



AI-BASED GENERATION OF SIMULATION MODELS FOR MATERIAL DEVELOPMENT FROM CT DATA

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SHORT SPEAKER BIOGRAPHY

2022 - now **Head of Digital Material Business, Math2Market GmbH, Kaiserslautern**
Responsible for Foams, Composites, Ceramics, Metals, Additive Manufacturing, Nonwovens, Technical Textiles

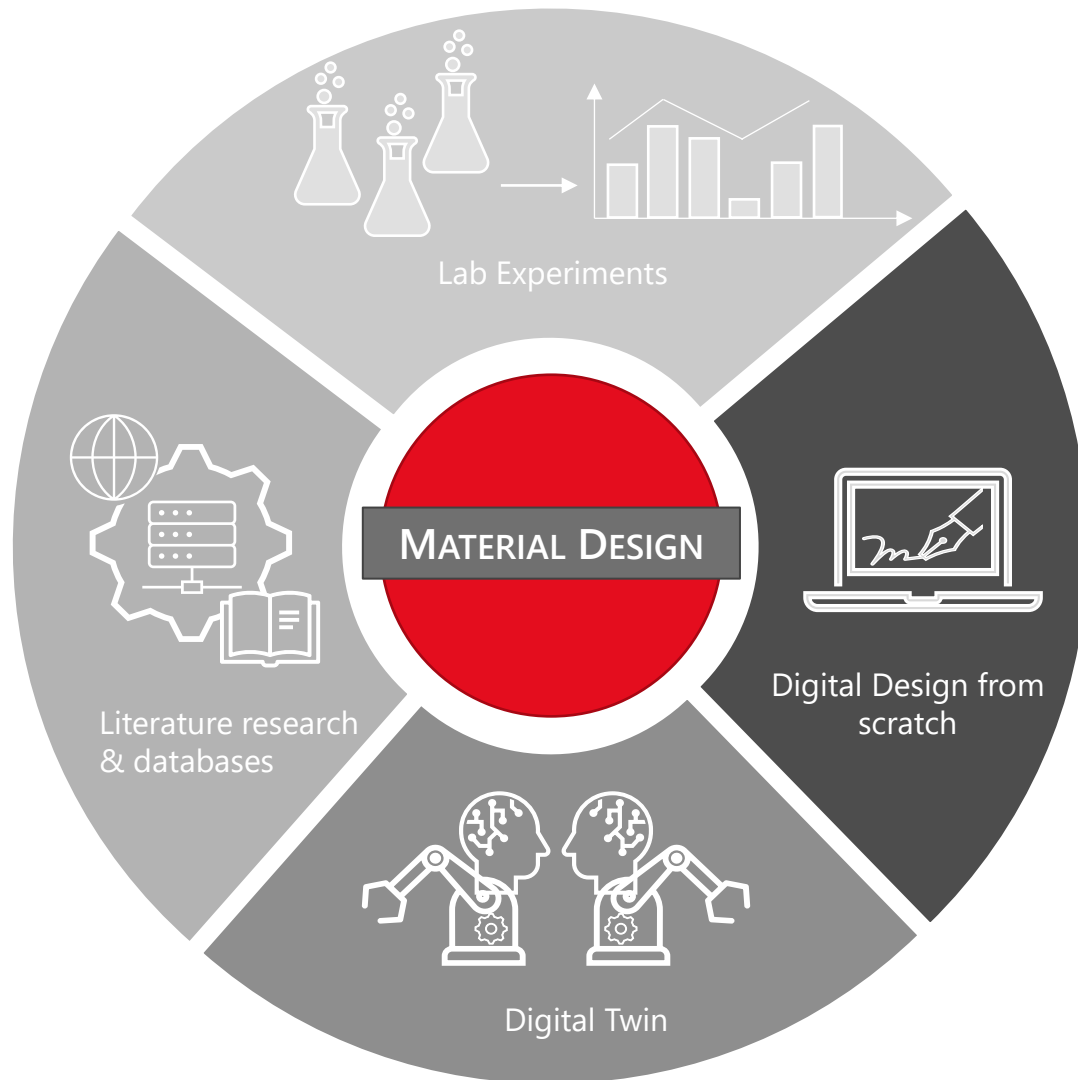
2020-2022 **Process Developer, PFW Aerospace GmbH, Speyer**
Responsible for process development in the area of laser metal deposition additive manufacturing

2015-2019 **PhD, Mechanical Engineering, TU Kaiserslautern**
At the **Leibniz Institute for Composite Materials**, department of Manufacturing Science
Topic: Experimental and simulative analysis of composite impregnation processes

2008 - 2014 **Diploma, Mechanical Engineering, TU Kaiserslautern**
Focus on material science and composites



Dr.-Ing. Oliver Rimmel



WHAT ARE THE OPTIONS TO IMPROVE A MATERIAL AND DESIGN A NEW AND BETTER ONE THAT SUITS YOUR SPECIFIC APPLICATION ?

INTRODUCTION: USING μ CT scans for composites development

Challenges

Start

Segmentation and analysis of the CT-Scans of fiber-reinforced polymer composites

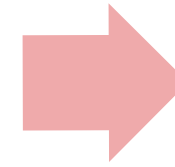
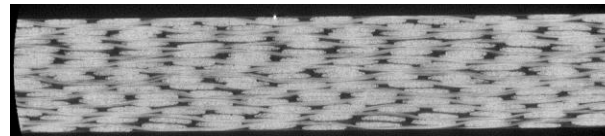
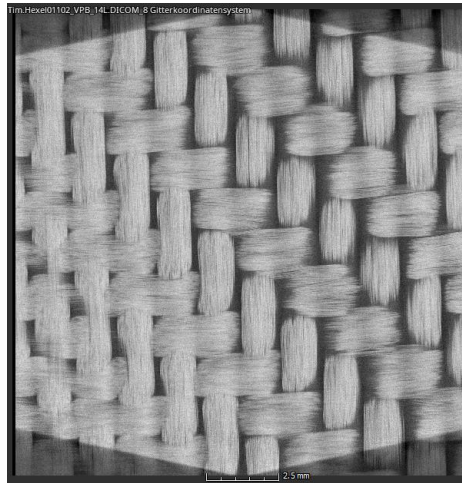


Fibers cannot be fully distinguished by the software



Approach

Human eye can distinguish individual fibers and tows



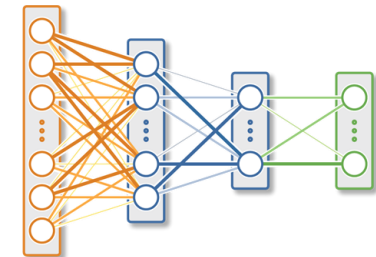
Solution

Goal

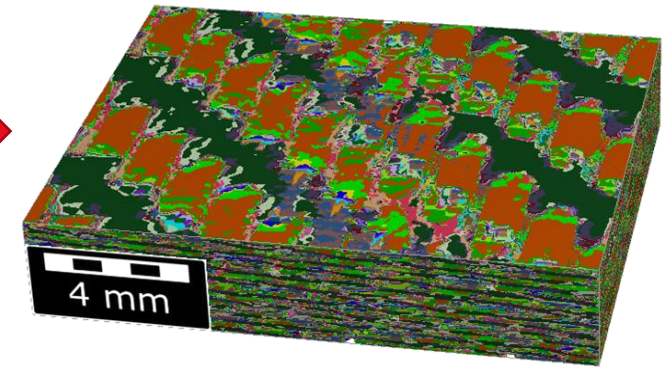
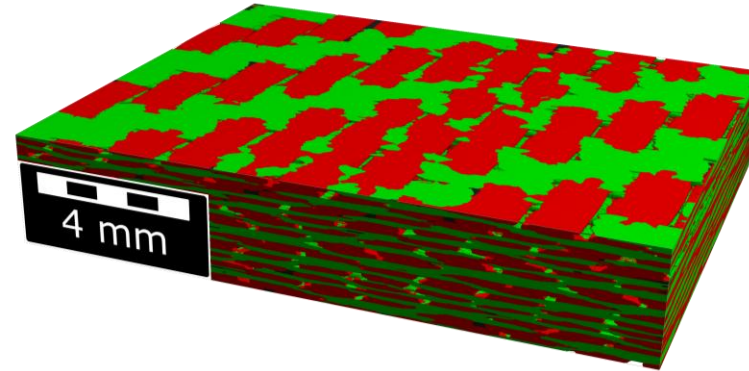
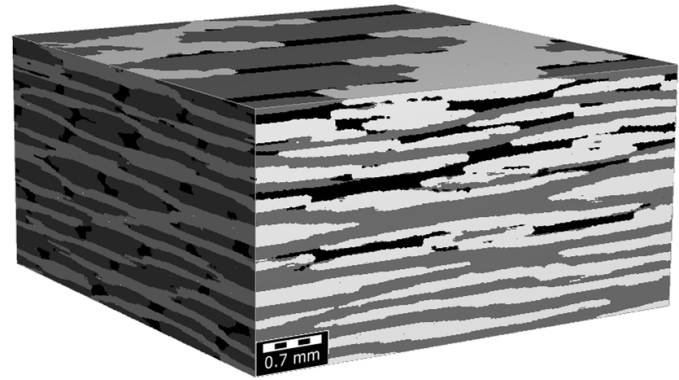
Discovering unknown material properties



Training a neural network



GOAL IN SCAN PROCESSING



Identification and separate segmentation of groups of objects (here 0° and 90° fiber bundles)

Identification of individual tows in the scan

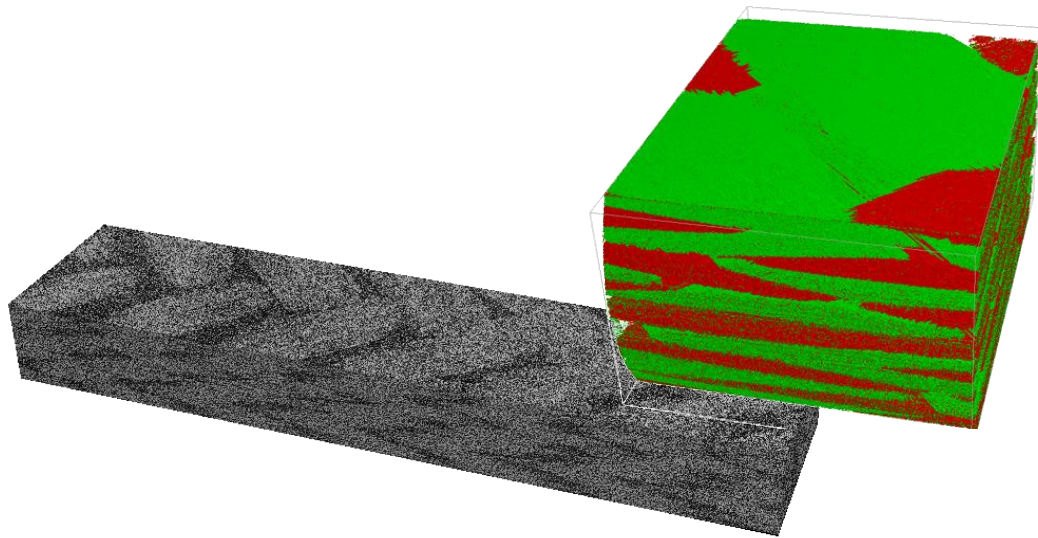
Identification of individual tows & additional information, e.g., local fiber orientation in tows

What is the goal?

Extracting detailed and quantitative information from the scans for the simulation models

AI-based simulation models from CT data

Development of an AI-based workflow using the example of fiber-polymer composites which closes the gap between 3D imaging techniques and synthetically generated geometry models based on statistical data from real structures to improve material development.



Funding Code

01IS23054 A

Duration

October 2023 – March 2026

Our partners

Supported by:



Federal Ministry
for Economic Affairs
and Climate Action

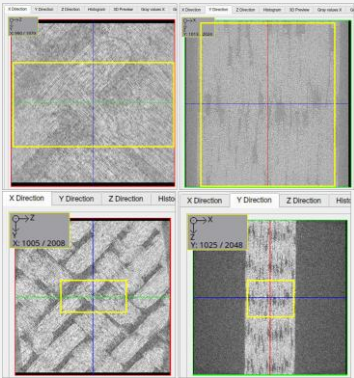
on the basis of a decision
by the German Bundestag



Leibniz-Institut für
Verbundwerkstoffe

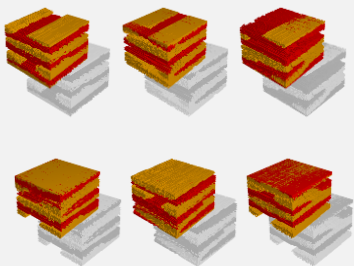
Leibniz
Leibniz
Gemeinschaft

Real world μ CT data



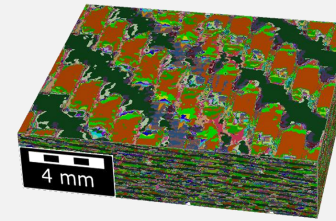
- + Real world data
- Resolution limits
Imaging artifacts
Missing data

Statistically Generated Models



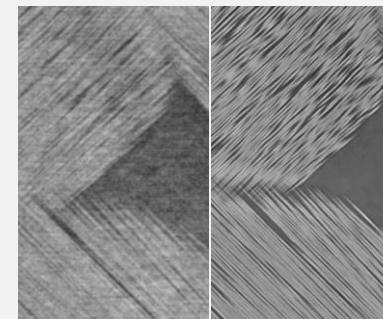
- + Parameter variation
all details known
- Less real variation

AI methods for object classification



- Easy training of AI networks for new materials
- Improved detection of geometrical features with reduced manual labeling

AI methods for image enhancement



- Trained with real world data and artificial data
- Largely improved workflow efficiency

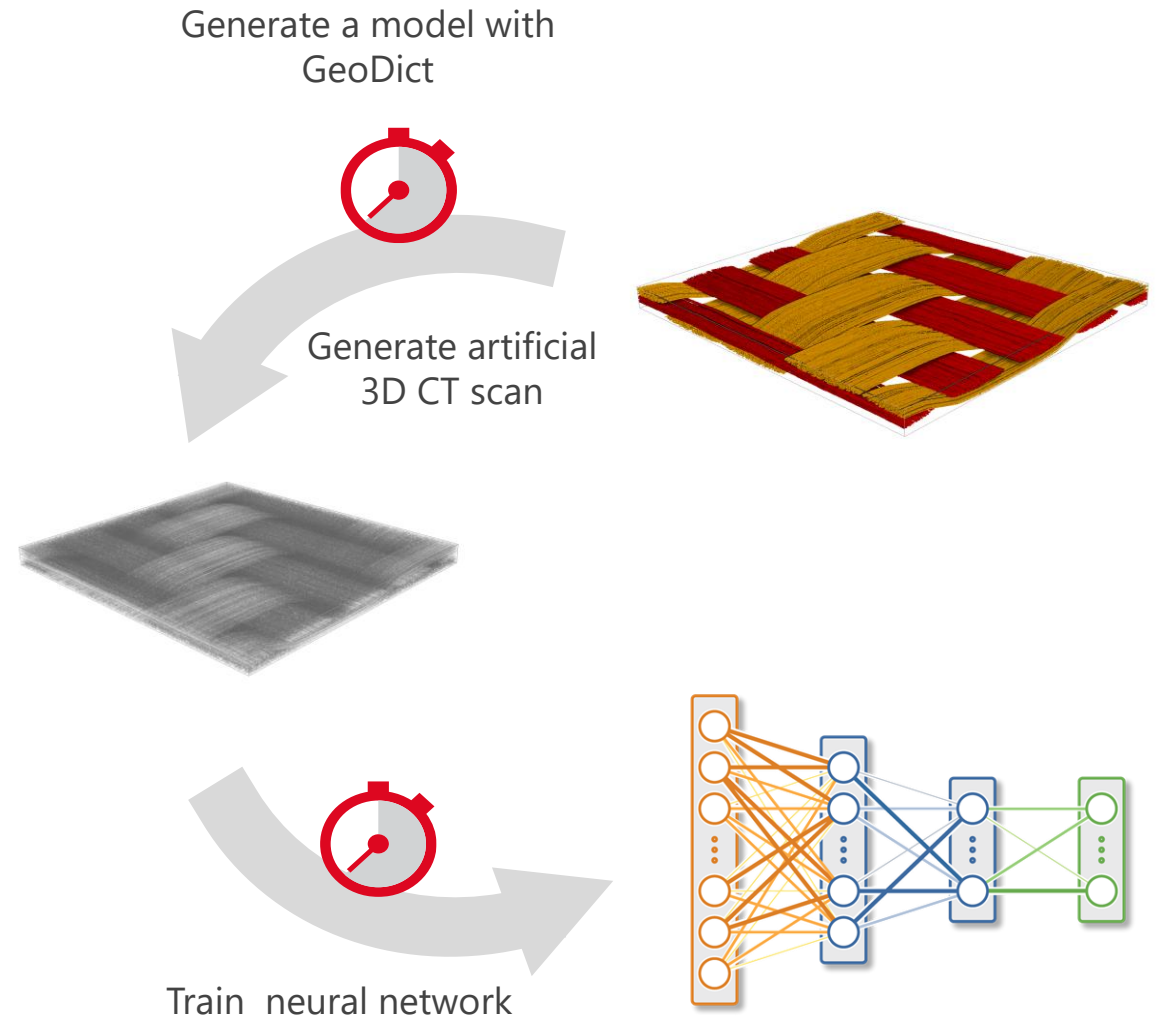
WHAT IS THE USE OF ARTIFICIAL μ CT IMAGES?

Why is it „fast“?

- No sinogram reconstruction
- No raytracing / beam simulation

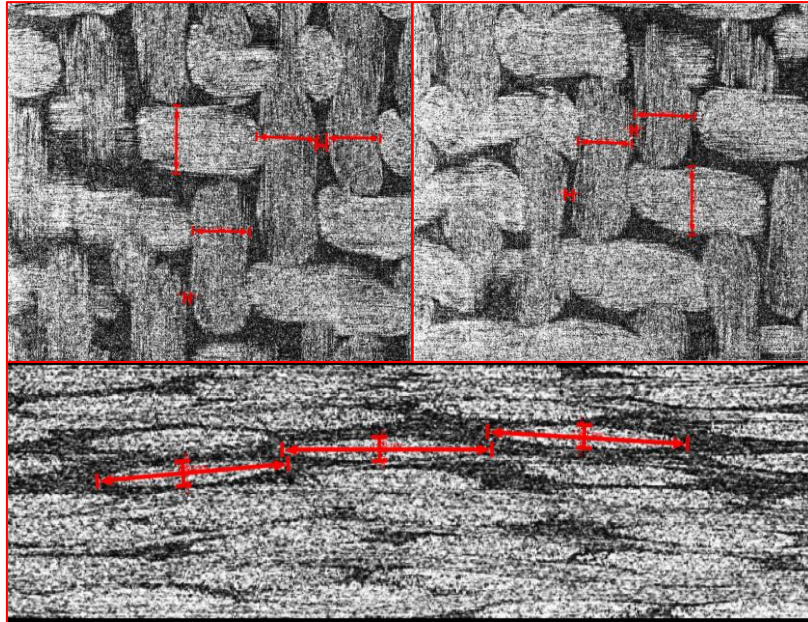
This enables usage in fast parameter studies:

- Create a CT scan of a 1000^3 model in 5 minutes
- Vary image artifacts and noise
- Use artificial CTs to train neural networks

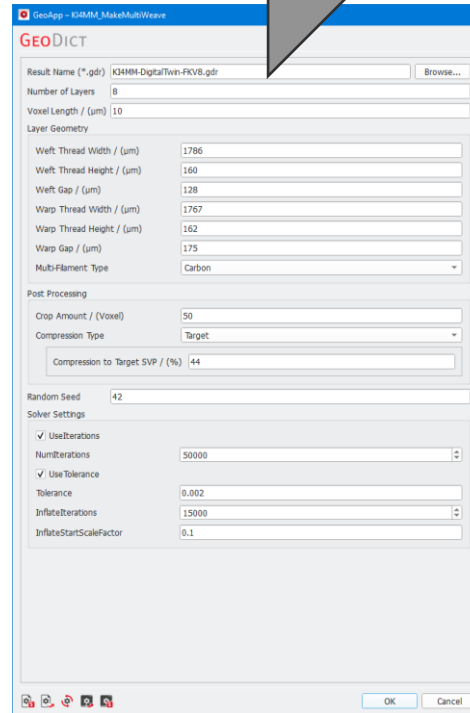


CREATING ARTIFICIAL CT SCANS: STARTING WITH UNIT CELL GENERATION

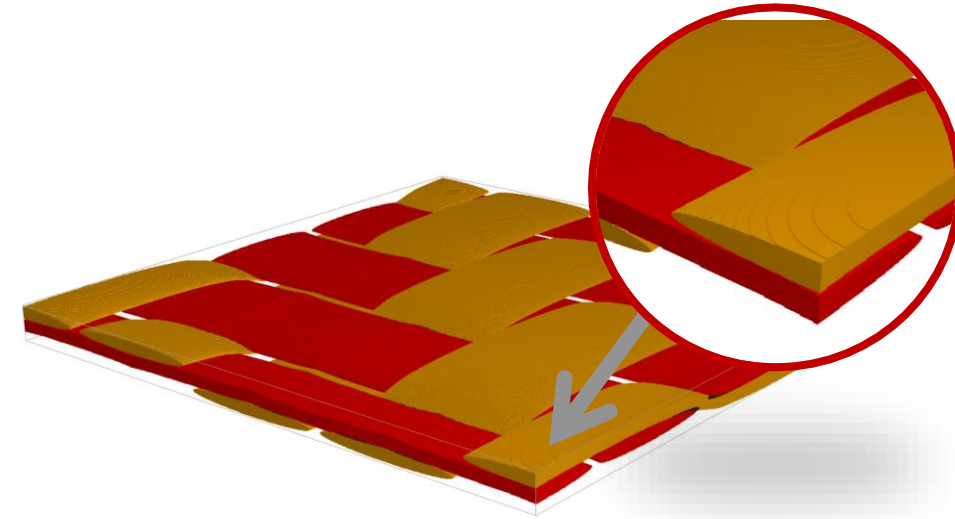
GEO DICT



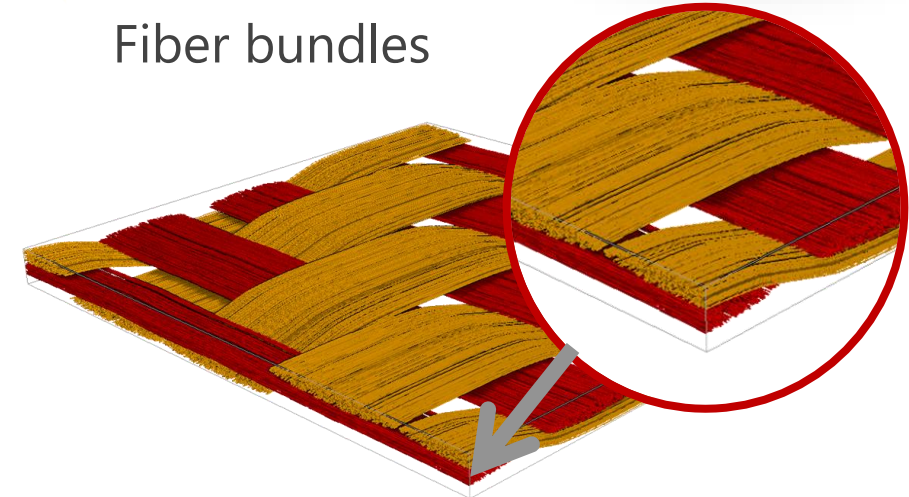
- Weft & Warp tows
- Width, Height, Gaps



Parameters for unit cell generation



Fiber bundles

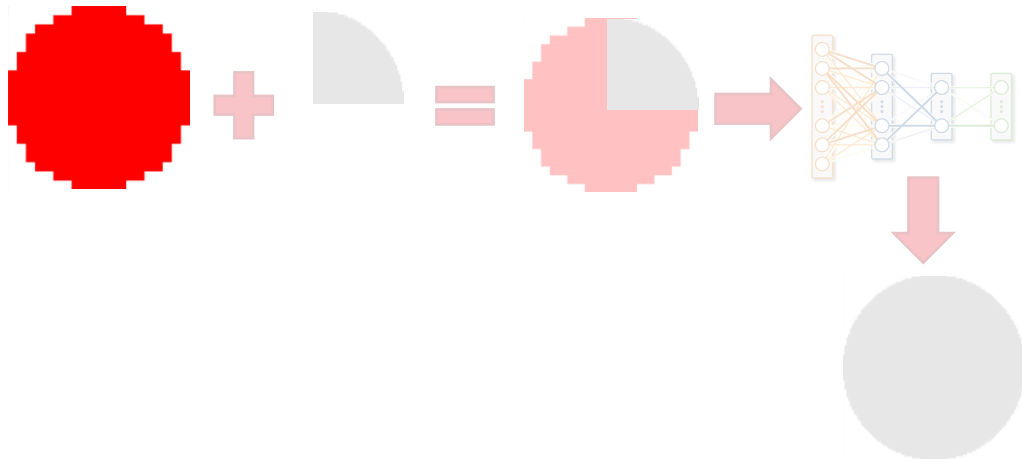
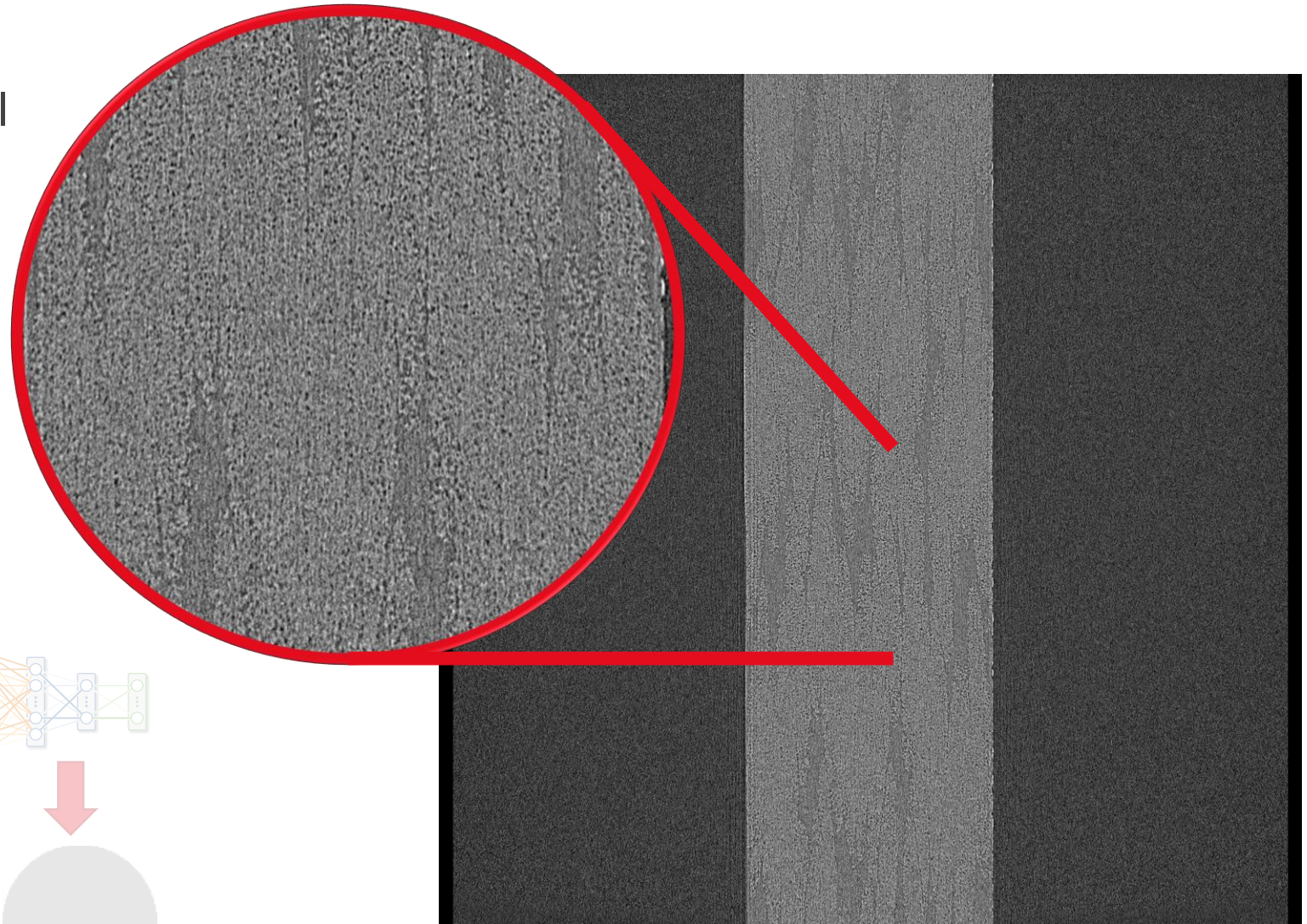


Single fibers within fiber bundles

SUPER RESOLUTION OF CARBON FIBERS – LOW QUALITY SCAN

Low Resolution scan at $3.5\mu\text{m}$ voxel length

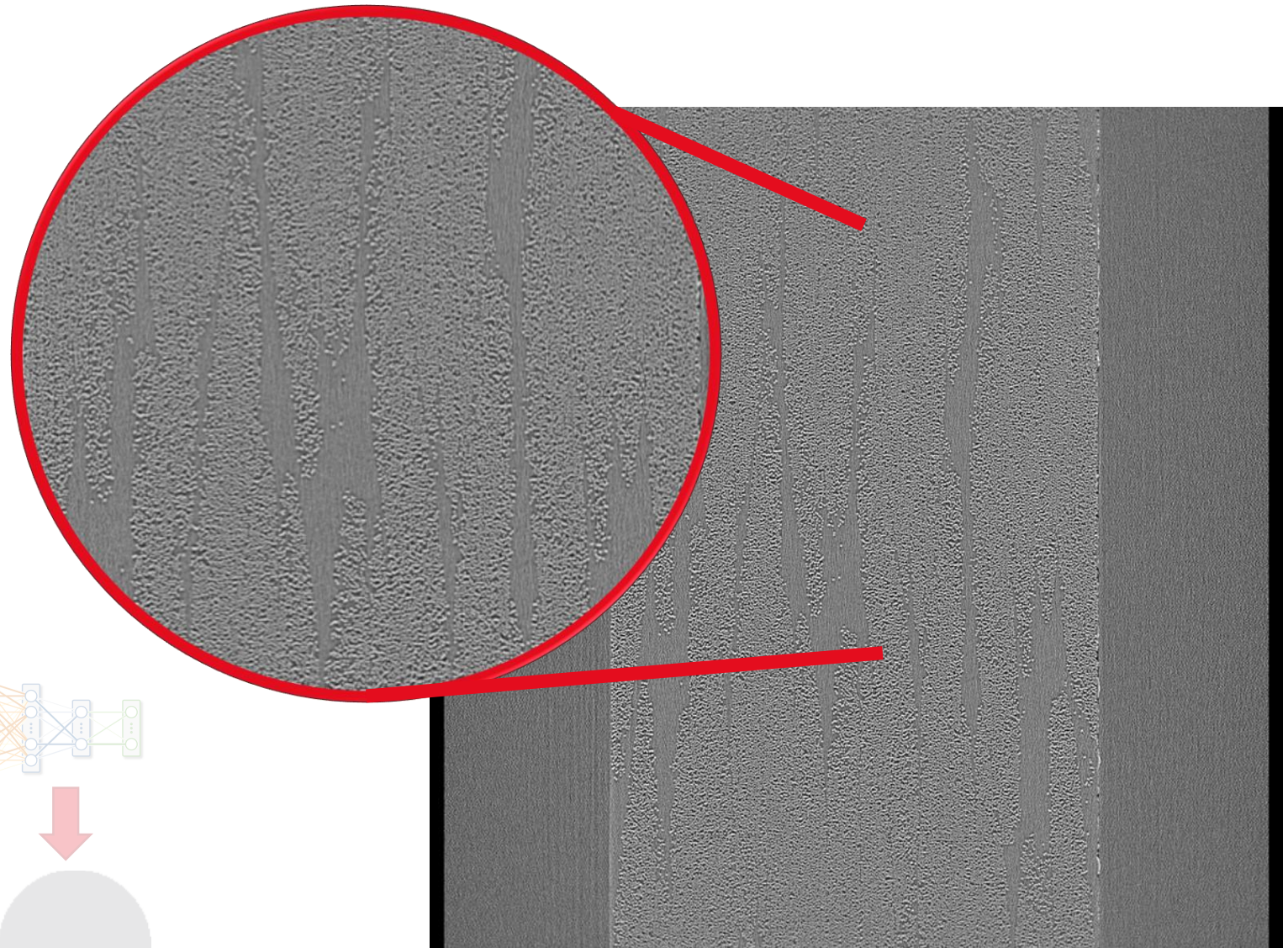
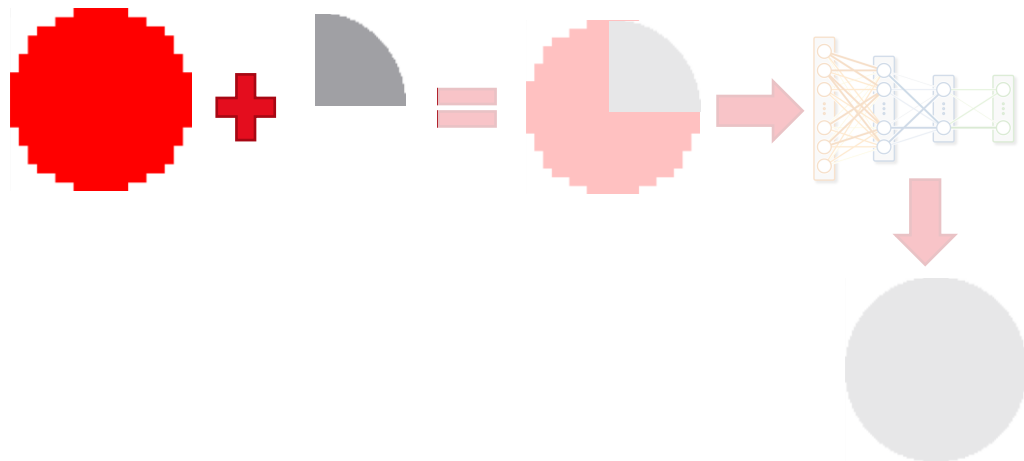
- High field of view
- Fiber details not visible



SUPER RESOLUTION OF CARBON FIBERS – HIGH QUALITY SCAN

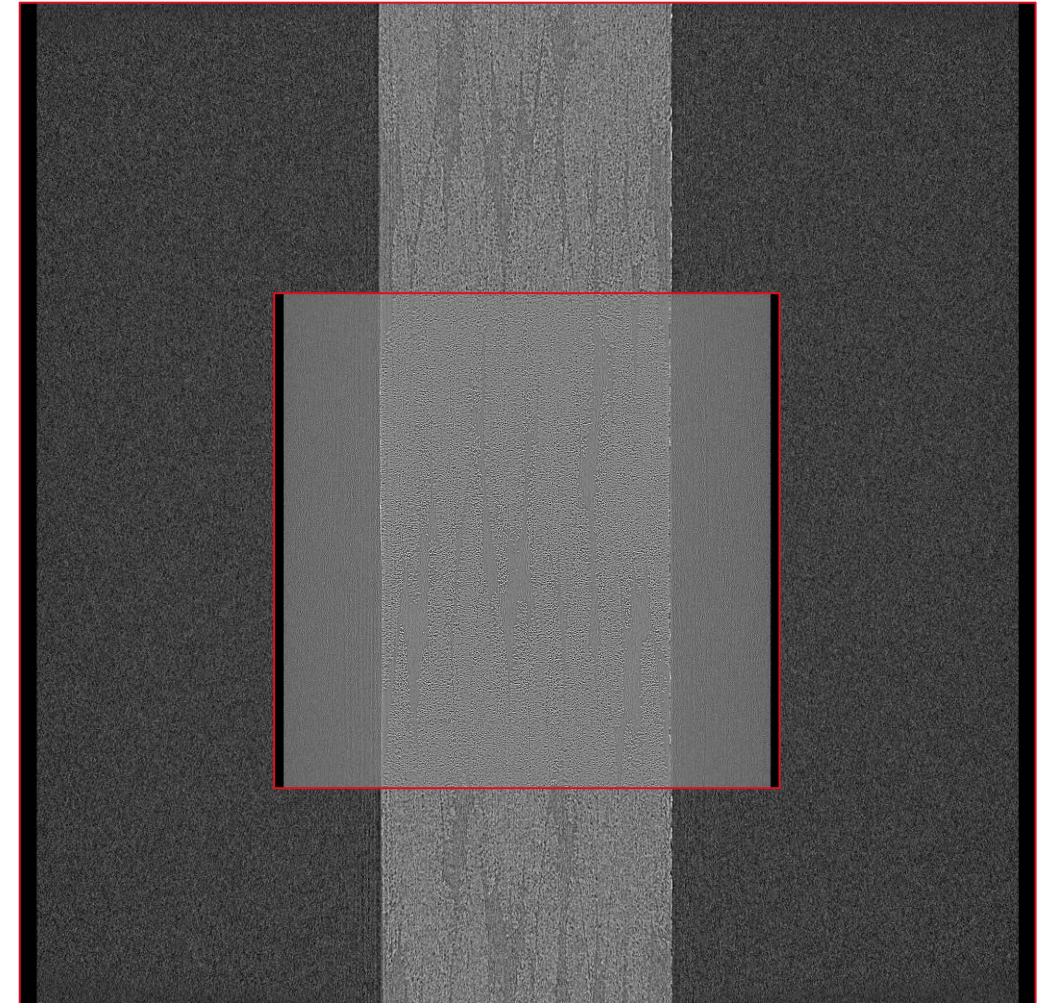
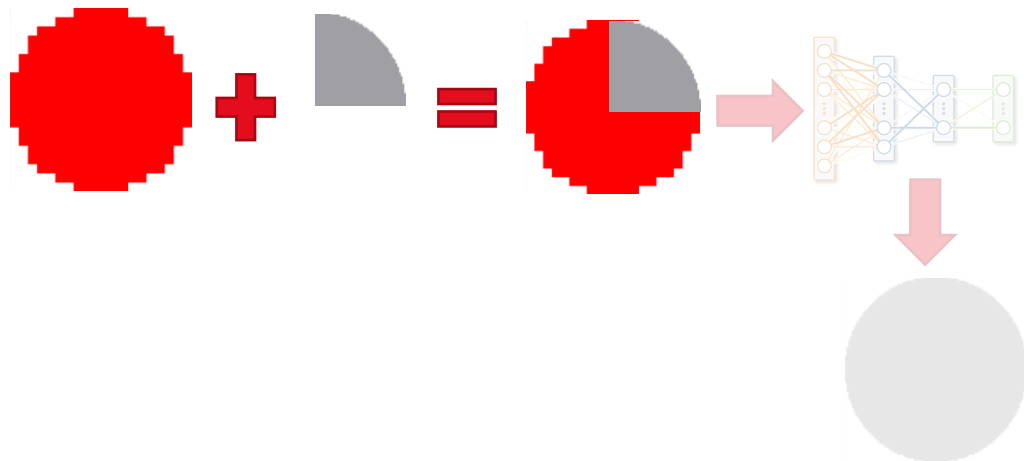
High Resolution scan at $1.75\mu\text{m}$ voxel length

- low field of view
- Fiber details visible

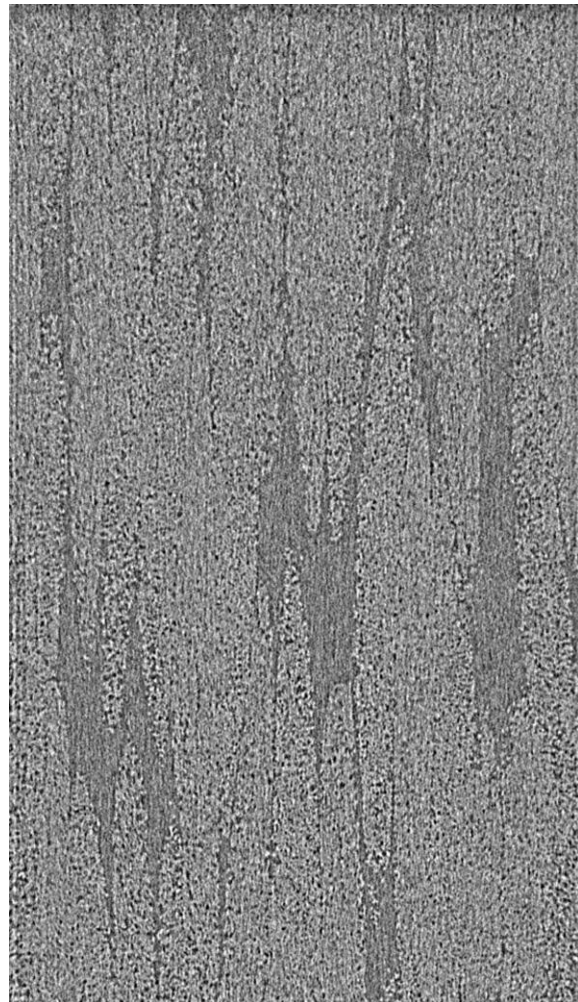


SUPER RESOLUTION OF CARBON FIBERS – COMBINE SCANS AND TRAIN NEURAL NETWORK

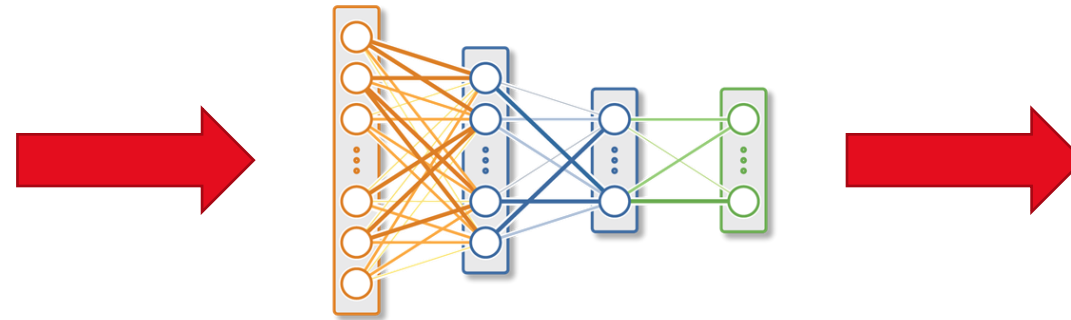
- High Resolution scan is located at the center of the low-resolution scan
- Overlapping Area can be used to obtain training data for super resolution
- Trained convolution neural network (modified U-Net)



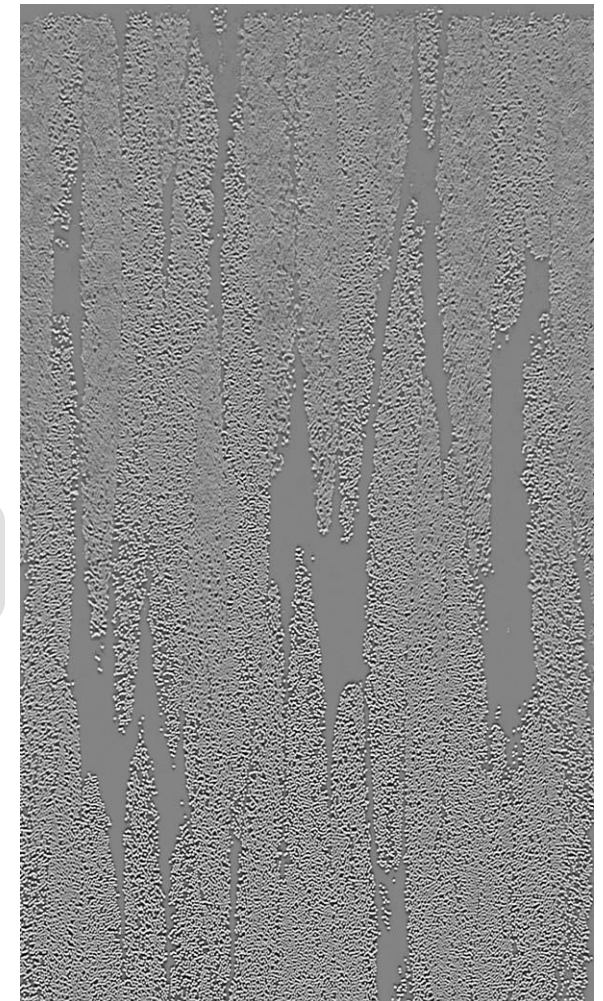
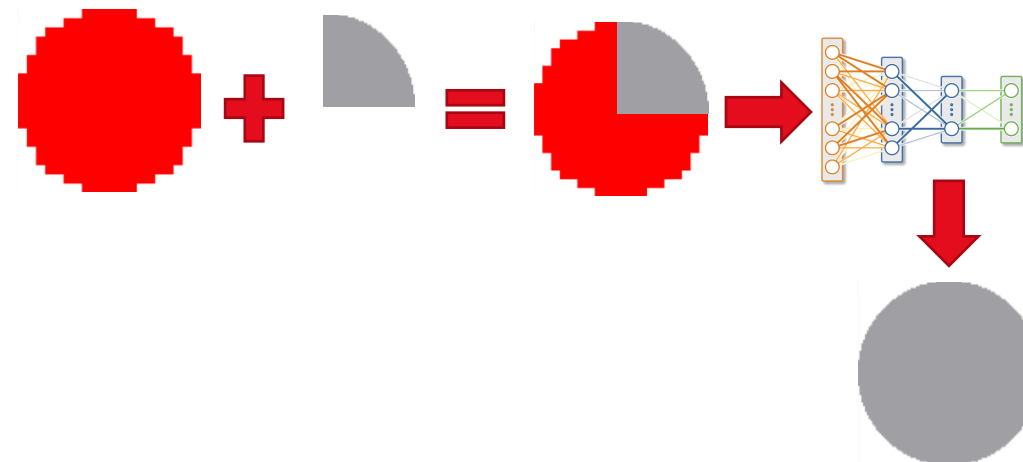
SUPER RESOLUTION OF CARBON FIBER – APPLY AI NETWORK



Original low-quality scan

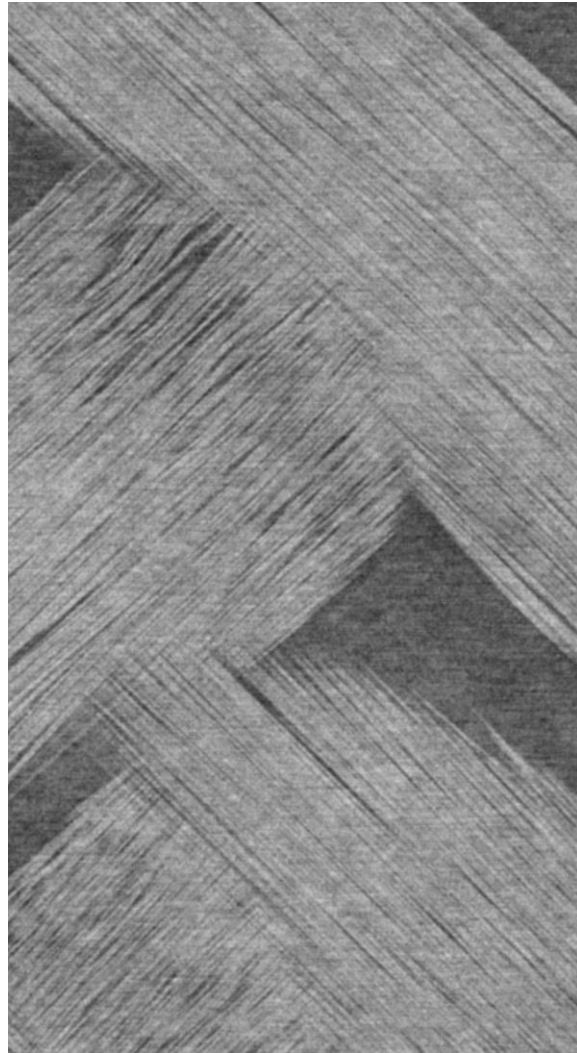


Train neural network and apply sample area that was not part of the training data

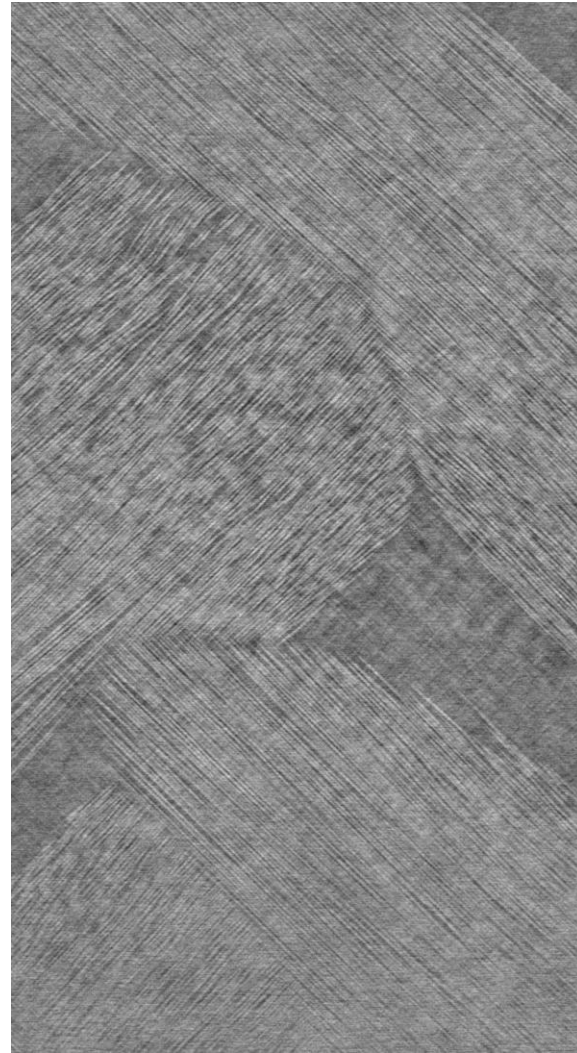


Enhanced Scan

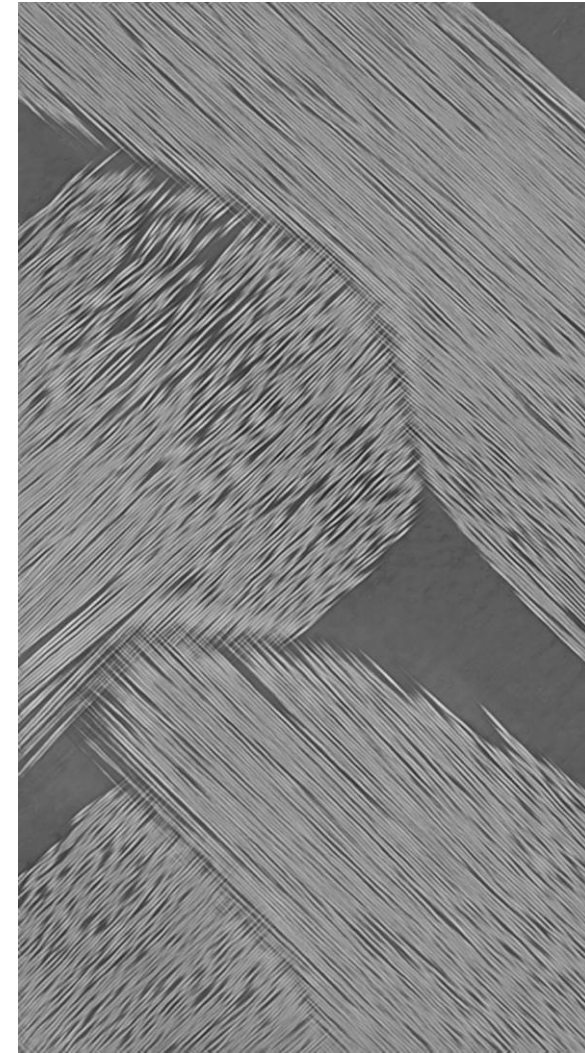
APPLY SUPER RESOLUTION TO GLASS FIBERS



4.5µm



1.75µm



1.75µm
super resolution

APPLY SUPER RESOLUTION TO GLASS FIBERS



4.5µm



1.75µm



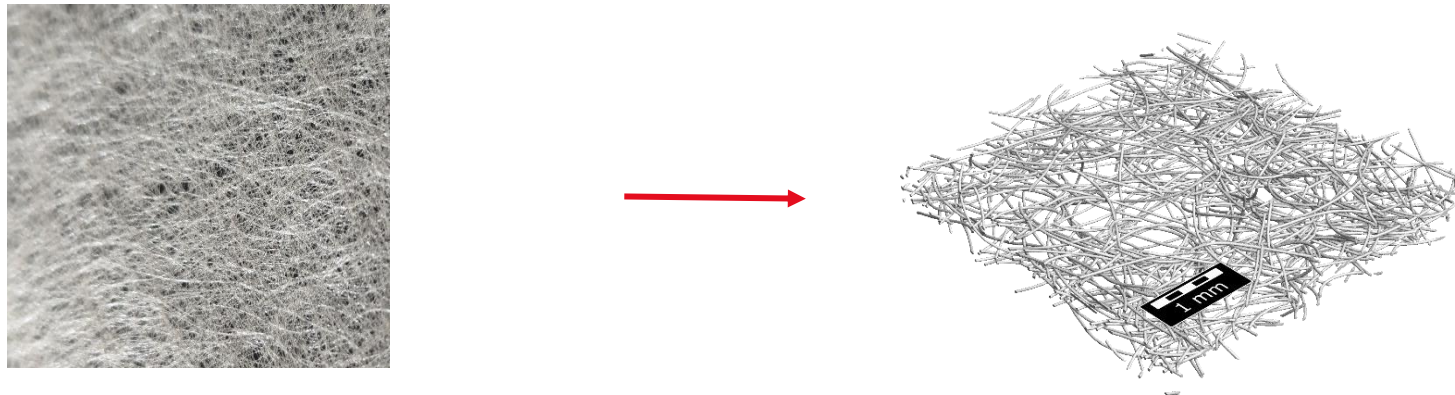
1.75µm
super resolution

This has been demonstrated with real scans, but in the next step, we will do the training with artificial CT scan data created with GeoDict!

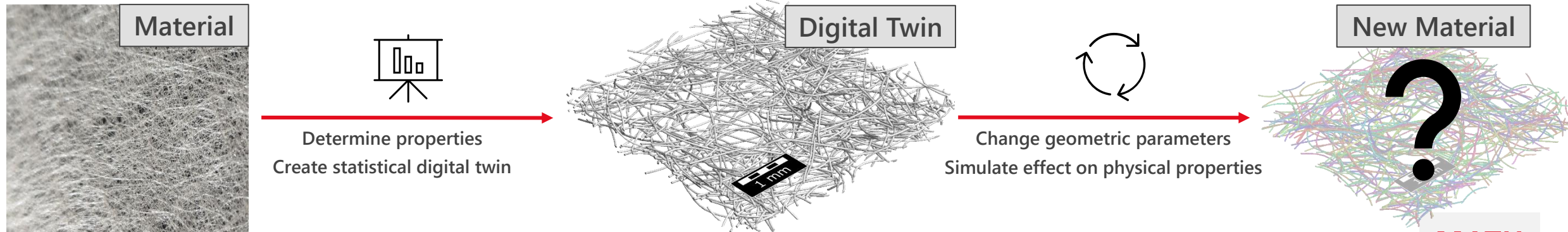
DIGITAL MATERIAL: WHAT IS A STATISTICAL DIGITAL TWIN

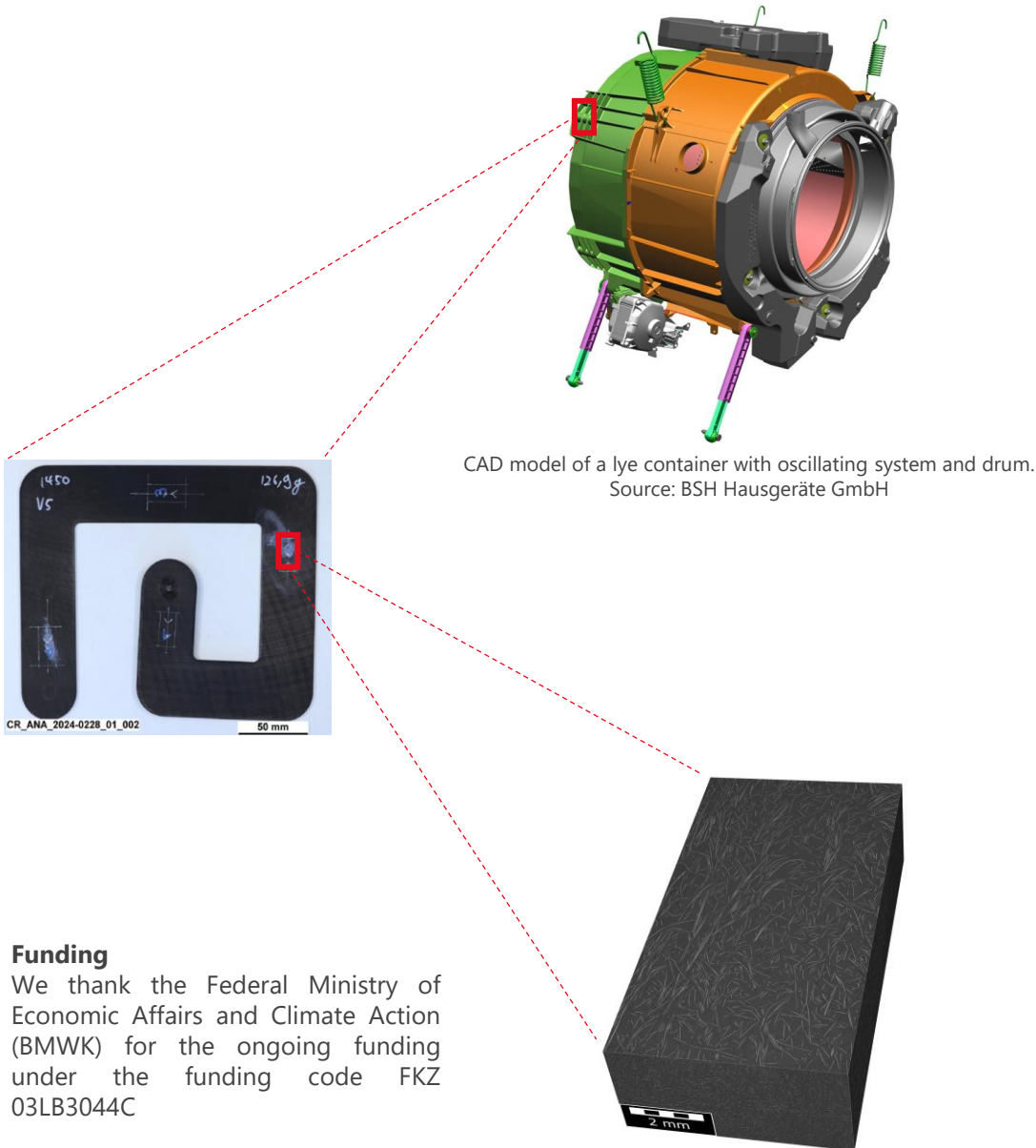
Statistical digital twin in GeoDict:

Parameters to generate microstructures with similar physical & geometrical properties as the real material

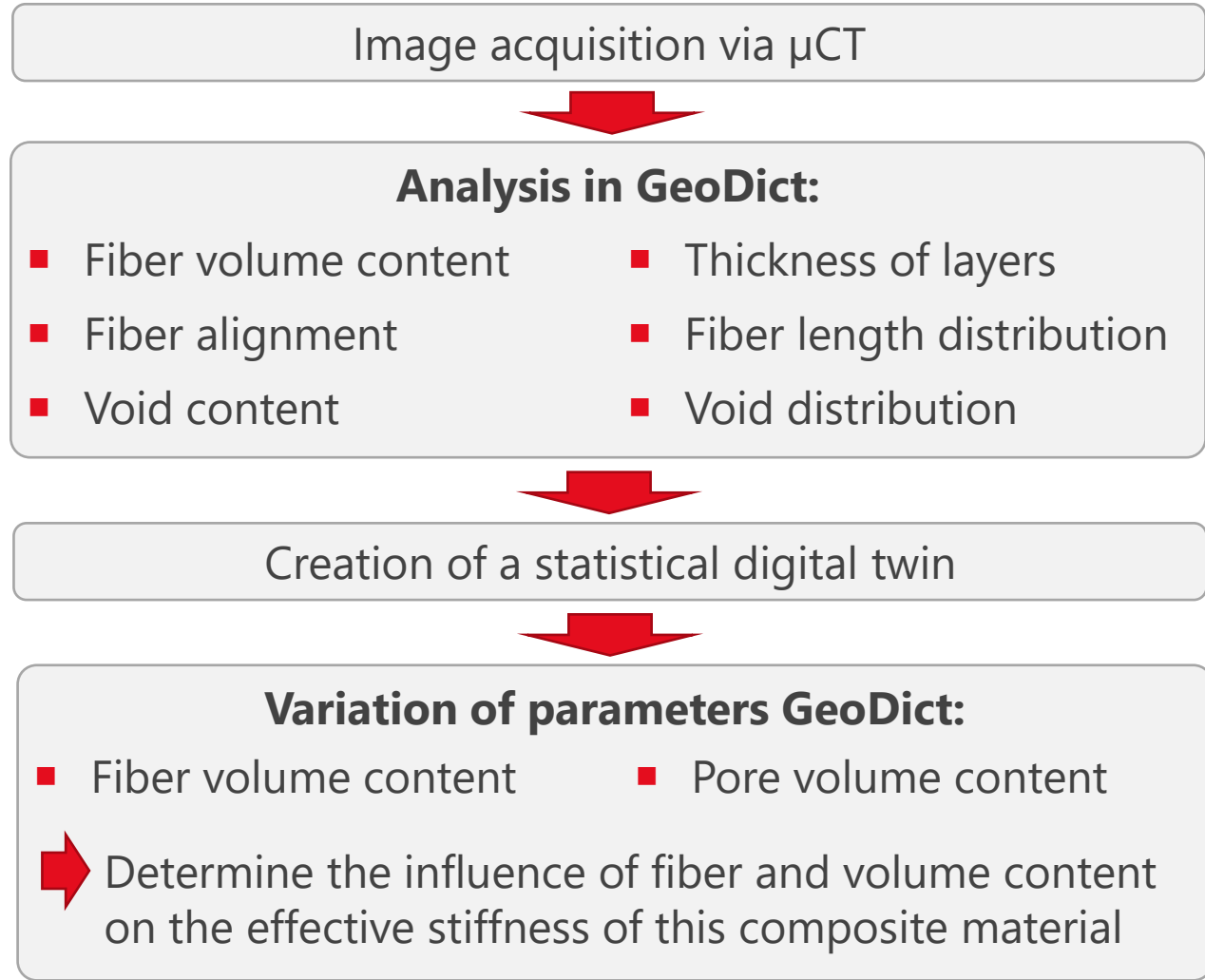


➤ Understand, improve and develop new materials

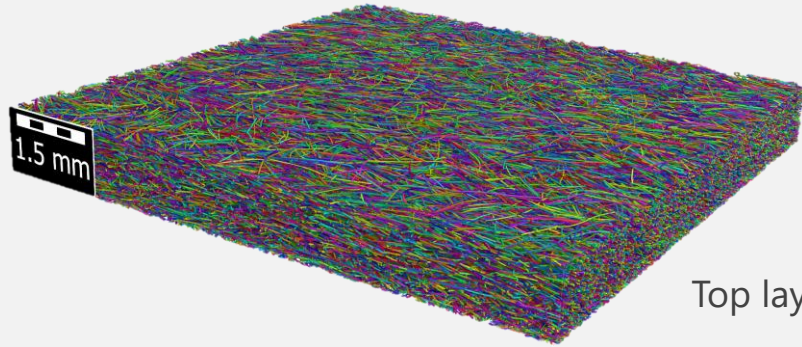




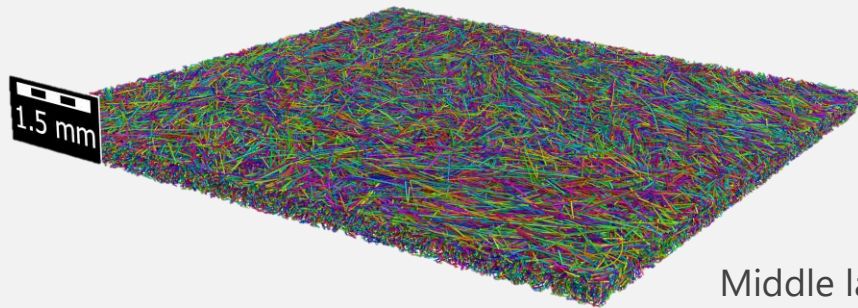
Funding
We thank the Federal Ministry of Economic Affairs and Climate Action (BMWK) for the ongoing funding under the funding code FKZ 03LB3044C



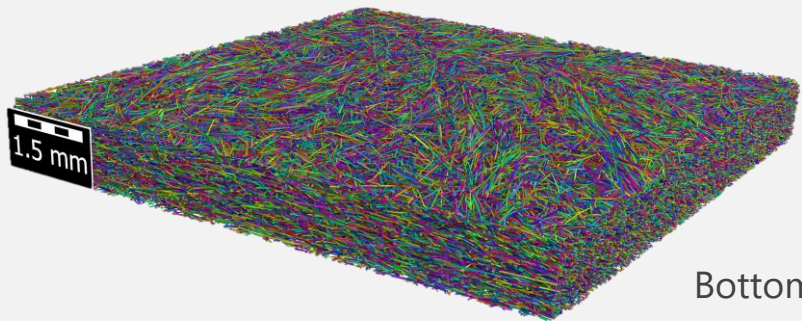
CREATING STATISTICAL DIGITAL TWINS OF ALL THREE LAYERS



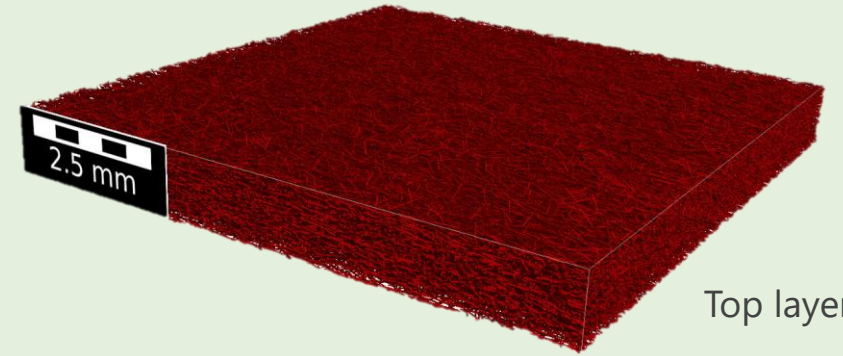
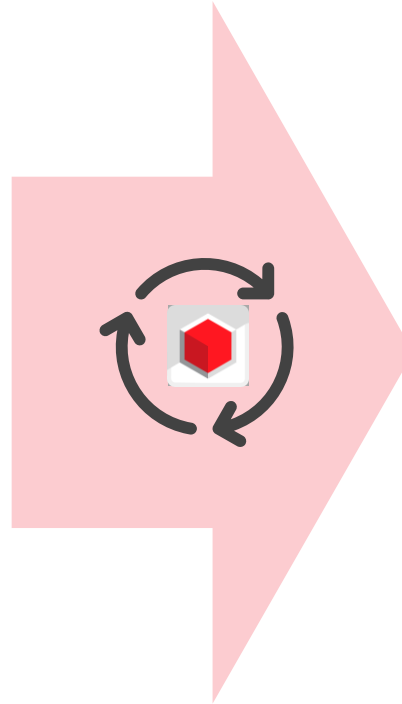
Top layer



Middle layer



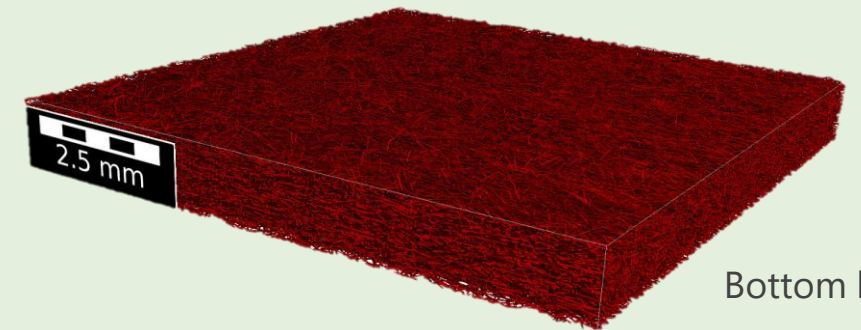
Bottom layer



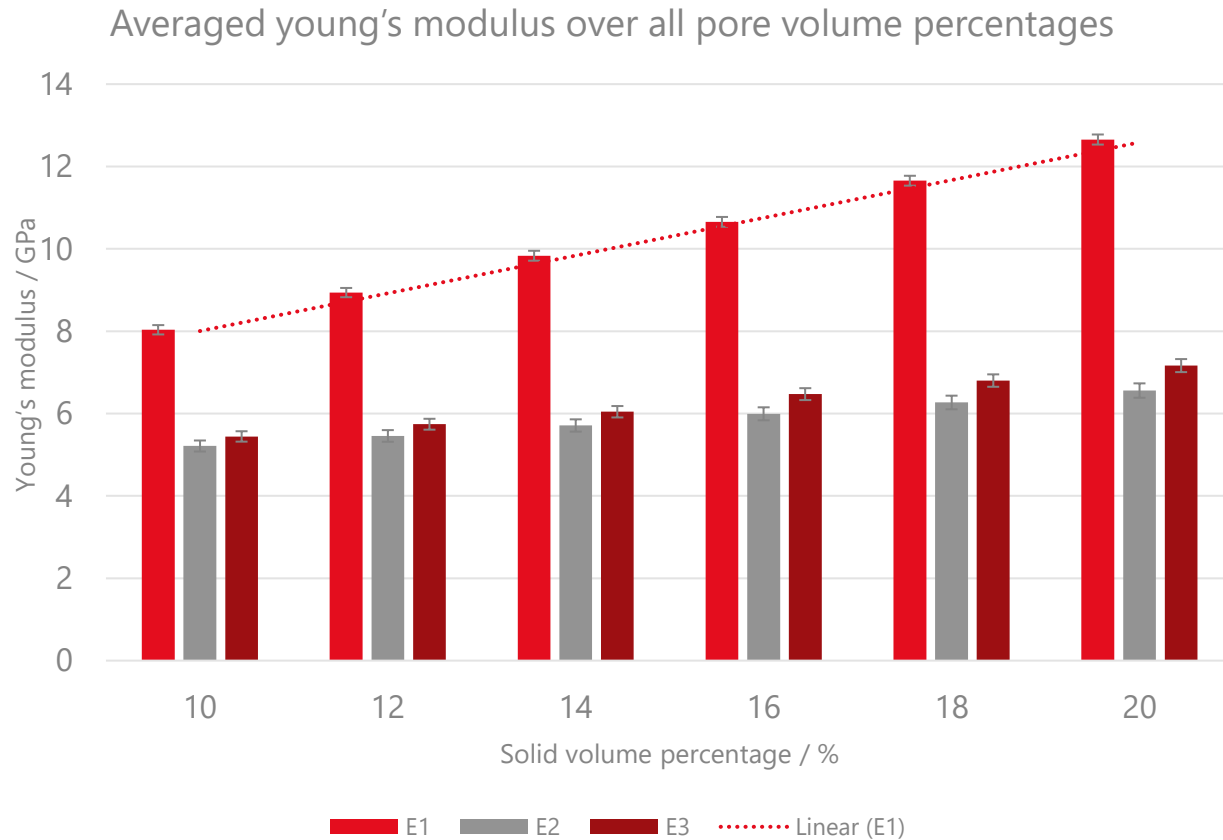
Top layer



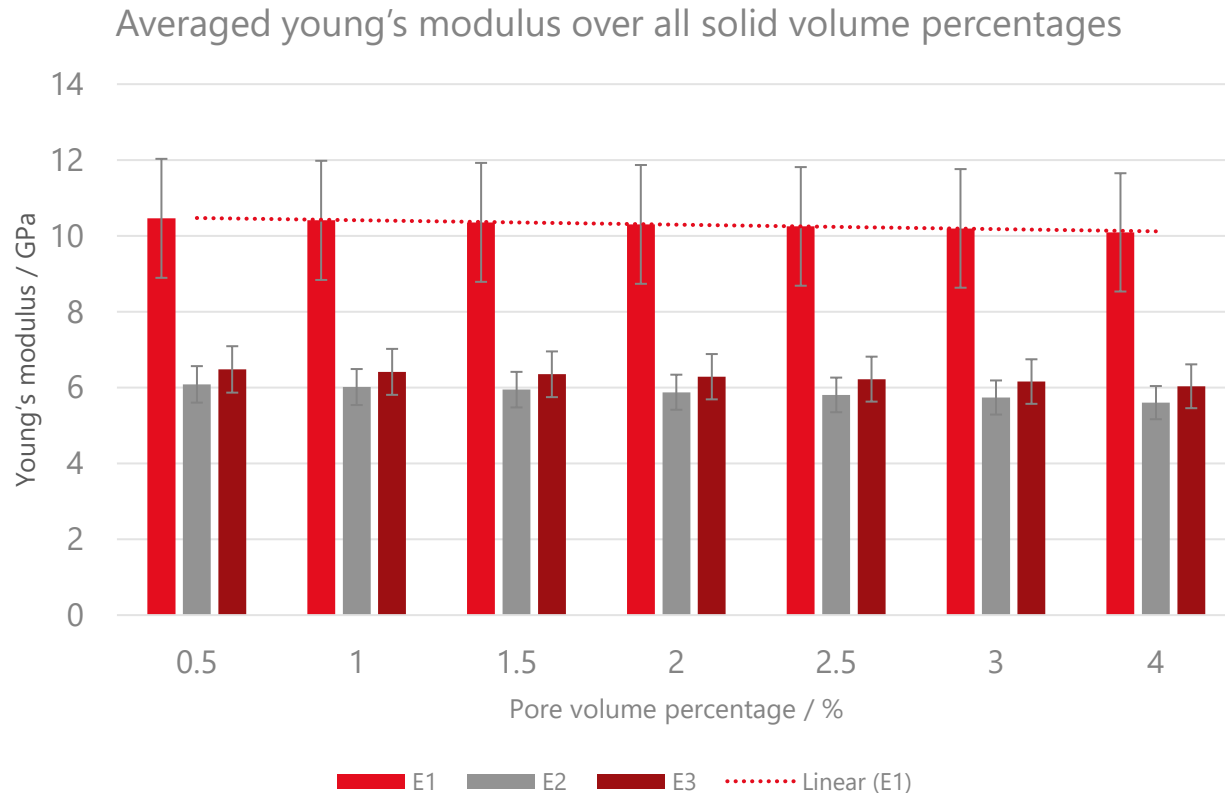
Middle layer



Bottom layer

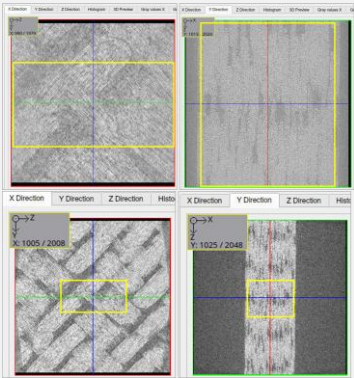


- Solid volume percentage influences E1 (stiffness along the fiber direction) heavily and the stiffness increases with higher solid volume percentages
- Lesser influence of the solid volume percentage on the stiffness in the transverse directions (E2 and E3)



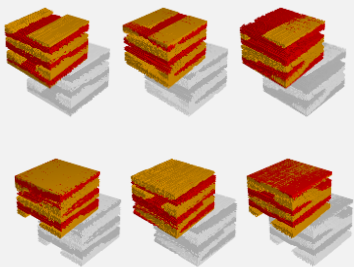
- Increasing pore volume percentage leads to an overall decrease of the stiffness
- Effect of increasing pore volume percentage is more pronounced for E2 and E3 than for E1

Real world μ CT data



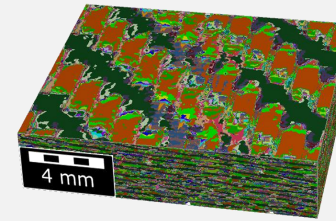
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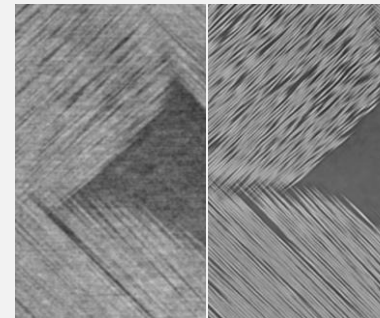
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AI methods for object classification



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AI methods for image enhancement



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WHAT IS GEO-DICT?

GEO-DICT IS

Data-Driven Digital Material Design
in an Easy-to-Use Software Solution

The innovative and easy-to-use material simulator GeoDict is the most complete solution for multi-scale 3D image processing, modeling of materials, visualization, material property characterization, simulation-based material development, and optimization of processes.



THANK YOU FOR
YOUR ATTENTION

Visit us at our booth 507



Mike Marsh, Ph.D.



Dr. Oliver Rimmel

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