Functional Failure Analysis

Wed., June 9, 10 am CDT

Presenter: Angela Criswell | **Co-presenter:** Ted Huang | **Host:** Viral Vaghela

- *You will be muted during the workshop*
- *You can ask questions using the Q&A tool.*
- *You should hear music if your sound is working*

Functional Failure Analysis

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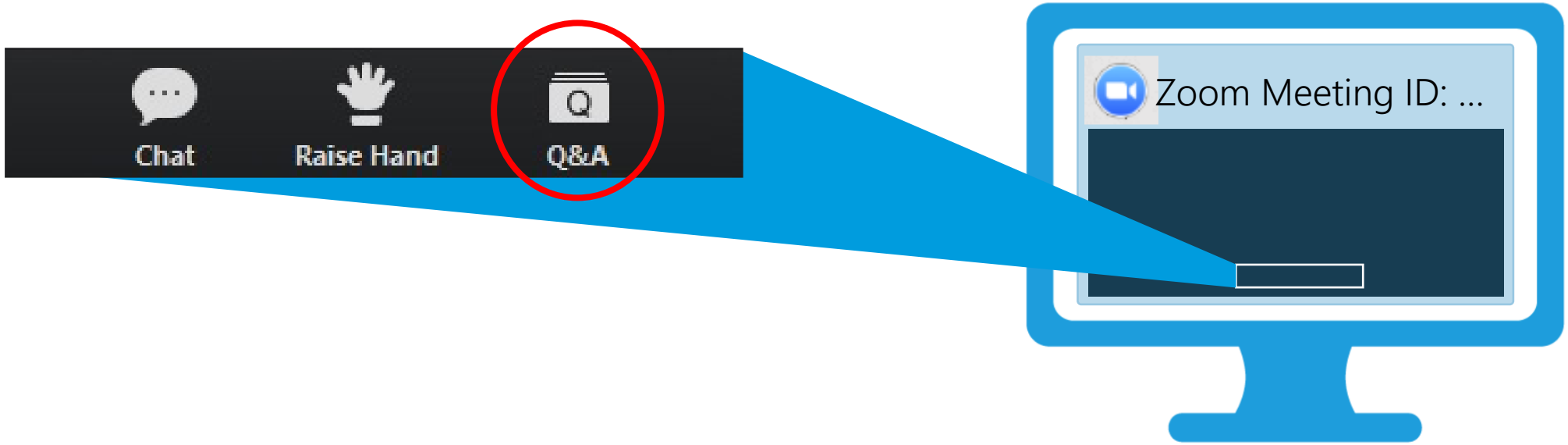
Presenter: Angela Criswell | **Co-presenter:** Ted Huang | **Host:** Viral Vaghela

We are starting now…

- Presenter: **Angela Criswell** | Director of X-ray Imaging
- Co-presenter: **Ted Huang** | Application Scientist
- Host: **Viral Vaghela** | Account Manager



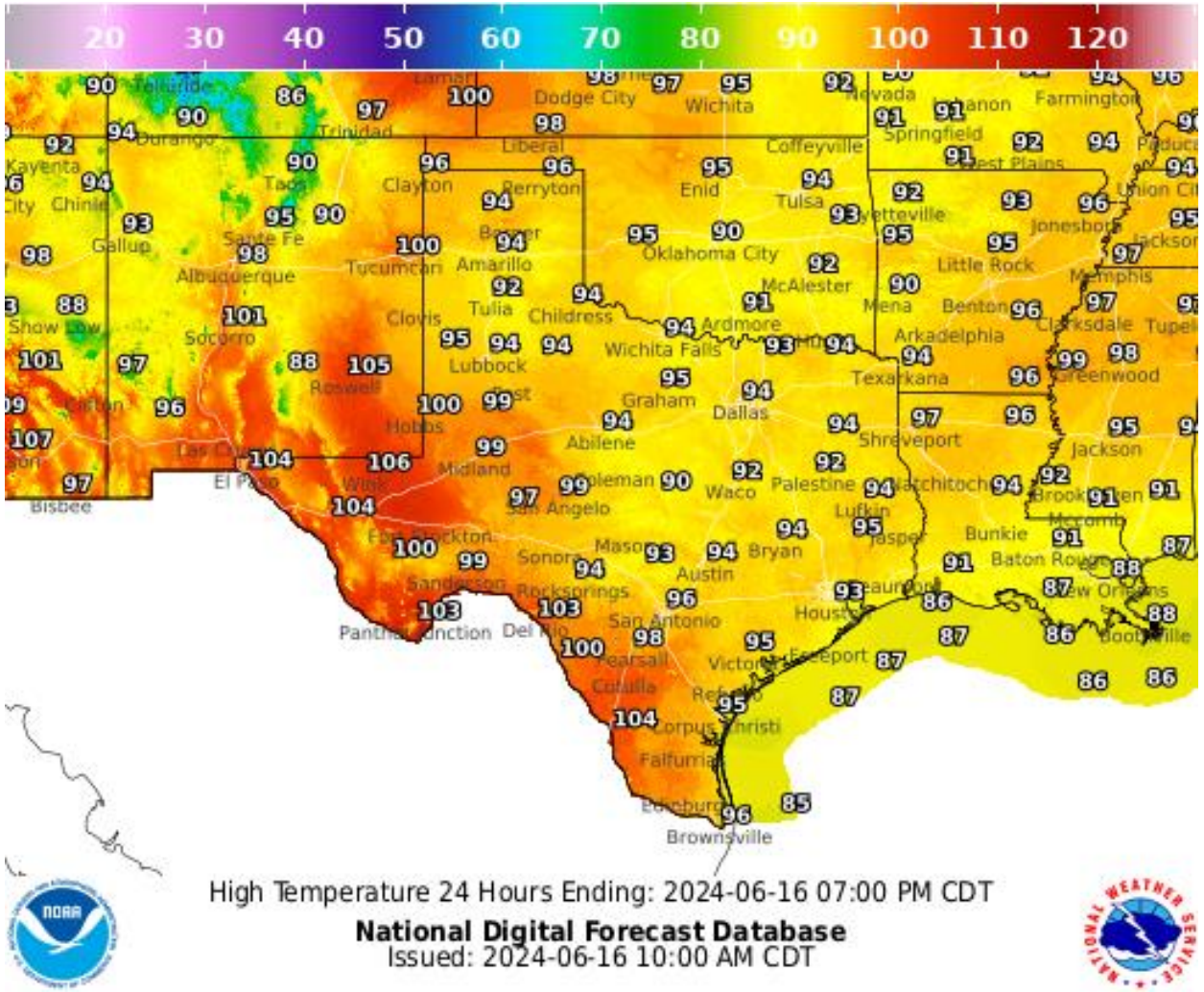
You can ask questions during the presentation.
Please use the Q&A to ask questions.

Recording will be available tomorrow.

Functional failure analysis

Polling Question #1

Microsoft Stock



https://www.noaa.gov/

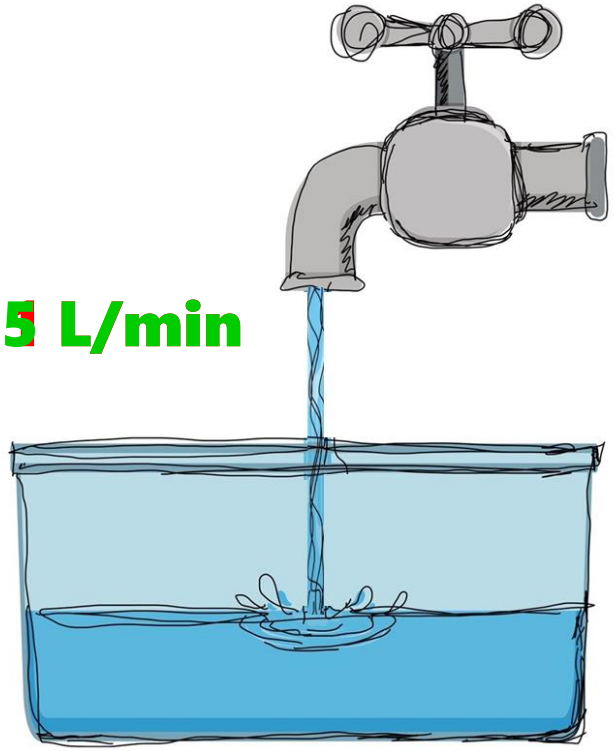
Pool Life Support System

You will learn

- What is functional failure
- What are the considerations when using X-ray CT to study functional failure?
- What information can we extract from CT data related to function?
- Functional failure examples

What is functional failure?

Loss of function

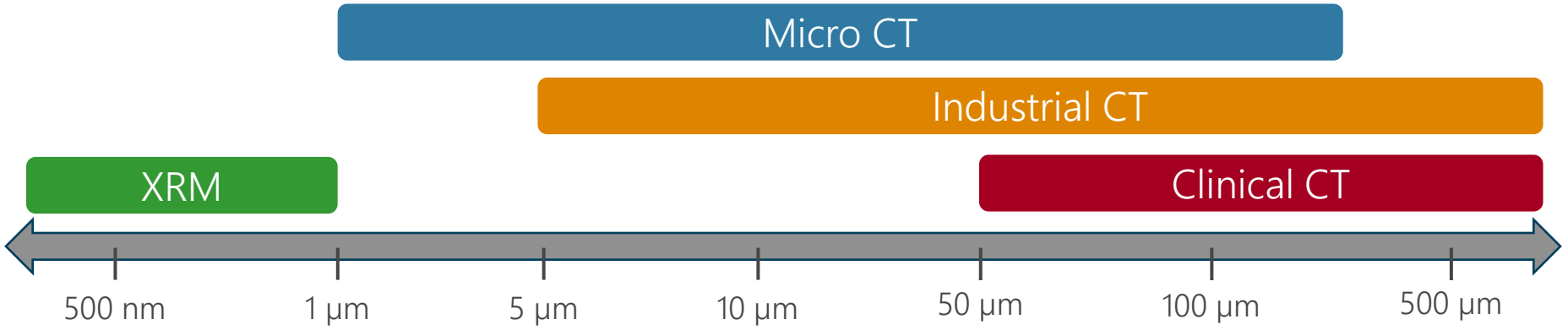


Loss of function

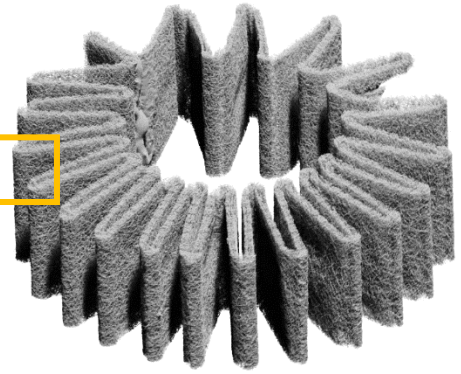
Diminished function

What can we investigate by CT?

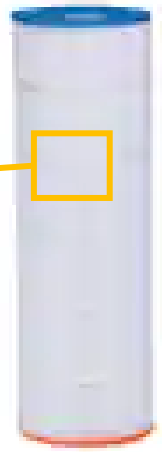
It’s a question of scale.



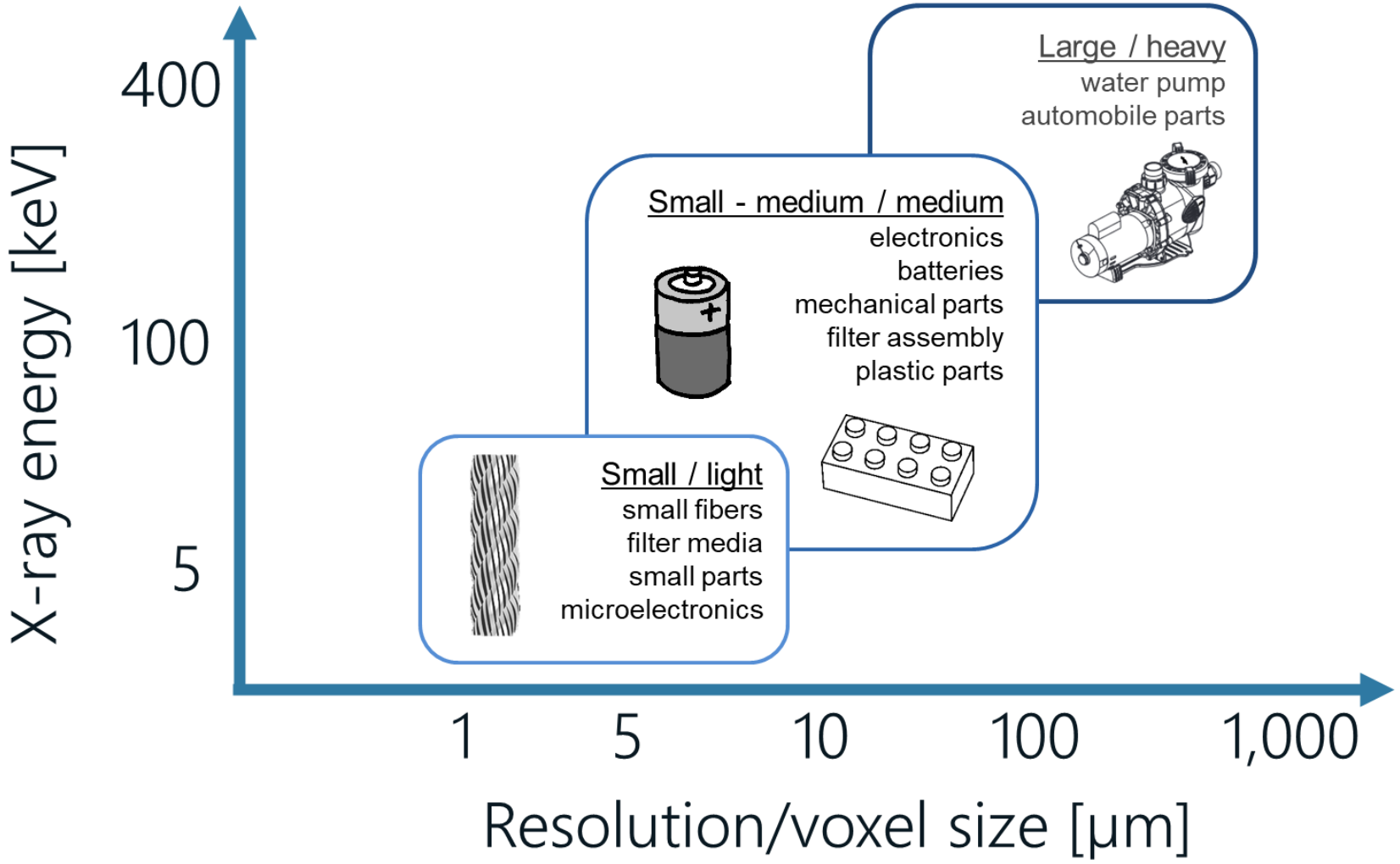
Filter media



Pleated filter



Complete filter

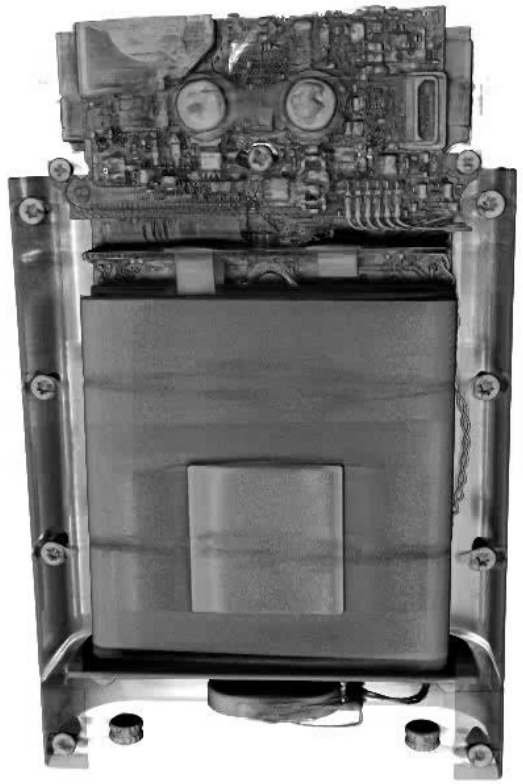


Analyzing CT data

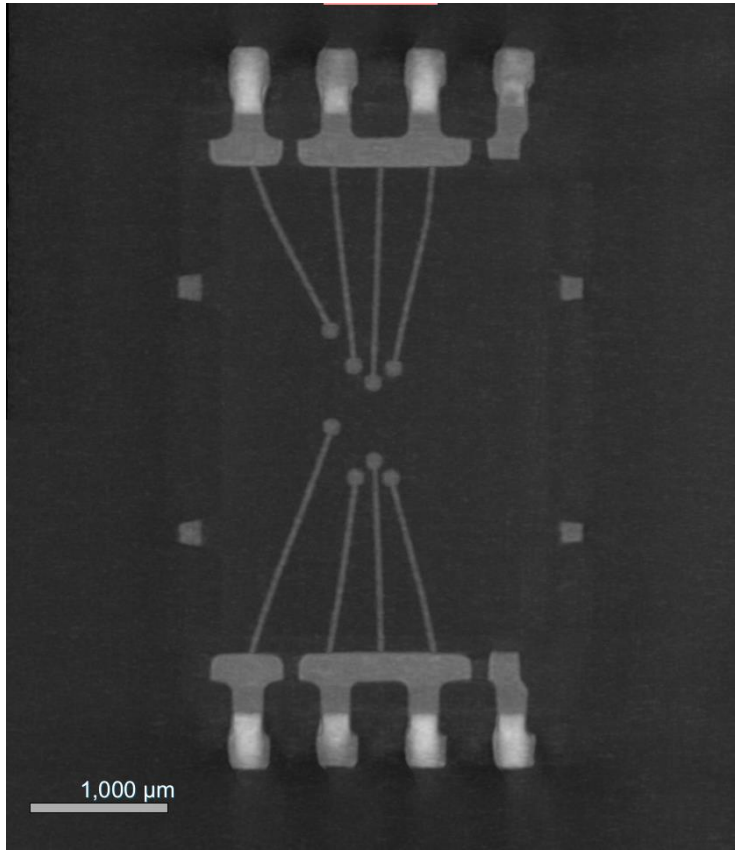
- Sometimes, 3D data inspection is enough.
- Quantitative analysis may require segmentation.
- Simulation can be powerful to optimize designs and life cycles.

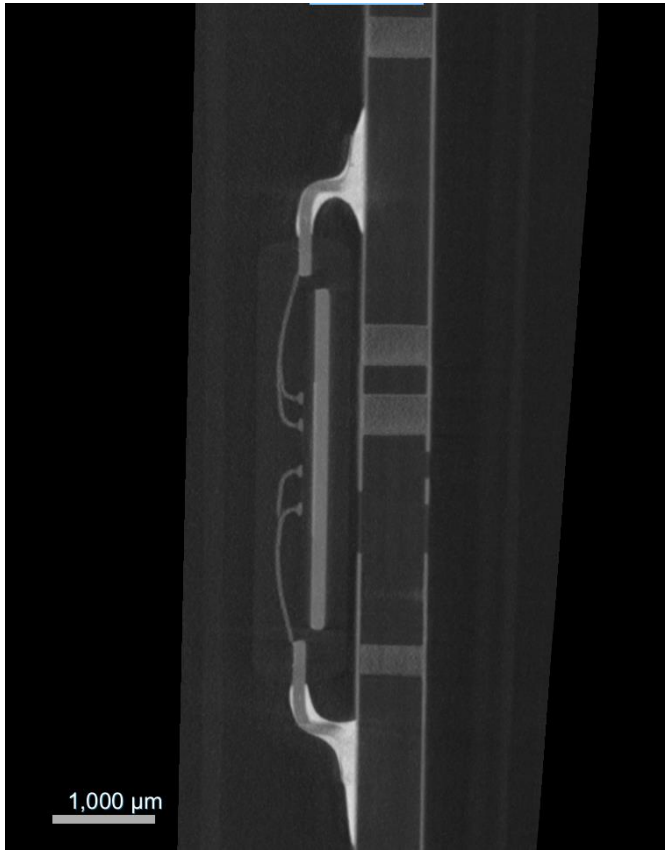
Sometimes simple inspection is enough

Sometimes simple inspection is enough

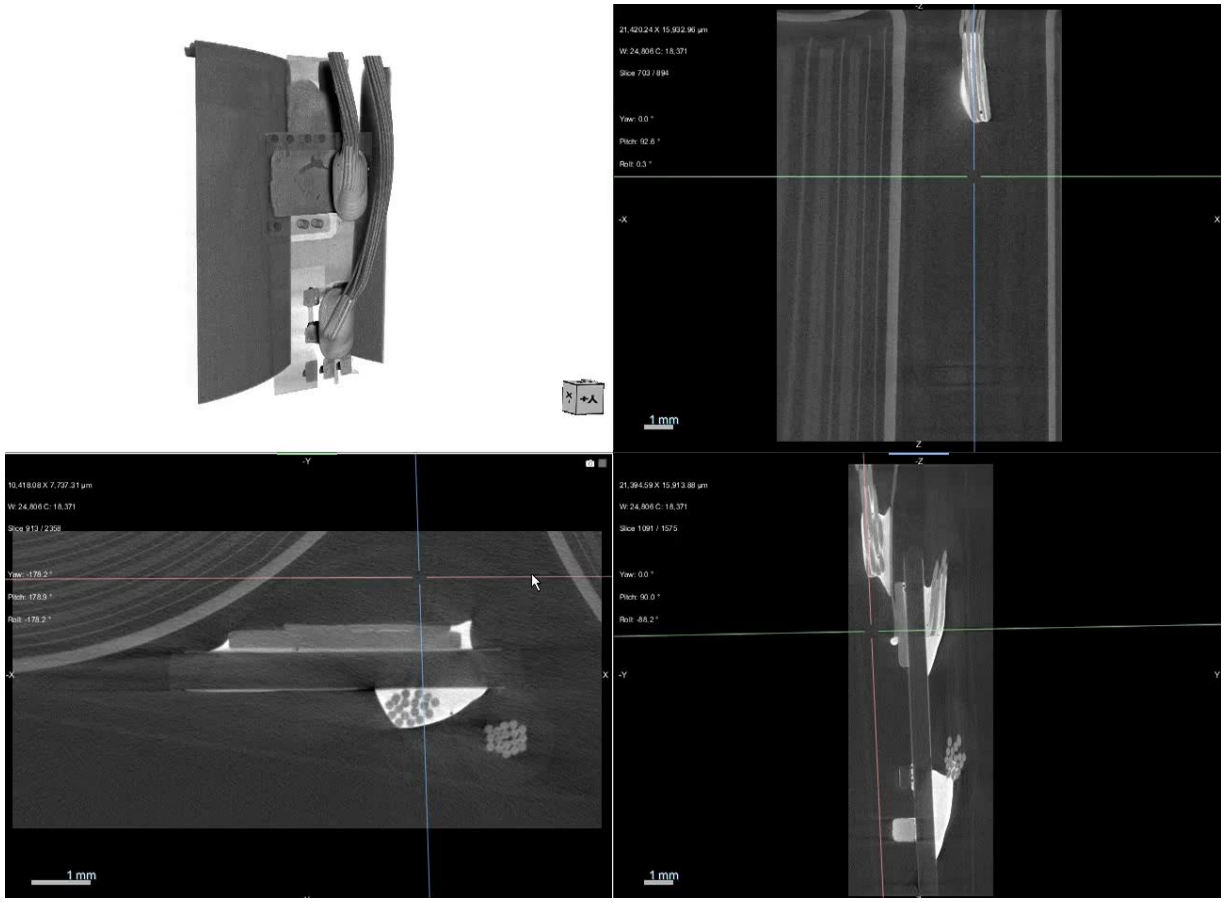


Sometimes simple inspection is enough





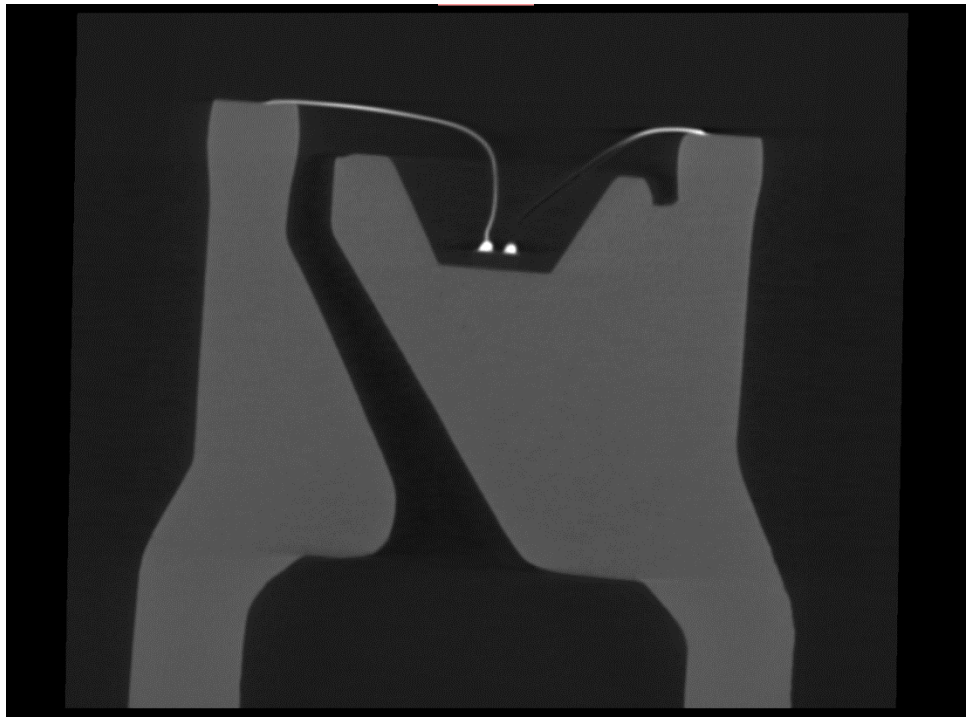
Sometimes simple inspection is enough

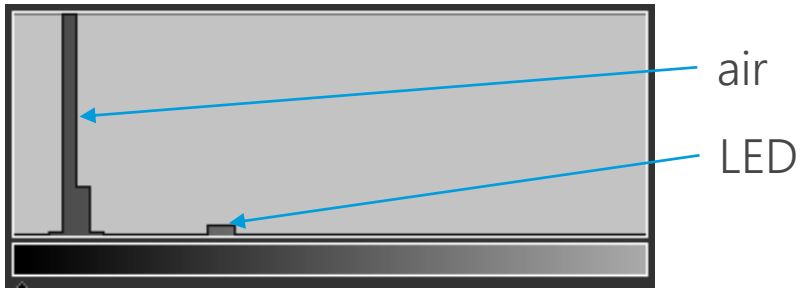


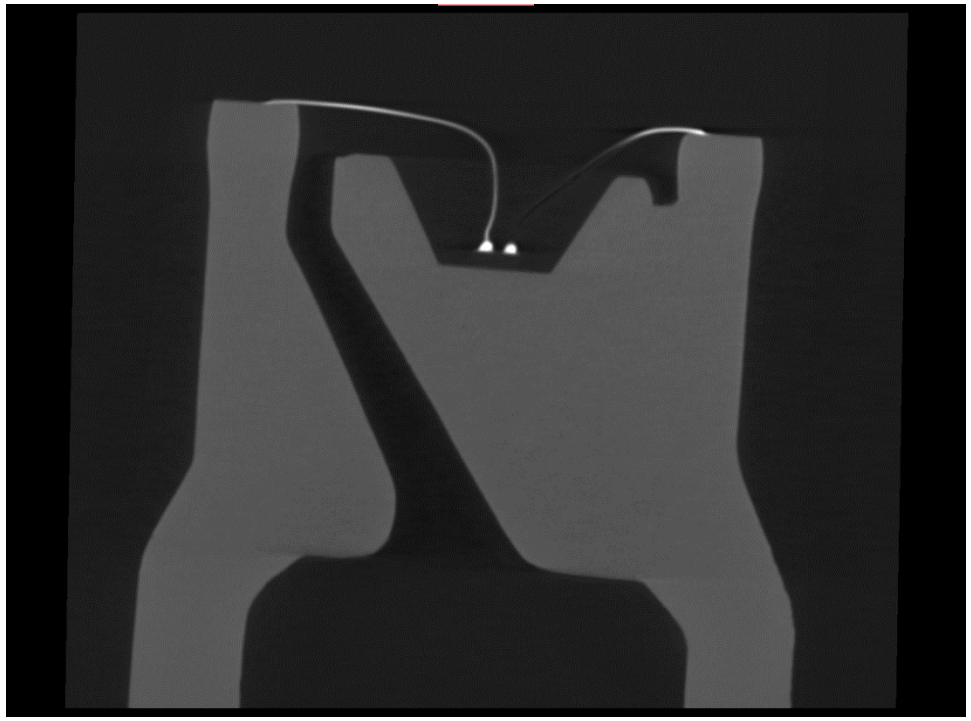
Sometimes simple inspection is NOT enough

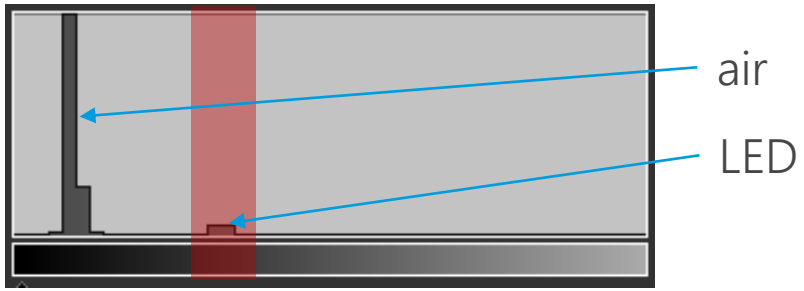
Polling Question #2

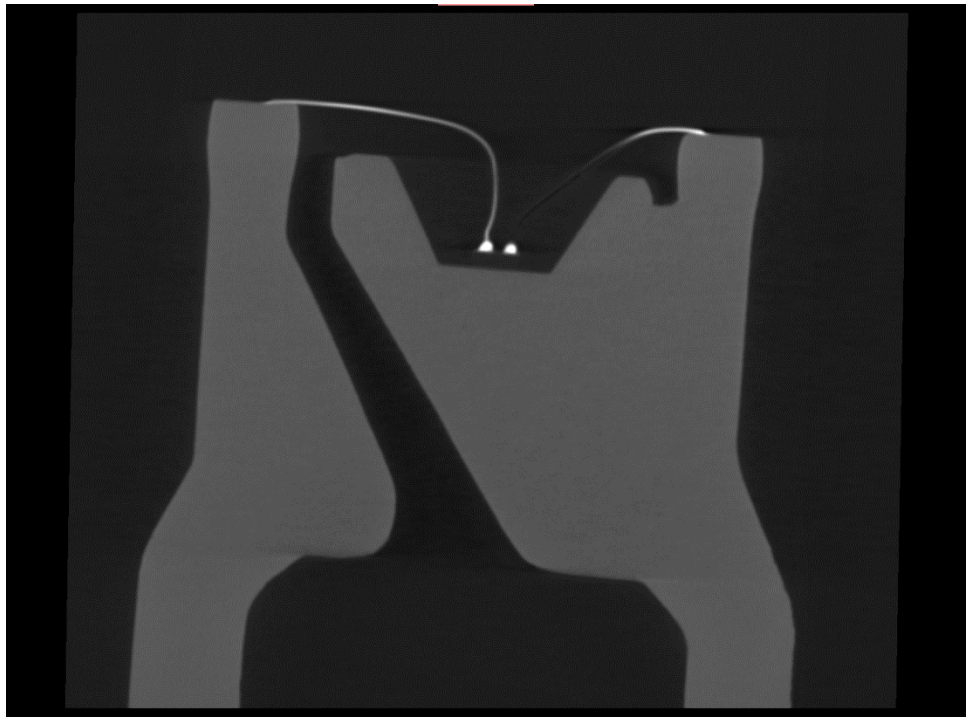
Microsoft Stock

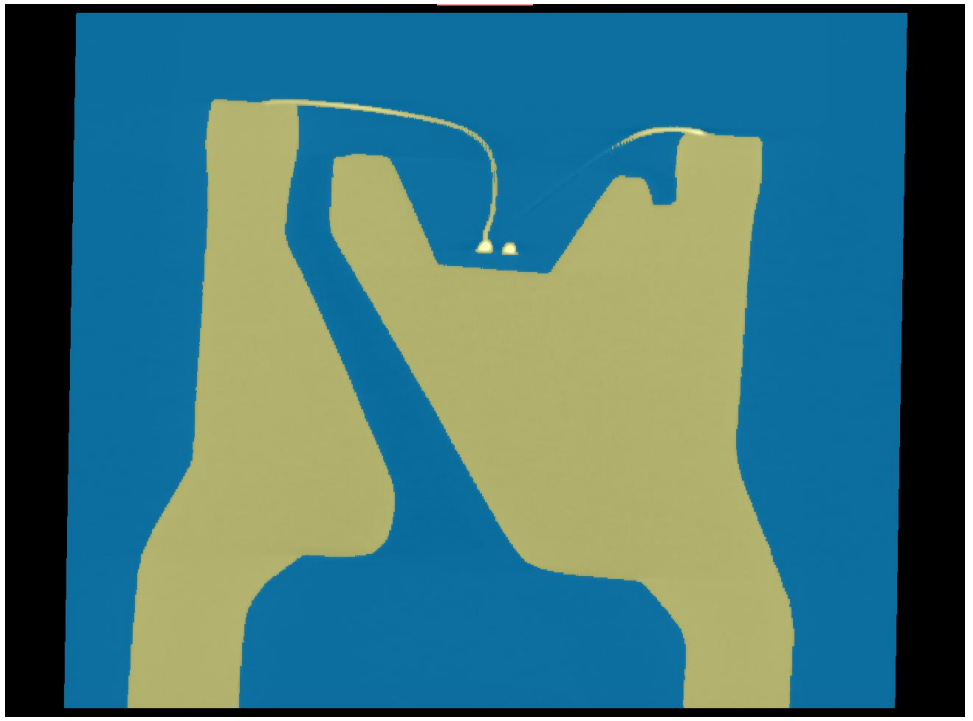


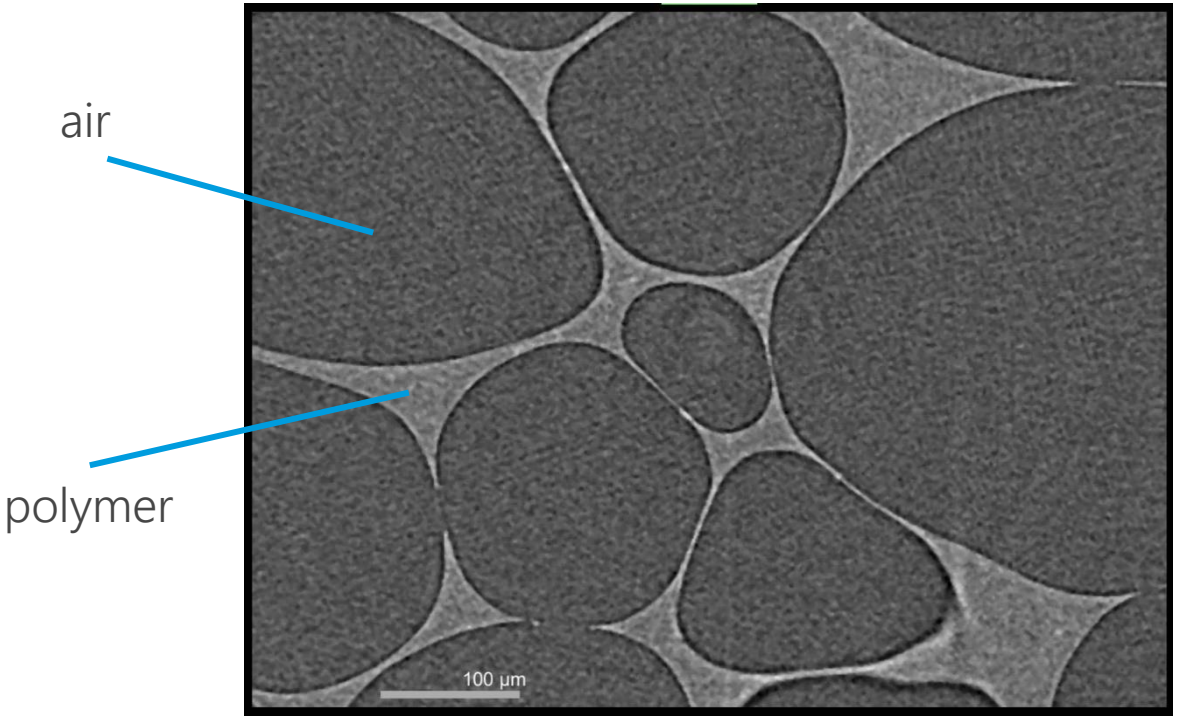


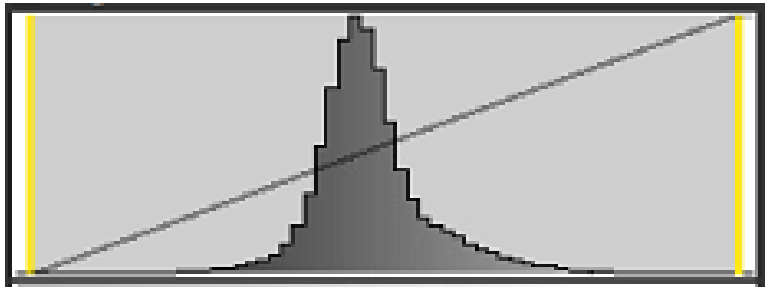


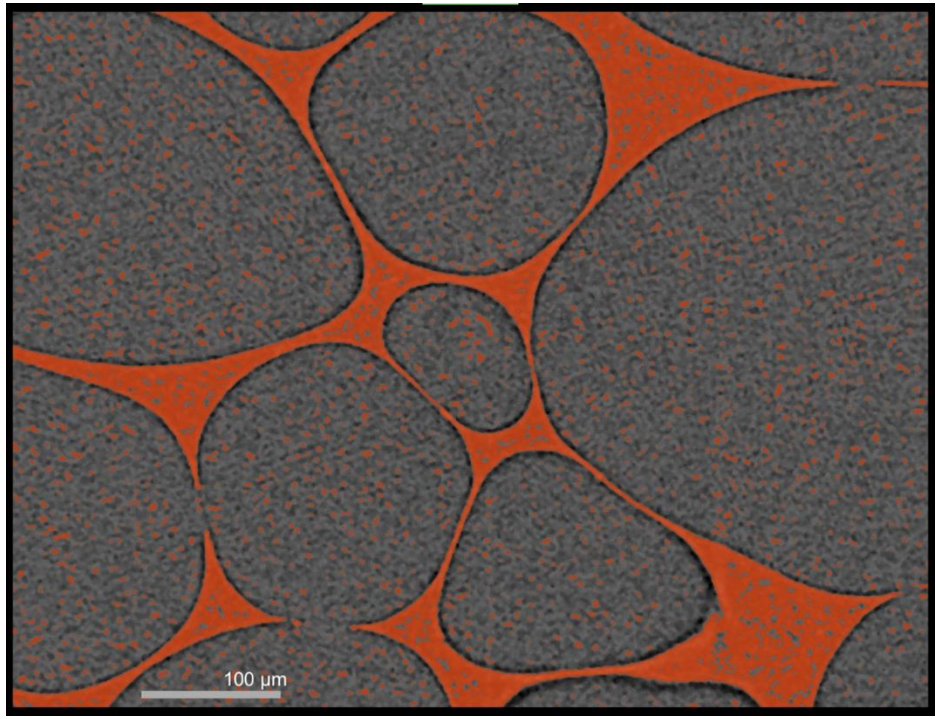


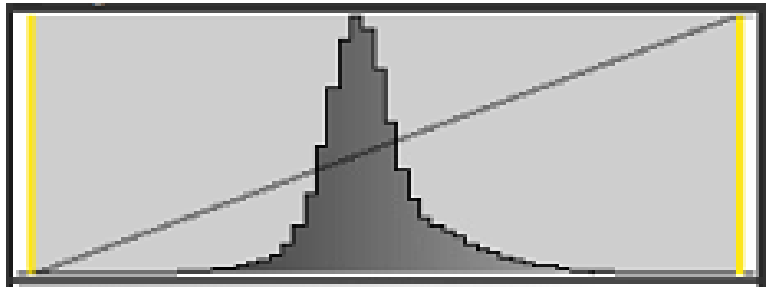


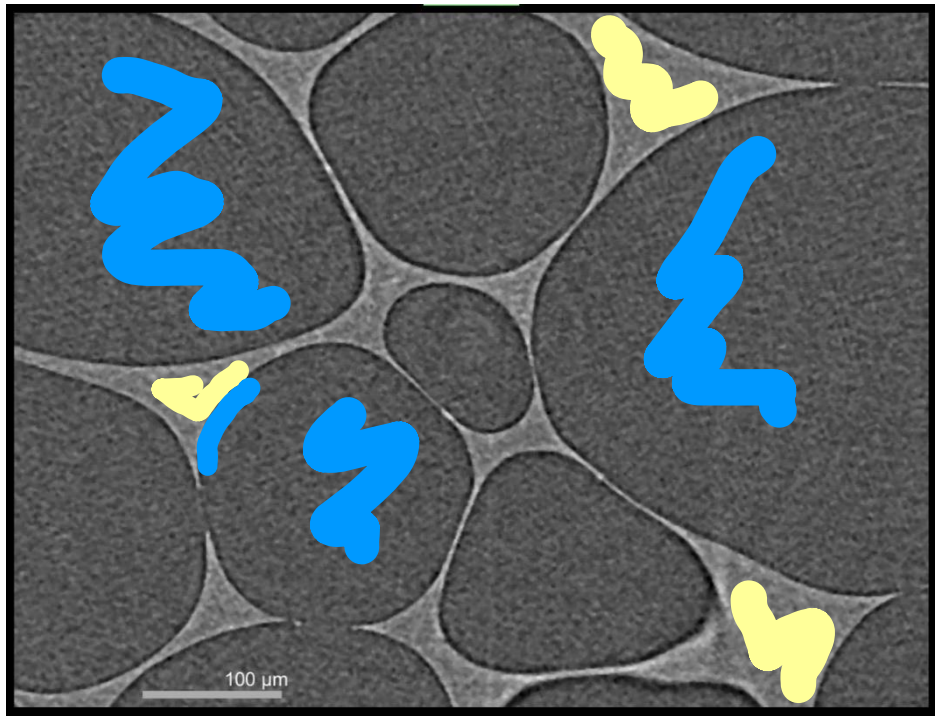






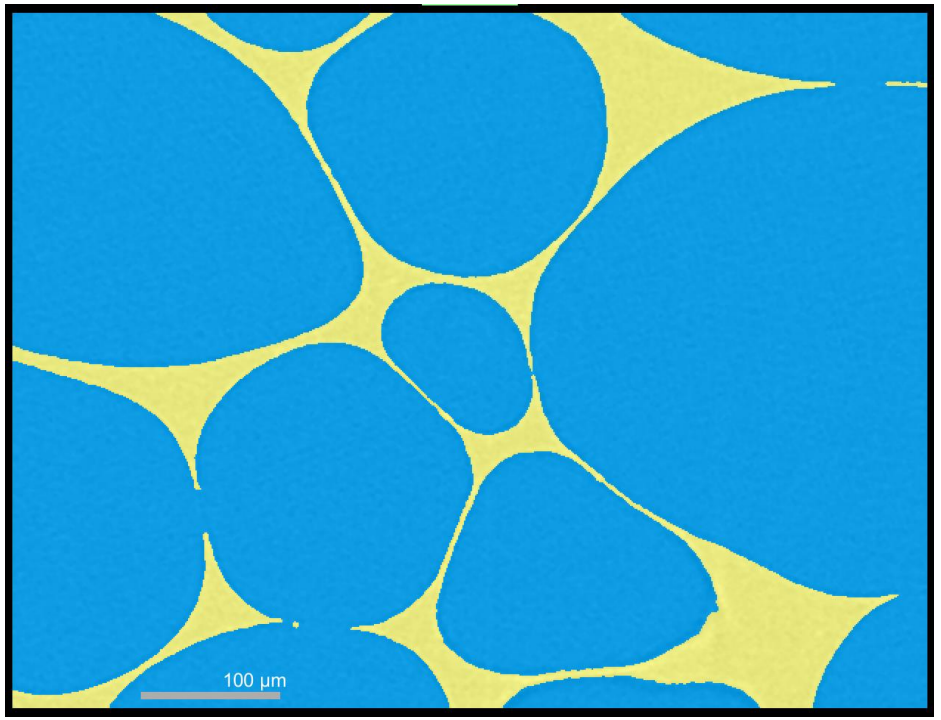


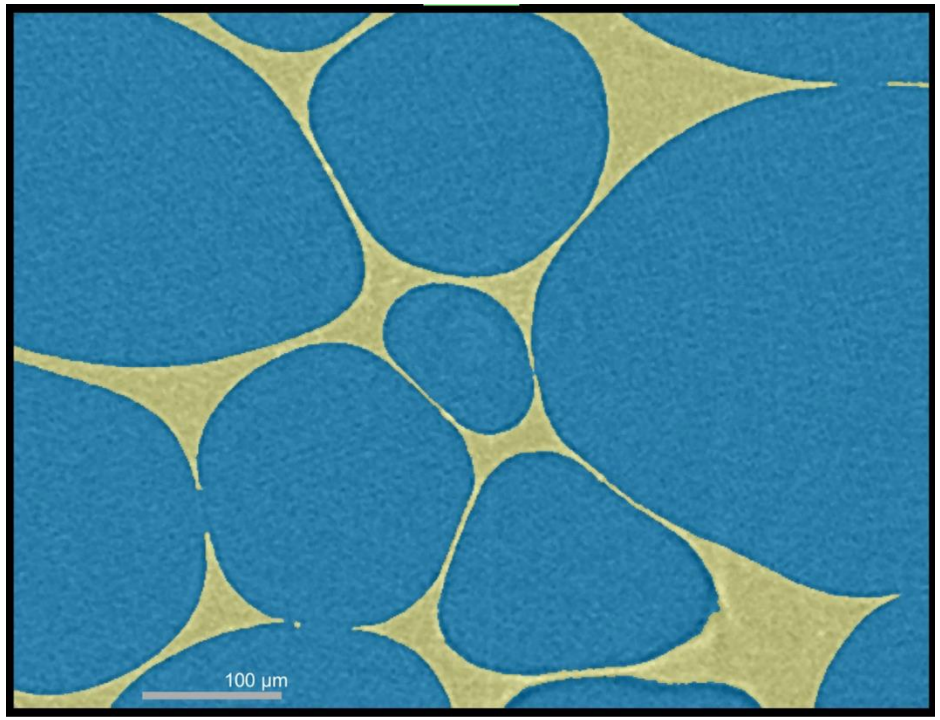




AI tools

Machine learning
Deep learning





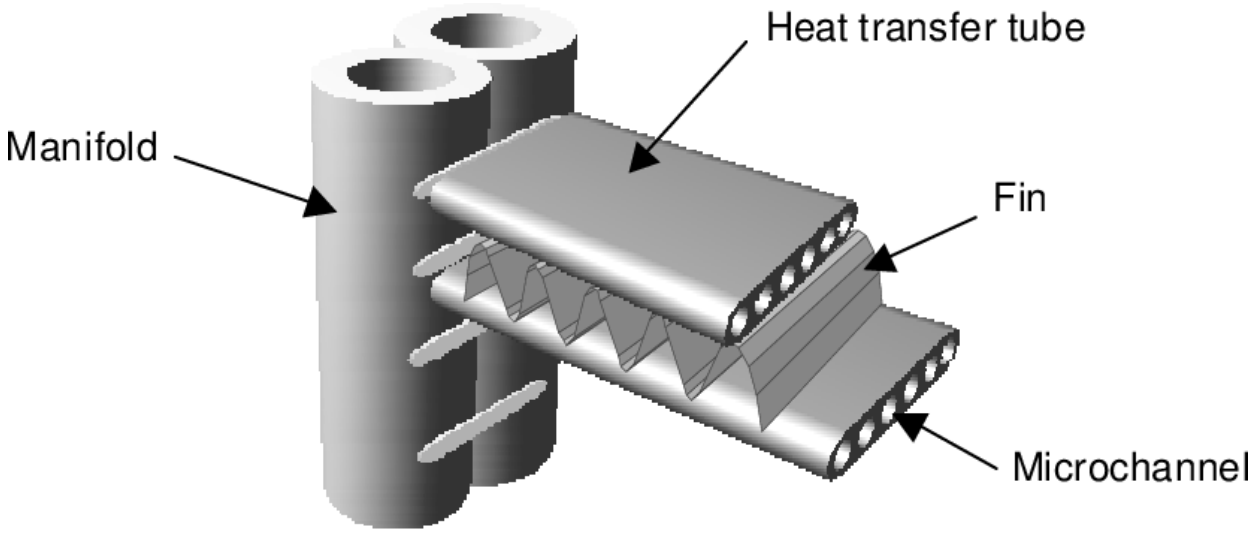
Phase	Color	Volume fraction [%]
Polymer	Yellow	18.04
Air	Blue	81.96

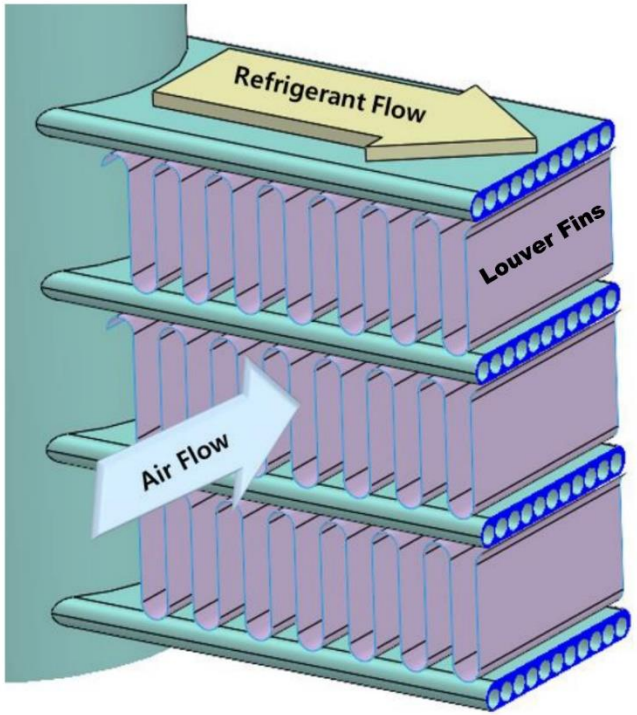
Failure analysis accessible by CT

- Volume fraction analysis
- Porosity
- Open vs. closed porosity
- Cracks and crack propagation
- Continuity/Discontinuity
- Orientation

Let’s look at some examples

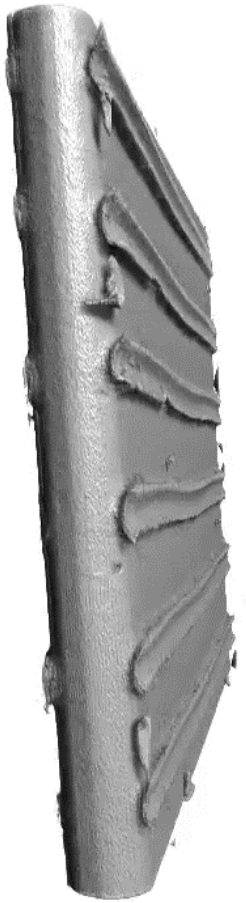
MicroChannel Heat Exchanger



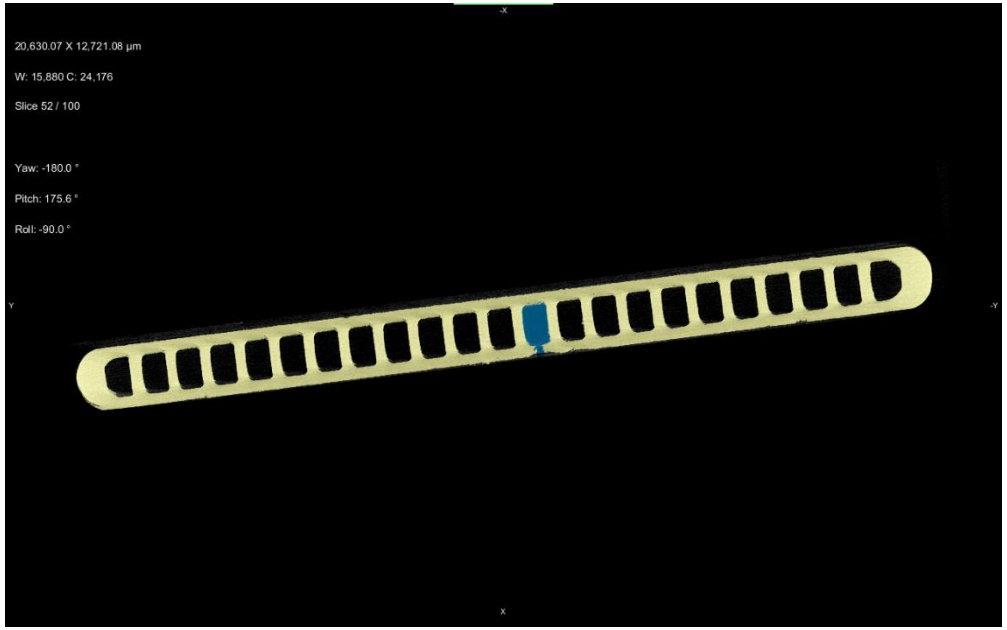


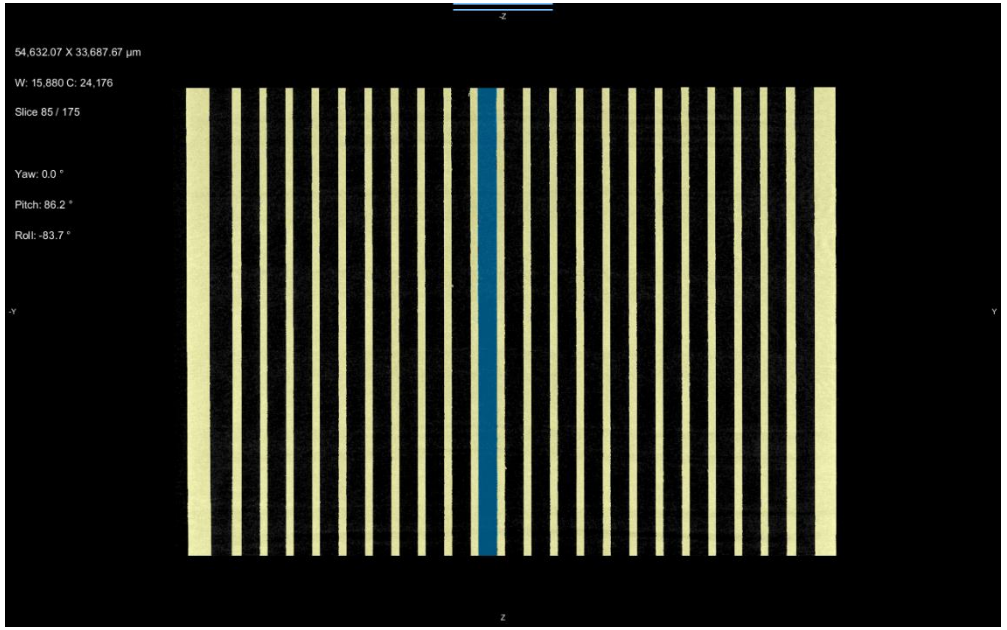
Ullah, N., *et. al.*, 2022. *Machines* 10, 1177.

MicroChannel Heat Exchanger



MicroChannel Heat Exchanger (MCHE)





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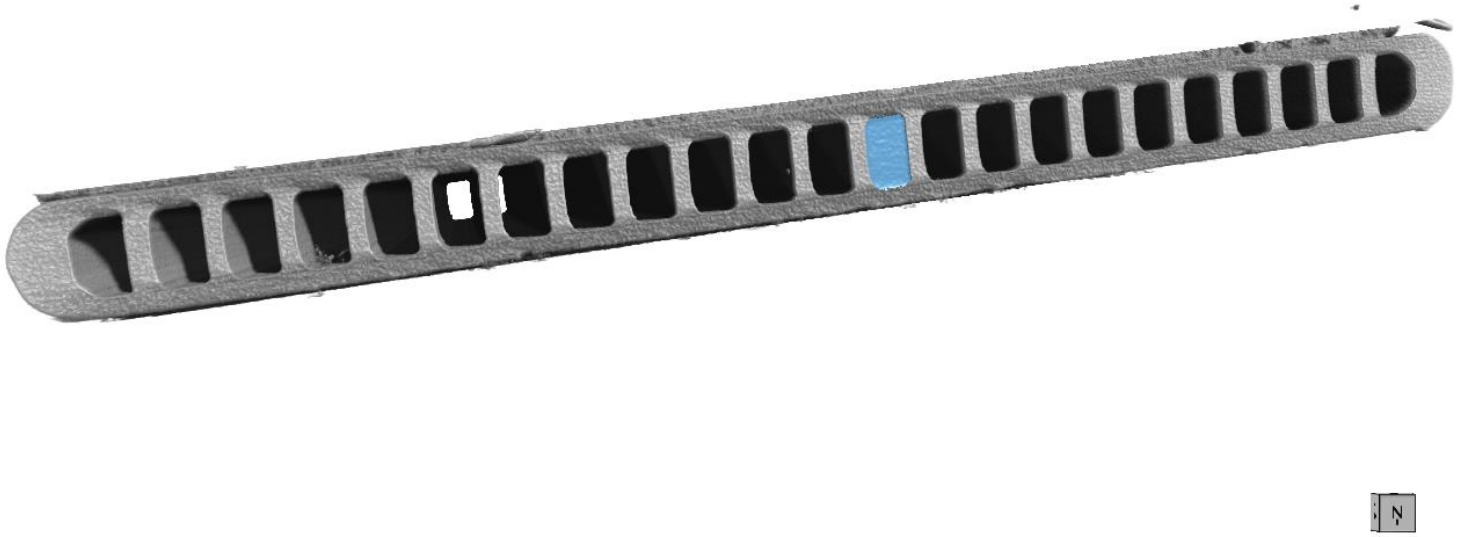

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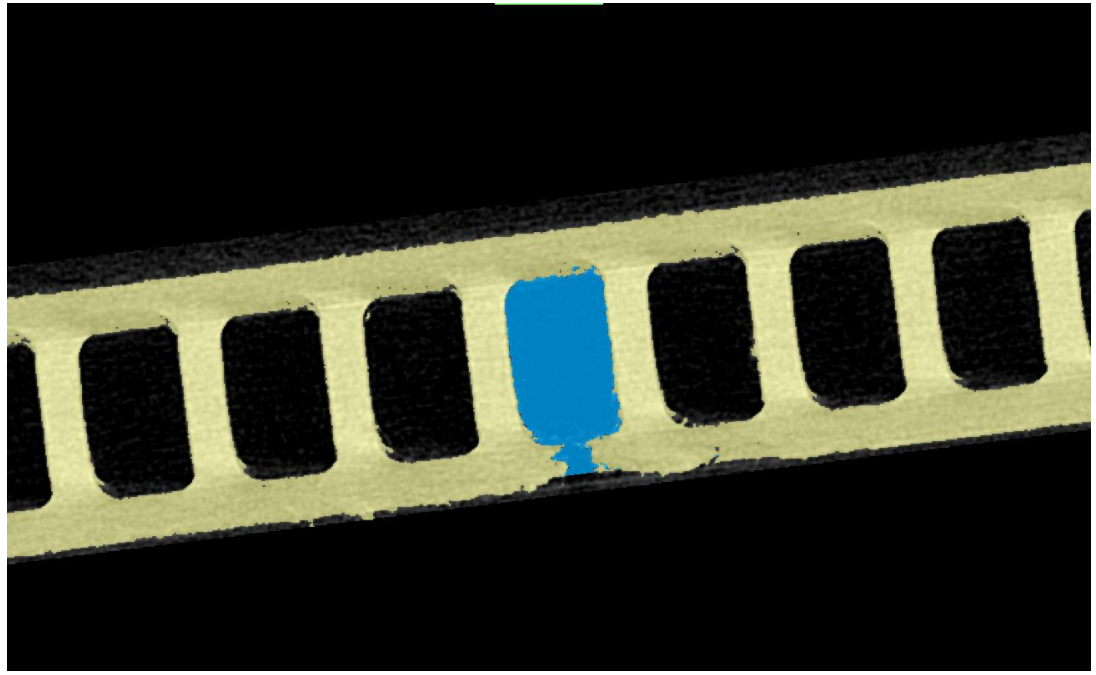

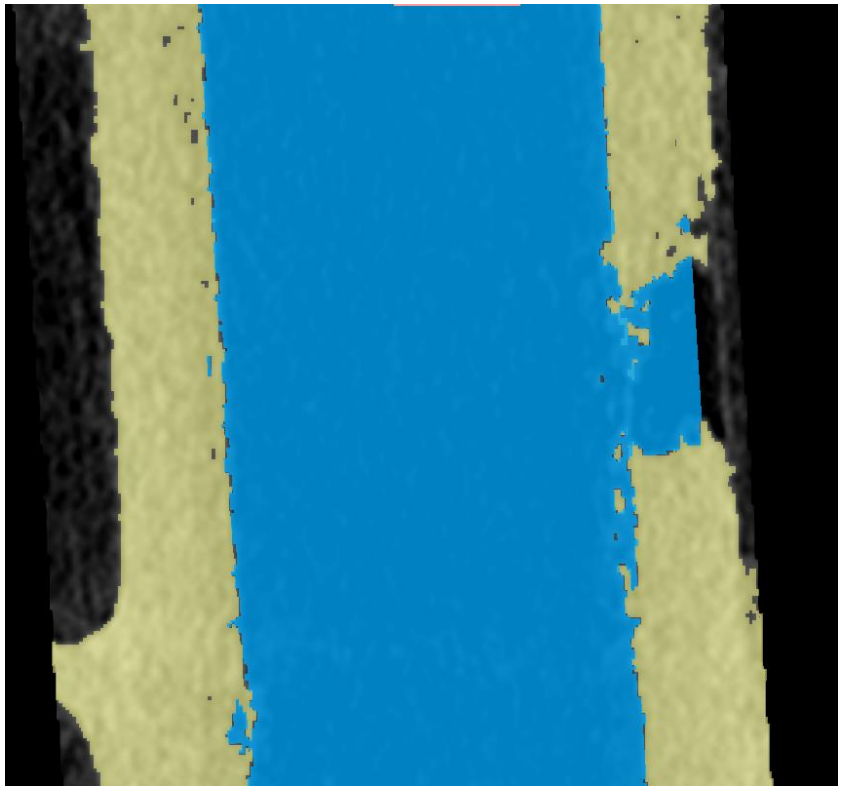

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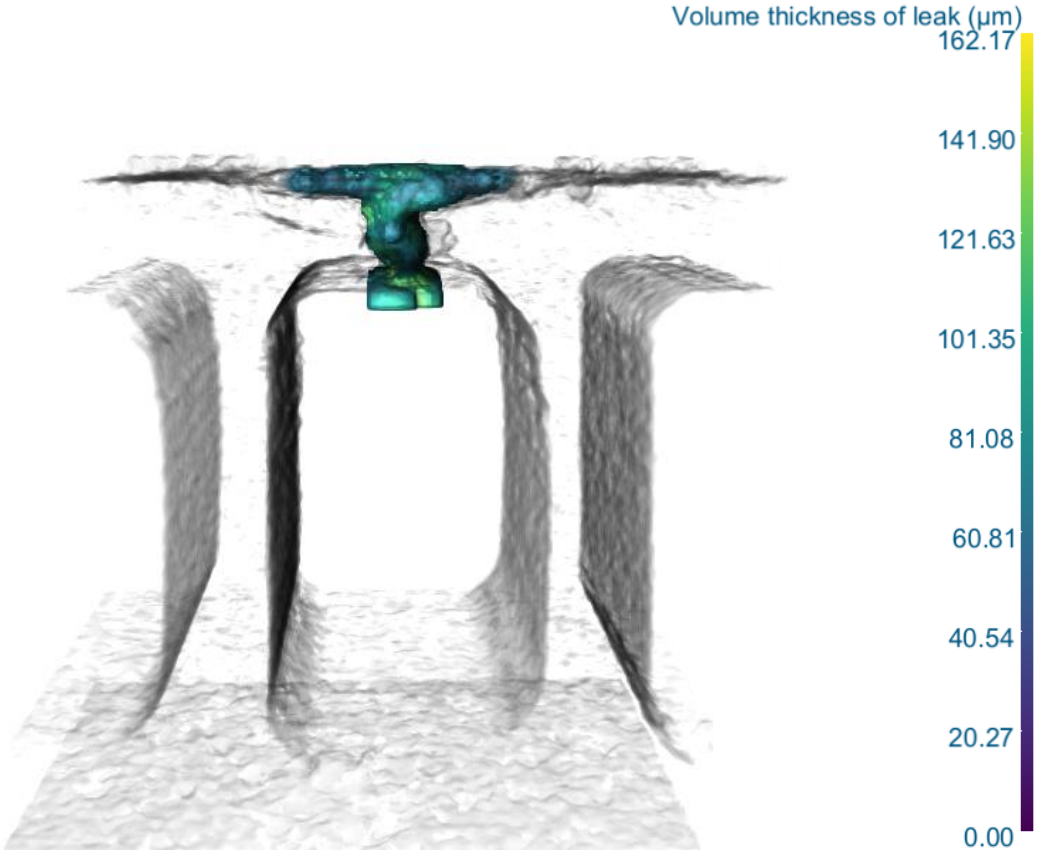
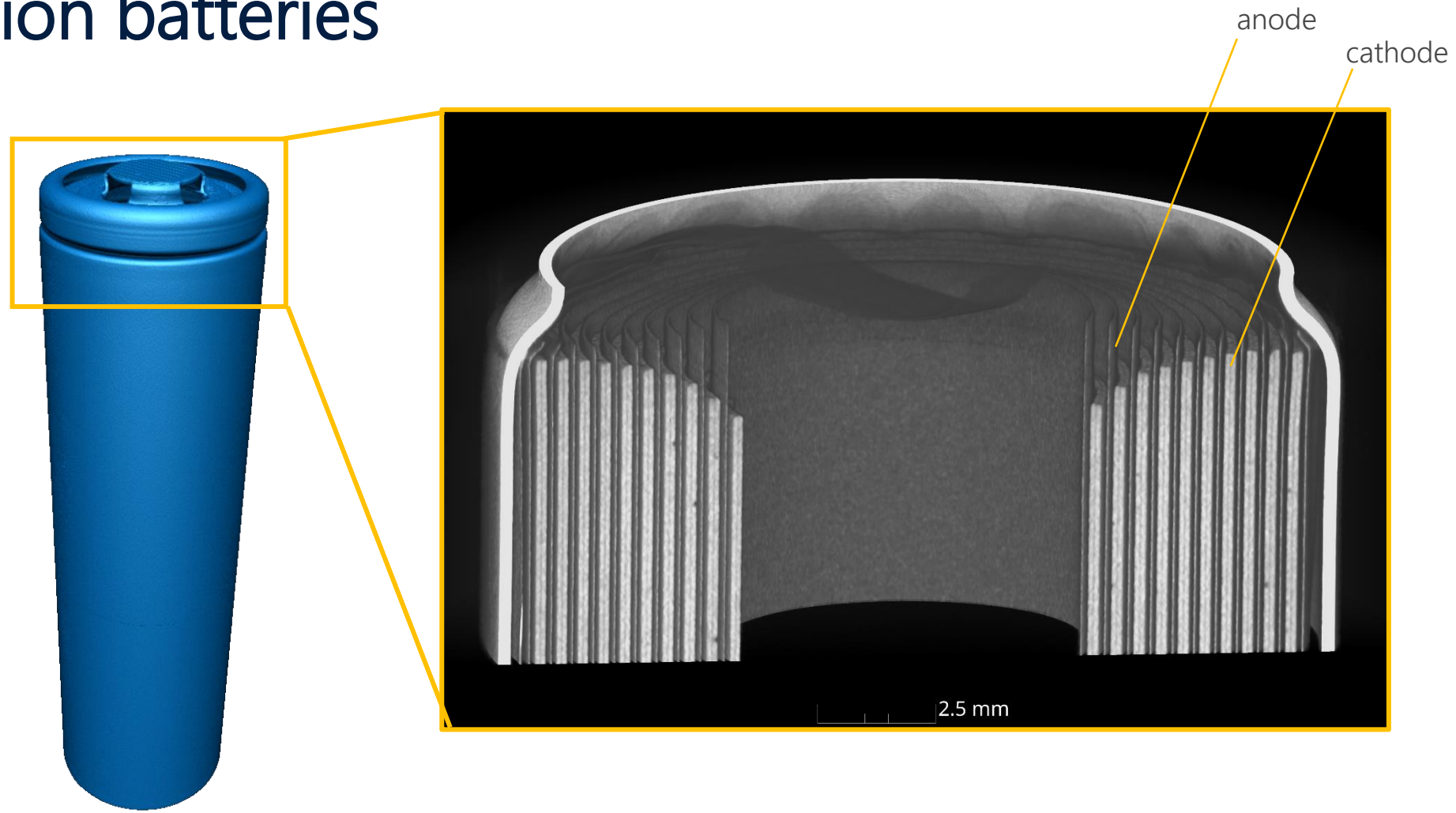
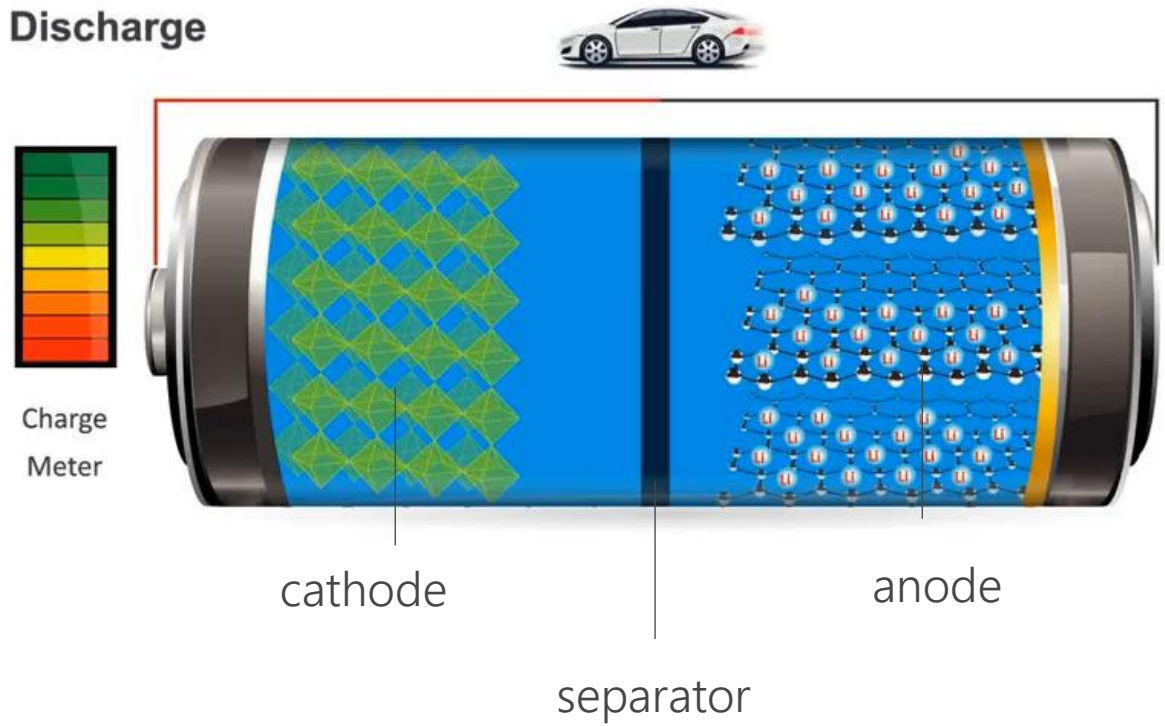
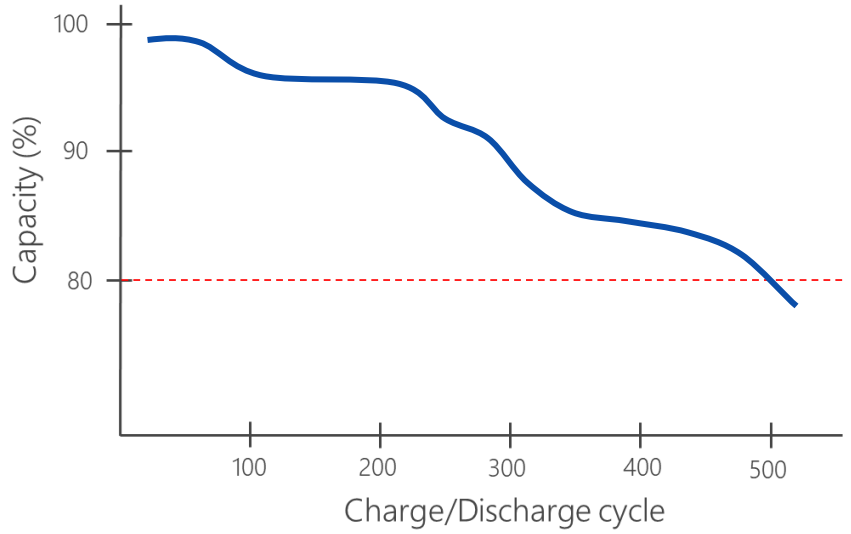


Li-ion batteries



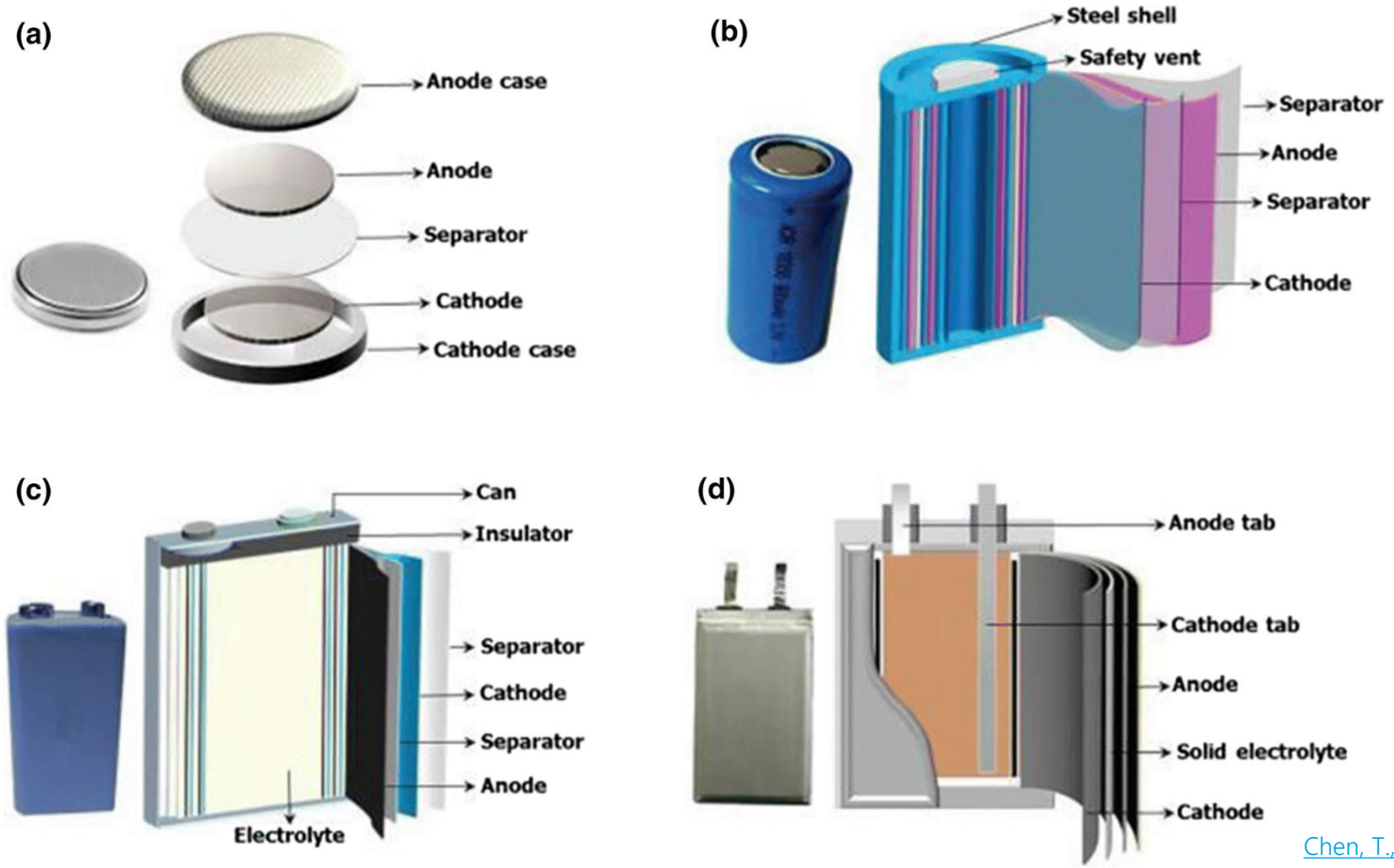
Li-ion batteries





https://www.energy.gov/energysaver/articles/how-lithium-ion-batteries-work

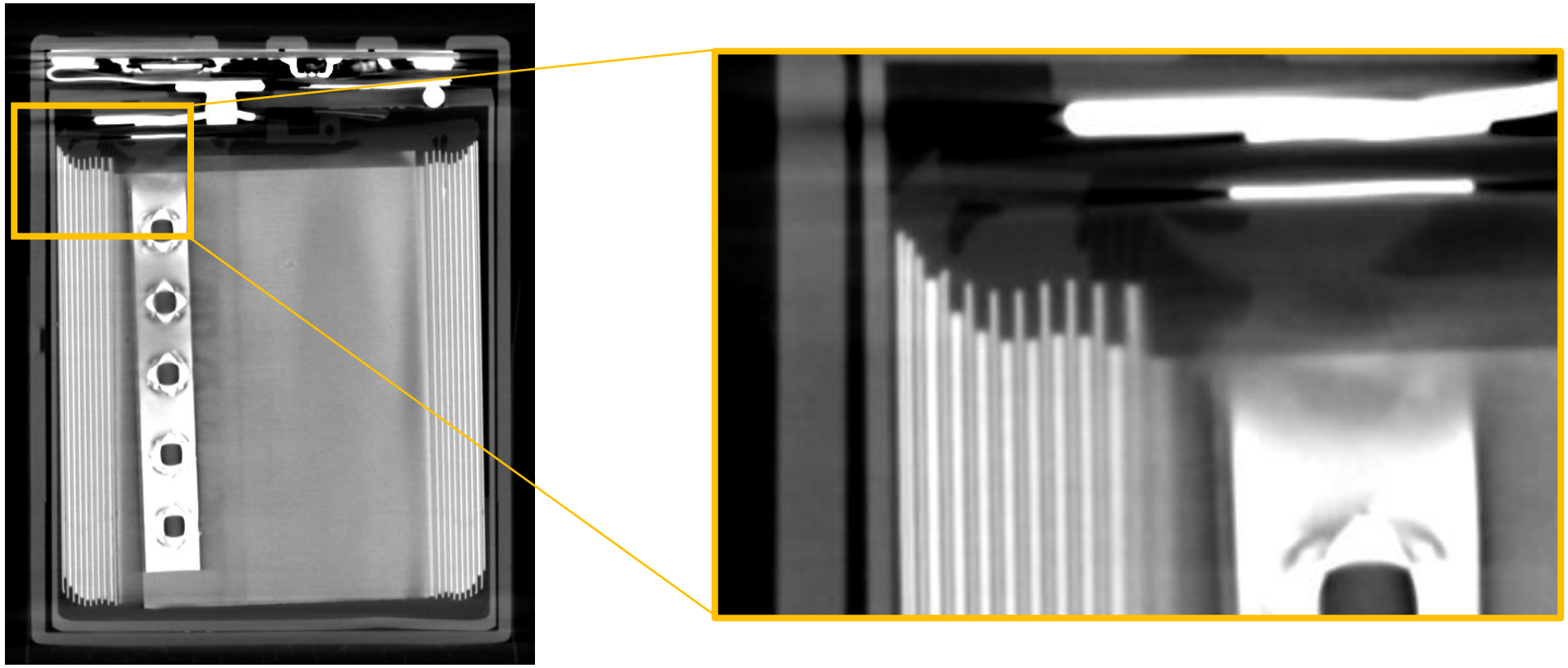
Li-ion batteries



Chen, T., *et.al.*, **2020**. *Trans. Tianjin Univ.* 26, 208–217.

Li-ion battery from digital camera

Li-ion battery from digital camera

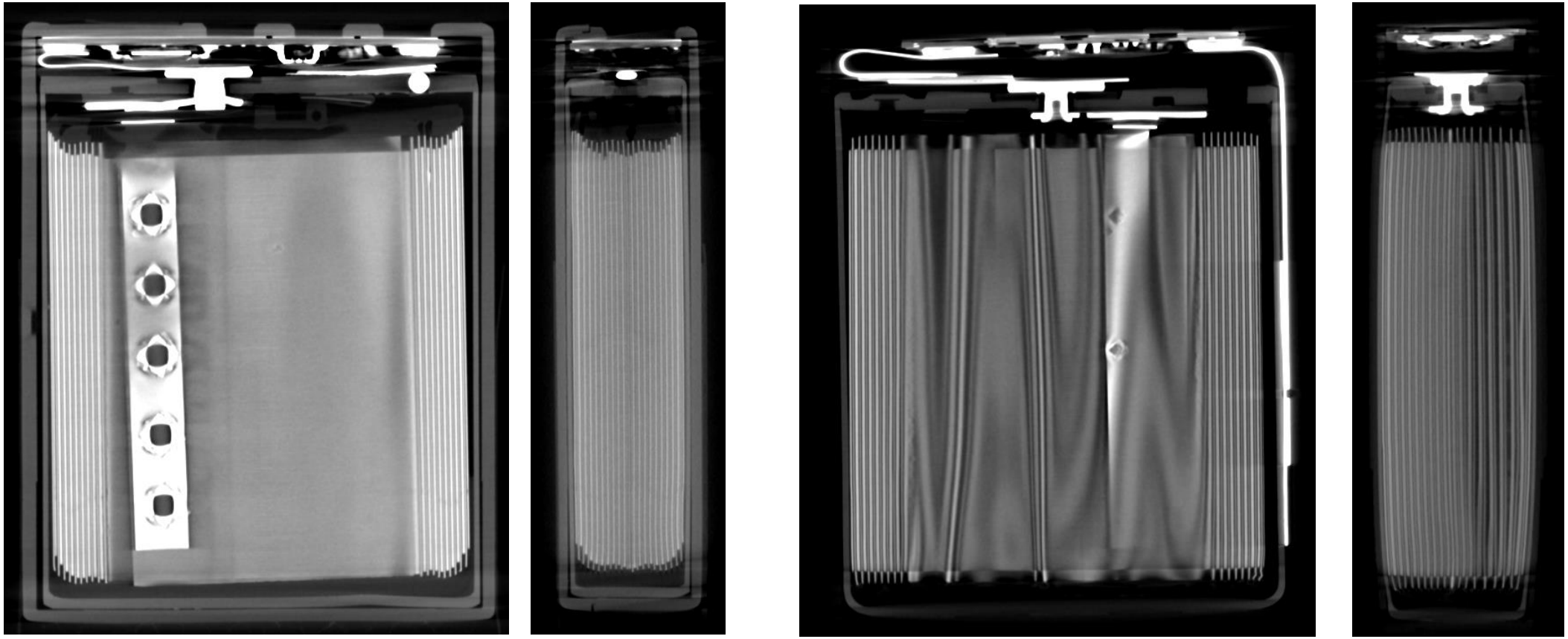


Li-ion battery from digital camera

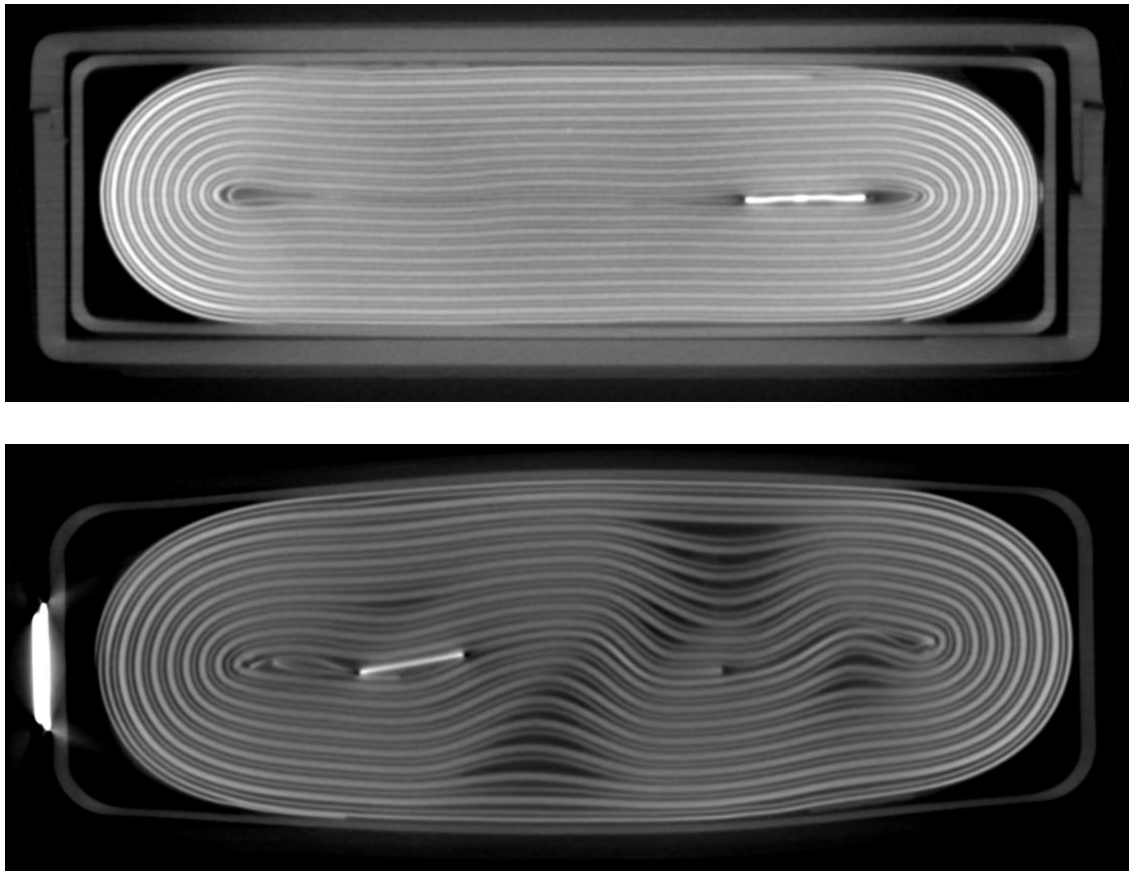
good

bad

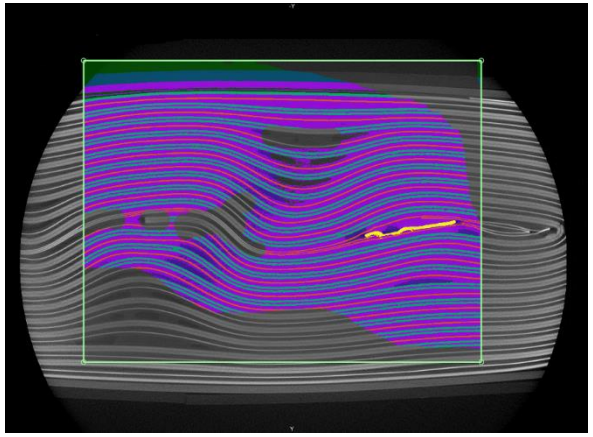
Li-ion battery from digital camera



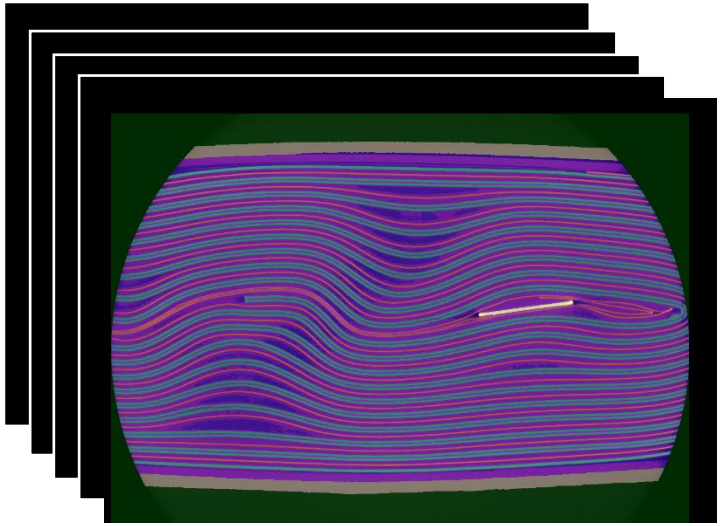
Li-ion battery from digital camera



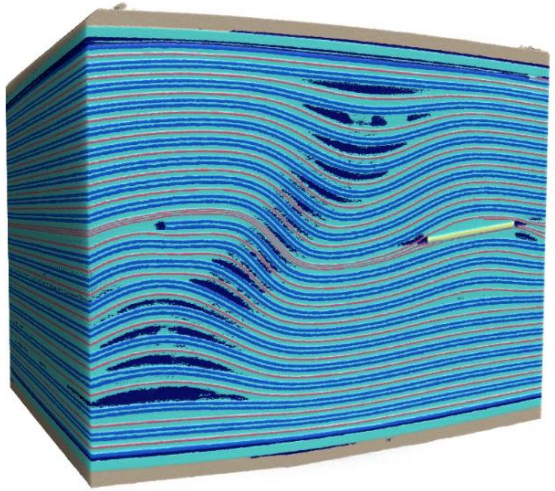
Li-ion battery from digital camera



Label Ground Truth and
train deep learning model

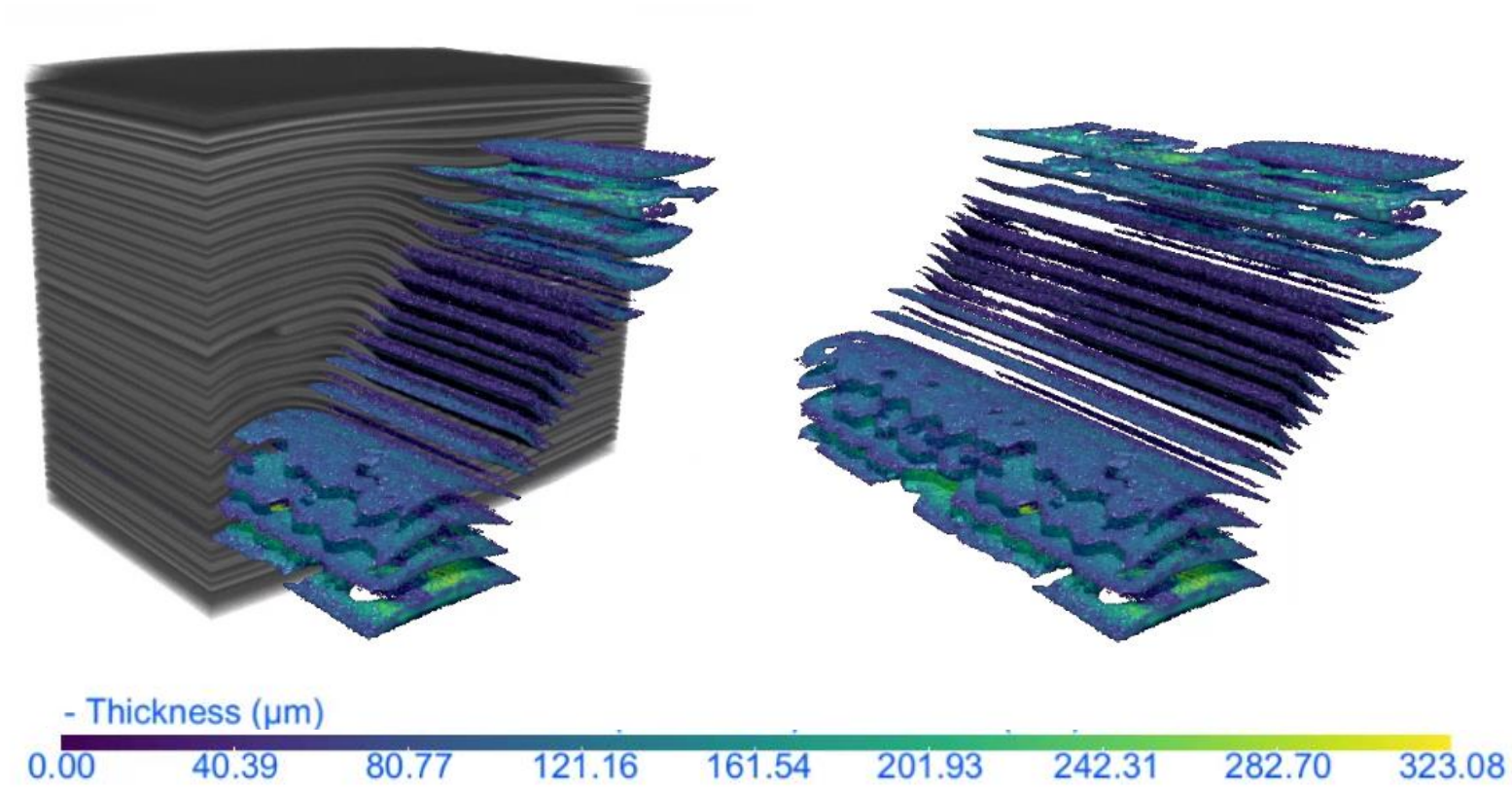


Deep learning segmentation



3D segmented data

Li-ion battery from digital camera



ACS APPLIED MATERIALS & INTERFACES

www.acsami.org Research Article

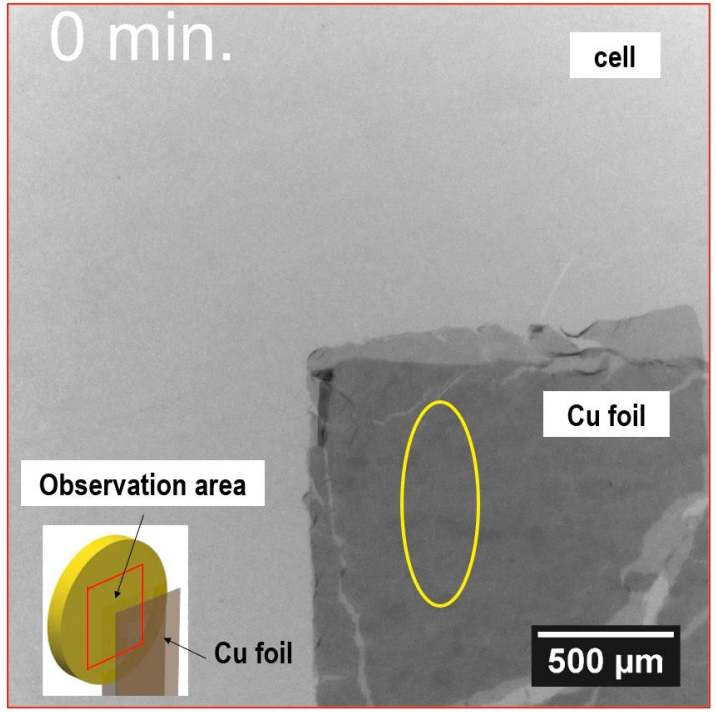
Visualization and Control of Chemically Induced Crack Formation in All-Solid-State Lithium-Metal Batteries with Sulfide Electrolyte

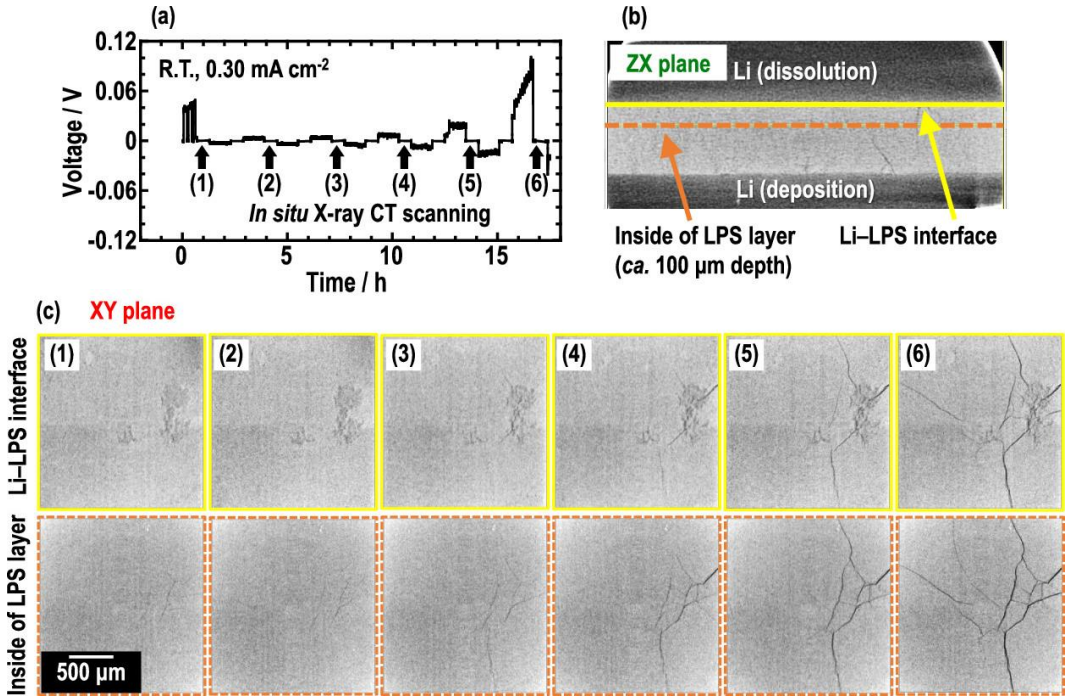
Misae Otoyama, Motoshi Suyama, Chie Hotehama, Hiroe Kowada, Yoshihiro Takeda, Koichiro Ito, Atsushi Sakuda, Masahiro Tatsumisago, and Akitoshi Hayashi*

Cite This: *ACS Appl. Mater. Interfaces* 2021, 13, 5000–5007 Read Online

Otoyama, M., *et. Al.*, 2021. *ACS Appl. Mater. Interfaces* 13, 5000–5007.

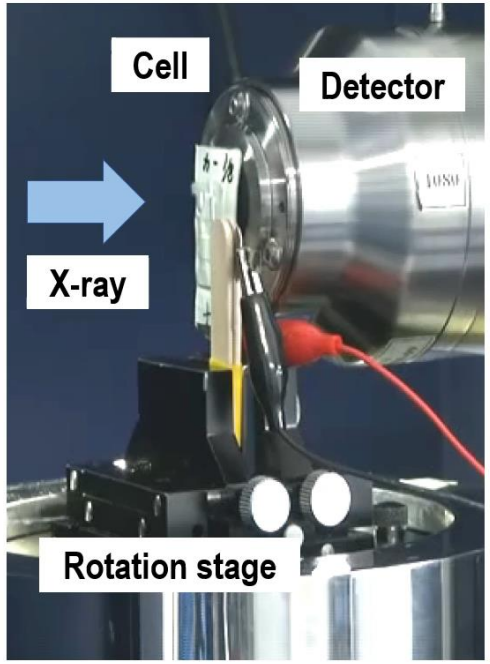
X-ray projection images during the galvanostatic test (without rotating)



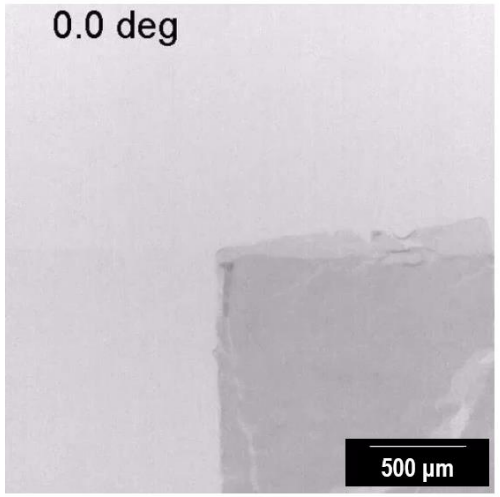


Otoyama, M., *et. Al.*, 2021. *ACS Appl. Mater. Interfaces* 13, 5000–5007.

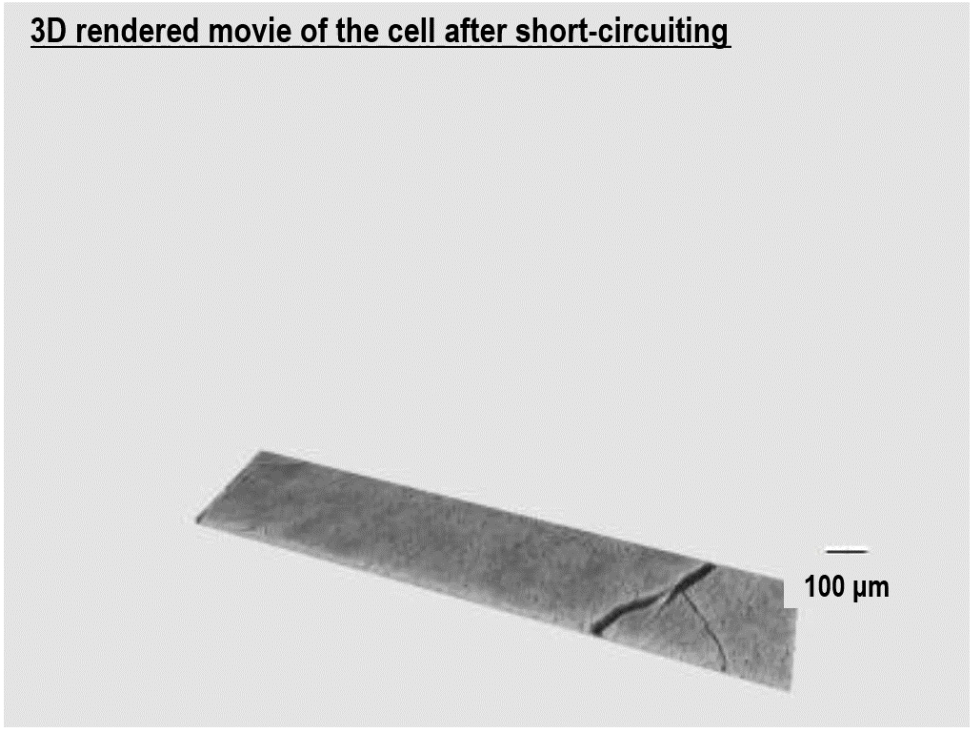
X-ray CT measurement



X-ray projection image



3D rendered movie of the cell after short-circuiting



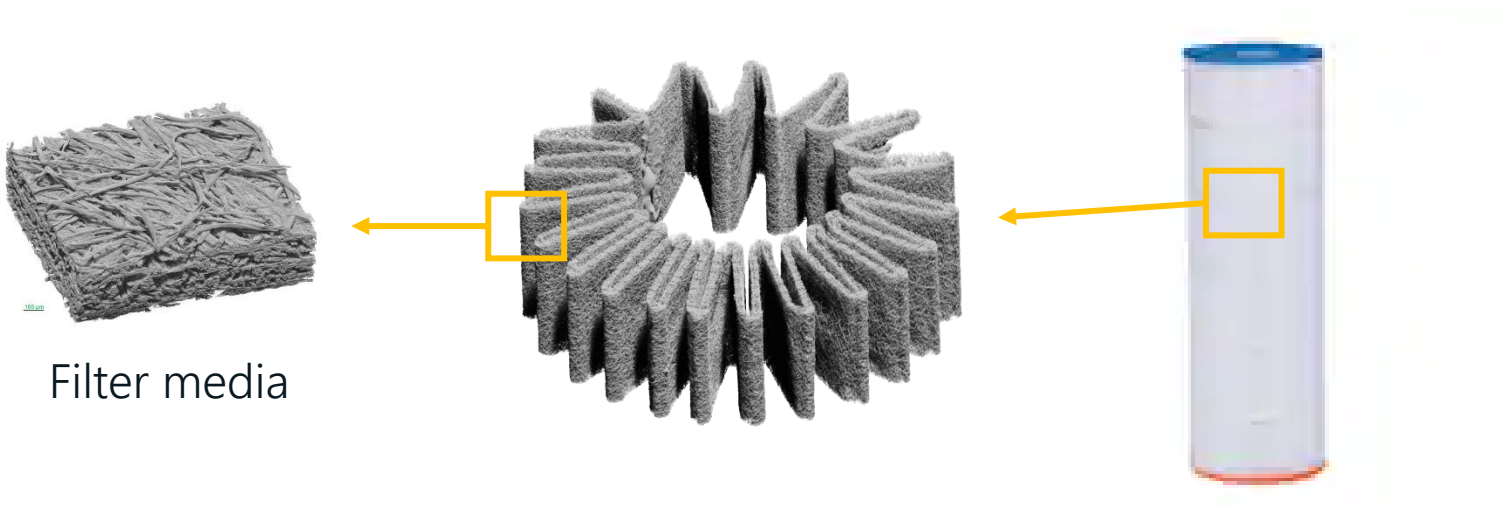
Otoyama, M., *et. Al.*, 2021. *ACS Appl. Mater. Interfaces* 13, 5000–5007.

How can simulations help?

Simulations are powerful for understanding failure

- Mechanical simulation
- Fixture Simulations
  - Examine part deformation tolerance in assemblies
- Pore analysis network modeling
  - Open/closed porosity and flow
- Battery simulations
  - Battery aging and optimization
- Filtration simulations
  - Filter media optimization and assembly design

Filtration simulation

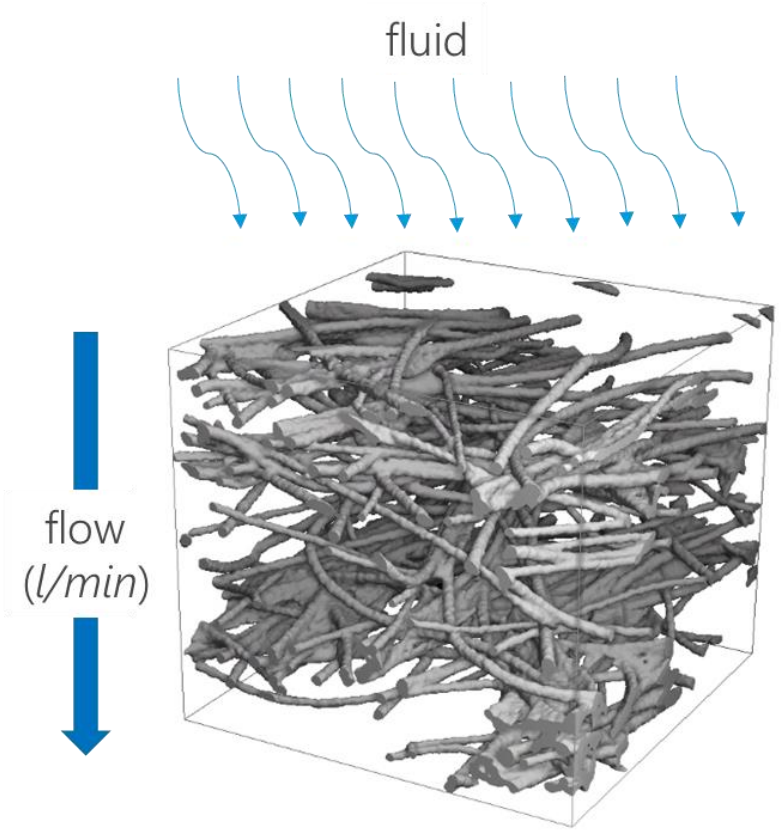


Filter media

Pleated filter

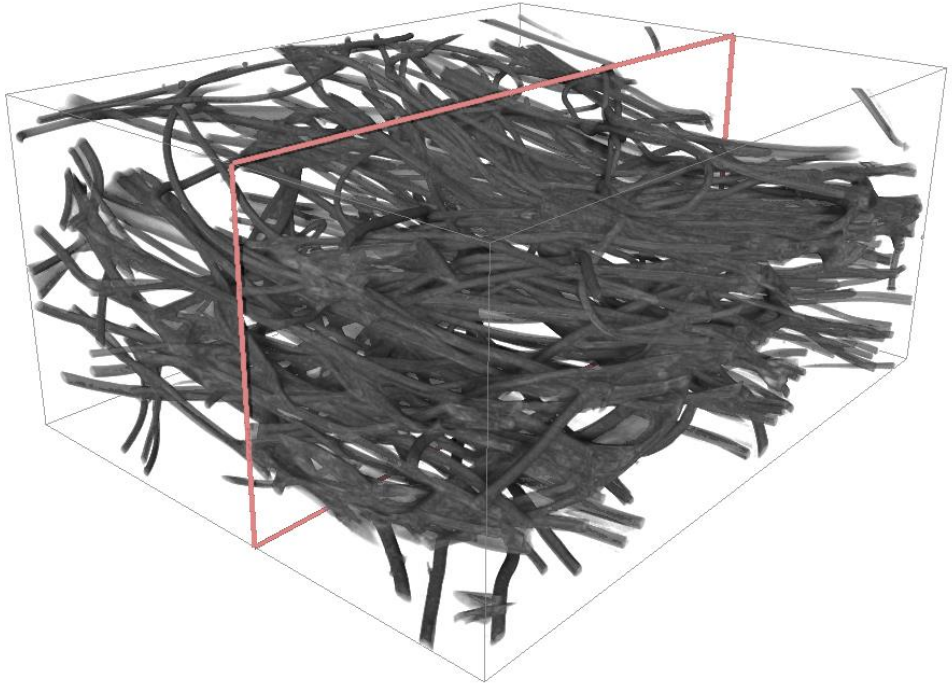
Complete filter

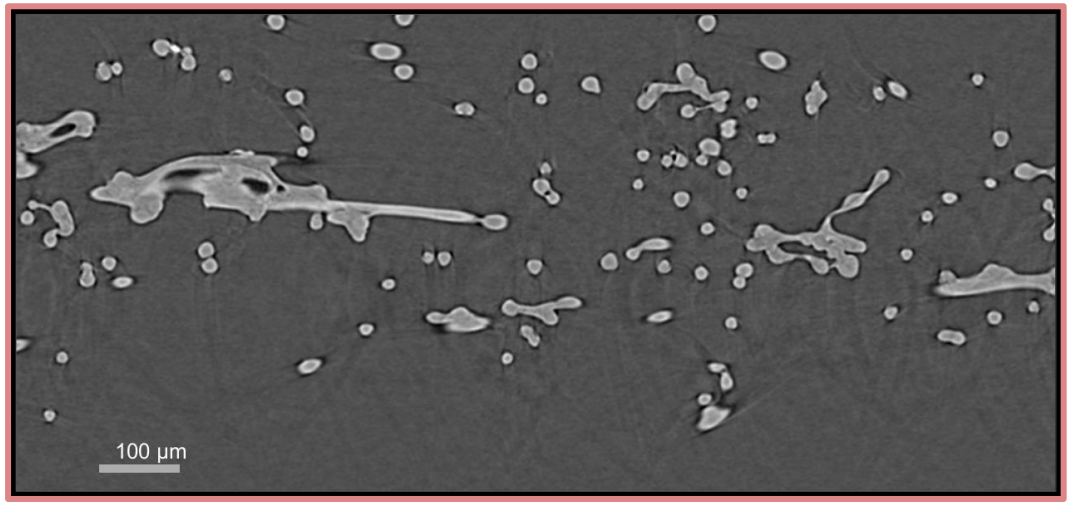
Filtration simulation



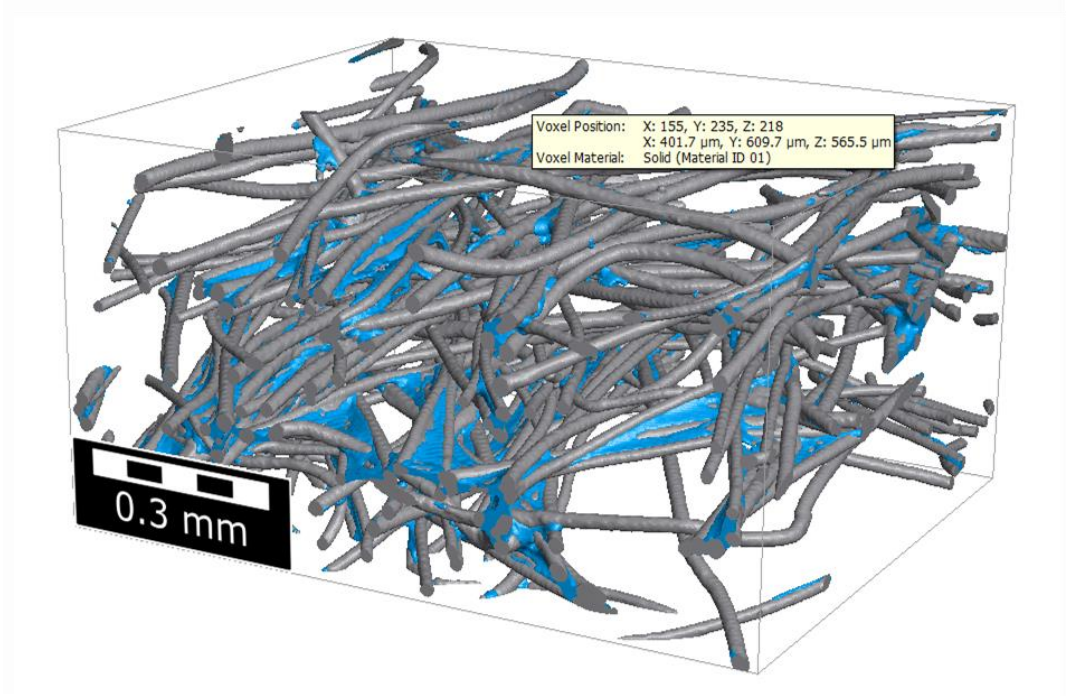
- Pressure drop
- Dust holding capacity
- Filter efficiency
- Filter lifetime

Air filtration

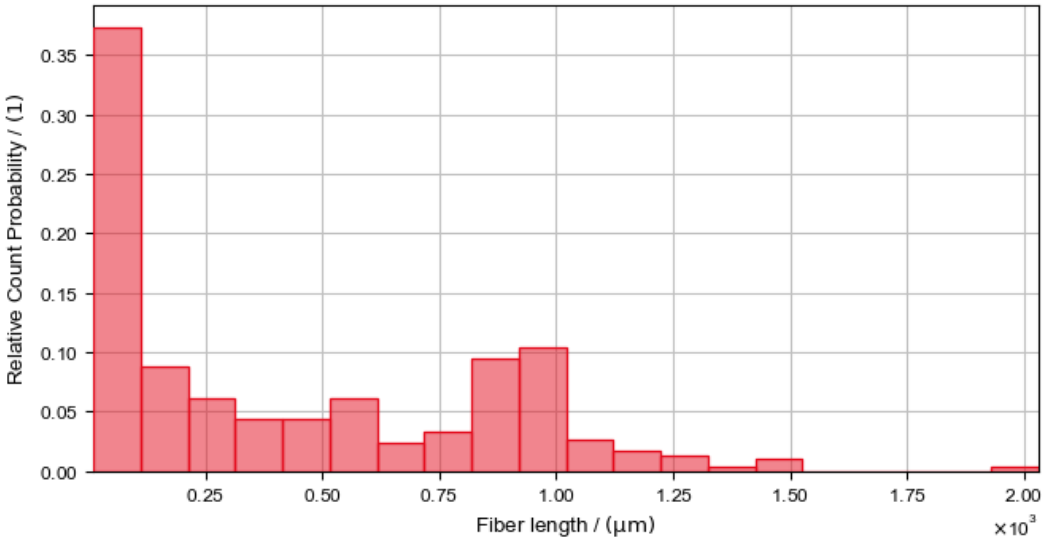


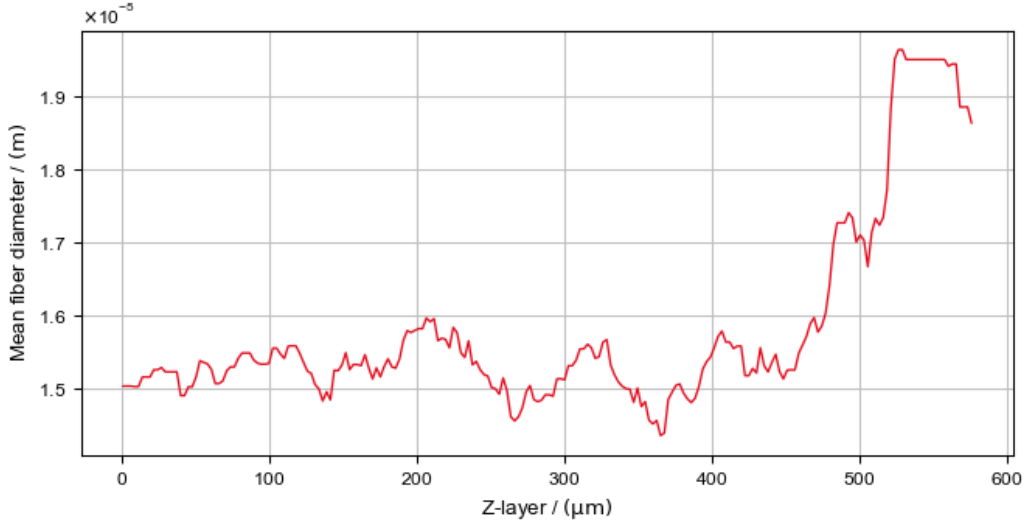


Filtration simulation

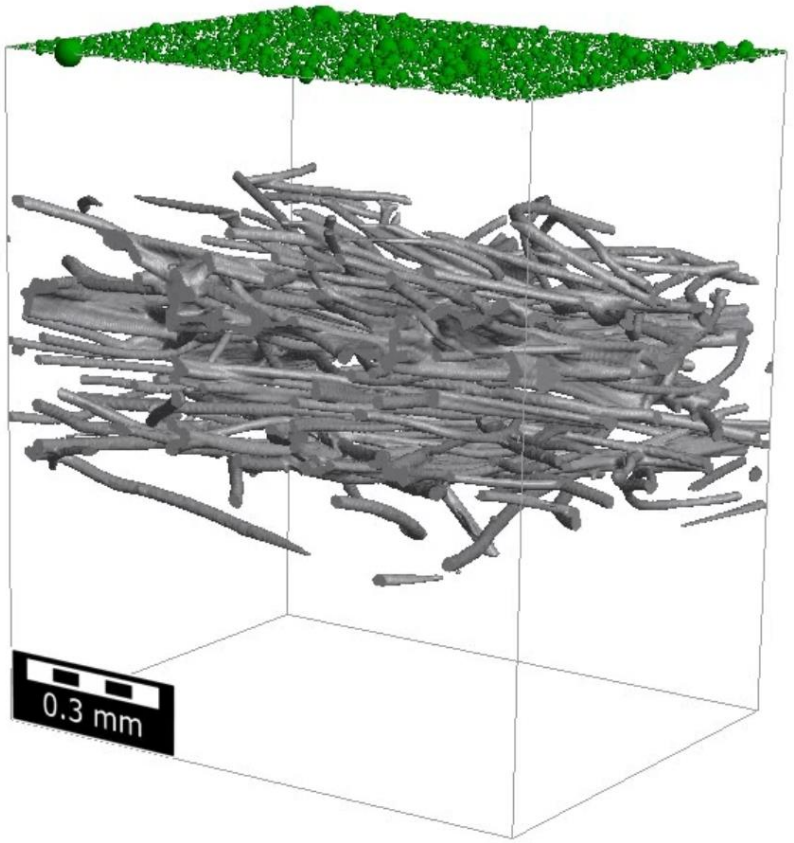


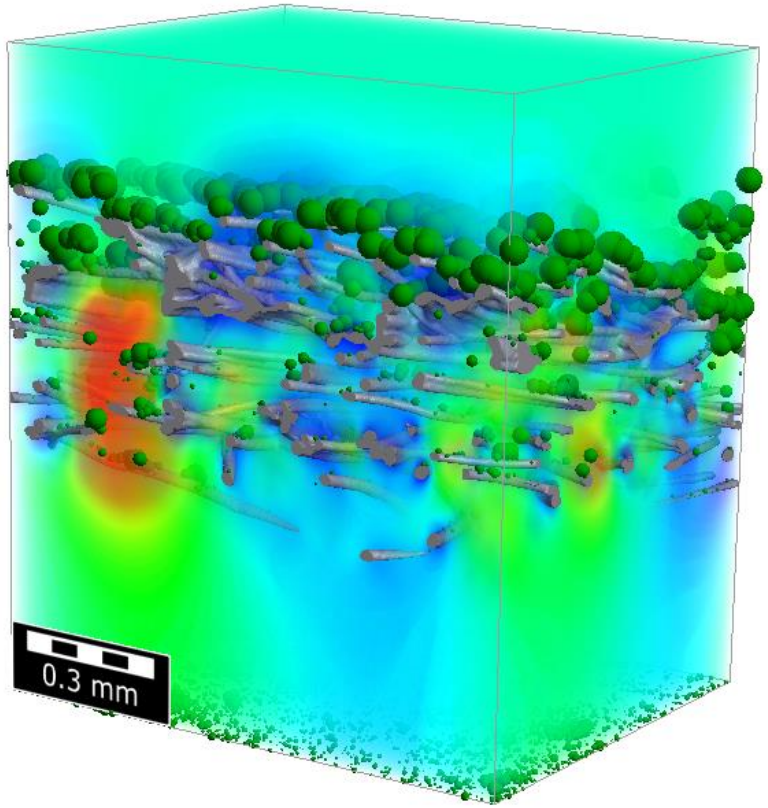
GEODICT



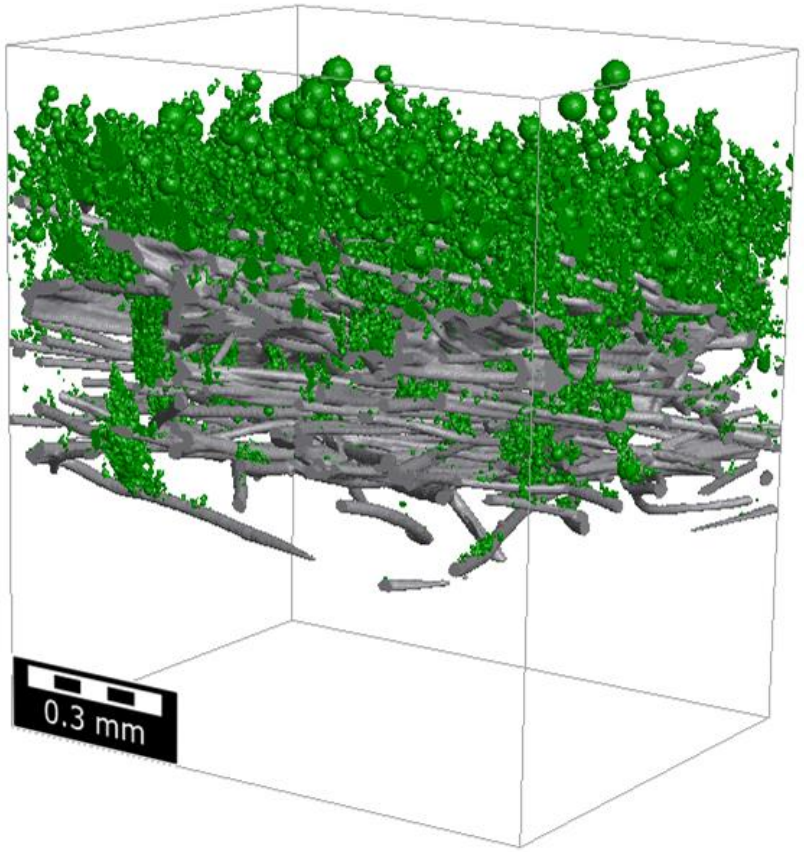


Filtration simulation





Filtration simulation

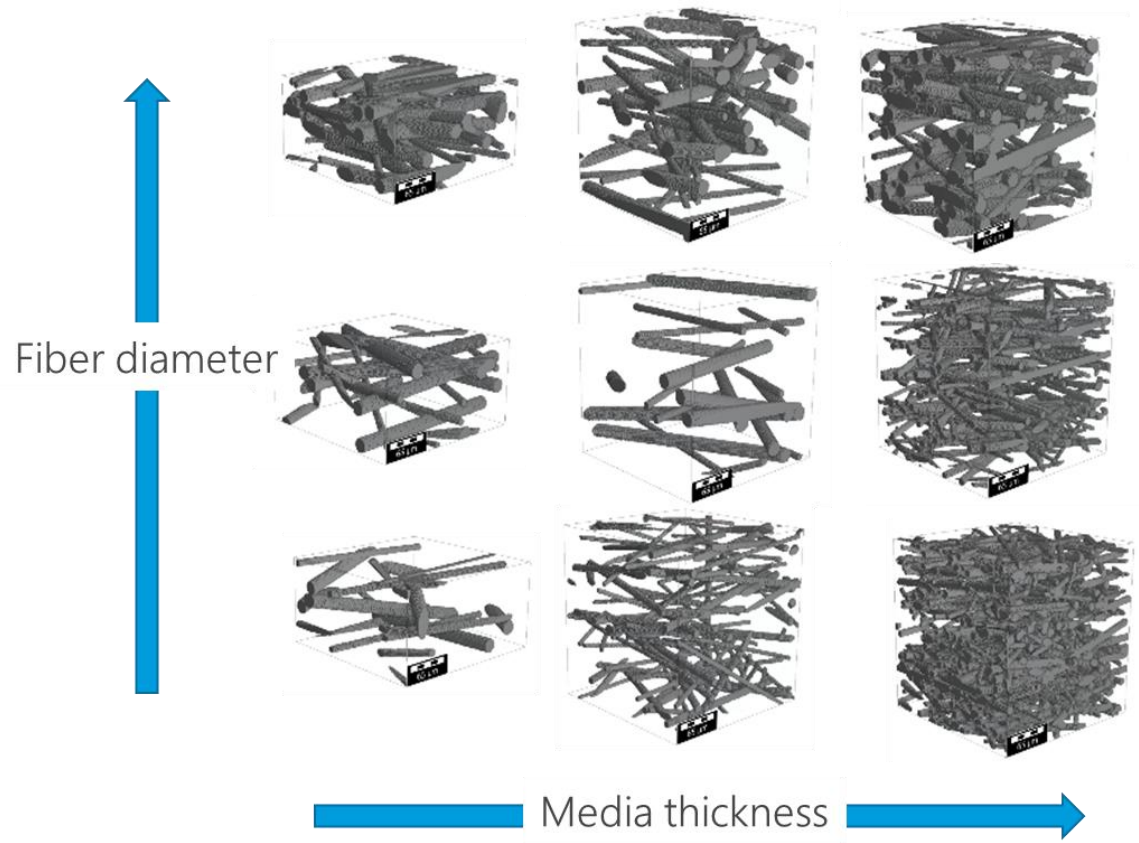


Filter lifetime:

Pressure Drop: 3.477 x 10^4 Pa

Dust holding capacity: 632 g/m^2

Filtration simulation



Microstructure	Pressure drop (10^4 Pa)	Dust holding (g/m^2)
1	3.867	129
2	4.247	361
3	3.477	632

You just learned

- What is functional failure
- What are the considerations when using X-ray CT to study functional failure?
- What information can we extract from CT data related to function?
- Functional failure examples

Q & A Session

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