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EPSRC
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2-Minute-2-Slide Quick-Fire Project Introductions

Second and Third Year CDT Students

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ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

Running Order

- Qing AI
- Anna BAKER
- Jamie CHILLES
- Michael DICKER
- Peter DUCKWORTH
- Ian GENT
- Rainer GROH
- Ettore LAMACCHIA
- Thomas LLEWELLYN-JONES
- Camilla OSMIANI
- Matthew SUCH

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Airfoil Flow and Noise Control Using Morphing Structures

Presented by: Qing Ai,

Supervisors:

Dr. Mahdi Azarpeyvand (Aeroacoustics research group)

Prof. Paul Weaver (Advanced Composites Centre for Innovation and Science)

This work was supported by EPSRC Engineering and Physical Sciences Research Council

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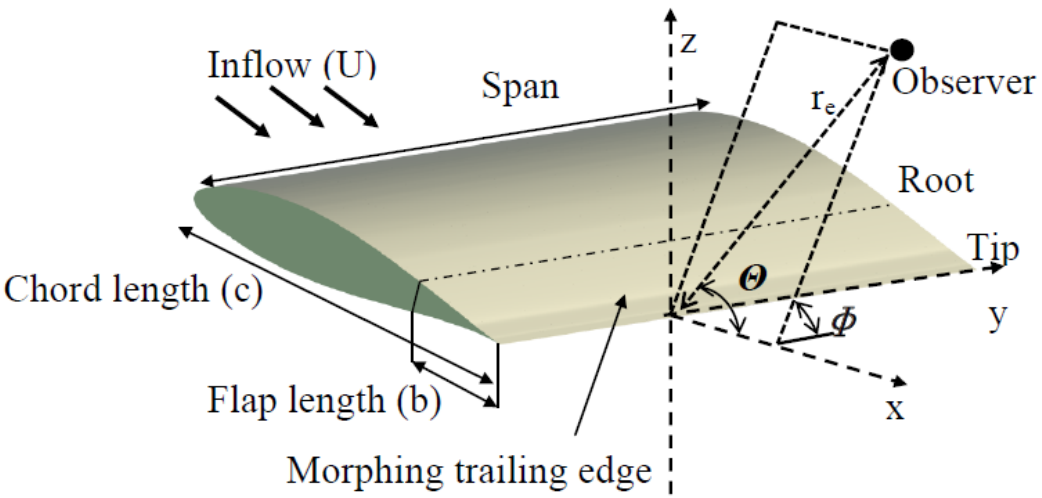
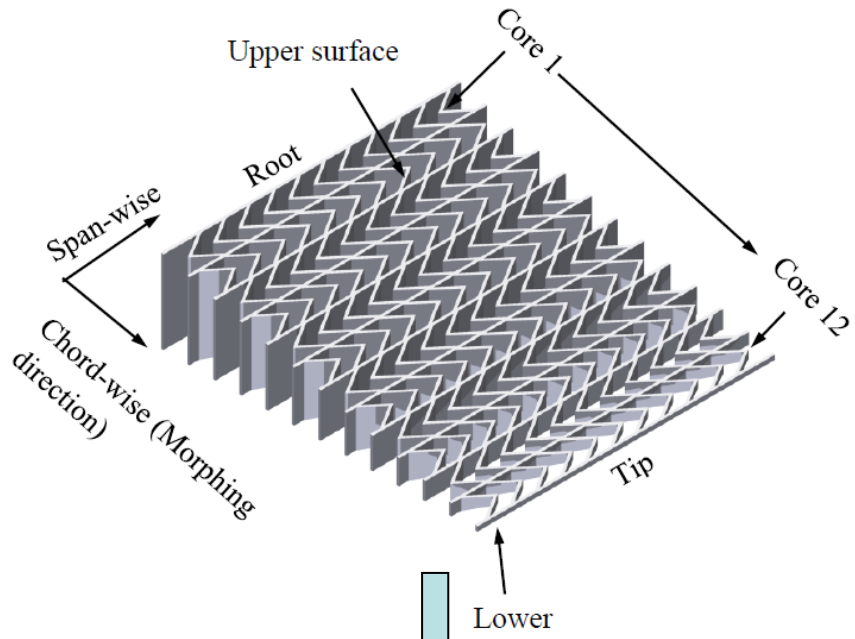
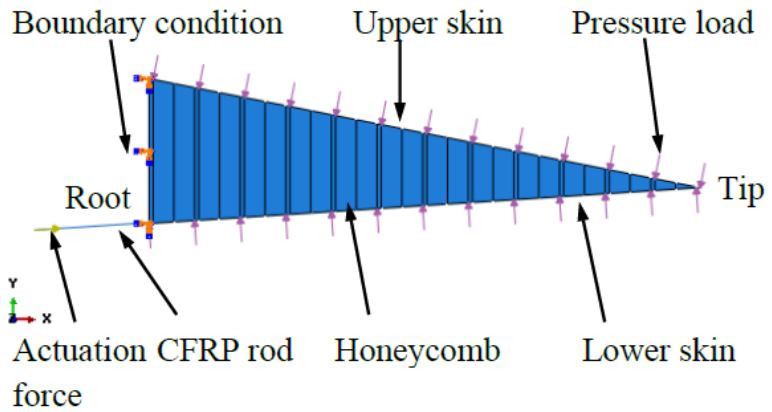
Morphing trailing edge



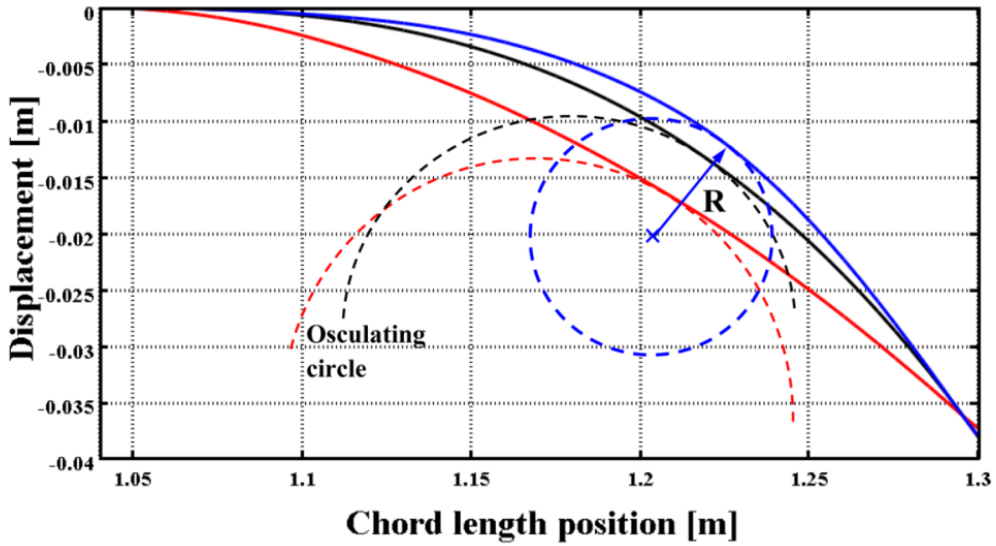


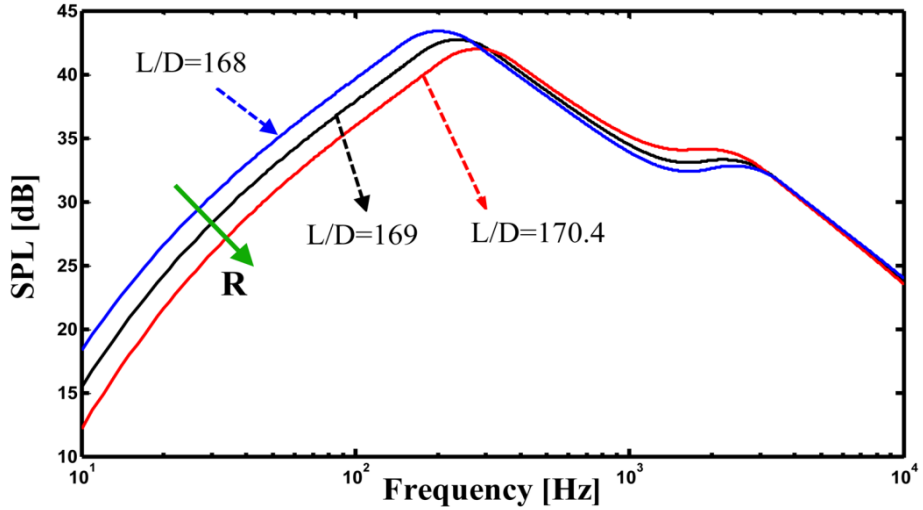


A novel morphing trailing edge concept is proposed for airfoil aerodynamic/noise control purposes:

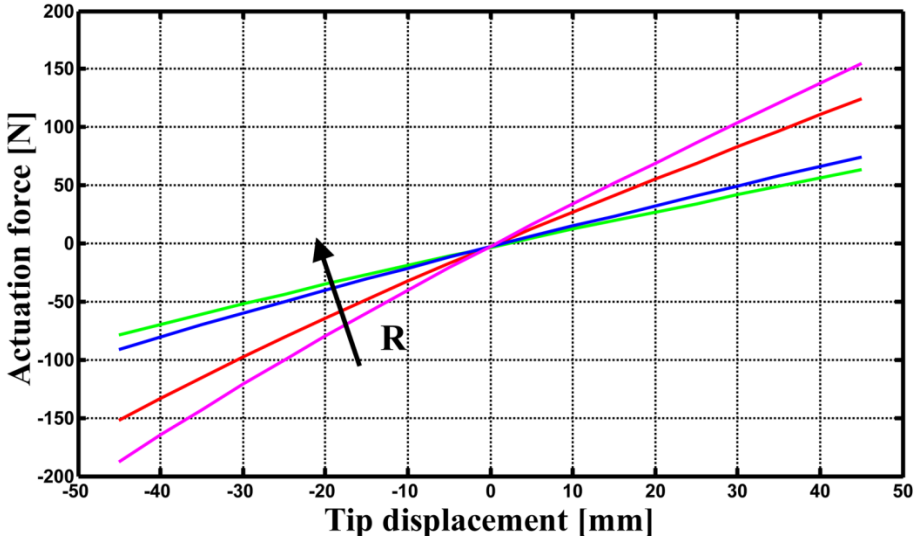
- a carbon fibre laminate upper skin
- a silicone lower skin
- a bending stiffness tailored honeycomb core

Morphing profiles





- The morphing flap yields large tip displacement and also enables the tailoring of the shapes of the deformed trailing edge.
- Noise reduction of up to 6 dB is achieved at low frequencies without affecting the aerodynamic performance
- The actuation force can be reduced using the bending stiffness tailored core



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Strain Induced Remodeling of Network Polymers for Repeatable Self-Healing

Anna Baker, Duncan Wass & Richard Trask

EPSRC
Engineering and Physical Sciences Research Council

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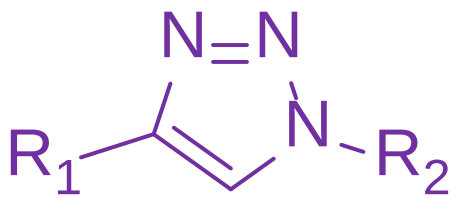
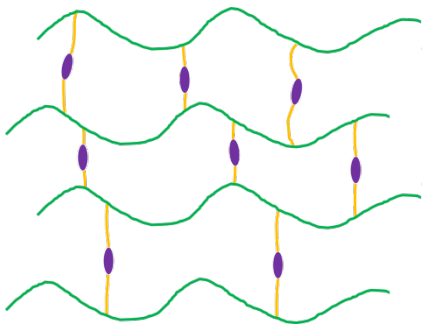
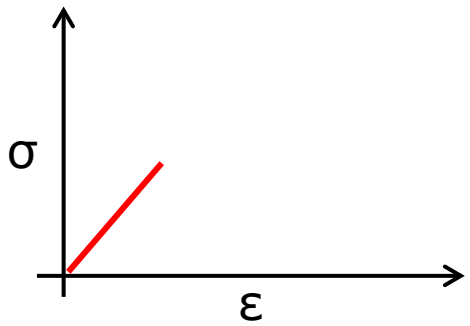
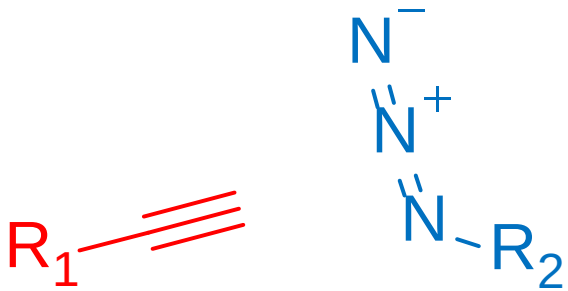
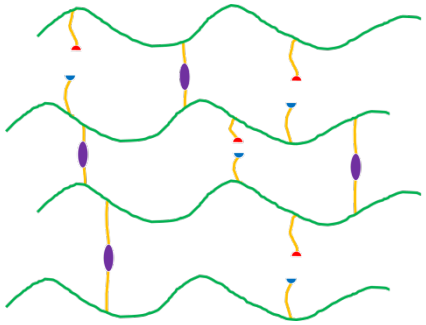
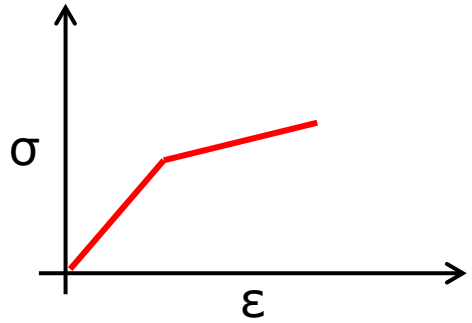
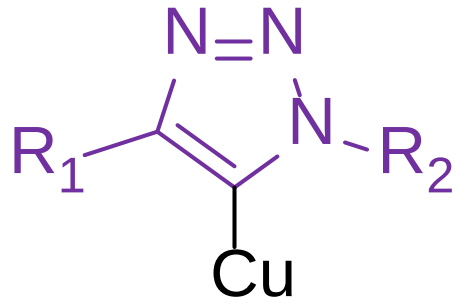
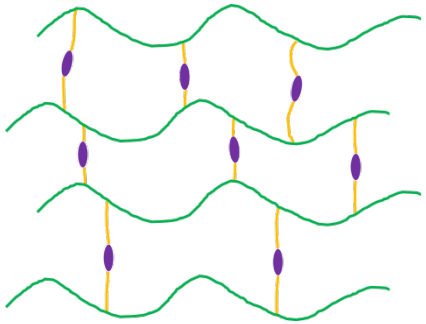
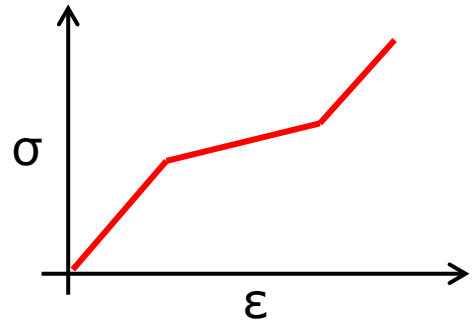
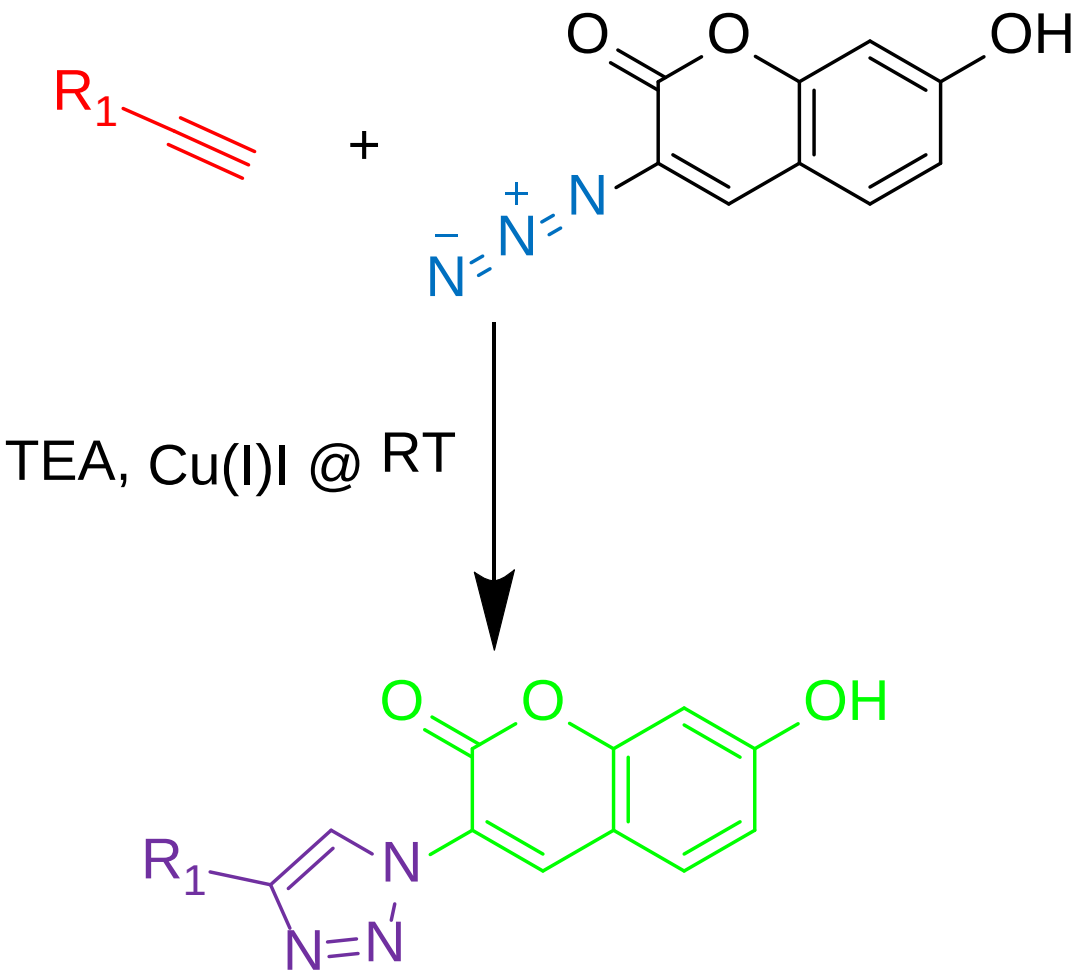
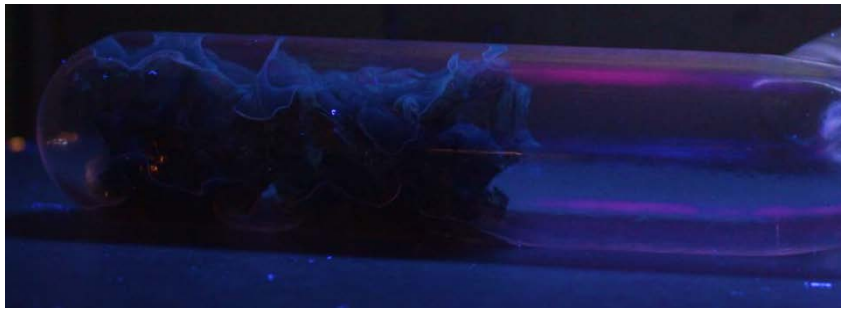
Self-Healing Network

	Crosslinks at the Molecular Level	Diagram	Macro Level
Initial			
Plastic Yielding- ”Damage”			
“Healing”			

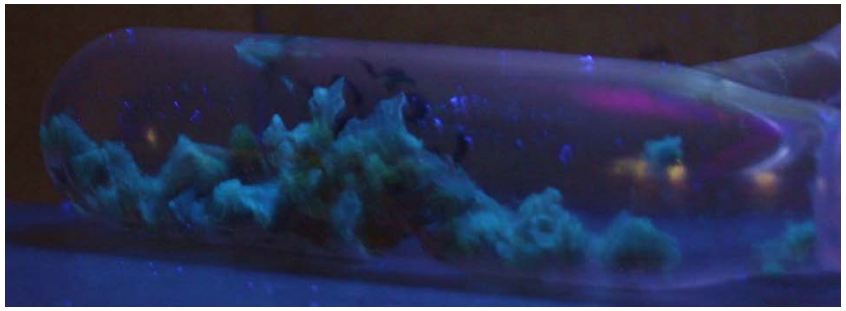
Splitting with the Force of Sound



Non-sonicated sample



Sonicated sample



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Embedded Inductively Coupled sensors for structural monitoring

Jamie Chilles

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System operation

Sensor structure

Inductance coil

Piezoelectric transducer

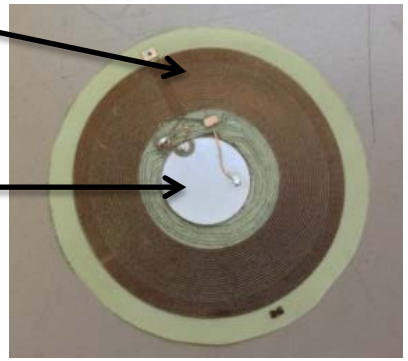
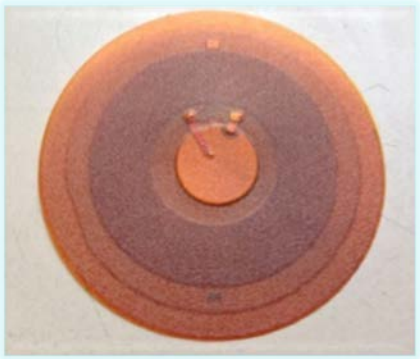


Fig 1) Photo of sensor package.



The sensors are encapsulated within a polyimide layer.

Fig 2) Sensor encapsulated within polyimide.

System Operation

Sensors are passive on the structure until activated by the inductance 'wand'.

Once excited by the wand the transducer emits a pulse of ultrasound.

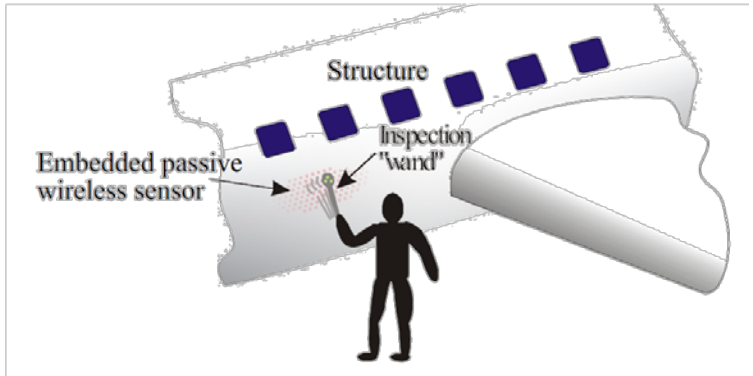


Fig 3) Schematic showing system operation.

Current Work

Mechanical Performance

- Four point bend tests.
- Sensors are embedded in the compression side.
- Through thickness position varied.

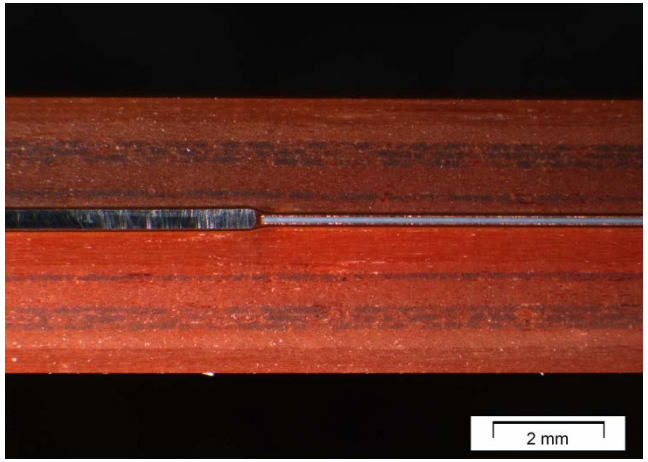


Fig 3: Frequency response of inductance coil at various temperatures.

Cure cycle monitoring

- Embedded sensors provide a possible method for cure cycle monitoring.
- Thermal dependence of the sensors has been assessed.

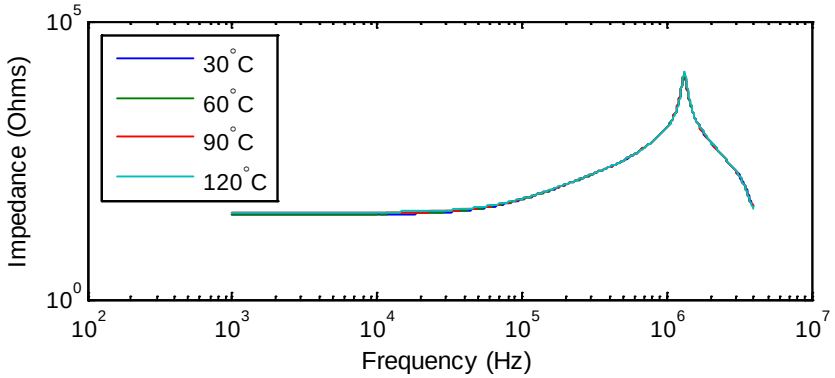


Fig 4: Frequency response of inductance coil at various temperatures.

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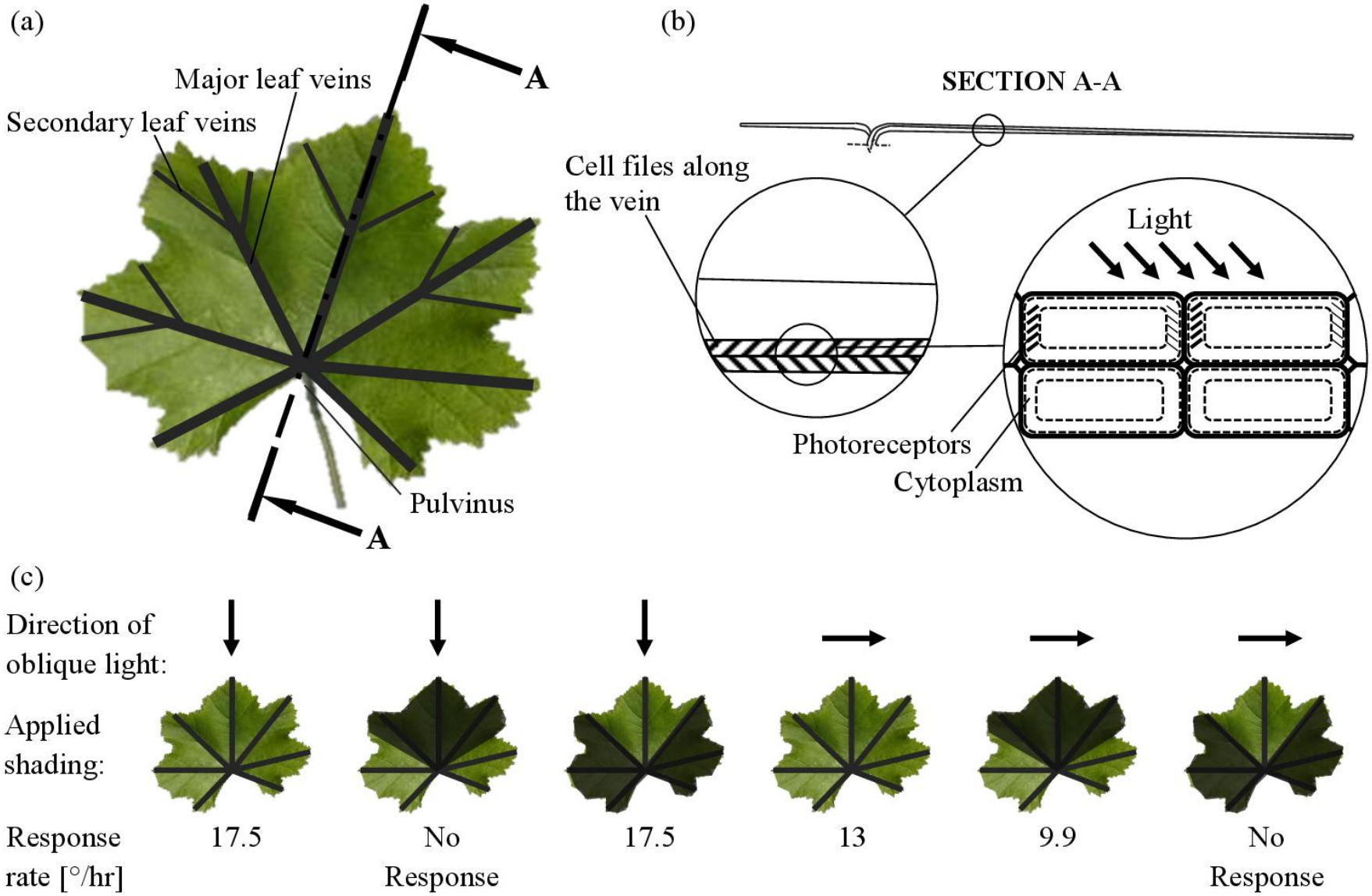
Biomimetic Photo-Actuation:

Remote Chemical Sensing, Signal Transmission and Control of Composite Hydrogel Actuators

Michael Dicker

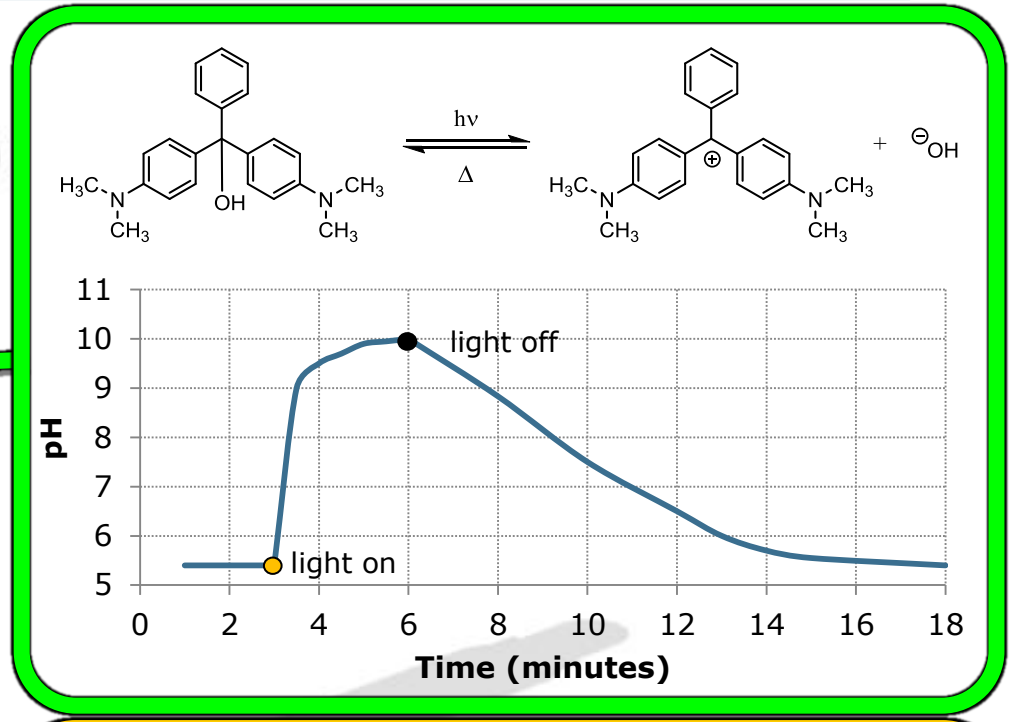
Supervisors: Jonathan Rossiter, Paul Weaver and Ian Bond

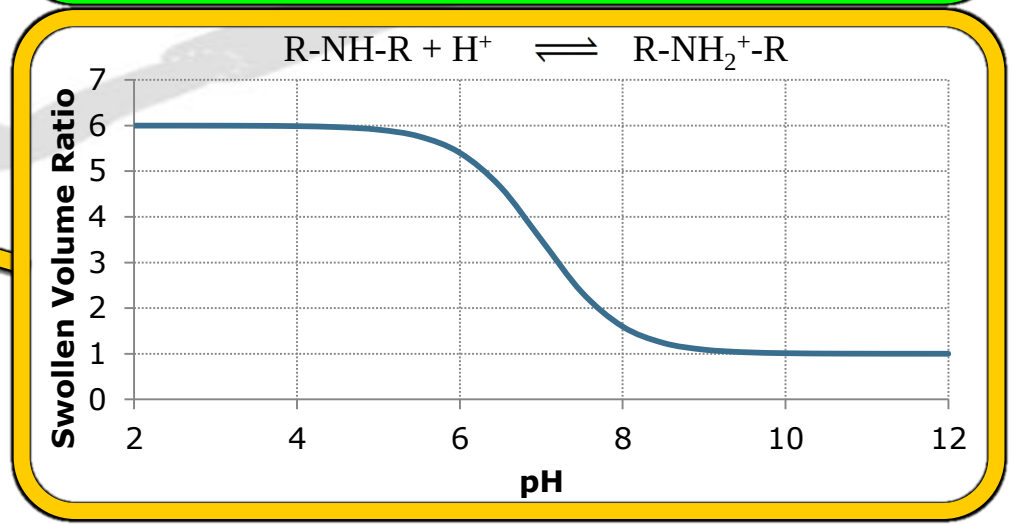
Analogue of Sun-Tracking Leaf



D. Koller, S. Ritter, W. R. Briggs, and E. Schafer, "Action dichroism in perception of vectoral photo-excitation in the solar-tracking leaf of Lavatera cretica L .*," Planta, vol. 181, pp. 184–190, 1990.
F. J. F. Fisher, D. L. Ehret, and J. Hollingdale, "The pattern of vascular deployment near the pulvinus of the solar-tracking leaf of Lavatera cretica (Malvaceae)," Canadian Journal of Botany, vol. 65, no. 10, pp. 2109–2117, 1987.

Analogue of Sun-Tracking Leaf

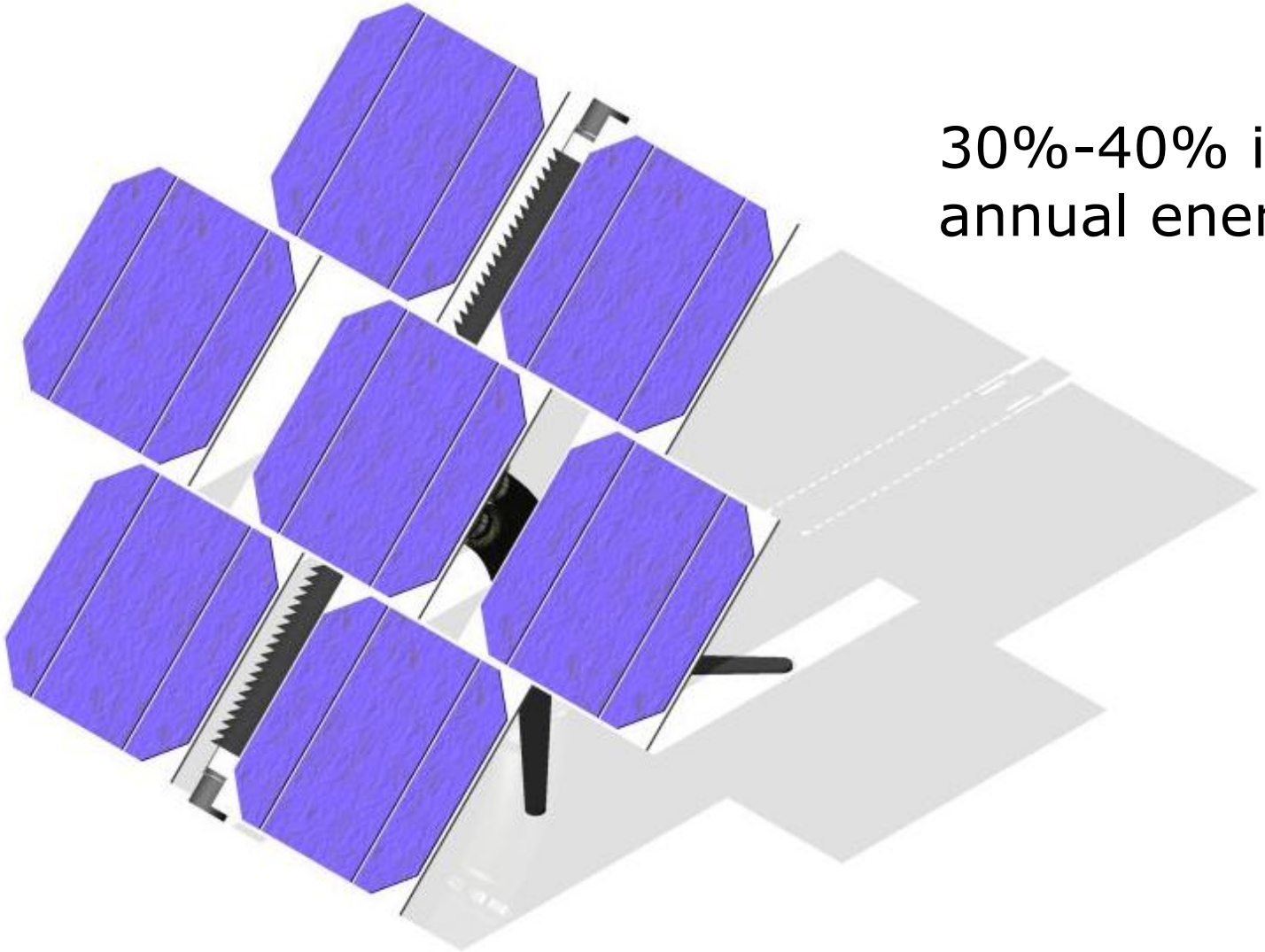




M P M Dicker, J M Rossiter, I P Bond, and P M Weaver. Biomimetic photo-actuation: sensing, control and actuation in sun-tracking plants. Bioinspir. Biomim., Submitted, 2014.

Analogue of Sun-Tracking Leaf

Applications



30%-40% increase in annual energy yield

Hossein Mousazadeh, Alireza Keyhani, Arzhang Javadi, Hossein Mobli, Karen Abrinia, and Ahmad Shari. A review of principle and sun-tracking methods for maximizing solar systems output. Renewable and Sustainable Energy Reviews, 13(8):1800-1818, October 2009.

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Antimicrobial Nanocomposite Wound Dressings

Peter F. Duckworth,
Michele Barbour & Sameer Rahatekar

Exploring non-structural medical applications of nanocomposite materials.

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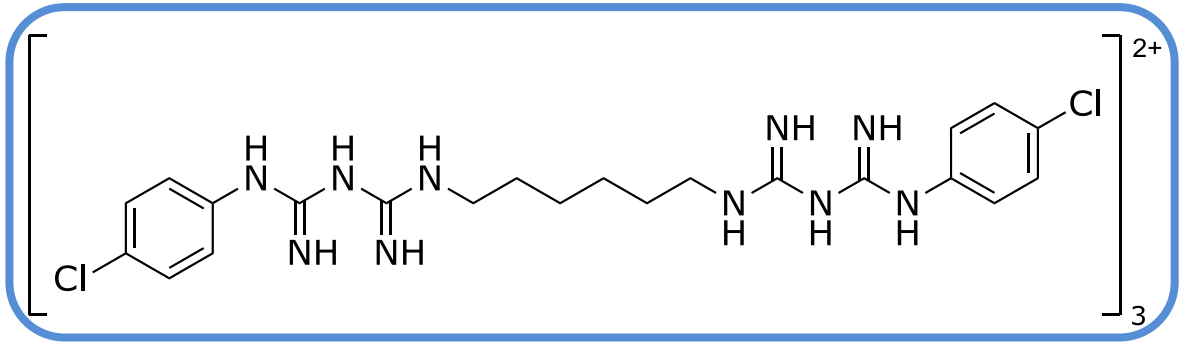
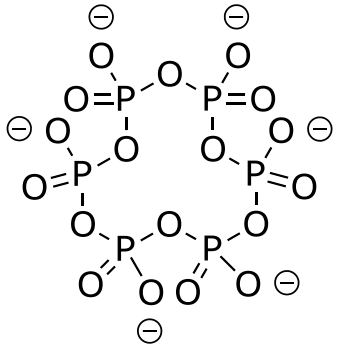
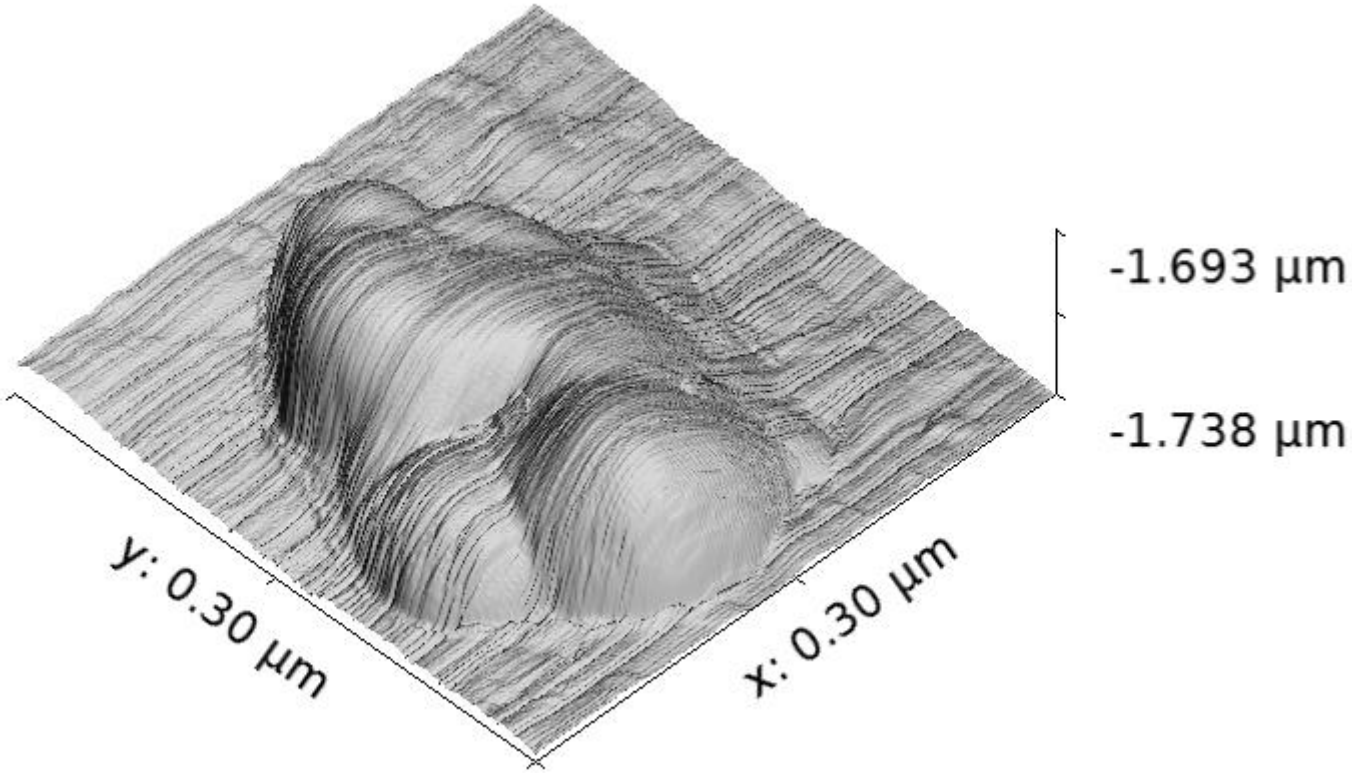
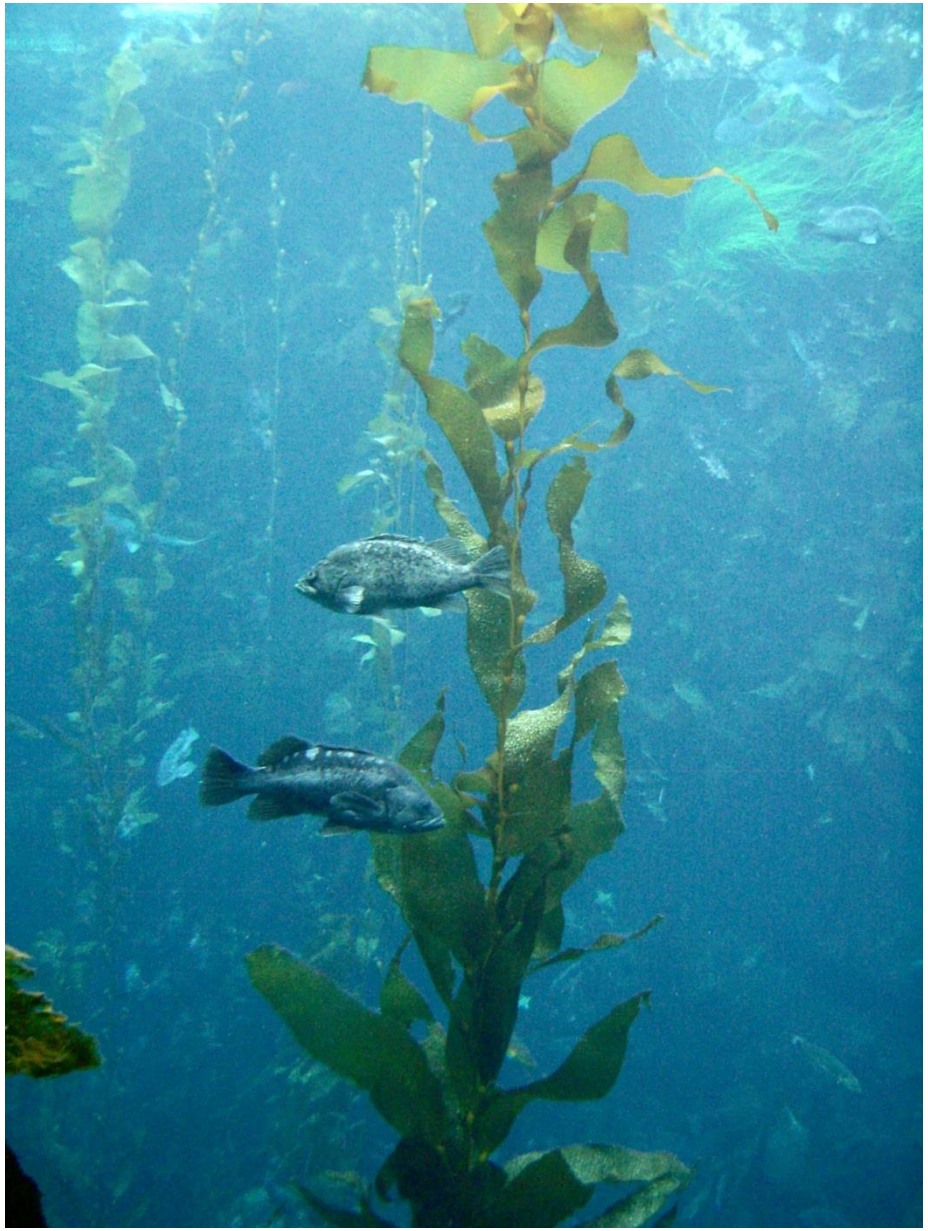
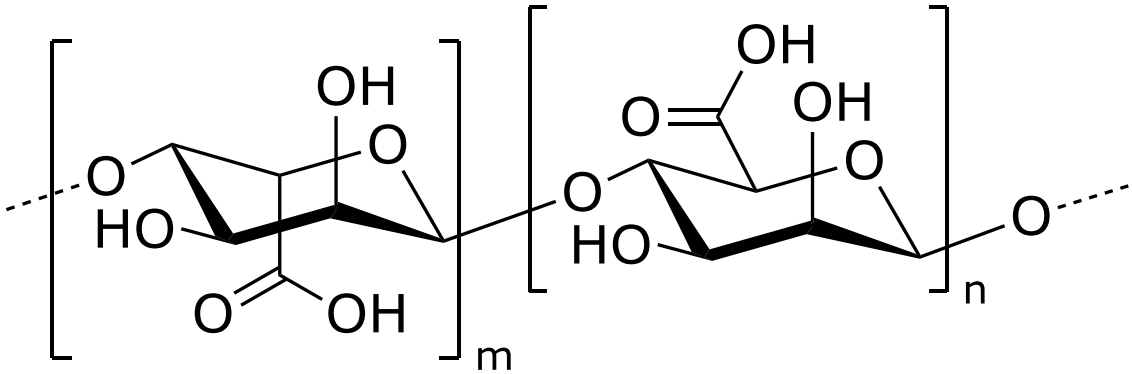





-1.693 µm
-1.738 µm
y: 0.30 µm
x: 0.30 µm





Alginate

Antimicrobial Work

Bacteria tested:

- *E. coli*
- MRSA
- *Psuedomonas*
- *Klebsiella*
- *Acinetobacter*

ANTIMICROBIAL NANOCOMPOSITE WOUND DRESSINGS

Peter F. Duckworth, Sarah E. Maddocks, Andrew M. Collins, Sameer S. Rahatekar & Michele E. Barbour**

*project co-supervisors

Aim: To produce a nanocomposite wound dressing material which elutes antiseptic at a sustained, and controlled, rate.

Background:

Chronic wounds

Chronic wounds are vulnerable to infection offering prolonged access for microbes.

Figure 1. Diabetic foot ulcers have a high risk of infection.

A **continuous supply of antiseptic** to the wound bed **would reduce infection rates**.

Antiseptic nanoparticles

Novel **antiseptic eluting nanoparticles**, developed at The University of Bristol are electrostatic aggregates of **chlorhexidine** and **hexametaphosphate** (Fig. 2).

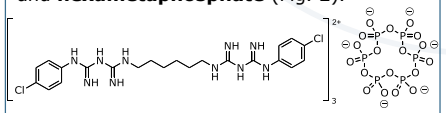


Figure 2. Chlorhexidine hexametaphosphate nanoparticles.

Progress:

Material development

Nanoparticles have been encased within a **polysaccharide matrix** and processed into films and fibres (Fig. 3).

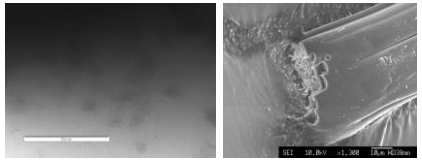


Figure 3. a) TEM of a nanocomposite film shows the intact nanoparticles. **b)** SEM of a nanocomposite fibre (ø ~ 50 µm).

Antimicrobial studies

Alginate nanocomposite films show a **dose-dependent antiseptic elution** (Fig. 4)...

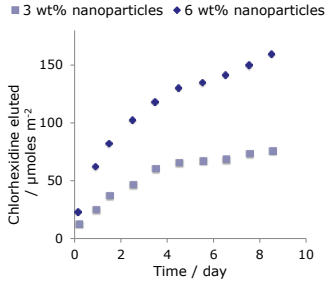


Figure 4. Chlorhexidine elution from alginate nanocomposite films.

...and hence **dose-dependent *in vitro* antimicrobial action** against MRSA (Fig. 5)

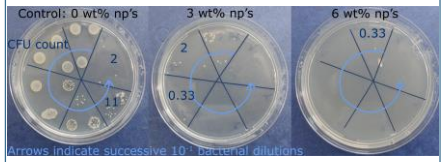


Figure 5. Antimicrobial action of alginate films against MRSA. (CFU = [bacterial] colony forming units)

Future work:

Project scope

- *in vivo* experiments (Fig. 6).

Figure 6. A guinea pig.

- Functionalise with embedded haemostatic chemistries to produce a blood clotting antimicrobial wound dressing.

Find out more:

Peter.Duckworth@bristol.ac.uk

Supported by EPSRC Engineering and Physical Sciences Research Council

ORAL NANOSCIENCE

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Polychromatic Composite Films for Adaptive Camouflage

Ian Gent, Annela Seddon, Nicholas Roberts, Karl Lymer, Richard Trask

Supported by EPSRC Engineering and Physical Sciences Research Council [dstl]®

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Polychromatic Composite Films for Adaptive Camouflage

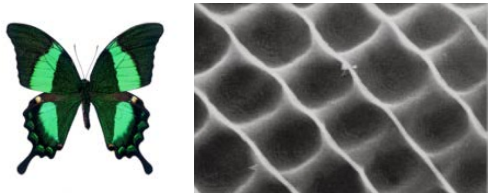
Aim: Development of a polychromatic smart material inspired by the microstructures responsible for structural colour in nature

Background

- There are a number of examples in nature of insects producing colour without pigmentation
- Colour is generated through the interaction of light with different layers of the microstructures present

Spheres- Weevil

Inverse Spheres- Butterfly

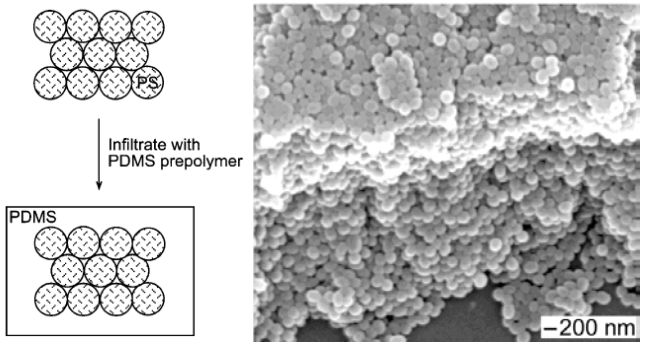


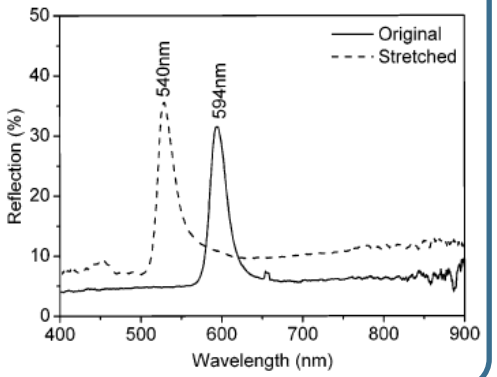
Layers & Channels- Golden Tortoise Beetle

J. Galusha, *J. Mater. Chem.* **20**: 1277–1284; P. Vukusic, *Nature* **404**: 457; J. Vigneron, Phys Rev E **76**: 031907

Experimental Investigation

- Polydimethylsiloxane and a solution of polystyrene spheres were cured into a thin film
- Two different sizes of spheres were used
- SEM used to analyse the packing





Y. Lu *et al. Langmuir* (2002) **18**:7722-7727

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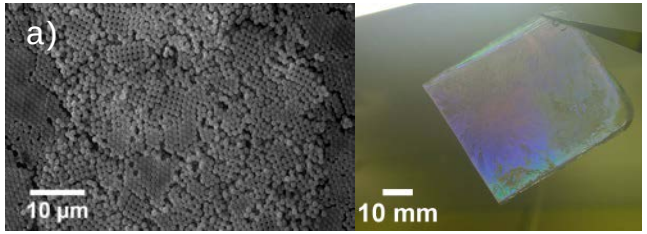
Polychromatic Composite Films for Adaptive Camouflage

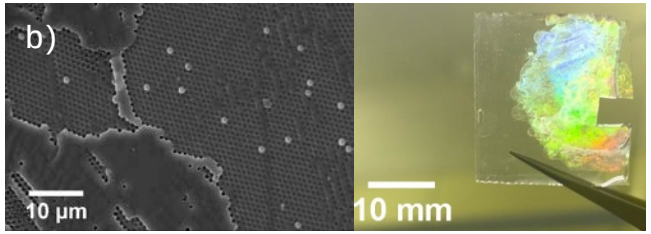
Aim: Development of a polychromatic smart material inspired by the microstructures responsible for structural colour in nature

Results

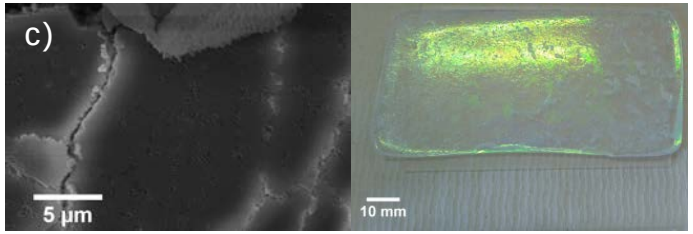
- 1000 nm spheres can be used to produce photonic crystals and inverse crystals, both produce iridescent films
- 240 nm spheres have been used to produce highly ordered photonic crystals, which produce more intense iridescence than 1000 nm spheres.



a) Photonic crystal of 1000 nm spheres



b) Inverse crystal of 1000 nm spheres



c) Photonic crystal of 240 nm spheres

Future Investigation

- Multi axial tensile testing of manufactured morphologies to quantify colour change
- Inclusion of liquid crystal phase into concave surface to allow for dual colour tailorability
- Chemical functionalisation of sphere surface to effect colour change with different fields

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Zig-Zag Displacement Fields in Composite and Sandwich Structures

Rainer Groh, Paul Weaver

EPSRC
Engineering and Physical Sciences Research Council

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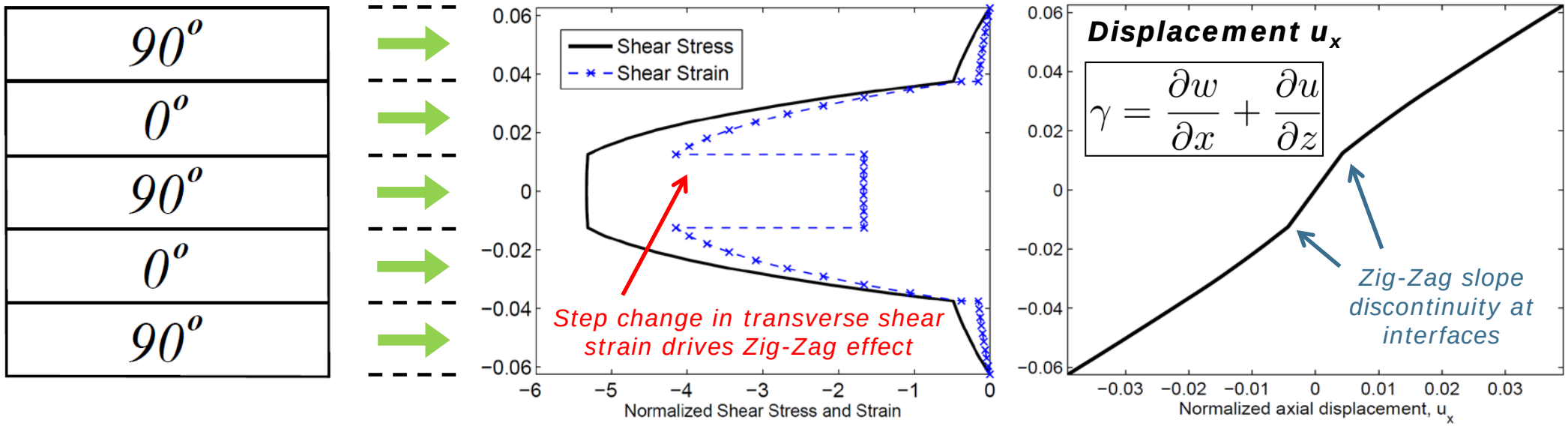
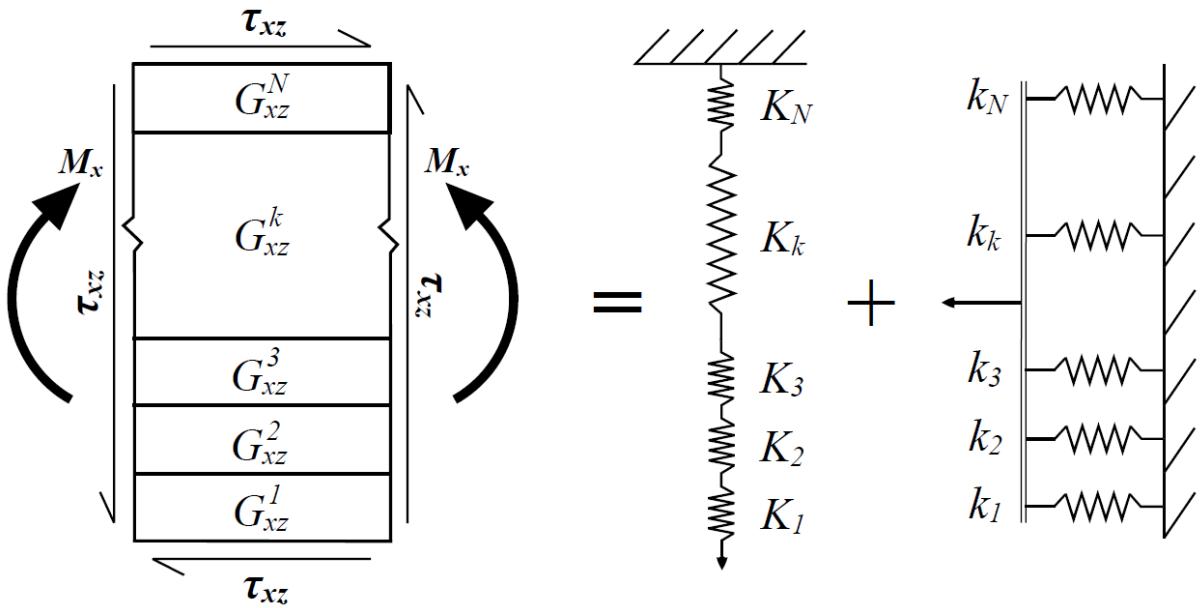
Origin of the Zig-Zag Effect



- ZZ effect driven by differences in shear modulus
- Interfacial requirements:
  - Displacement continuity
  - Transverse shear stress continuity
- Can represent this using a mechanical spring model

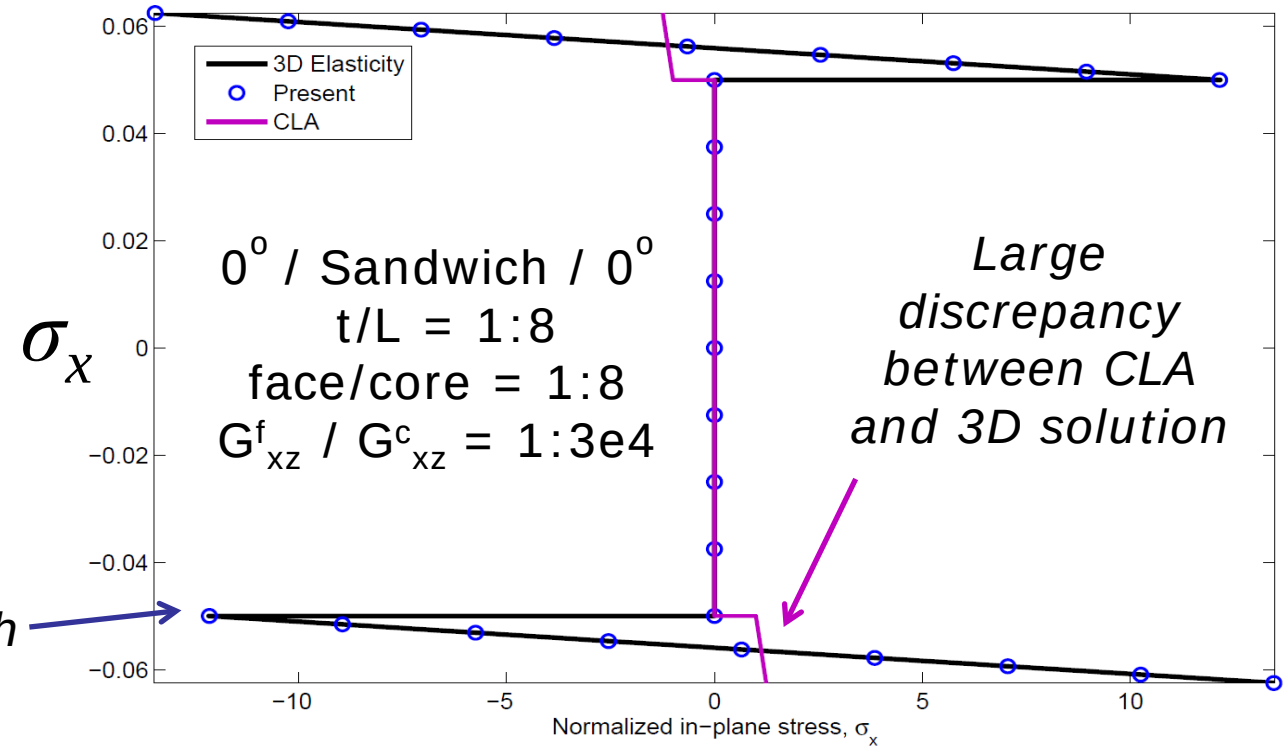


Hellinger - Reissner Model

$$G = \left[\frac{1}{t} \sum_{k=1}^{N} \frac{t^{(k)}}{G_{xz}^{(k)}} \right]^{-1} \quad g^{(k)} = G / G_{xz}^{(k)}$$

$$u_x^{(k)}(x,z) = \underbrace{\boxed{u_0(x) - z w_{,x}(x)}}_{\text{CLA}} + \underbrace{\boxed{\left(g^{(k)} z + c^{(k)} \right) \bar{\gamma}_{xz}(x)}}_{\text{ZZ + continuity}}$$

- Minimise the potential energy using the Hellinger-Reissner Mixed Variational Principle to derive new governing equations!
- 3 equations and 3 unknowns (w, M and M^{ZZ}) for a beam



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On the Multistability of Shells for Morphing Applications

Ettore Lamacchia, Alberto Pirrera and Paul Weaver

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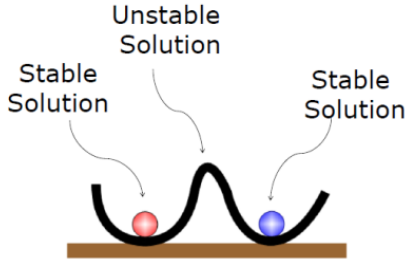
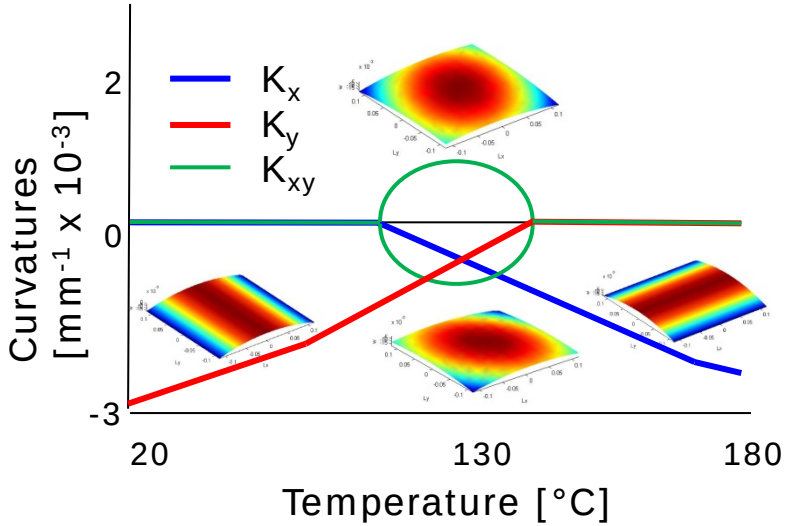
Semi-Analytical Model

- Legendre polynomial used to approximate the out-of-plane displacements
- Total Potential Energy: $\Pi_{tot} = \Pi_m + \Pi_b + \Pi_{ext}$
- Membrane problem solved together with compatibility conditions using DQM
- Equilibrium configurations given by the minima of the total potential energy with respect to curvatures only



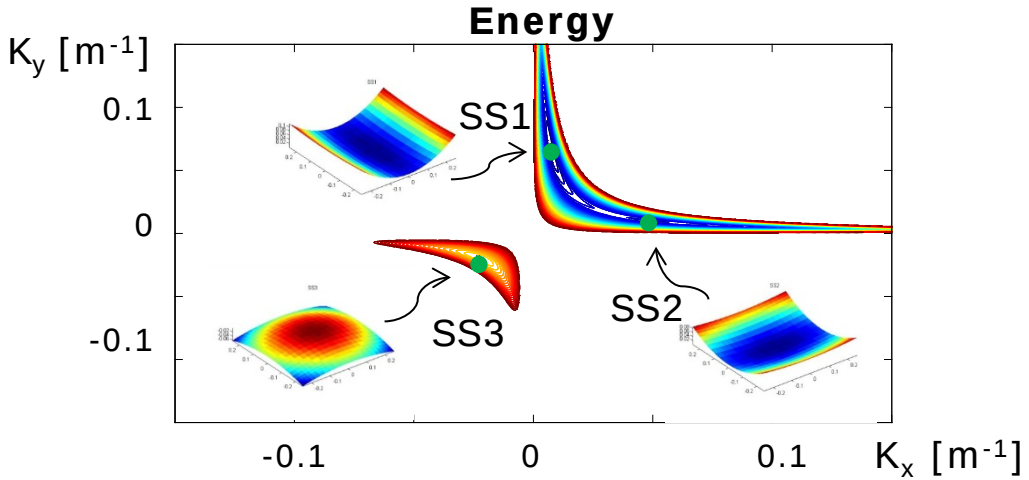
Validation 1 – Multi-mode Morphing

- Initially cilindrically-curved shell
- ss=[0_3,90_3] and material properties function of T°
- Results in agreement with Eckstein et al. 2014



Validation 2 – Tristable Shell

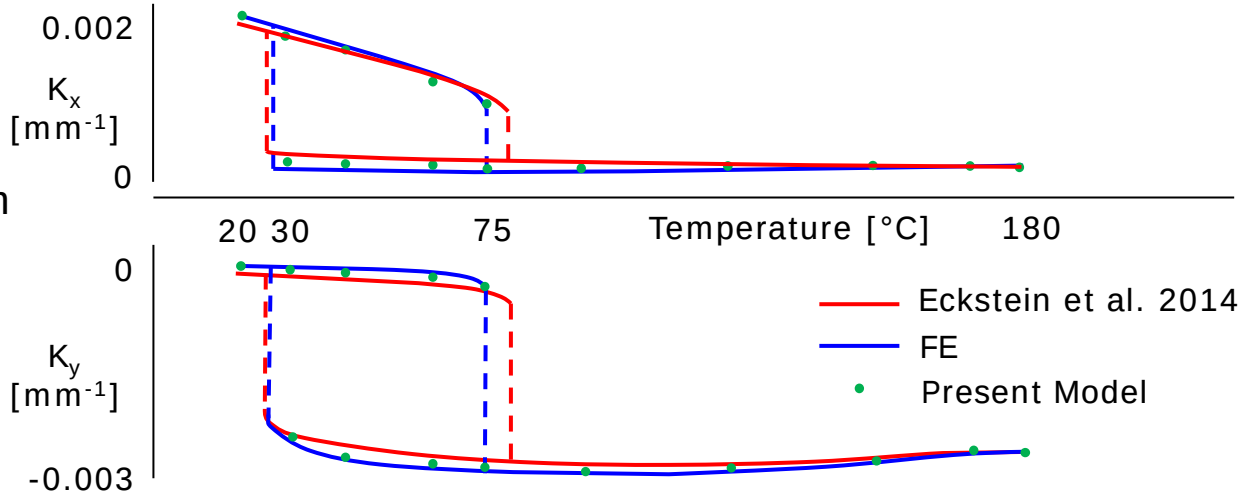
- Initially double-curved shell
- ss=[45,-45,-45,45,-45,45,45,-45]
- Results in agreement with Coburn et al. 2013 and Vidoli 2013



Case study

Thermally-driven snap-through and multistability using laminated fiber-metal shells

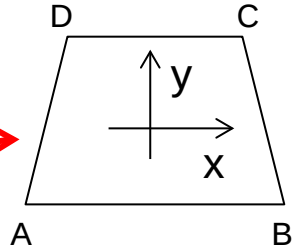
- Material properties as function of T°
- AS7 / M21, $[0]_4$, ply thickness = 0.262mm
  Aluminum 2024T4, thickness 1.2mm
- Near step-change curvature response
- Bistable behaviour near the snapping temperature



Future work

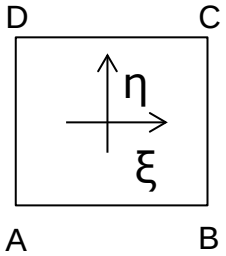
- *Mapping*

Passive Chevron Deployment



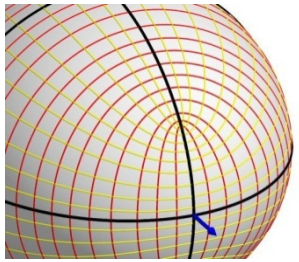
Physical Domain

Blending Functions



Computational Domain

- *Curvilinear Coordinates*



Investigation of the stability behaviour of shell with general shape using curvilinear coordinates.

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Ultrasonic Manipulation of Cellulose Nanowhiskers

Thomas Llewellyn-Jones

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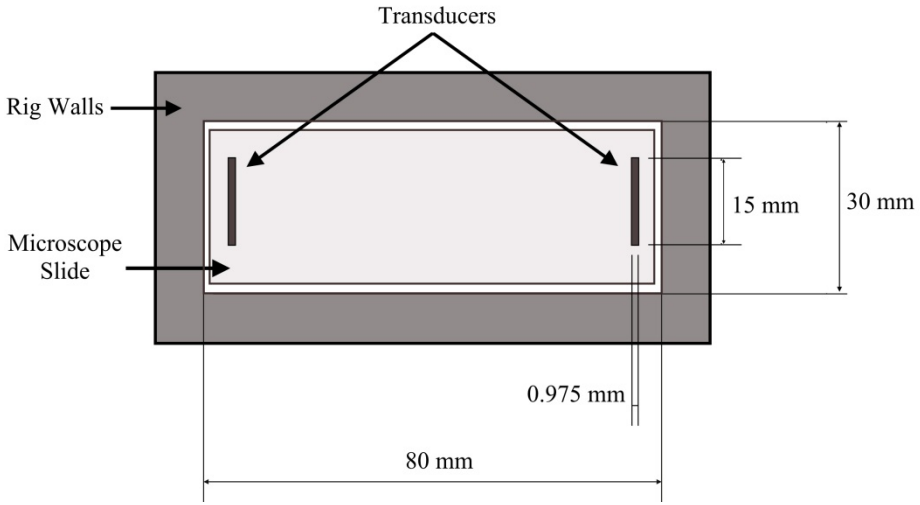
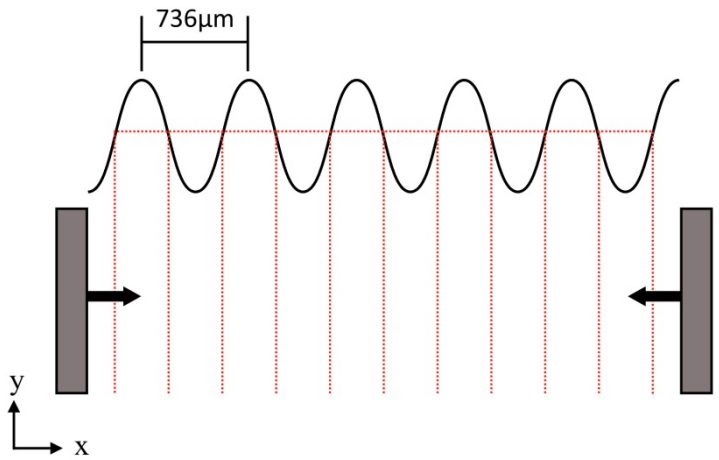
Aims and Method

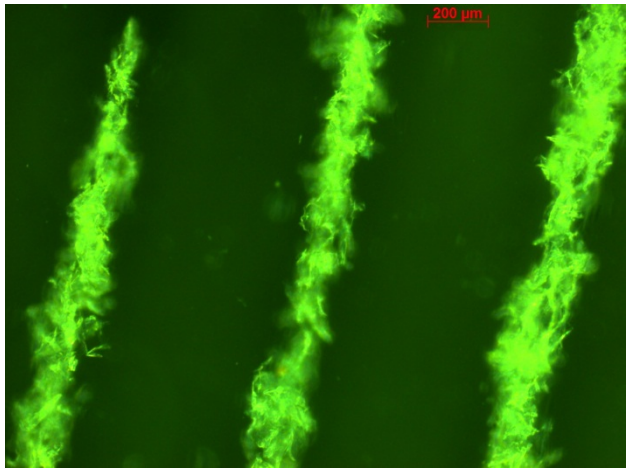
- Aim to ultrasonically manipulate cellulose nanowhiskers.
- Determine degree of alignment of individual whiskers.
- Counter propagating waves produce standing wave field.
- Dense particles move to pressure nodal planes.
- Fibres align along nodal plane.

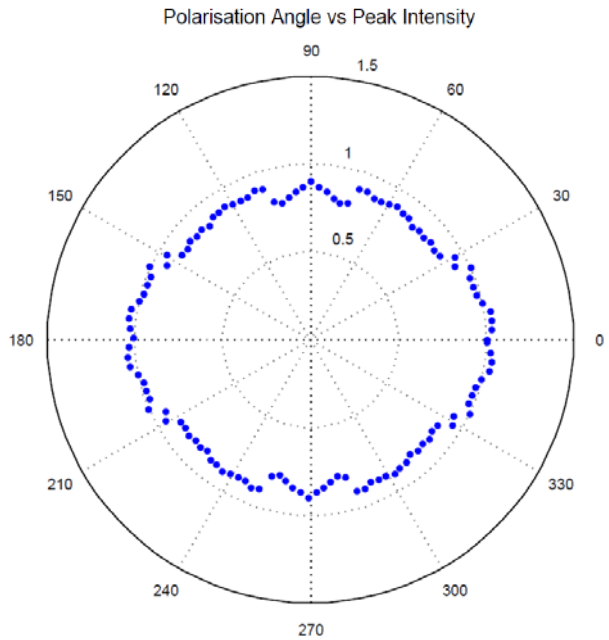




Alignment Analysis

- Polarised Raman Spectroscopy used.
- Raman spectra taken for every 3° from 0° to 90°.
- Intensity ratio of two cellulose peaks gives qualitative degree of alignment.
- Approximately 20% variation in aligned content from 0° to 90°.





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EPSRC
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Rolls-Royce

Establishing a Micro-Mechanical Modelling Framework for Tufted Composites: Mode I

Camilla Osmiani

Giuliano Allegri, Ivana K. Partridge

ACCIS CDT Conference
15th April 2014

www.bris.ac.uk/composites

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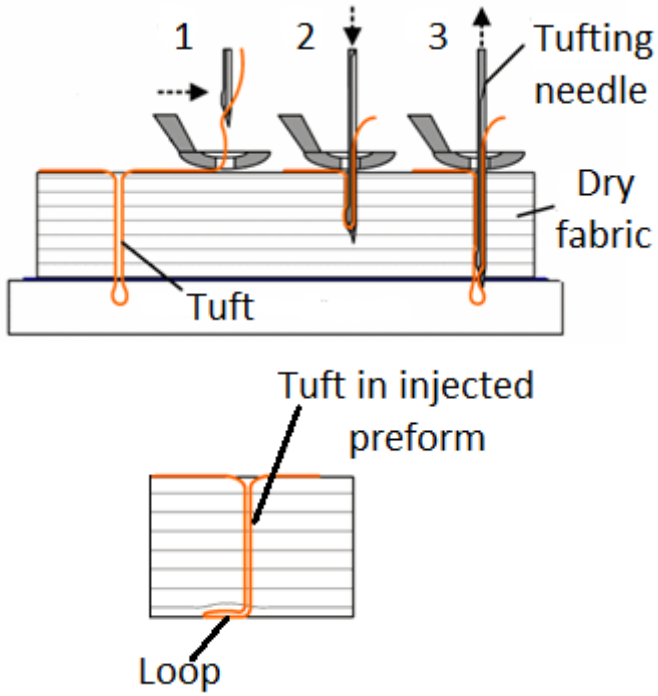
Introduction & Background

Tufting

Through-the-Thickness Reinforcement (TTR) technique for dry preform/liquid resin infusion systems.

*Tufting robot at **National Composites Centre**, Bristol, UK*



Tufting process, from [1]

Objectives

Development of an **analytical model** for the prediction of the closure force exerted by a single tuft as a function of the relative **delamination crack** opening, so called "**bridging law**".

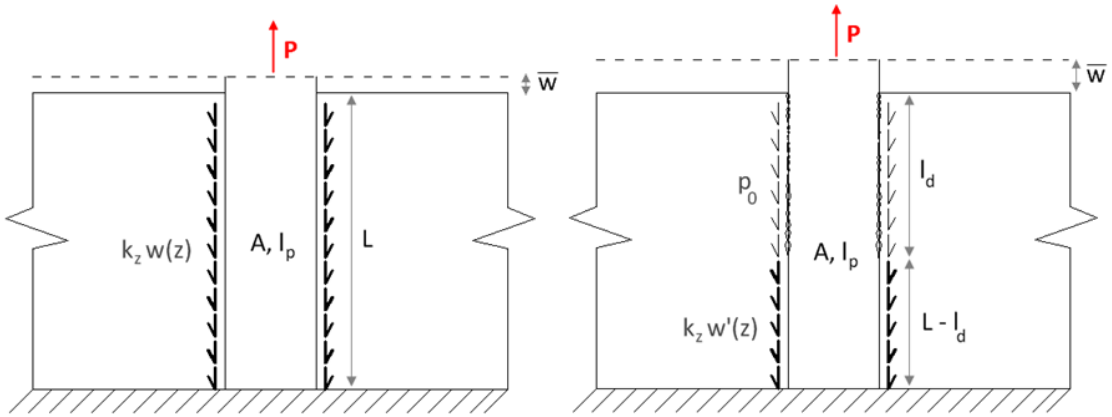
[1] J.W.G. Treiber, PhD Thesis, Cranfield University, 2011

Project Overview

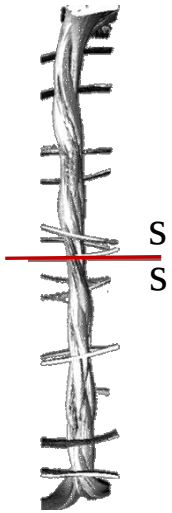
Experimental testing of pre-delaminated single-tuft specimens – **Mode I**

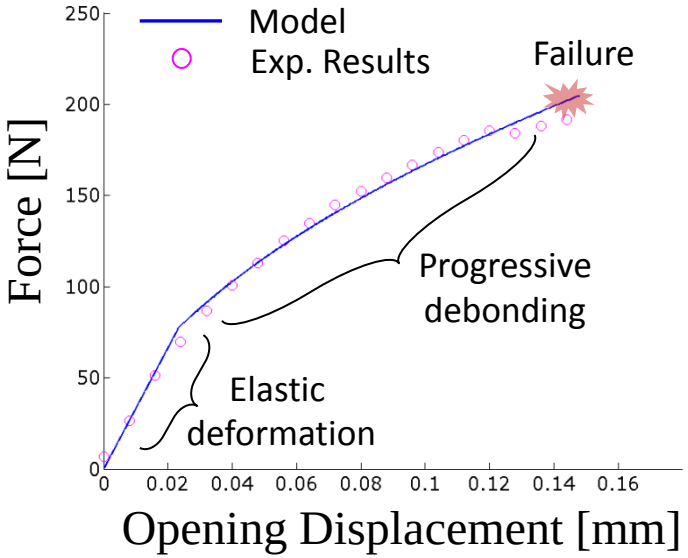
Analytical modelling of single-tuft bridging laws (**micro-scale**)

Implementation in FE **meso-scale** models via cohesive elements



1. Bonded Regime **2.** Debonding Regime





Outcomes

- Bridging mechanisms captured
- Influence of laminate thickness investigated
- FE implementation verified

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Intelligent Composite Layup by the Application of Tracking and Projection Technologies

Matthew Such

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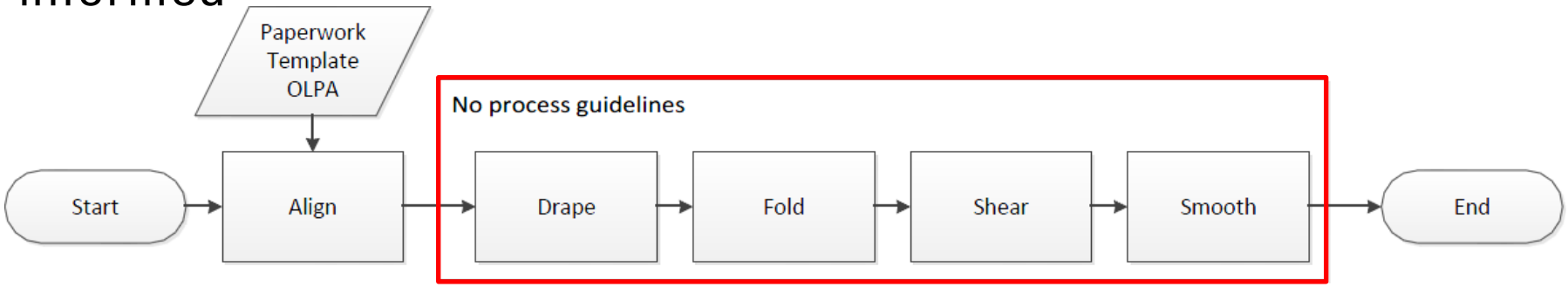
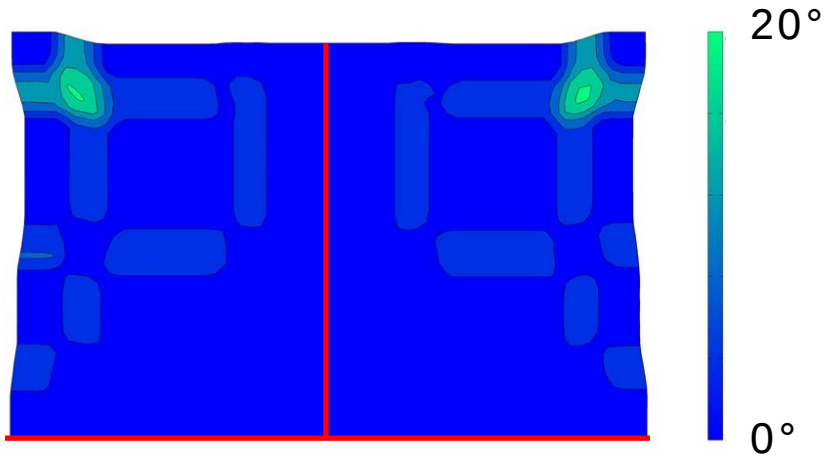
Layup Guidance

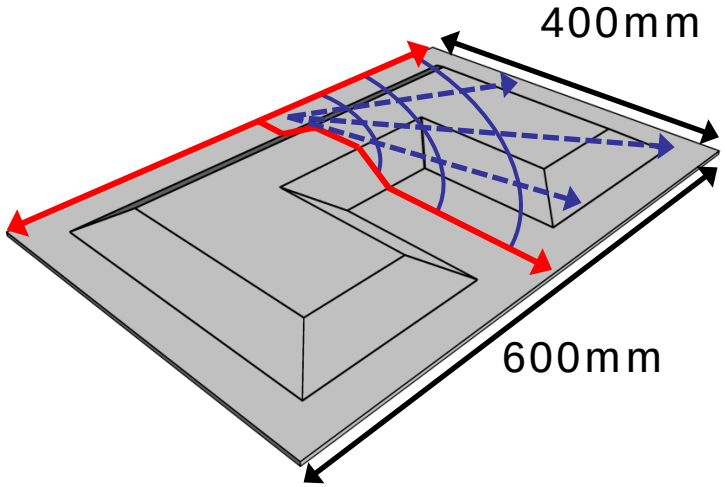
- Hand layup is a dominant forming process which is poorly understood and informed



- Benchmark tool assessed with Virtual Fabric Placement (VFP)



In-plane shear deformation with tool path overlay



1) Tack rear base and cut-out
2) Smooth towards net free edges

Sequential Features

- Global solution translated into feature by feature method, sequential features are projected while laminator actions are tracked