHAT IS *IN-SITU* CT?

In situ

Latin: on site, in position

→ *Measurements in the same place the phenomenon is occurring*

WHAT TO CONSIDER?

Duration of the process

Sample environment

Duration of the process

Sample environment

Popcorn?

Duration < 0.1 sec*

Temperature ~ 180°C**

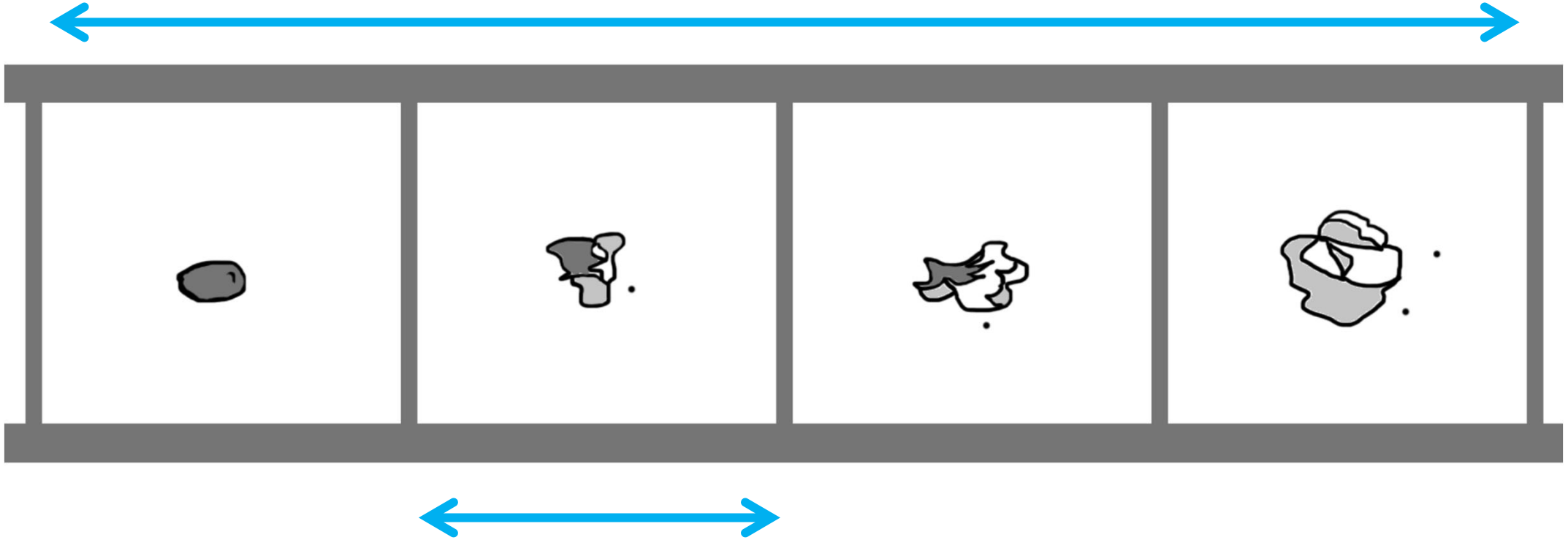
* https://www.latimes.com/science/sciencenow/la-sci-sn-popcorn-science-20150210-story.html
** https://www.scientificamerican.com/article/explore-the-pop-in-popcorn/

WHAT IS TOO FAST?

Process duration > CT scan duration

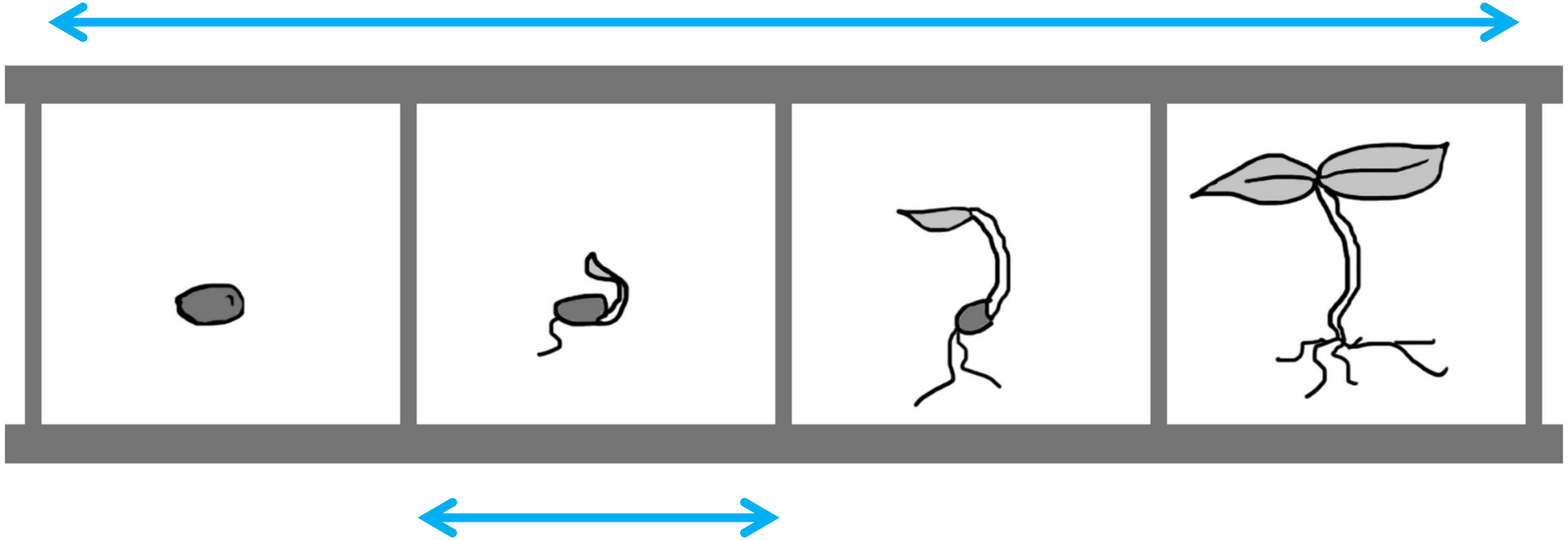
a few sec ~ hrs. /scan

~ 0.1 second / process

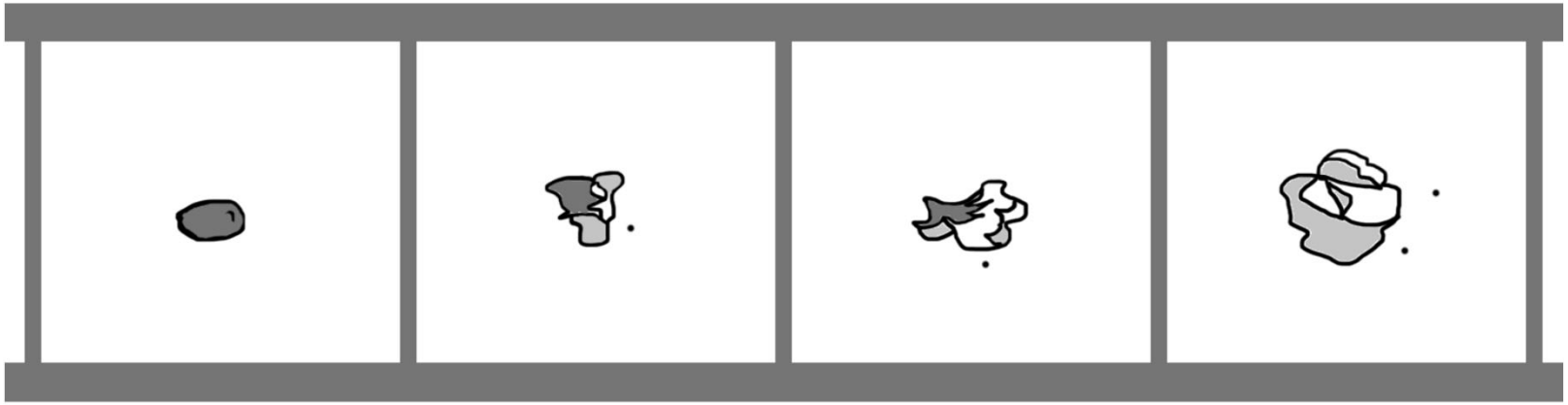


~ 0.025 second / scan

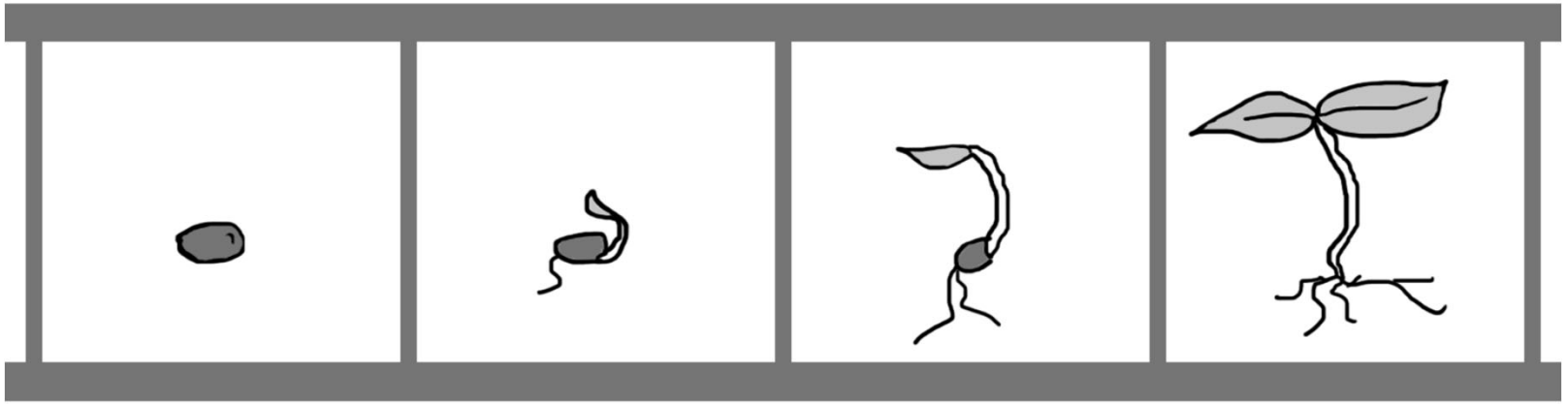
~ 4 days / process



~ 1 day / scan



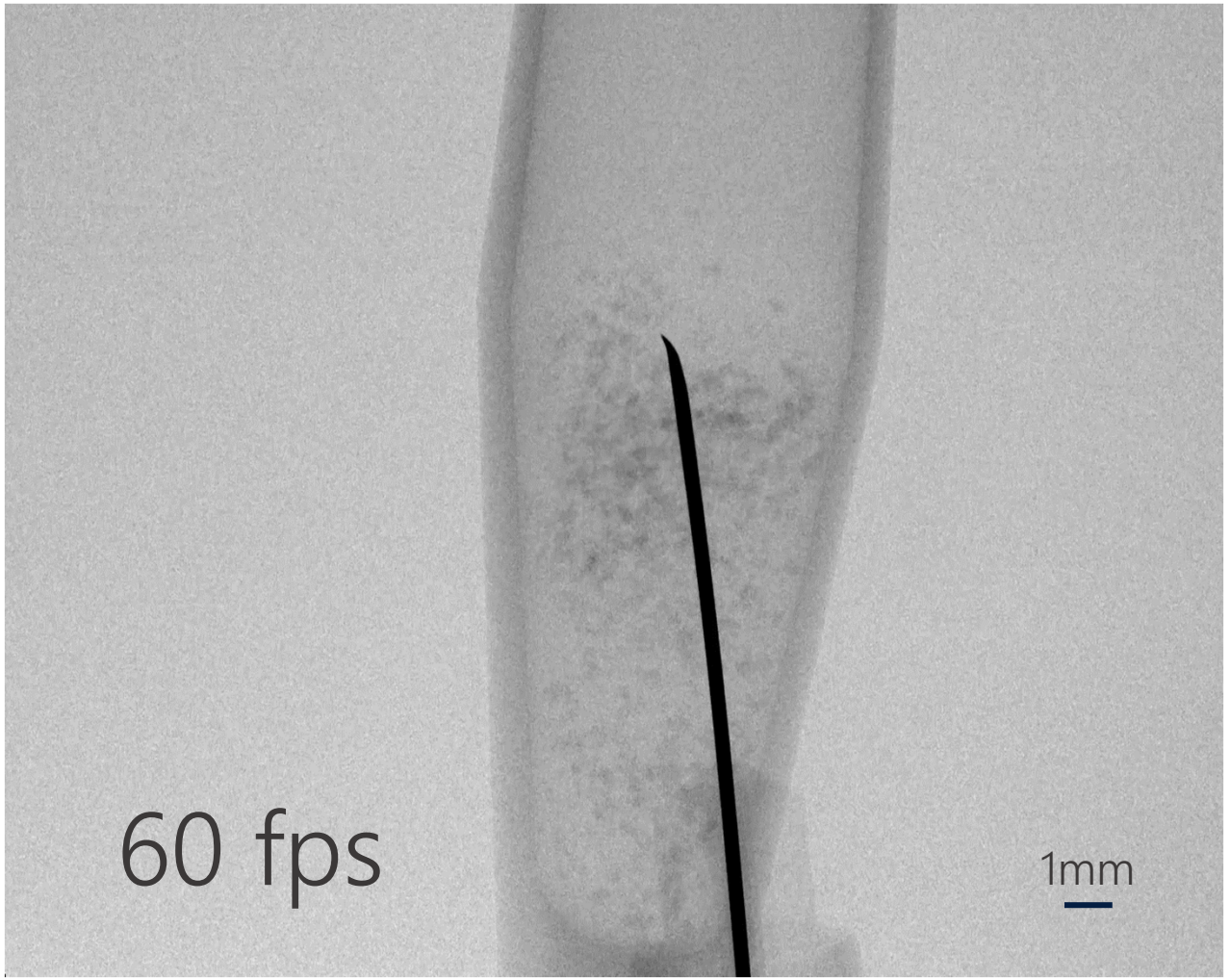
Too fast



Good pace

DO WE NEED TO GIVE UP IF IT'S TOO FAST?

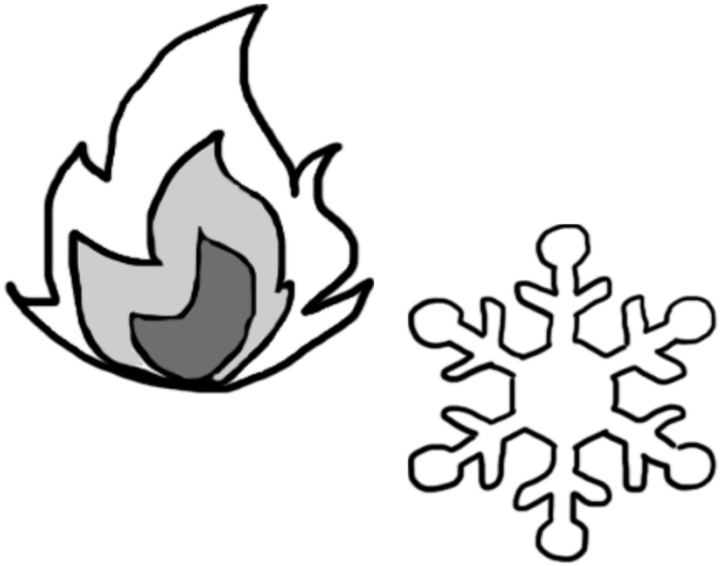
Water injection into superabsorbent



Duration of the process

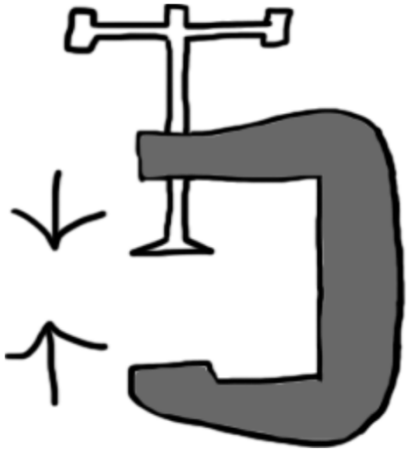
Sample environment

Temperature

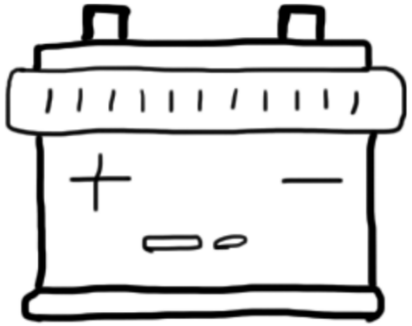


Humidity

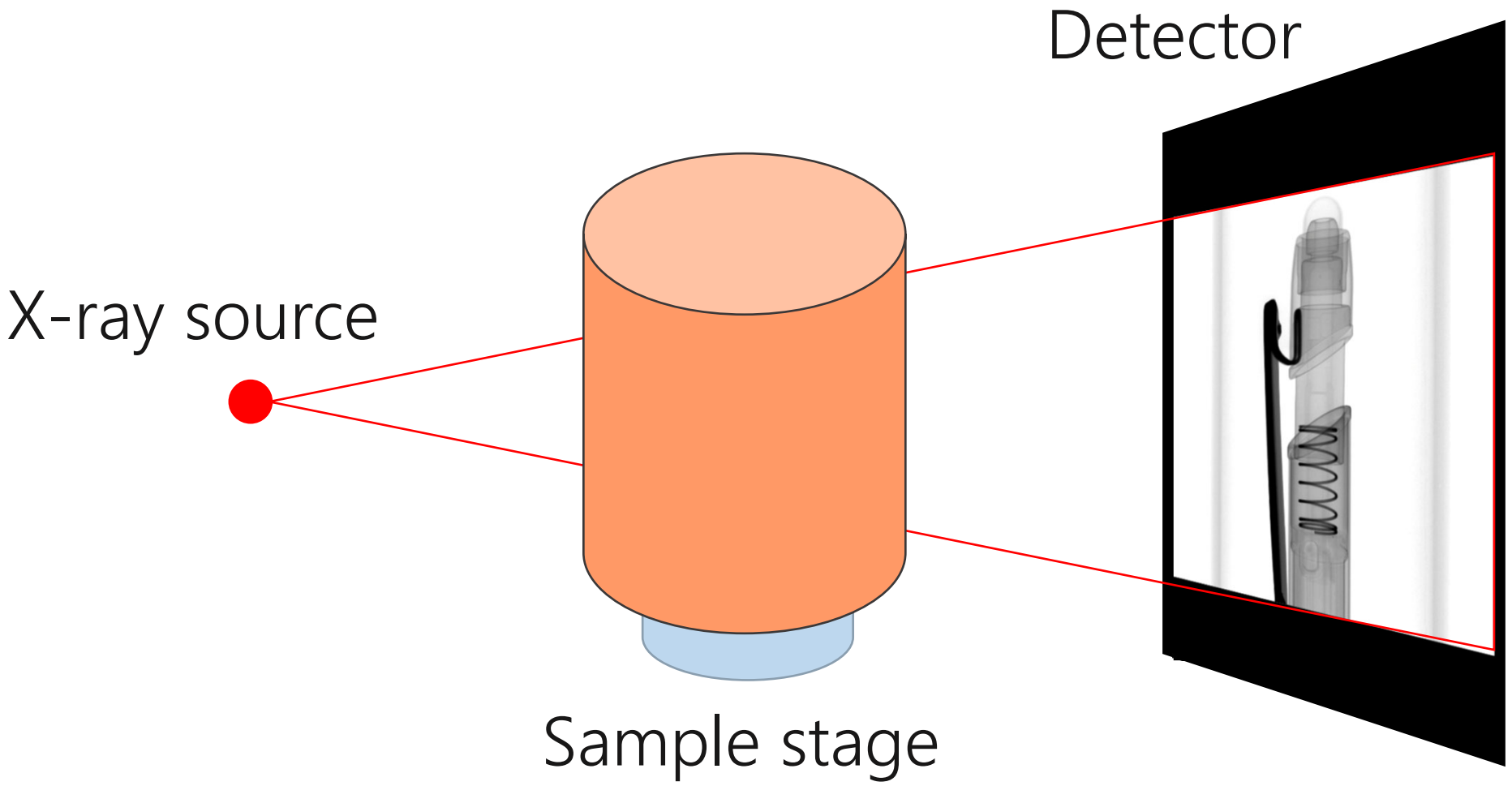
Stress



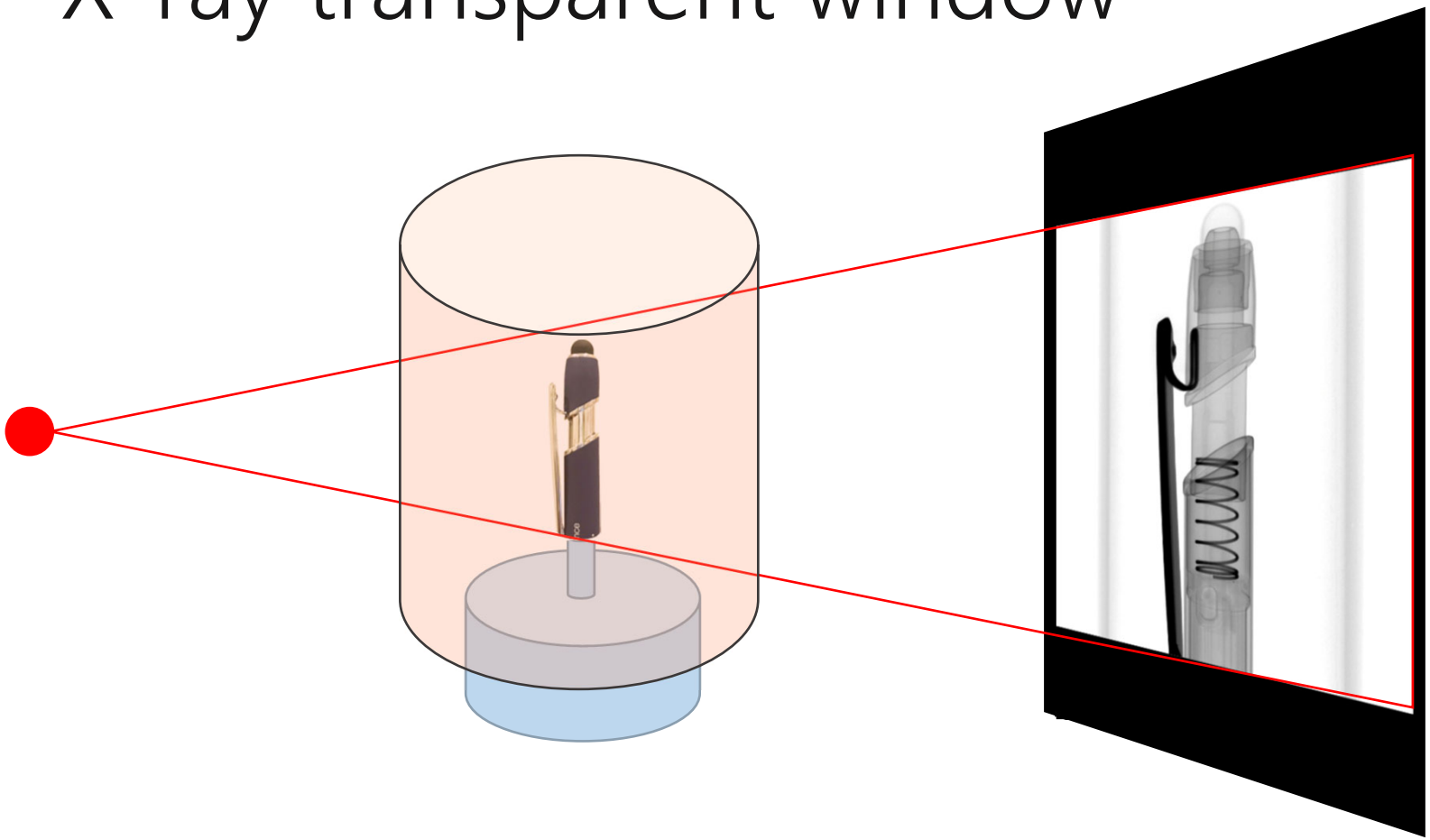
Charge



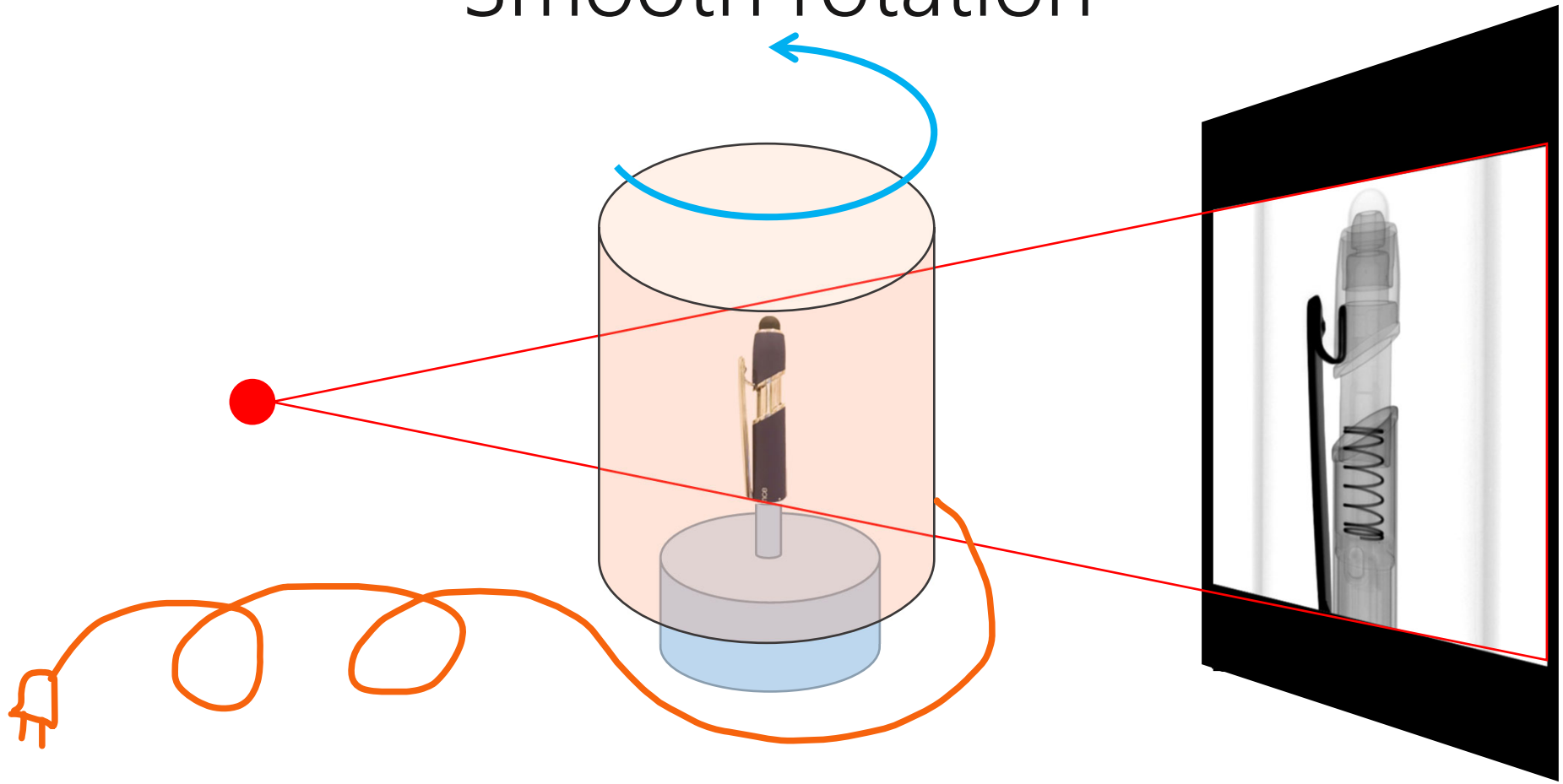
WHAT IS REQUIRED OF AN *IN-SITU* CHAMBER?


Detector
X-ray source
Sample stage

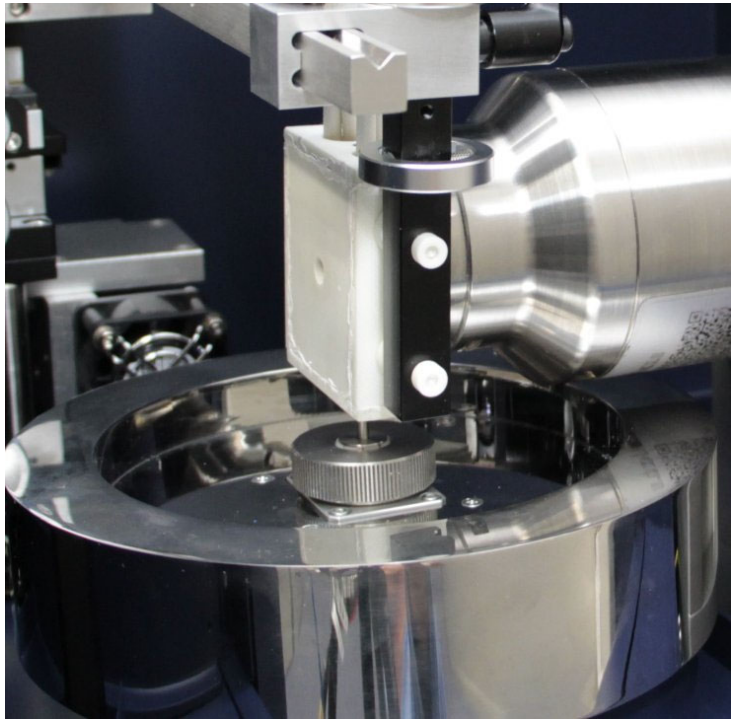
X-ray transparent window



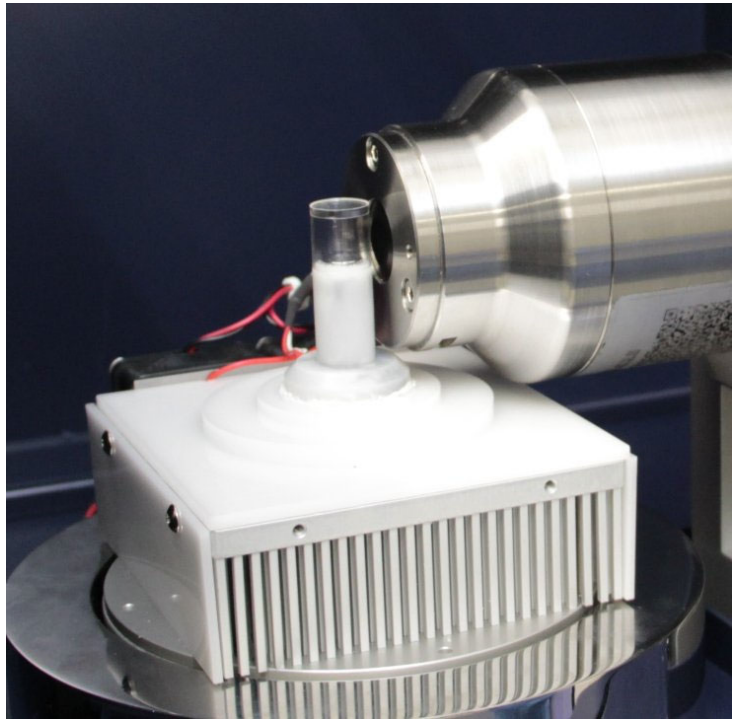
Smooth rotation



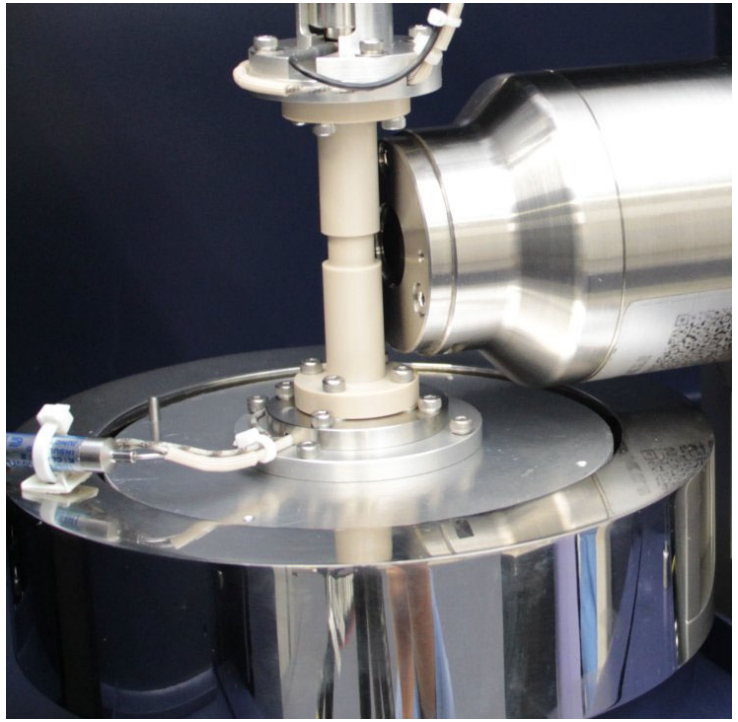
WHAT KIND OF CHAMBERS ARE AVAILABLE?



RT – 200°C
Sample size ~ 5 mm

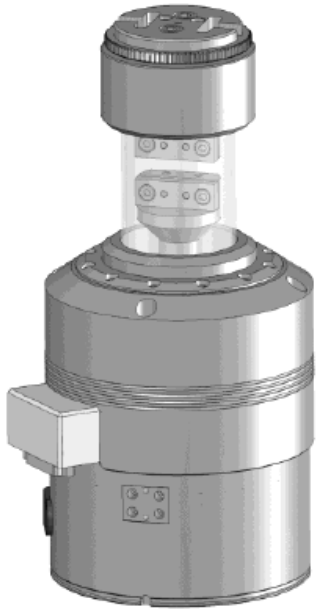


-20°C – RT
Sample size ~ 5 mm

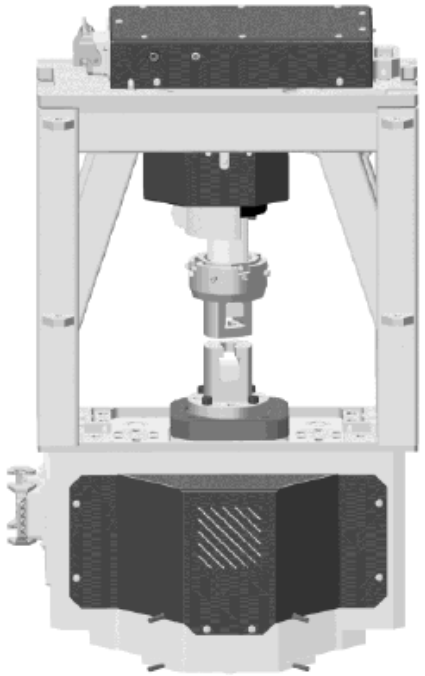


RT – 200°C & 1 – 200 N
Sample size 10 x 2 mm

DEBEN deben.co.uk

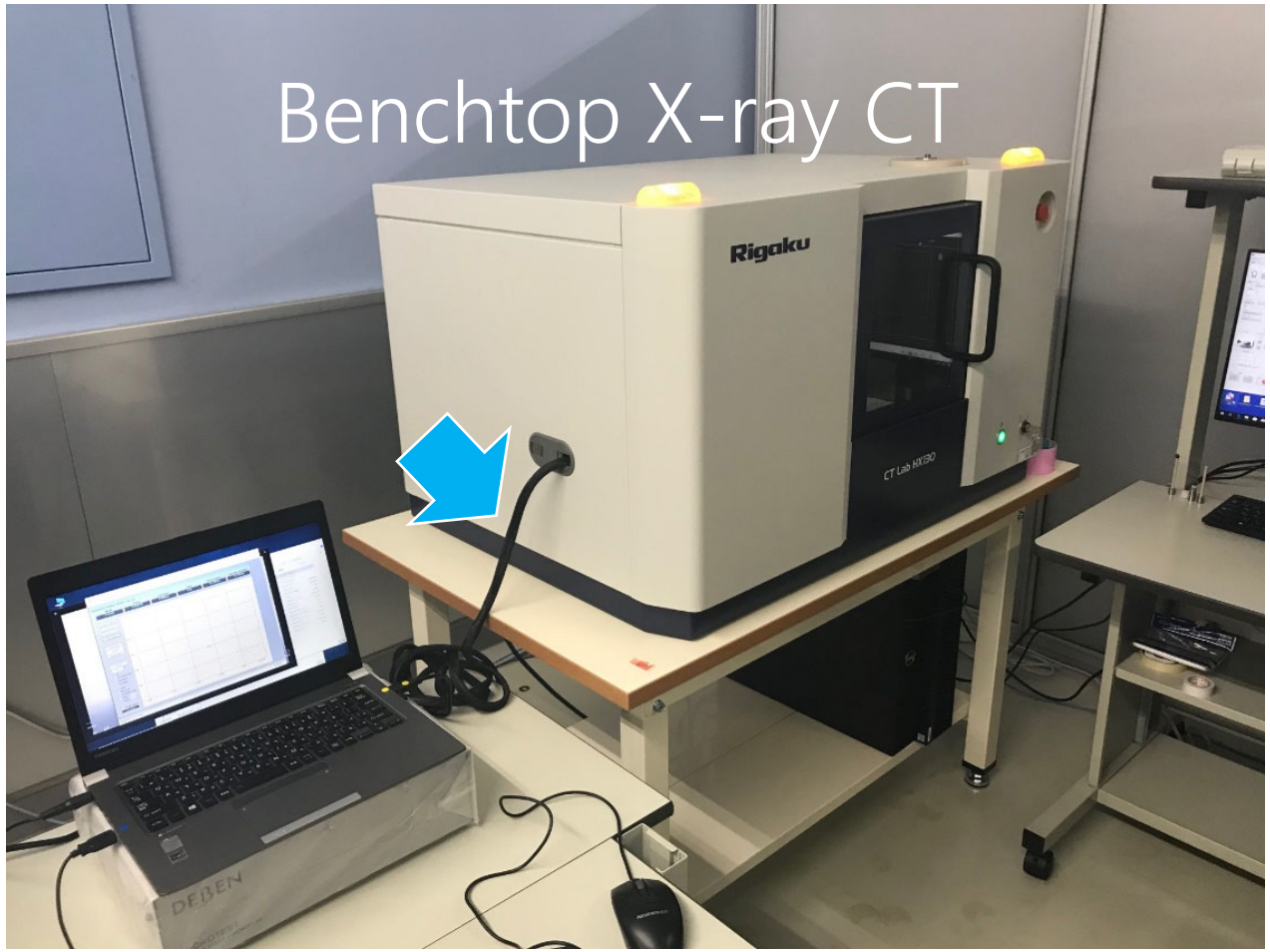


5K N, 250°C

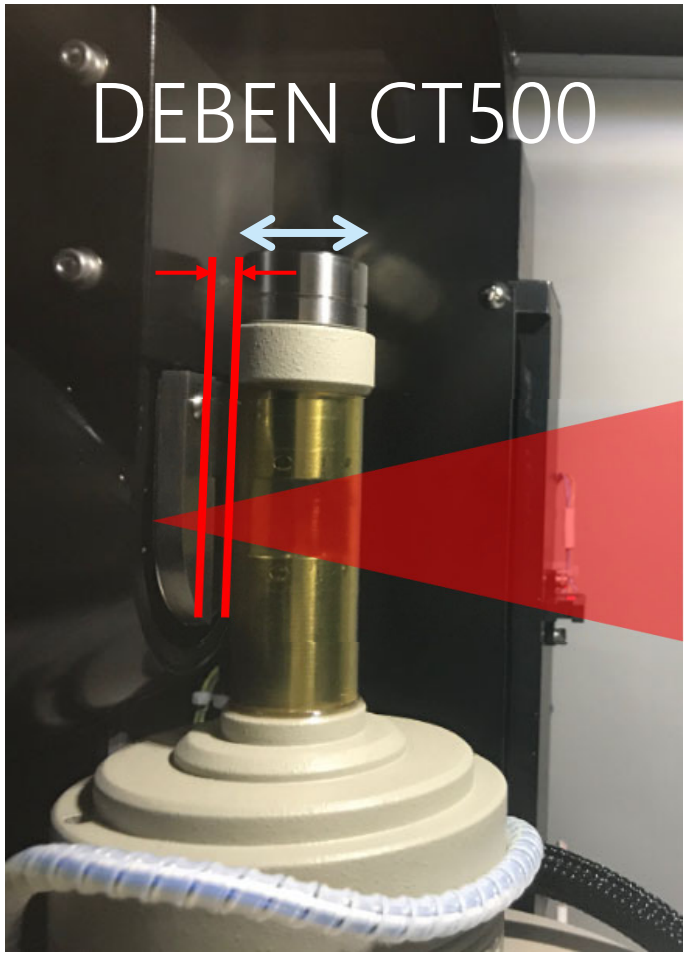


10K N

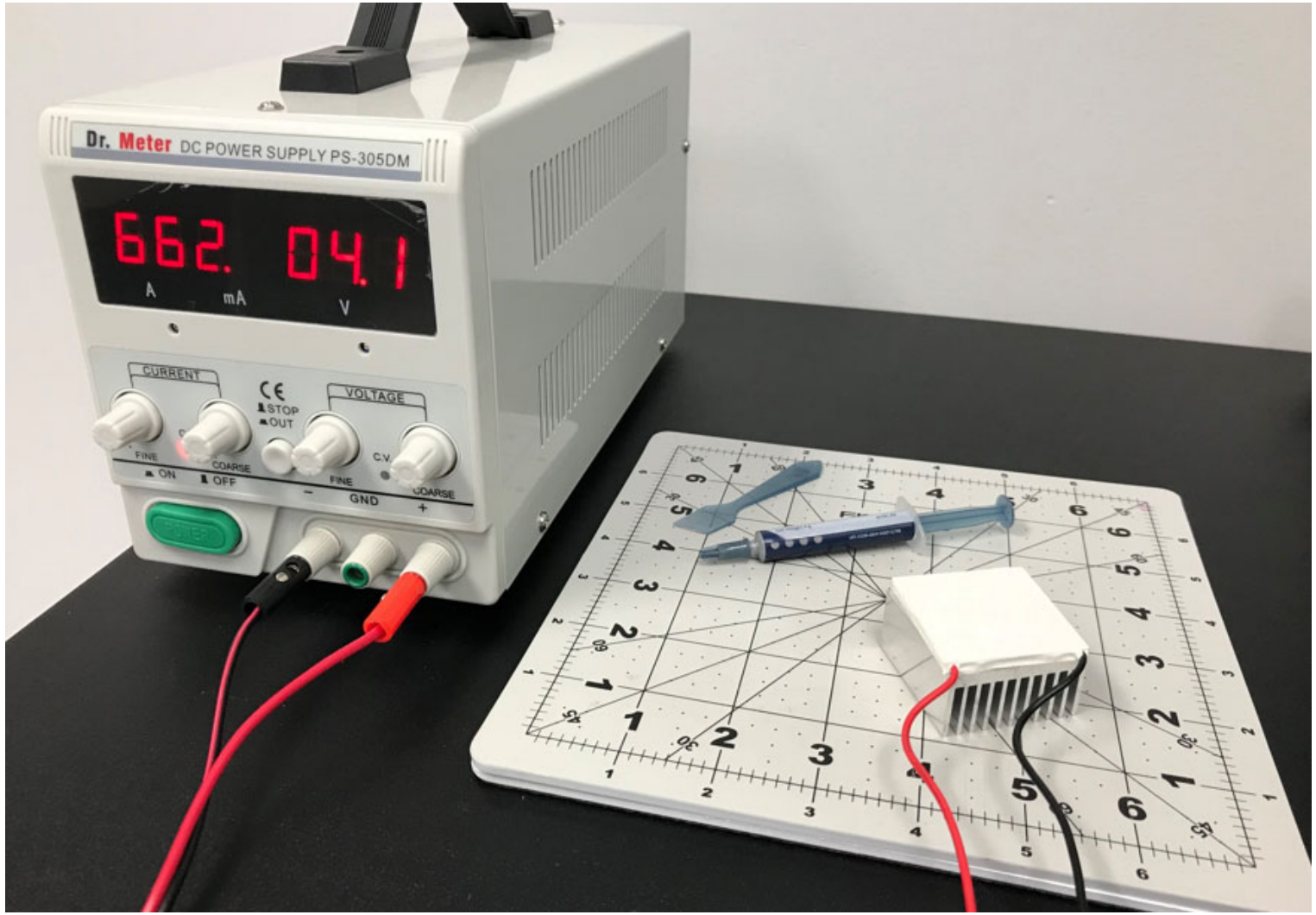
Benchtop X-ray CT



DEBEN CT500

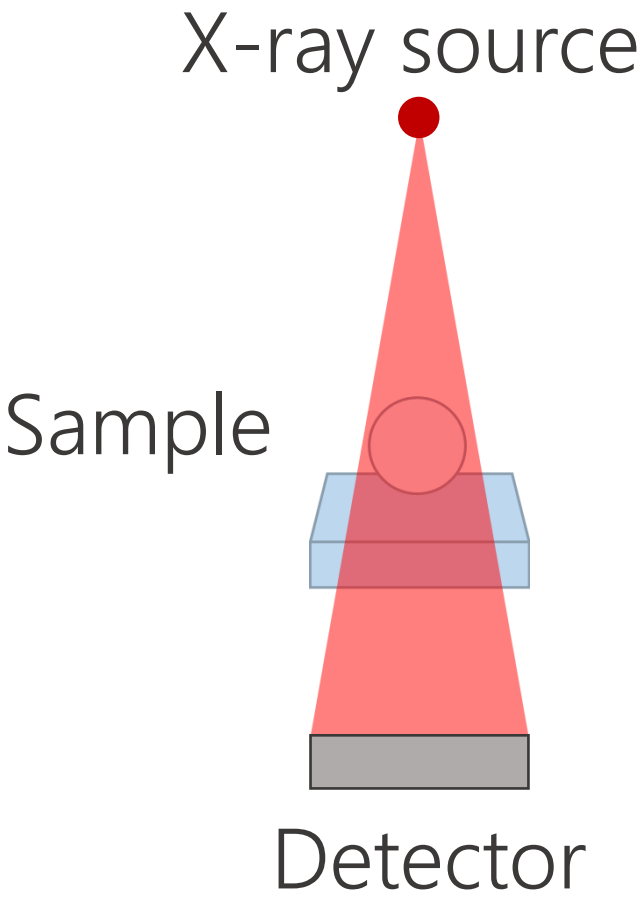


CAN WE MAKE OUR OWN STAGE?


Dr. Meter DC POWER SUPPLY PS-305DM
662. 04.1
A
mA
V
CURRENT
VOLTAGE
FINE
COARSE
STOP
OUT
ON
OFF
FINE
COARSE
C.V.
GND

WHAT IF WE DON'T WANT TO ROTATE THE SAMPLE?

Gantry system

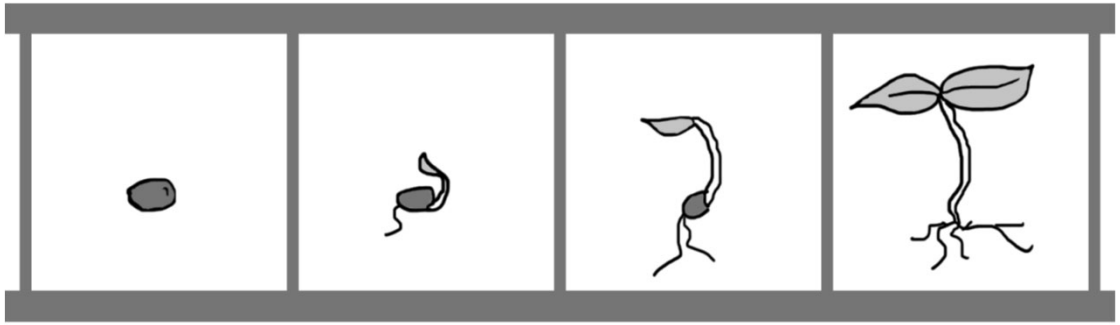


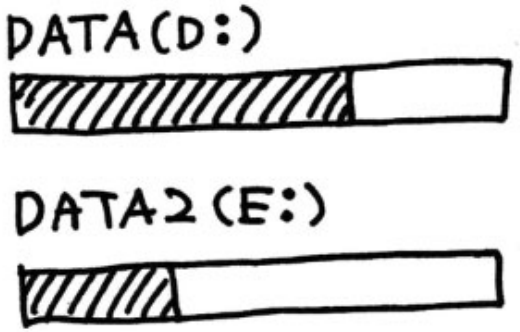

CT Lab

Duration of the process

Sample environment

HOW TO PLAN EXPERIMENTS?





Run test scans and analysis.

How long is the whole process?

How many scans do I want to analyze?

Duration / scan

Fast change

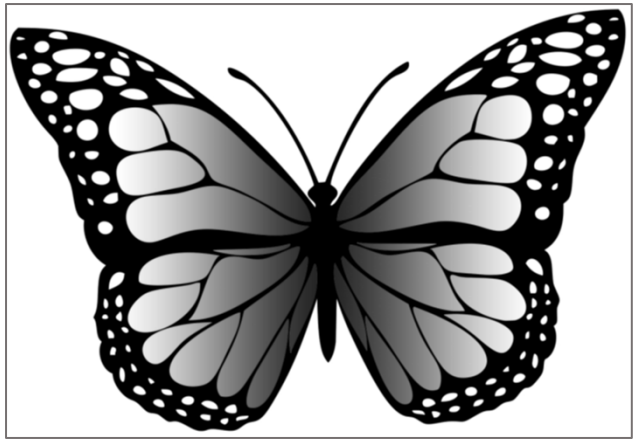
Slow change

Fast change

Slow change

HOW CAN WE SCAN FASTER?

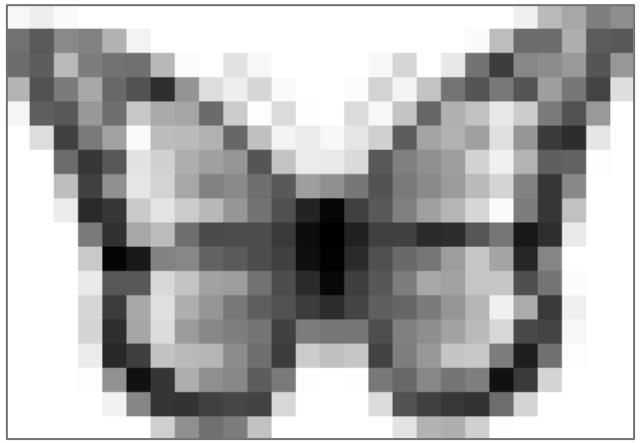
High resolution
Low noise



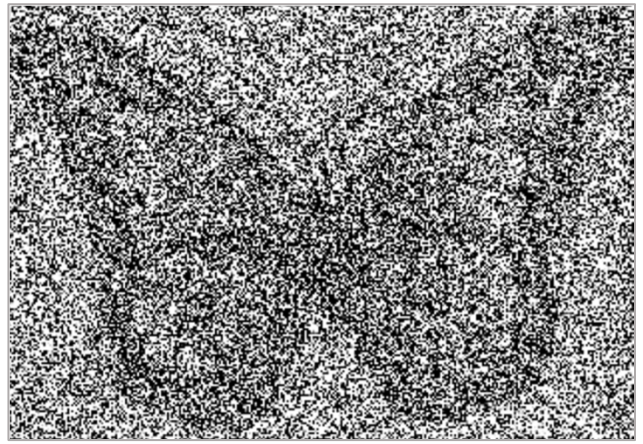
Smaller voxel size
Lower tube current

Higher X-ray power
Slower scan

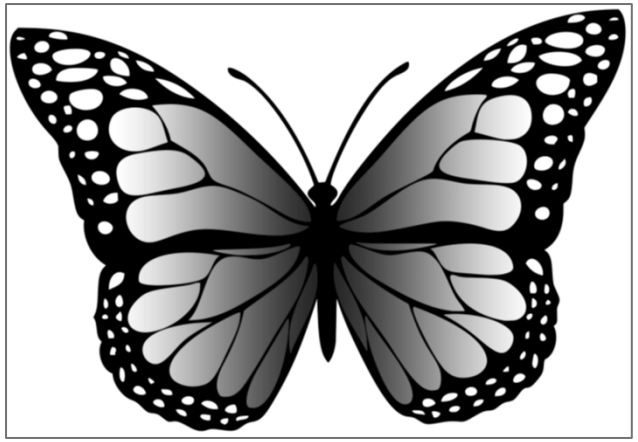
Low resolution



High noise

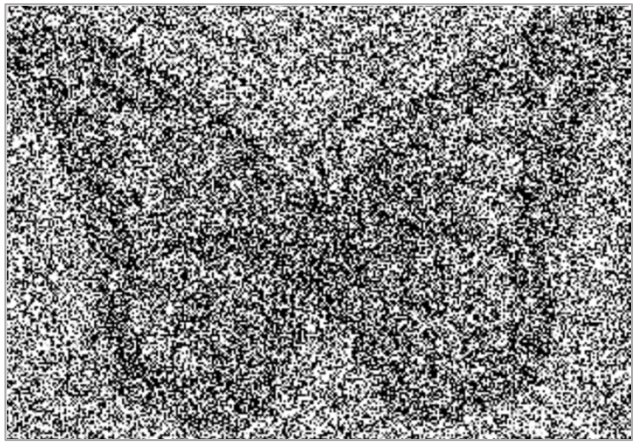


High resolution
Low noise



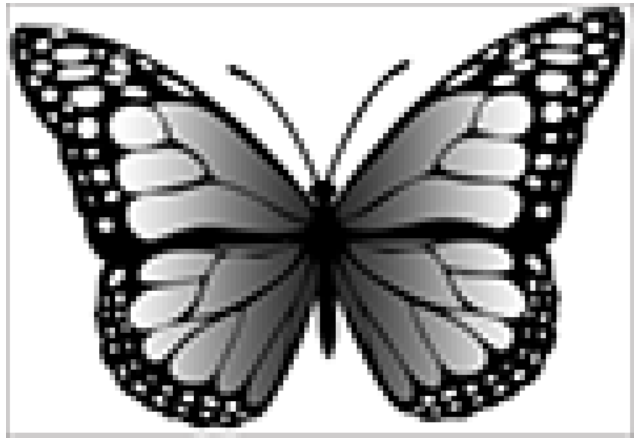
Faster scan

High noise

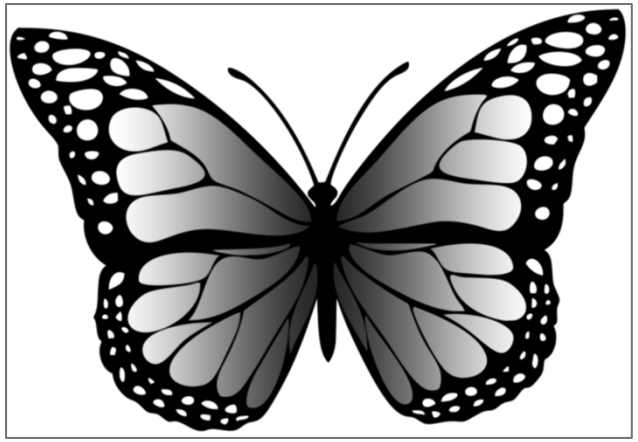


Shorten SDD
Higher tube current
Bin pixels/voxels

Medium resolution



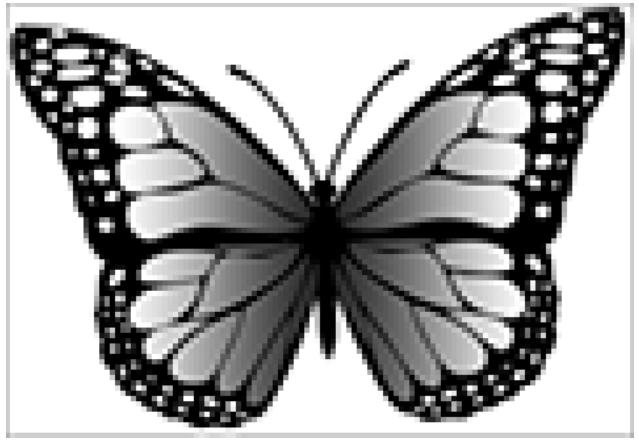
High resolution
Low noise



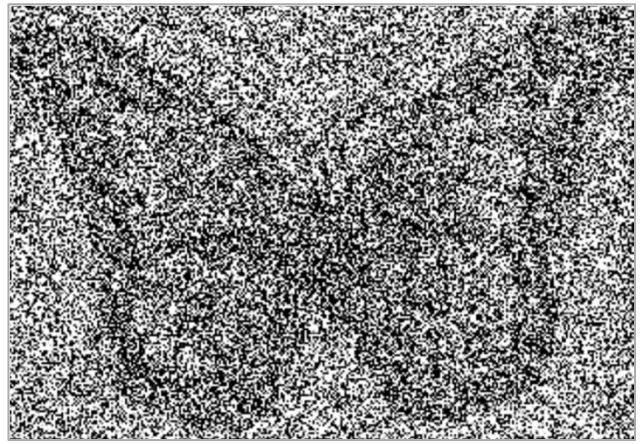
Deep learning
super resolution

Faster scan

Medium resolution

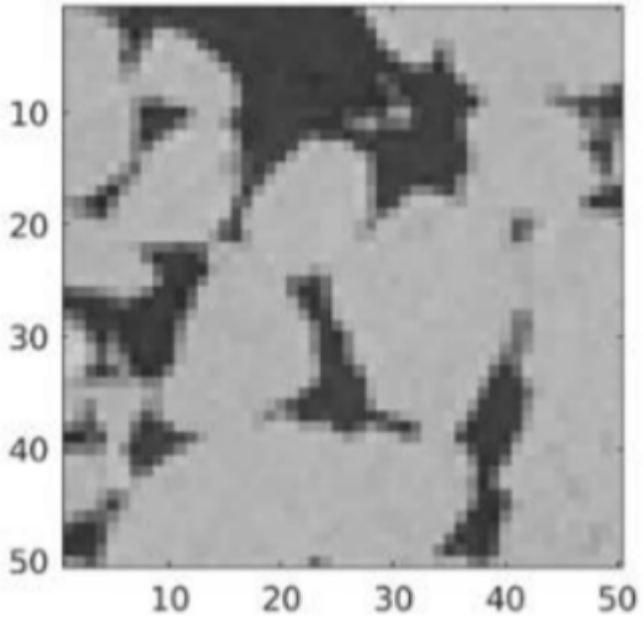


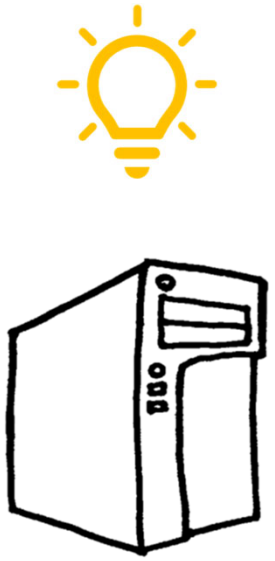
High noise



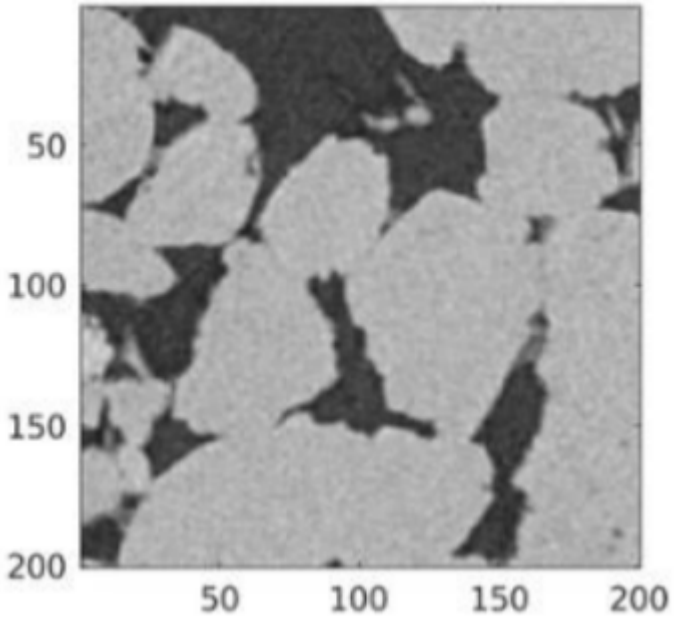
Shorten SDD
Higher tube current
Bin pixels/voxels

Low resolution data



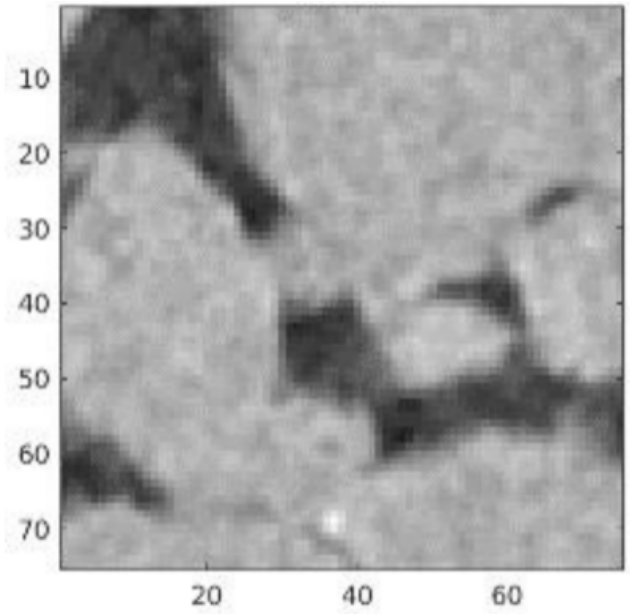


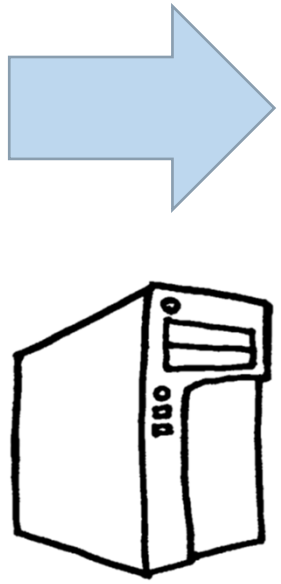
High resolution data



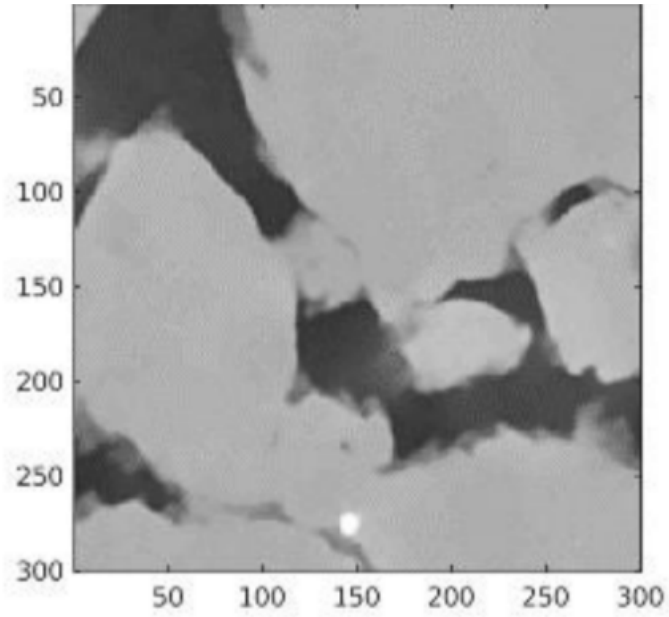
Ying Da Wang, Ryan Armstrong, Peyman Mostaghimi, "*Super Resolution Convolutional Neural Network Models for Enhancing Resolution of Rock Micro-CT Images*" ArXiv. 2019

Low resolution data





Super resolution data



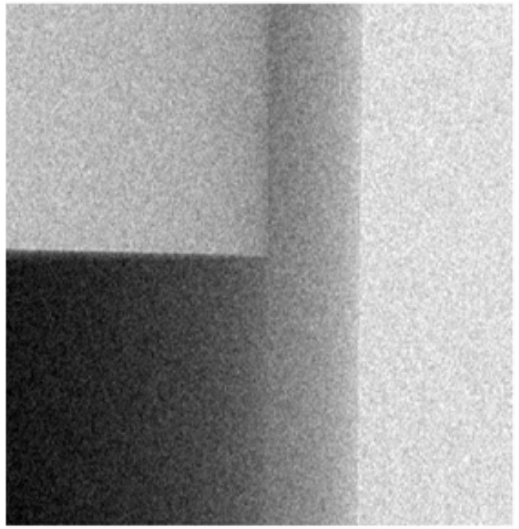
Ying Da Wang, Ryan Armstrong, Peyman Mostaghimi, "*Super Resolution Convolutional Neural Network Models for Enhancing Resolution of Rock Micro-CT Images*" ArXiv. 2019

Fast change

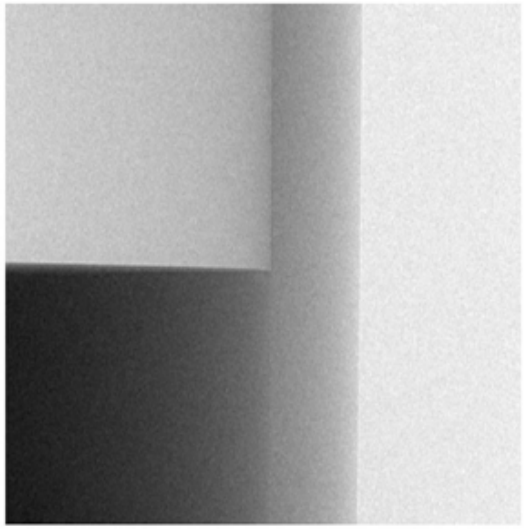
Slow change

THE LONGER THE BETTER?

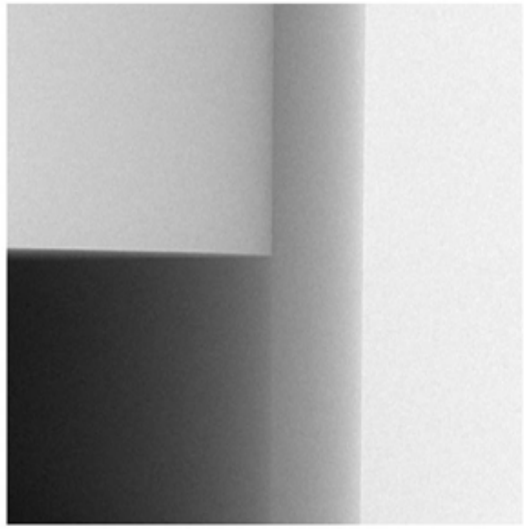
0.125 sec



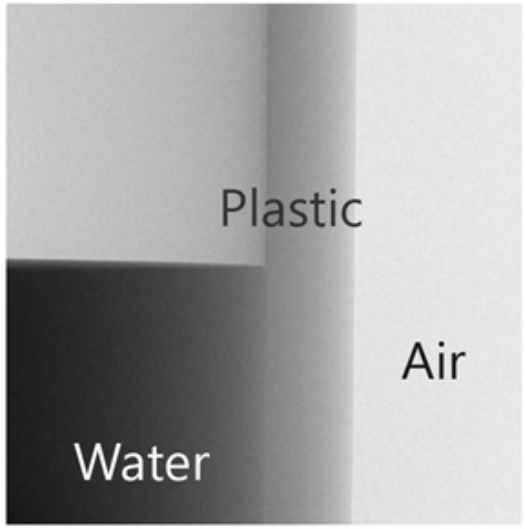
1.25 sec



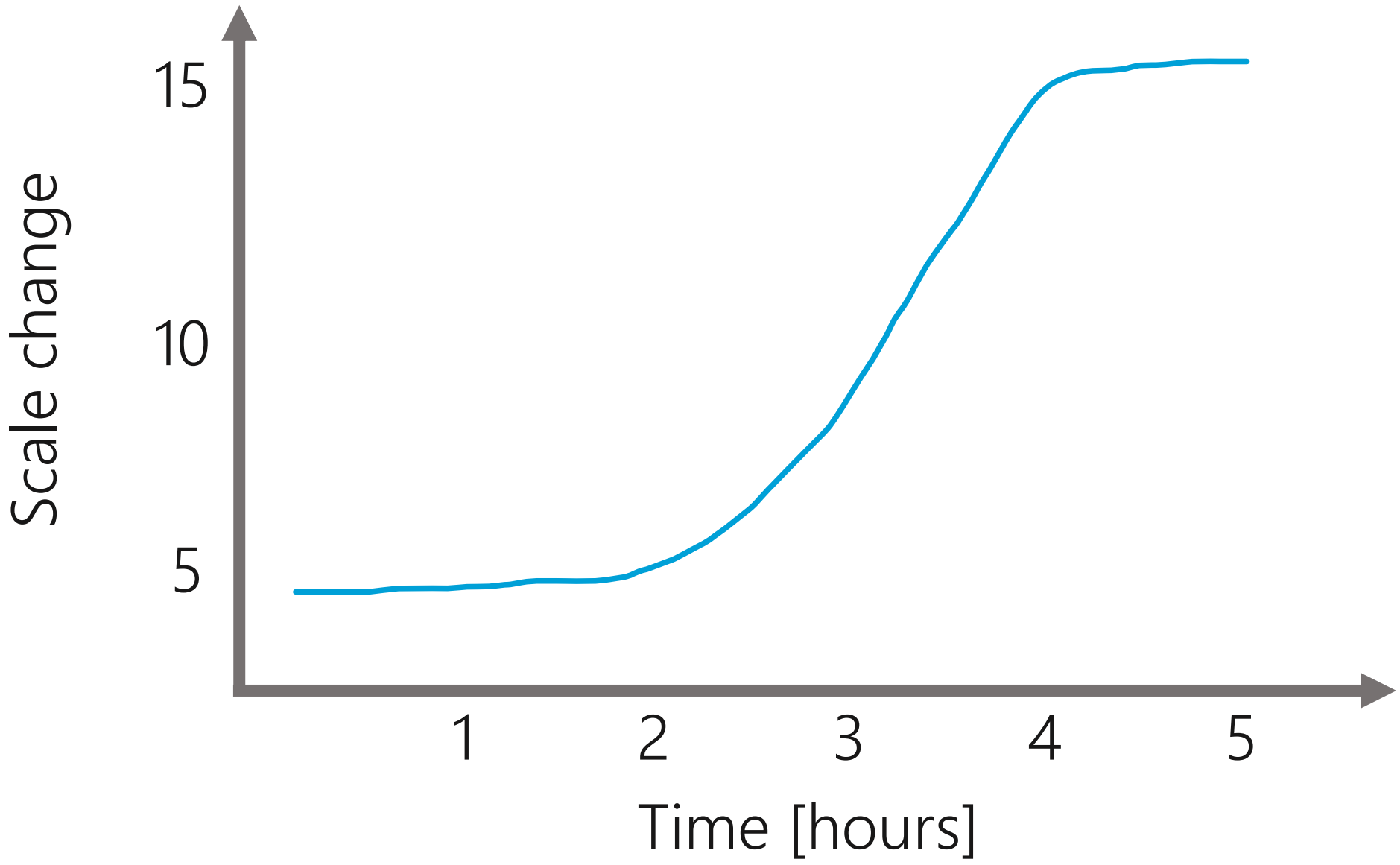
6.25 sec



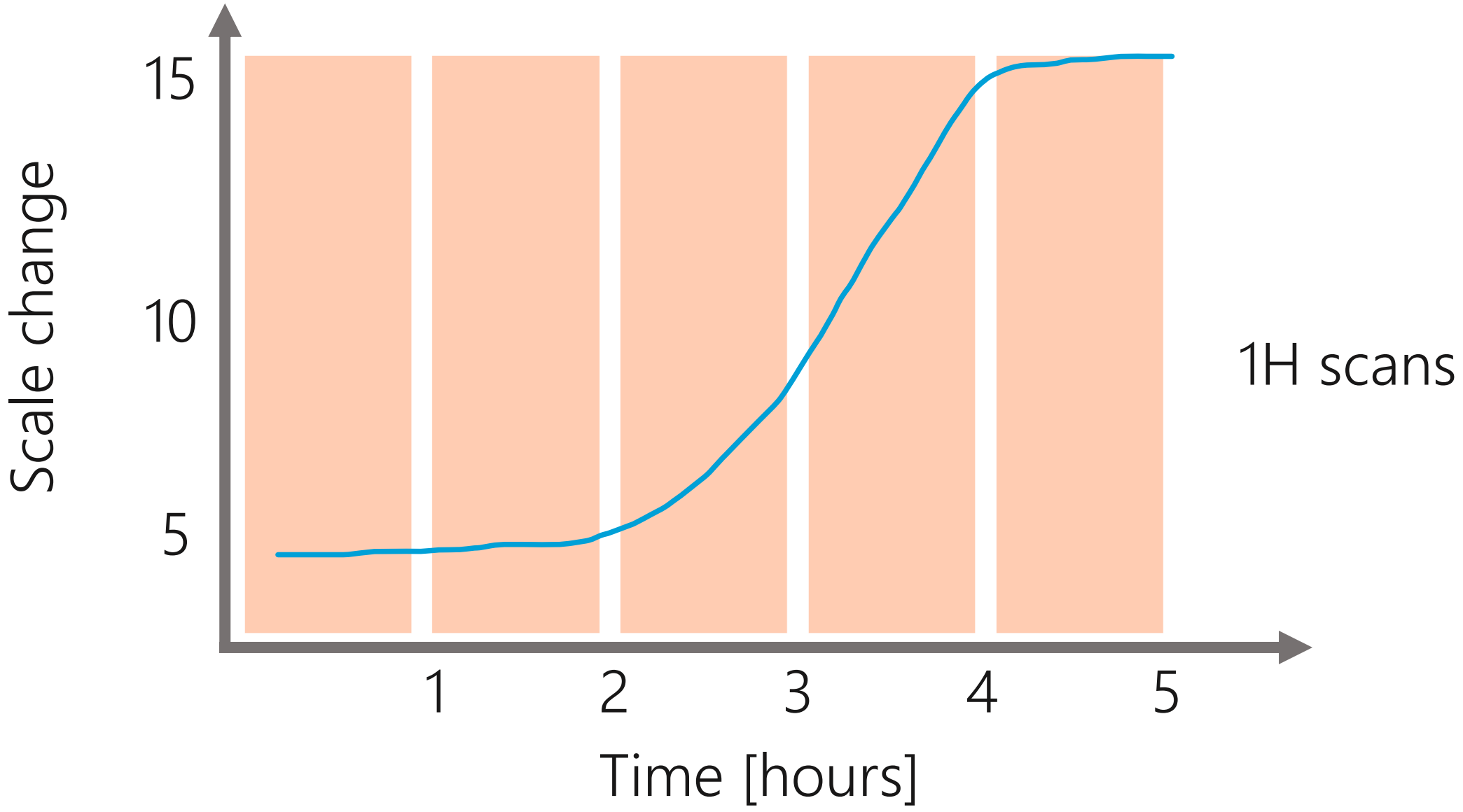
12.5 sec

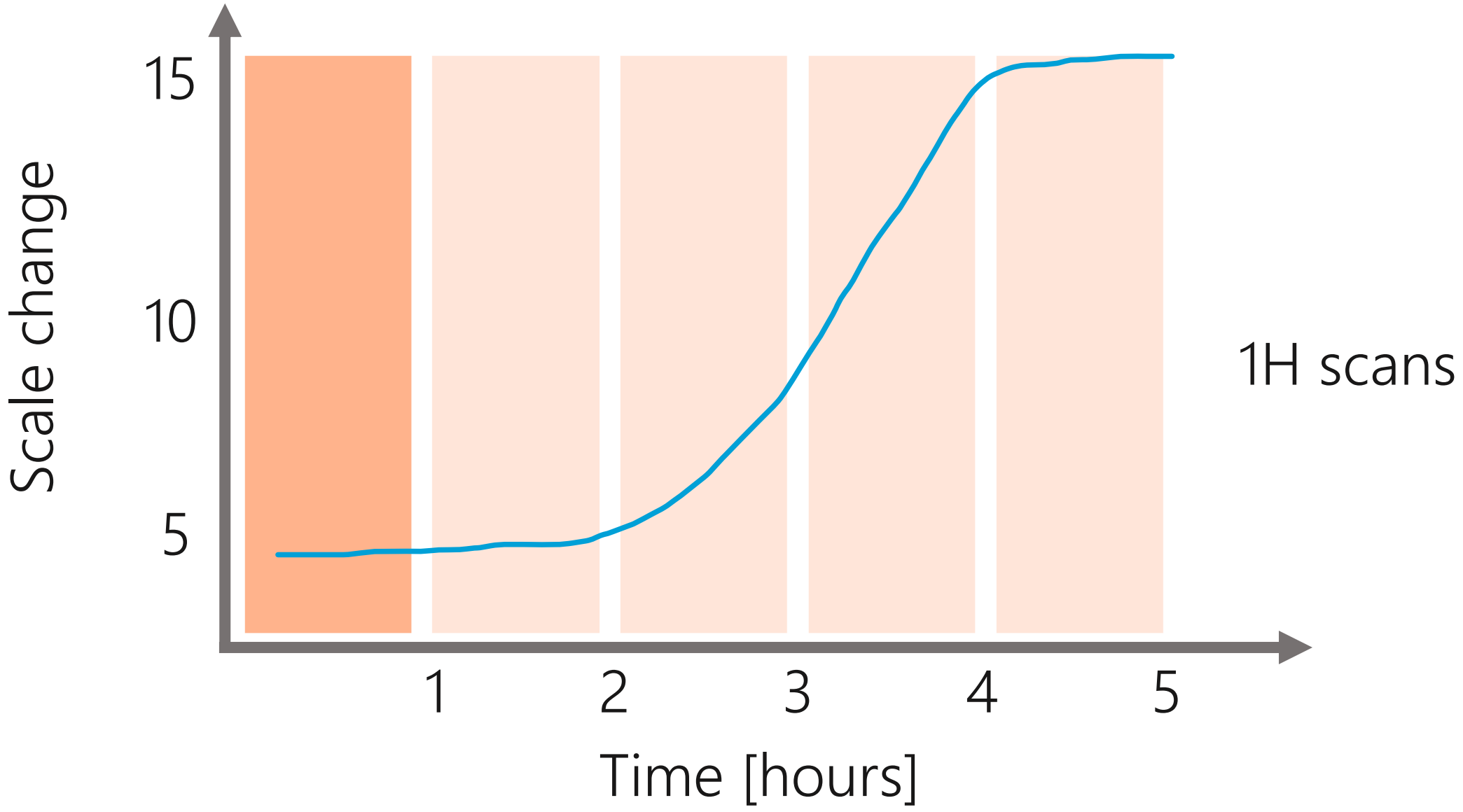


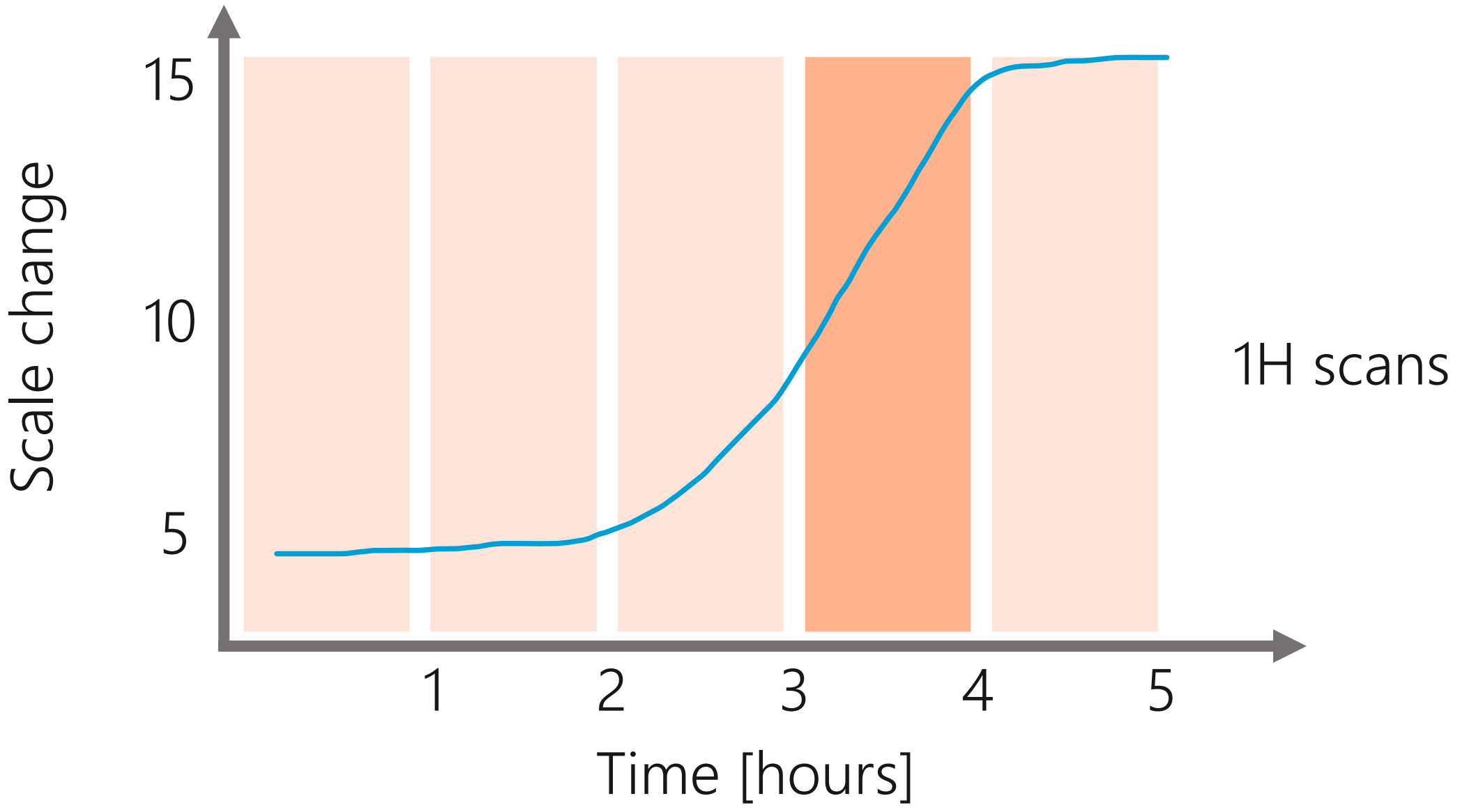
Better S/N

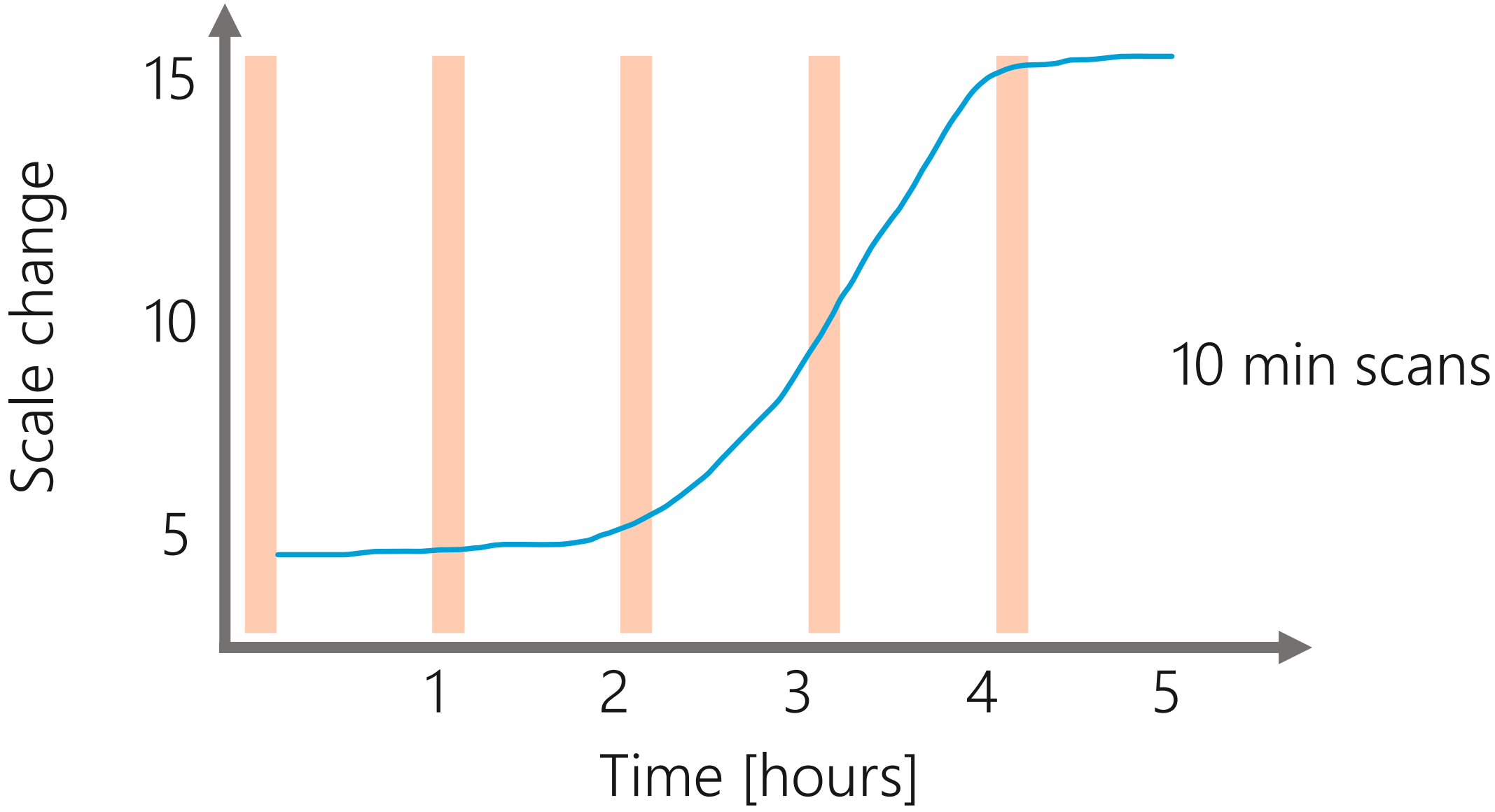

Scale change
15
10
5
1
2
3
4
5
Time [hours]

WHAT HAPPENS IF WE RUN 1H SCANS?

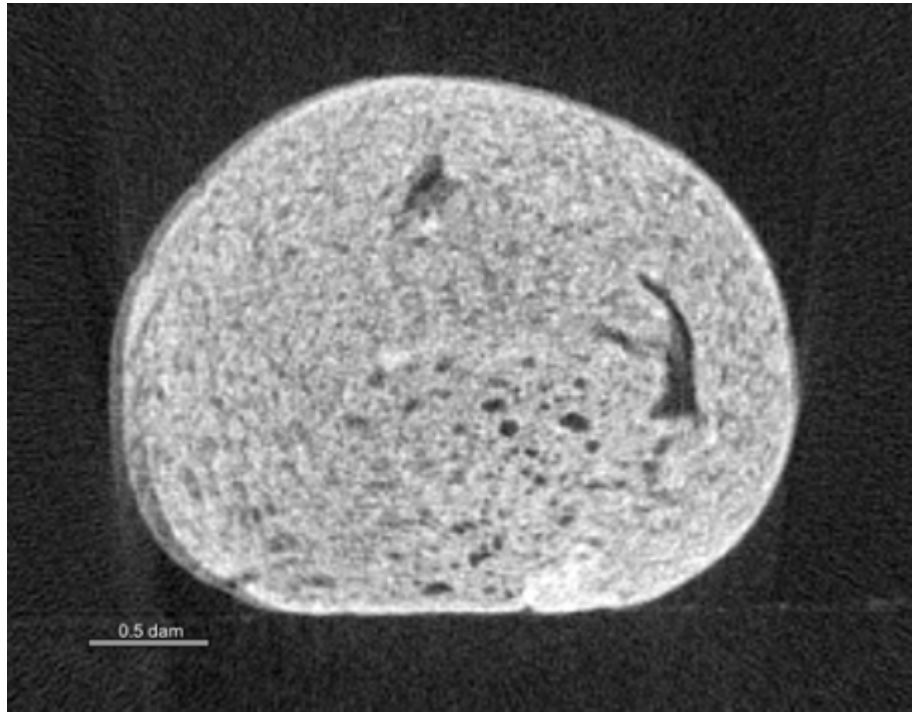

Scale change
15
10
5
1
2
3
4
5
Time [hours]
1H scans


Scale change
15
10
5
1
2
3
4
5
Time [hours]
1H scans

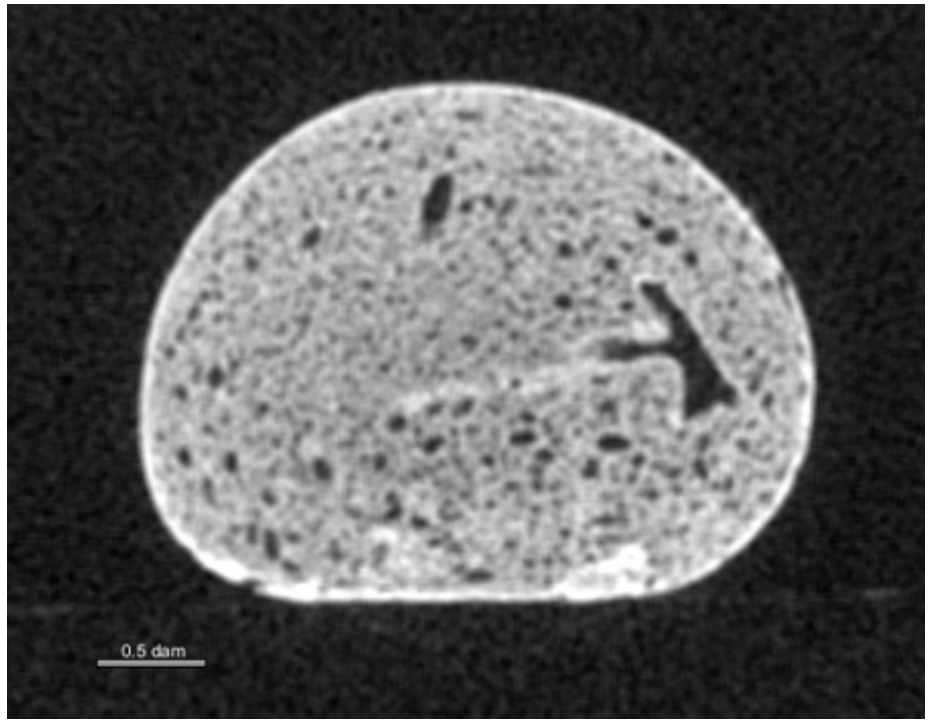

Scale change
15
10
5
1
2
3
4
5
Time [hours]
1H scans


Scale change
15
10
5
1
2
3
4
5
Time [hours]
10 min scans

Rising bread dough



4 min / scan



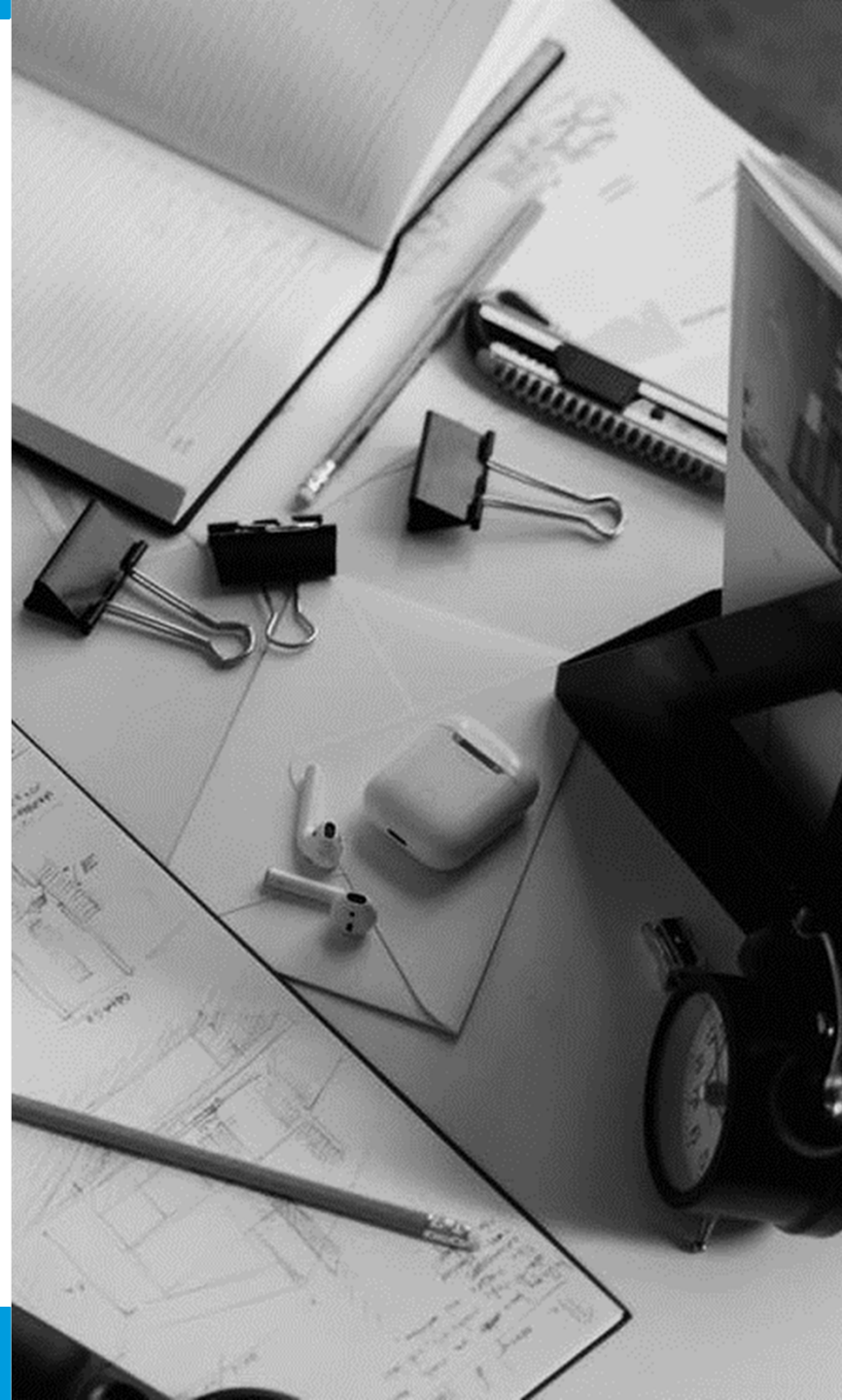
18 sec / scan

Fast change

Slow change

Plan experiments based on

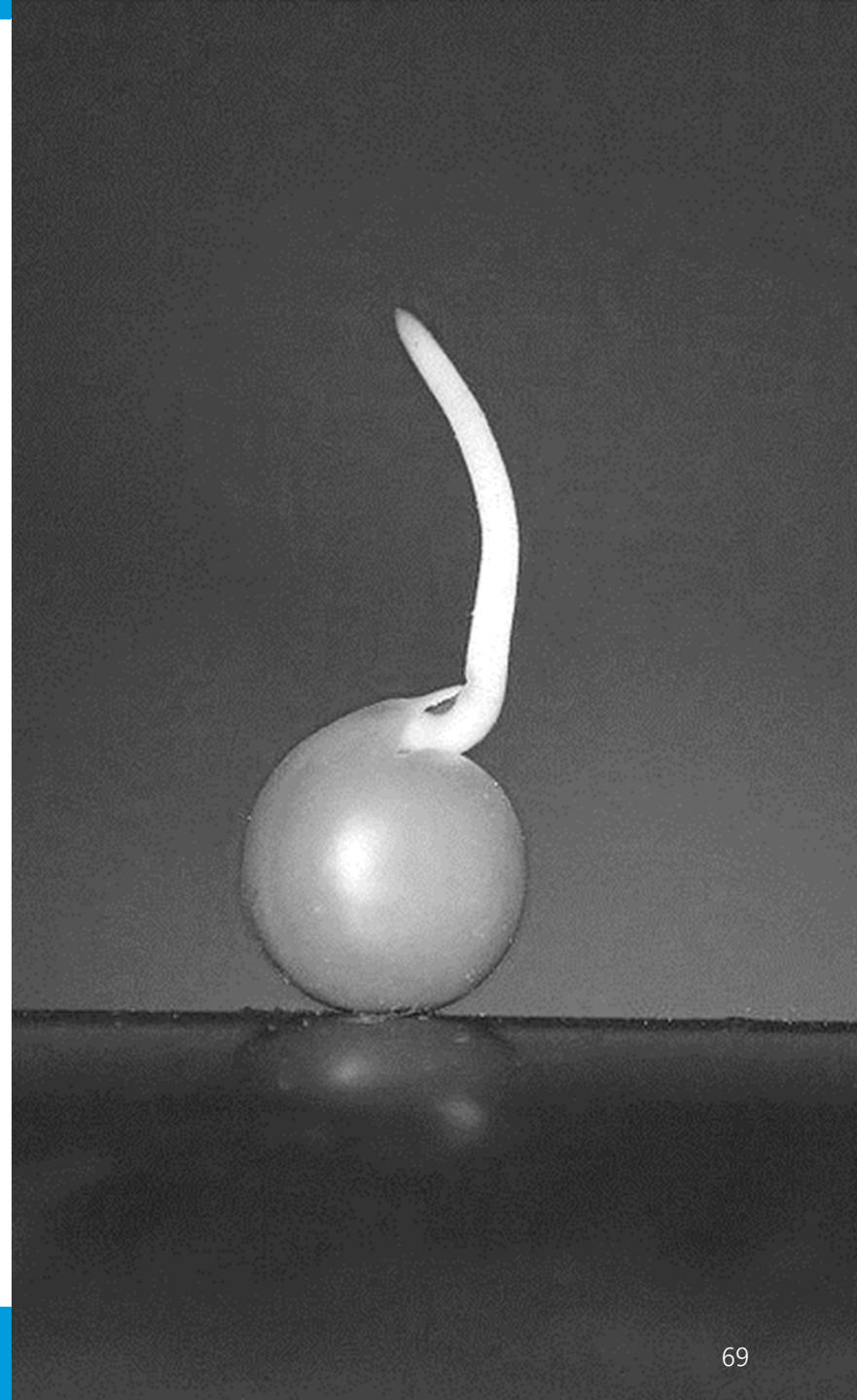
- Duration of the process
- Rate of the change
- Necessary image quality
- File size



WHAT ARE THE TYPICAL PROCESSES TO SEE?

4D & *IN-SITU* APPLICATIONS

- Heating/cooling process
- Shape change under stress
- Diffusion process
- Growth process
- Degradation process



CAN WE IMAGE AN EXPLOSION?

Explosive agent mixed in clay (9 sec/scan)

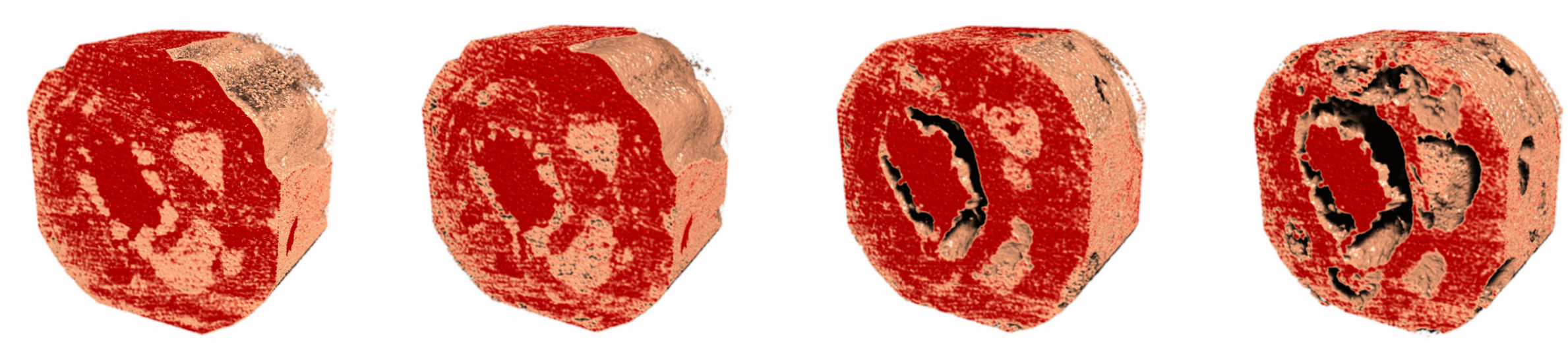
WHAT HAPPENS WHEN WE HEAT SALAMI?

Salami

Before heating

After heating

Salami (18 sec/scan)

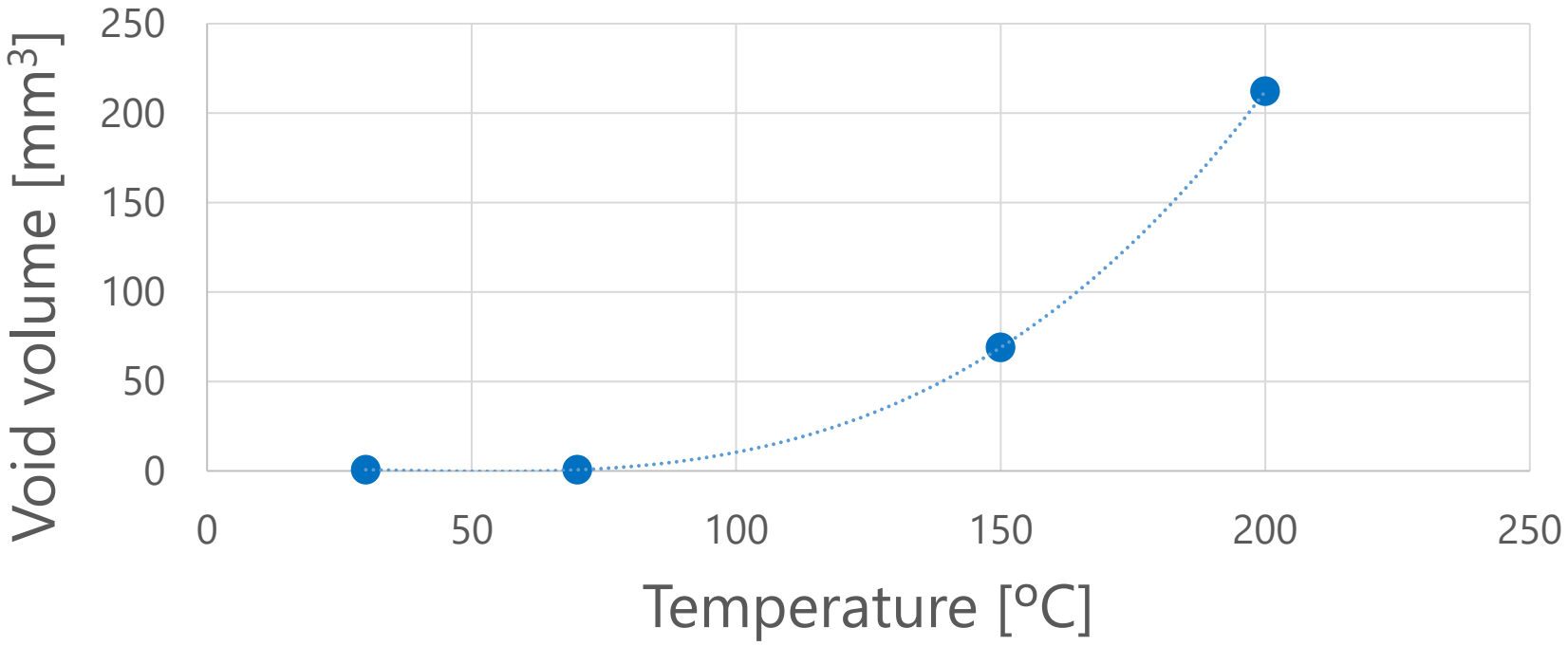


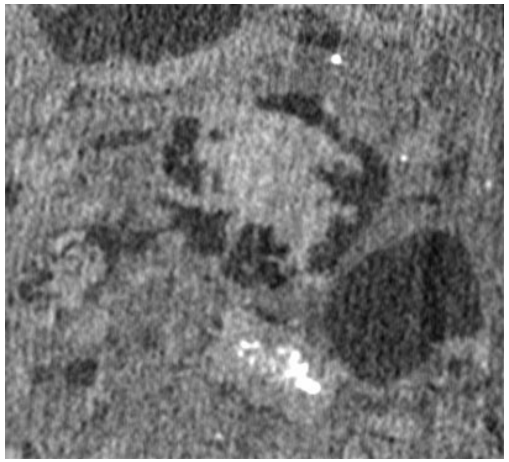
30°C

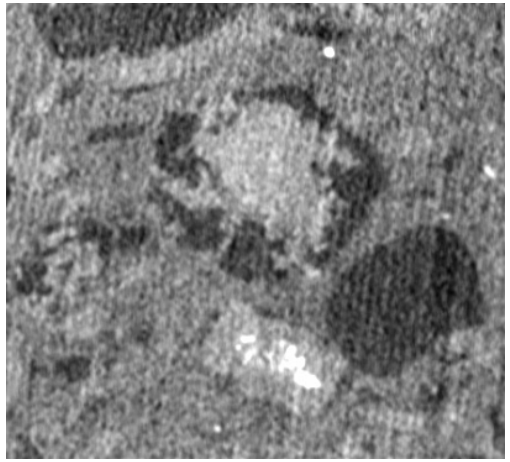
70°C

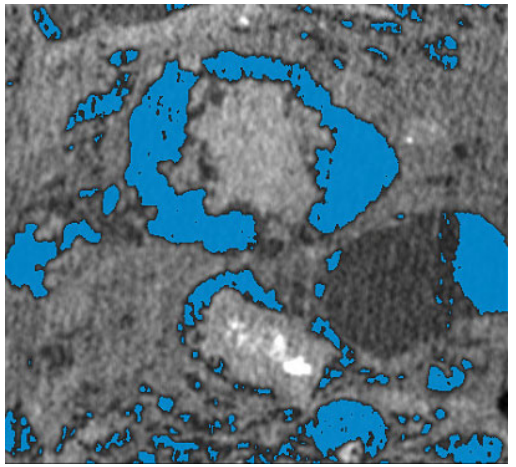
150°C

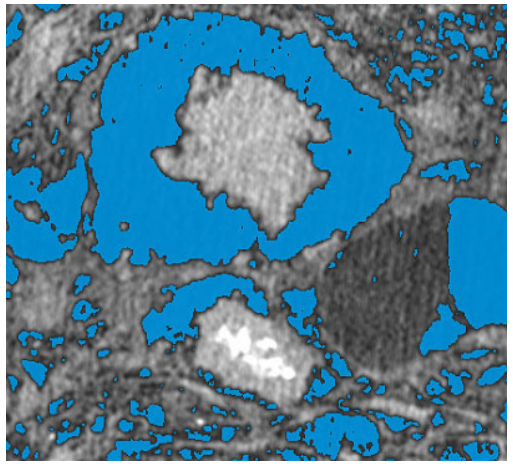
200°C


Void volume [mm3]
250
200
150
100
50
0
0
50
100
150
200
250
Temperature [°C]



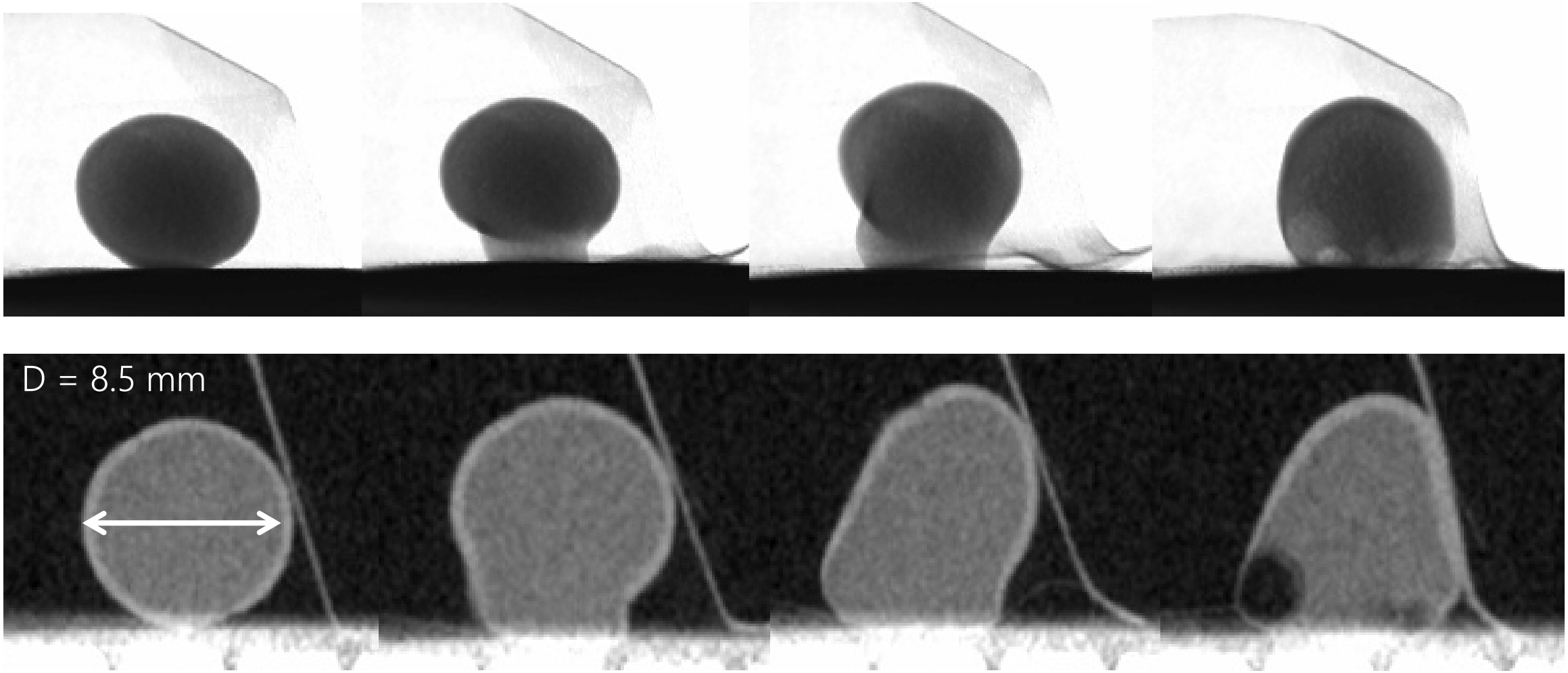






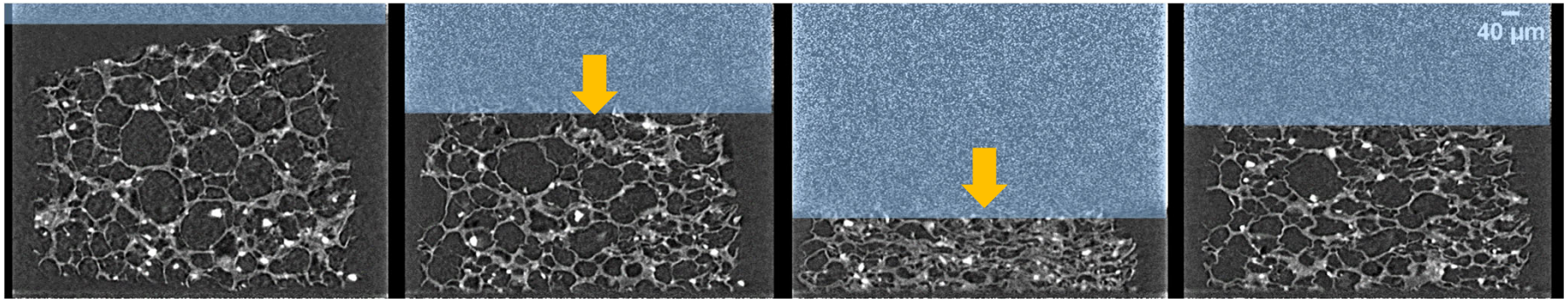
WHAT HAPPENS IF WE LEAVE SOFT GEL CAPSULES IN A CAR?

Vitamin E soft gel in 50°C (18 sec/scan)

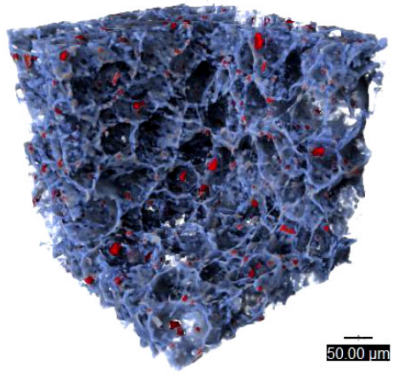


CAN WE ADD STRESS?

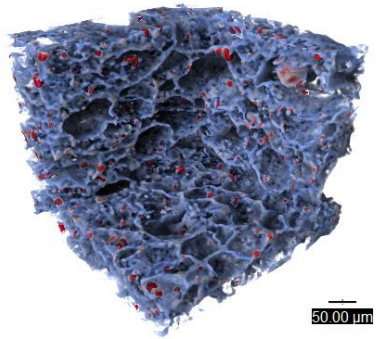
Shoe sole compression

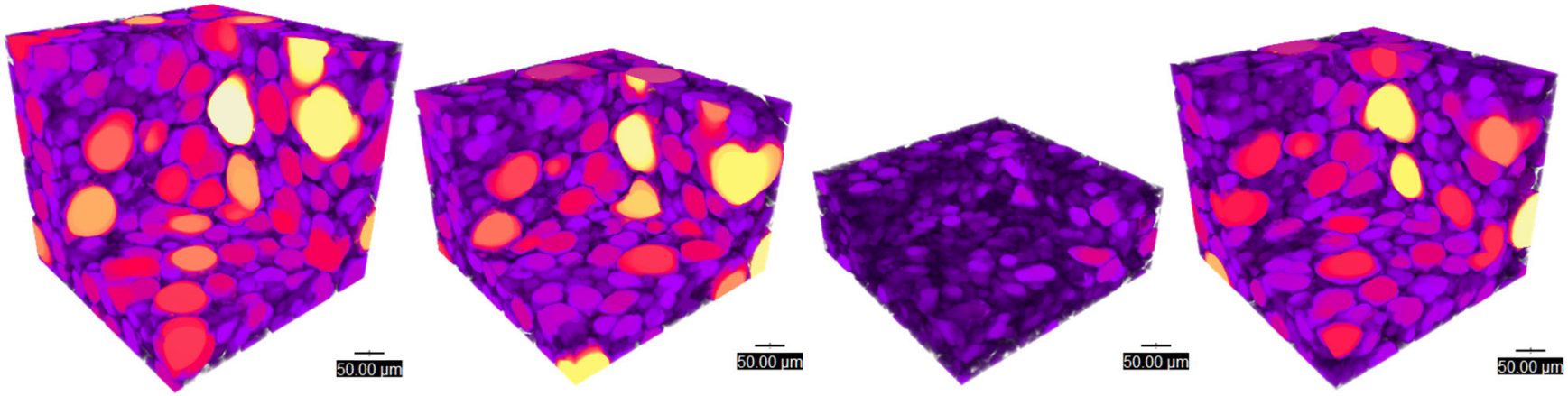


0 MPa 7 MPa 14 MPa 0 MPa



Step4: 0MPa

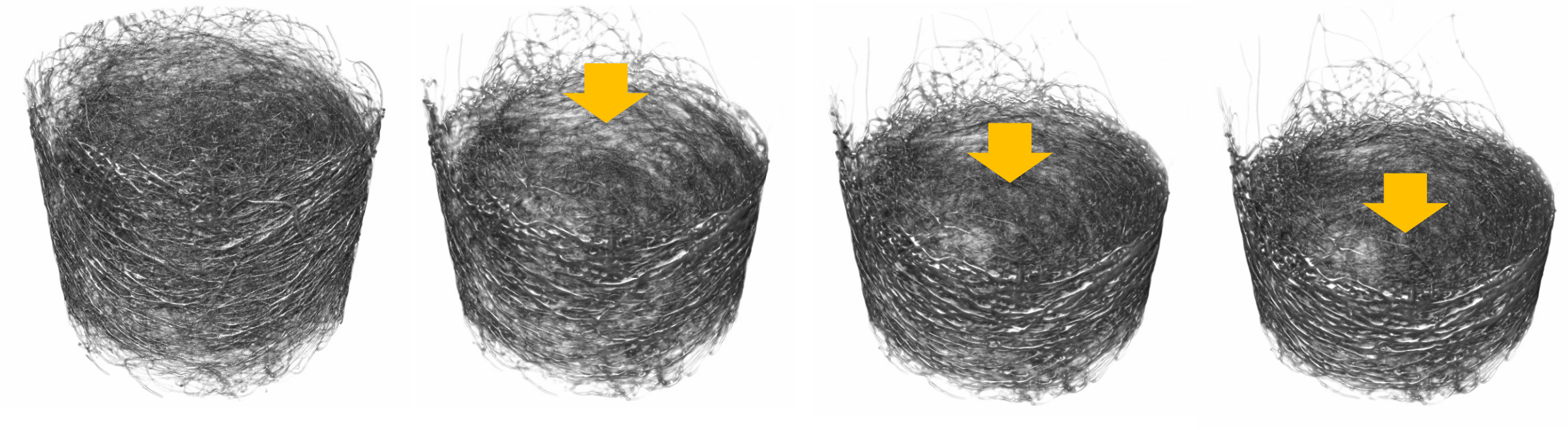




0 MPa 7 MPa 14 MPa 0 MPa

0µm Pore size 100µm

Steel wool

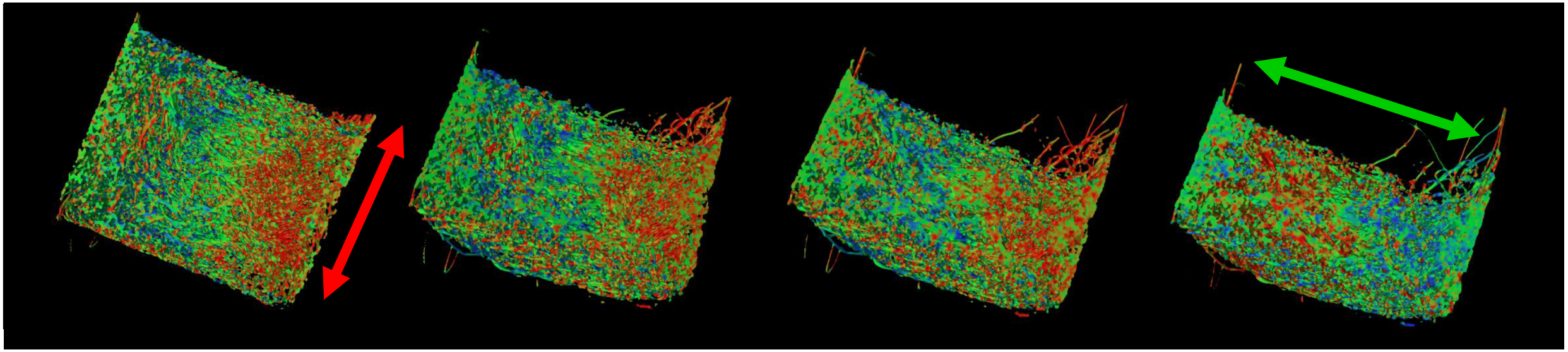


0 N

100 N

150 N

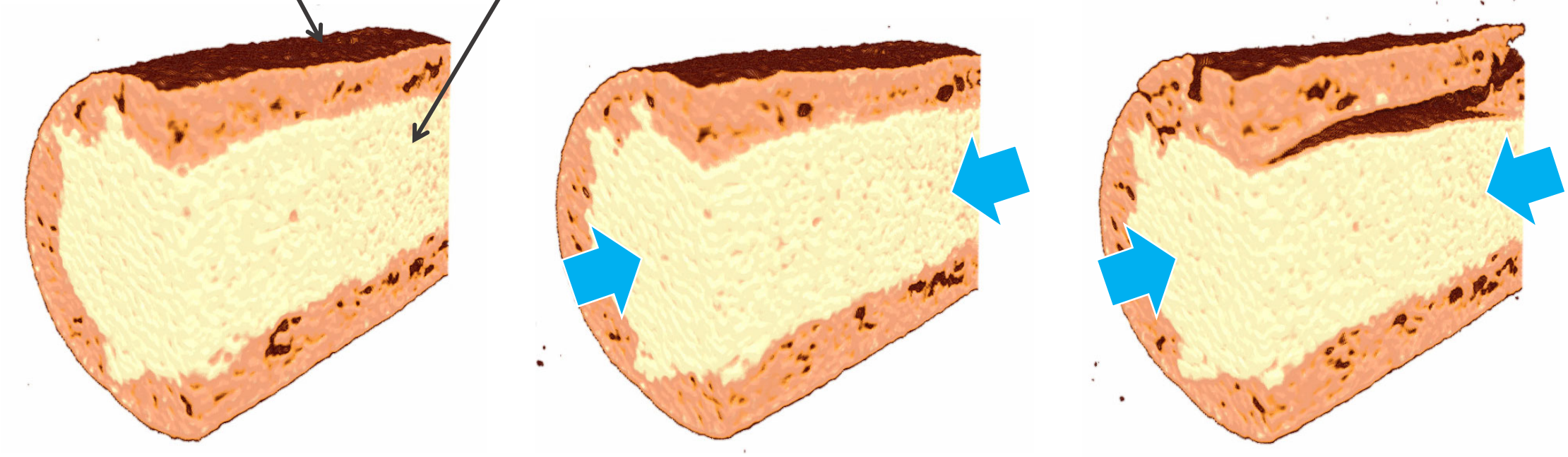
200 N



0 N 100 N 150 N 200 N

Sintered material

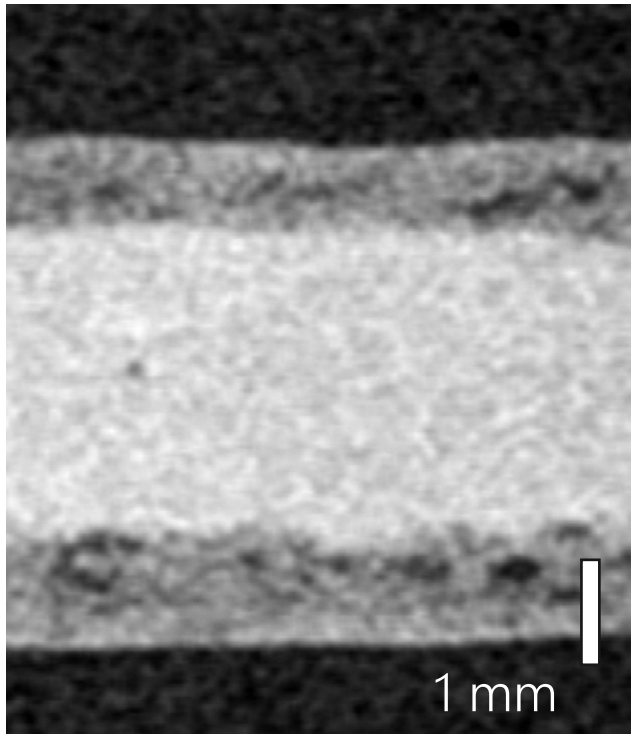
Low density material



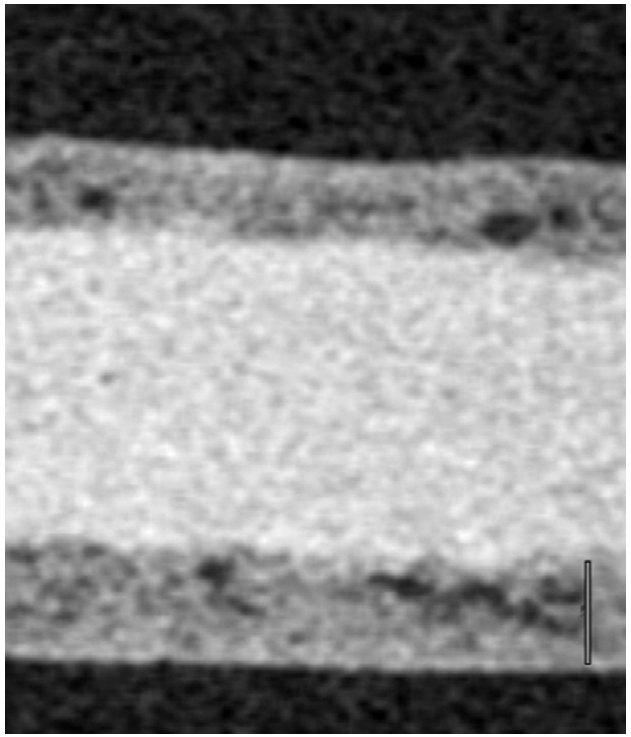
0 N

20 N

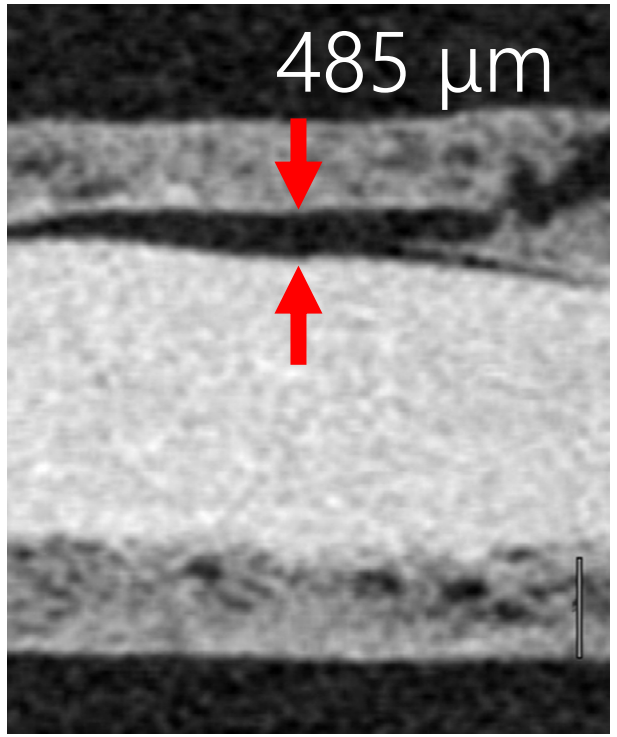
50 N



0 N



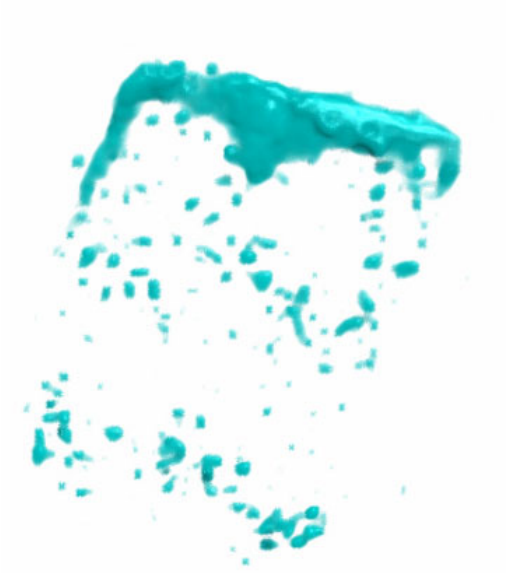
20 N



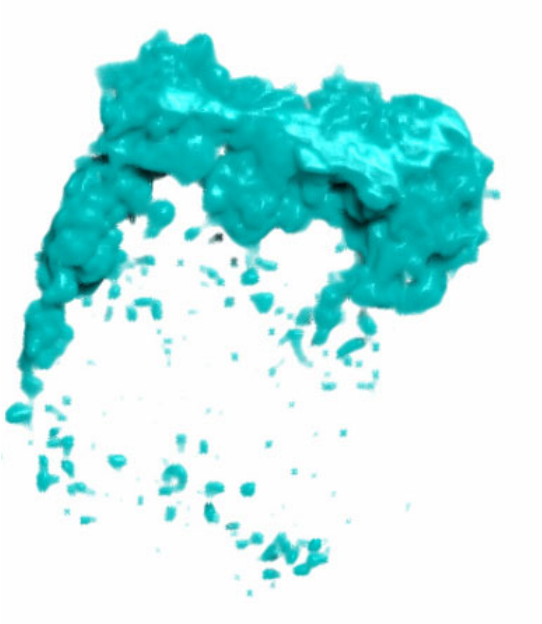
50 N

CAN WE SEE DIFFUSION/ABSORPTION?

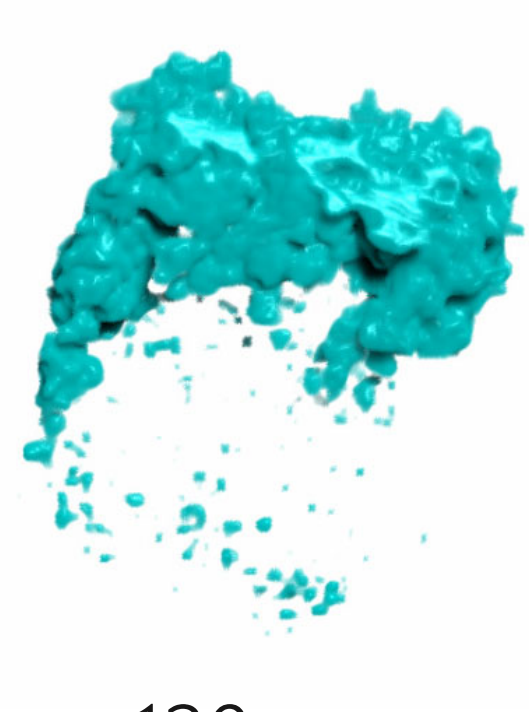
0 sec



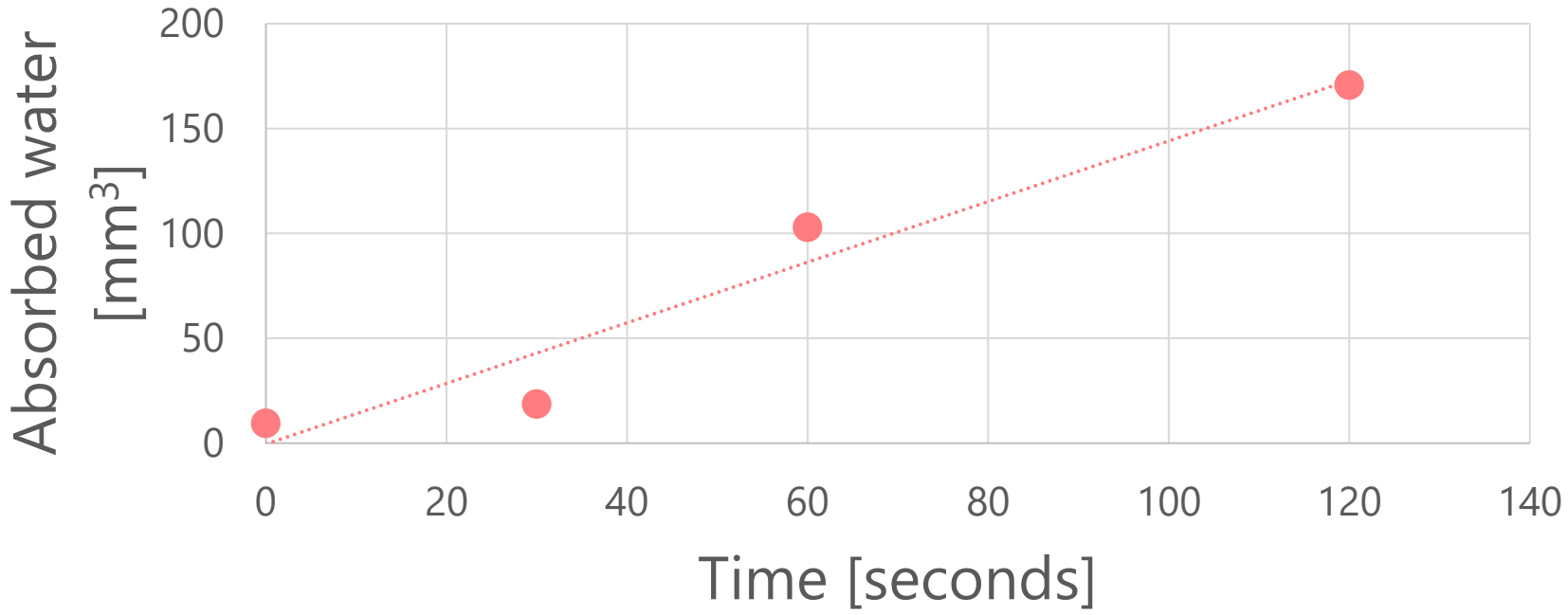
30 sec

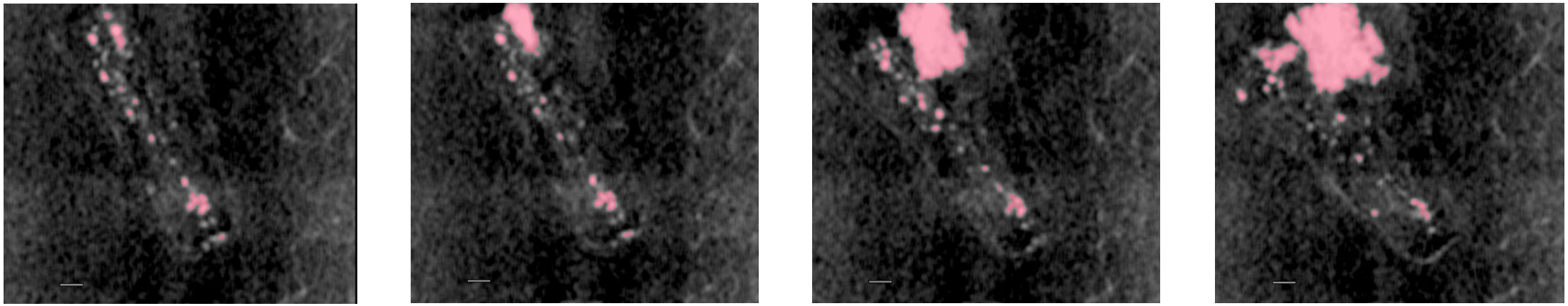


60 sec



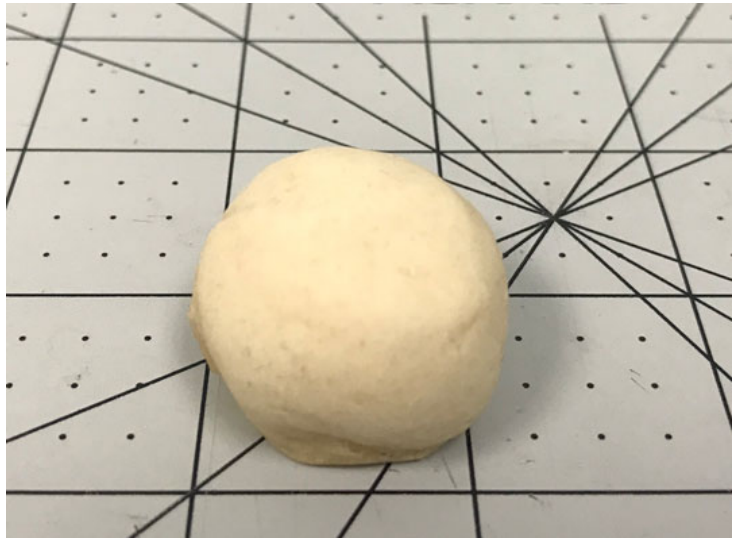
120 sec

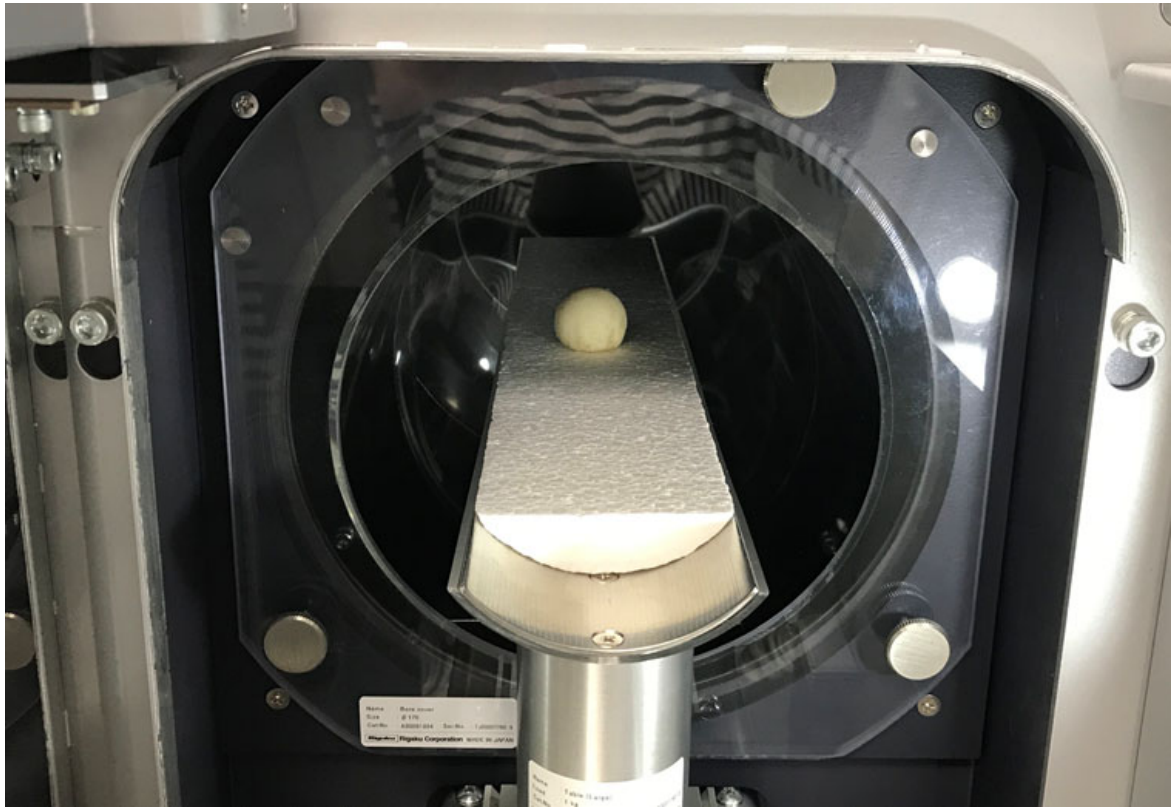

Absorbed water [mm3]
200
150
100
50
0
0
20
40
60
80
100
120
140
Time [seconds]

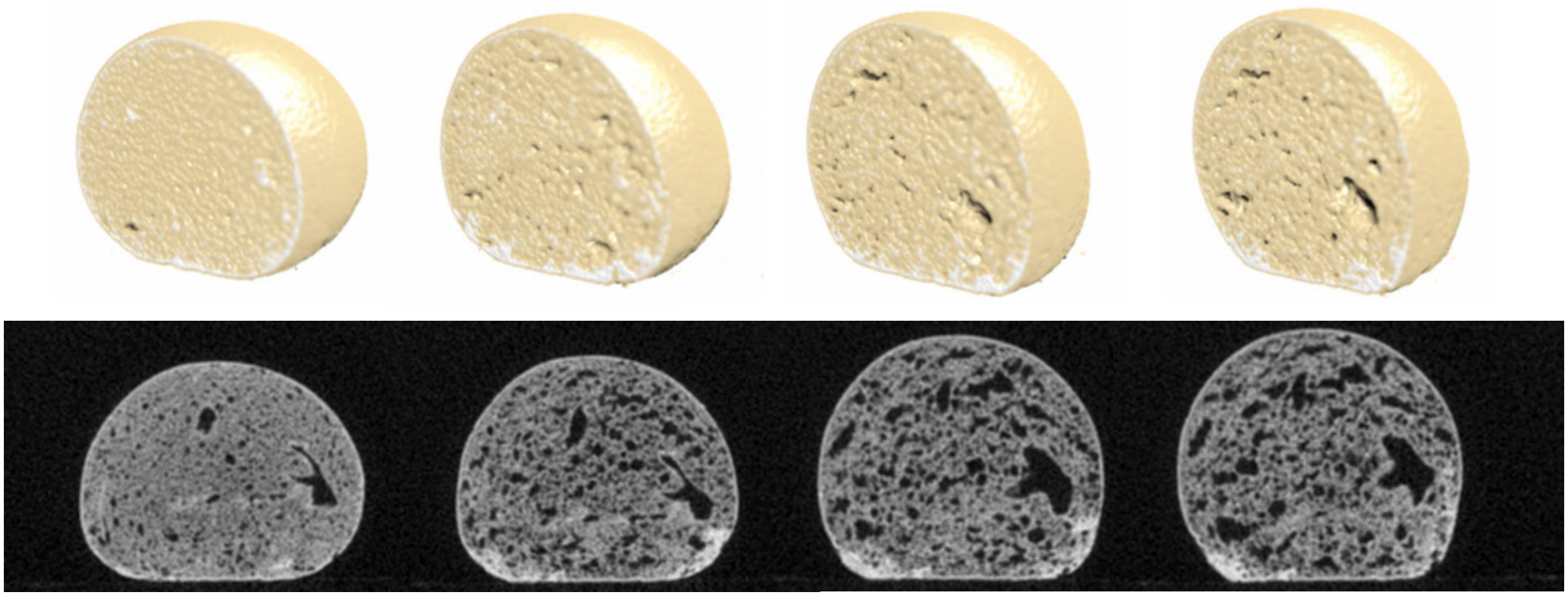


CAN WE SEE BREAD DOUGH RISE?

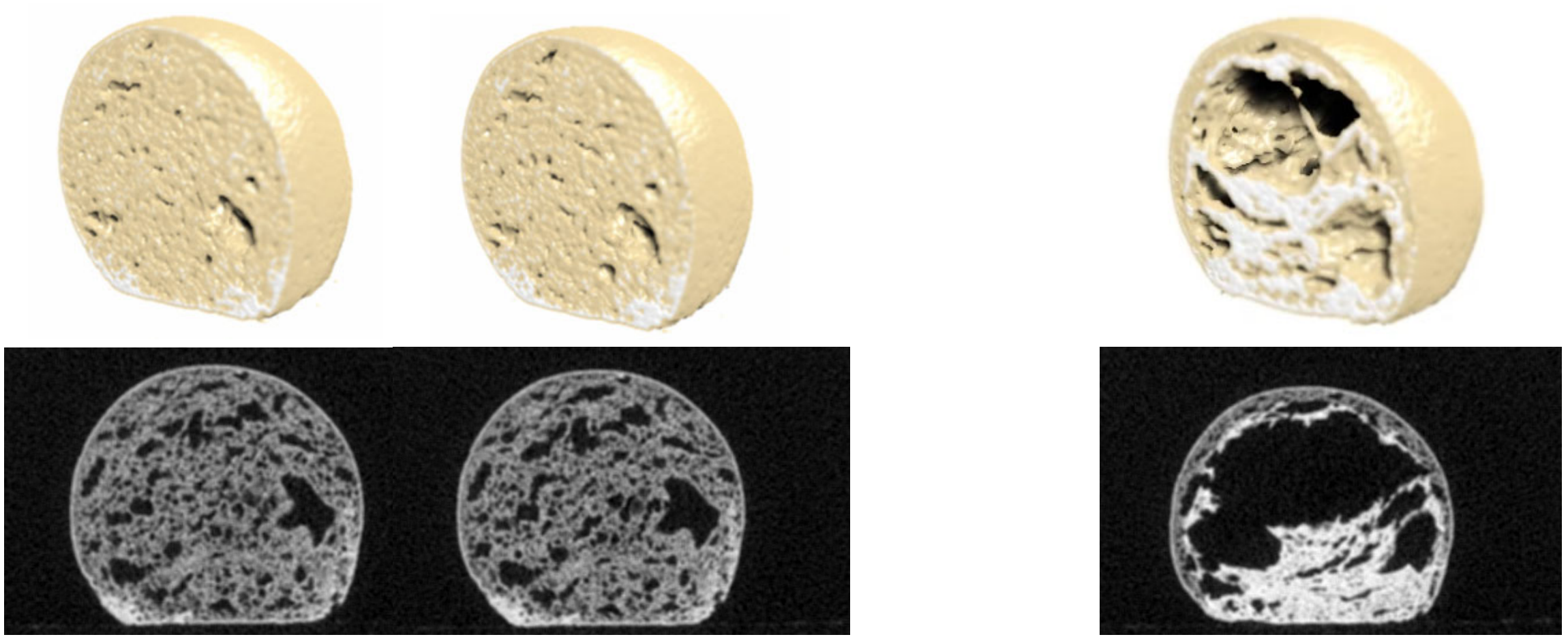
Bread dough



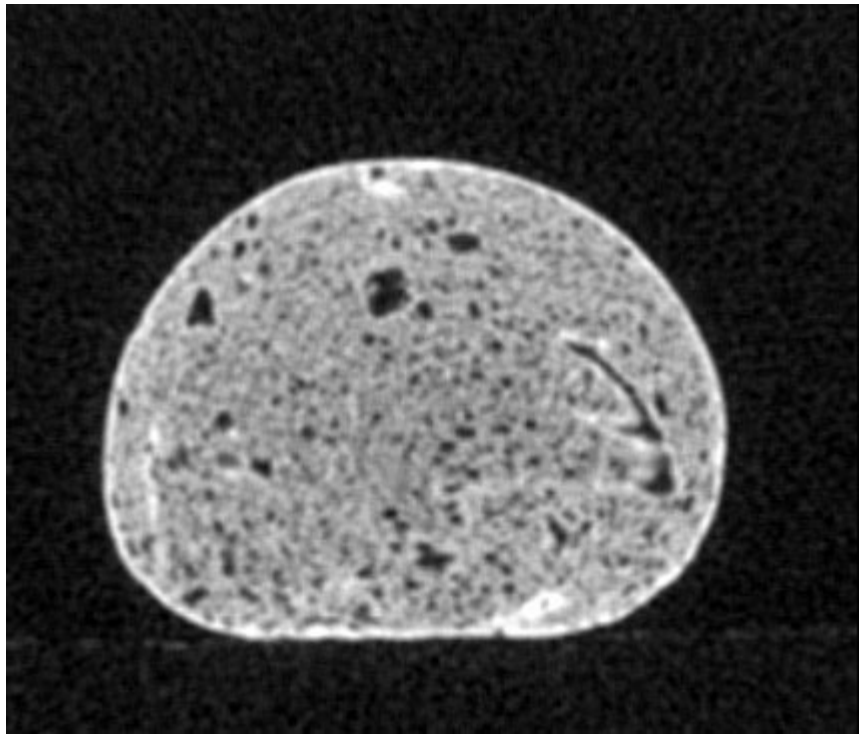


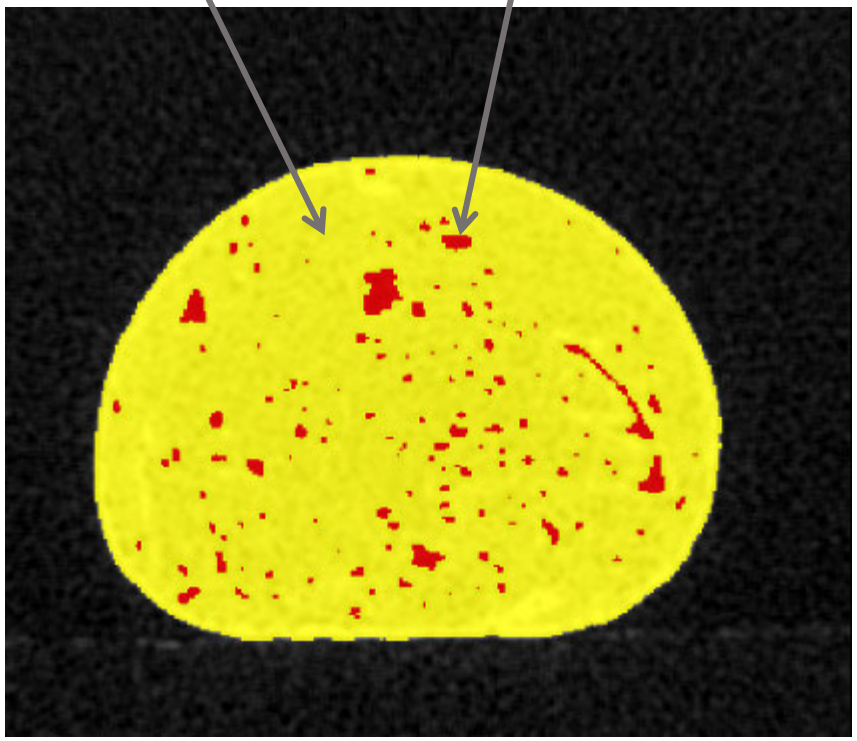


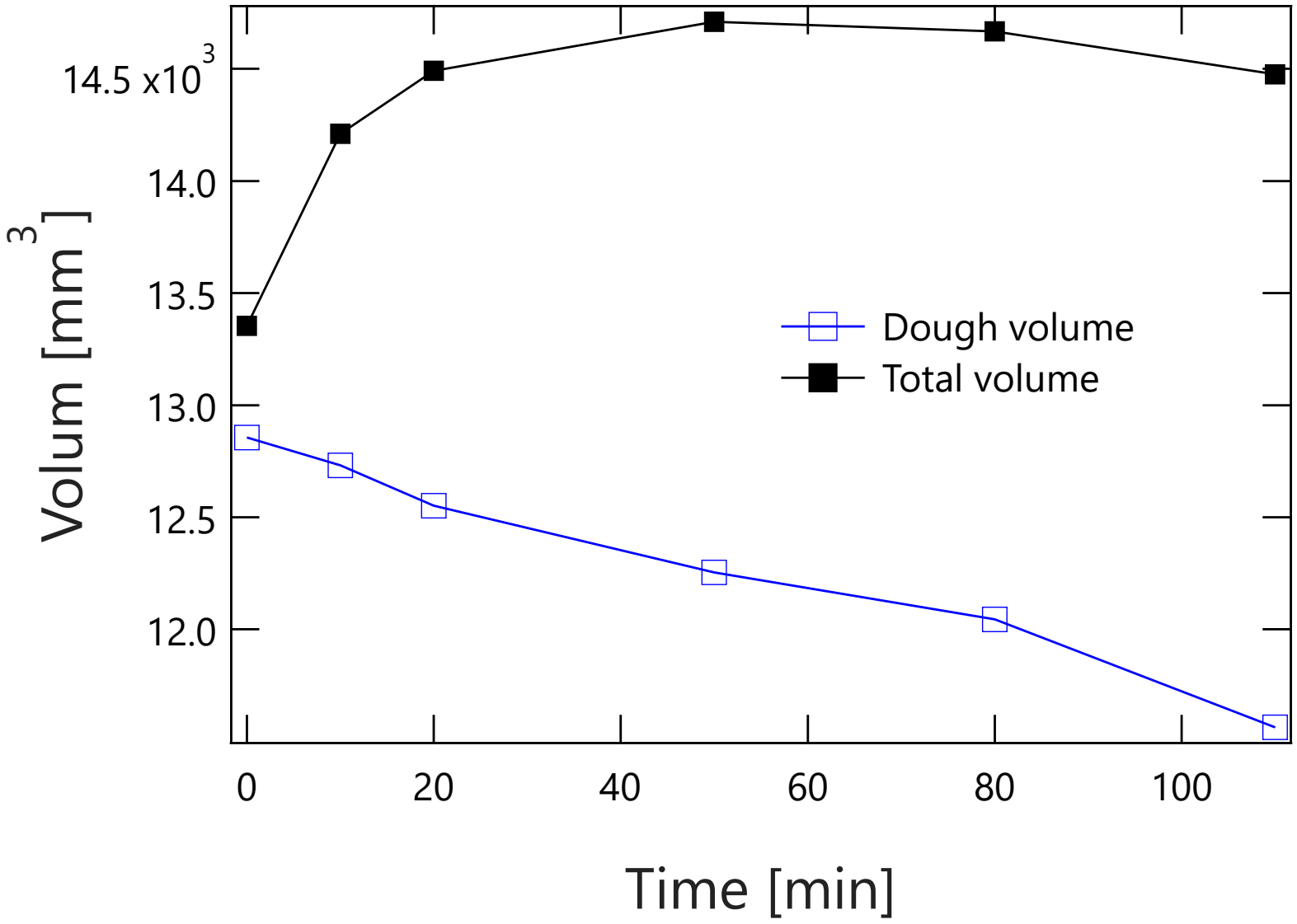
0 min 20 min 50 min 80 min

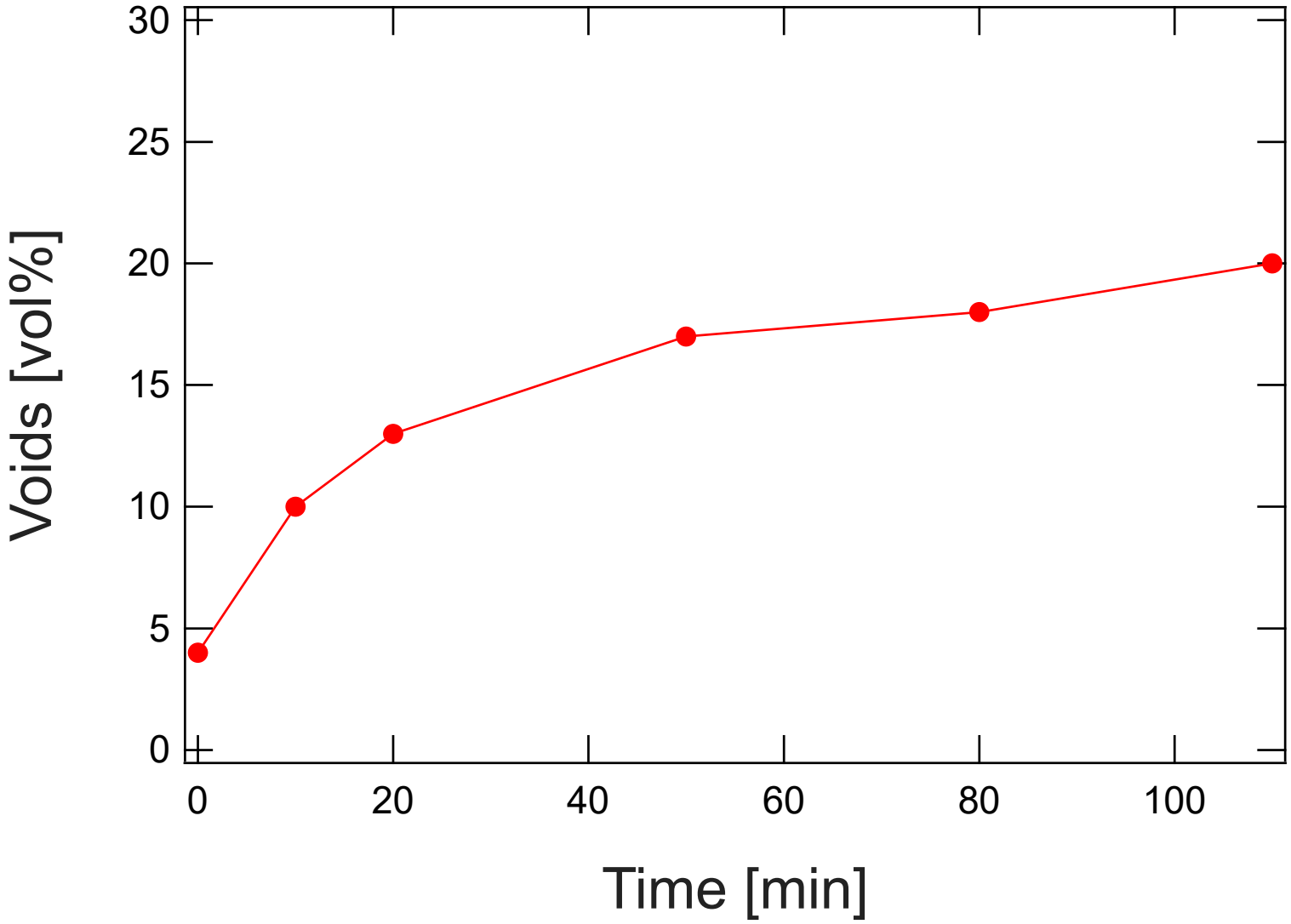


80 min 110 min 18 hrs



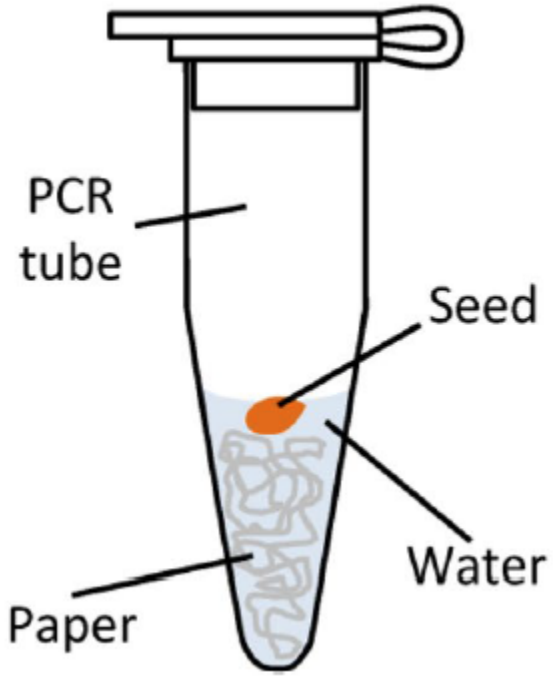

Dough
Voids

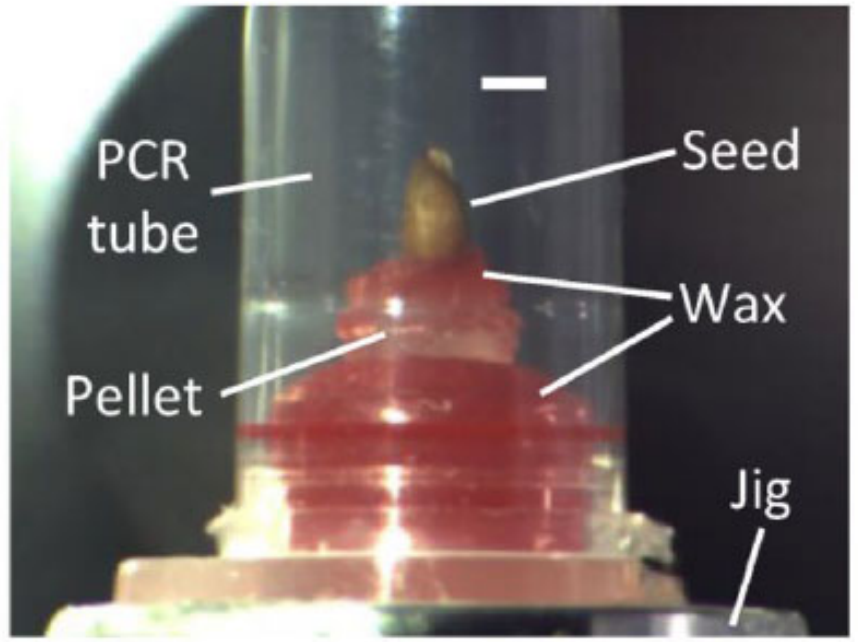

14.5 x10^3
14.0
13.5
13.0
12.5
12.0
Volum [mm^3]
0
20
40
60
80
100
Time [min]
Dough volume
Total volume


Voids [vol%]
30
25
20
15
10
5
0
0
20
40
60
80
100
Time [min]

CAN WE SEE GERMINATION PROCESS?

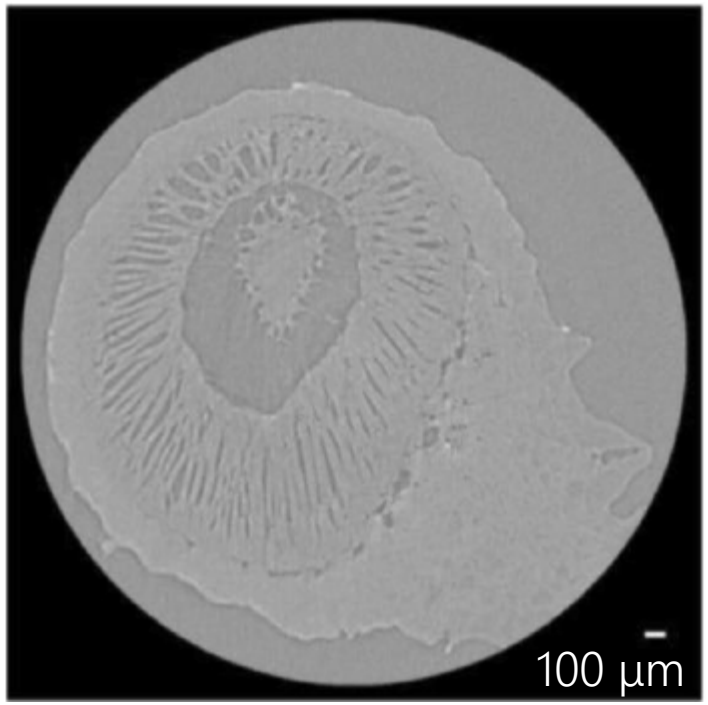
Pansy seed



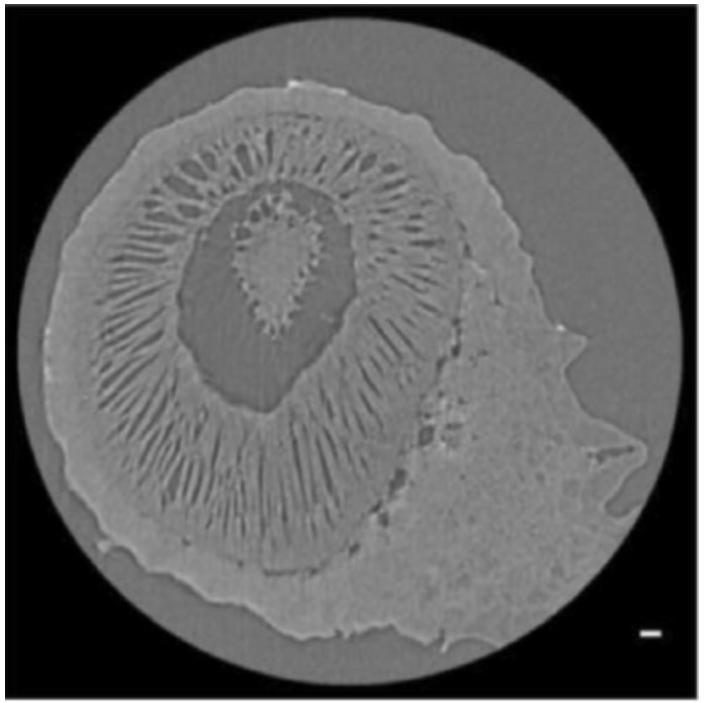


Kunishima, *et al.* Visualization of internal 3D structure of small live seed on germination by laboratory-based X-ray microscopy with phase contrast computed tomography. *Plant Methods* **16,** 7 (2020). https://doi.org/10.1186/s13007-020-0557-y

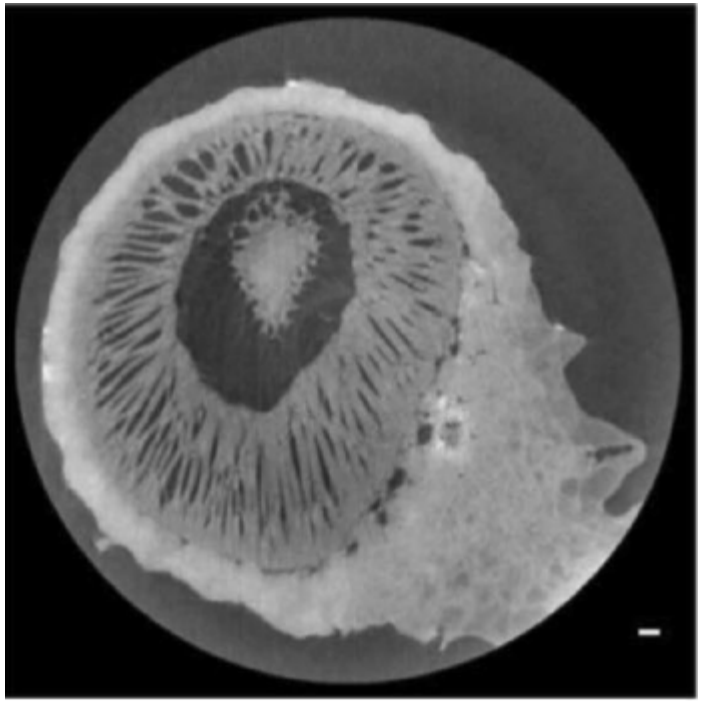
Absorption



Denoise

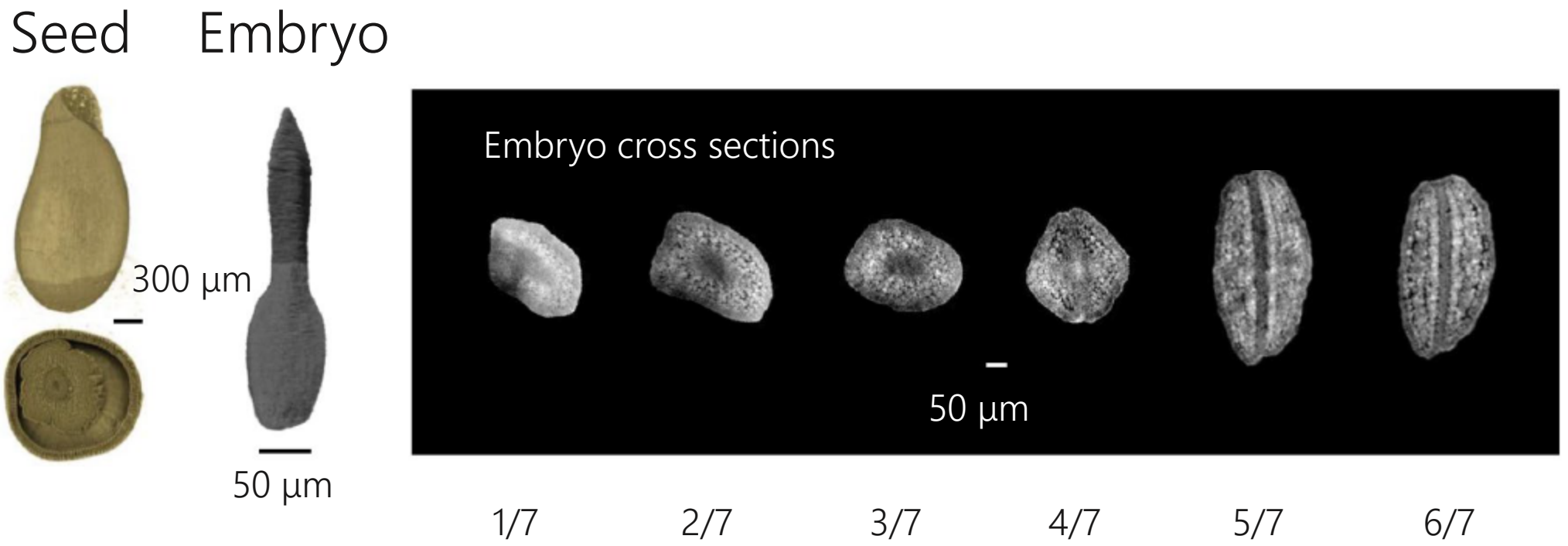


Phase retrieval



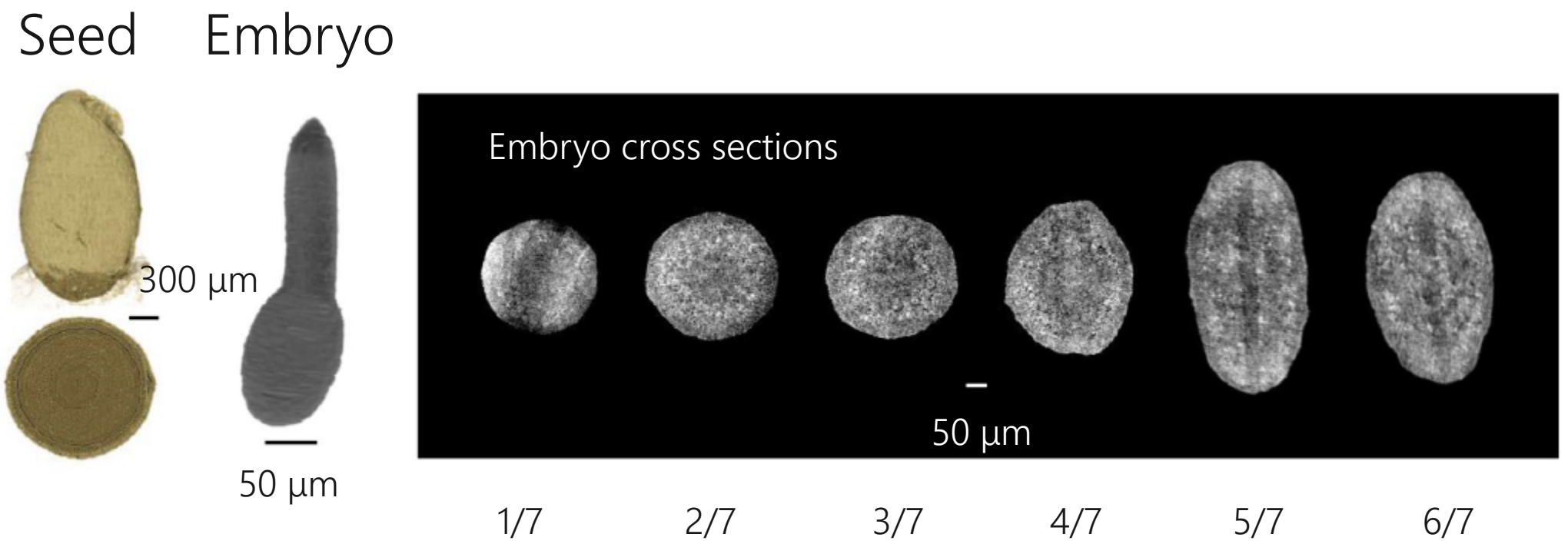
Kunishima, *et al.* Visualization of internal 3D structure of small live seed on germination by laboratory-based X-ray microscopy with phase contrast computed tomography. *Plant Methods* **16,** 7 (2020). https://doi.org/10.1186/s13007-020-0557-y

Dry seed



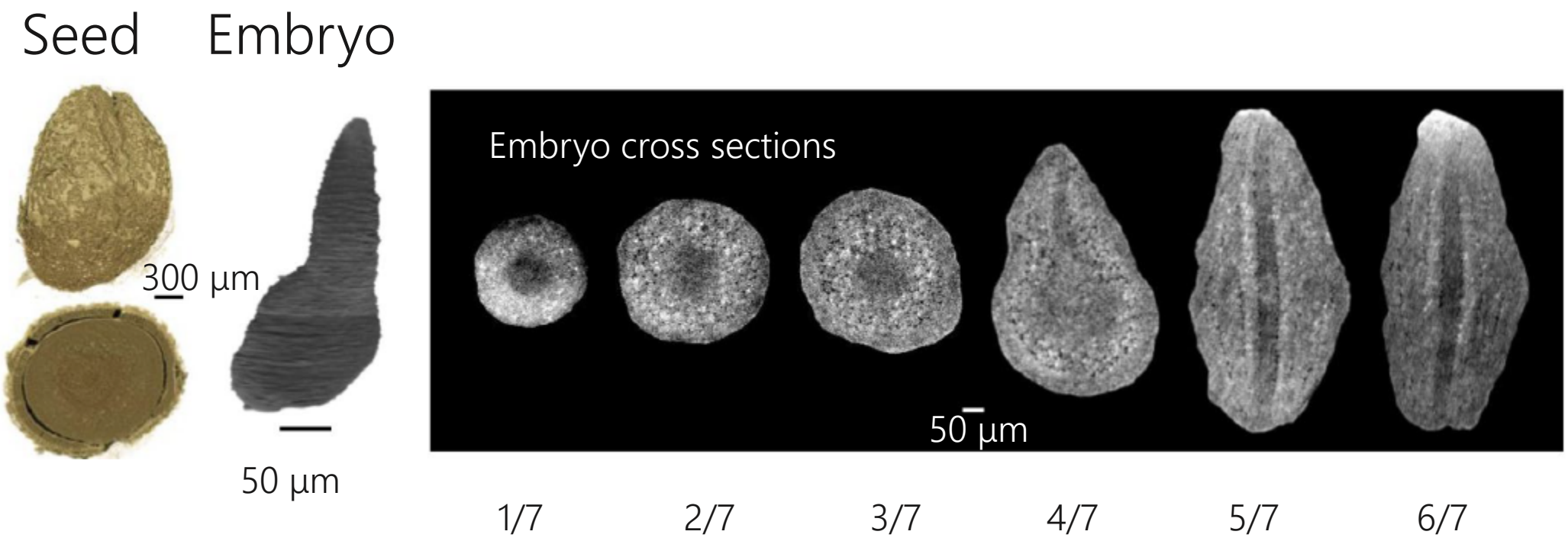
Kunishima, *et al.* Visualization of internal 3D structure of small live seed on germination by laboratory-based X-ray microscopy with phase contrast computed tomography. *Plant Methods* **16,** 7 (2020). https://doi.org/10.1186/s13007-020-0557-y

Seed after 8 hours of watering

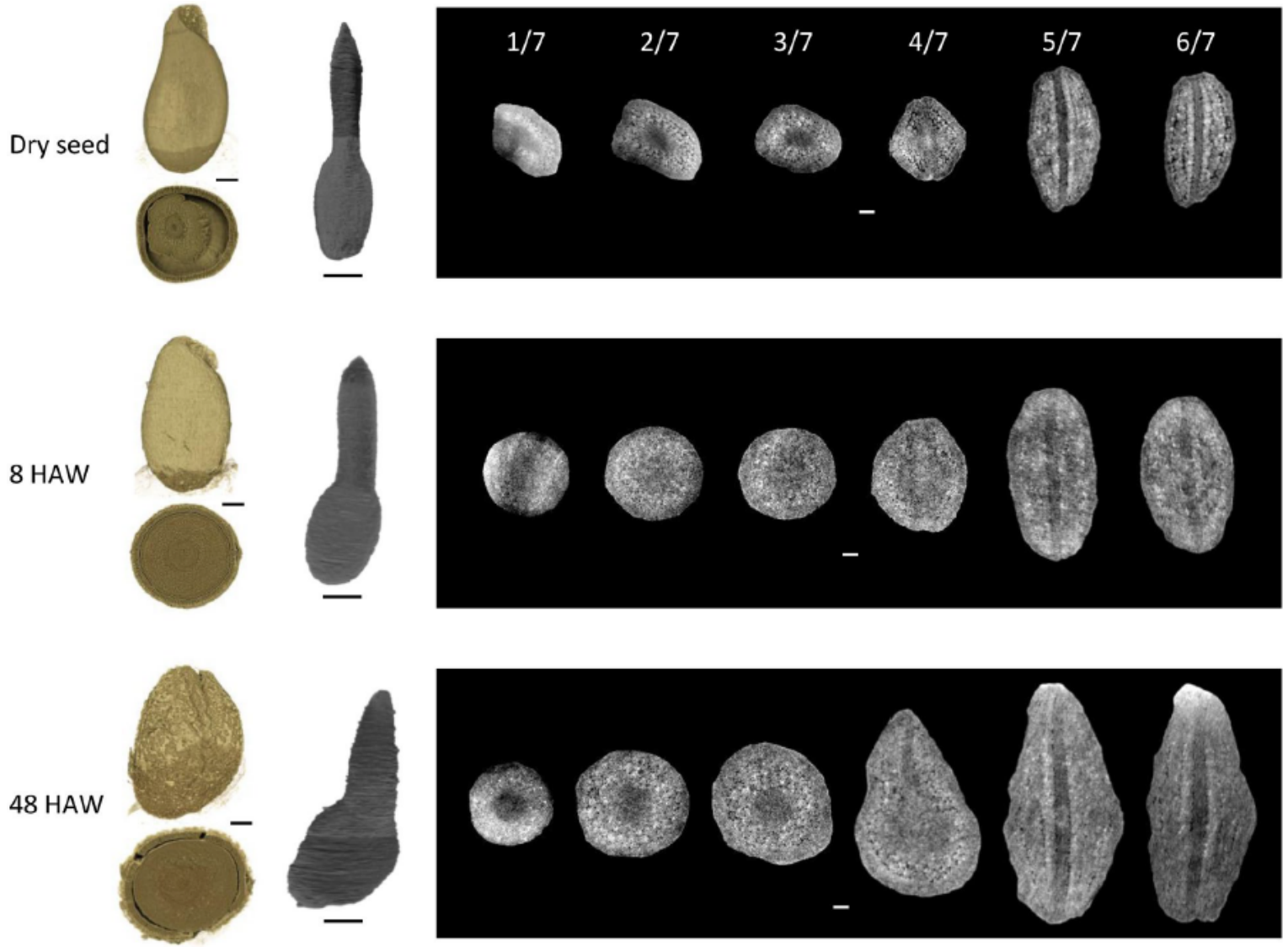


Kunishima, *et al.* Visualization of internal 3D structure of small live seed on germination by laboratory-based X-ray microscopy with phase contrast computed tomography. *Plant Methods* **16,** 7 (2020). https://doi.org/10.1186/s13007-020-0557-y

Seed after 48 hours of watering



Kunishima, *et al.* Visualization of internal 3D structure of small live seed on germination by laboratory-based X-ray microscopy with phase contrast computed tomography. *Plant Methods* **16**, 7 (2020). https://doi.org/10.1186/s13007-020-0557-y



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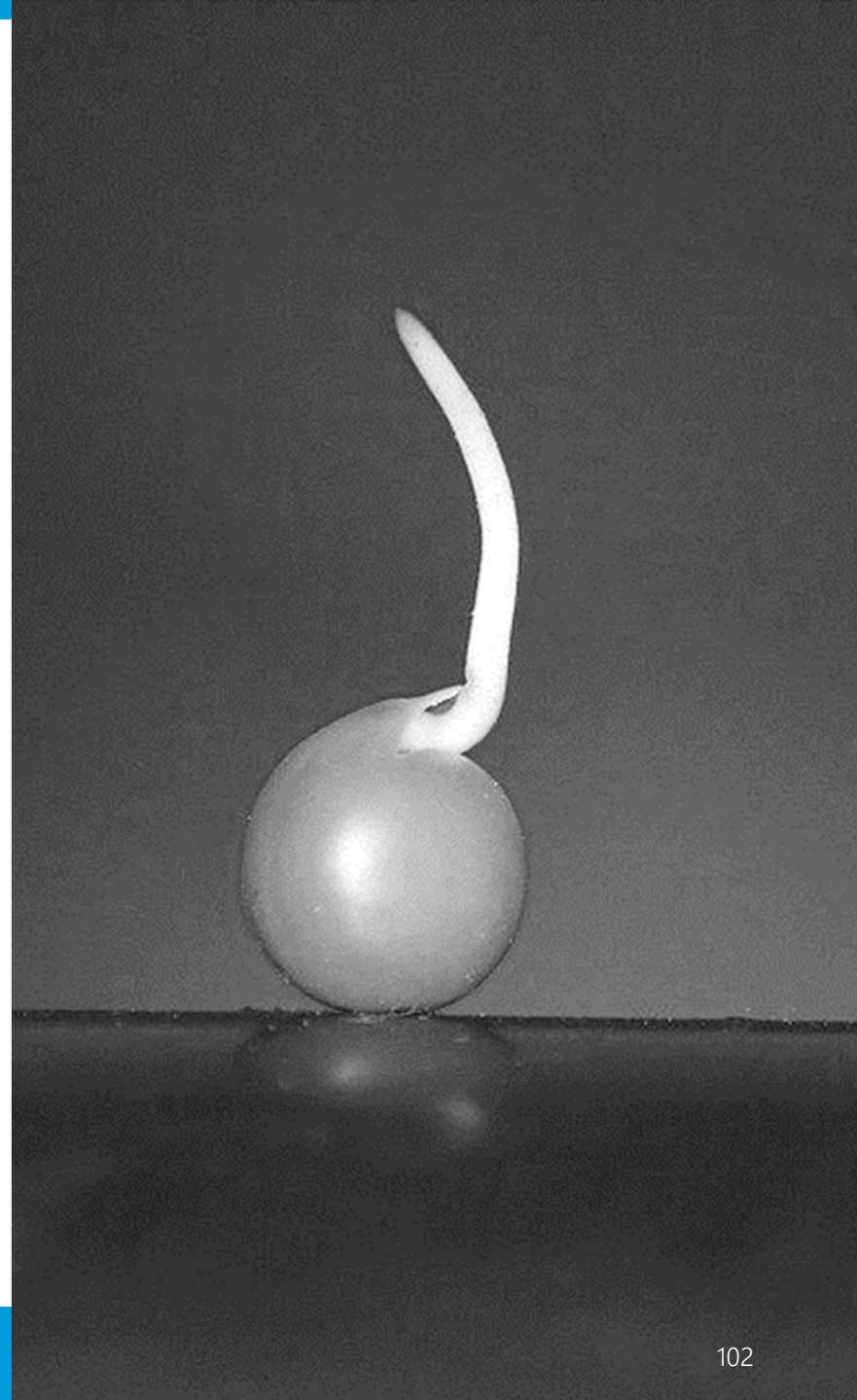
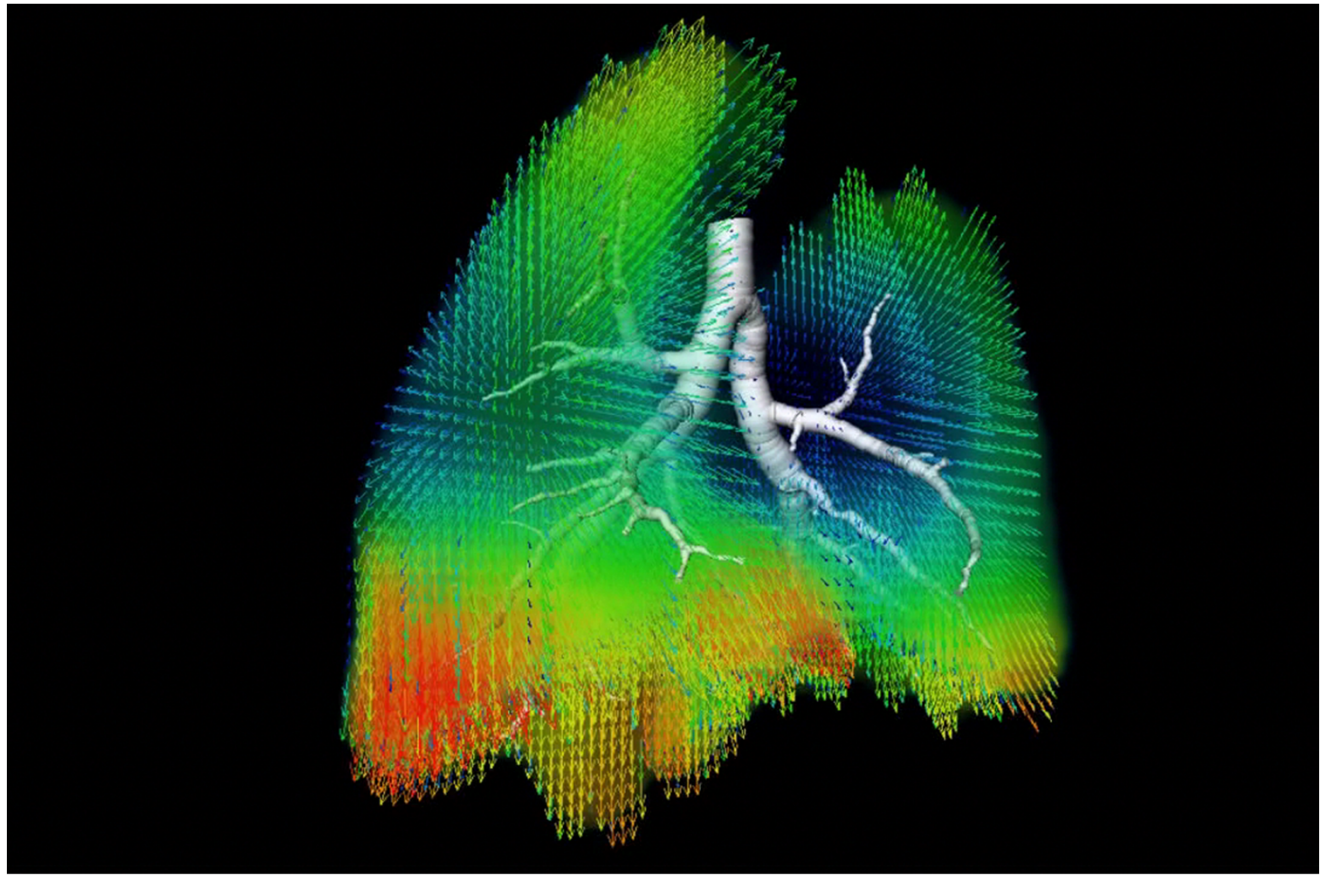
4D & *IN-SITU* APPLICATIONS

- Heating/cooling process
- Shape change under stress
- Diffusion process
- Growth process
- Degradation process



CAN WE SEE AIR FLOW IN LUNGS?

Air flow in mouse lungs



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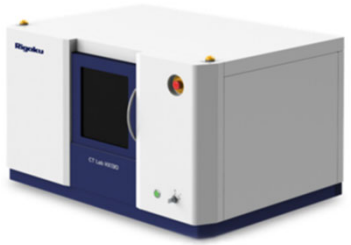
- How to plan experiments
- 4D & *in-situ* applications

ALL IMAGES WERE COLLECTED ON…

nano3DX CT Lab HX CT Lab GX



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X-ray CT Virtual Workshop Series
Viewers Choice - ImageJ
November 17th Wednesday
11:00 am PST / 2:00 pm EST

Q & A SESSION

Aya Takase

Tom Concolino

We'll follow up with your questions.

Recording will be available tomorrow.

Register for the next workshop.


THANK YOU FOR JOINING US
SEE YOU NEXT TIME!