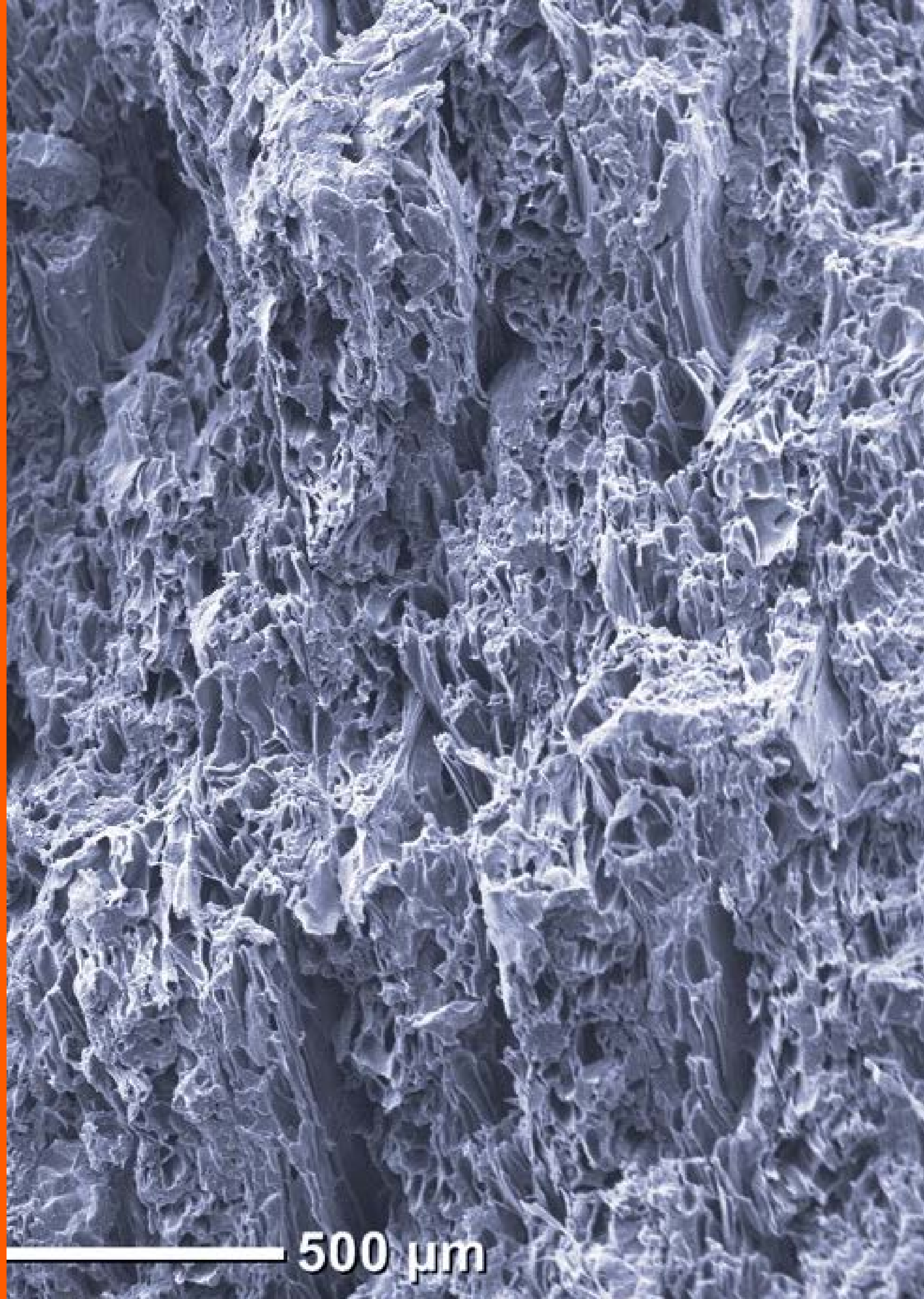
MICROTIMBER

FWPA Research Seminar 21th September 2016

Sandra Löschke



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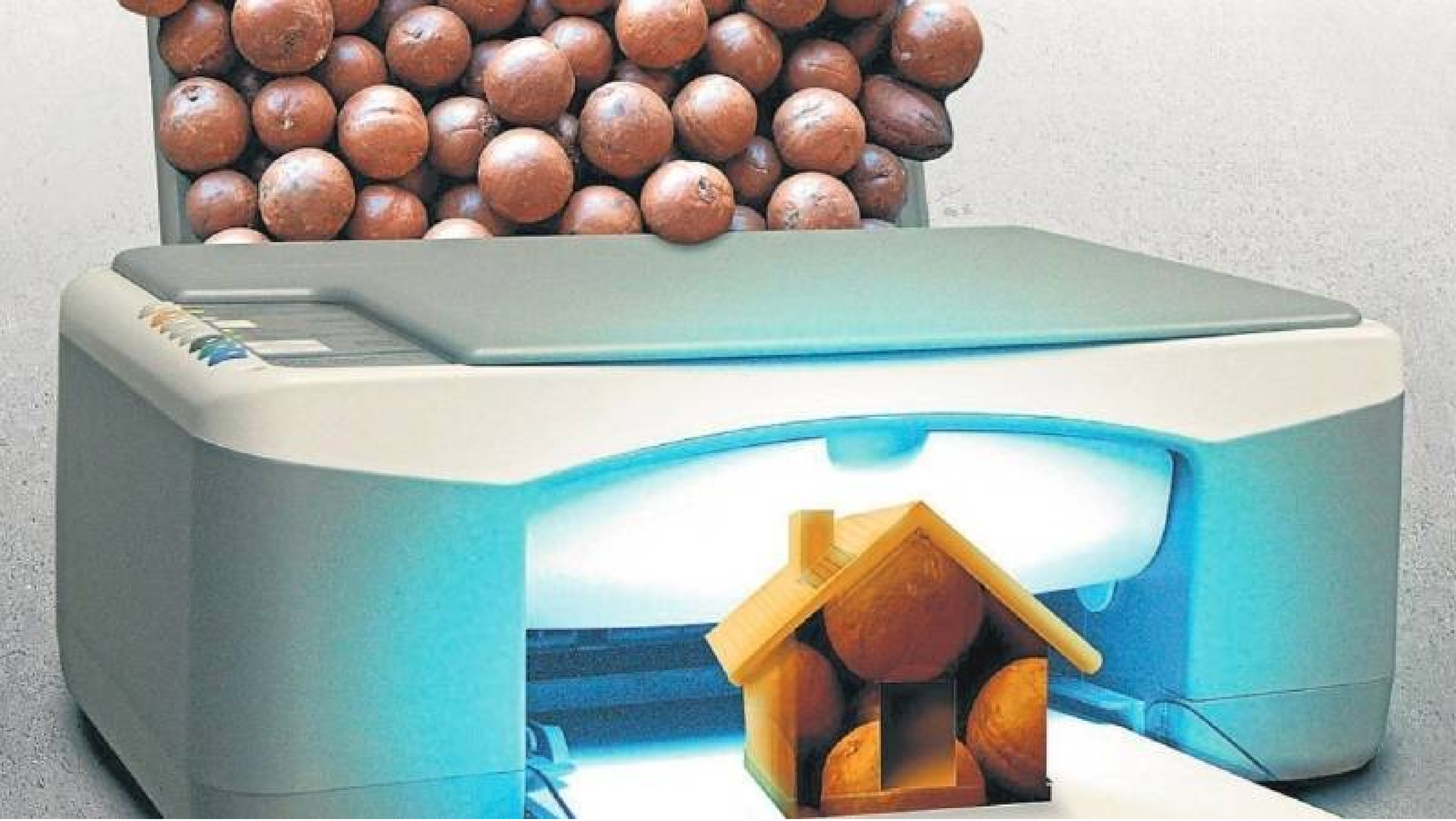
MICROTIMBER:

Development of a 3D-printed, gradient timber panel composed of forestry waste- and by-products



“Grand Designs meets macadamia farming: Researchers at the University of Sydney are investigating ways to use macadamia shells to create timber building products using 3D printing technology.”

MICROTIMBER:

Development of a 3D-printed, gradient timber panel composed of forestry waste- and by-products

Team: Sandra Löschke
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Andy Dong
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Partner: Arup (Richard Hough)

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No single expert can do this project on their own.

Multi-disciplinary team:

- Architecture
- Material Science
- IT
- Structural Engineering
- Industry Experts

Various kinds of sawdust

Macademia nutshell powder

+

ABS Plastic pellets

=

Graded material with varying performance raw material

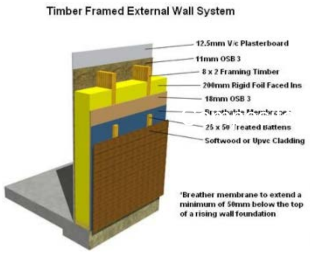
construction material

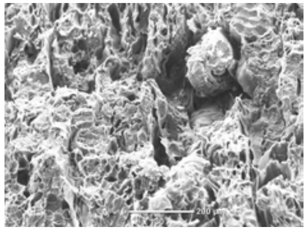
construction systems

composite materials

fused materials

graded materials





raw material

construction material

Raw material

•in its natural state

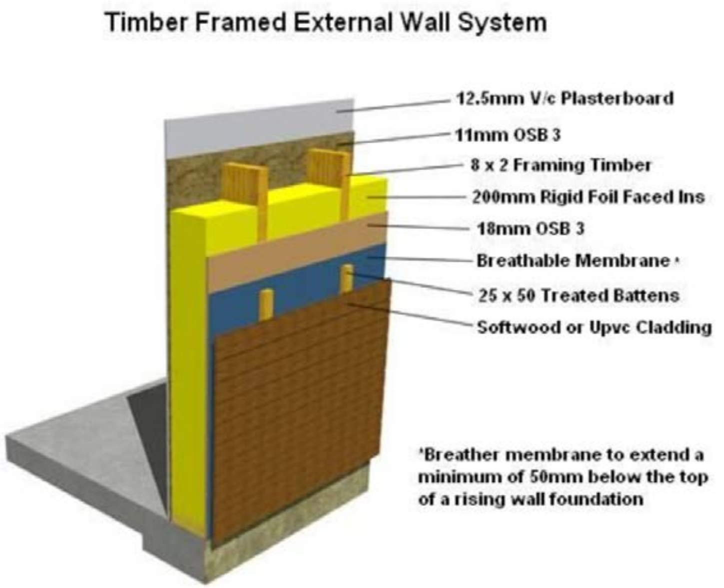
•everyday element is different

Construction material

•cut and processed to ensure homogenous properties

•suitable for serial production

construction system



Construction System

•a layering of systems with discrete performances

•mechanical fixings

composite materials

Composite Materials

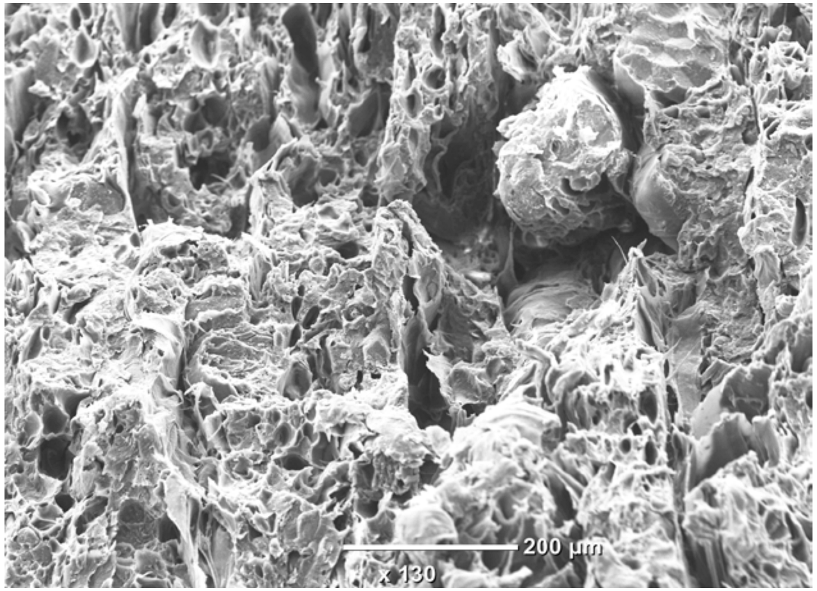
•Lamination: joining layers by means of glue

•Binder: joining small particles with a binder such as resin

•No mechanical but chemical fixings

fused materials

graded materials: microtimber

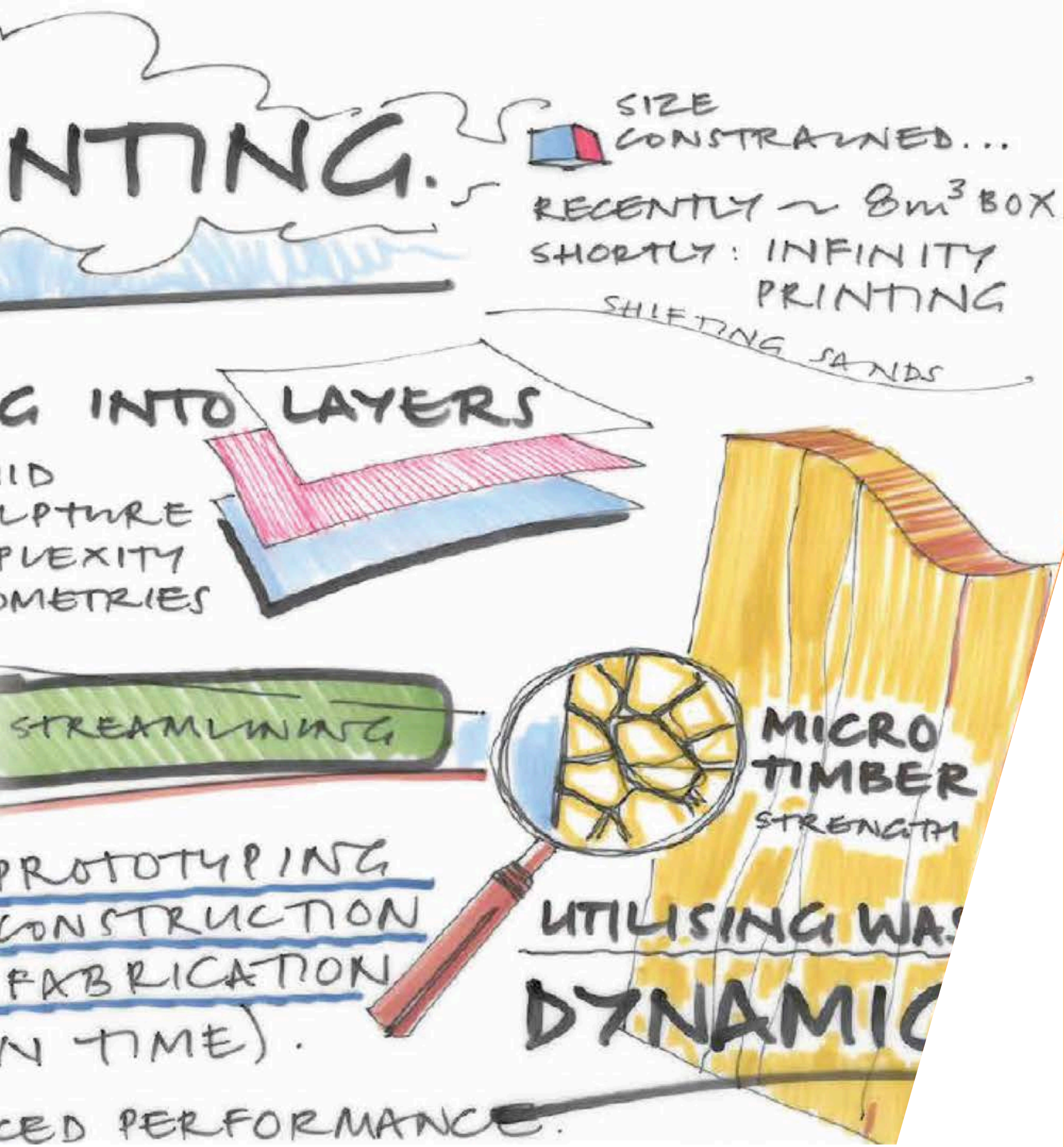


fused materials

•Fused chemically on a micro-scale and/or chemically

graded materials

•Performative gradient whreby **structure, durability and other performance criteria are articulated as fluid variation of the material**



3D Printing: The state of technology

3D Printing: The State of Technology

Fundamental principles:

- the reduction of a 3-dimensional object into a series of 2-dimensional layers by means of computation
- the virtual layers are individually built up into a 3-dimensional object

3D Printing: The Built Environment

Current uses in construction:

- Architectural model making and proto-typing
- Fabrication of individual elements with complex geometries
- Replacement of steps in construction processes such as formwork-making in cast concrete construction (Laing O'Rourke)
- Prefabrication of building elements and small-scale buildings

Prefabrication of individual elements

Dinitec, Italy: sand + inorganic binder

This is a new pilot project of DUS Architects' *3D Print Living Lab* : The *3D Printed Urban Cabin.* The 8m2 house is located in an industrial areas in Amsterdam and of a bio-material to which black pigment has been added to offer optimized insulation.

At the interface with the floor and the terrace the surfaces have been reinforced with concrete. The surface patterns are intended to illustrate the design possibilities of 3D printing

3D Printing: Opportunities

Production/Construction Processes:

- Permits the integration of different performative criteria such as structure, durability and surface aesthetics as part of the material composition
- Eliminates the need for mechanical and chemical fixings such as screws or adhesive interlayers
- Production/Construction in one step
- Eliminates interfaces between different processes: designing, fabricating, constructing
- 3D printing in-situ and in-time production – eliminates need for off-site production, warehousing and transport

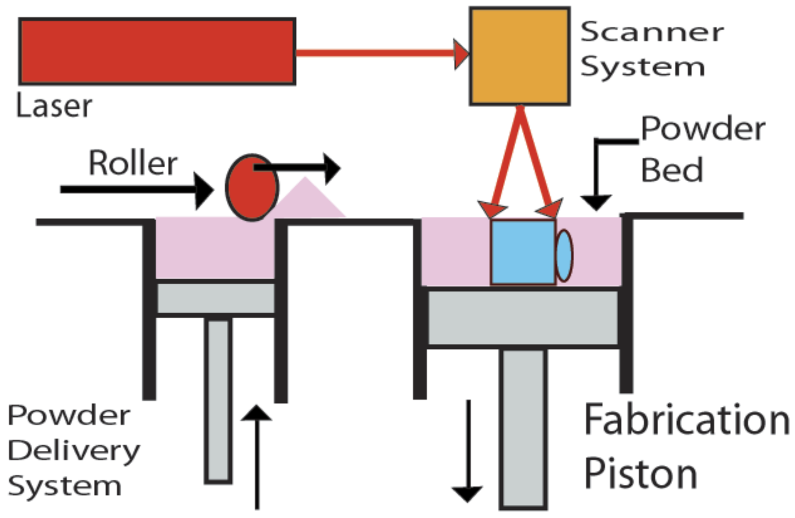
3D Printing: Opportunities

MX3D: Stainless steel bridge 3d-printed by robotic arms on gantry
http://www.faz.net/aktuell/stil/drinnen-draussen/architektur-aus-dem-drucker-13707451.html

3D Printing – Processes

Powder-based 3D Printing

- A thin layer of a powder material is applied to a platform within a box
- A liquid binder is inkjet-printed onto select areas and then hardened, for example in a polymerisation process using UV light.
- After completion the object is moved out of the powder box
- Disadvantage: ‘unpacking is time-consuming’
- Element size limited by box (around 8m^3)



3D Printing – Processes

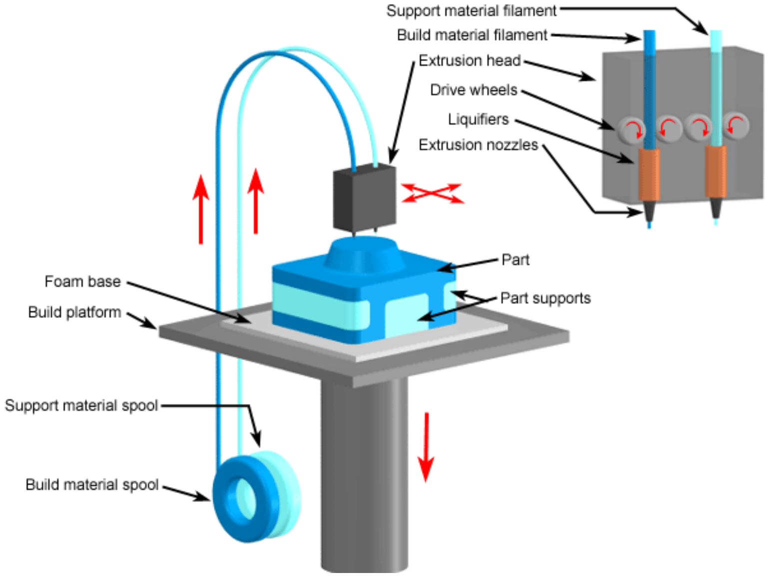
Selective Laser Sintering (SLS)

- A thin layer of a powder material is applied to a platform within a box
- Laser rays fuse areas of the powder into a solid element, layer by layer
- After completion the object is moved out of the powder box
- Replacement for injection moulding processes

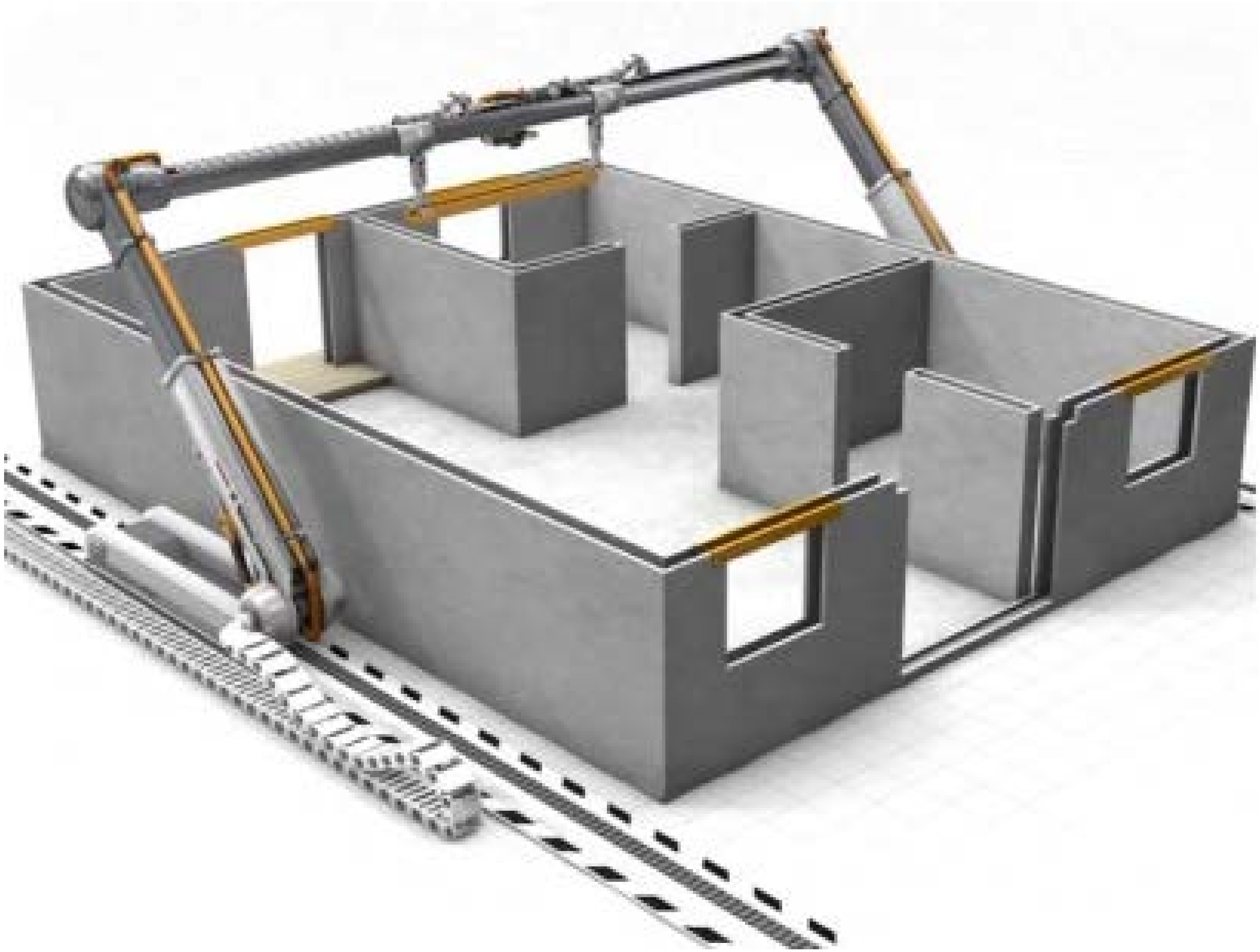
3D Printing – Processes

Fused Deposition Modelling (FDM)

- A plastisizable (mouldable) material is extruded through a heated nozzle or printer head as it moves across a construction platform.
- Overhangs/ require the printing of a support structure that can be removed once printing is completed
- Materials are usually plastics, wax, or ceramics, most commonly thermoplastic polymers



Ultimate aim: on-site production rather than preproduction



Multiple printers on travelling gantry

What significant designs approaches does 3D printing open up for construction and design that were not possible with previous construction techniques?

Chinese company WinSun 3D printed 10 single storey houses in 24 hours

The project focuses on:

- turning ***waste*** macadamia nut shells and other byproducts from the forestry and agricultural industries into ***high-performance products***.
- A *graded material*: developing *variable* material compositions that allow the ***fluid variation of performative criteria*** across a panel
- Creating a discrete *timber-like* aesthetic that does not mimic timber but evoke its qualities

3D Printing: Microtimber

Performance Optimisation

The wood composition can be optimised to respond to important performative criteria:

- Structure
- Appearance
- Durability

3D Printing: Microtimber

Benefits:

A gradient timber element can be:

- stronger
- more durable
- material-efficient
- attractive
- customized for a wide variety of applications

The project investigates:

- Optimisation of material properties
- Optimisation of aesthetic of printed products
- Scaling up the printing process

Optimization of material properties:

What has been done:

- Production of Wood Plastic Composite materials for 3D printing using different ratios of ABS plastics + macademia nut shell flour + maleic anhydride)
- Tension and compression testing of coupons for each of these different compositions

In progress:

- Water absorption testing
- Weathering of coupons
- Use of lignin to replace maleic anhydride
- Increase amount of flour in filaments
- Investigating effect of particle size of flour on final product

Methodology

Specimen produced and testing:

Table 1 – Composition of samples subject to investigation

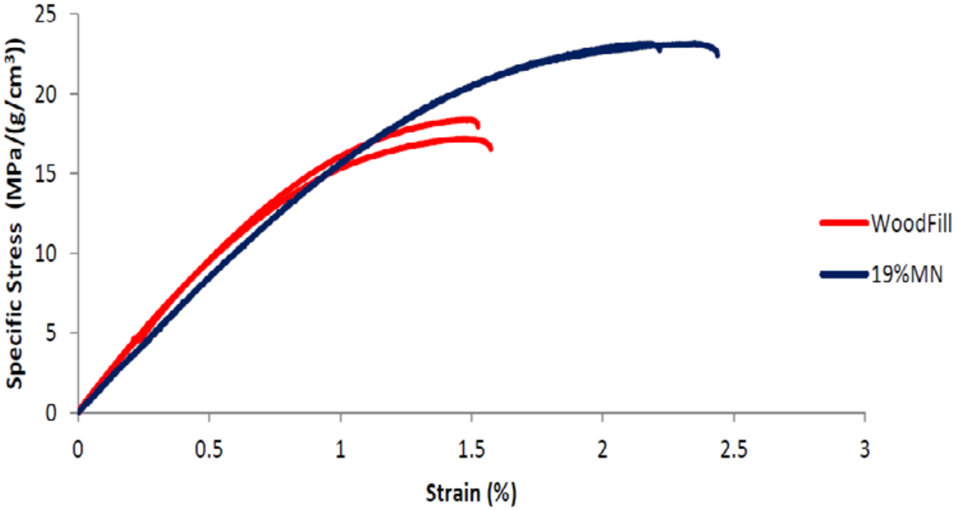
Sample	%wt Macadamia Nutshell	%wt Maleic Anhydride	%wt ABS
ABS	0	0	100
19%MN	19	3	78
29%MN	29	3	68

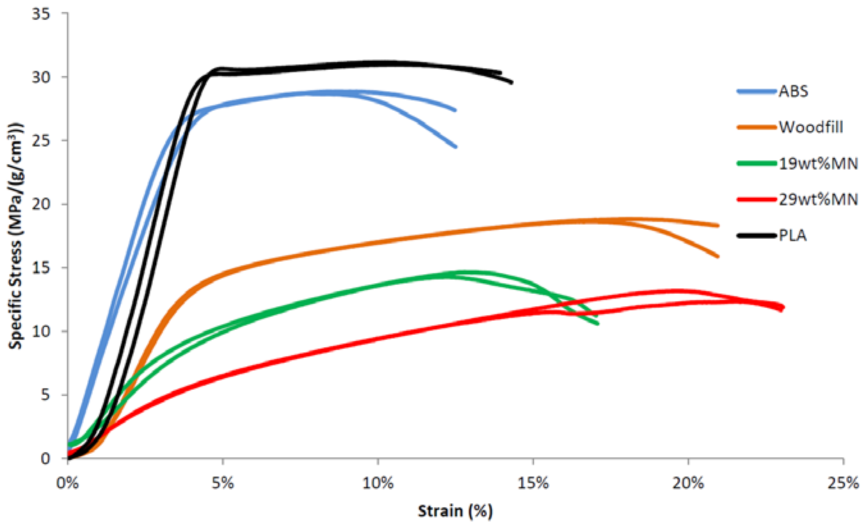
Density measurements:

Table 2 – Density comparison of printing filaments

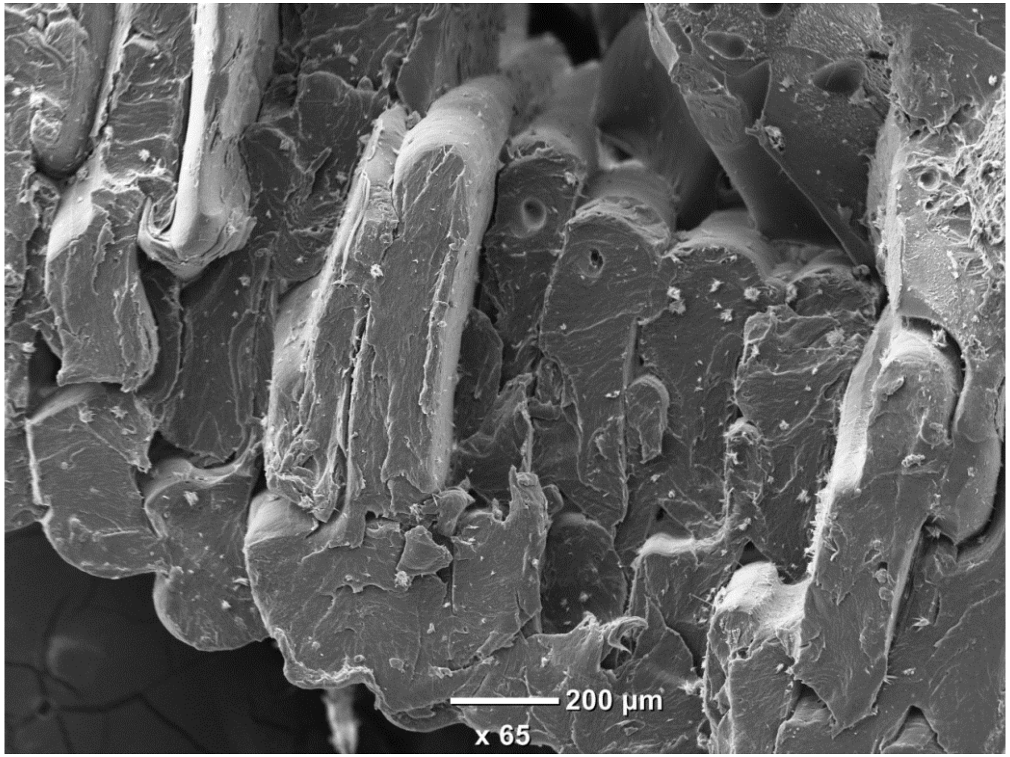
Material	Measured Density of Filament (g/cm^3)	Reduction Compared with pure polymer (%)
ABS	1.06	N/A
19%MN	0.83	21.7
29%MN	0.77	27.4
PLA	1.28	N/A
Woodfill	1.14	10.9

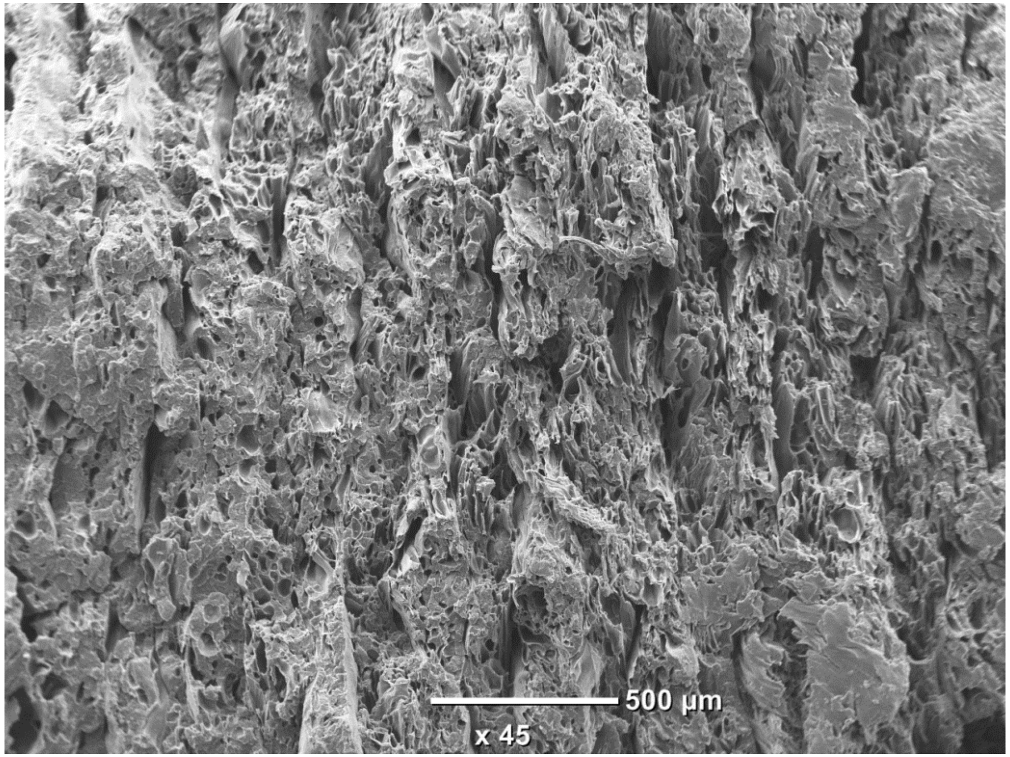
Mechanical properties:





Investigation of failure mechanisms – scanning electron microscopy imaging





Development of a Microtimber “Aesthetic” that evokes natural wood

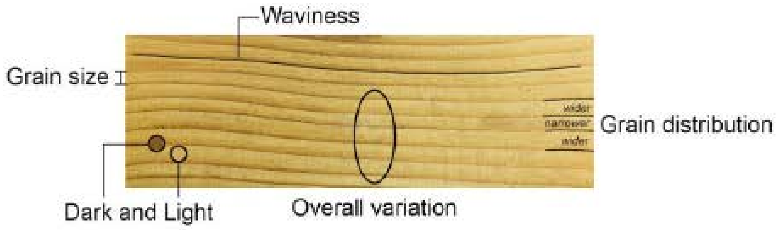
What has been done:

- Production of 2D element

In progress:

- Production of 3D elements using a standard 3D printing methods
- Production of 3D elemnts using a robotic arm and 3D printing head

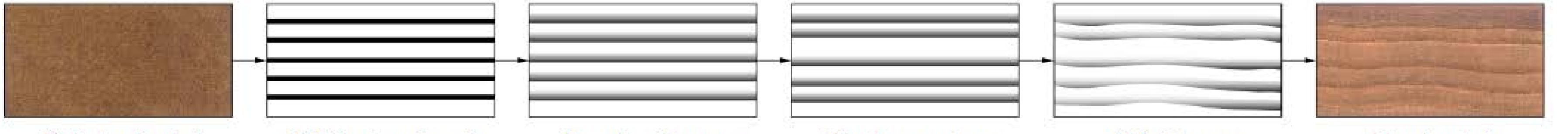
Methodology



Identifiable characteristics of wood

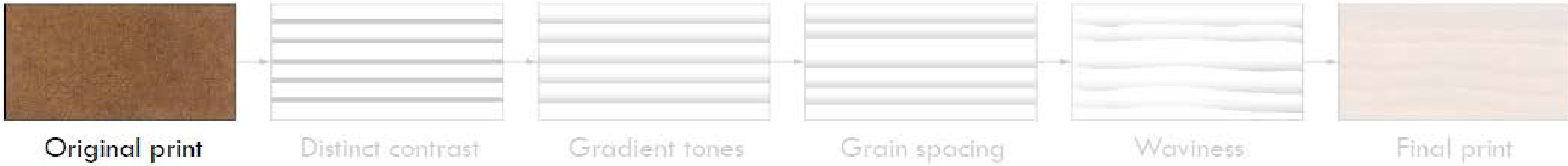
180°C 200°C 220°C 230°C 250°C

Cubes printed with LAYWOO-D3 at different temperatures



Original print → Distinct contrast → Gradient tones → Grain spacing → Waviness → Final print

Original print



Contrast

- Hot end temperature change
- Head movement variation

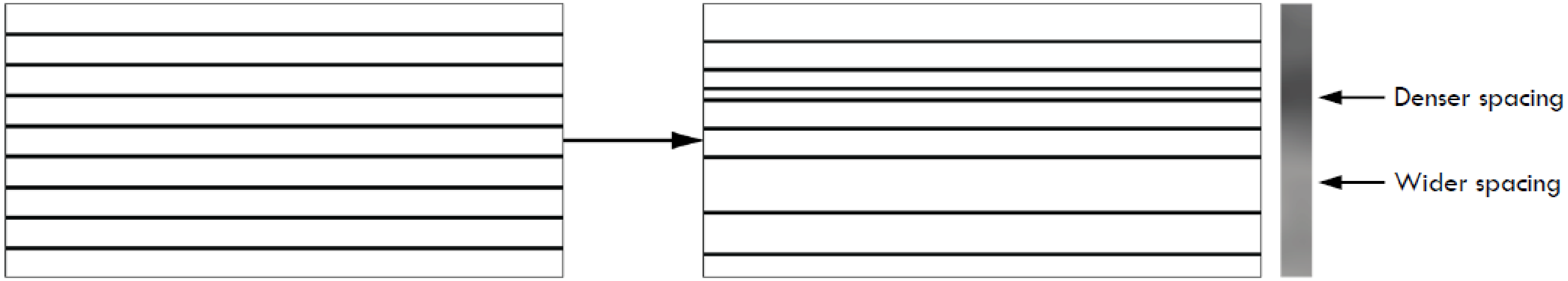
Gradient

- Temperature change more successful in producing gradient
- Movement of head while hot end cools down creates gradient

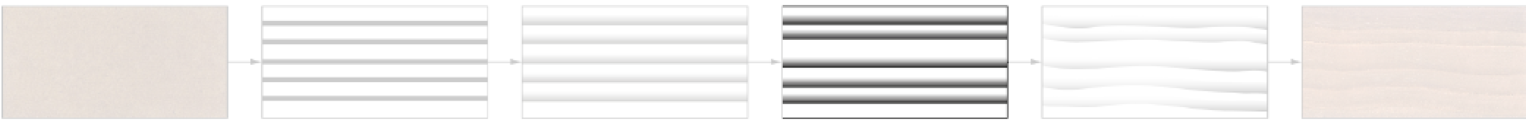
Grain Spacing

Applying Perlin noise scale to change grain spacing

- Darker regions produce closer spacing
- Lighter regions produce wider spacing



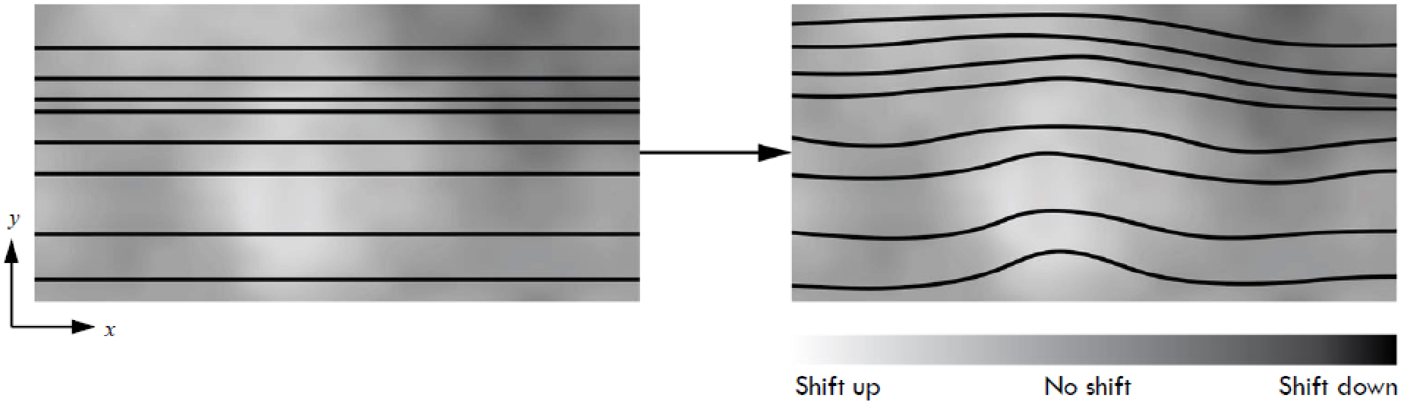
Using perlin noise scale to change grain width



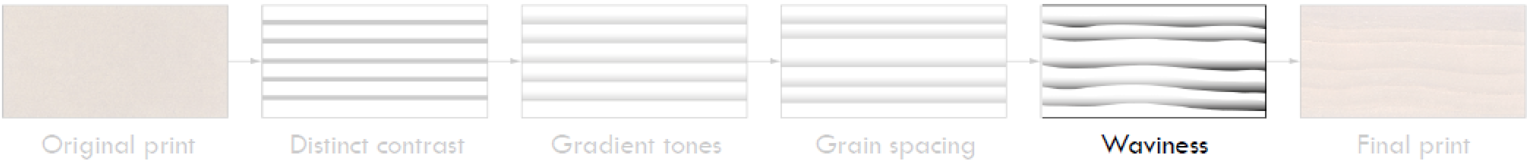
Grain Waviness

Applying Perlin noise map to change grain waviness

- Darker regions creates a shift down from the original position
- Lighter regions creates a shift up from the original position



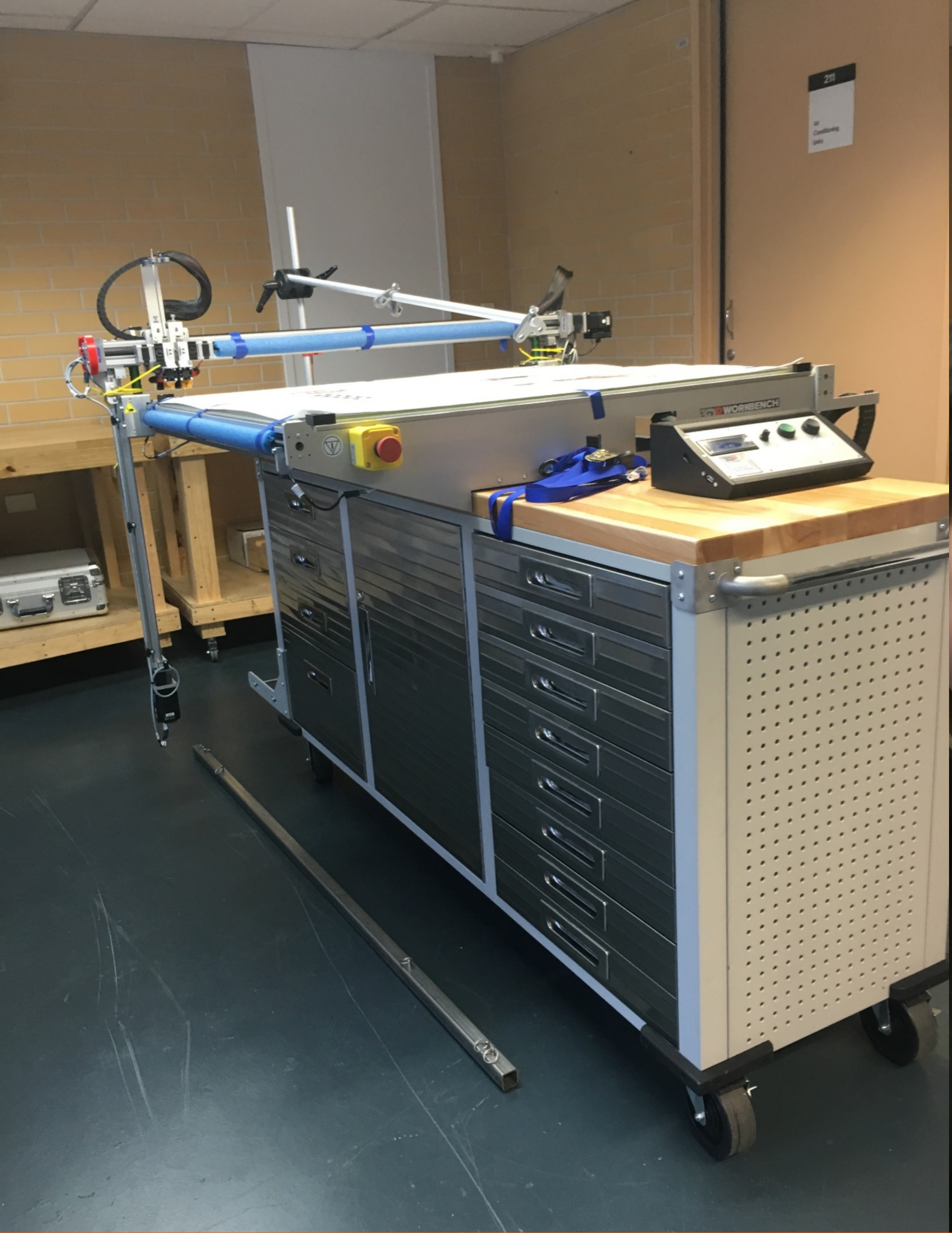
Using perlin noise map to add waviness

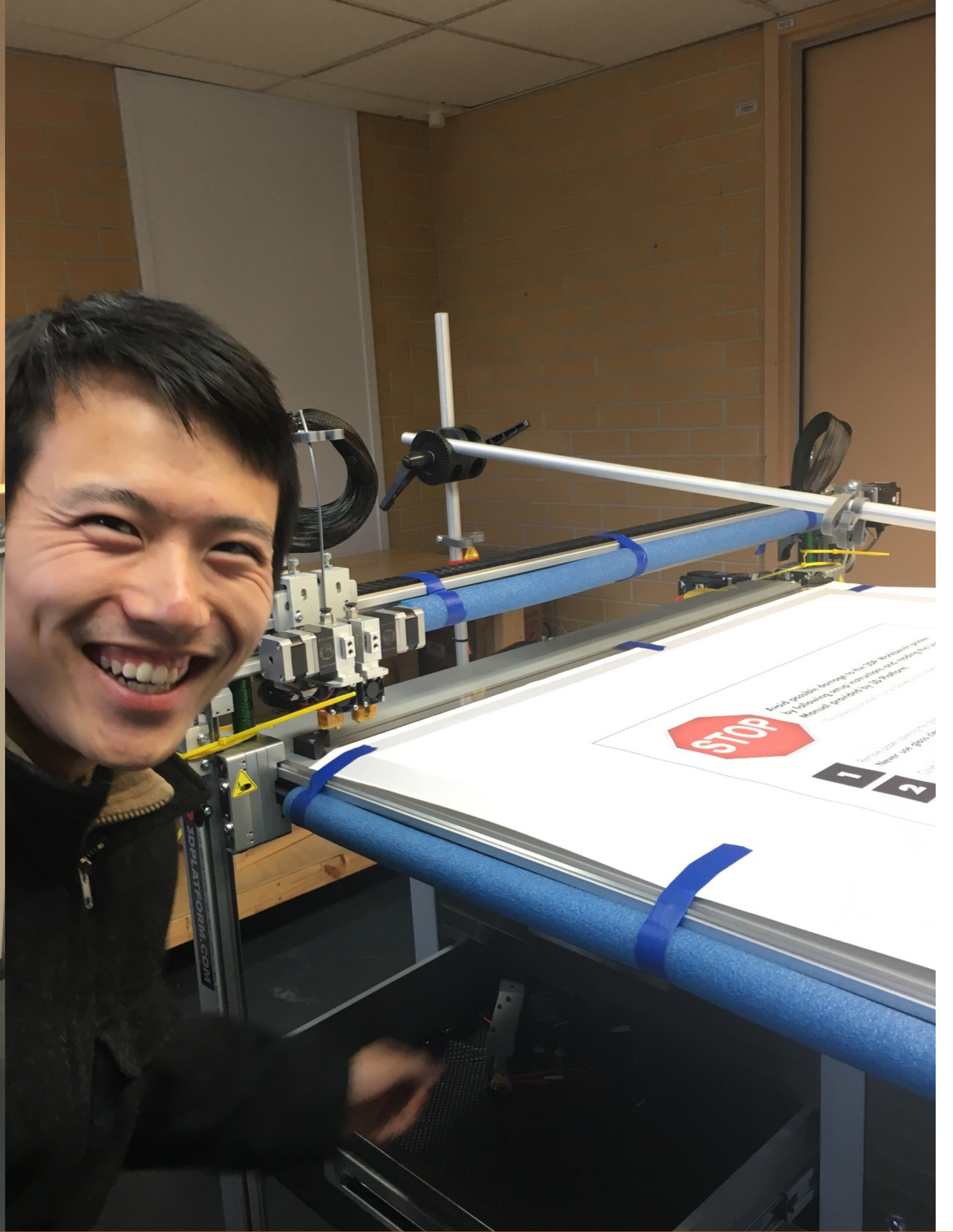


Next steps: Scaling up

What has been done:

- A state-of the art 3D Printing Platform has been acquired and staff have been trained.
- The machine has two printer heads and a fabrication platform that allows the production of scaled prototypes to a maximum size of 800x1500





Towards a *Microtimber* prototype


Natural wood


WPC filament with traditional 3D printing


WPC filament with improved 3D printing technique

3D Printing: Microtimber

In short:

“We want to create innovative, environmentally-resilient panels that are customised to react optimally to structural stress and weather exposure of a building”

“The innovation lies in the micro-layering and fusing of different 3D-printed timber compositions, to provide a unique material performative gradient suitable for building projects.”

Benefits to the forest and wood product industry

- An innovative, high-performance product will create a **progressive marketing image** for what is currently perceived as a traditional, low-tech material.
- A graded panel represents a sustainable and highly marketable timber product whose material composition can be **adapted for a wide range of uses** – walls, cladding, internal screens, louvres etc
- The use of waste- and by-products **counters negative environmental perceptions**, which are largely based on the fact that people do not like trees to be cut down
- Overall, this project adds to the industry's ability to **market itself in a more positive, future-oriented manner**.

Significance

The project will fundamentally change the way we conceive of and produce timber products - as advanced technological products rather than simply as a commodity.

THANK YOU

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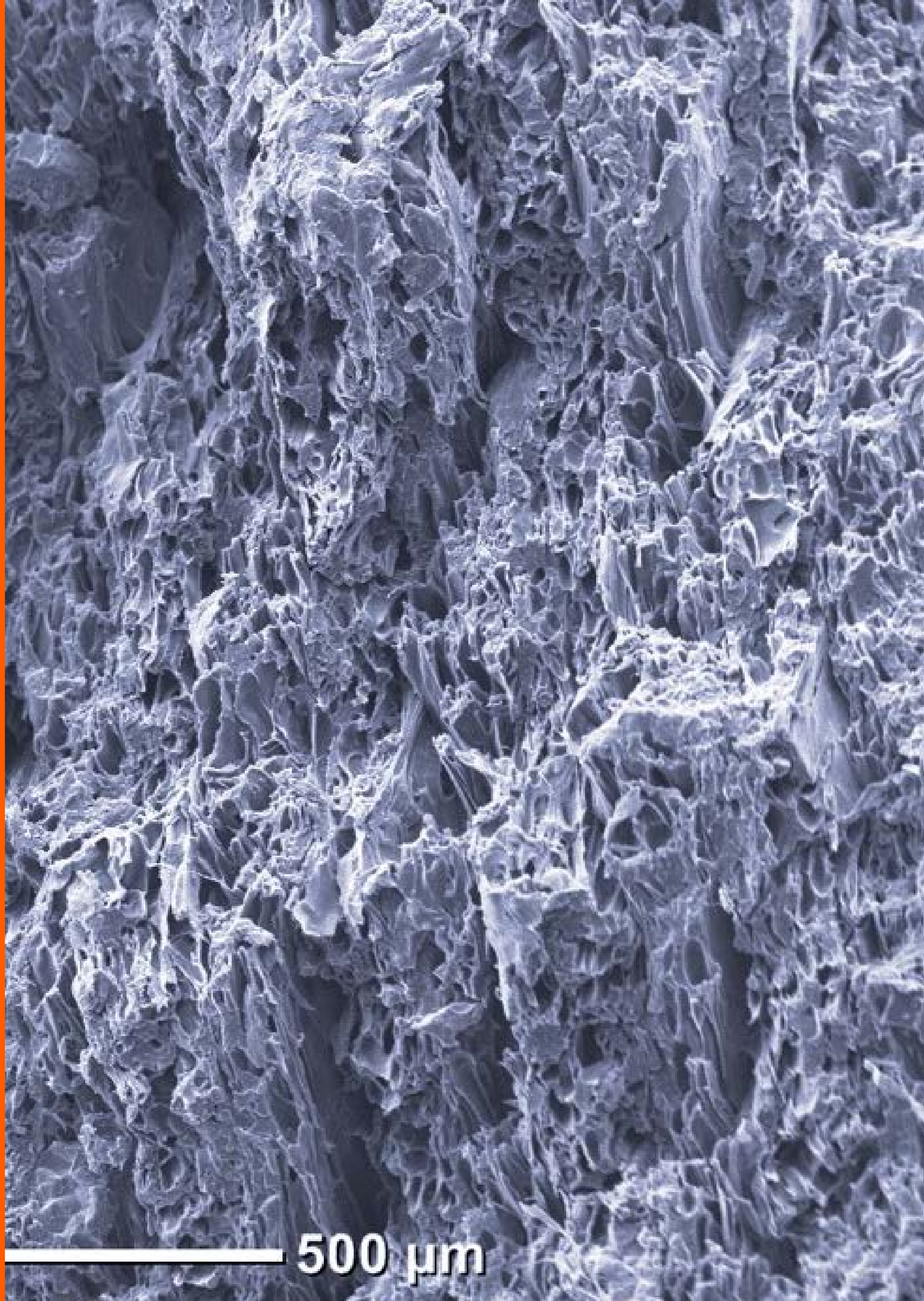

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