Nanocomposite-Coated Scaffold Materials with Tailorable Hydrated Mechanical Behaviour

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Introduction

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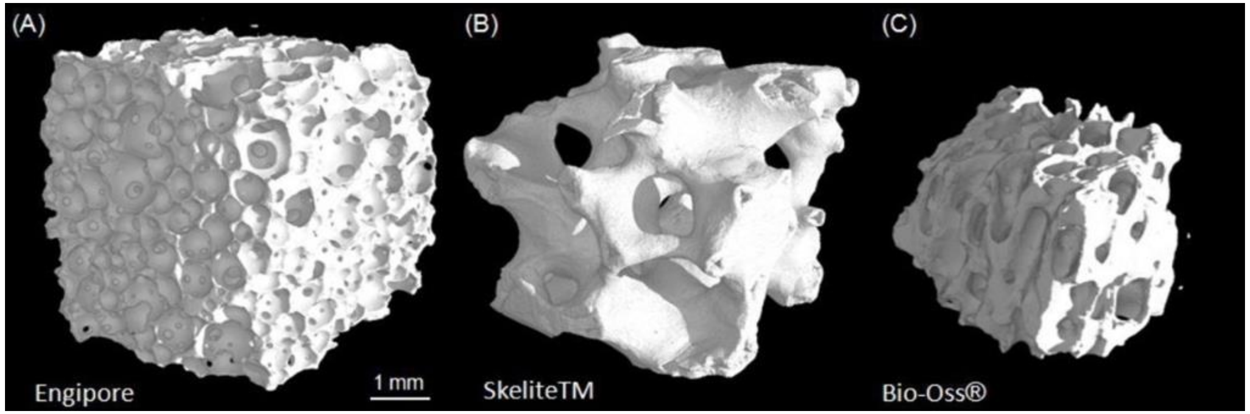
- Tissue engineering solutions are an attractive alternative to autograft treatment for bone trauma patients

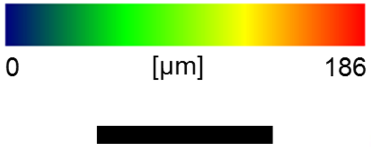
- Bone tissue scaffold development has challenges:-
  - High porosity in conjunction with suitable mechanical properties
  - Limitation in selection of materials

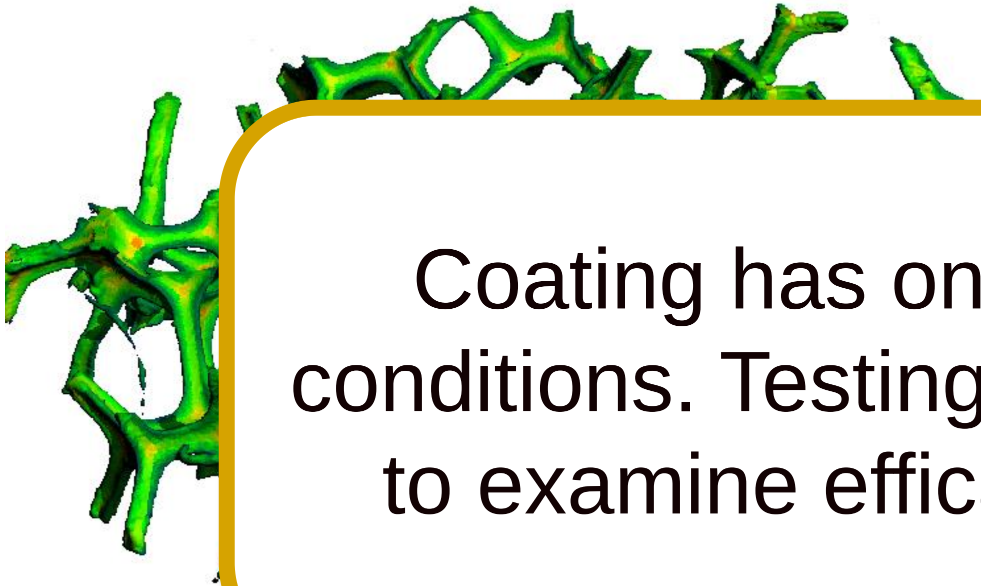


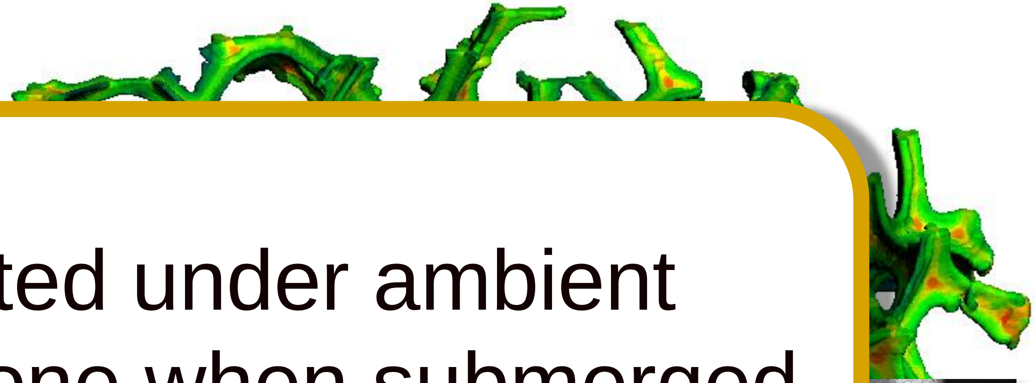
Thin film nanocomposite coating to tailor mechanical properties of open cell structures

[Image] Alessandra Giuliani, Synchrotron Radiation and Nanotechnology for Stem Cell Research, Stem Cells in Clinic and Research, **2011**

Tunable Structure of Porous Materials



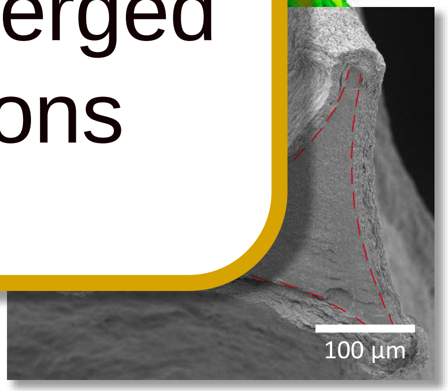




Coating has only been tested under ambient conditions. Testing must be done when submerged to examine efficacy under hydrated conditions

Un-coated

Coated



- Highly porous
- Less than desirable mechanical properties

- Slightly reduced porosity
- Tailored mechanical properties to match surroundings

–73.

Hydrated Testing Materials and Methods

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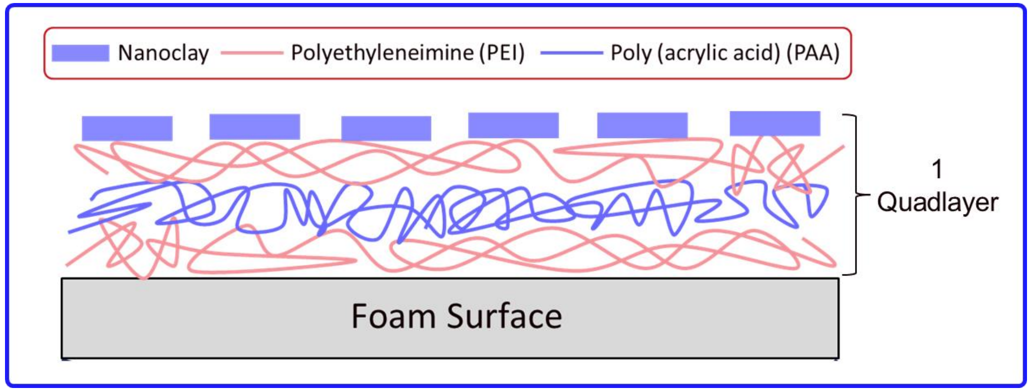
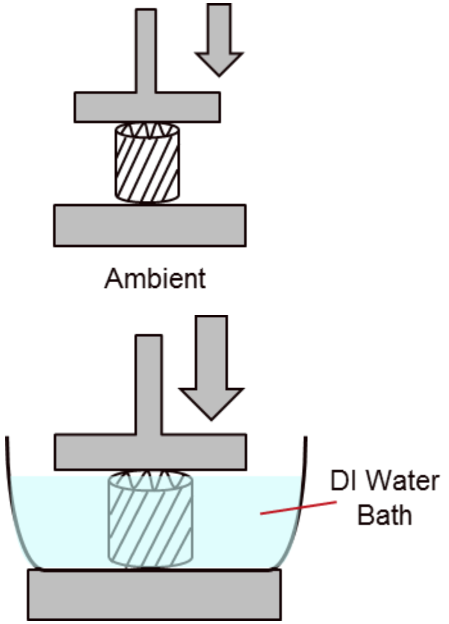
Materials

- Open cell polyurethane foam
- Coated with varying number of quadlayers of:
  - » Poly(ethyleneimine)
  - » Poly(acrylic acid)
  - » Cloisite Na^+ nanoclay



Methods

- Uniaxial compression testing
- SEM
- Surface profilometry
- MicroCT
- Mass and elastic modulus in environments of increasing RH



Coated Foam Properties when Dry

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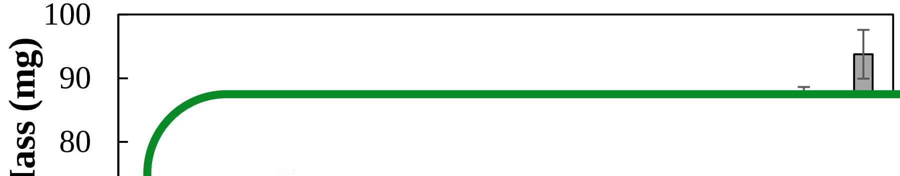

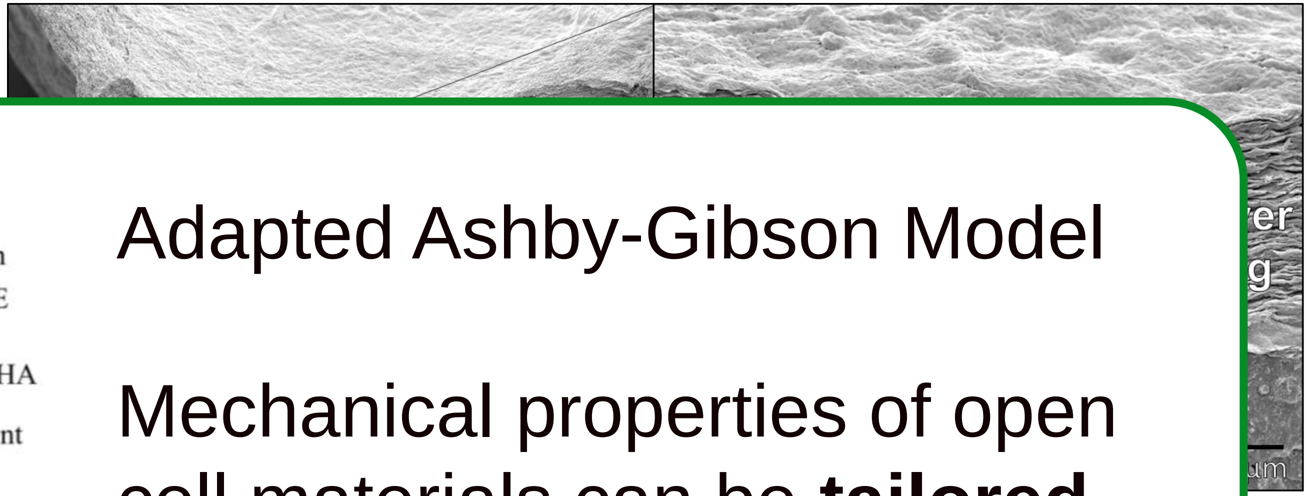

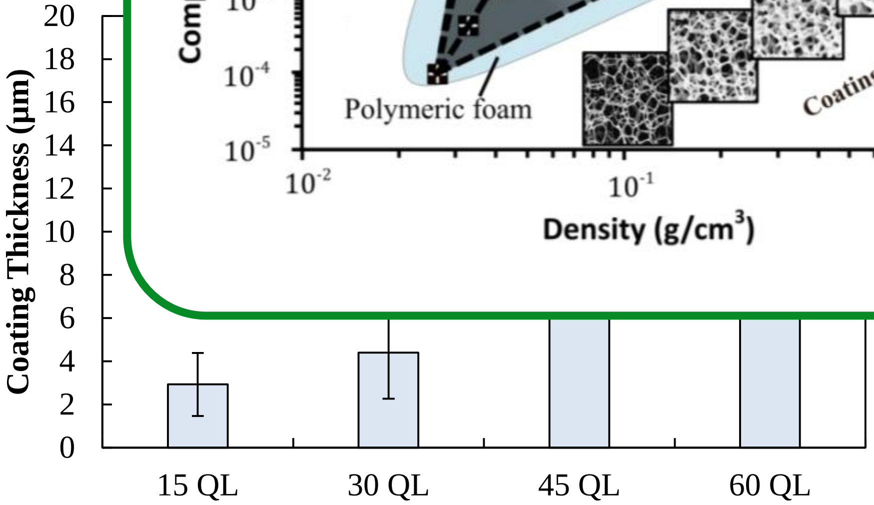

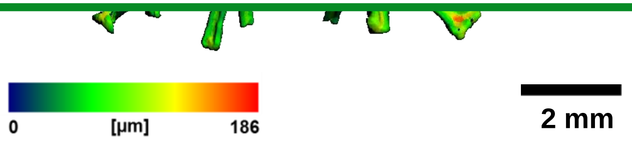

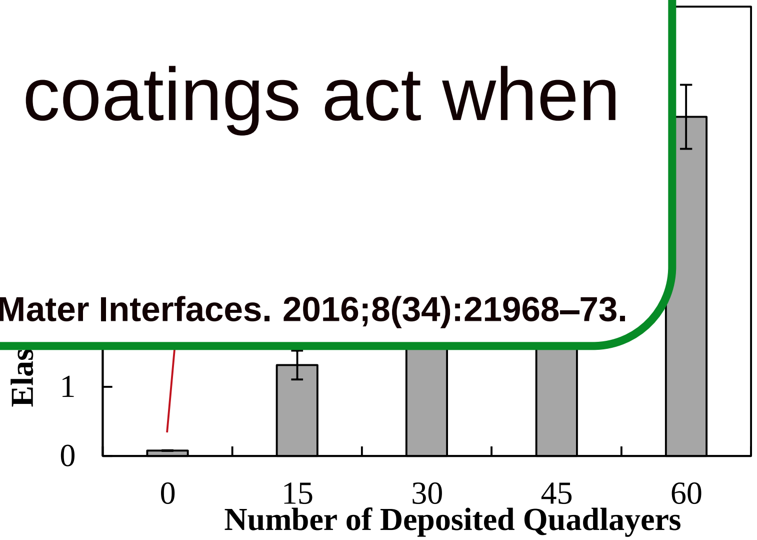

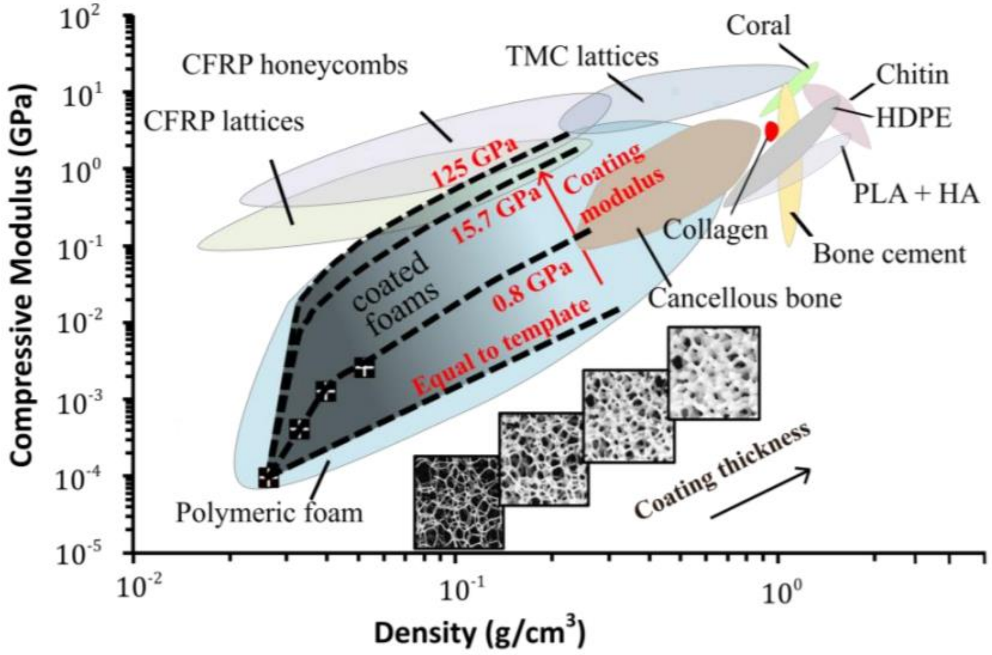

Adapted Ashby-Gibson Model

Mechanical properties of open cell materials can be **tailored**

How do these coatings act when **hydrated**?

Ziminska, et al. ACS Appl Mater Interfaces. 2016;8(34):21968–73.

Coated Foam Properties when Wet

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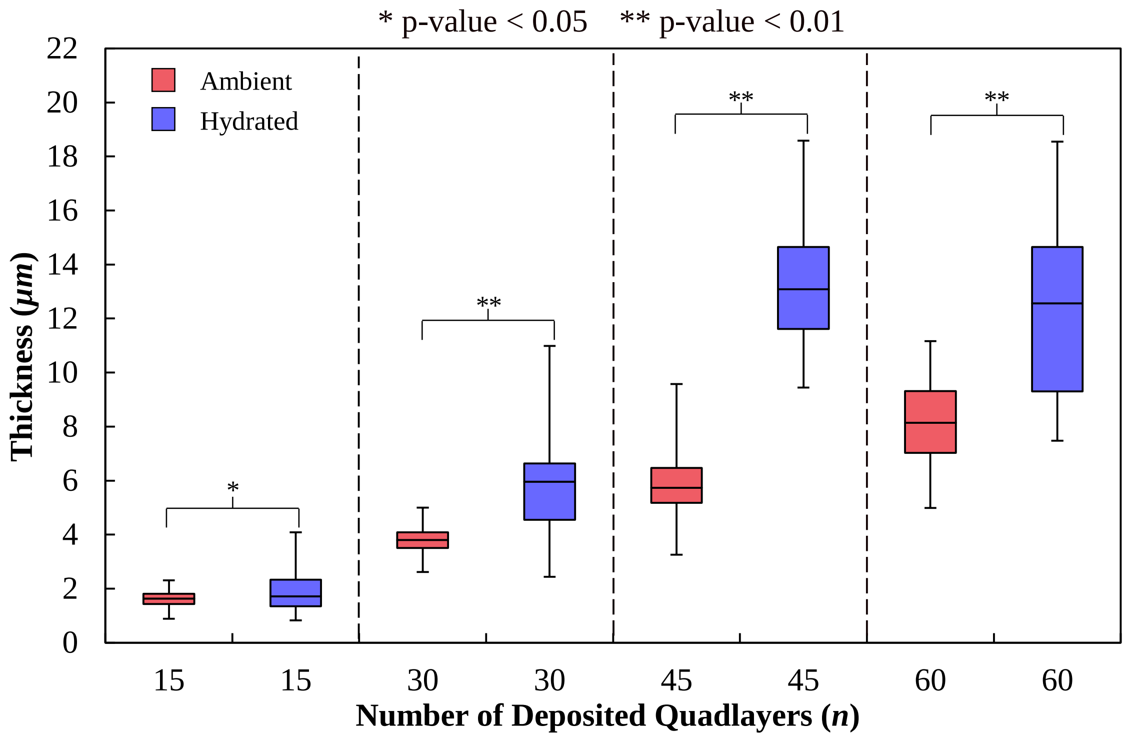
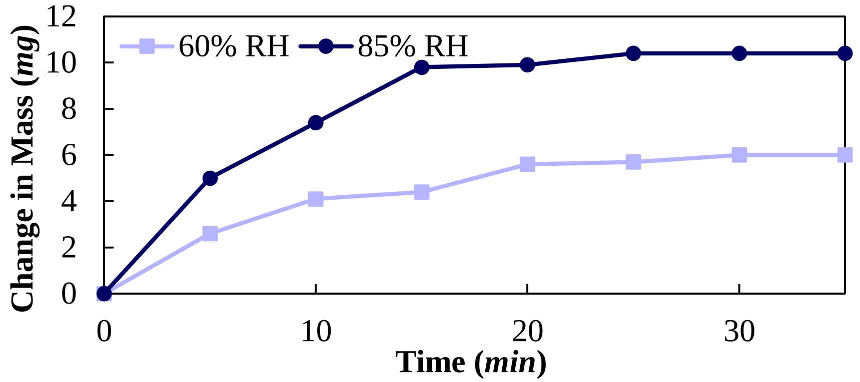
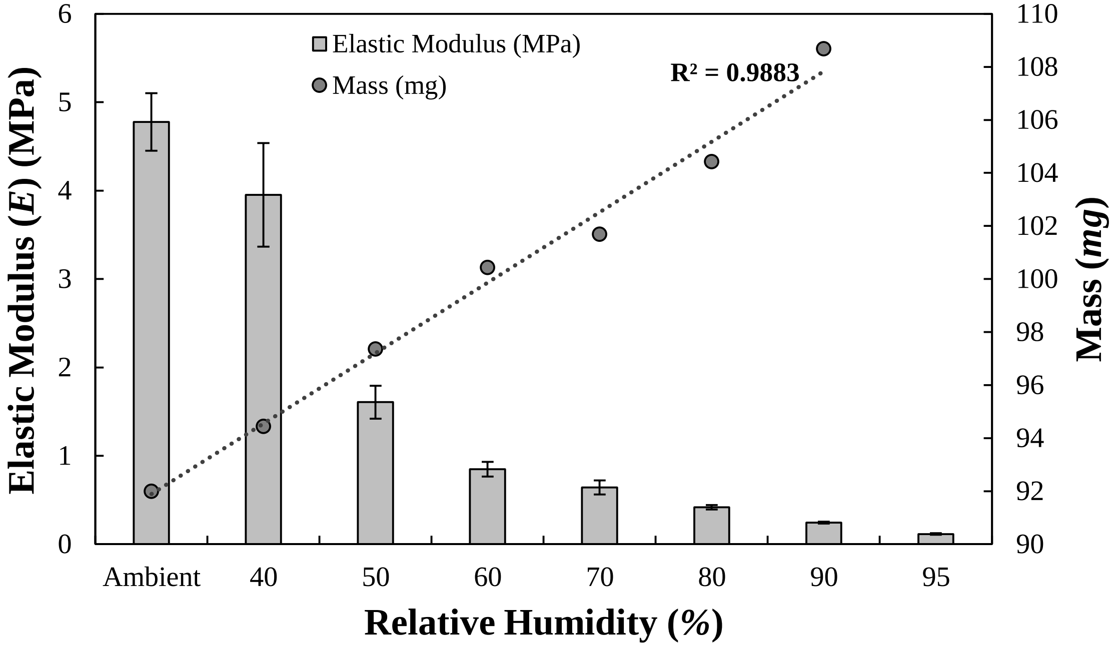
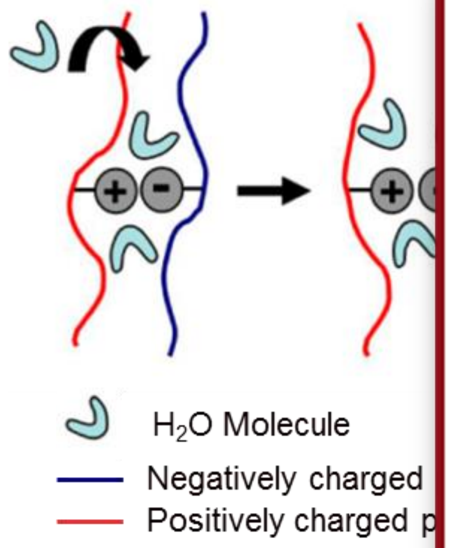


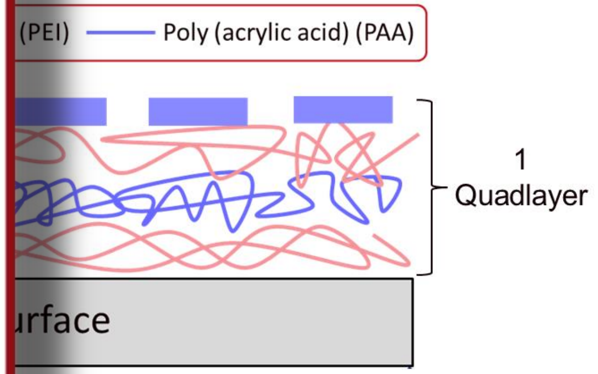




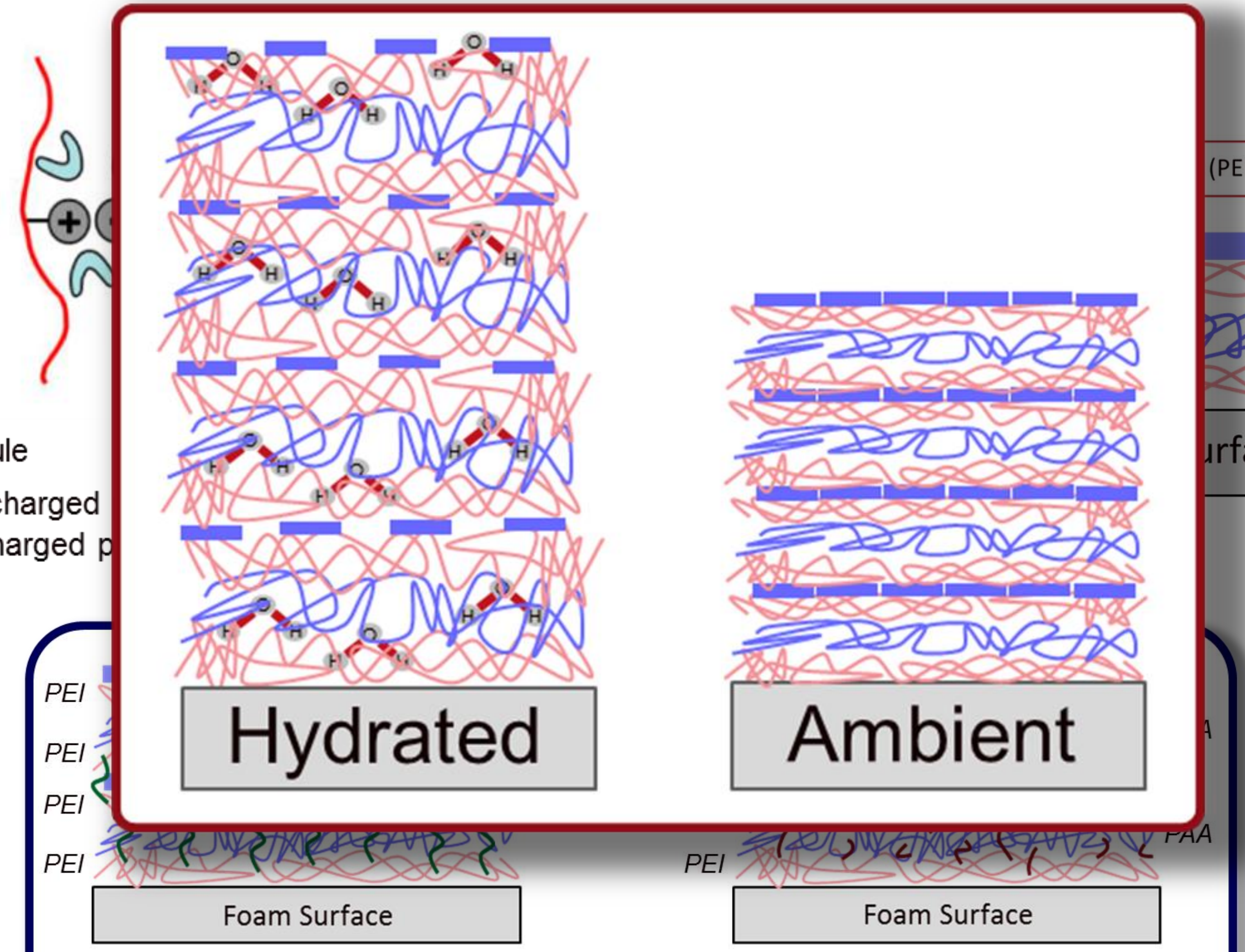
Quadlayers	Ambient E ± SD (MPa)
0	0.08 ± 0.00
15	1.31 ± 0.21
30	2.78 ± 0.26
45	3.19 ± 0.28
60	4.90 ± 0.46

Mechanism of Mechanical Property Loss





Proposed Solution:



Glutaraldehyde
Links PEI chains

Thermal
Links PEI and PAA chains

Hariri, et al. 2012. Macromolecules 45, 9364–9372.

Crosslinking of Coating Design Outline

Two-level factorial design of experiments (DoE) to investigate crosslinking effect

Table 5.1 Design of Experiment Factors

Factor	Parameter	Low	High	Units	Factor Type
A	Glutaraldehyde Molarity	0	2.5	M	Continuous
B	Glutaraldehyde Time	30	300	mins	Continuous
C	Temperature	0	120	°C	Discrete
D	Temperature Time	60	1500	mins	Continuous
E	Crosslink Interval	5	30	QL	Discrete

Optimise for output:
Hydrated elastic modulus

Optimal Crosslinked Coated Foams Characterised:

- Hydrated elastic modulus
- Coating thickness SEM
- Hydrated coated thickness surface profilometry
- Mass and elastic modulus in environments of increasing RH
- FTIR

Design of Experiments

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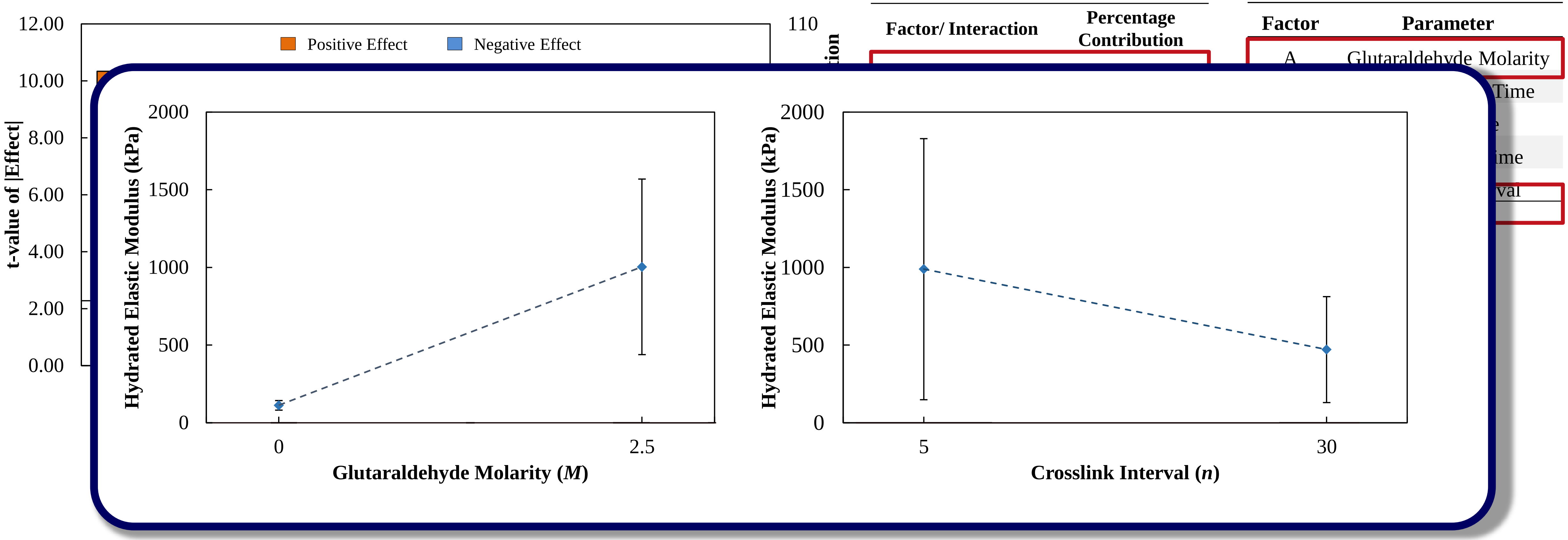
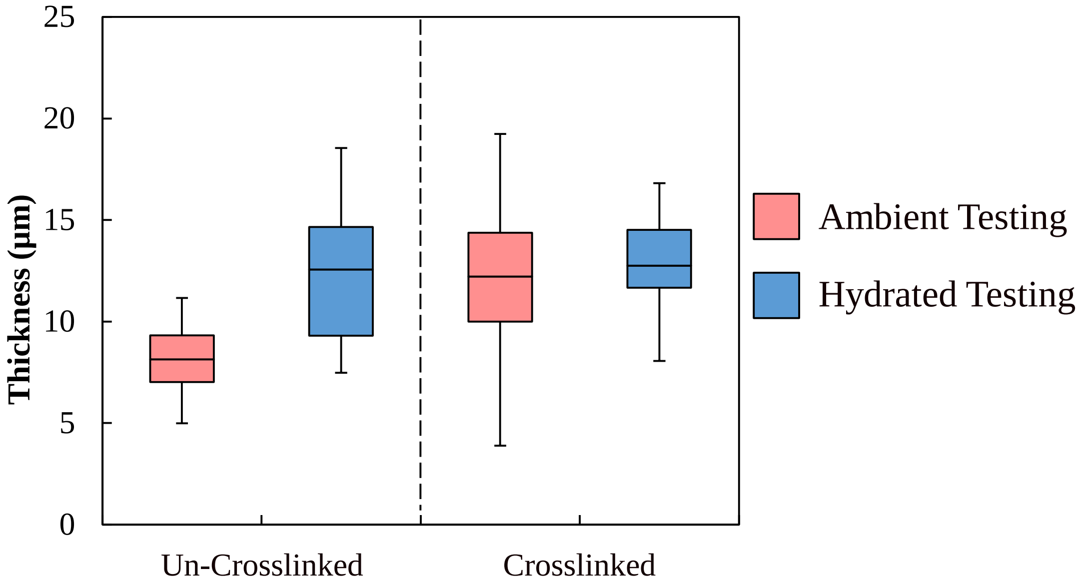
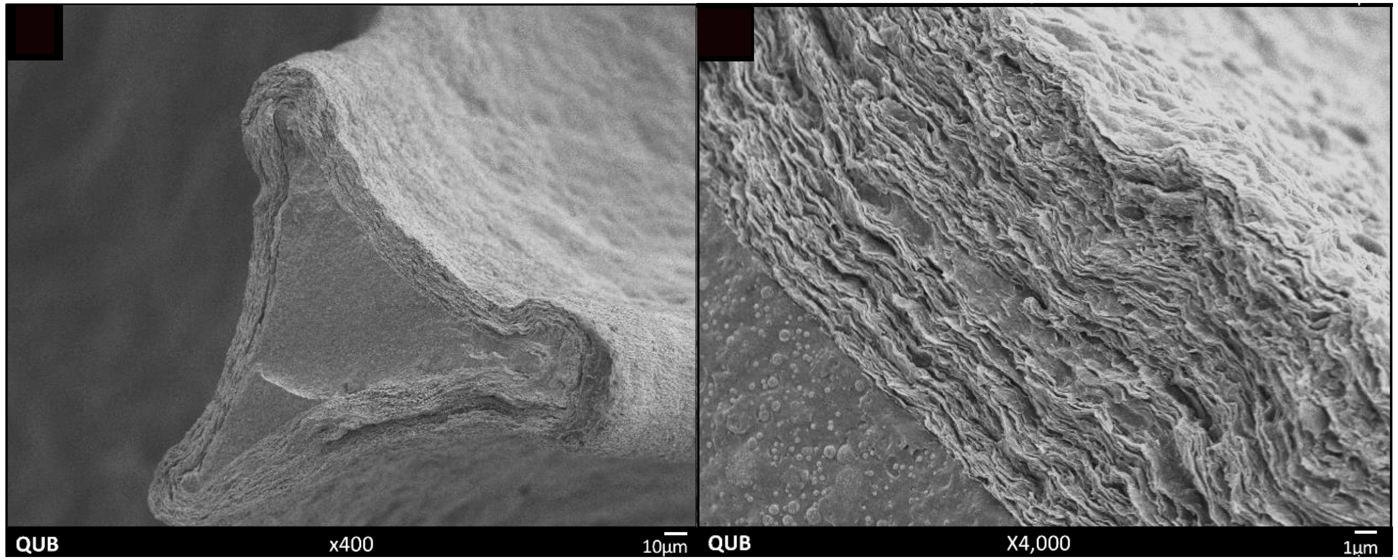


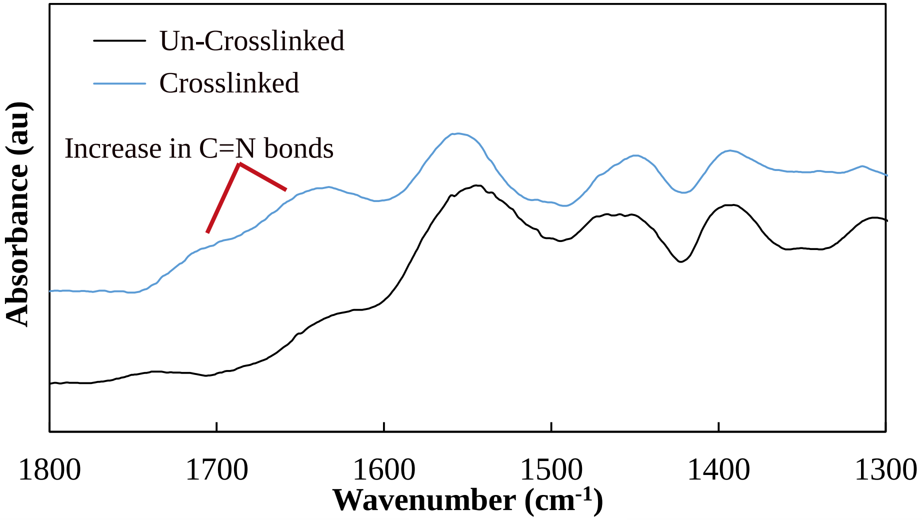
Optimal Crosslinking:

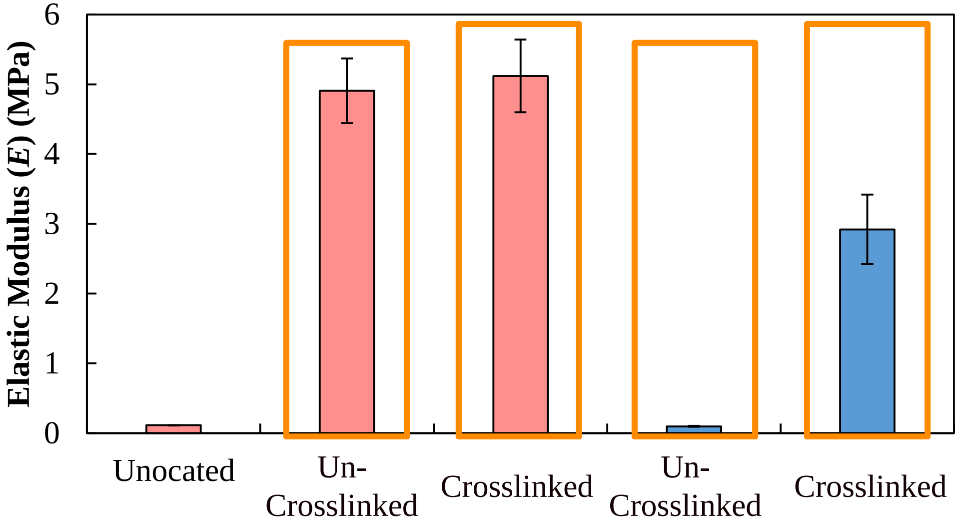
- Glutaraldehyde Crosslinking at 2.5 M
- Glutaraldehyde treatment time of 30 mins
- Crosslinking coating every 5 quadlayers deposited

Optimal Crosslinked Coated Foams









5.9%
17%

INTRODUCTION → MATERIALS AND METHODS → **RESULTS** → CONCLUSIONS

Conclusions

- Nanocomposite coatings provide significant improvement in elastic modulus, **under ambient conditions**
- Coating loses almost **all of its mechanical properties** when hydrated
- Effects of water on coating analogous with **water acting as a plasticiser** as described by others[1,2]
- Design of Experiments identified optimised crosslinking parameters:
  - Glutaraldehyde treatment at **2.5 M** for **30 mins**, every **5 quadlayers**
- Crosslinked coated foams retained **57%** of their ambient mechanical properties when hydrated compared to **1.97%** for uncrosslinked coated foams
- Crosslinking of coating allows for **tailored hydrated physio-mechanical properties**
- **Coatings can be used to tailor the mechanical and physical structure of bone tissue scaffold materials to match that of surrounding bone**

[1] Tanchek et al. Langmuir. 2006;22(11):5137–43.
[2] Nolte, et al. Macromolecules, 2008:41, 5793–5798.

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