APS Beamline 2-BM micro-tomography system
High throughput fully automated 1μm resolution tomography

Robot Tweezer

APS 2-BM

X-ray beam

CCD Camera
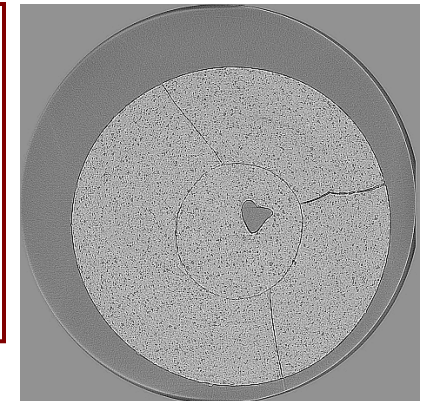
SAMPLE

ROTA

Sample Tray

1500 projections 2048x2048.
Total collection time: 4-25 min/sample
Data analysis time: 6 min/sample

**System throughput:
> 200 samples/day**
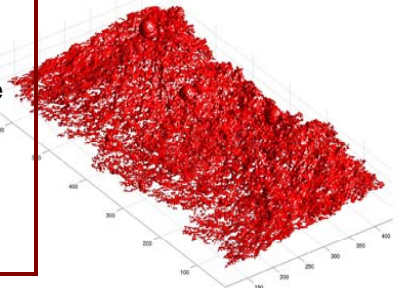
• Efficient sample handling & precision alignment

• Local and remote beam line operation

• Fast 64-CPU computer cluster for data analysis

• 5-30 keV multi-layer or Si 111
• Mineralized tissue density
• Crack propagation in dental composite materials
• Al corrosion
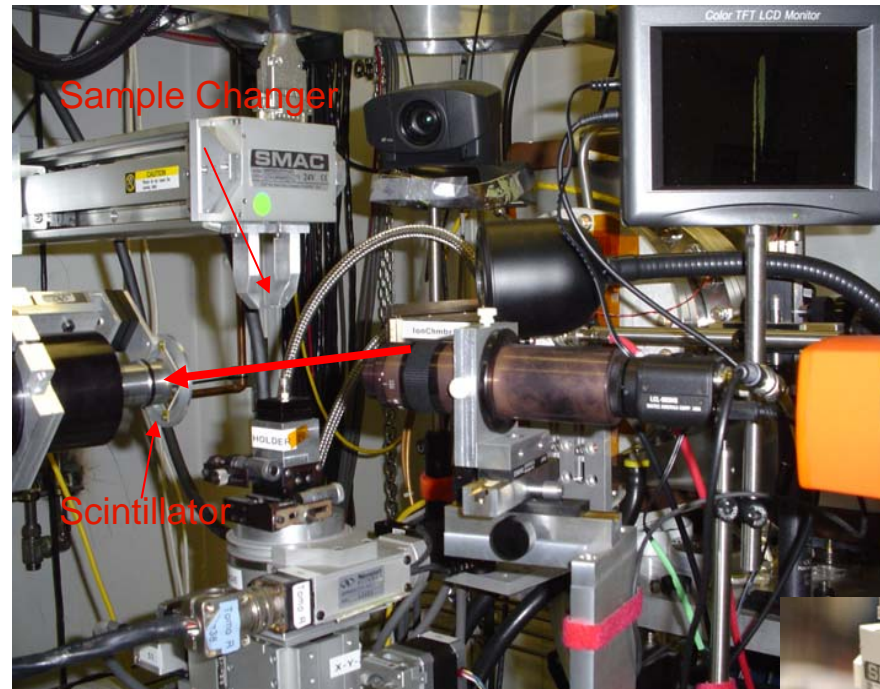• Foam deformation
• ….
• Ancient fossils from China
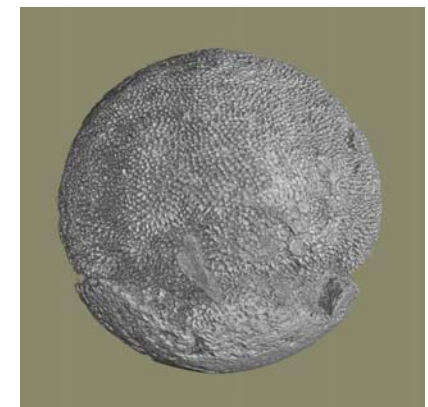
Contact: Francesco De Carlo: decarlo@aps.anl.gov

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Off-line Pre-alignment

Sample Changer

Scintillator
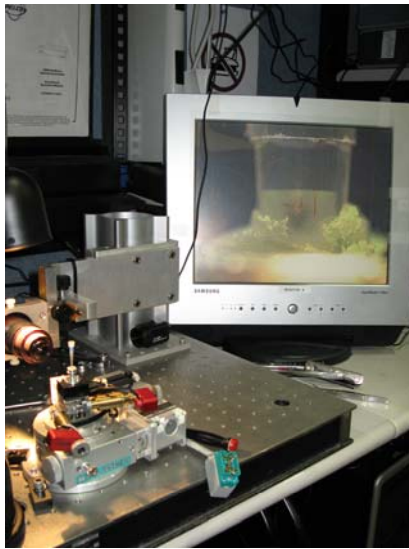
Automatic Sample Changer

Standard Sample Holders

Data handled per sample (every ~ 25 min)

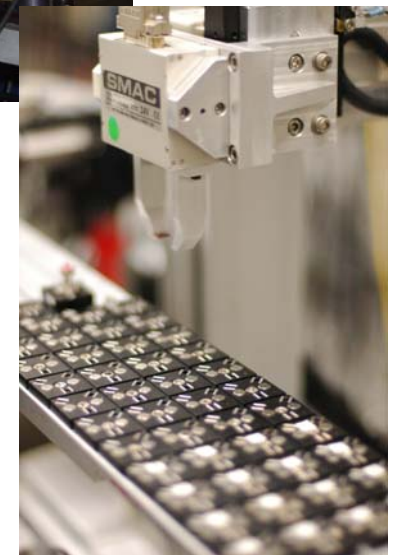|	Pixels	Gbytes	
CCD single projection	2,048 x 2,048	8.00	MByte
Raw Data Set	2,048 x 2,048 x 1,440	11.25	GByte
Normalized	2,048 x 2,048 x 1,440	22.50	GByte
Reconstructed	2,048 x 2,048 x 2,048	32.00	GByte
Total		**73.75**	**GByte**

Data Processed **4.15 TB/day**
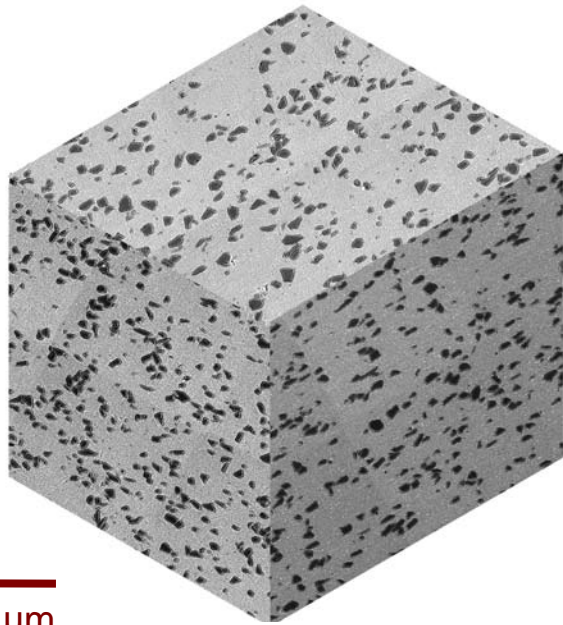
Data Distributed to users **2.43 TB/day**

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APS Beamline 2-BM micro-tomography system

3D Microstructure Visualization and Modeling of Deformation in Metal Matrix Composite

N. Chawla, Arizona State University with Alcoa, Ford, GM, and Chrysler
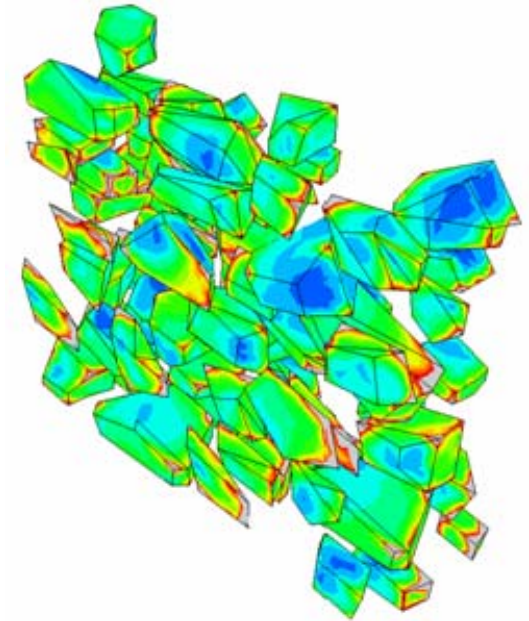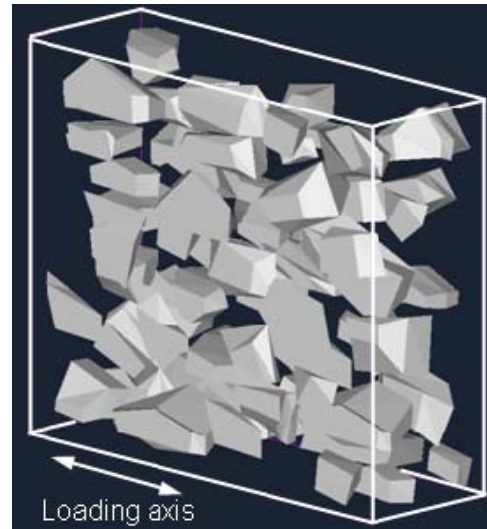

100 µm

Particle Reinforced
Metal Matrix Composites

The APS micro-tomography system will allow to make lightweight connecting rods for passenger cars by

- Visualizing and quantifying the fraction and distribution of SiC, pores, and Fe-rich inclusions

- Understanding the role of Fe-rich inclusions and pores on tensile and fatigue resistance of MMCs

- Quantifying the degree of damage as a function of distance from the fracture plane
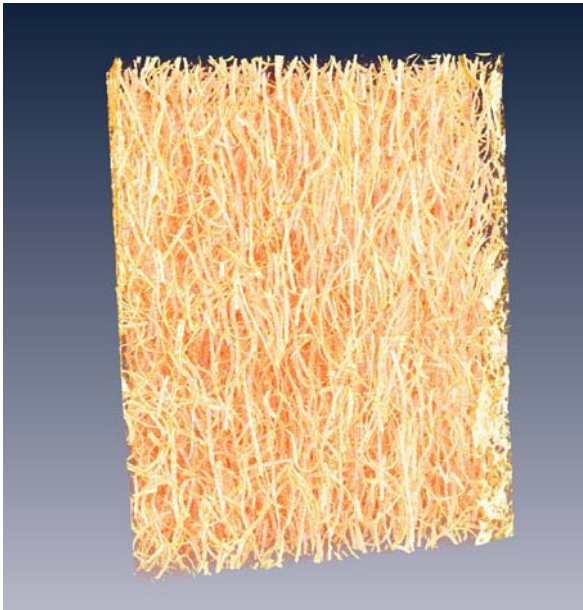
ALCOA   Ford   GM   CHRYSLER
INSPIRATION COMES STANDARD

APS Beamline 2-BM micro-tomography system
New Reusable Solid Rocket Motors Insulation
Mark Gentz, Alliant Techsystem - ATK Launch Systems

Fiber Alignment and Distribution

Filler Size and Distribution

The APS micro-tomography system allows to study:

- The Reusable Solid Rocket Motors of the Space Shuttle
- The new internal rocket motor insulation for NASA that is designed to replace the current asbestos fiber based insulation.

- The characteristic of the alignment and distribution of the fibers
- The particle size and distribution of the fillers for this insulation material
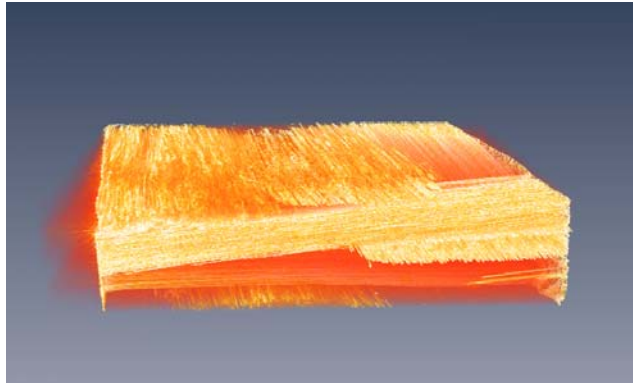- Materials processed under various conditions.

ATK

A premier aerospace and defense company

APS Beamline 2-BM micro-tomography system

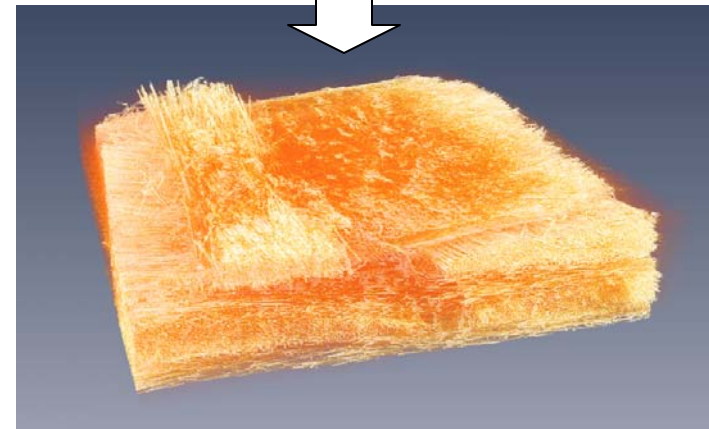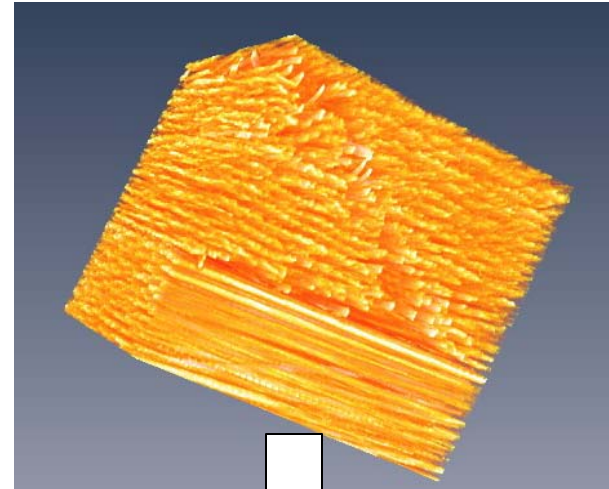## Self healing composite materials microstructure and healing efficiency

PI Fabrizia Ghezzo Duke University with SensorMetrix Inc. and NanoComposix Inc.
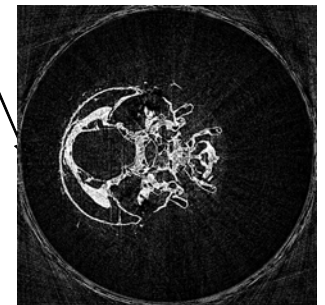
2 x 2mm samples 3 layers

New (non-thermo-shocked) sample, small section, CFRP-2MEP4F
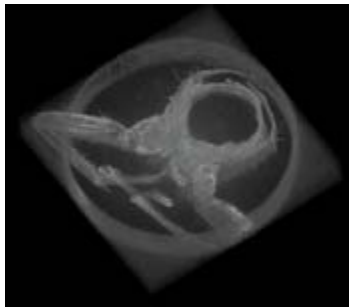

New sample, CFRP epoxy

The APS micro-tomography system allows to study:

- Fibers distribution in composite laminates (quality of the fabrication process)

- Presence of voids or defects into the matrix phase of the composite

- Presence of cracks

- Healing of cracks

- If healing at temperatures close to Tg (glass transition temperature) of the polymer the material deforms (identification of creep phenomena)

Same sample, Healed over 100C (close to polymer glass transition temperature): polymer viscosity issues

SensorMetrix
Advanced Materials and Integration Technology

nanoComposix

MPI System

Data Storage (local RAID)

Data Acquisition System

eSCSI

gridftp

tomo or orthos

10Gb

MPI Server

Pre-processing

Sinograms

Data Storage

Infiniband

MPI Clients

Reconstruction

Reconstruction

Reconstruction

Reconstruction

Infiniband

MPI Front End & Data Distribution

Data Analysis Clusters Fully Scalable (disk space and CPU power)

- **Dedicated Beamline cluster (tomo)**
  - 8 x [2 x dual-core 2- GHz] CPU compute nodes on a Infiniband bus.
  - 40 TByte scalable high performance parallel file system (lustre)
  - 3D rendering: Amira
  - Sample reconstruction in ~ 22 min

- **Shared APS cluster (orthos)**
  - 17 x [2 x dual-core 2.6- GHz] compute nodes on a Infiniband bus.
  - 70 TByte scalable high performance parallel file system
  - 1 Head node - 500GB of local user space, 8GB RAM, 2 x 2.6Ghz Dual Core opteron
  - 1 Administrative node - 250GB local user space, 8GB RAM, 2 x 2.6Ghz Dual Core opteron.
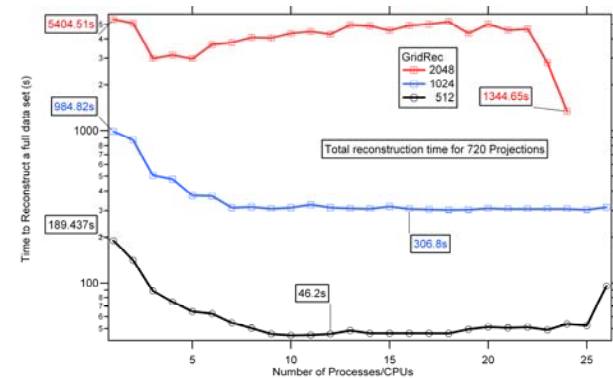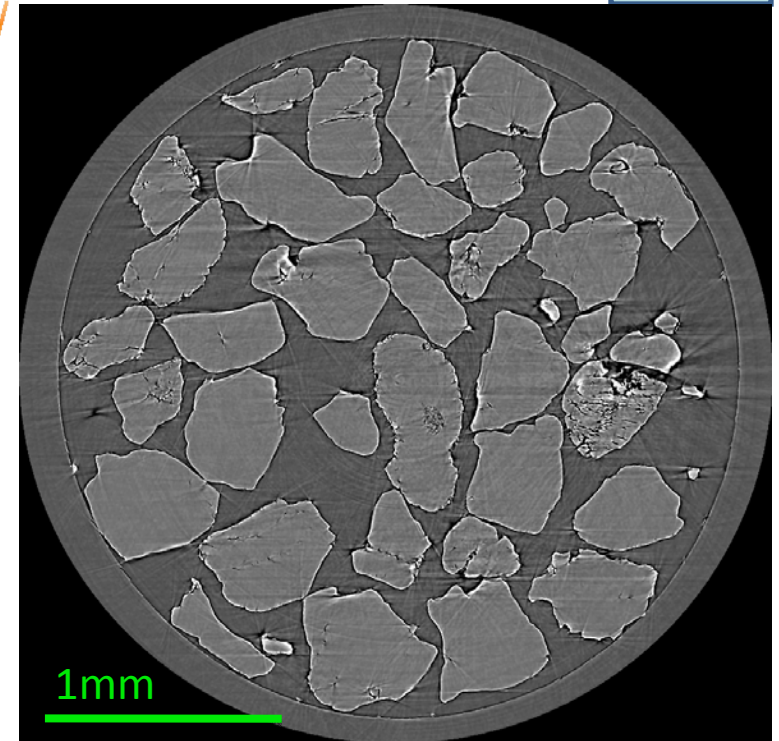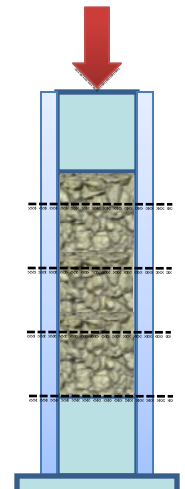
APS Beamline 2-BM micro-tomography system

Mechanical behavior of sand under compression through direct observation of 3D Microstructure,
Jay Hanan Oklahoma State University

4 tomographs are combined per strain step to examine the full column.
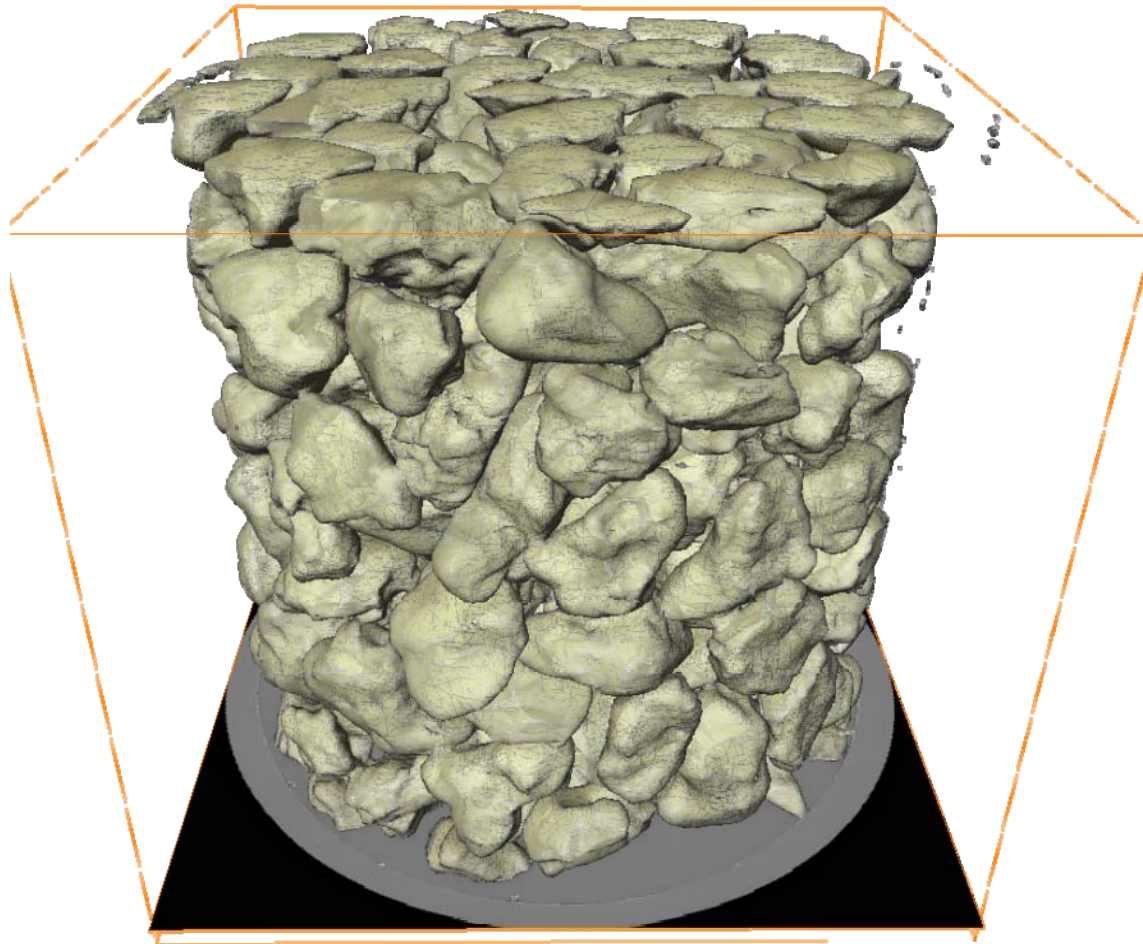
76 tomography datasets in total for the 34% maximum strain reached.

1mm

2D slice of the sand grains
2.6 μm/pixel resolution

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Mechanical behavior of sand under compression through direct observation of 3D Microstructure,
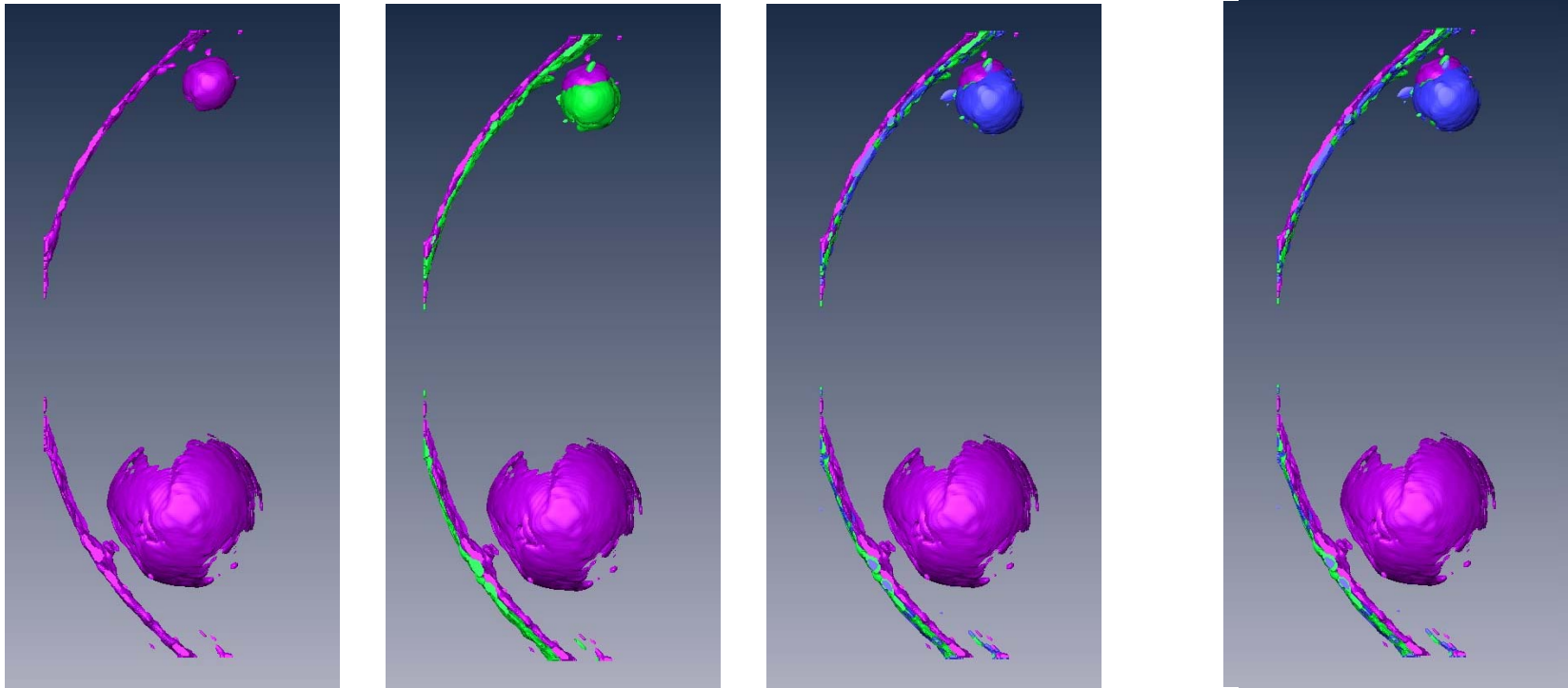Jay Hanan Oklahoma State University
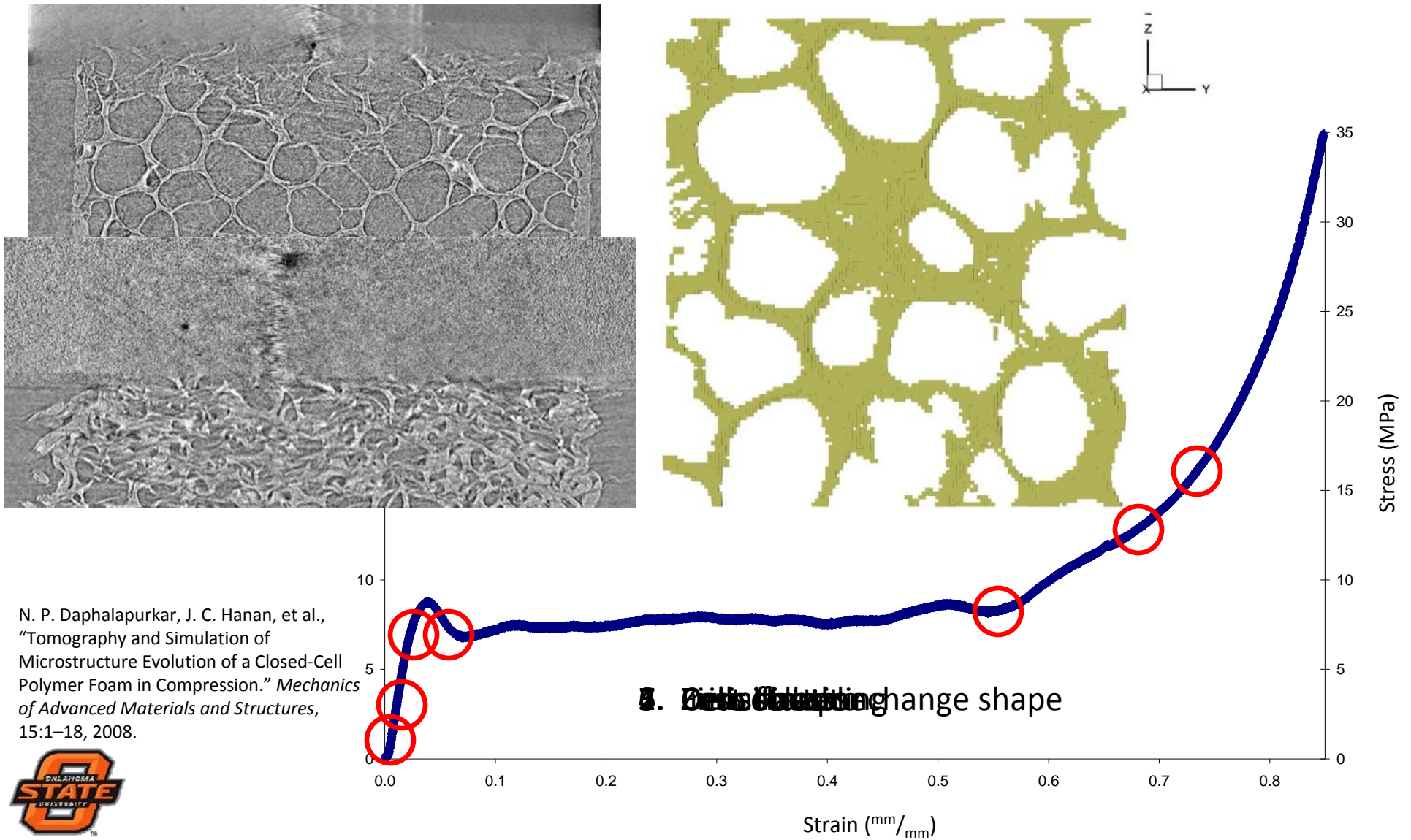
N. P. Daphalapurkar, J. C. Hanan, et al., "Tomography and Simulation of Microstructure Evolution of a Closed-Cell Polymer Foam in Compression." *Mechanics of Advanced Materials and Structures*, 15:1–18, 2008.

Ultra-fast Tomography: A Bubble Growing (4Hz Tomography)

| 0 ms | 1500 ms | 3000 ms |

> 10 PB/day …..

GPU developments