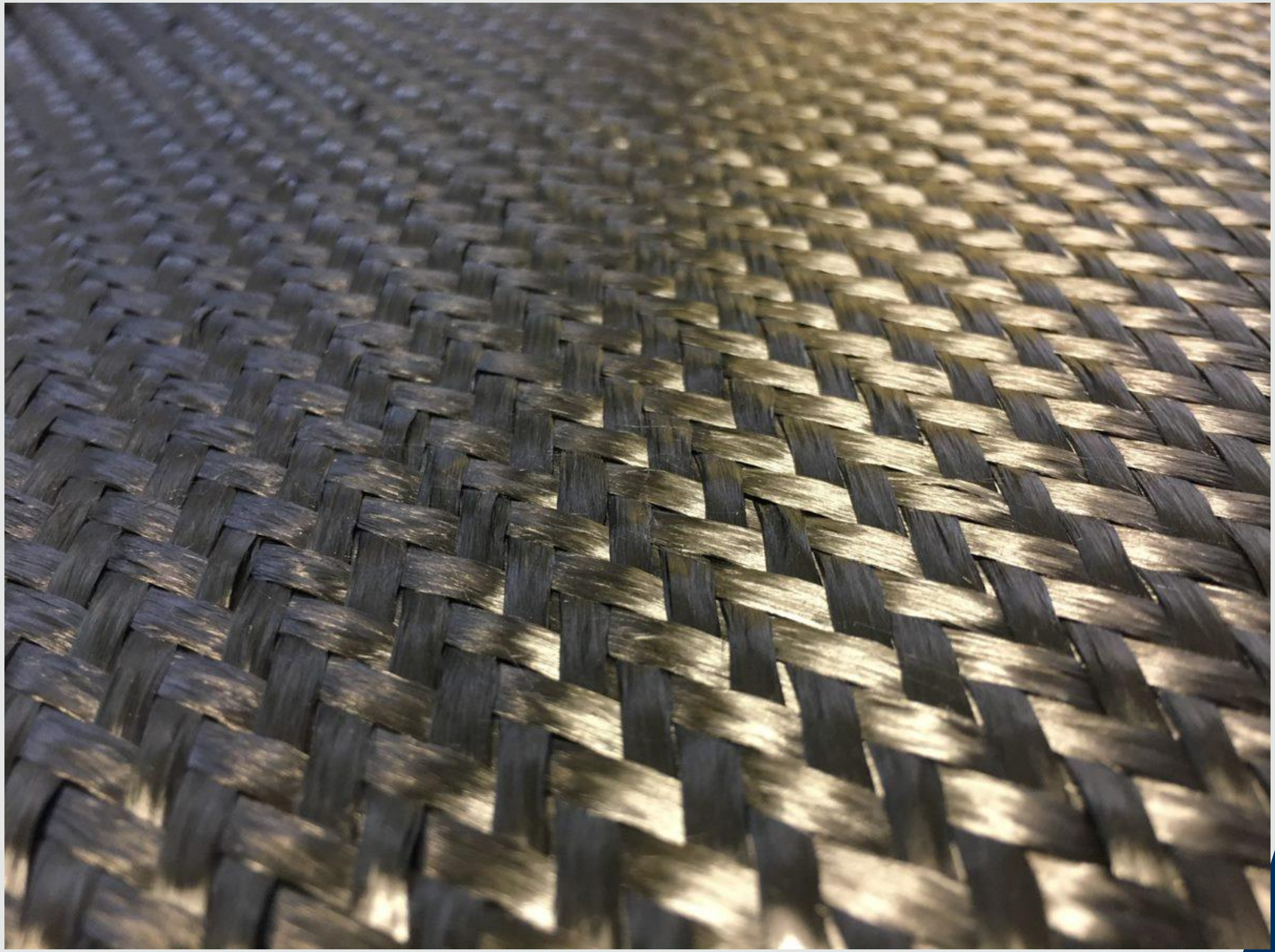

MATERIALS

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PLA-HYDROGEL FRACTAL ACOUSTIC COMPOSITE METAMATERIAL FOR SOUND INSULATION

Gianni Comandini, Fabrizio Scarpa,
Mahdi Azarpeyvand, Valeska Ting

BCI Doctoral Research Symposium

12th April 2022

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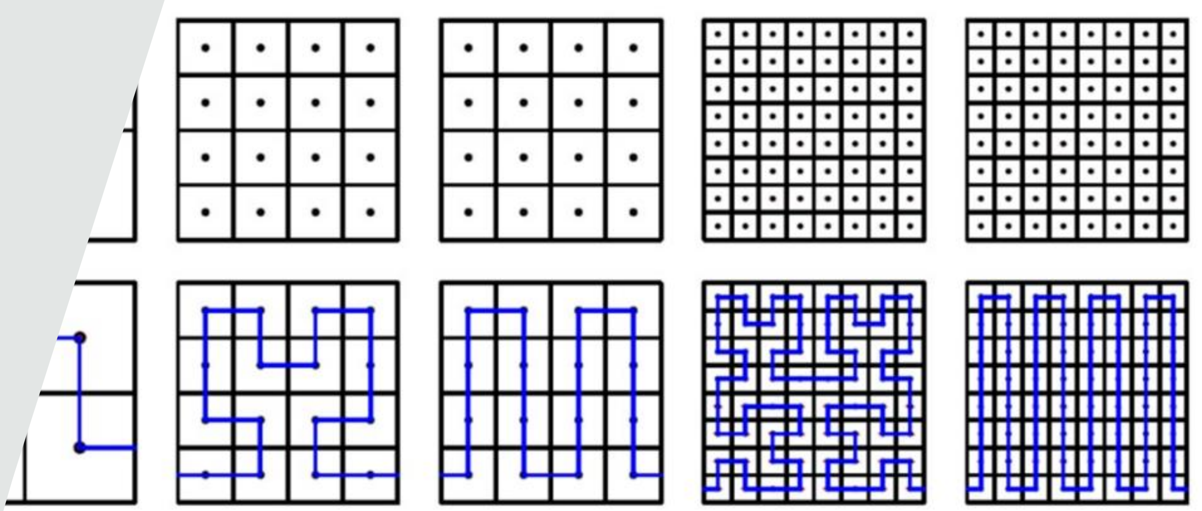
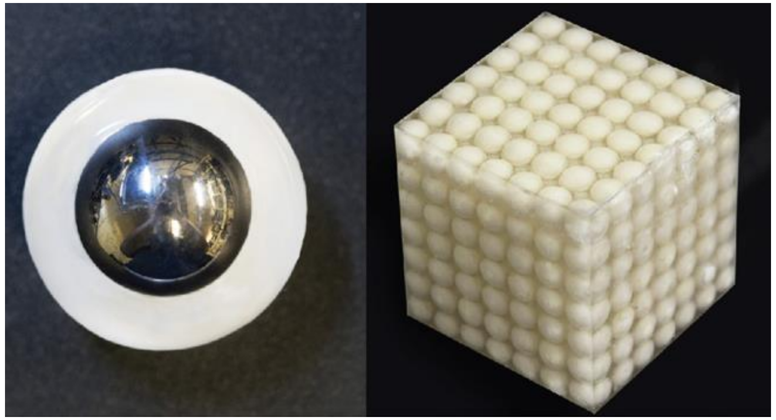
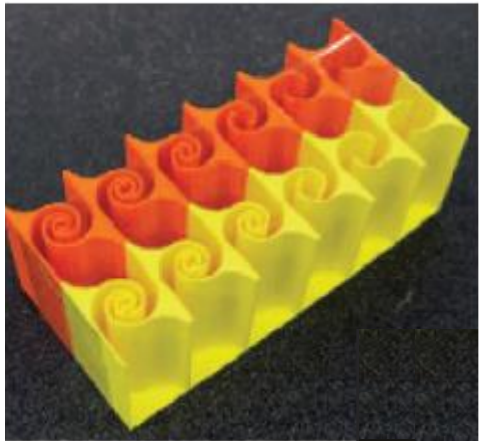


Understanding of acoustic metamaterials:

Alternative noise control techniques → Metamaterials → Space-coiled structures → Fractals

(1)



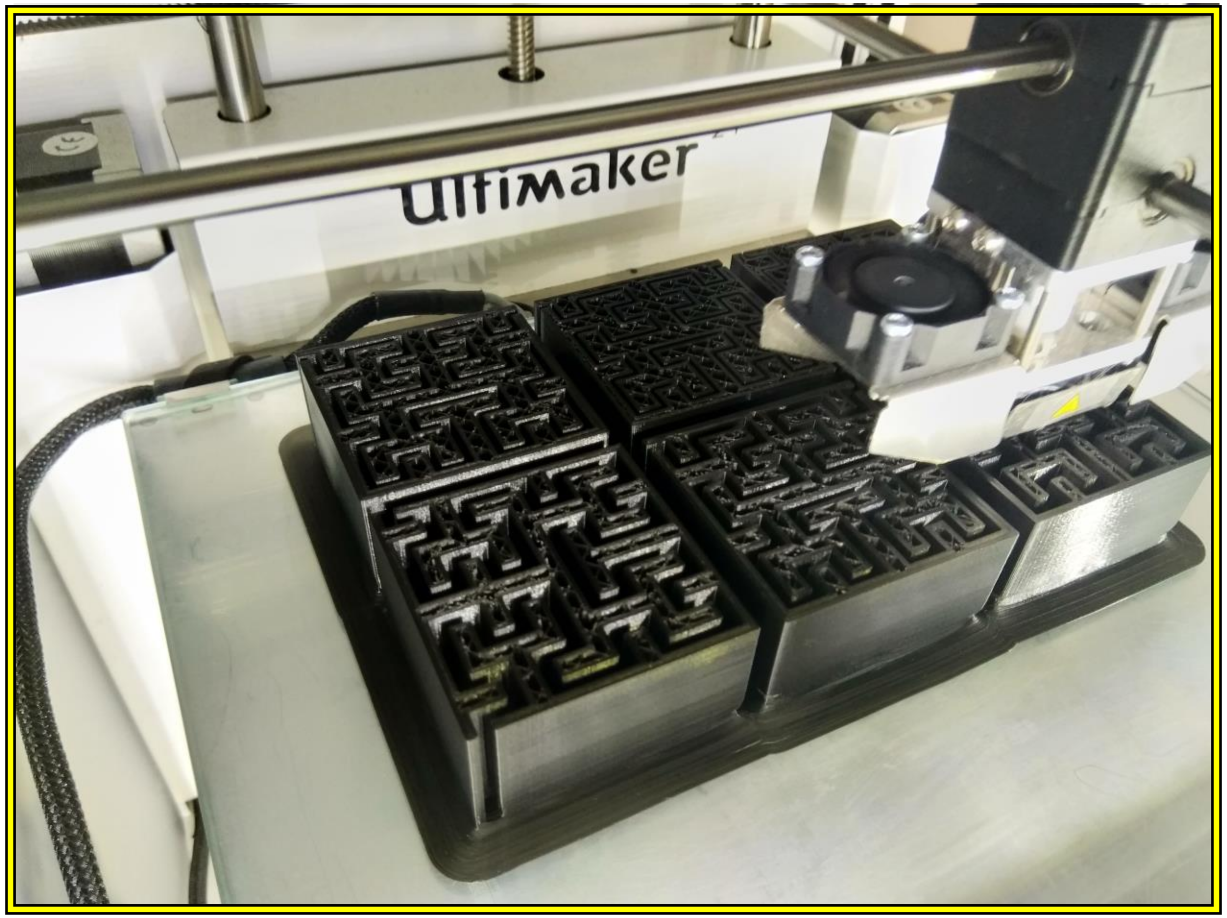


(2)

(3)

(1) researchgate.net/publication/295943900_Acoustic_metamaterials_From_local_resonances_to_broad_horizons/figures?lo=1
(2) researchgate.net/publication/325586257_Wavefront_manipulation_by_acoustic_metasurfaces_From_physics_and_applications
(3) aip.scitation.org/doi/pdf/10.1063/1.5038431

Manufacturing process



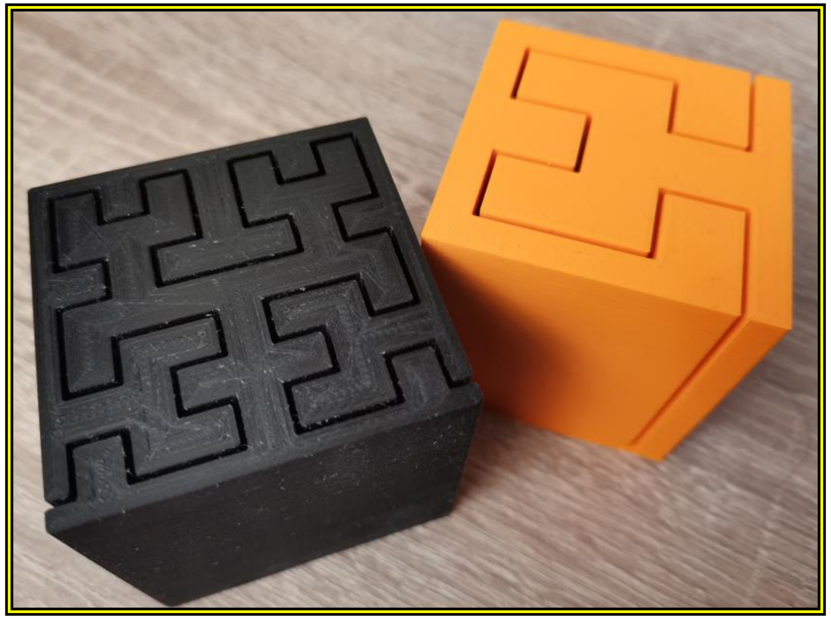
AIP Applied Physics Letters

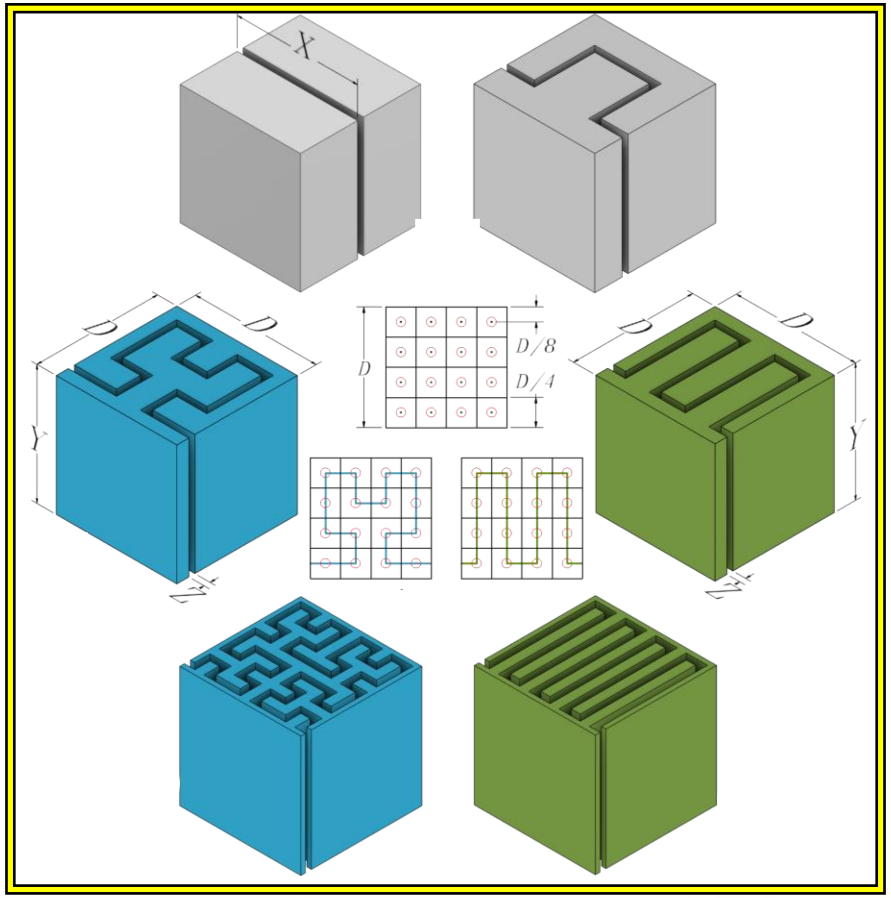
Open • Submitted: 22 November 2021 • Accepted: 26 January 2022 • Published Online: 07 February 2022

Sound absorption in Hilbert fractal and coiled acoustic metamaterials

Appl. Phys. Lett. **120**, 061902 (2022); https://doi.org/10.1063/5.0079531

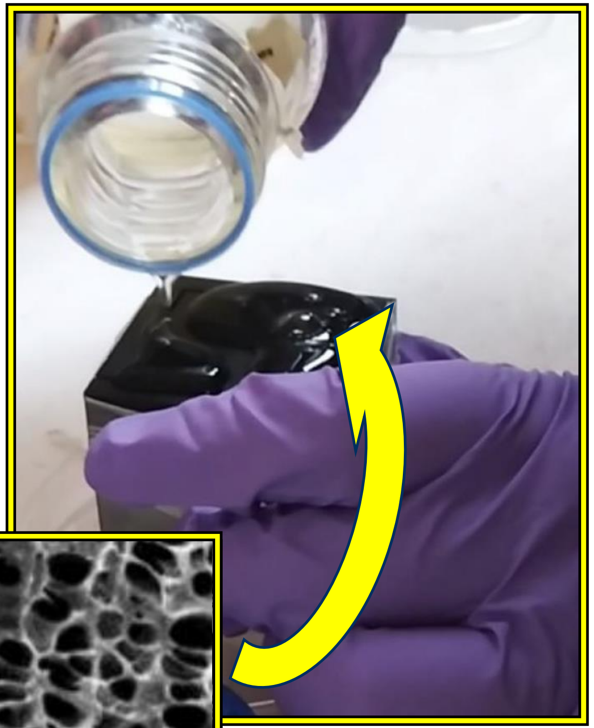
G. Comandini[1,a], C. Khodr[2,b], V. P. Ting[1,c], M. Azarpeyvand[3,d], *and* F. Scarpa[1,e]

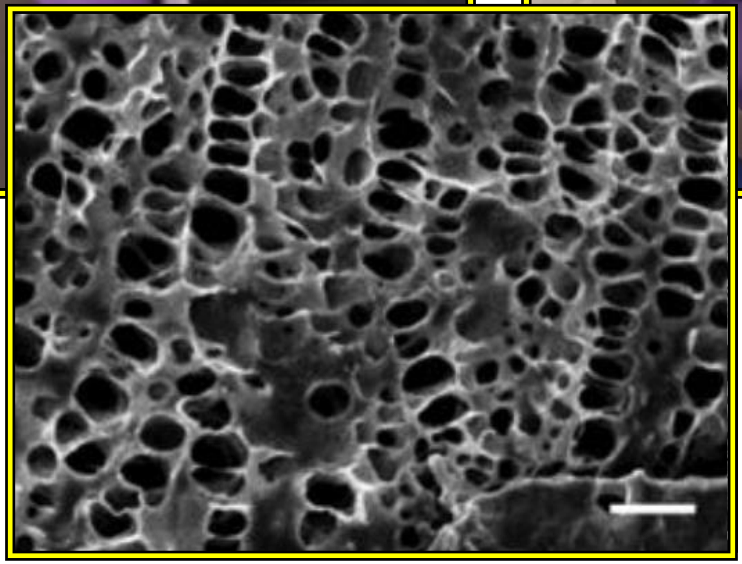




Composite fabrication

- F127 alginate hybrid gel biocompatible with sterilized water used as infill material
- Microporous structure
- Interesting acoustics properties that have not been fully investigated as yet



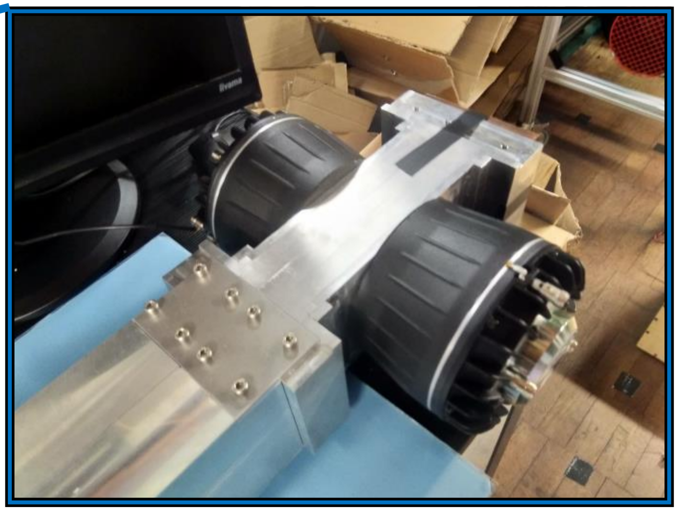


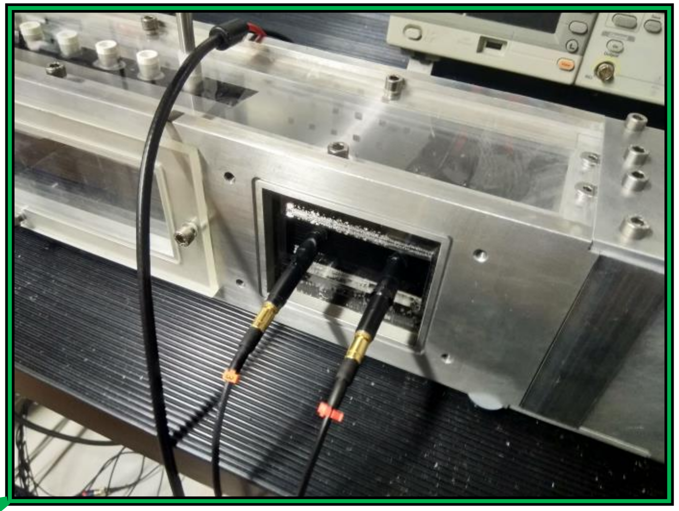
(1)

(1) **3D Bioprinting Using a Templated Porous Bioink**
James P. K. Armstrong , Madeline Burke , Benjamin M. Carter, Sean A. Davis , and Adam W. Perriman

Testing set up

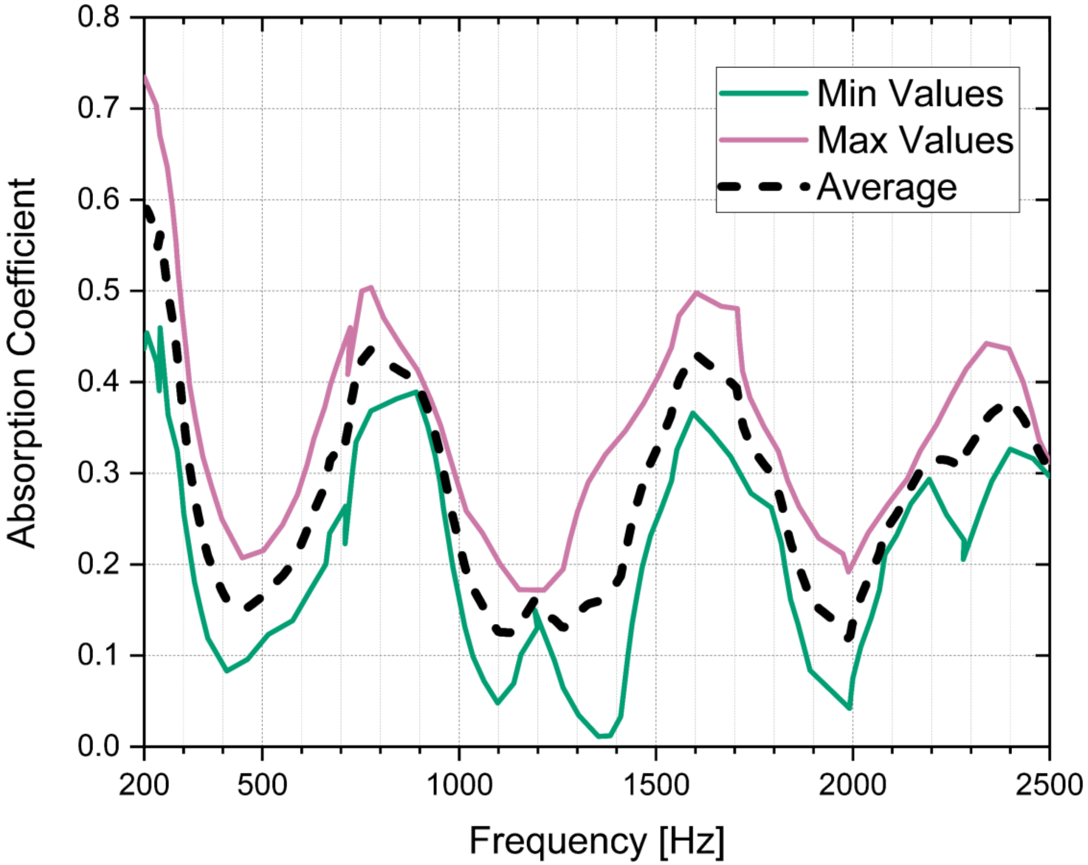
(1)





Composite metamaterial preliminary results

- Average acoustic absorption with maxima and minima values
- Absorption coefficient ~0.5 around 200 Hz
- All the measurements made using two samples with hydrogel and 7 measurements each.



International Placement

Google Maps

Next steps

- A poroelastic COMSOL model of the hydrogel inside the metamaterial
- Understanding the physics behind the high energy dissipation at low frequency ranges
- Evaluate how the manufacturing process of the hydrogels affects the acoustic performances

Acknowledgements

- The support of UK EPSRC through the ACCIS Composites Centre for Doctoral Training
- My Supervisors, Valeska Ting, Fabrizio Scarpa and Mahdi Azarpeyvand
- Paul Weaver
- All the BCI and Aeroacoustics Technicians

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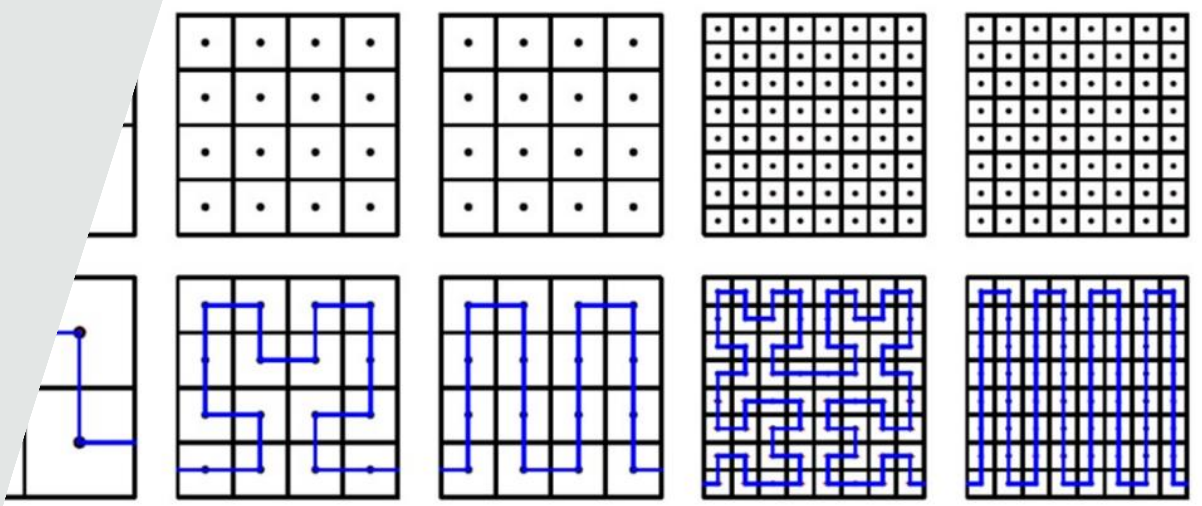
Thanks for listening

gianni.comandini@bristol.ac.uk



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The influence of the humidity on the mechanical properties of 3D printed continuous flax fibre reinforced poly(lactic acid) composites.

24th March 2022

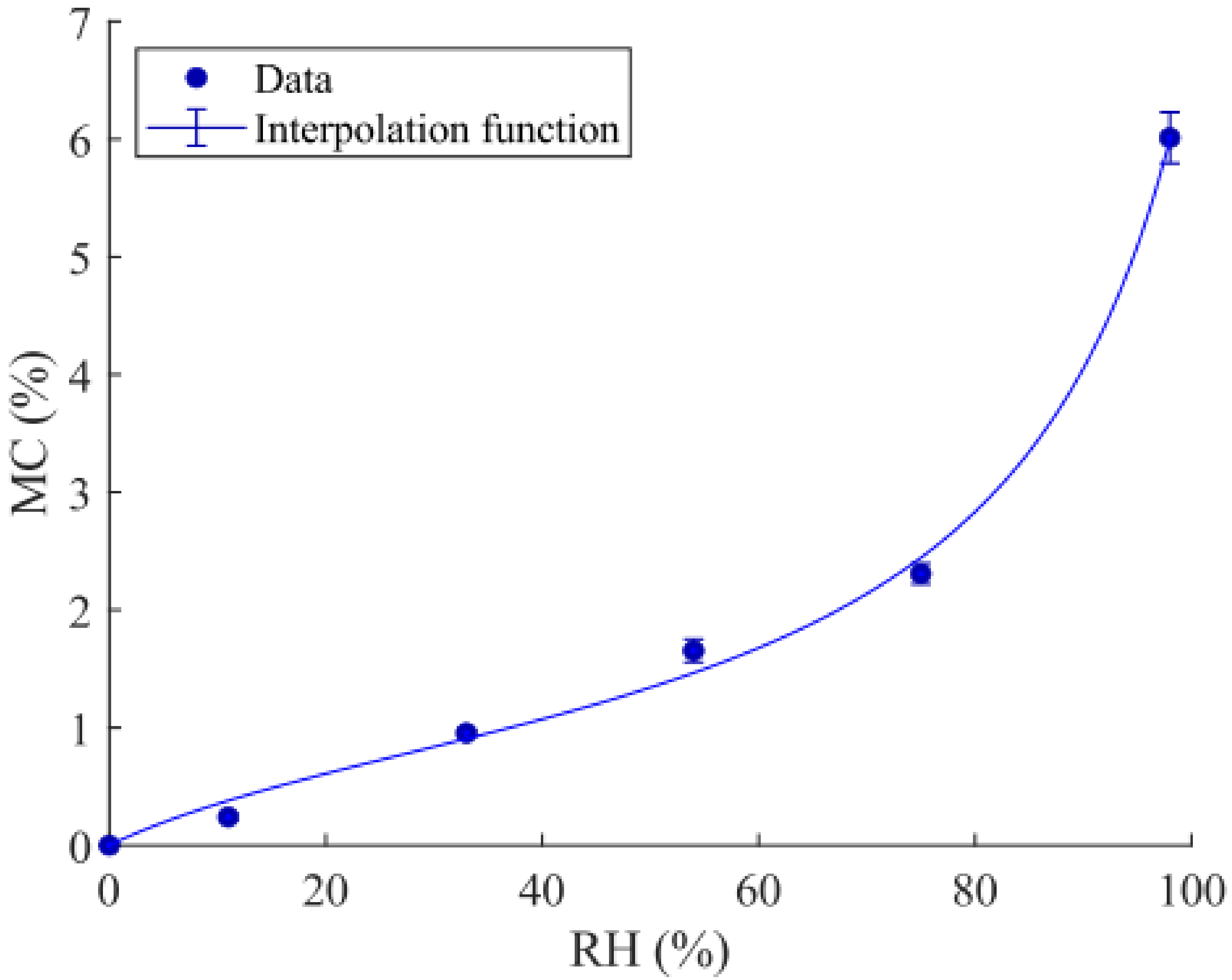
Supervisor: Fabrizio Scarpa

Charles de Kergariou CDT 2018

bristol.ac.uk/composites

[dstl]

Context



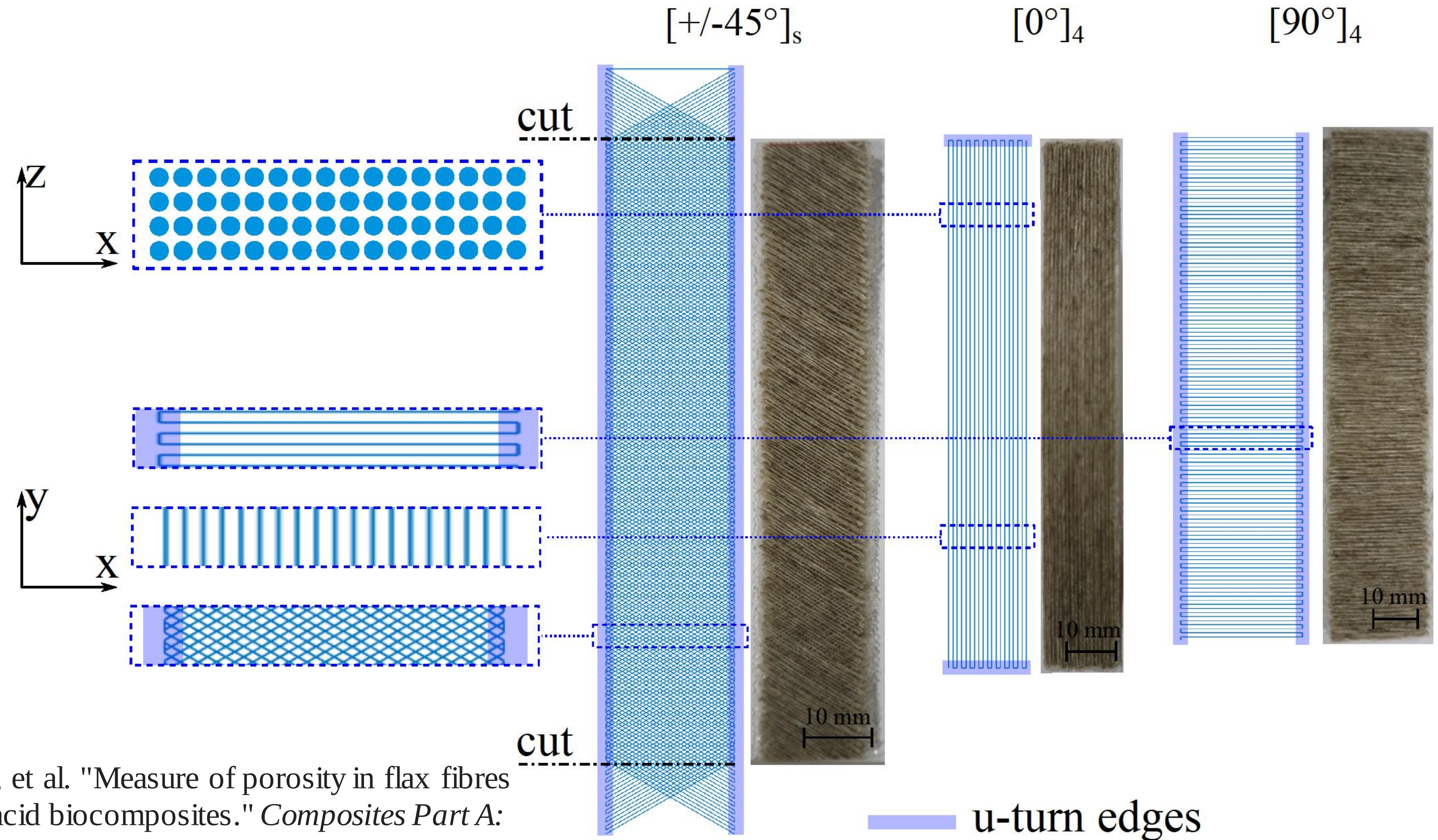
Questions I wanted to solve

1- How moisture influences general mechanical properties?

2- How moisture influences the microstructure of the composite and its fracture?

3- How does this material sits among the rest of the literature?

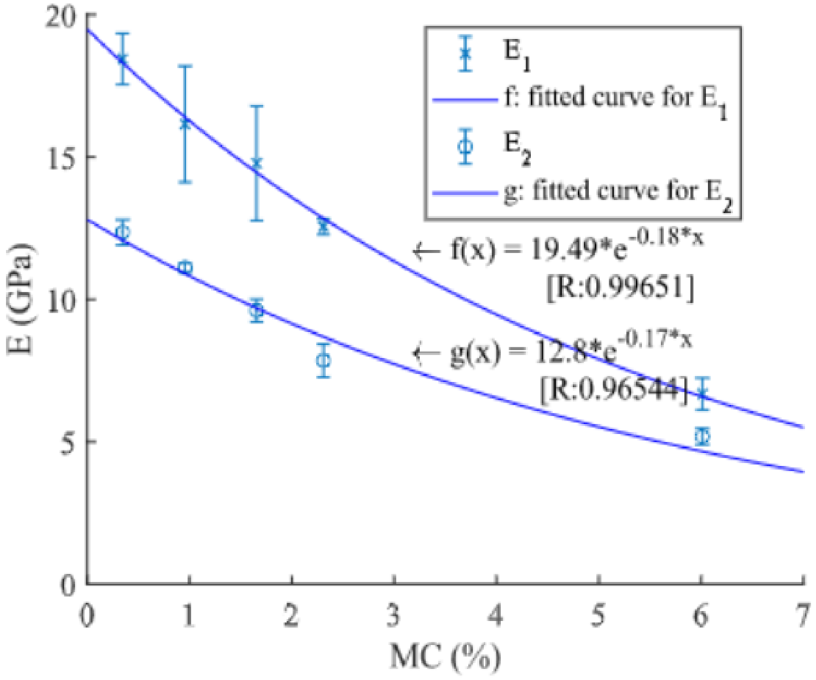
Specimen print



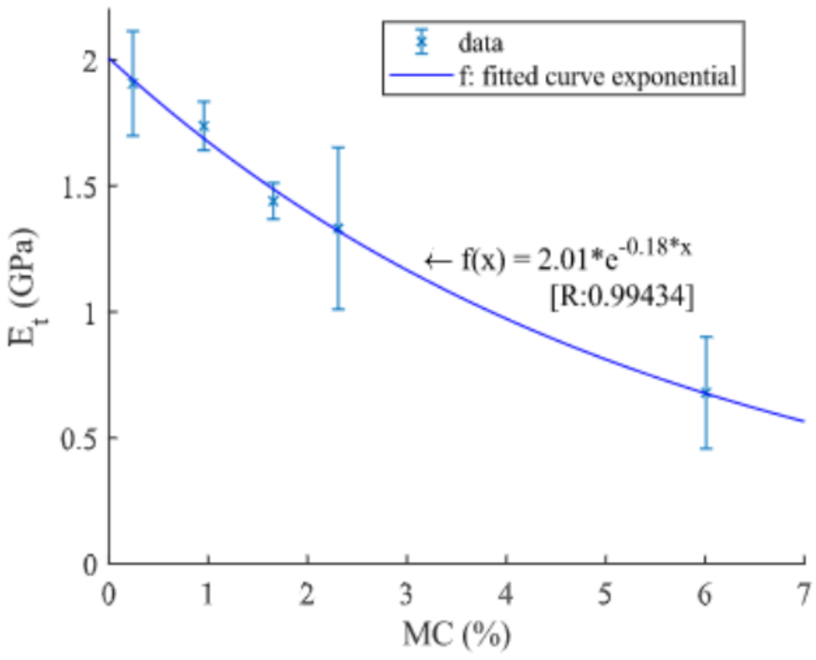
de Kergariou, Charles, et al. "Measure of porosity in flax fibres reinforced polylactic acid biocomposites." *Composites Part A: Applied Science and Manufacturing* 141 (2021): 106183.

Stiffness vs moisture content

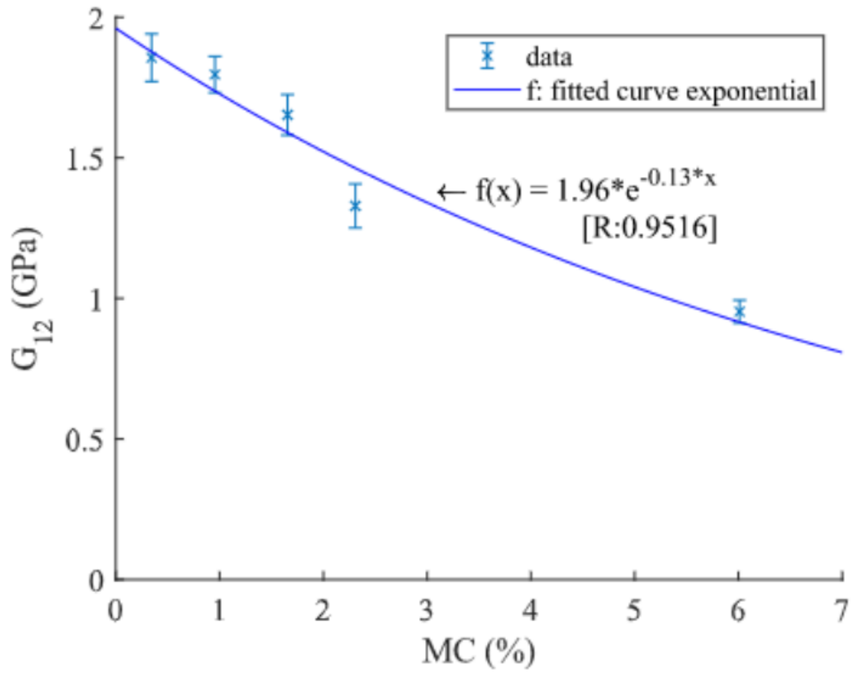
Longitudinal



Transverse

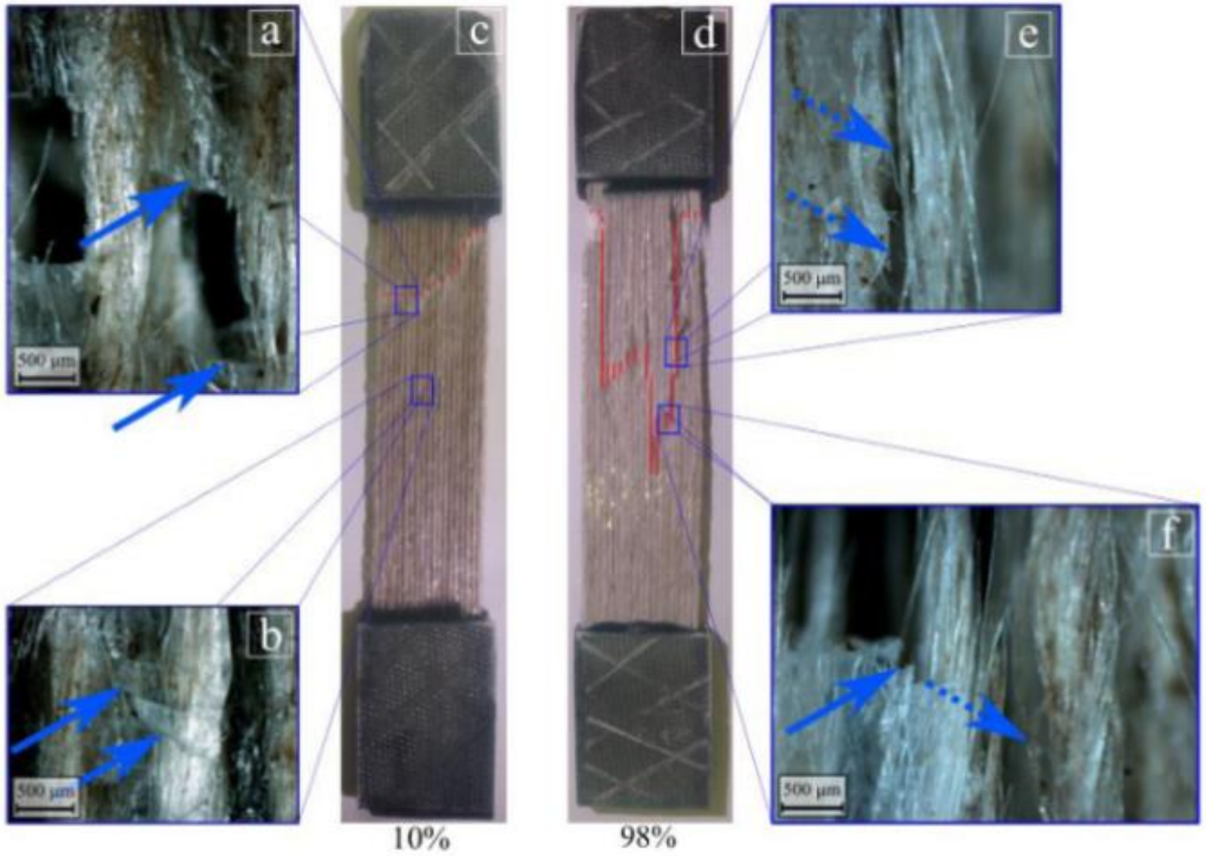


Shear

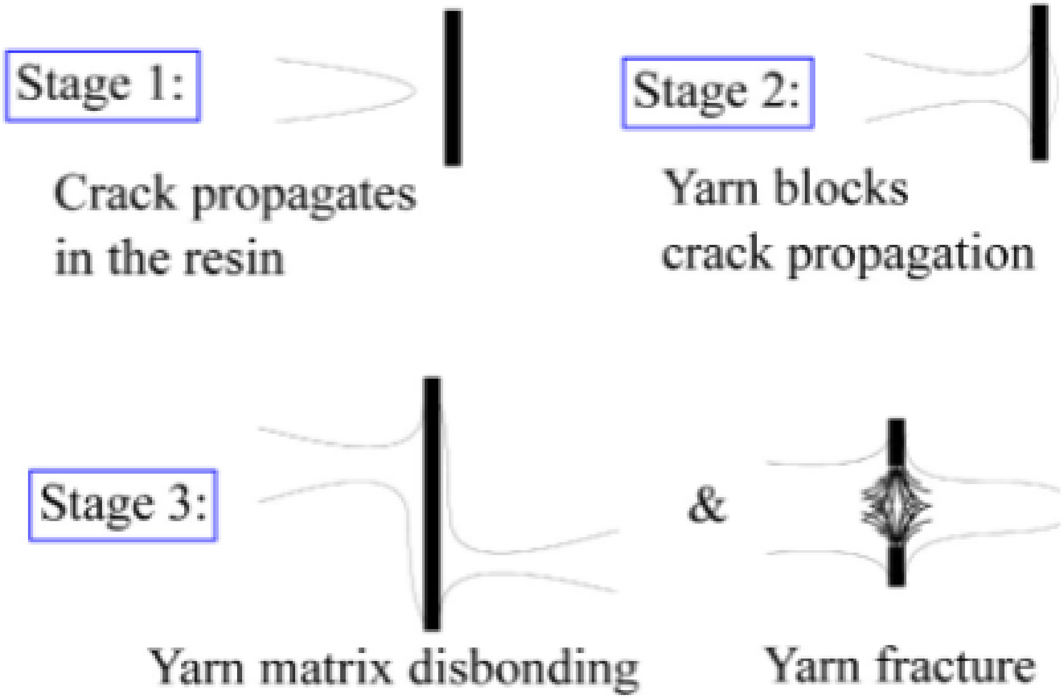


Longitudinal fracture

Fractography

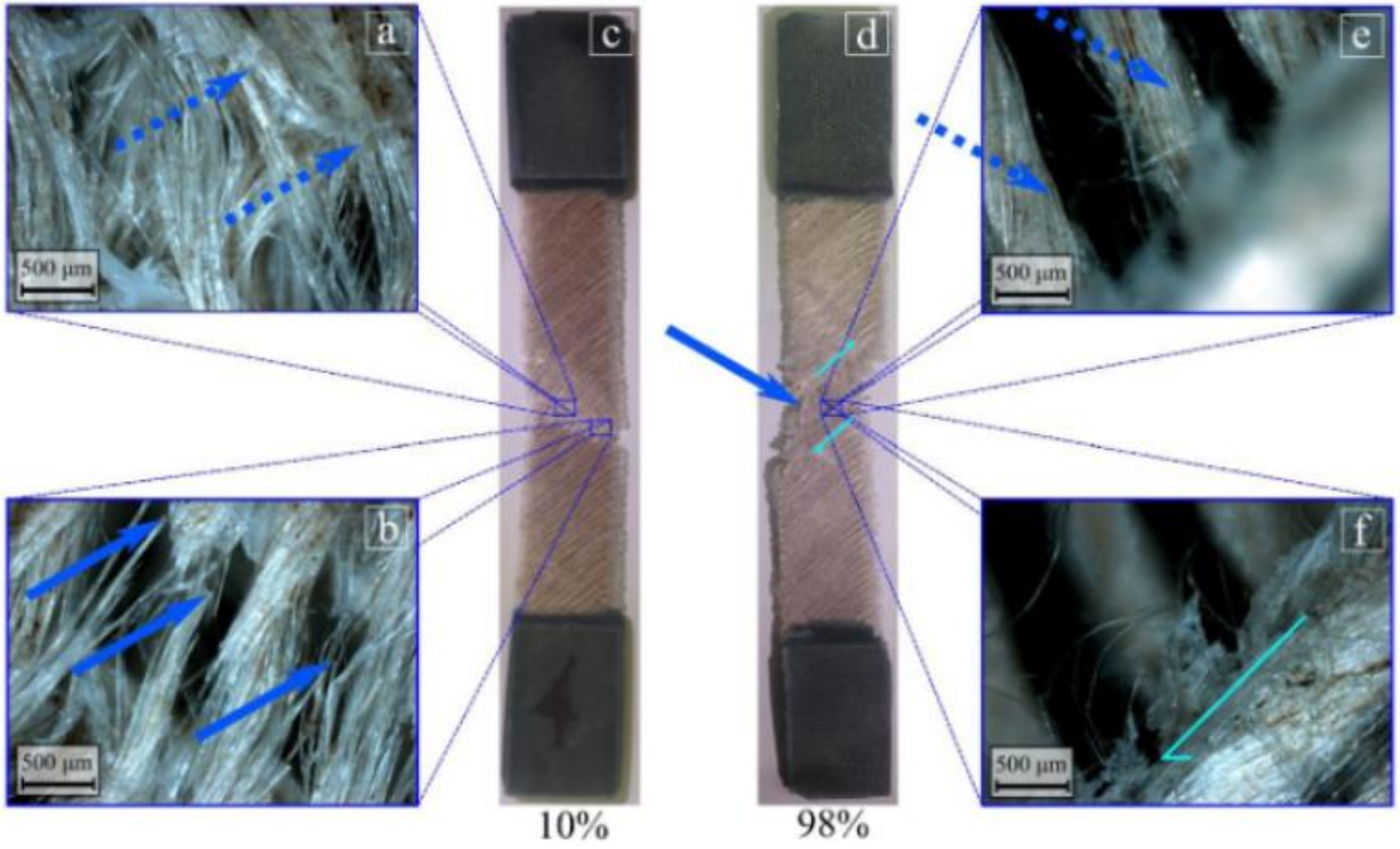


Fracture mechanism: Cook and Gordon

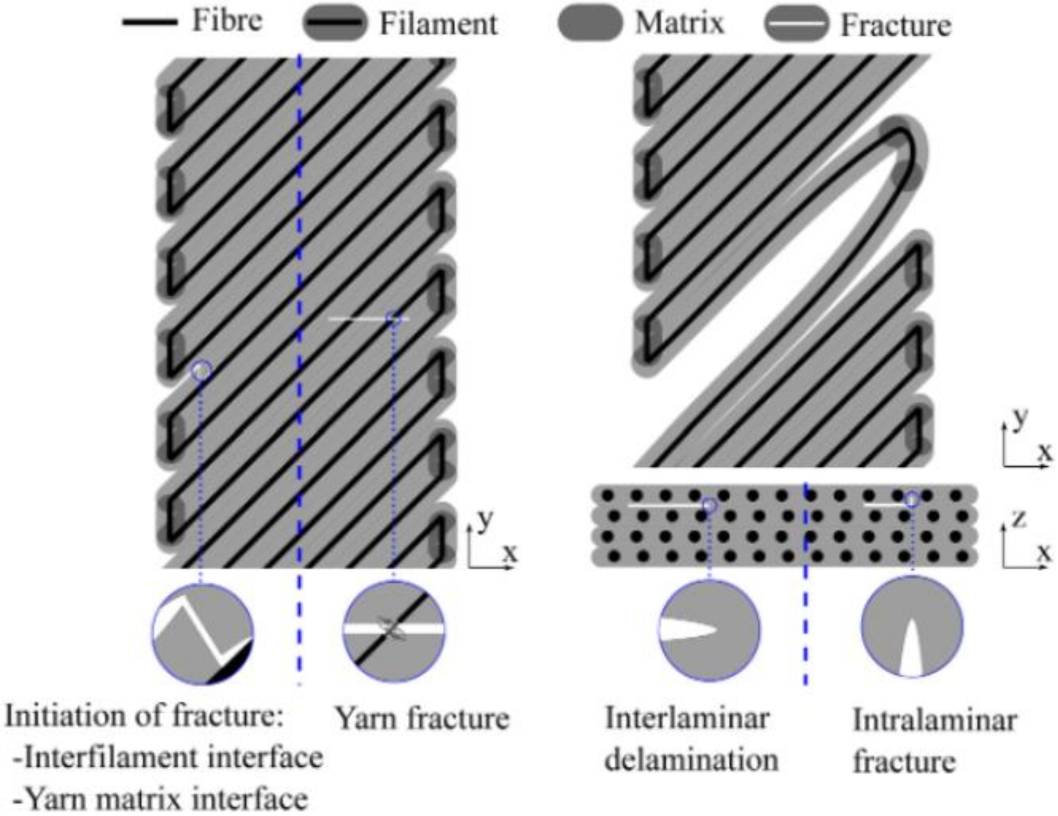


Shear fracture

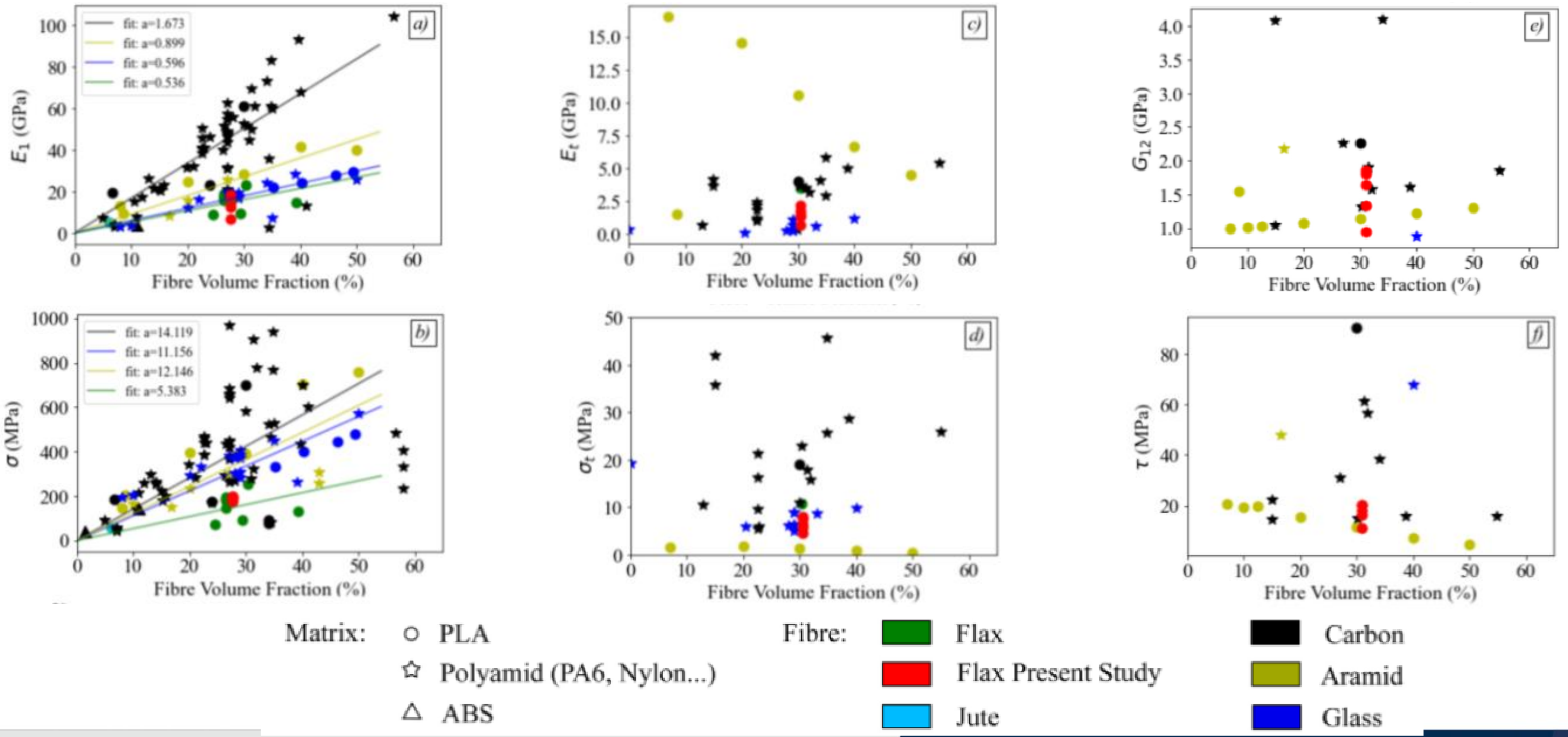
Fractography



Fracture mechanism



Our material versus literature



Conclusion

1- Shear, transverse and longitudinal stiffness present an exponential decrease as the moisture content conditioning increases.

2- Constant longitudinal strength apart from 98%RH. Decreasing transverse and shear strength with humidity conditioning.

3- As MC increases: Constant energy dissipated shear and transverse. Increasing longitudinal energy dissipated

4- Higher humidity:

-longitudinal: greater yarn debonding/ lower yarn fracture

-transverse: no influence on fracture

-shear: lower yarn breakage and high filament disbonding

5- Similar longitudinal stiffnesses to glass and aramid

Paper

C. de Kergariou, H. Saidani-Scott, A. Perriman, F. Scarpa, and A. Le Duigou, “**The influence of the humidity on the mechanical properties of 3D printed continuous flax fibre rein-forced poly(lactic acid) composites**,” Composites Part A: Applied Science and Manufacturing, vol. 155, pp. 106805–106827, 4 2022.

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Thank you very much for your time

charles.dekergariou@bristol.ac.uk

[dstl]

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Life Cycle Engineering and its application to marine component design

Will Proud *Ian Hamerton*
Richard Trask *Marco Longana*

12th April 2022

University of BRISTOL
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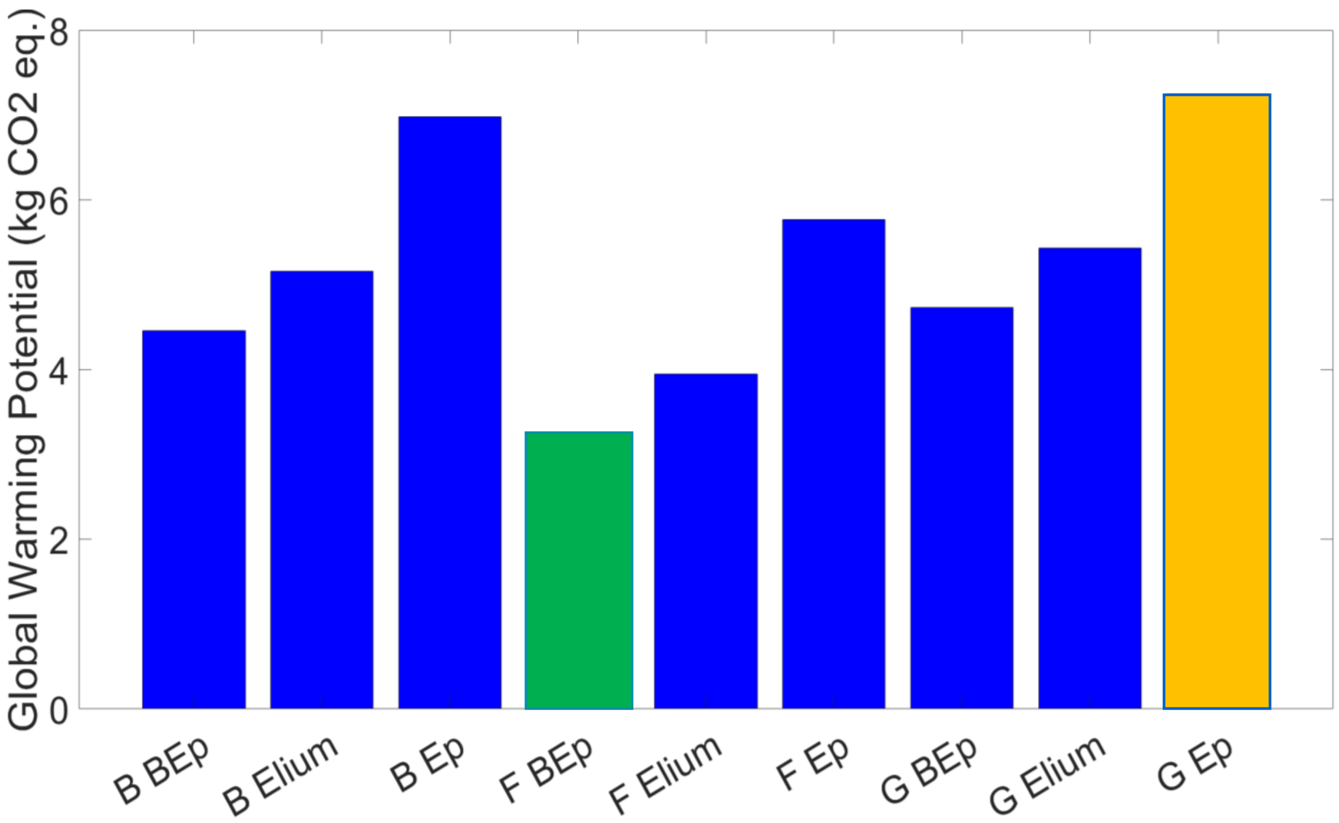
The challenge



Marine industry has historically been dominated by **glass fibre reinforced epoxy composites**

Increased uptake in marine industry of 'green' offerings such as **flax** reinforcement and **bio-epoxy resin** systems

What are the optimised solutions against **technical** and **environmental** factors?

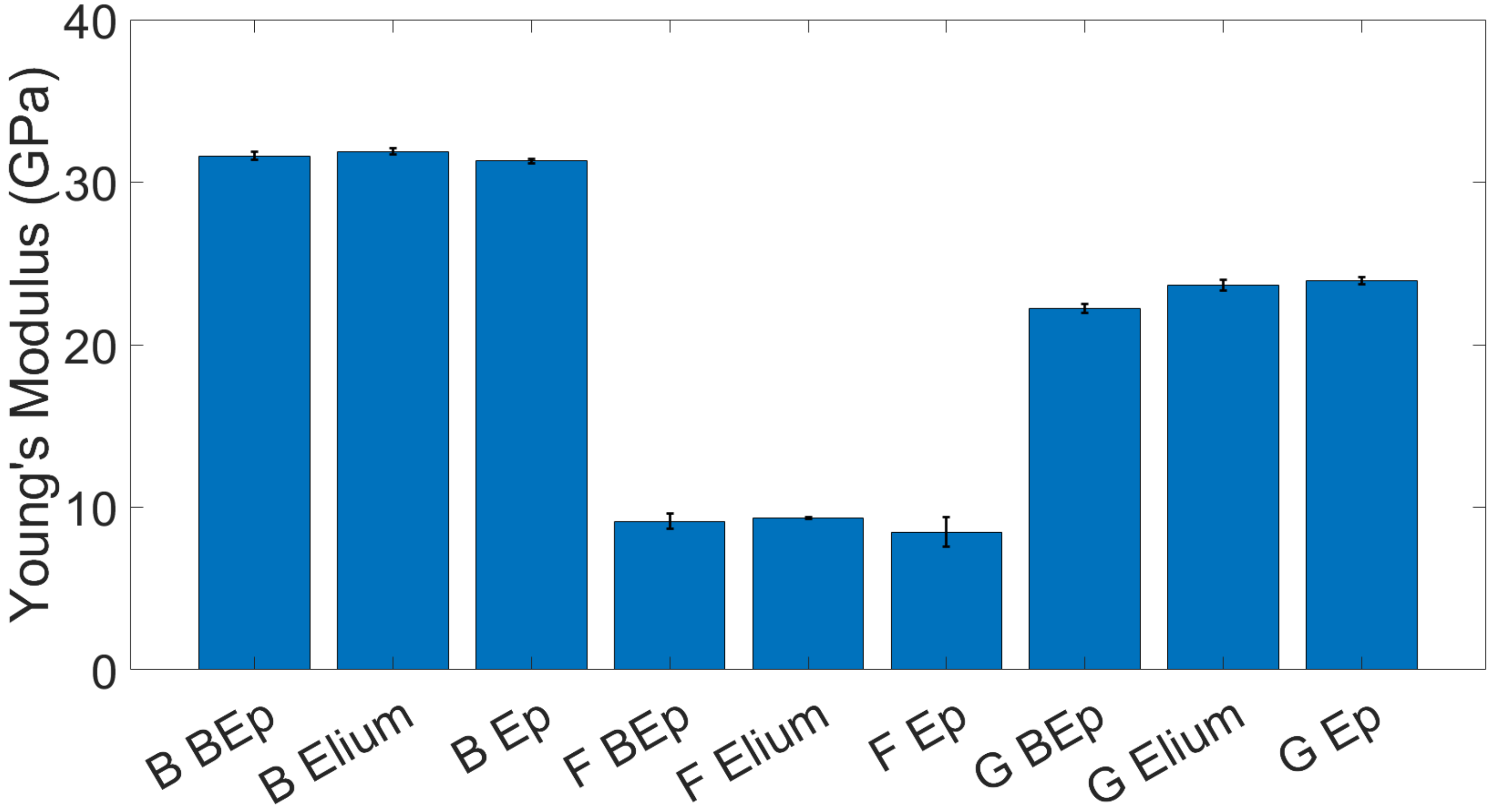
Life Cycle Engineering

Life Cycle Design

1. **System Boundary** - Temporal span definition
2. **Product requirements** – Significant life cycle drivers
3. **Data source –** Quality, time, cost
4. **LCE Methodology –** LCE tool selection
5. **Results and interpretation –** Results -> design decision

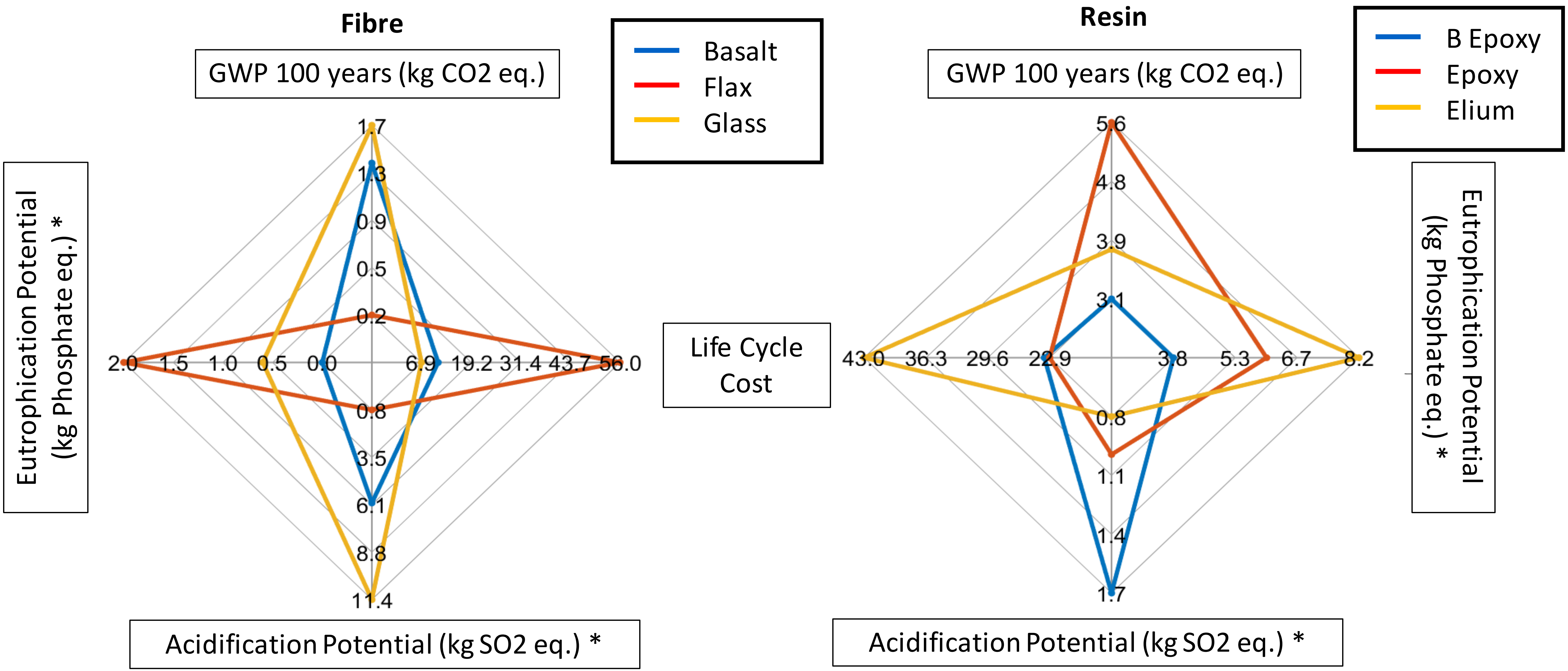
What data was included?

Mechanical Testing Data



- ASTM D3039 and ASTM D3518
- Basalt fibre showed widest range of failure modes
- At approximately equivalent areal weight, basalt fibre fabric has superior tensile performance

What data was included?



Life Cycle Engineering Optimisation

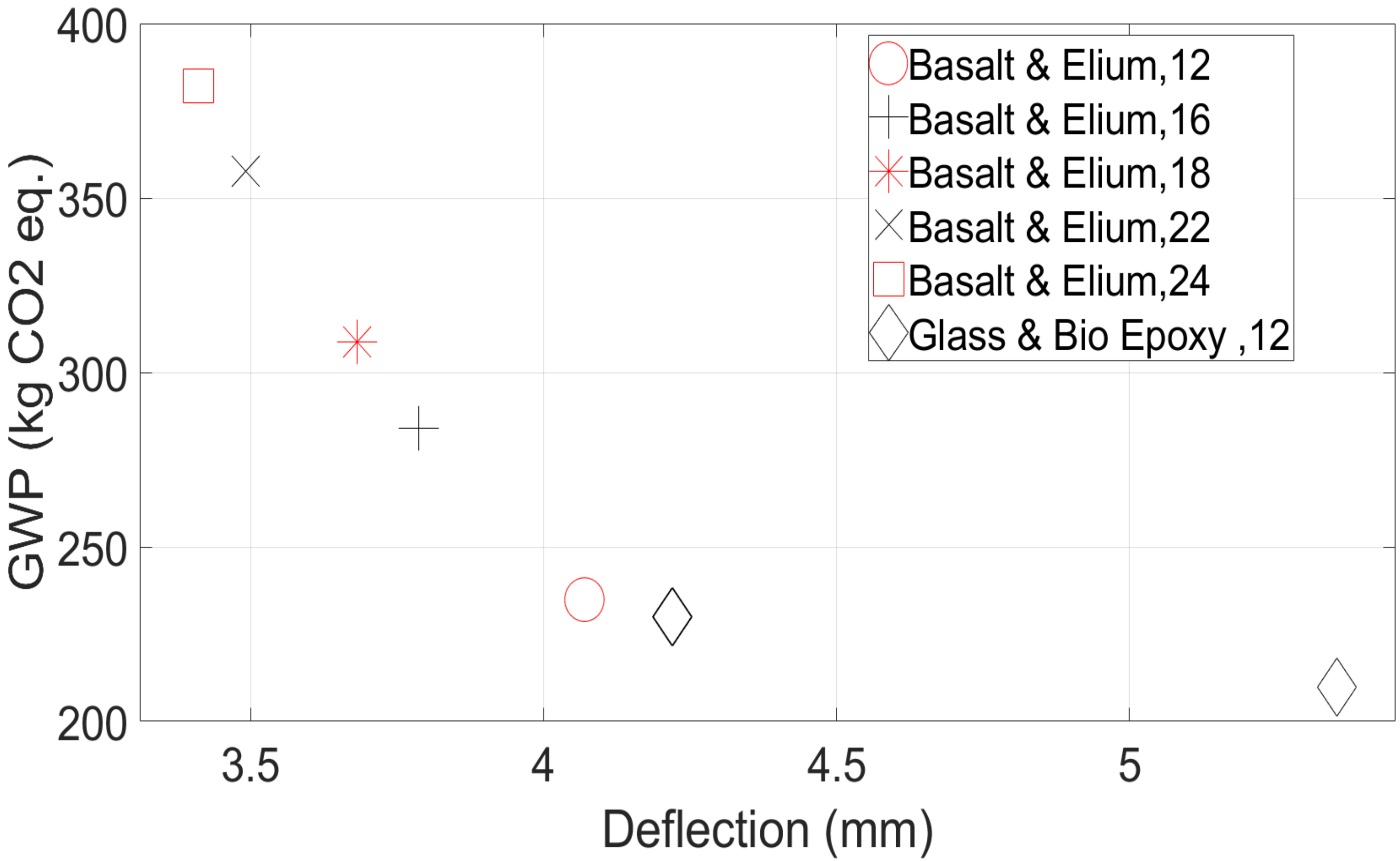
$$Minimise\ f_1(x) = \frac{Pl^3}{B_1(EI)_{eq}} + \frac{Pl}{B_2(AG)_{eq}}$$

$$Minimise\ f_2(x) = EI_{eq}$$

***Subject to*:**

$$\sigma_f < \sigma_{yf}$$

$$\sigma_f < \frac{3\ E_f^{\frac{1}{3}} E_c^{*\frac{2}{3}}}{(12(3 - v_c)^2(1 + v_c)^2)^{\frac{1}{3}}}$$



Conclusions and Future Work

Scenario	Facing material – Layup
Mechanical performance preference	Glass & Bio Epoxy - $[(0/90)_W]_{12}$
Balanced	Basalt & Elium - $[(0/90)_W]_{12}$
Environmental performance preference	Basalt & Elium - $[(0/90)_W]_{16}$

- Demonstrated an integrated Life Cycle Engineering framework incorporating LCA, LCC and Functional performance analysis and applied to marine industry
- Lack of applicable Life Cycle Inventory (LCI) data on basalt, flax and glass reinforcements
- Need for clearer targets for LCA data – relative vs absolute

Acknowledgements

- Professor Richard Trask, Professor Ian Hamerton and Dr Marco Longana for their supervision
- Greenboats for provision of ampliTex 5040
- Arkema for provision of Elium 188XO resin
- Dr Luca Andena, Stefano Tagliabue, and Lorenzo De Noni (Polimi)

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Thank you for listening. Any questions come and find me at my poster!

will.proud@bristol.ac.uk

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A computational chemistry approach to modelling high strain rate viscoelastic materials

Matthew Bone

Brendan Howlin

Ian Hamerton

Terence Macquart

University of BRISTOL

EPSRC Centre for Doctoral Training in Composites Science, Engineering and Manufacturing

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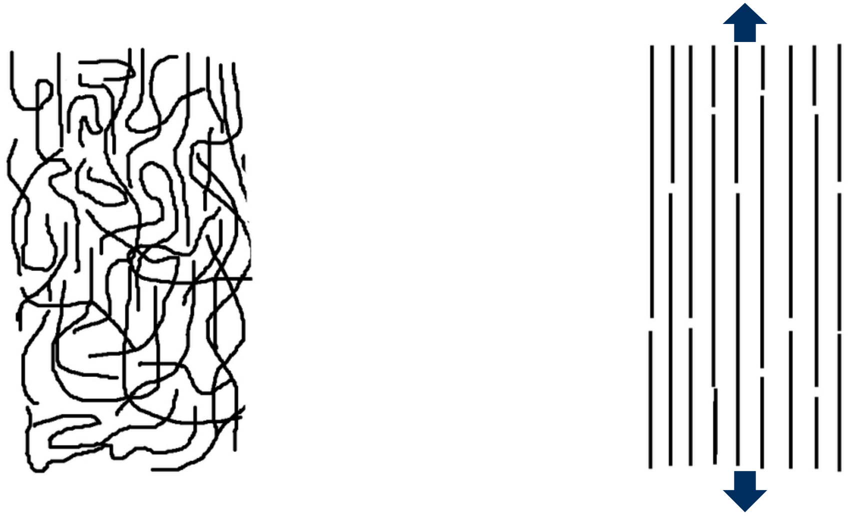
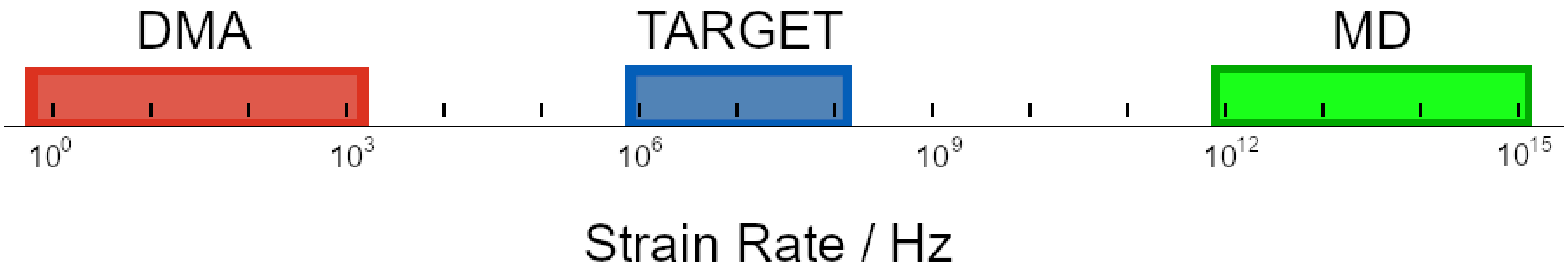
Viscoelasticity

- Materials with viscous liquid and elastic solid properties
- Polymer chains rearrange as strain is applied
- Time dependence key for fast droplet impacts



High Strain Rate Viscoelasticity

- Wind turbine droplet impact strain rate 10^6 – 10^8 Hz
- DMA unable to directly measure target range
- MD exceeds target range – can work backwards



University of BRISTOL
Bristol Composites Institute
matthew.bone@bristol.ac.uk
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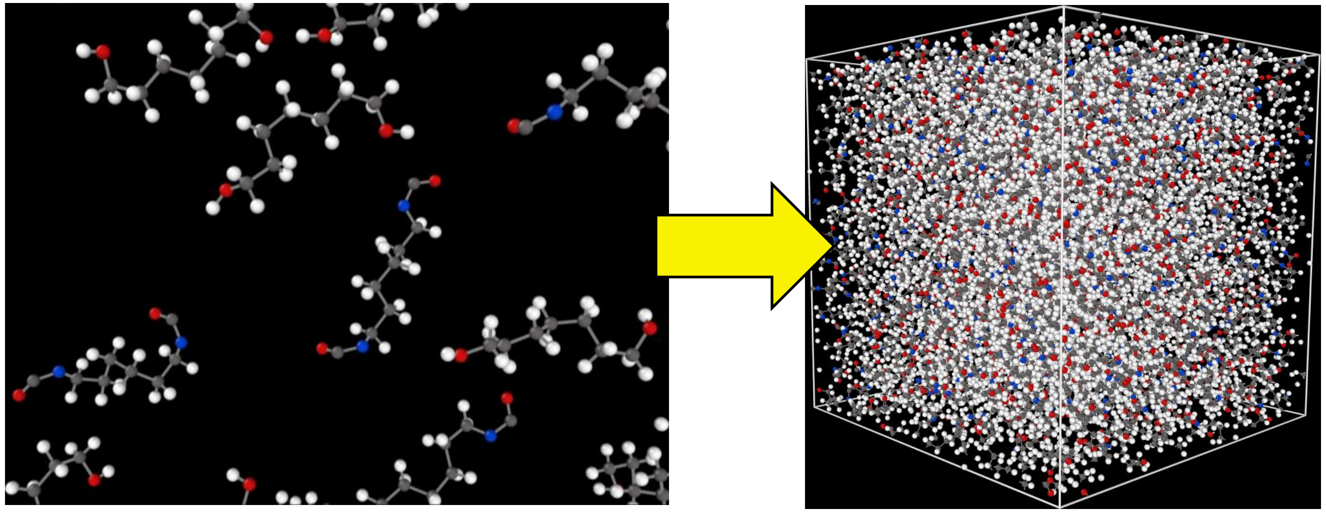
Molecular Dynamics

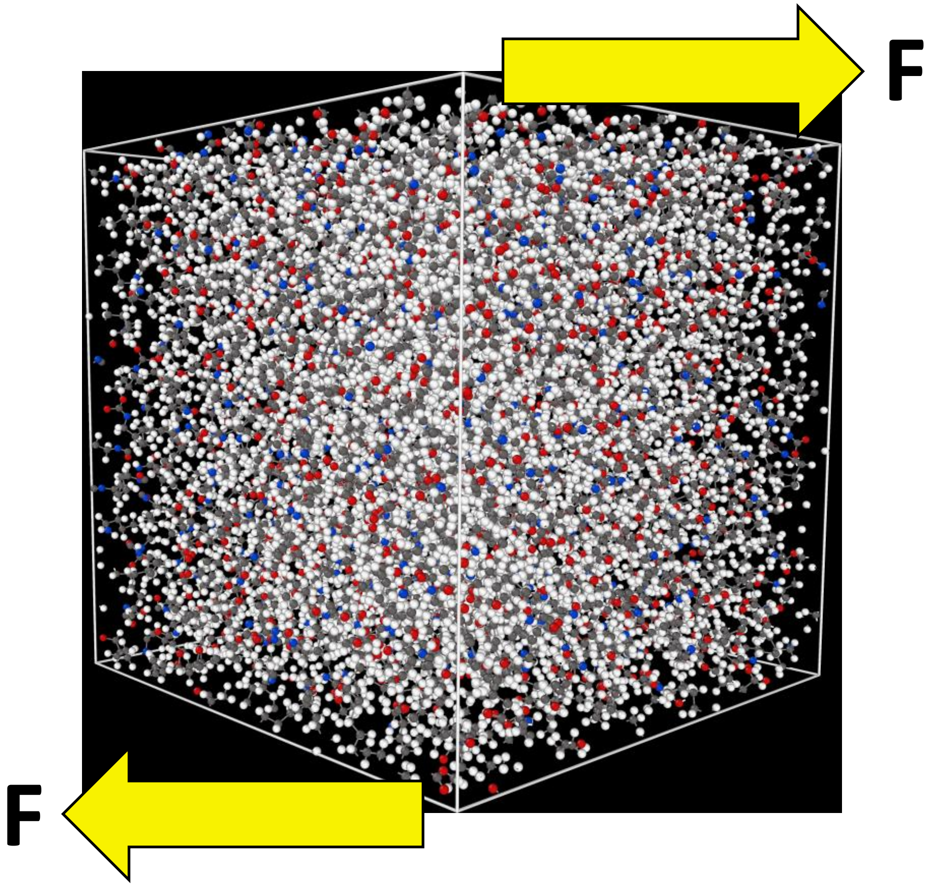
- Modelling chemistry using classical mechanics
- Model large repeating structures like polymers
- Enable rapid exploration of material design space



matthew.bone@bristol.ac.uk

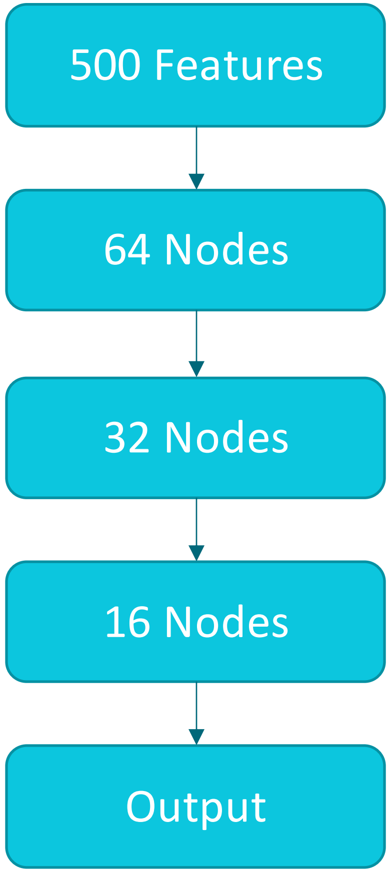
MD Predictable Properties

- Glass Transition Temperature (T_g)
- Storage & Loss Modulus
- Density and Free Volume
- Degree of Crosslinking
- Coefficient of Thermal Expansion (CTE)
- Young’s Modulus
- Shear Modulus
- Poisson’s Ratio
- Yield Stress



Machine Learning

- Current MD simulations: 24 – 36 hrs
- Eliminate MD simulation through prediction
- Using small neural network architecture
  - Low computational cost to train



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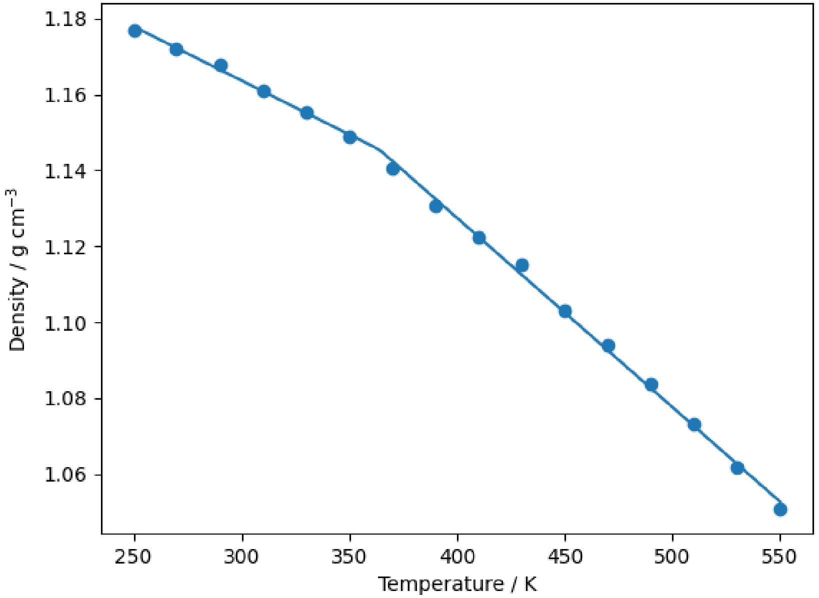
Glass Transition Temperature

- 96 characterised polyurethane models
- T_g range 320 – 450 K
- Close prediction from simple feature
  - MAE: 10-20 K; RMSE: 20-30 K



Conclusion

- ML use significantly reduces runtime – 75% reduction
- Rapidly identify the T_g of polyurethane coatings
- Use same methodology to explore viscoelastic properties in polyurethanes

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Questions?
Come find my poster!

Email: matthew.bone@bristol.ac.uk

Acknowledgements
Supervisors: Brendan Howlin, Ian Hamerton, Terence Macquart
Funding: EPSRC

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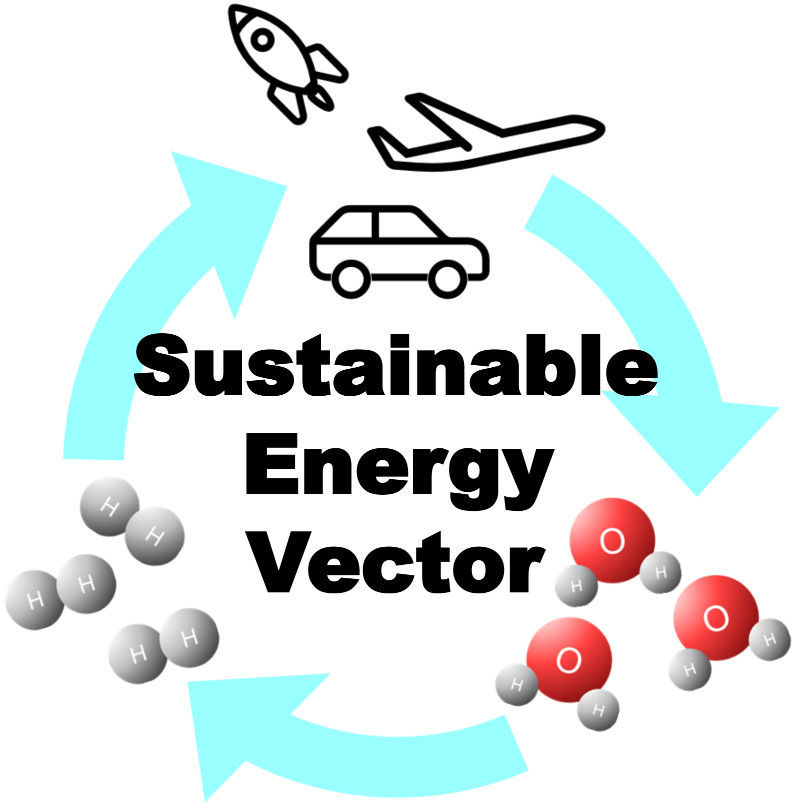
Microporous Carbon/Sulfur Composites for Hydrogen Storage

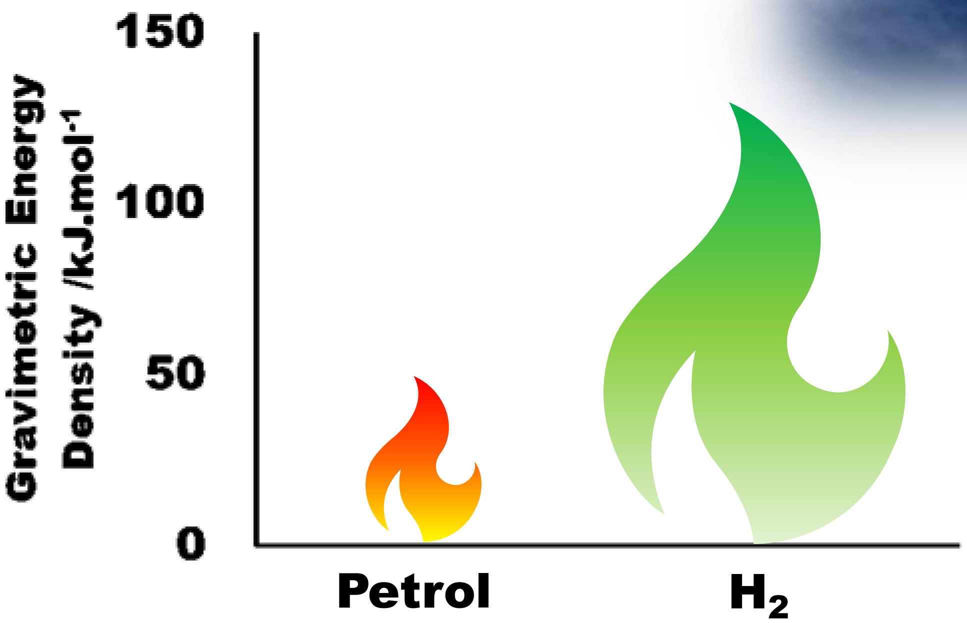
Charles Brewster, Lui R Skytree, Sebastien Rochat, Valeska P Ting

2022 Doctoral Research Symposium

12/04/2022

Why should we care?

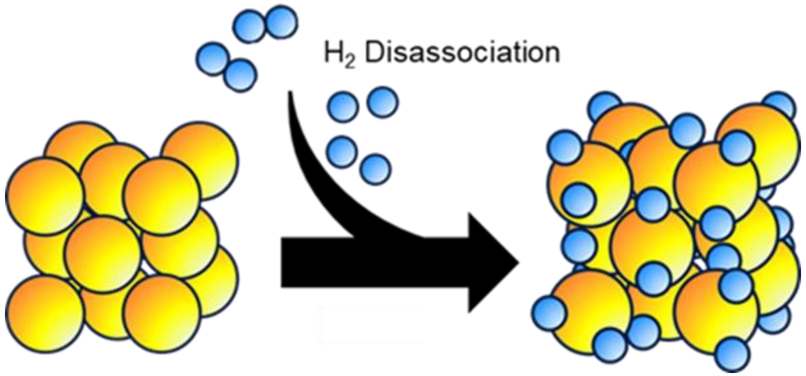




Concept

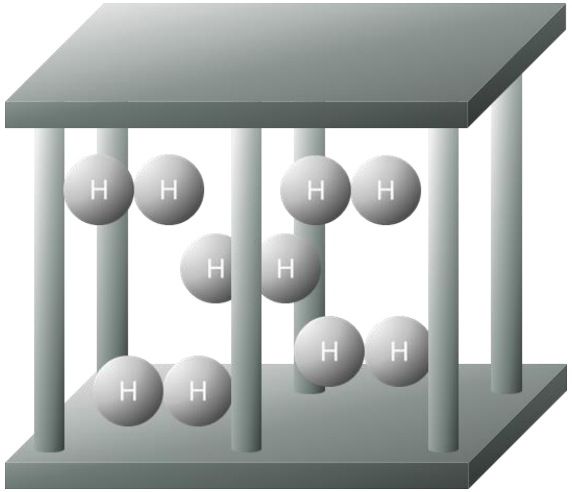
Composite-based Solution

Hydrides



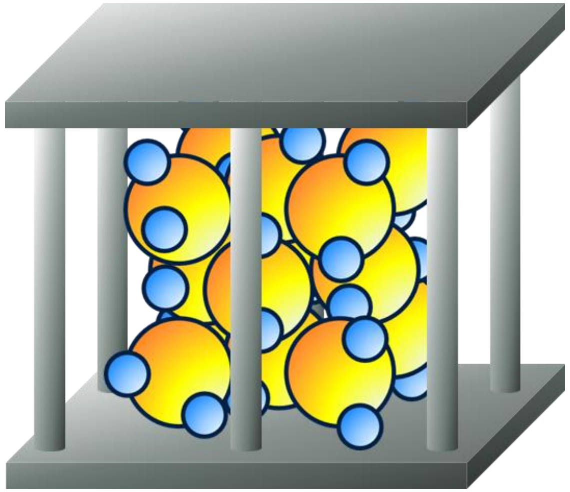
- ✓ High volumetric and gravimetric hydrogen densities.
- × Poor cyclability.
- × Unfavourable pressure and temperature.
- × Long recharge times

Nano-porous Material



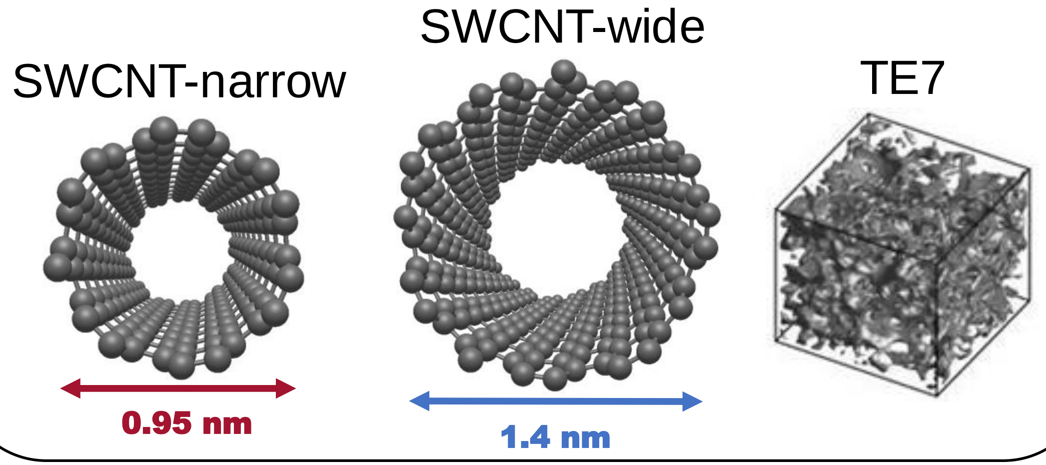
- ✓ Full discharge.
- ✓ Good cyclability.
- × Requires cryogenic conditions.
- × Low Volumetric hydrogen density.

Nanoporous Composite



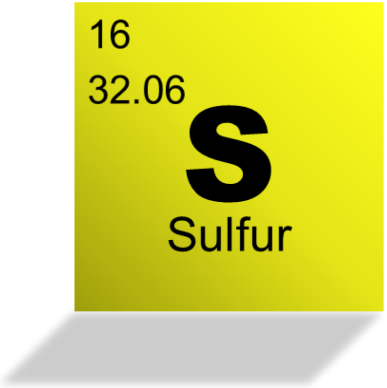
Materials

Porous Material

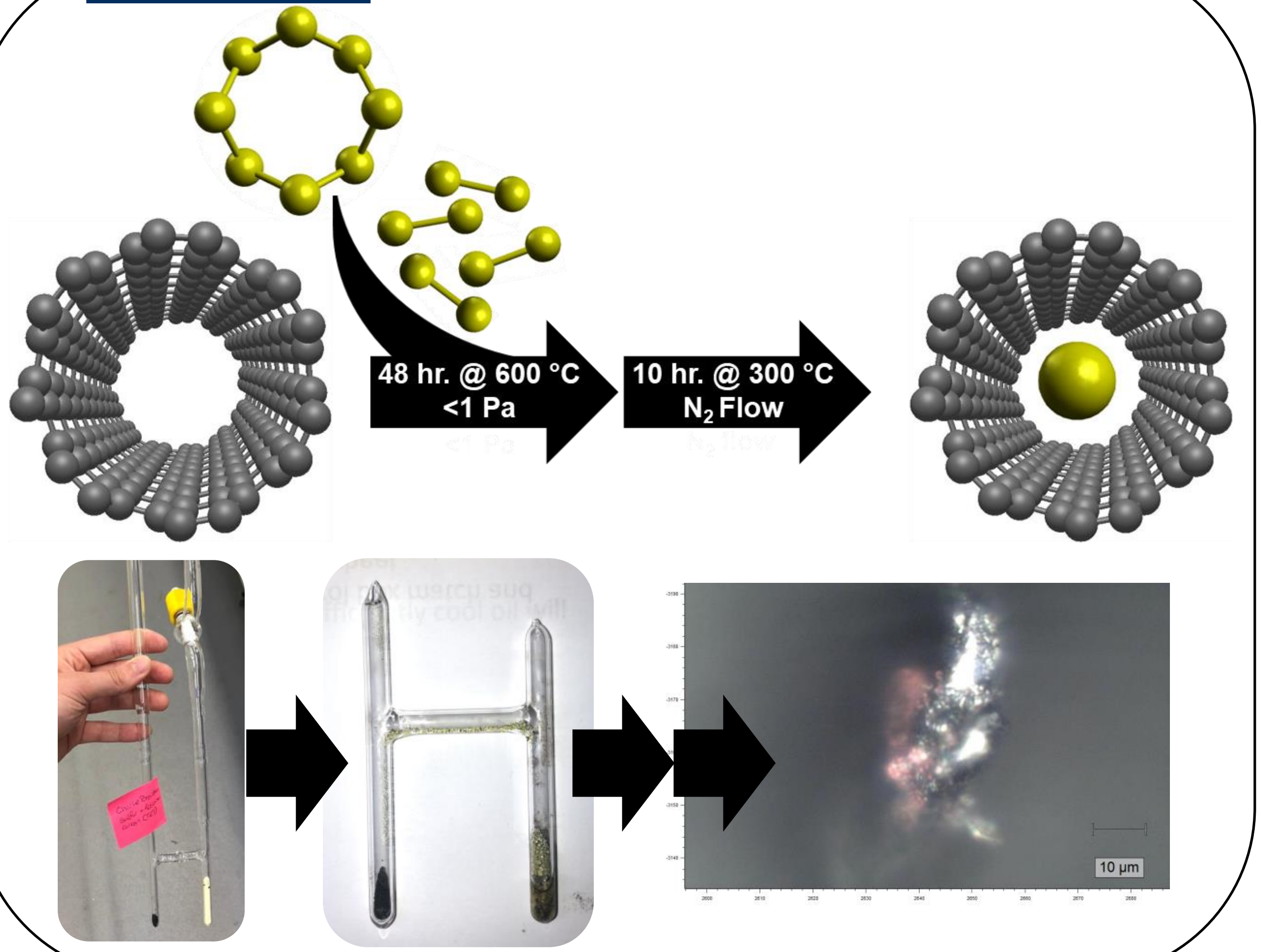


Heteroatom

- Inexpensive waste material.
- Non-hazardous.
- Boiling point = 445 °C.
- Predicted improved H_2 sorption in SWCNTs.

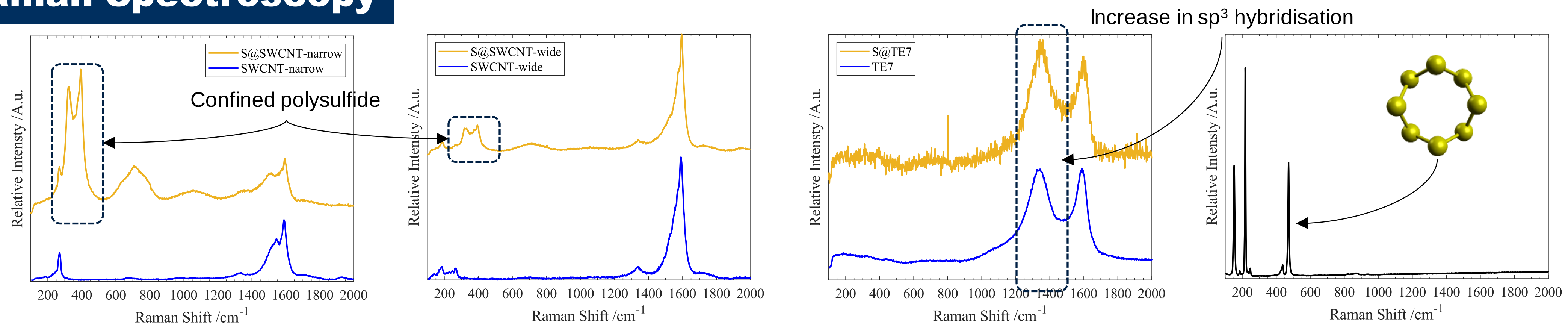


Synthesis

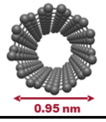
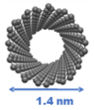


Results

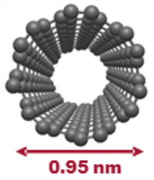
Raman Spectroscopy



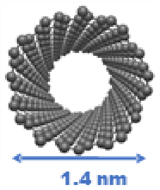
N_2 Gas Sorption

	Sample	Specific Surface Area /m².g-1		Pore Volume /cm³.g⁻¹	
	SWCNT-narrow	869±2	↓	0.95	↓
	S@SWCNT-narrow	752±6		0.94	
	SWCNT-wide	1011±3	↓	0.95	↓
	S@SWCNT-wide	764±2		0.78	
	TE7	1200±2	↓	0.68	↑
	S@TE7	1008±6		0.71	

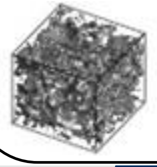
H_2 Sorption



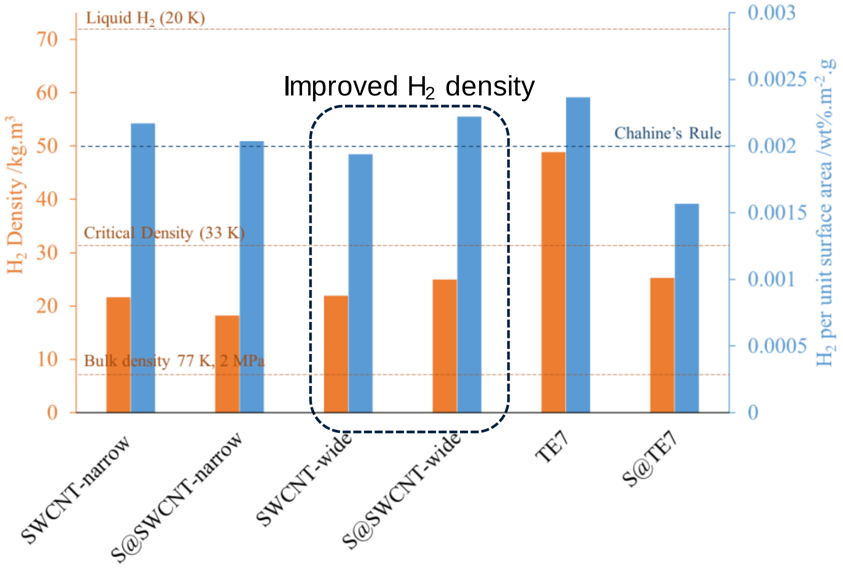
- -6.0% H_2 per SSA
- -15% H_2 density



- +15% H_2 per SSA
- +14% H_2 density



- -33% H_2 per SSA
- -48% H_2 density



Summary

- Proven synthesis and determined structure by **matching similarities to literature**.
- Determined the **BET surface area** and pore size distribution using N_2.
- **Evaluated the H_2 sorption** performance of the composite materials.
- Maintaining the integrity of **micropores is vital for hydrogen storage**.

Future Work

- Identify the location of hydrogen within the material via **neutron scattering**.
- Determine origin of enhancement through **Raman Spectroscopy**.
- Conduct low-pressure H_2 sorption experiments to determine **enhanced monolayer surface packing.**

Acknowledgements

Special thanks to:

Dr Lui Skytree

Dr Sebastien Rochat

Prof. Valeska Ting

CDT19

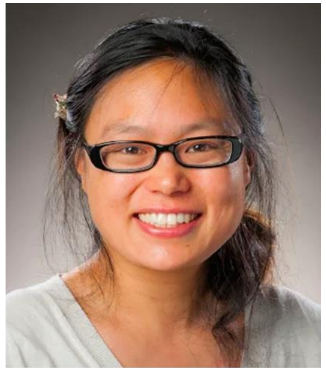
Ting-group

ONE-group

Supervisory Team

Dr Lui Skytree

Dr Sebastien Rochat



Prof. Valeska P Ting

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For a discussion please visit (and vote for) my poster

c.d.brewster@bristol.ac.uk

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Advanced High-Fidelity Modelling of Woven Composites

Ruggero Filippone

BCI Symposium

12 April 2022

University of BRISTOL
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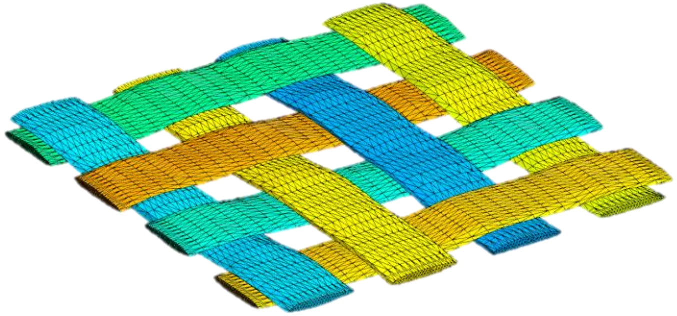
Advanced High-Fidelity Modelling of Woven Composites

Project Objectives

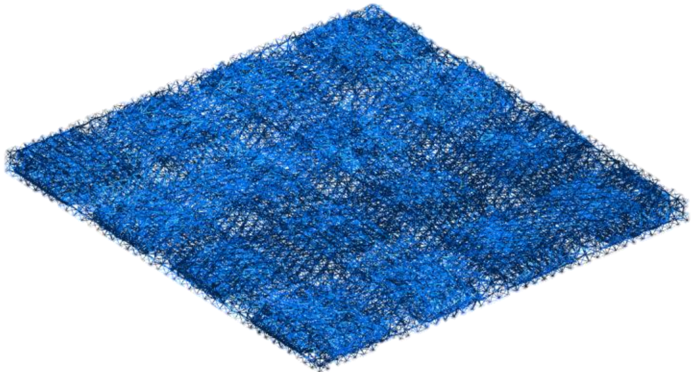
This research aims to investigate the mechanical behaviour from the fibre/matrix constituents up to the components level to characterise woven composite materials.

Developing a cutting-edge modelling capabilities for meso-scale damage in woven textile composites.

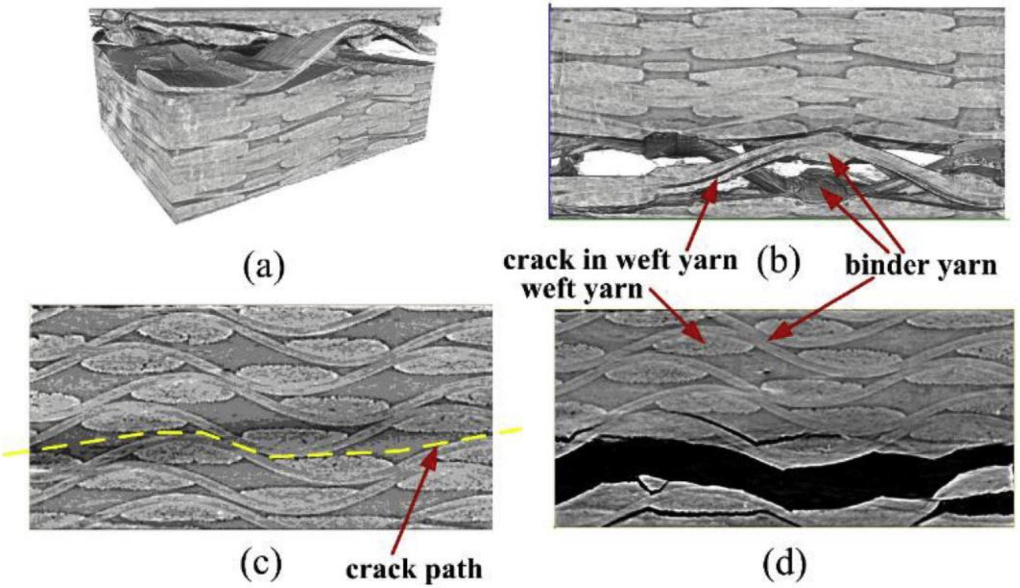
- Enhanced Meso-scale model framework.
- Investigation of premature failure of 3D woven composites due to debonding failures.



2D Woven Fabric structured mesh



Matrix structured mesh



Delamination following debonding failure. *Zhixing Li et ali.* (2018)

Advanced High-Fidelity Modelling of Woven Composites

Multi-Scale Framework

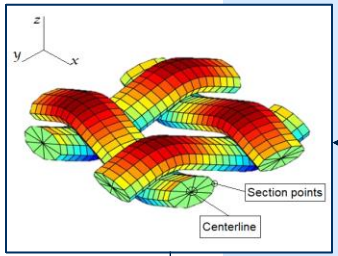
Geometric Simulation Algorithm

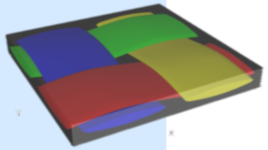
From the features of the woven fabric, a representative unite cell is modelled in order to obtain a real shaped model, simulating the fabric compaction process.

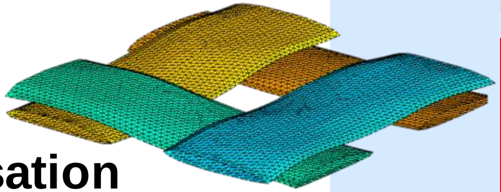
Key points of Mechanical Characterisation

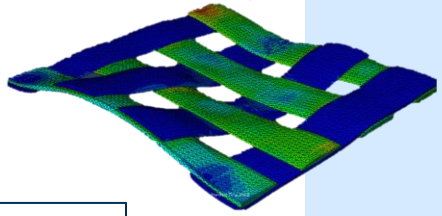
- High Fidelity structured mesh for *RUC*
- Cohesive mesh generator
- Dedicated mechanical damage model propagation and Cohesive Law

Transition region from pure matrix to the yarn









Meso-Scale Modelling

Geometric Simulation Algorithm

- TexGen geometry modelling
- Input of basic fabric parameters
- LS-Dyna textile Compaction Simulation
- Geometry output .csv

Mechanical Characterisation

API Algorithm
- RUC geometry generator
- Conformal and Cohesive Mesh generation
- FEA Subroutine implementation

Finite Element Analysis

Continuum Damage Model and Cohesive Law implementation

Post-Processing: Mechanical Properties

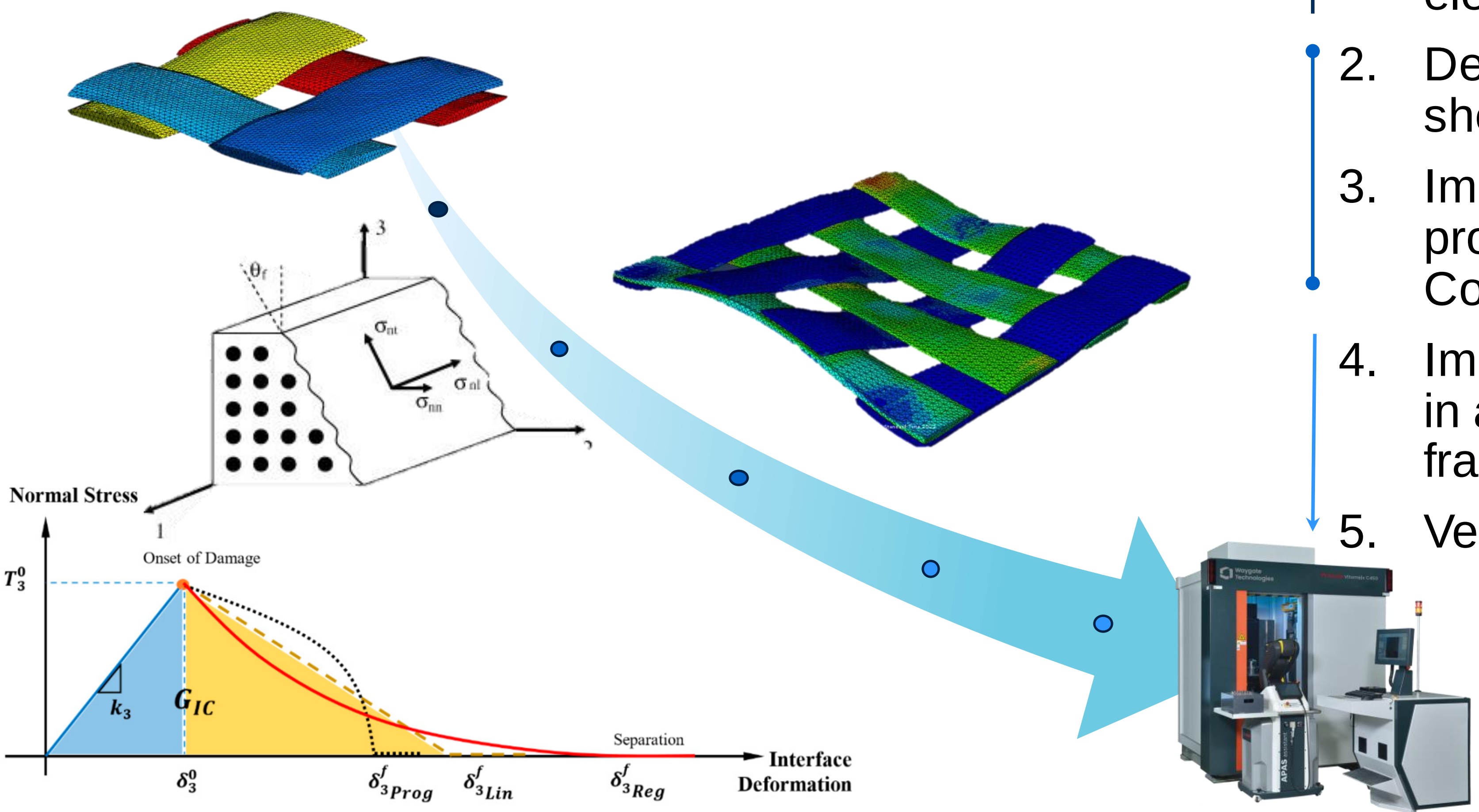
Micro-Scale Analysis

Mechanical properties of the components

Macro-Scale Analysis

Advanced High-Fidelity Modelling of Woven Composites

Milestones of the project



1. 3D Woven dedicated conformal meshing methods with cohesive elements.
2. Dedicated matrix modelling including shearing non-linearity.
3. Implementation of specific damage progression algorithms and Cohesive Law
4. Implementation of damage models in an implicit Multi-Scale integration framework.
5. Verification against CT-scans.

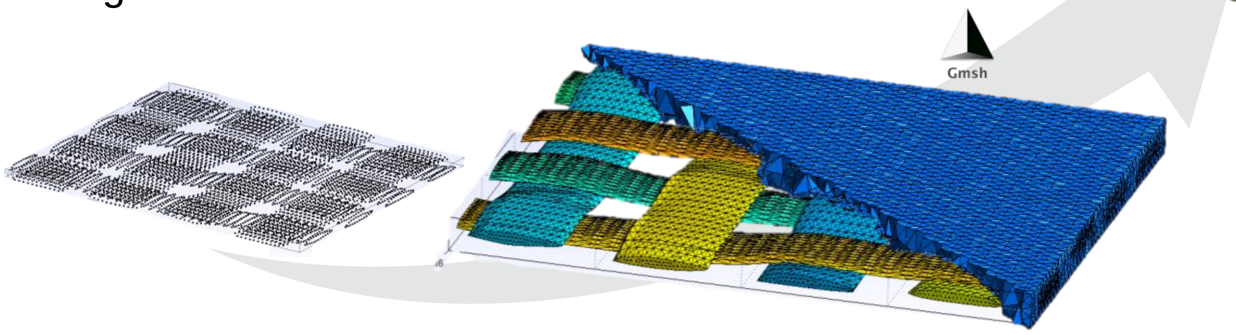
Advanced High-Fidelity Modelling of Woven Composites

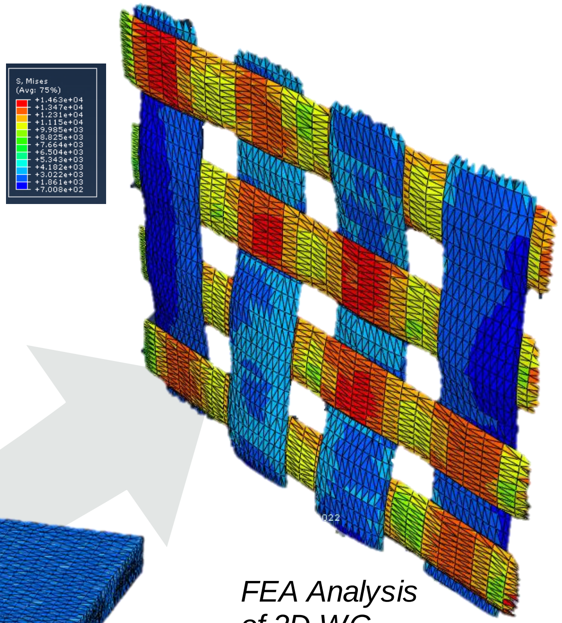
Achievements

- **High-Fidelity meso-scale model framework of woven composites**

1. Structured mesh generator of Representative Unite Cell of Woven Composites.
2. FEA subroutine to run simulation with cohesive elements.

3. <u>Computational enhancements</u>: Reduced computational time and detailed stress gradients.



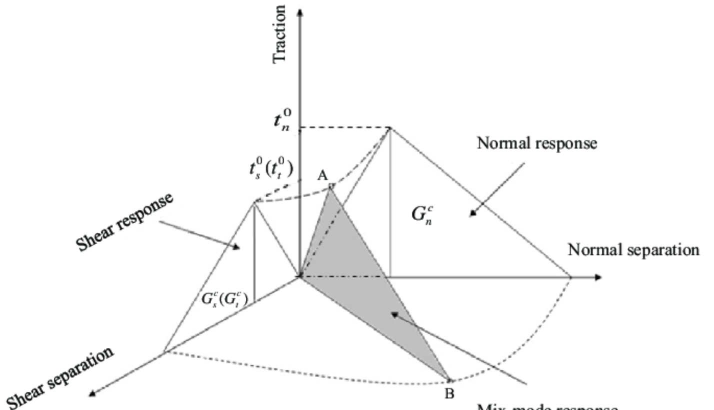


FEA Analysis of 2D WC

Working On

- Investigation of Yarn/Matrix debonding damage model, exploiting the cohesive elements.

- Enhancement of Damage progression algorithm for structured mesh



Chao Zhang et ali. (2015)

Acknowledgements

The authors wish to acknowledge the support of Rolls-Royce plc through the Composites University Technology Centre (UTC) at the University of Bristol and the EPSRC through the ACCIS Centre for Doctoral Training grant, no. EP/G036772/1.“

And all my supervisors:

Bassam Elsaied, Adam Thompson, Peter Foster and Stephen Hallett

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Advanced High-Fidelity Modelling of Woven Composites

Ruggero Filippone

r.filippone@bristol.ac.uk

Thank you.

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Architecture optimization of 3d-printable lattice structures with an evolutionary-based approach

Athina Kontopoulou, Bing Zhang, Fabrizio Scarpa, Giuliano Allegri

BCI Doctoral Research Symposium

12th April 2022

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Motivation

- Lattice structures:
  - Periodic structures characterized by the repetition of a unit cell.
  - Mechanical properties depend on the material and the topology of the unit cell.

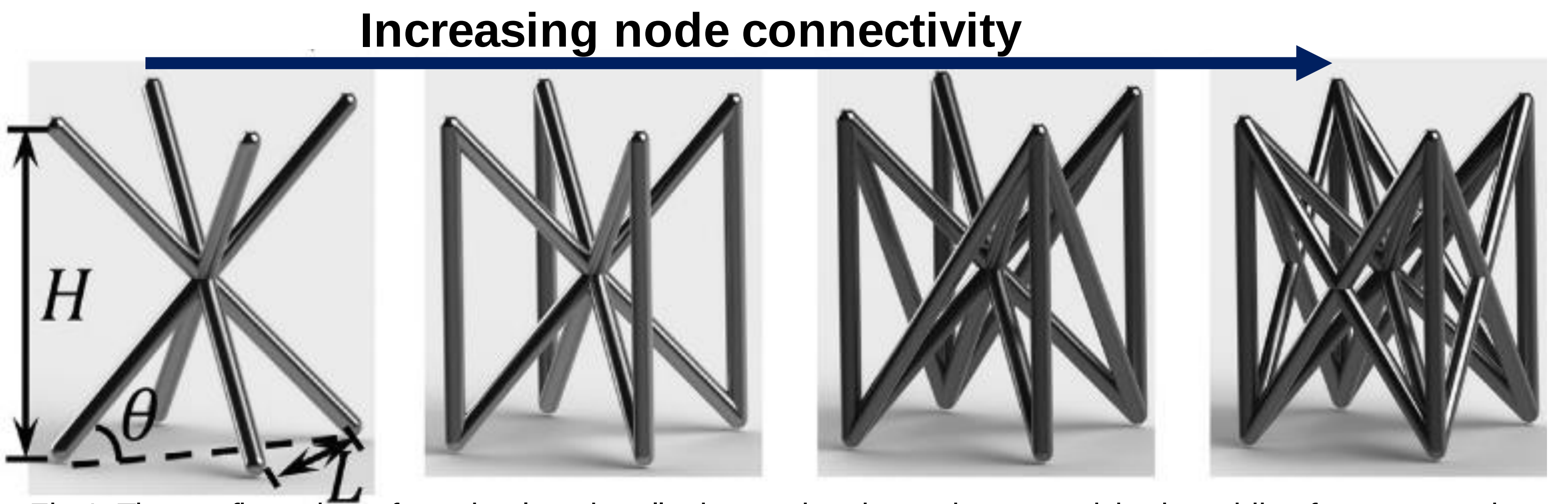


Fig.1: The configuration of quadruple unit cells, increasing the node connectivity by adding face centered, diagonal struts to one and two directions [1].

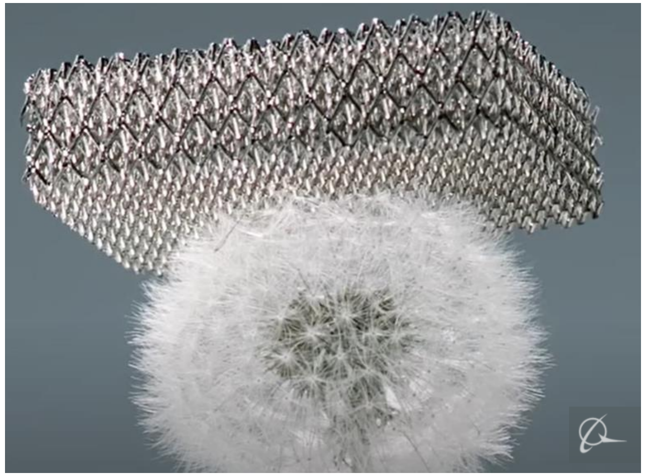


Fig.2:The lightest metal microlattice [2].


Fig.3: Thin-wall structure and lattice in-fills for the deep-space probes of the moon [3].

Computational approach

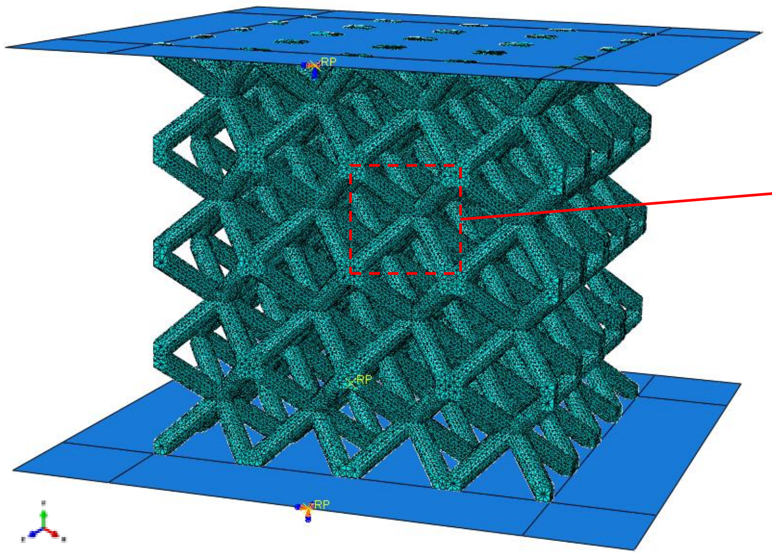


Fig.4: Lattice structure of body centered configuration.

Representative Volume Element

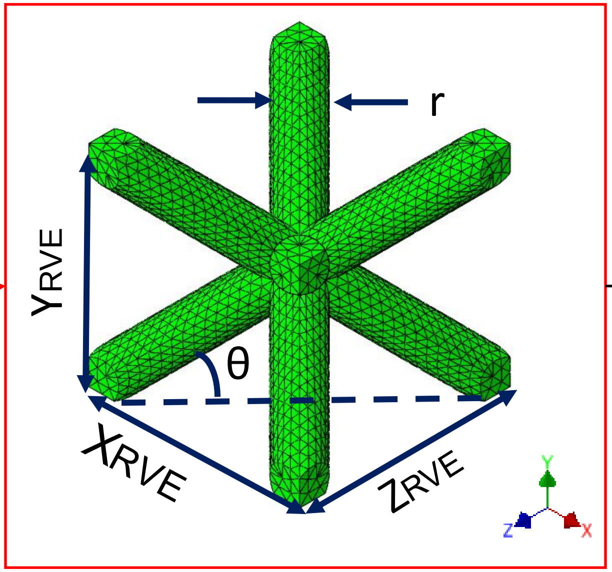
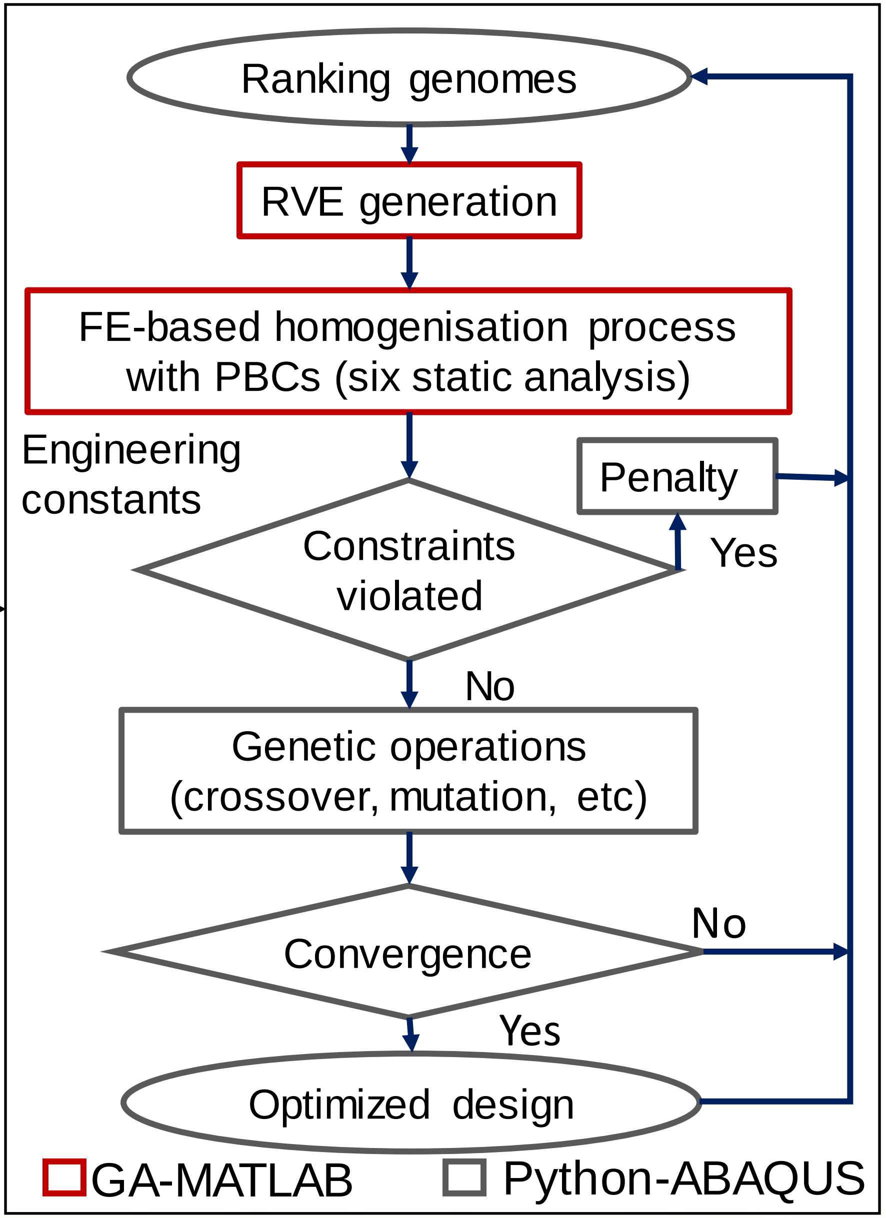


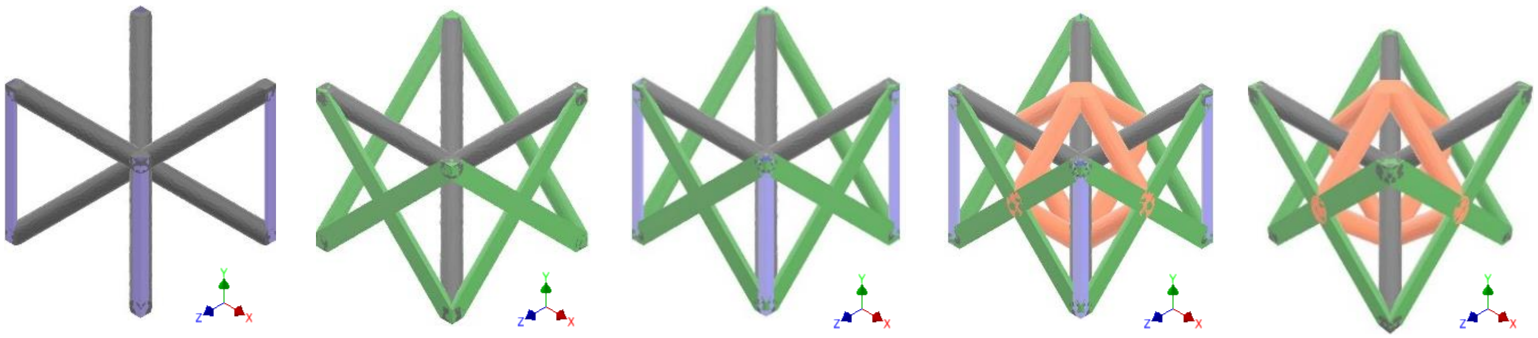
Fig.5: Unit cell of body centered cubic lattice.

Variables	Lower bound	Upper bound
r	0.3 mm	0.7 mm
YRVE	5.0 mm	9.0 mm

Fig.6: The lower and upper bounds of the continuous geometric variables in the genetic algorithm.

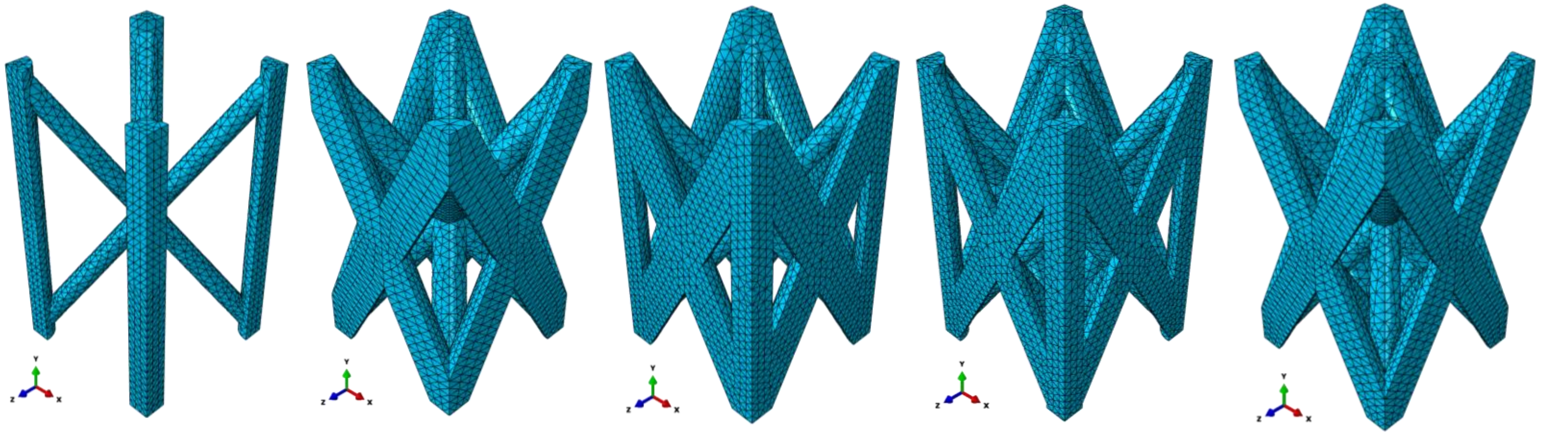


Results of a case study



(D1) (D2) (D3) (D4) (D5)

Optimization



(D1opt) (D2opt) (D3opt) (D4opt) (D5opt)

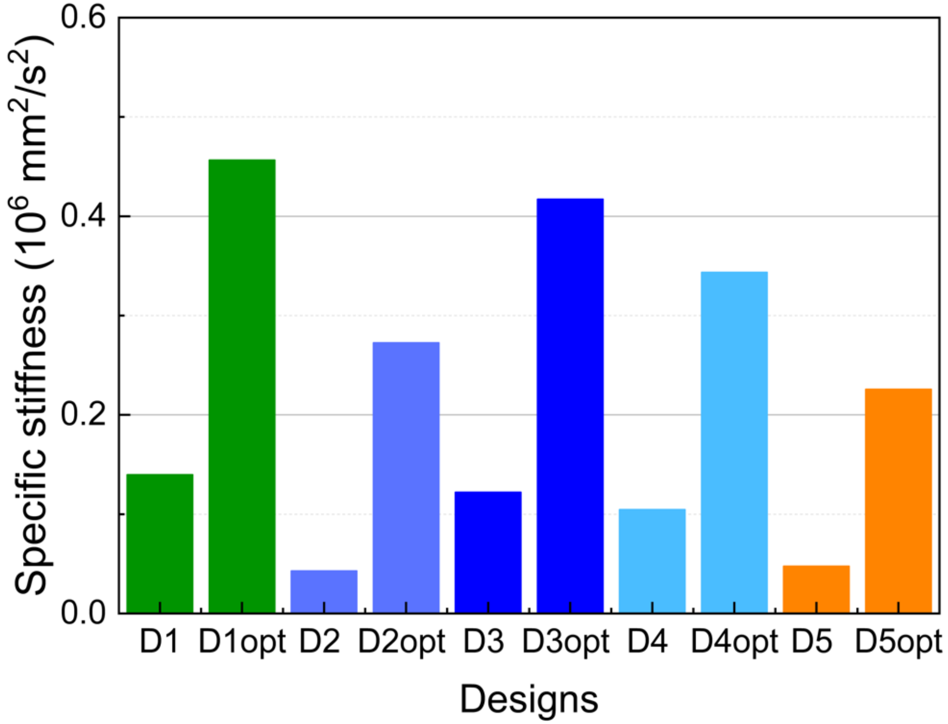


Fig.7: Bar chart of the specific compressive stiffness of the lattice RVEs (D1-D5) before and (D1opt-D5opt) after the optimization.

Conclusions & Future work

- Conclusions:
  - Increase the specific compressive stiffness of lattice designs.
  - Impose manufacturing and density constraints.
  - Investigate the effect of struts orientation to the specific stiffness.
- Future work:
  - Additive manufacturing and experimental work.
  - Investigation of vibration transmissibility properties.

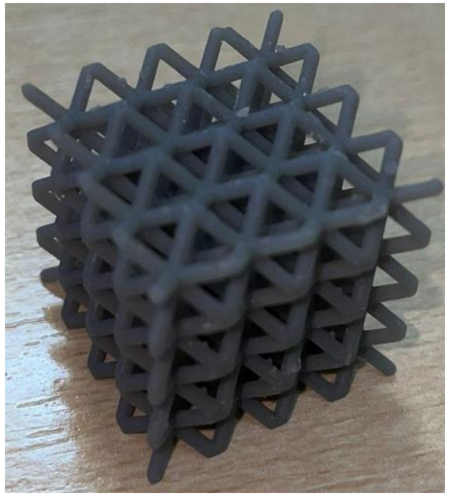


Fig.8: BCC lattice structure fabricated with stereolithography.

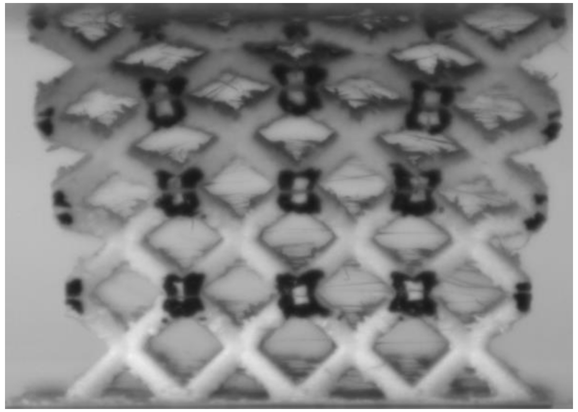


Fig.9: BCC lattice structure fabricated with Fusion Deposition Modelling under compression.

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Thank you for listening!

athina.kontopoulou@bristol.ac.uk

Acknowledgements:

- Supervisory team: Dr Giuliano Allegri, Prof Fabrizio Scarpa, Dr Bing Zhang
- Dr Riccardo Manno
- BCI Lab support Technicians

References:
[1] Energy absorption diagram characteristic of metallic self-supporting 3D lattices fabricated by additive manufacturing and design method of energy absorption structure (2021), Zhang et al.
[2] https://www.youtube.com/watch?v=k6N_4jGJADY&ab_channel=Boeing
[3] Design of self-supporting lattices for additive manufacturing (2021) Zhou et al.

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4DBioMArc: Project Overview

Joe Surmon

25/05/21

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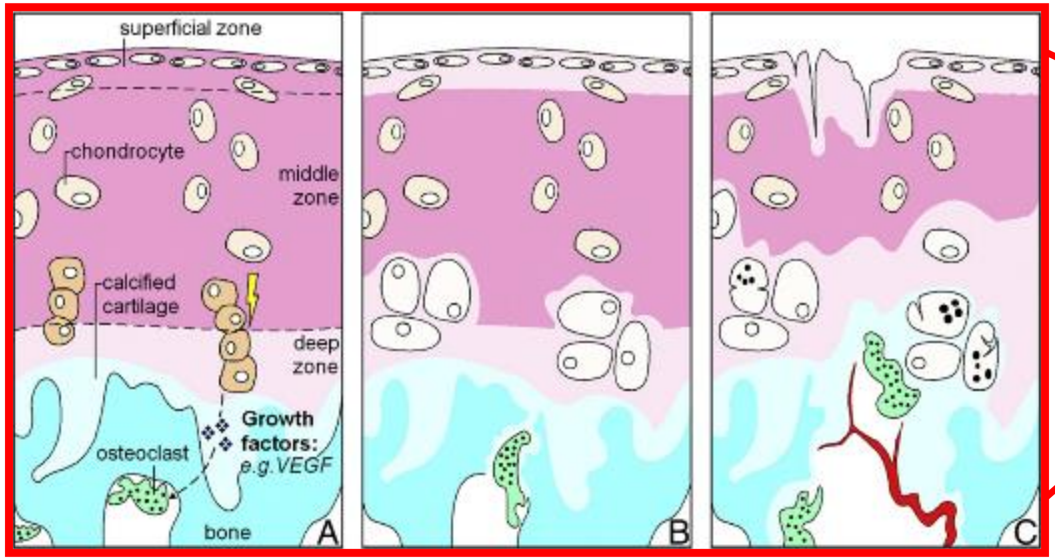
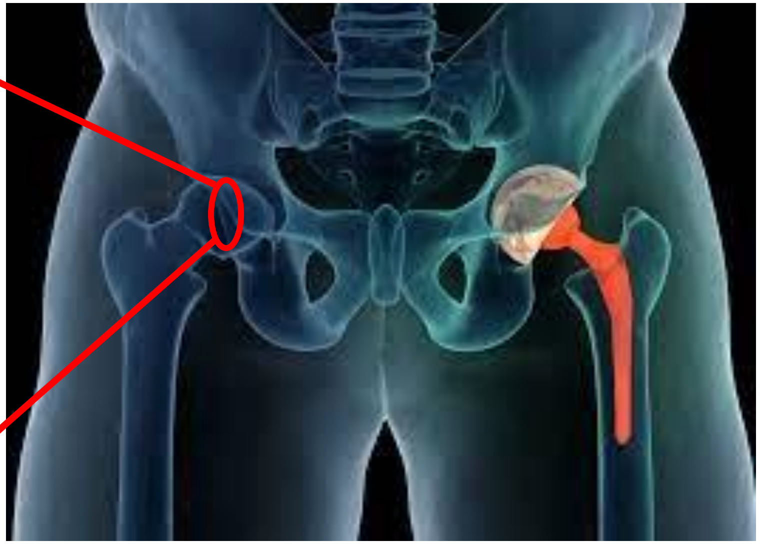
Challenge

Osteoarthritis

- Affecting hundreds of millions worldwide (>10% over 60s worldwide)
- Significantly damaging QOL, independence and mobility
- Current treatment: pain management and complete joint replacement





Gen1 – Bioinert (Metals)

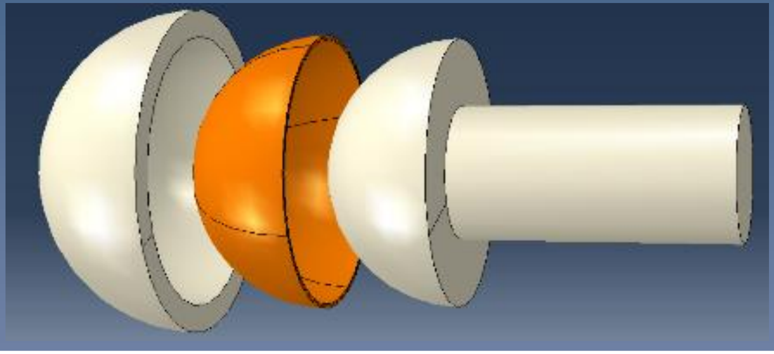
Gen2 – Bioactive (Bioglass)

Gen3 – Bioinductive (?)

Project Aims

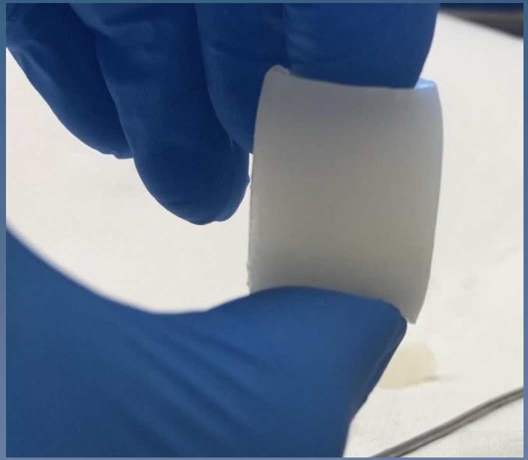
Develop soft material scaffold:

- Eliminate the need for complete joint replacement
- Allow intervention at a much earlier stage
- Improve quality of life for ageing population



Material Aims:

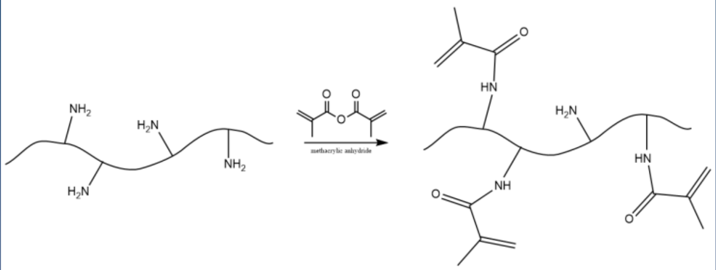
1. Biocompatible
2. Deployable
3. Mechanically robust
4. Easily of manufacture



Materials

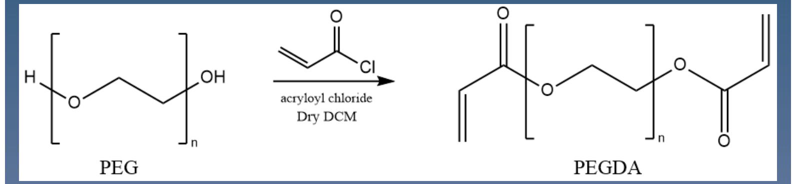
1. GelMA - Alginate DN

- Natural



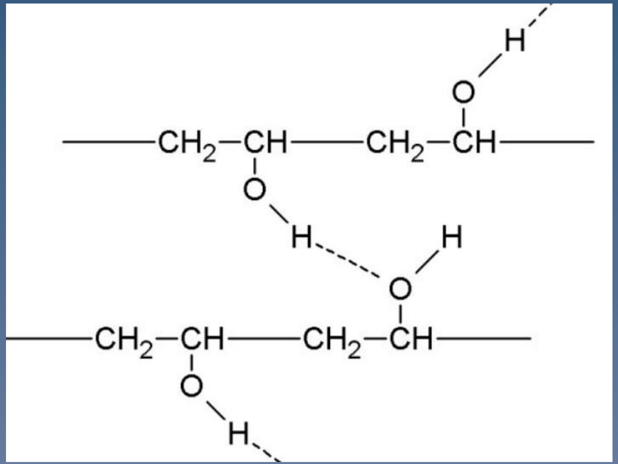
2. PEGDA – Alginate DN

- Synthetic

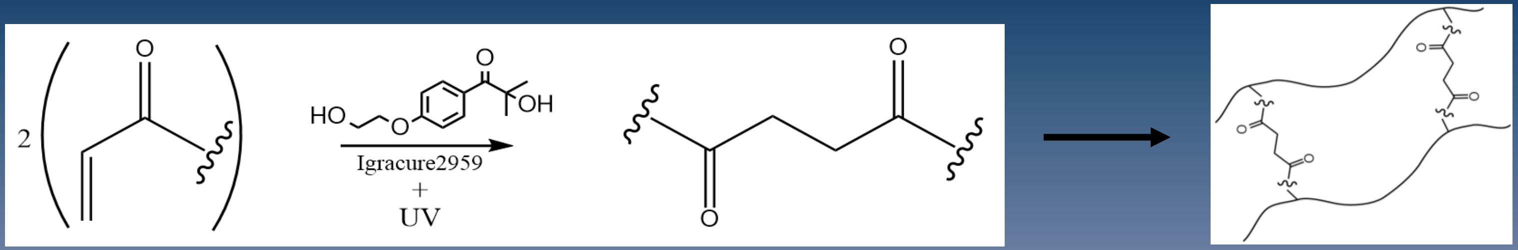


3. PVA – Alginate DN

- Hydrogen bonding
- Processability



Network Formation



Methods

Lab-based

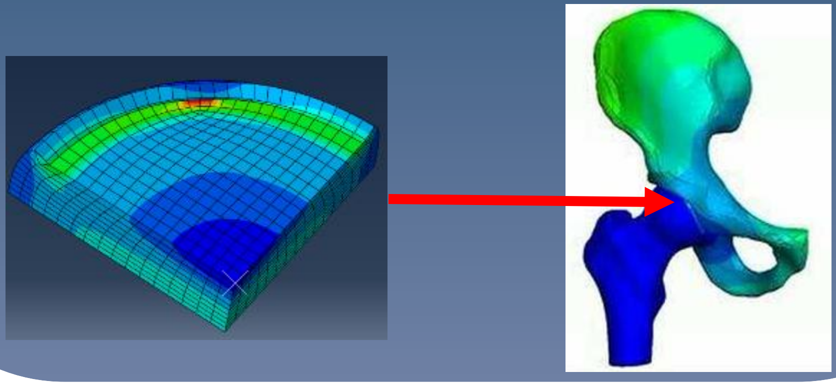
- Physical Characterisation
  - LVER Determination
  - Swelling
- Mechanical Characterisation
  - Compressive strength
  - Shear strength
  - Fatigue life

Generate Material properties

Inform and supplement experimental direction

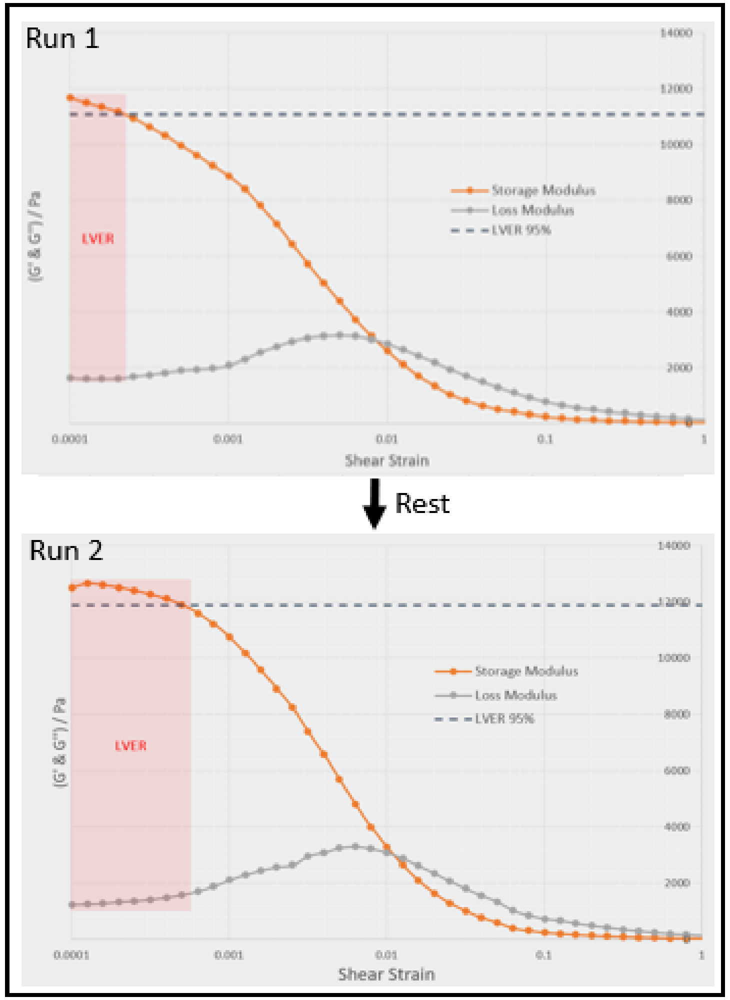
Simulation

- Parametric studies into:
  - Shear
  - Compression
- Incorporate CT hip scans



Results

- Rheological Characterisation
  - LVER Determination
  - Temperature Sweep



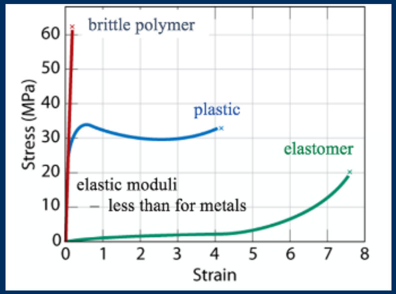
Results

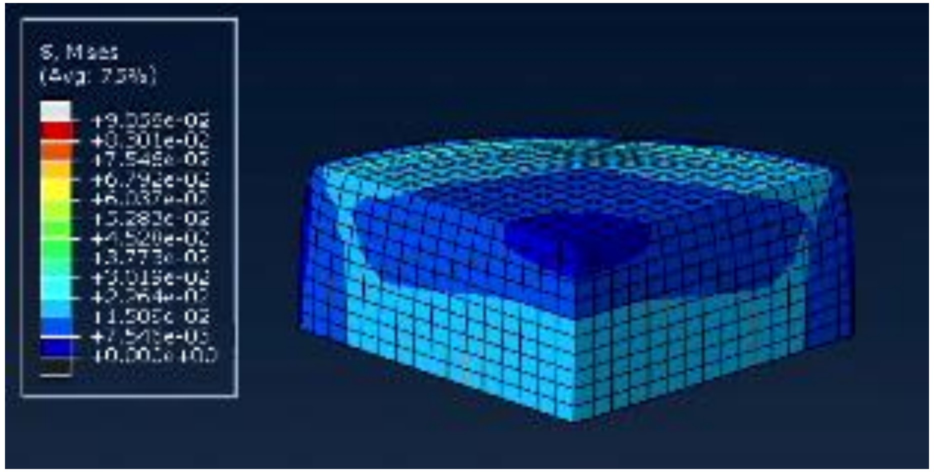
Hyperelastic Yeoh Model

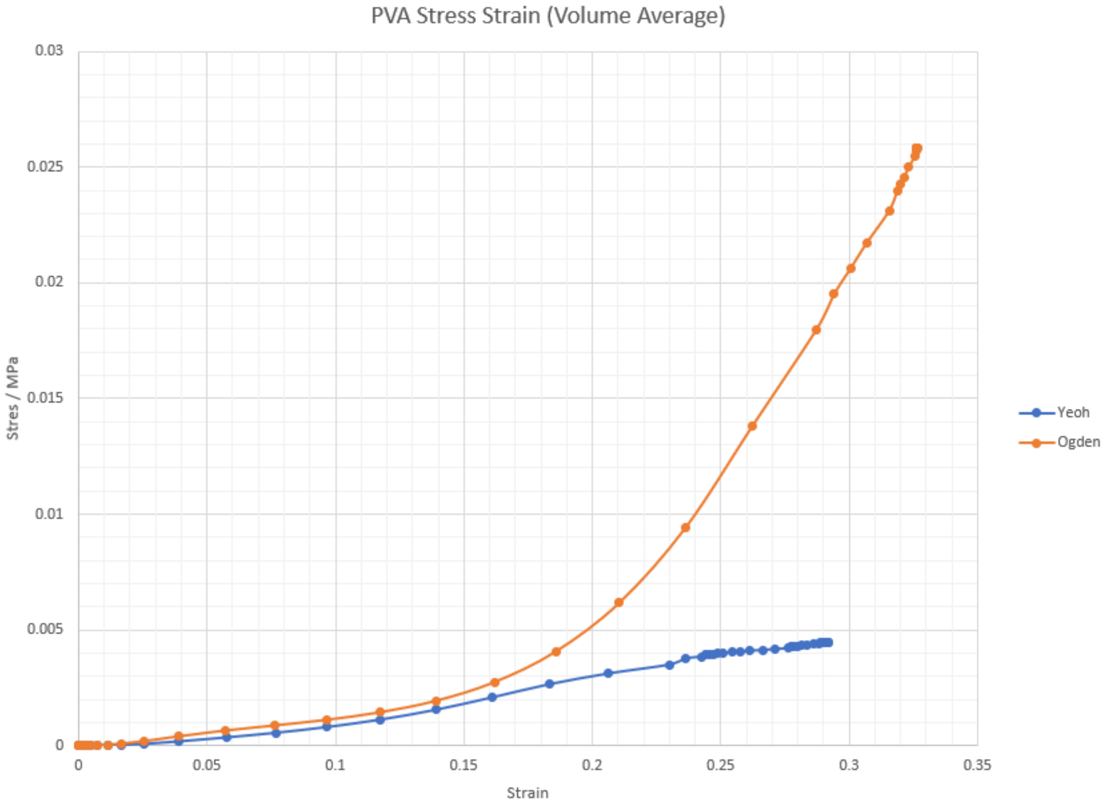
1. Rubber
2. Agarose gel
3. PVA gel

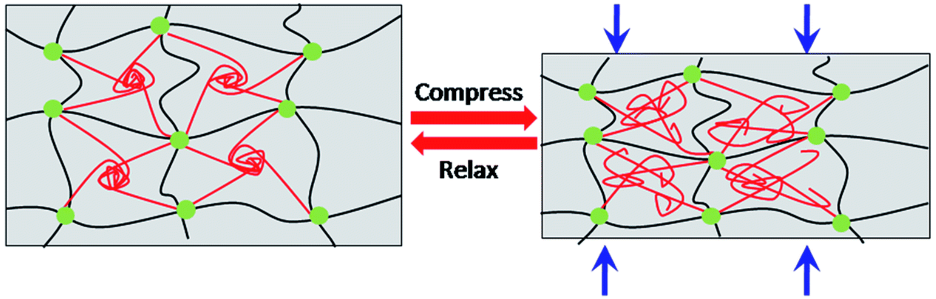
Hyperelastic Ogden Model

1. Rubber
2. Agarose gel
3. PVA gel





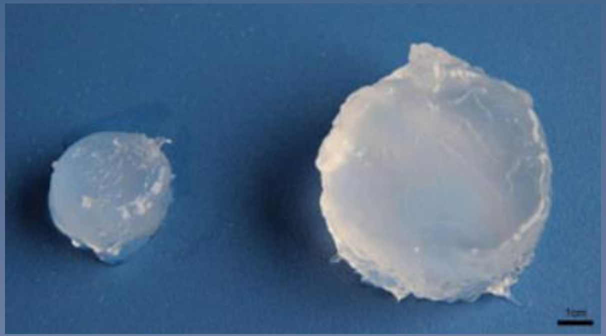




Overview

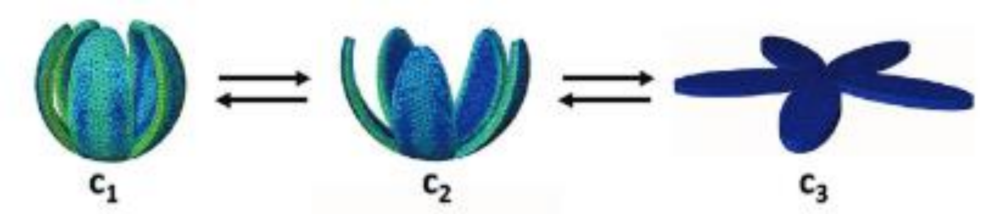
Current Work

- Gel processing and manufacture
- Physical characterisation and LVER determination
- Simulation benchmarking against literature data



Future Work

- Full mechanical characterisation
- Parametric simulation studies within hip joint
- Functionality and deployability



1. https://onlinelibrary.w iley.com/doi/10.1002/adfm.201704568
2. https://www.researchgate.net/publication/257546496_Synthesis_and_characterization_of_mechanically_flexible_and_tough_cellulose_nanocrystals-polyacrylamide_nanocomposite_hydrogels/figures?lo=1

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Thanks for listening

joe.surmon@bristol.ac.uk

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