

ENHANCEMENT OF TOW VISUALISATION IN CARBON COMPOSITES

Presented by Luke Djukic

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Presentation outline

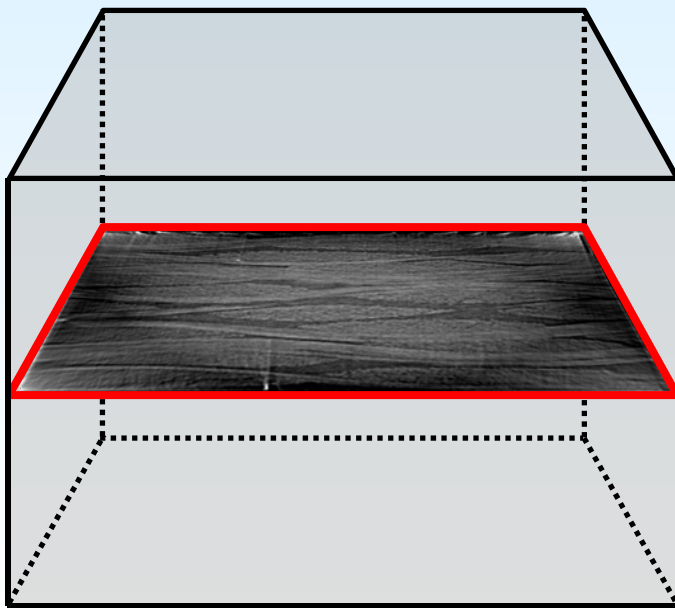
- Introduction
- Benchmark samples
- Contrast enhancement techniques
- Volume reconstructions
- Conclusions



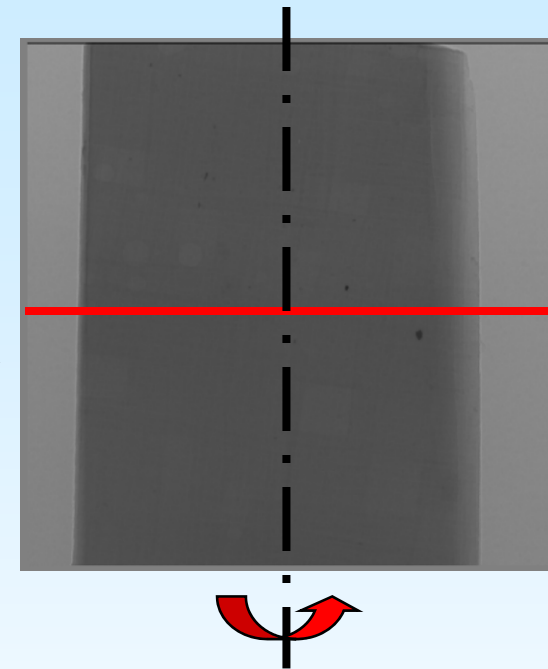
Skyscan 1072

MicroCT Scanning

1) X-ray images acquired at a number of orientations over total angle change of 180° or 360° .



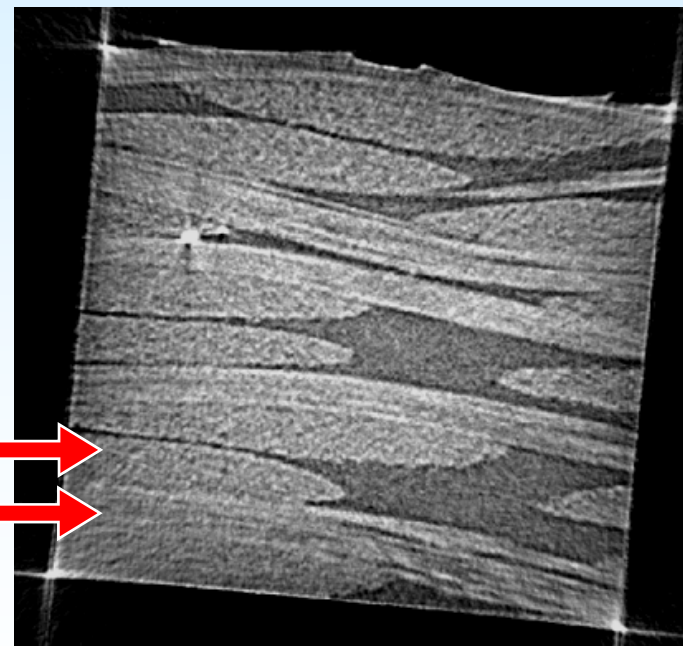
Reported images



2) Line of pixels selected from each image to reconstruct perpendicular cross section.

Objectives

- Aim:
 - To determine the exact weave pattern for an infused composite laminate using a microCT scanner
 - Investigate contrast enhancement techniques
 - Additives not permitted to interfere with pressure induced tow deformations
 - Results used to characterise woven preforms.
- Main issues:
 - Differentiating between tows and resin
 - Determining fibre direction
 - Determining tow interfaces.
- Possible Solutions:
 - Resin additives
 - Tow/fibre coatings.



Out of plane tow →
Transverse tow →

Carbon/Epoxy plain weave

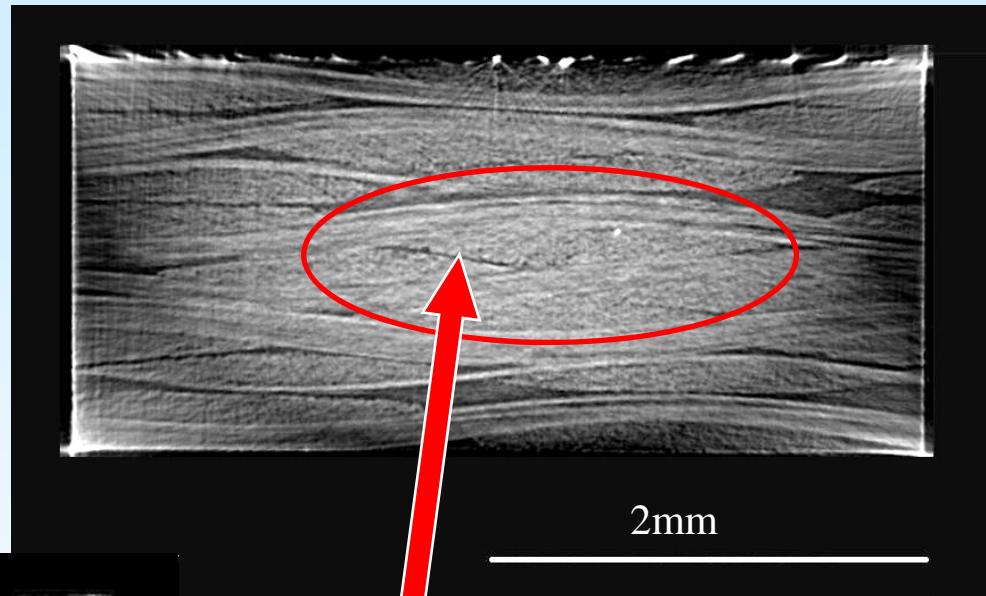
Benchmark Carbon/Polyester

Manufacture:

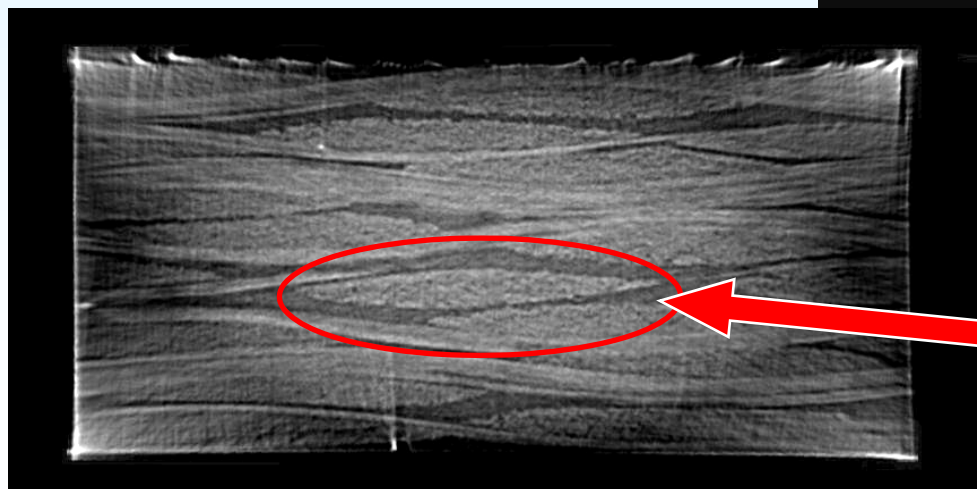
- Plain weave fabric
- Vacuum Bag Resin Infusion (VBRI) with polyester – similar to VARTM.

Results:

- Tow deformations visible in some locations
- Similar greyscale shades in both resin and tows.



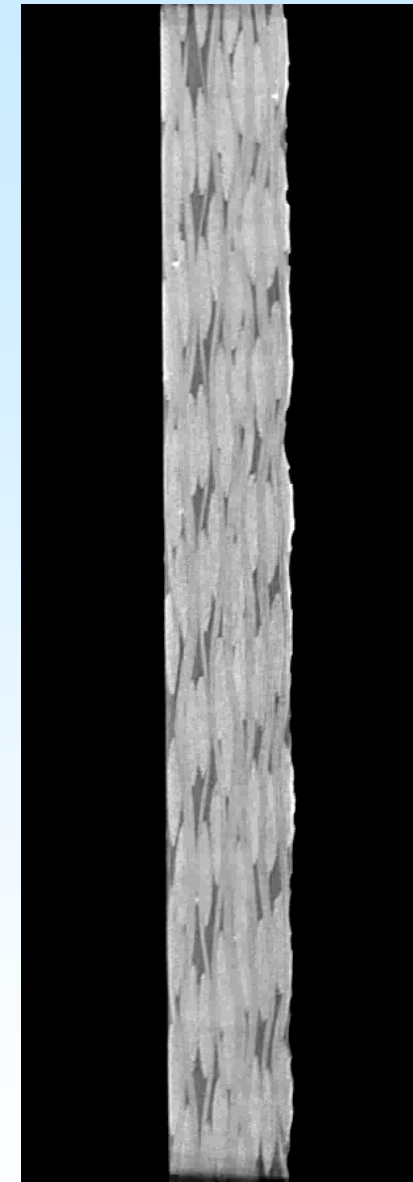
Poorly visualised
tow interfaces



Clearly defined tow with
consolidation deformations,
oriented out of page

Comments

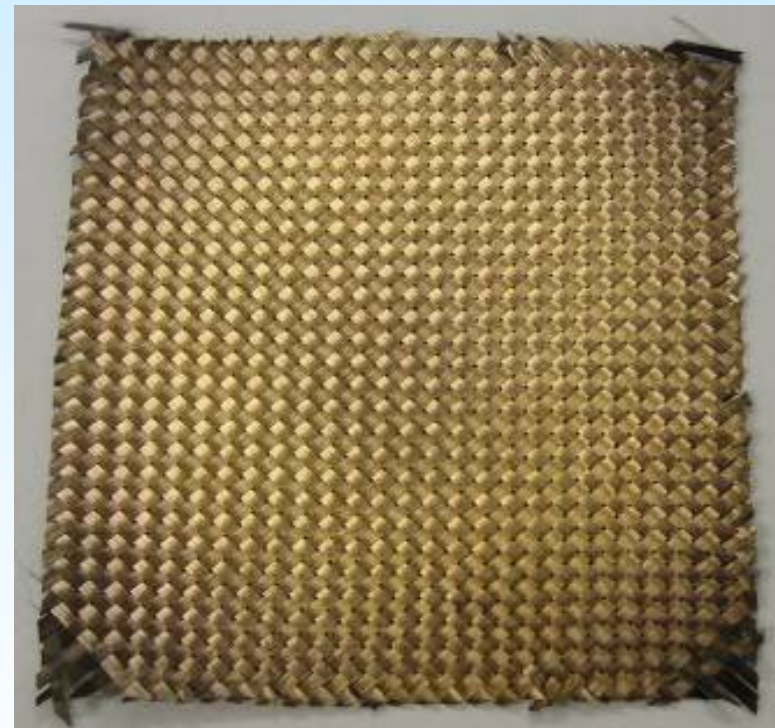
- Can discriminate tow direction in some cases
- Tow deformations visible
- Difficulty determining tow interfaces, particularly when tows in contact are aligned in the same direction.
- Leads to need for contrast enhancement.



Video courtesy of AFRL

Contrast enhancements

- Fabric coating:
 - Gold sputter
 - Copper vapour deposition
 - Iodine based contrast agent
 - Barium Sulphate particles
 - Gadolinium Fluoride particles
 - Comparison to glass fabrics.
- Resin additives:
 - Aluminium Oxide powder
 - Barium Sulphate.
- Tow coating prior to weaving:
 - Gold sputter
 - Copper electroplating
 - Iodine contrast agent
 - Comparison to glass tows.
- 3D preforms:
 - 3D preform with Iodine coating
 - Iodine coated fabric with glass stitching.



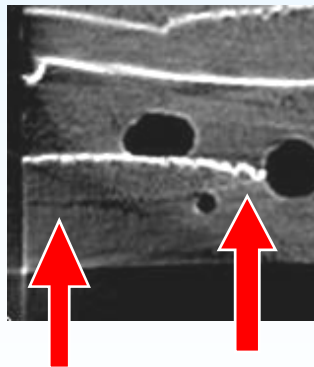
Terminology

- Ring artifact

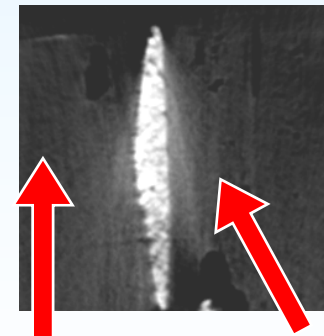


- Beam hardening:

- Appears as a difference in attenuation
- Free edges or corners of samples
- In low density material near material of higher density.



Brightness difference



Brightness difference

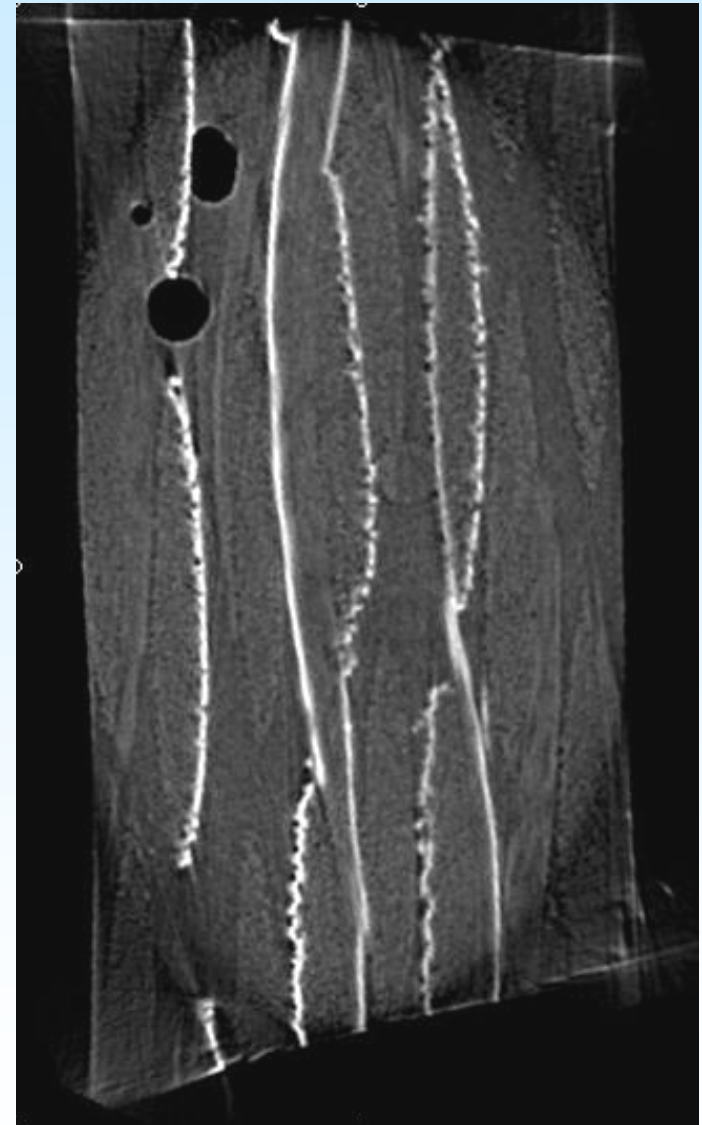
Gold Coating - Fabric

Manufacture:

- 25nm and 50nm gold layers applied to dry fabric – sputter coating
- VBRI with polyester resin.

Results:

- Allows good visualisation of ply interface.
- Visualised layer thickness is not indicative of actual dimension.
- Not able to see interface of tows within same ply.



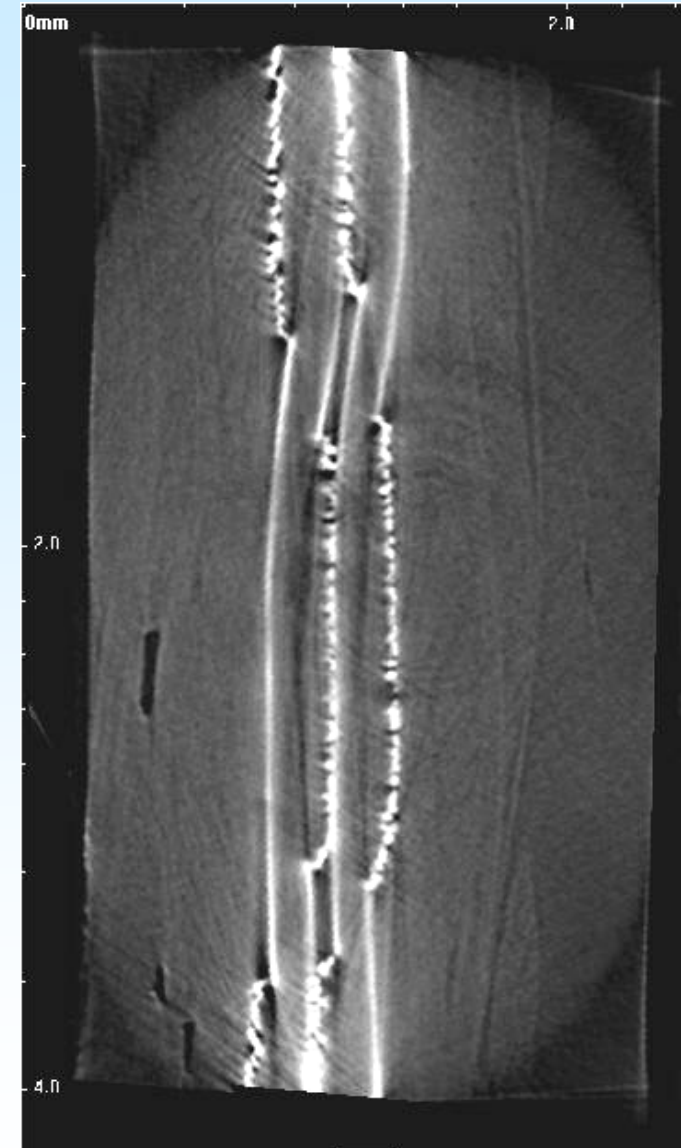
Copper Coating - Fabric

Manufacture:

- Carbon fabric coated with copper using vapour deposition technique prior to infusion
- VBRI.

Results:

- Similar results to gold
- Additional beam hardening artifact around copper layers.



Iodine Tracer Coating – Fabric

Manufacture:

- Plies soaked in Iodine based medical tracer (Isovue 370).
- Two coated plies at centre of lay-up.
- VBRI.

Results:

- Fabric found to stiffen as a result of soaking
- Poor distinction of tow interfaces within ply
- Coated fabrics contrast well to uncoated
- Higher void content than gold specimen.



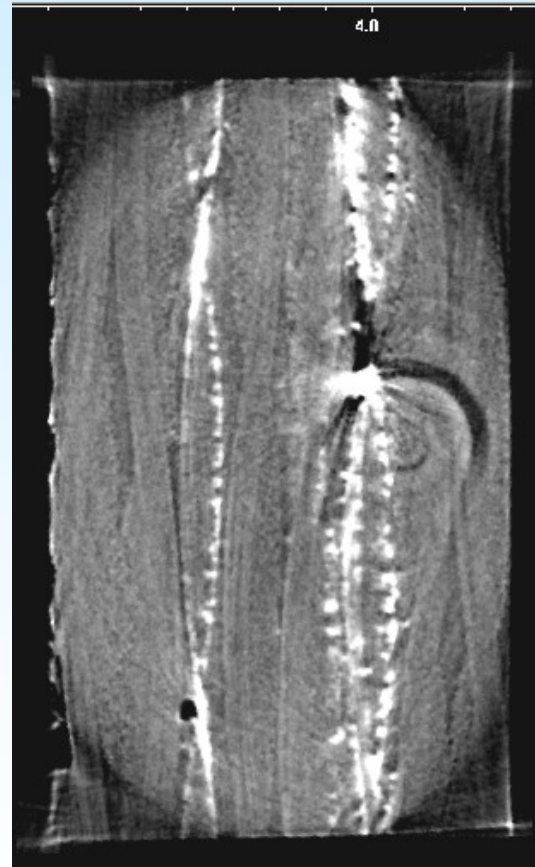
Particle Coatings – Fabric

Manufacture:

- Barium Sulphate or Gadolinium Fluoride particles in propanol solution
- Wet lay-up with vacuum compaction.

Results:

- Particles found by scan, but poor contrast generated due to poor dispersion
- High level of artifact due to concentrated high density regions.



Barium Sulphate



Gadolinium Fluoride

Glass Fabric Comparison

Manufacture:

- Interleaved glass and carbon fabrics
- Wet lay-up with vacuum bag compaction.

Results:

- Visualisation of glass much less problematic than carbon
- Some beam hardening artifact - light and dark patches within carbon
- Poor distinction of tow interface within glass ply, but better than carbon.



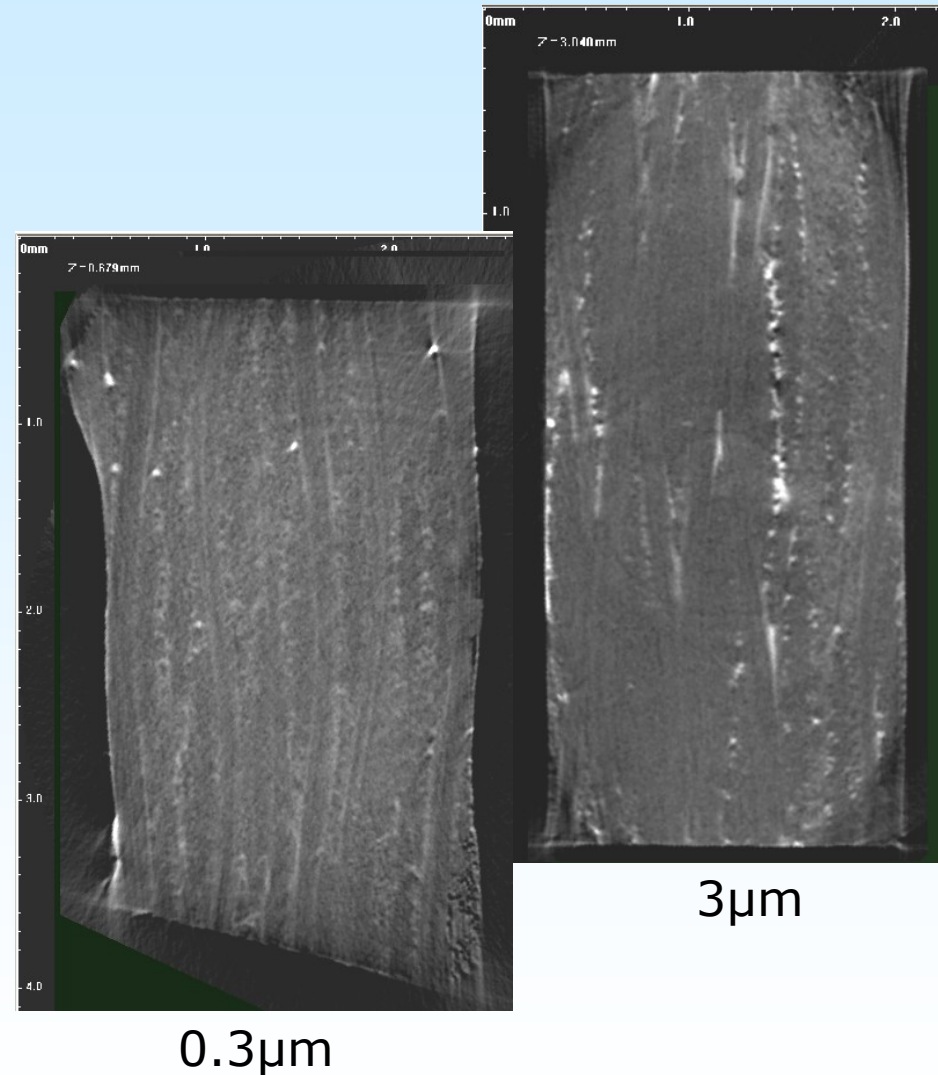
Aluminium Oxide – Resin Additive

Manufacture:

- Aluminium oxide polishing powder resin additive
- 3 μ m and 0.3 μ m grit sizes
- VBRI.

Results:

- 3 μ m: settling on tow interfaces in uncontrolled fashion
- 0.3 μ m: more uniform dispersion than 3 μ m
- Presence of 0.3 μ m powder in tows reduces contrast
- Need controlled settling on tow interfaces.



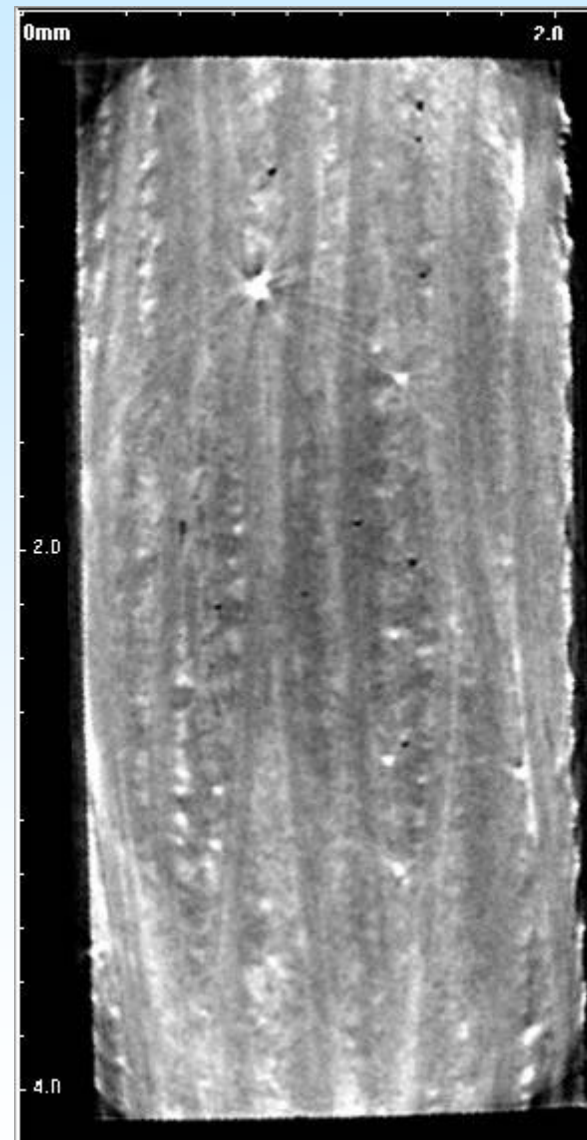
Barium Sulphate – Resin Additive

Specimen manufacture:

- Barium Sulphate
- 1:10 mass ratio between resin and particles
- Wet lay-up with vacuum compaction.

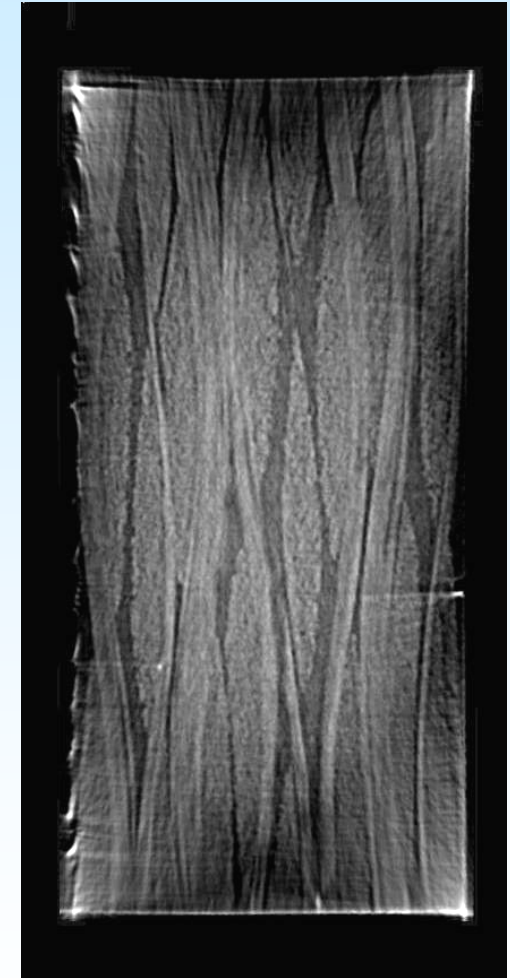
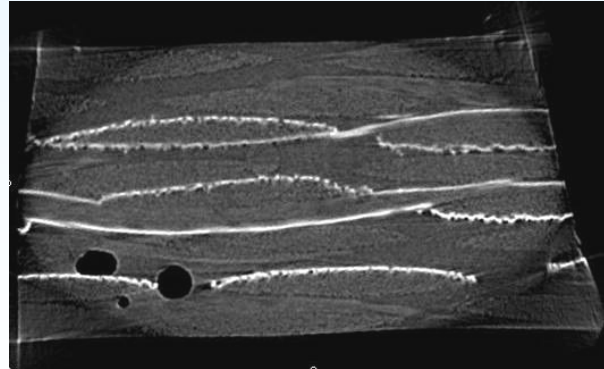
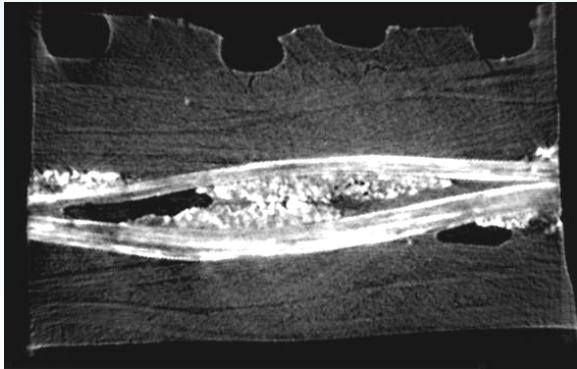
Results:

- Better dispersion than bone cement due to wet lay-up
- Entire resin highlighted
- Tows also highlighted, but to lesser extent.



General Comments

- Fabric coating methods:
 - Best methods – gold, copper, iodine
 - Poor distinction of internal tow interfaces
 - Need for individual tow coating prior to weaving
- Resin particle additives:
 - General poor performance
 - Random settling locations
 - Smaller particles penetrate into tows, reducing contrast

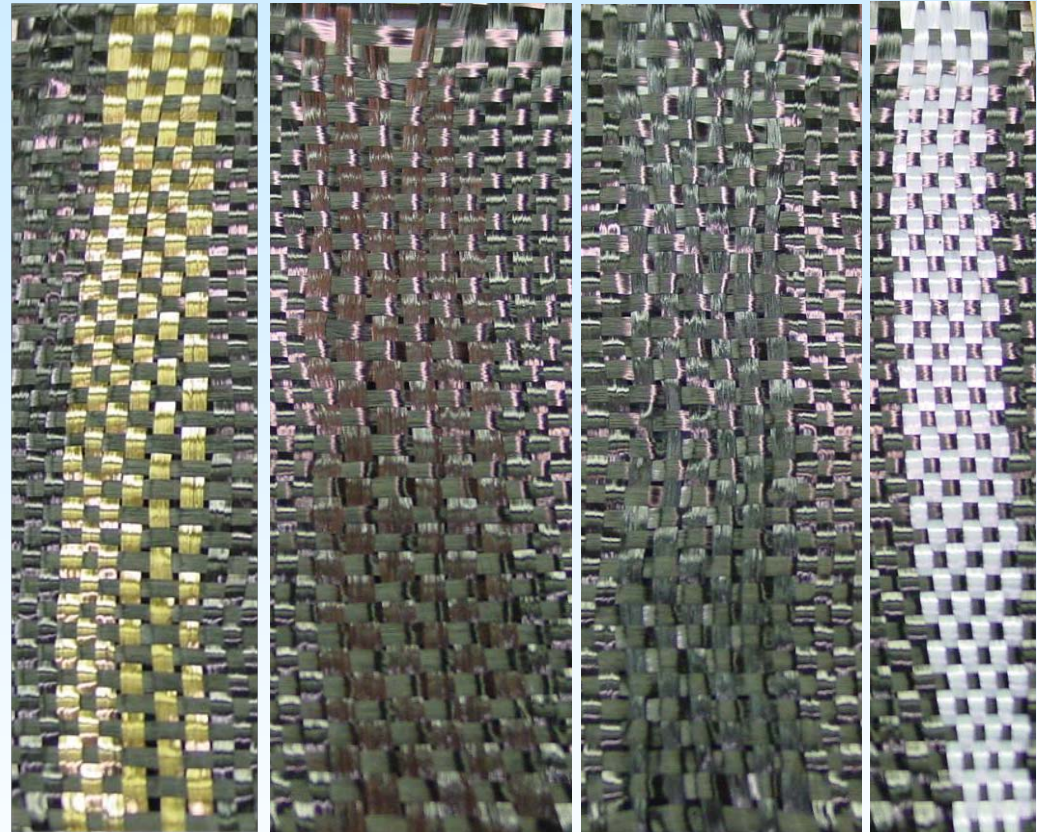


Tow Coating Prior to Weaving

Best fabric methods applied to coating of individual tows.

Manufacture:

- Tows treated, then woven into fabric
- Warp left untreated
- Single ply placed in centre of 7 ply laminate
- Wet lay-up with vacuum bag compaction.



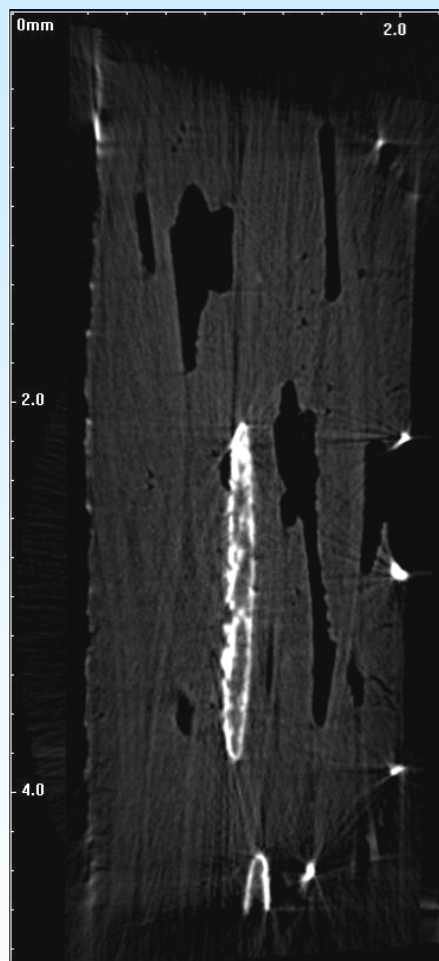
Gold

Copper
(electroplated)

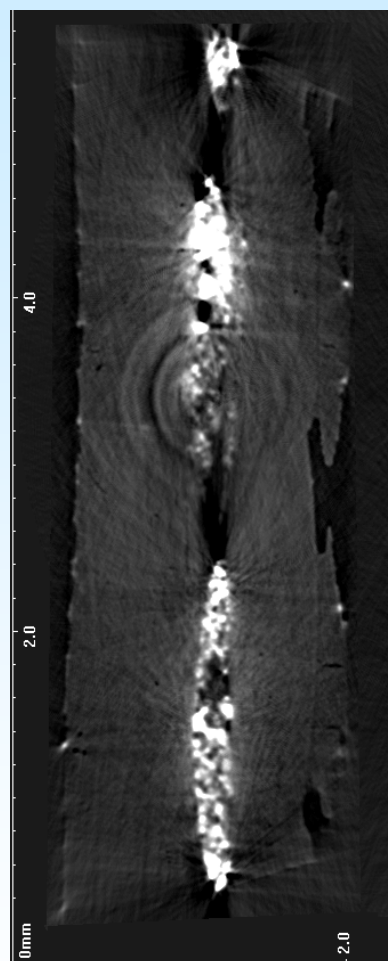
Iodine

Glass

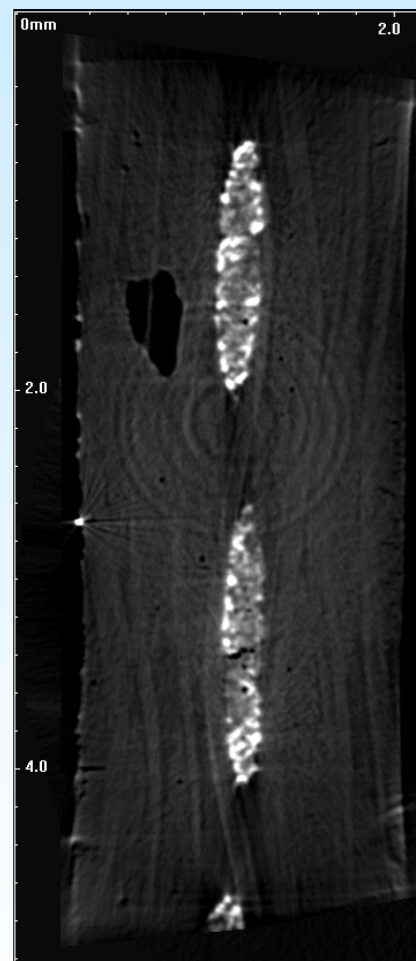
Tow Coating Prior to Weaving



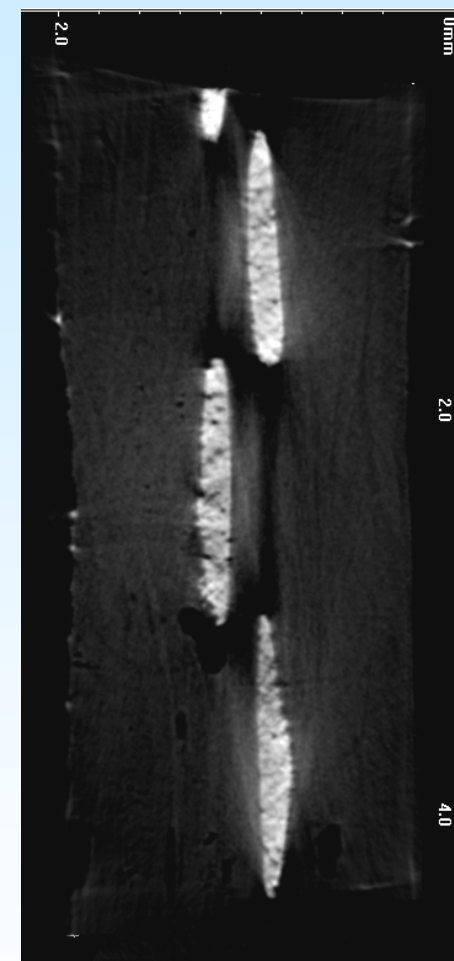
Gold



Copper



Iodine



Glass

Tow Coating Prior to Weaving

- General comments:
 - Visualisation of gold, iodine and glass similar to previous
 - Tows can be isolated and investigated.
- Copper electroplate:
 - Density variations in coating
 - Large number of artifacts
 - Combination of above two factors make this sample unsuitable for 3D reconstruction
 - Poor performance in comparison to copper vapour deposition.

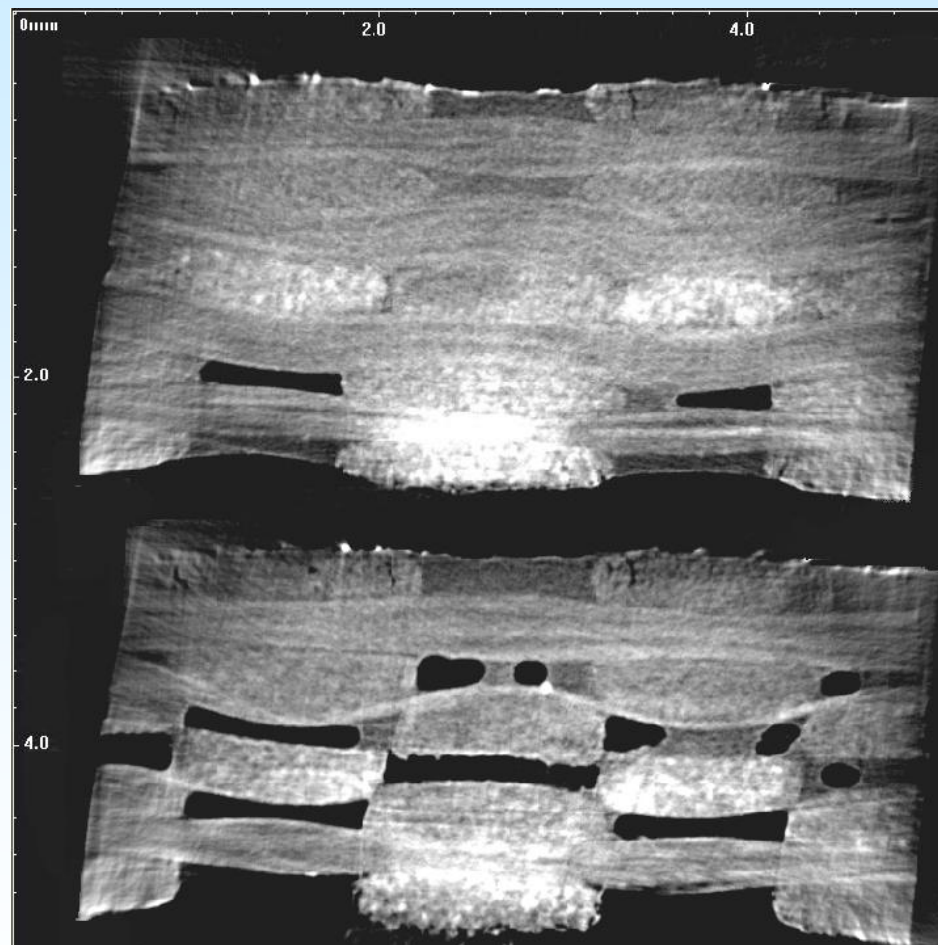
Iodine coated 3D preform

Specimen manufacture:

- Coated in Iodine based medical tracer under pressure prior to infusion
- Necessary due to observed stiffening of fabric during coating
- VBRI.

Results:

- Some non-uniformity in coating
- Difficult to determine exact tow interfaces
- Need multiple levels of contrast.



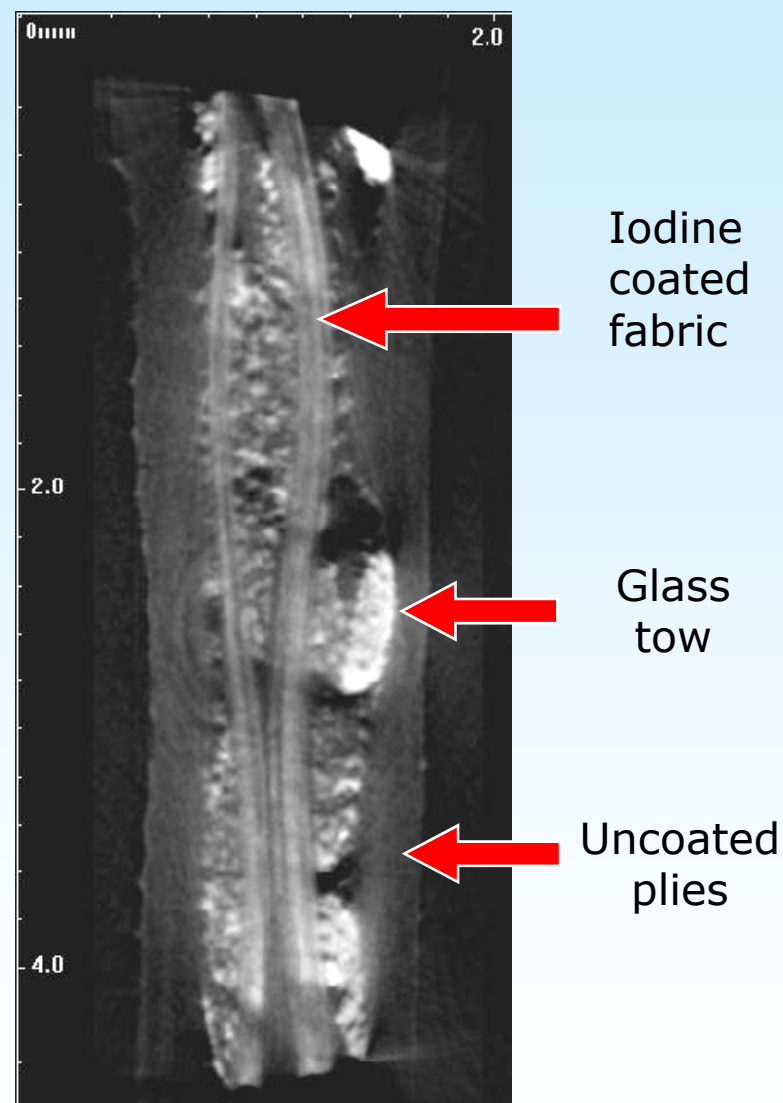
Iodine Fabric with Glass Stitching

Manufacture:

- Two layers of plain weave coated with Iodine tracer
- Woven together with glass tows
- Two untreated layers of carbon plain weave placed in either side
- Wet lay-up with vacuum bag compaction.

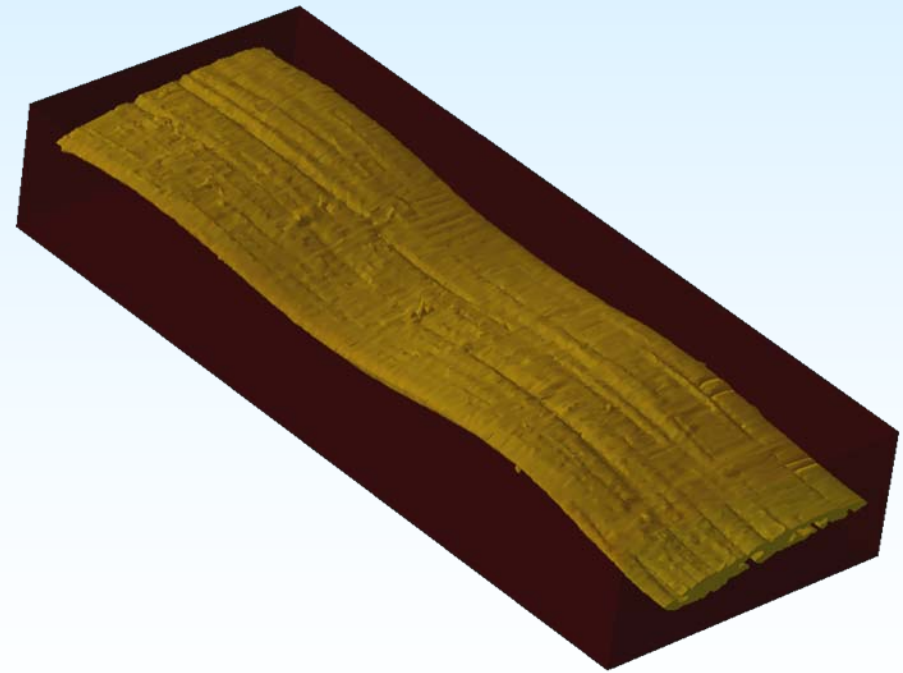
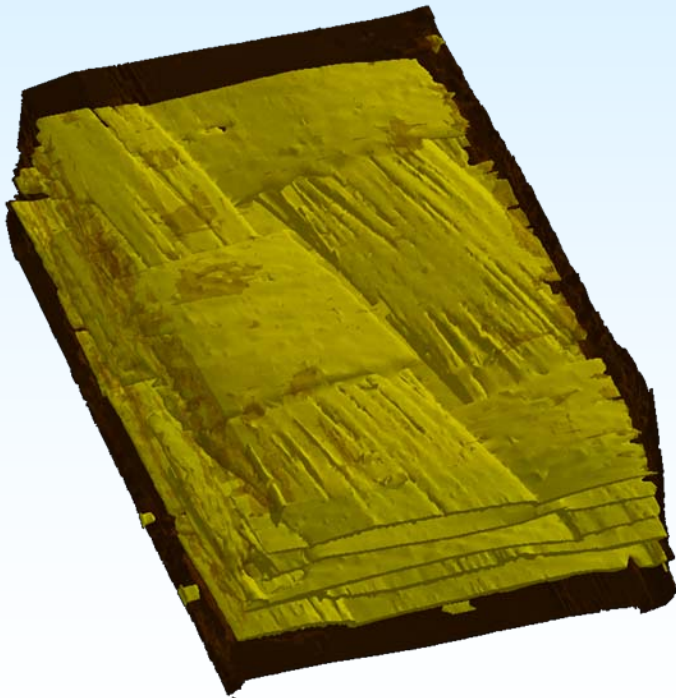
Results:

- Difficulties due to beam hardening artefact and regions of coated fabric appearing as similar
- Densities separable by greyscale level for most part.



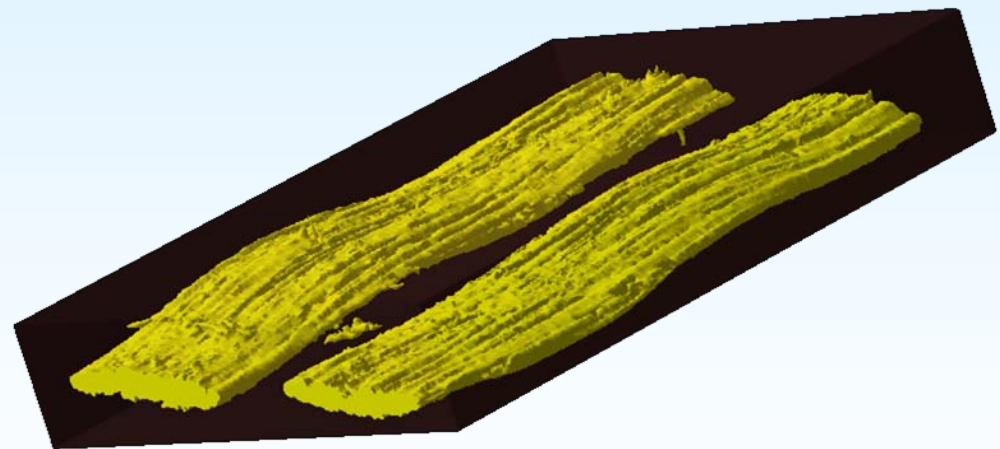
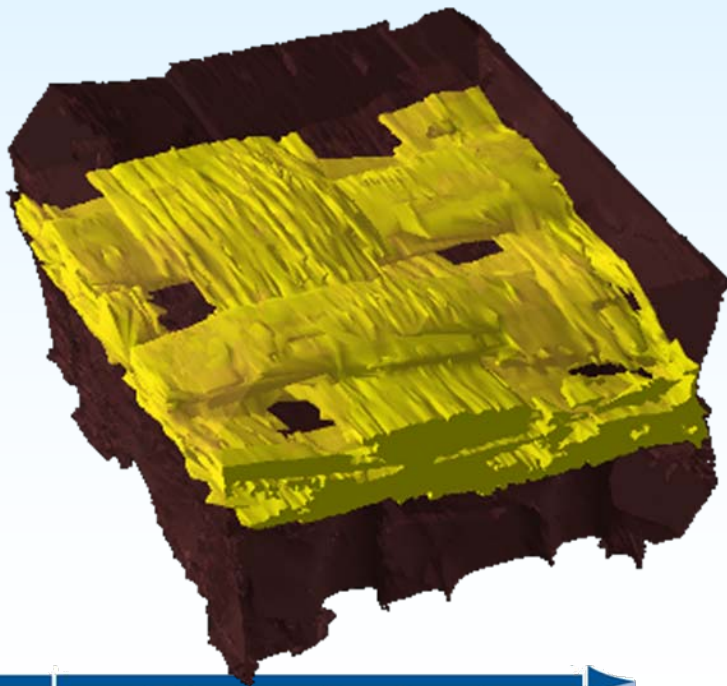
Gold 3D Reconstructions

- Reconstructions made from cross-sectional images in 3D Creator
- Plain weave:
 - Reconstruction of gold layers on fabrics
 - Grooves in tow surface indicate fibre direction.
- Individual tow:
 - Outline of tow – interior not reconstructed.



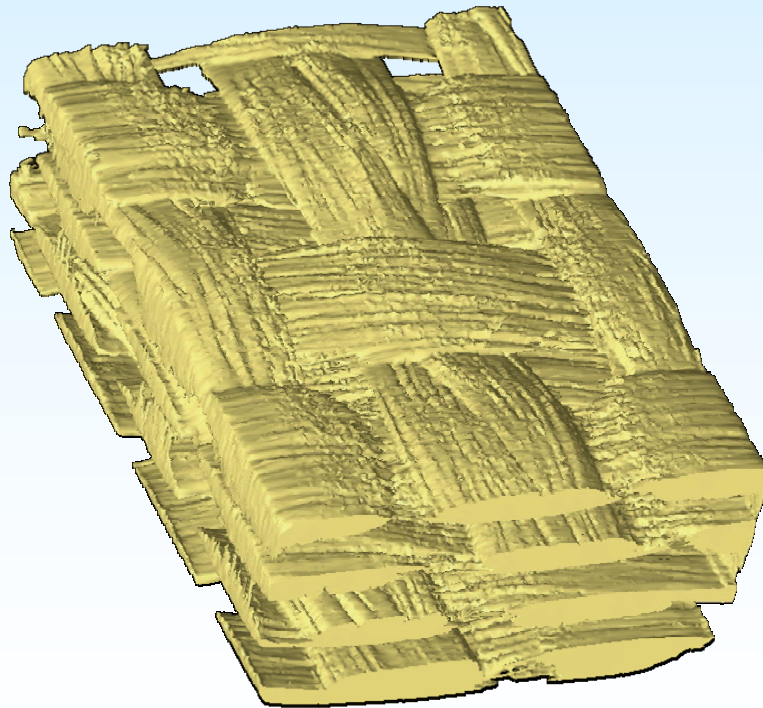
Iodine 3D Reconstructions

- Plain weave:
 - Reconstruction of entire fabric.
- Individual tows:
 - Have to account for beam hardening artifact, resulting in loss of tow perimeter definition
 - Inside of tows reconstructed
 - Artifacts reconstructed along with tows.



Glass 3D Reconstructions

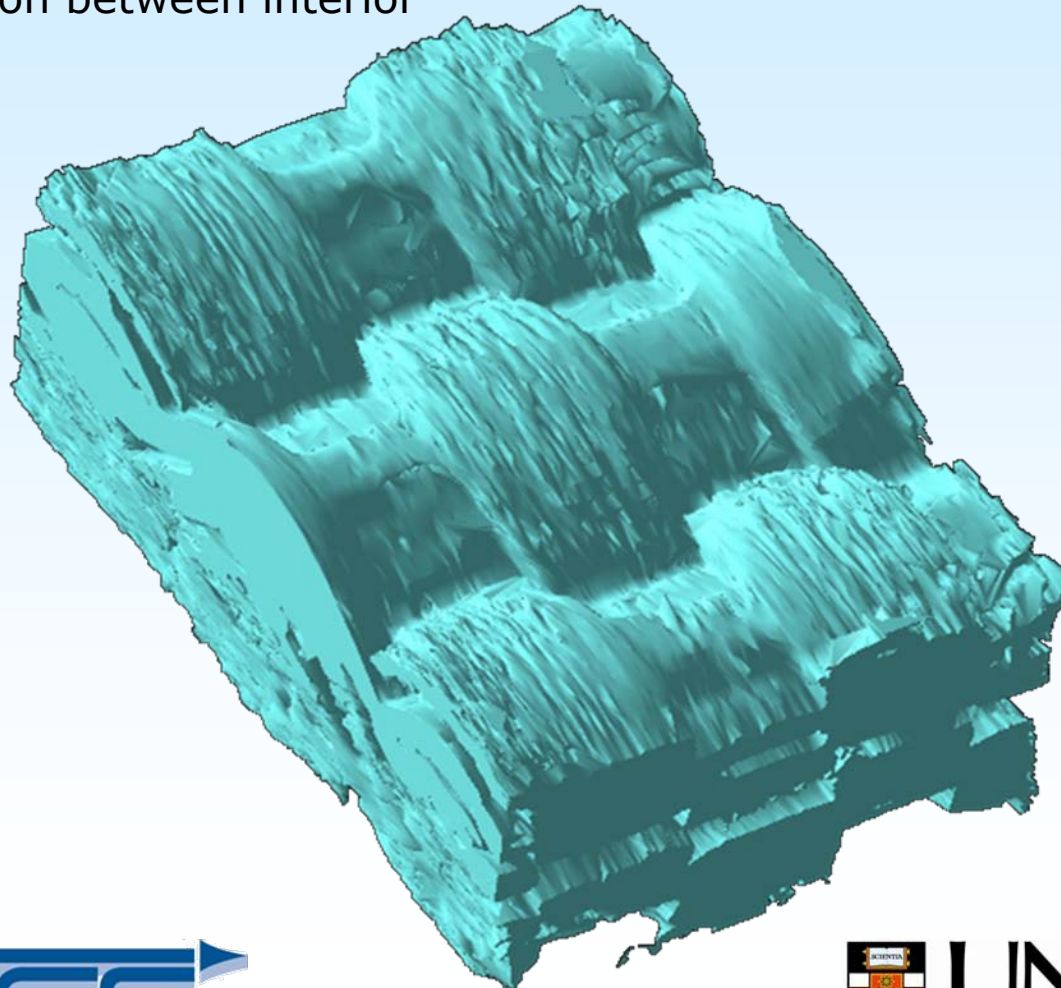
- Plain weave:
 - Loss of accuracy at some locations
 - Adequate reconstructions without additives.
- Individual tows:
 - Loss of accuracy leading to "broken" edges.



Iodine coated 3D carbon preform

Iodine coated 3D carbon preform:

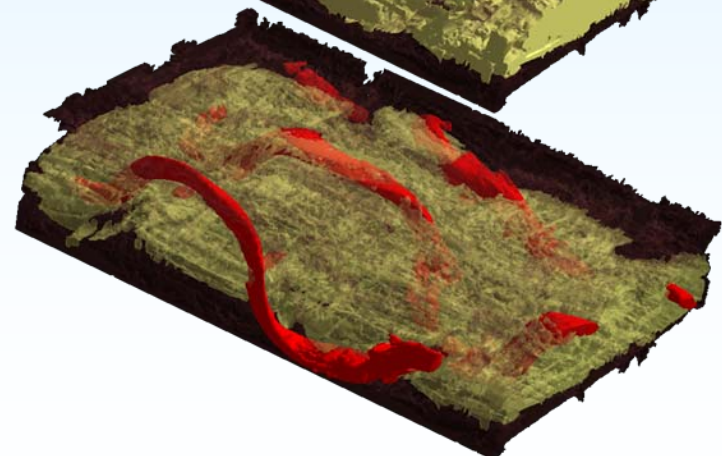
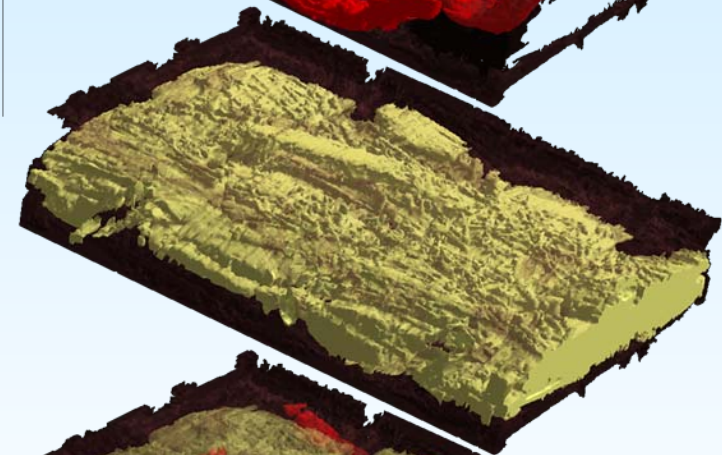
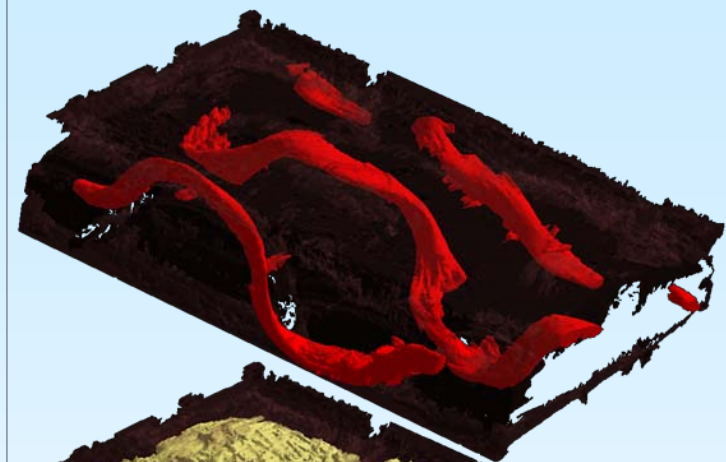
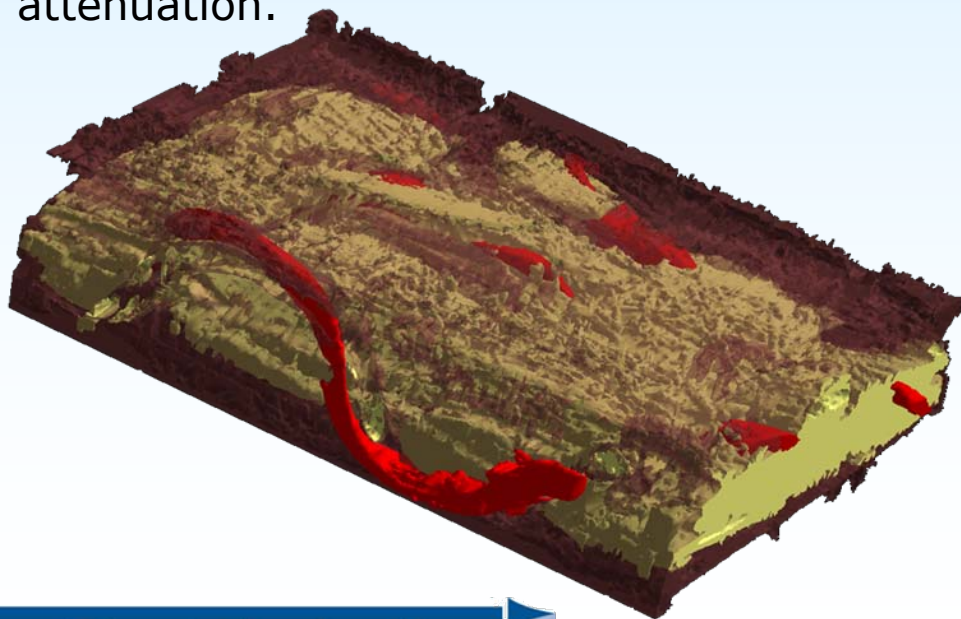
- Good representation of exterior
- Poor distinction between interior tows.



Iodine Fabric with Glass Stitching

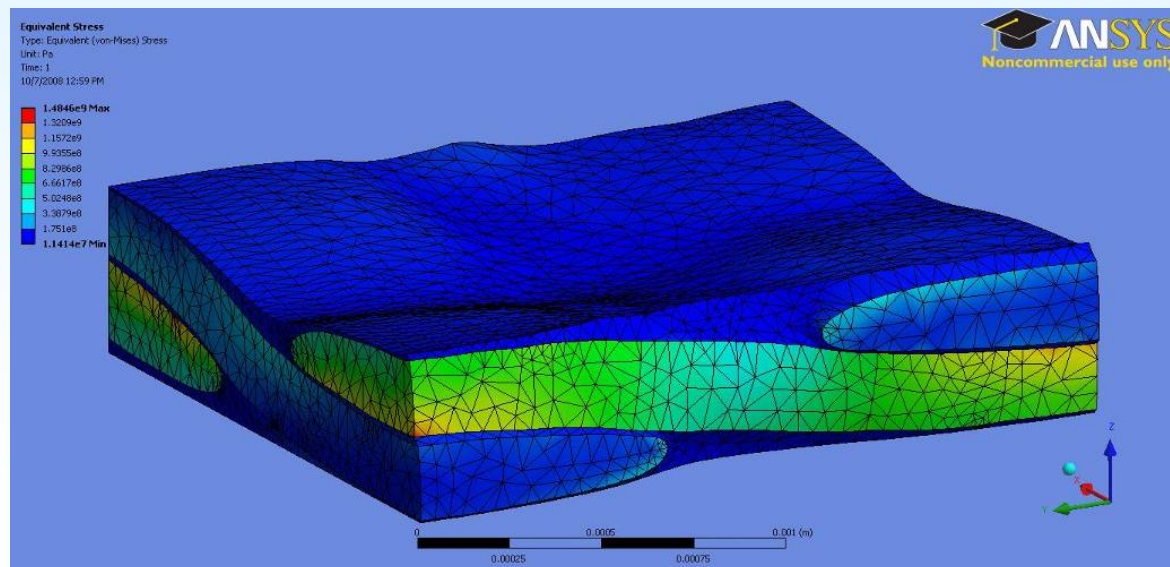
Iodine plain weave with glass stitching:

- Iodine coated plain weaves in centre (beige), layer reconstructed poorly
- Through thickness stitching with glass tows (red)
- Untreated carbon plain weave outer plies (brown)
- Separate into different volumes using X-ray attenuation.



Summary

- There is a need for contrast enhancement when CT scanning carbon/epoxy and carbon/polyester composites
- Best performance – gold, iodine, copper coatings
- Poor performance – fabric particle coatings and resin particle additives
- Good visualisation of glass without additives
- Need to coat tows individually to determine internal tow architecture
- Multiple levels of contrast enhancement allow better visualisations
- Finite element modelling underway.



Acknowledgements

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- Mr John Pettitt – NSW Manager, Regional Health Care Group.
- Van Bui and Ken Houghton from the Cooperative Research Centre for Advanced Composite Structures

- Thank you for your attention.

