Application of CT scanning in Industry: Nano and Micro-CT for Materials Science

Danish Technological Institute, 31/5/2011

Agenda

01 SkyScan

02 CT scanners for Materials Science

03 Examples and Results

04 Conclusions

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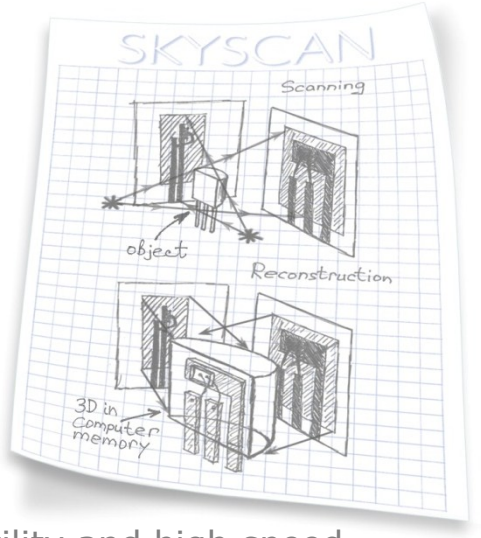
History of SkyScan



1980-1990: Pioneering work in micro-CT technology

01 1996: SkyScan established

02 1997: First desktop micro-CT (SkyScan 1072)

03 1999: First portable micro-CT scanner (SkyScan 1074)

04 2002: First in vivo desktop micro-CT (SkyScan 1076)

2004: First 10Mpixel micro-CT with variable geometry for versatility and high speed (SkyScan 1172)

2004: First laboratory nano-CT (SkyScan 2011)

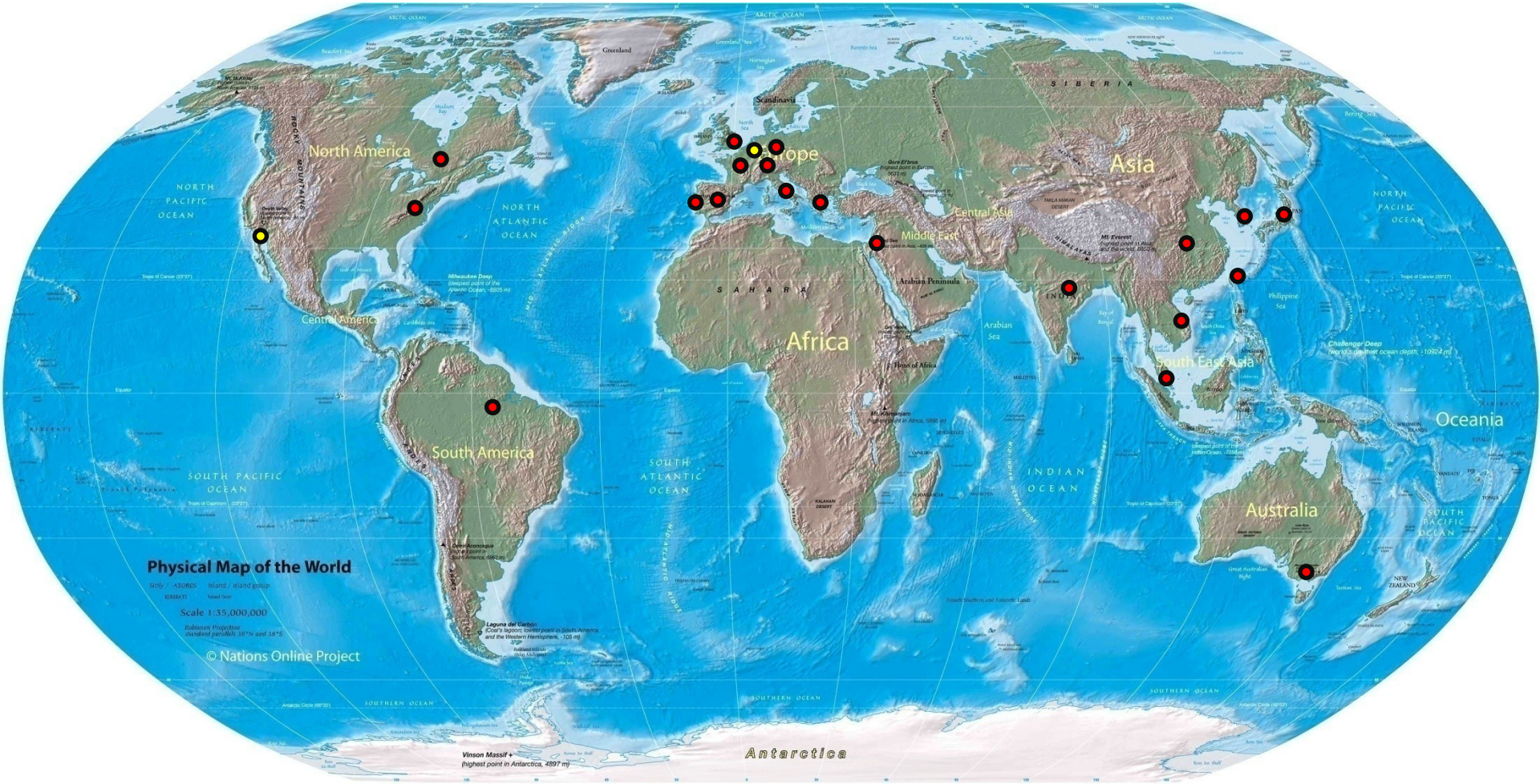
2004: Micro-CT for multimodality imaging with PET, SPECT and bioluminescence imaging (SkyScan 1178)

2006: Optical projection tomography developed with the UK MRC, Edinburgh (SkyScan 3001)

2007: Compact micro-CT scanner (SkyScan 1174)

2010: New high performance in vivo micro-CT for preclinical research (SkyScan 1176)

Distributors



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What is x-ray micro-CT?

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X-ray microfocus computer tomography (μ-CT) is a non-destructive experimental technique where the 3D internal microstructure of the sample is virtually reconstructed with micrometer accuracy with the use of x-ray shadow images of different orientations of the sample.

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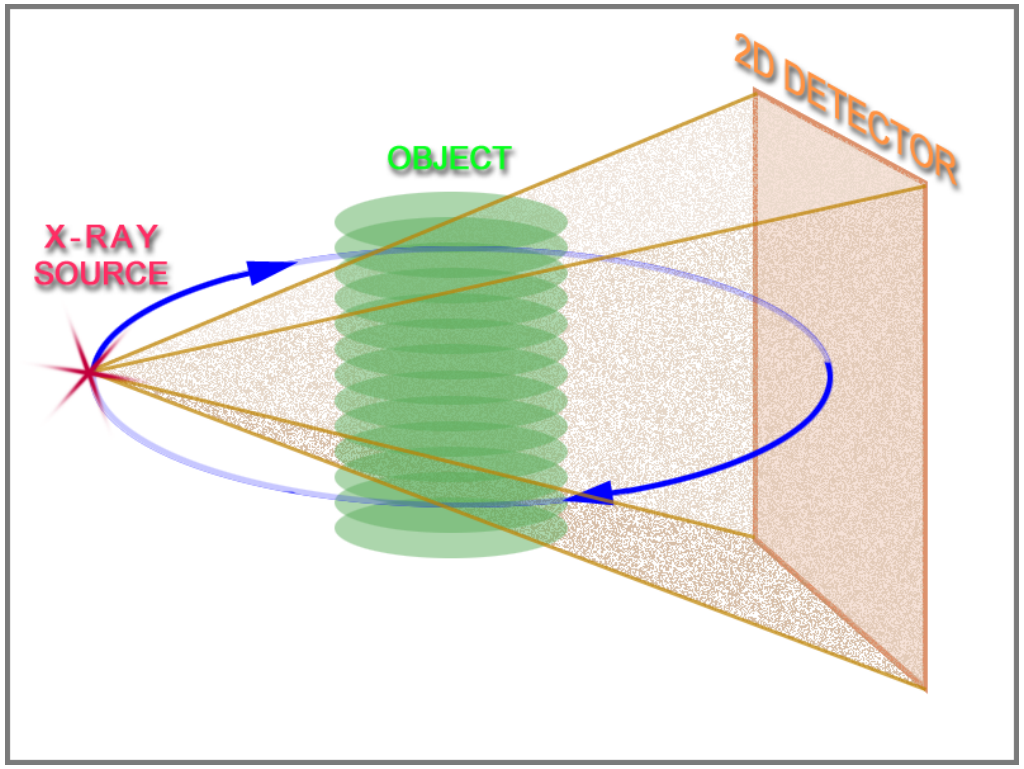
Object rotates between a static x-ray source – detector



High resolution μ-CT:

- low-energy X-ray source
- high-resolution detectors

Geometrical magnification by cone beam

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An example in images

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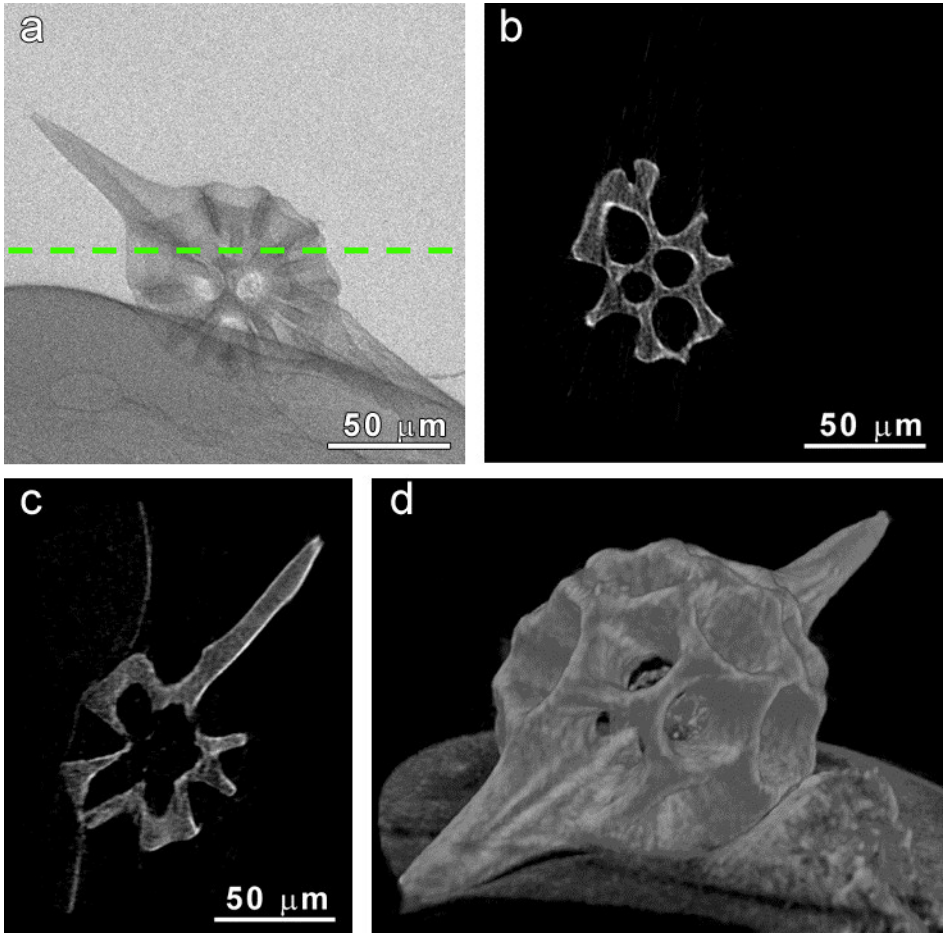
Projection image of a radiolarian

Transaxial virtual cut through the sample



Coronnal virtual cut through the sample

3D volume-rendered model of the sample based on the reconstructed slices

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SkyScan portfolio

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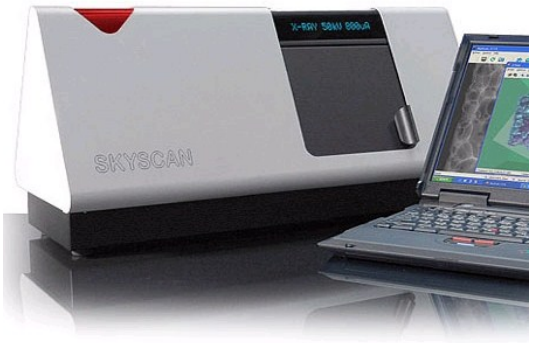
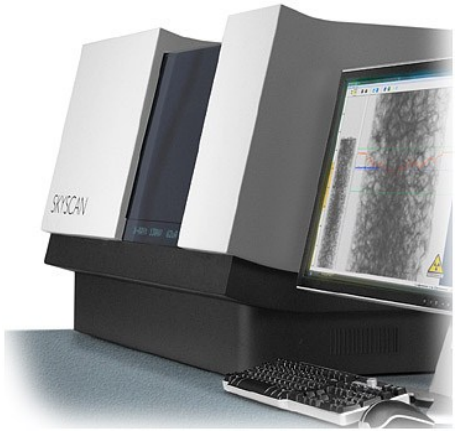


SkyScan 1174

SkyScan 1172



SkyScan 1173

SkyScan
2011

SkyScan
SEM-CT

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SkyScan Software

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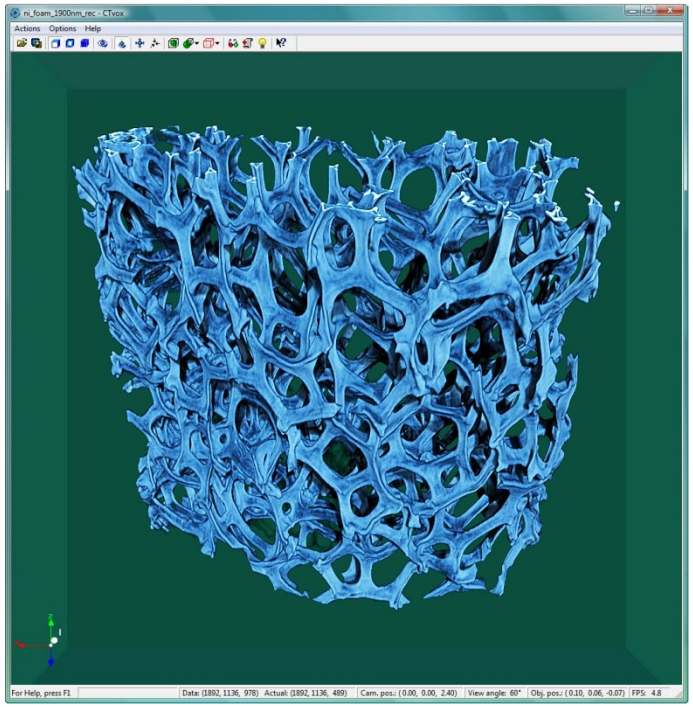
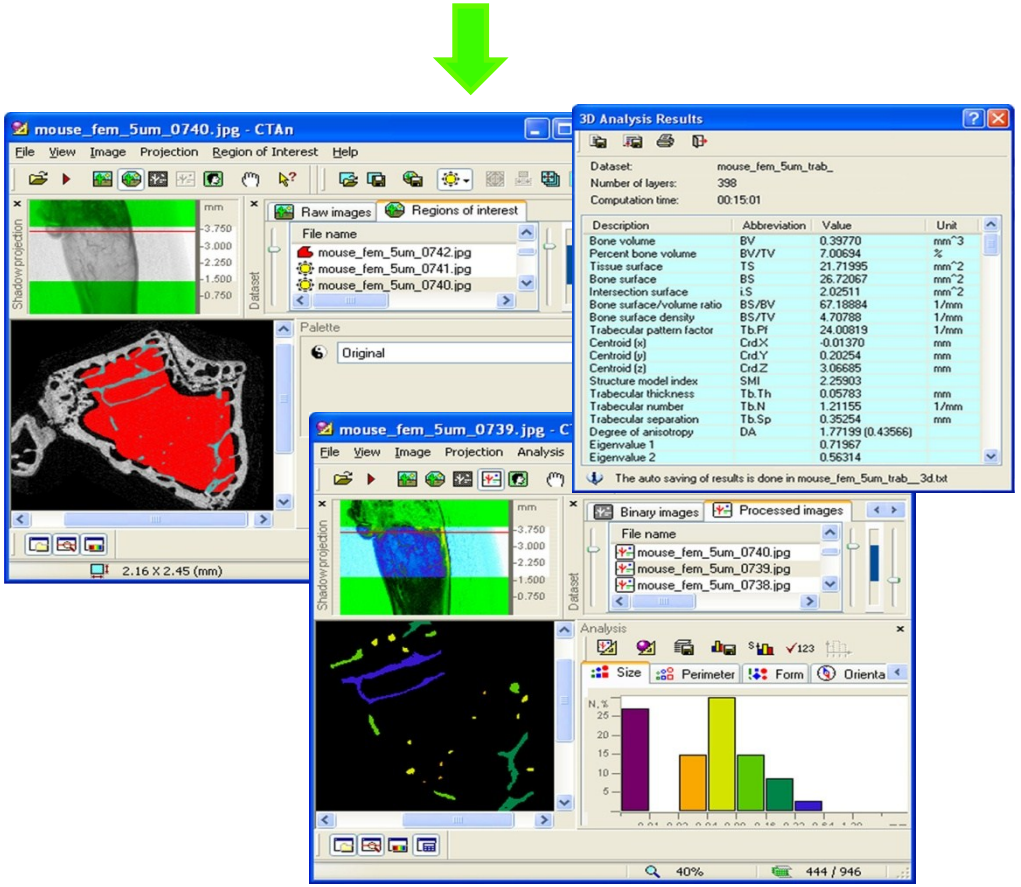
- Reconstruction software: NRecon + NReconServer
- Dataviewer: viewer for reconstructed slices
- CTVox: Volume rendering
- CT Analyser: Accurate and detailed study of micro-CT data
- CTVol: Surface rendering



Volume rendering of Ni foam, scanned at 1.9 μm on 1172



Stages for Materials Research

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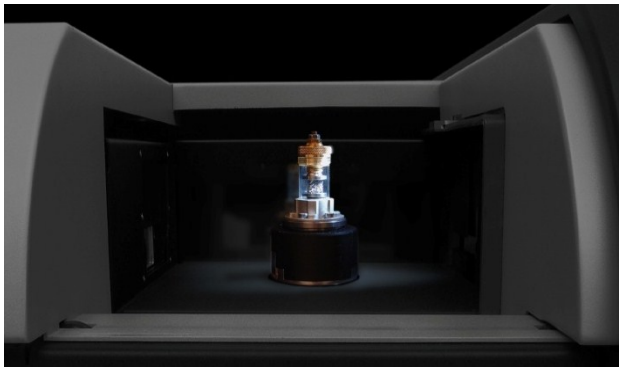
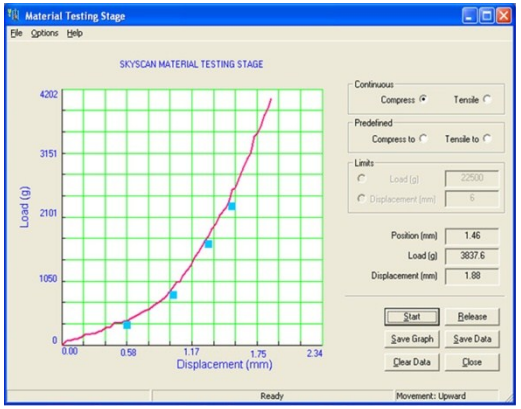
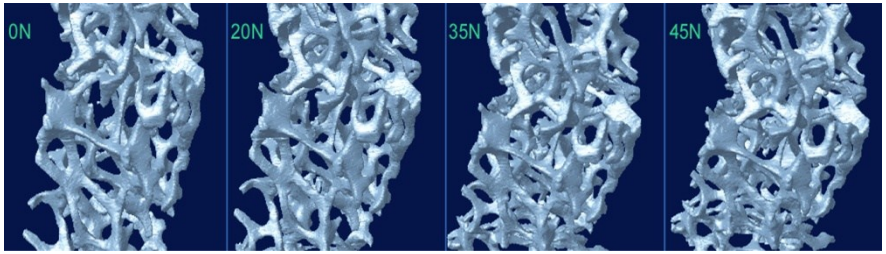
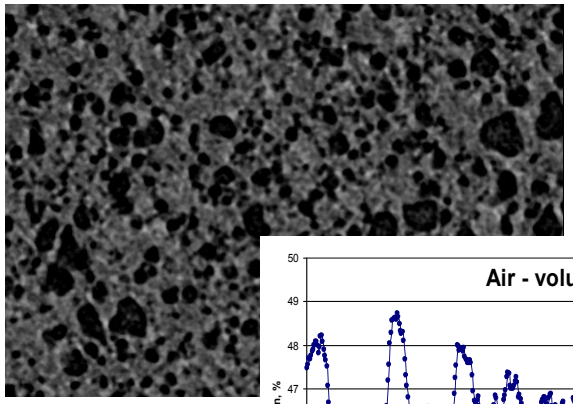
- Material testing stage

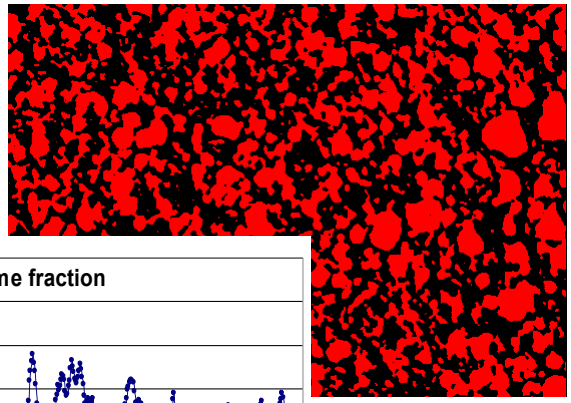


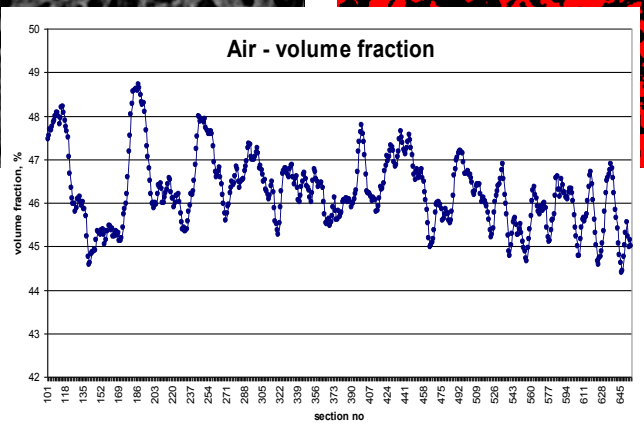




- Cooling/Heating stage







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PLA scaffold on 1172

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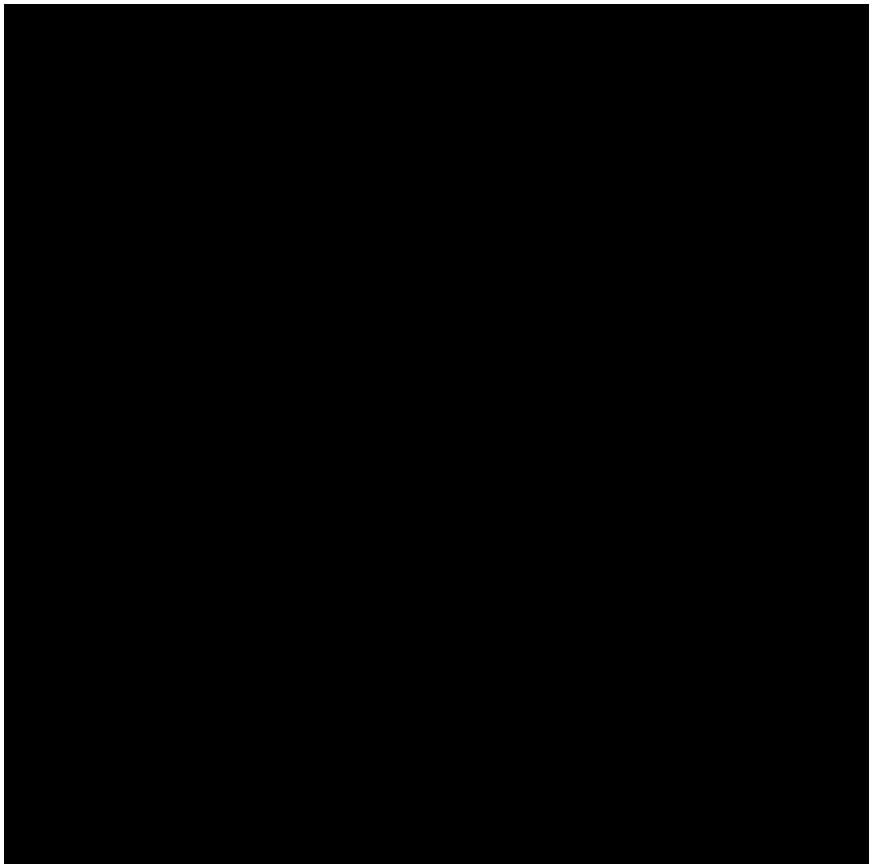
- Polylactic acid scaffold, scanned at 5.4 micron, scan duration : 65 min.



How to further characterize this scaffold?

- Porosity?
- Pore distribution?
- Specific surface?
- Strut thickness?

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Image processing in CTAn

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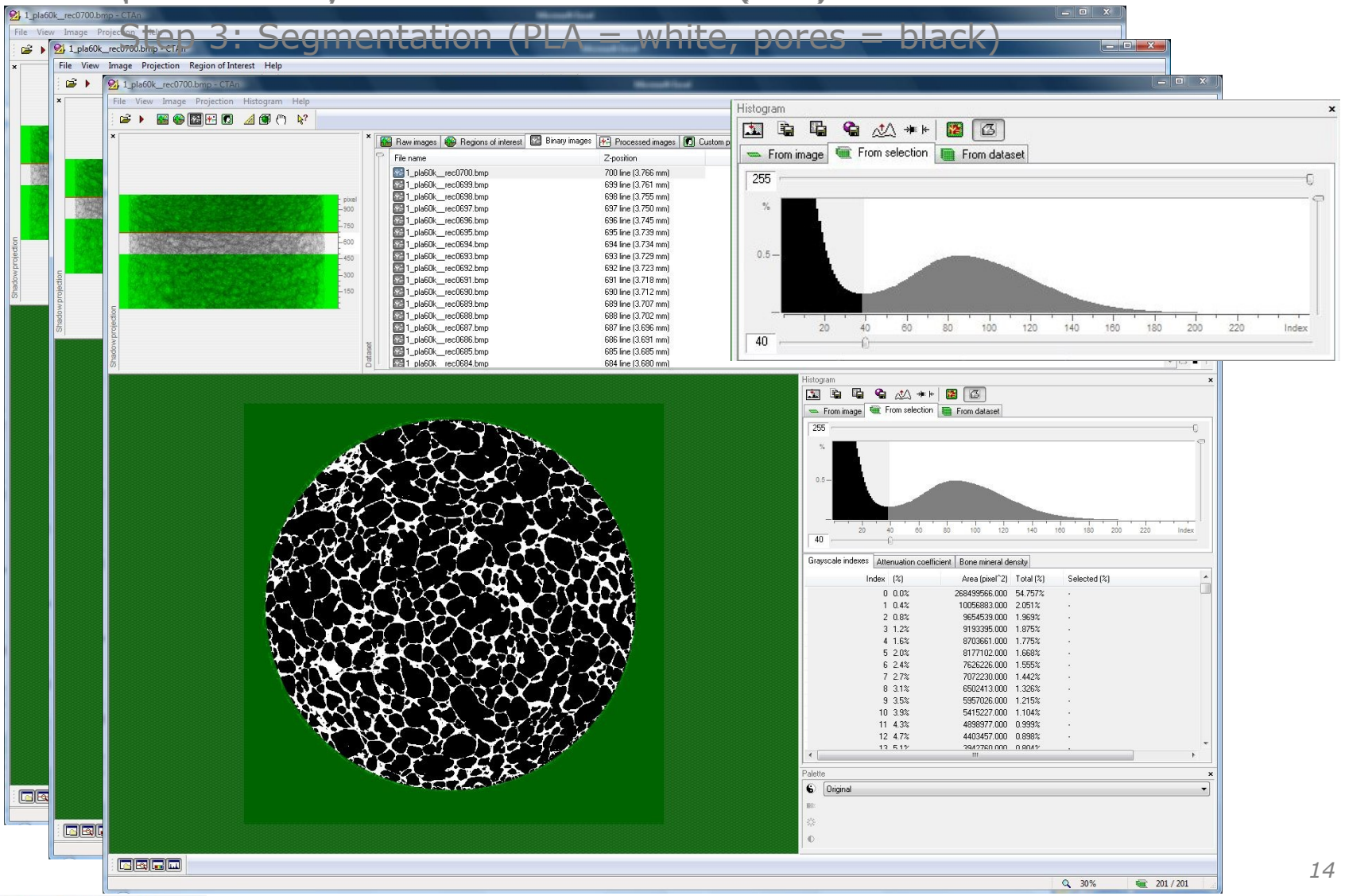
Step 1: Load a stack of 2D images

Step 2: Define your volume of interest (VOI)

Step 3: Segmentation (PLA = white, pores = black)



http://www.skyscan.be/next/CTAn03.pdf

Step 4: Calculations

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[10/25/10 13:21:49] 3D analysis			
Date and time	25.10.2010 13:21		
Operator identity	SkyScan		
Computer name	ANALYSIS01		
Computation time	0:46:56		
Dataset	1_pla60k__rec		
Location	F:\SCAFFOLD_datasets\PLA scaffold\		
Description	Abbreviation	Value	Unit
Number of layers		201	
Lower vertical position		2.69012	mm
Upper vertical position		3.76617	mm
Pixel size		5.38025	um
Lower grey threshold		40	
Upper grey threshold		255	
Total VOI volume	TV	76.36765	mm^3
Object volume	Obj.V	16.44264	mm^3
Percent object volume	Obj.V/TV	21.5309	%
Total VOI surface	TS	175.4985	mm^2
Object surface	Obj.S	878.26327	mm^2
Intersection surface	i.S	34.69621	mm^2
Object surface / volume ratio	Obj.S/Obj.V	53.41376	1/mm
Object surface density	Obj.S/TV	11.50046	1/mm
Structure thickness	St.Th	0.07185	mm
Structure linear density	St.Li.Dn	2.99652	1/mm
Structure separation	St.Sp	0.30831	mm
Number of objects	Obj.N	494	
Number of closed pores	Po.N(cl)	17	
Volume of closed pores	Po.V(cl)	0.03582	mm^3
Surface of closed pores	Po.S(cl)	1.69803	mm^2
Closed porosity (percent)	Po(cl)	0.21739	%
Volume of open pore space	Po.V(op)	59.88919	mm^3
Open porosity (percent)	Po(op)	78.4222	%
Total volume of pore space	Po.V(tot)	59.92501	mm^3
Total porosity (percent)	Po(tot)	78.4691	%

Calculation on the object surface (with respect to the object volume)

Calculation on the average PLA thickness and separation thickness

Porosity calculation

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Image analysis with CTAn

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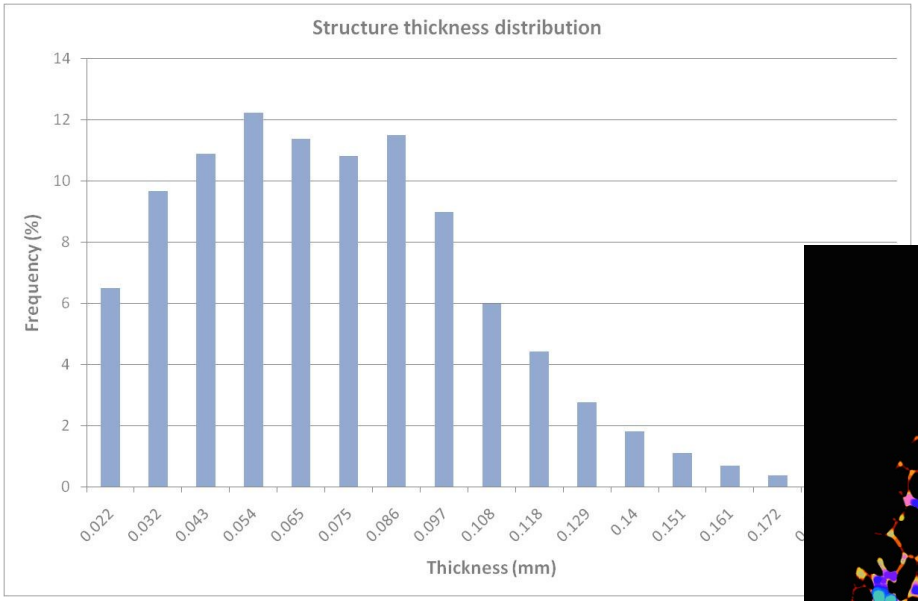

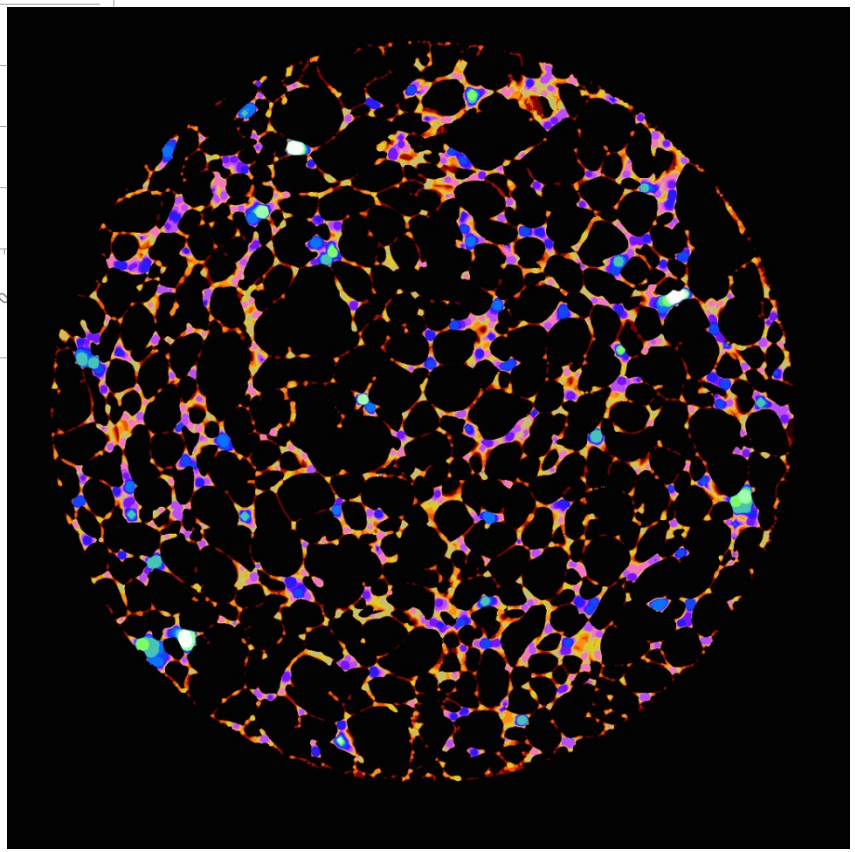

A true 3D thickness can be measured which is model independent. (Hildebrand & Ruegsegger). Bias from the 3D orientation of the structure is kept to a minimum in this case.

Hildebrand T and Ruegsegger P, *J. Microsc. 185, 67-75.*

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Stone cores

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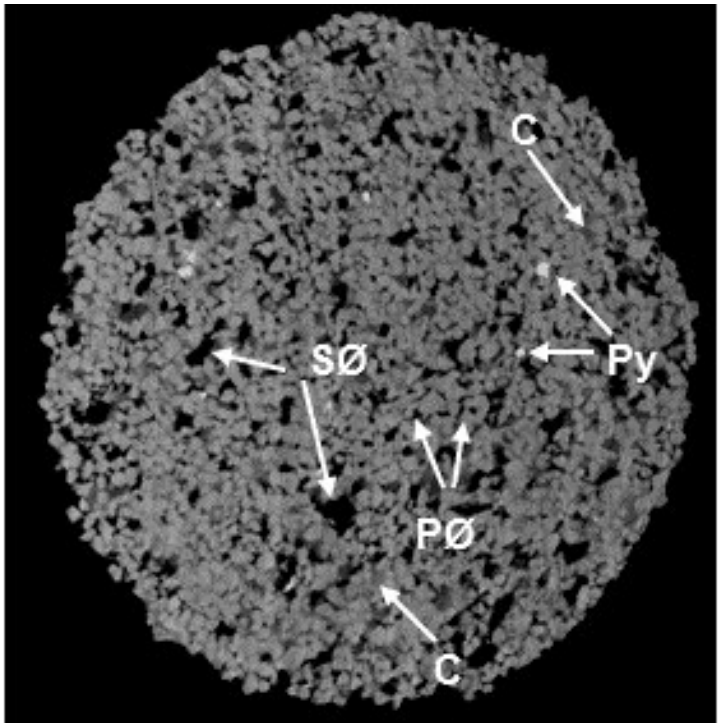
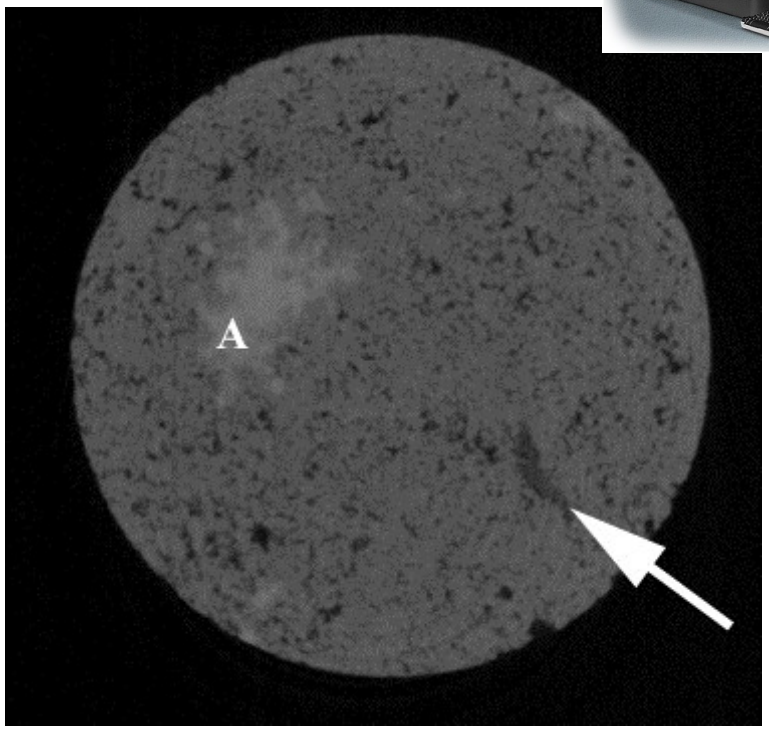
Sandstone



Carbonate



Progress in further development of 3D petrographical analysis (rock texture, mineralogy and porosity) to link the data to petrophysical parameters such as permeability, acoustic signals…

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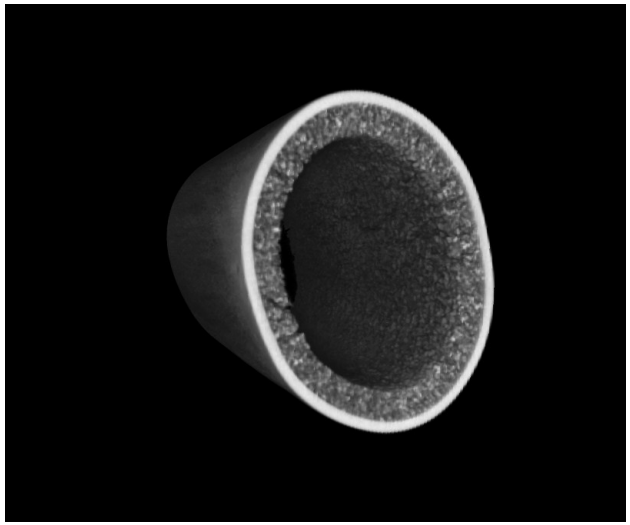
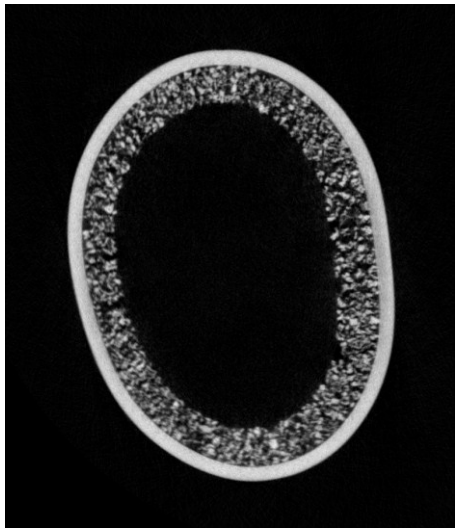
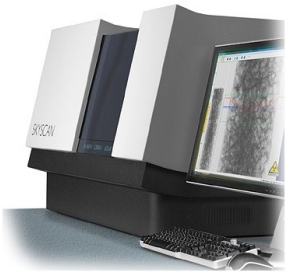
Metal parts

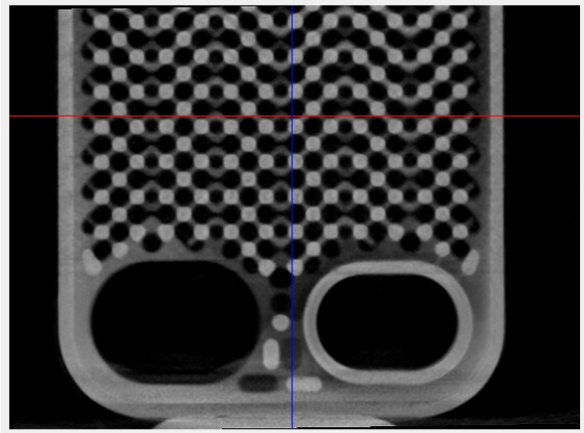


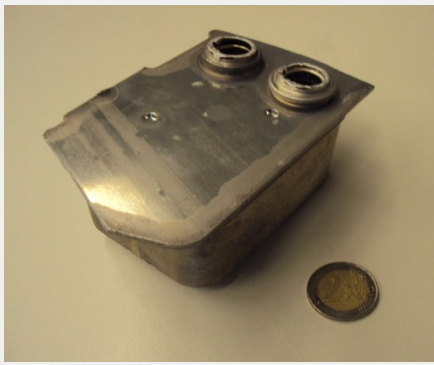


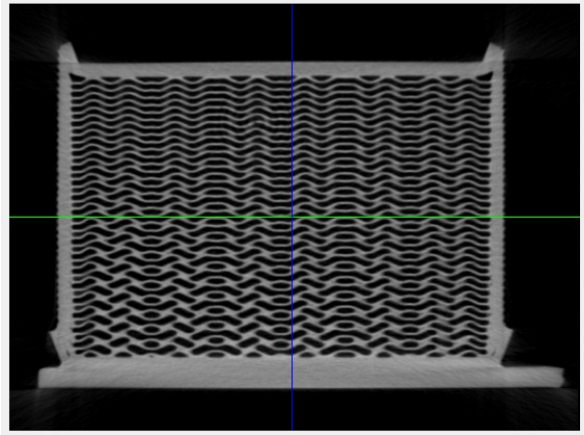


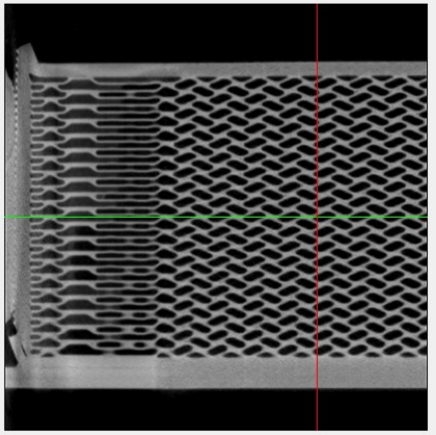
Visualising the internal structure of a copper tube

Aluminum cooler









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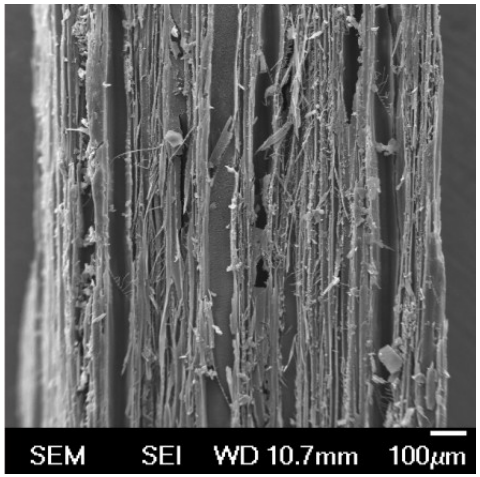
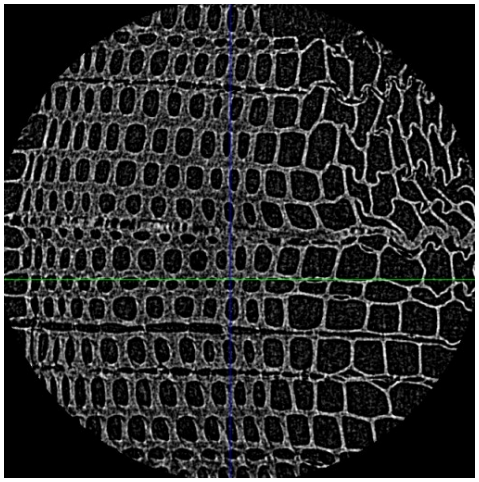
SEM
Topology and chemical composition of surface layers



X-ray CT
Internal microstructure of the sample



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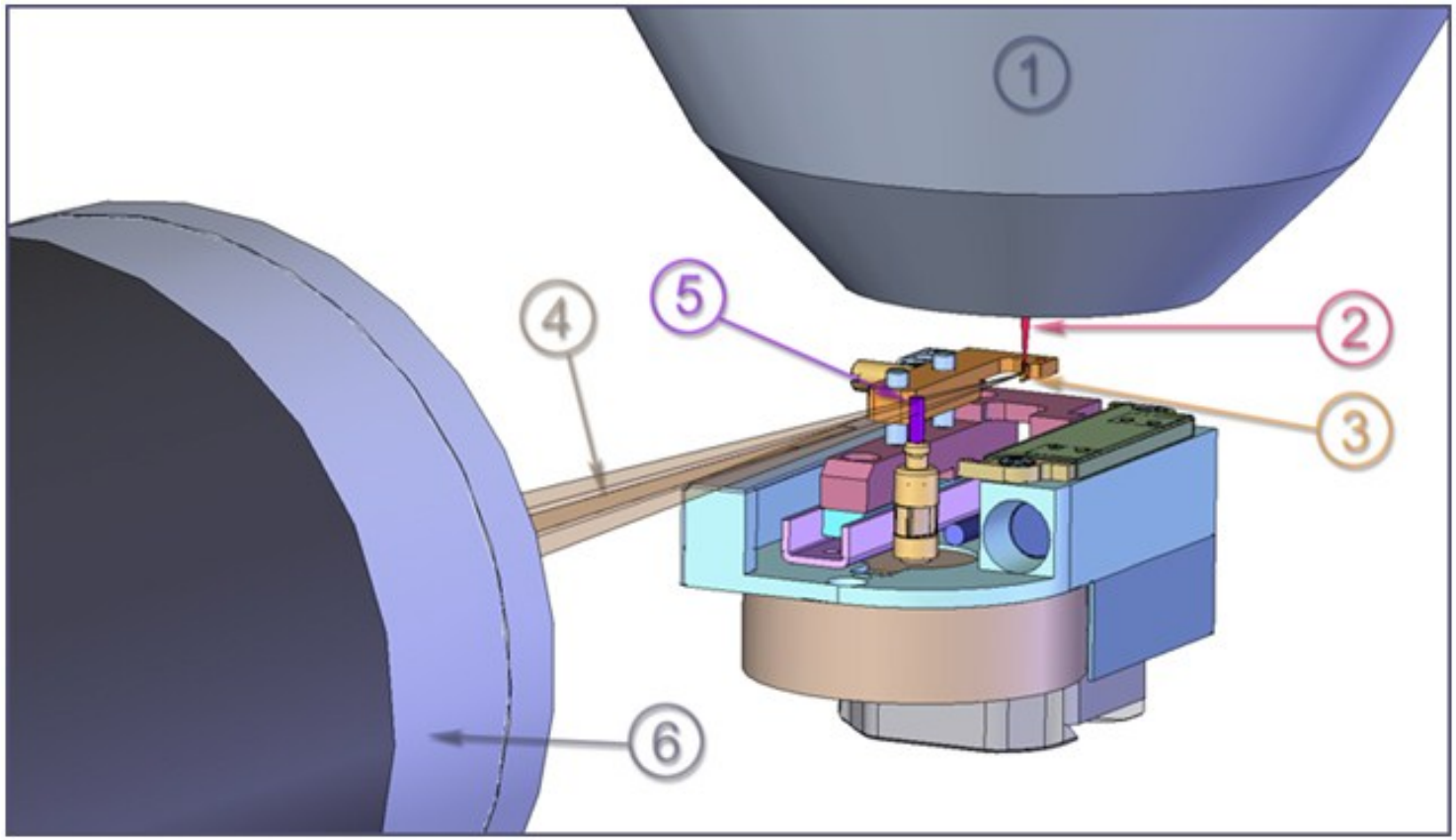
Working principle



1. Objective lens
2. Electron beam
3. Target
4. X-ray beam
5. Object
6. 2D X-ray detector

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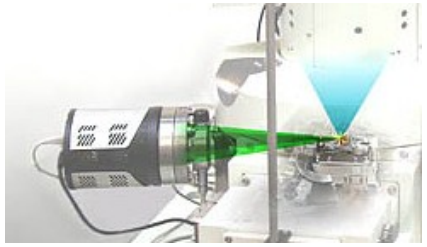
Radiolarian



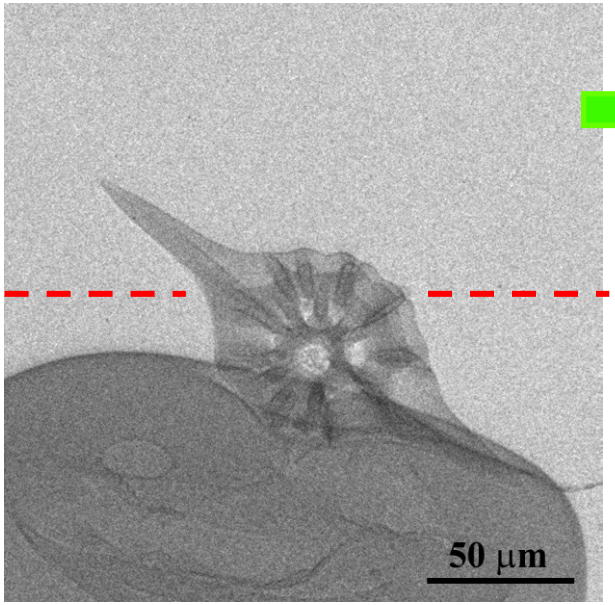
Early Cretaceous radiolarian Pantanellium Riedeli Pessagno from a rock at a depth of 6,316 m in the Mariana Trench, western Pacific.

01

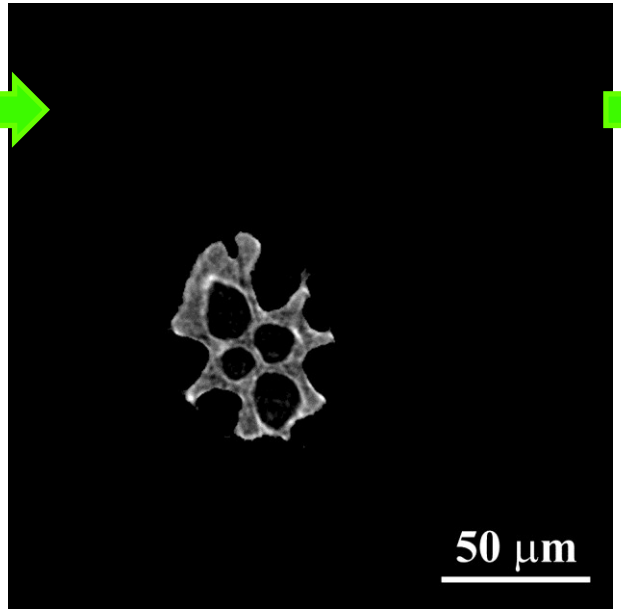
Pixelsize 396 nm, Voltage: 30 keV, Beam current: 780 nA

02

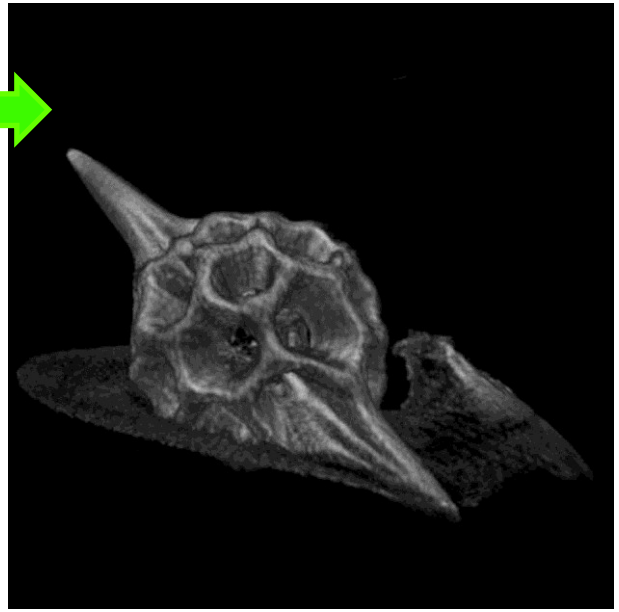
SEM with Schottky FE filament



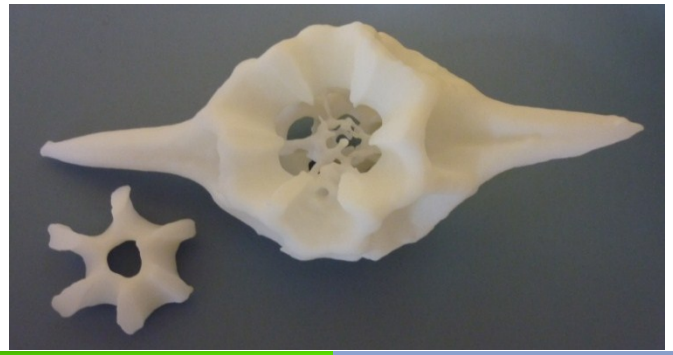
X-ray projection image of the radiolarian



Transaxial virtual slice



Volume rendered 3D model of the radiolarian created from reconstructed slices



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Conclusions

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- X-ray nano and micro-CT, with subsequent 3D image analysis, is a very usefull tool for the characterization of the microstructure of different types of samples and materials.
- With the use of special object stages, the change in microstructure can be studied in-situ under different conditions.

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Questions?

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- For further questions, sample scanning and demos, feel free to contact me:

bart.pauwels@skyscan.be

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