BITS Pilani
Hyderabad Campus

Characterisation of Natural fibres for Composite applications

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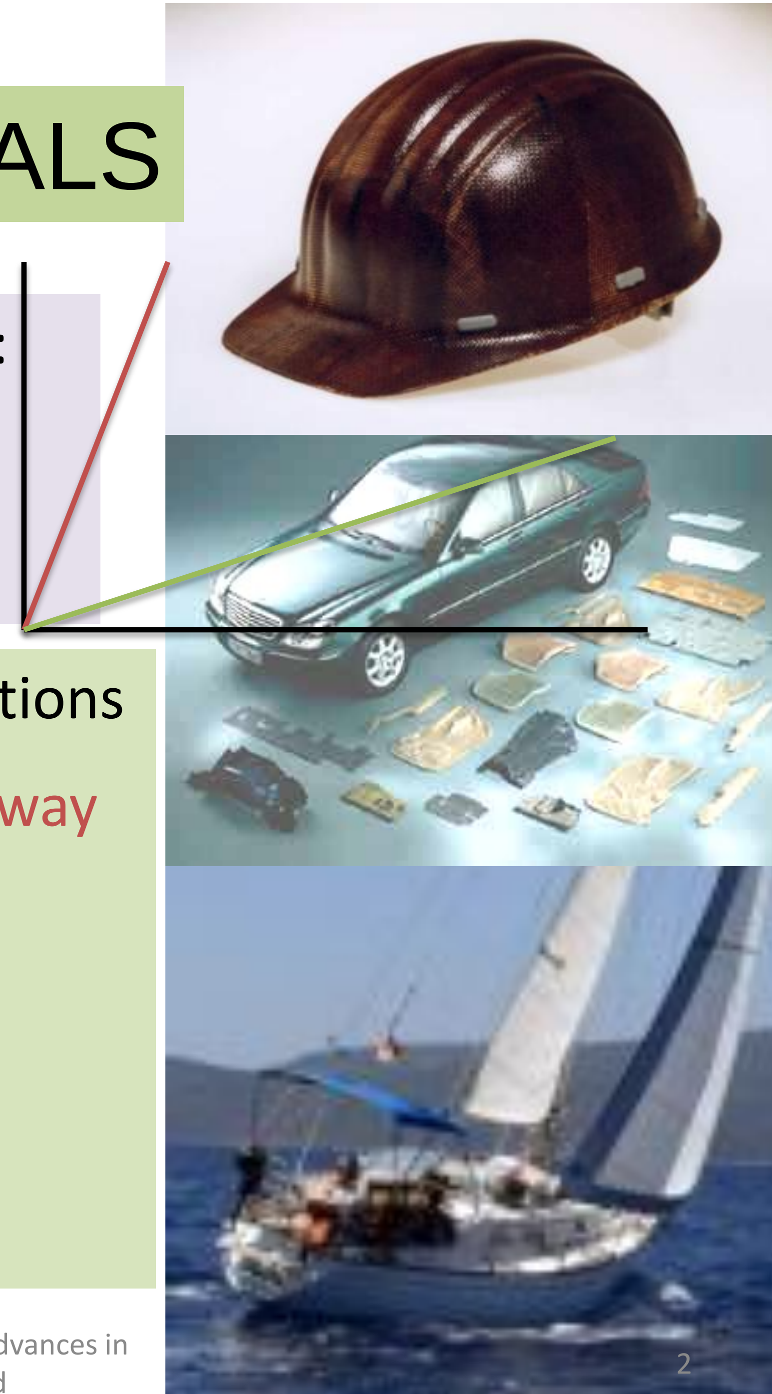
COMPOSITE MATERIALS

Polymer Matrix Composites (PMC):

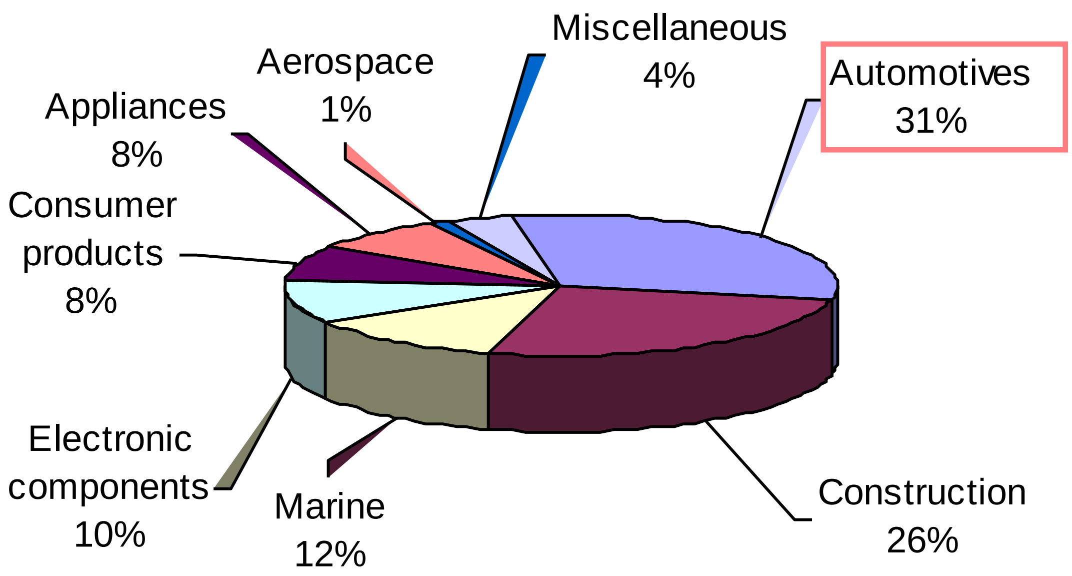
- Low modulus matrix

- High modulus fibers



- High potential for lightweight constructions
- Tailoring of properties in user-defined way
- High damping properties?
- Good corrosion resistance
- Environmental toxicity?
- Production and life cycle costs ??

Introduction Polymer Composites



Fiber-reinforced Polymer composites used in 2002

Glass Fiber Reinforced Polymer composites – GFRP

Carbon Fiber Reinforced Polymer Composites – CFRP

Aramid Fiber Reinforced Polymer composites-AFRP

Glass fibers are used in 95 % of the cases to reinforce plastics
Market: 2.2 Million tones (2002)

Source: Mohanty, Misra, Drzal; Natural fibers, Biopolymers and Biocomposites; 2005

European legislation

	2006	2015
Material utilization and re-use	> 80%	>85%
Thermal utilization	< 5%	<10%
Utilization	>85%	> 95%
landfill	< 15 %	< 15 %

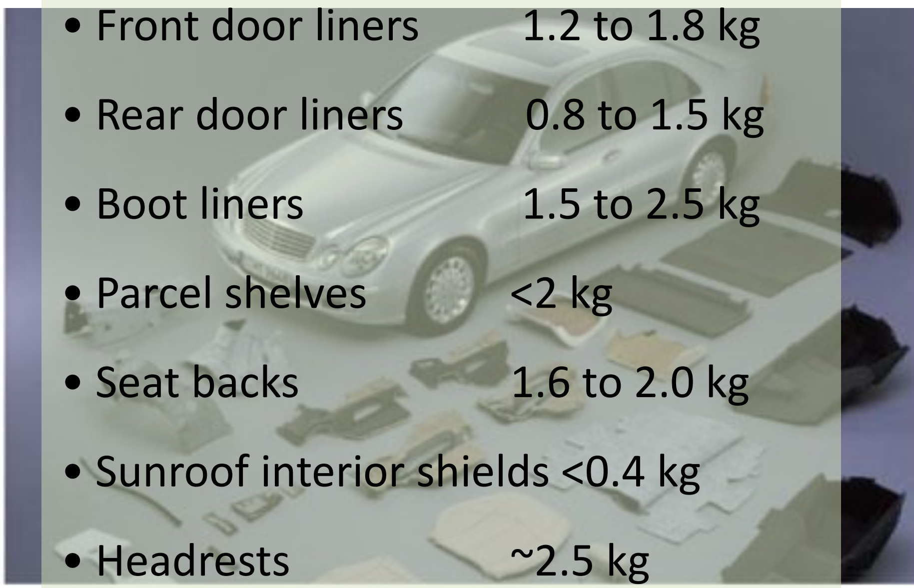
End-of-life vehicles regulation (ELV) and “European Composite Recycling Concept” imposed significant and strict regulations on composite waste management.

Starting from 2006 at least 85 % of the average weight of an old vehicle are to be used or reused to at least 80 % materially or rawmaterially.

Till 2015 these utilization must be increased up to 95 % (utilization) and/or 85% (material utilization and re-use).

Is there any alternative to glass fibres in polymer composites?

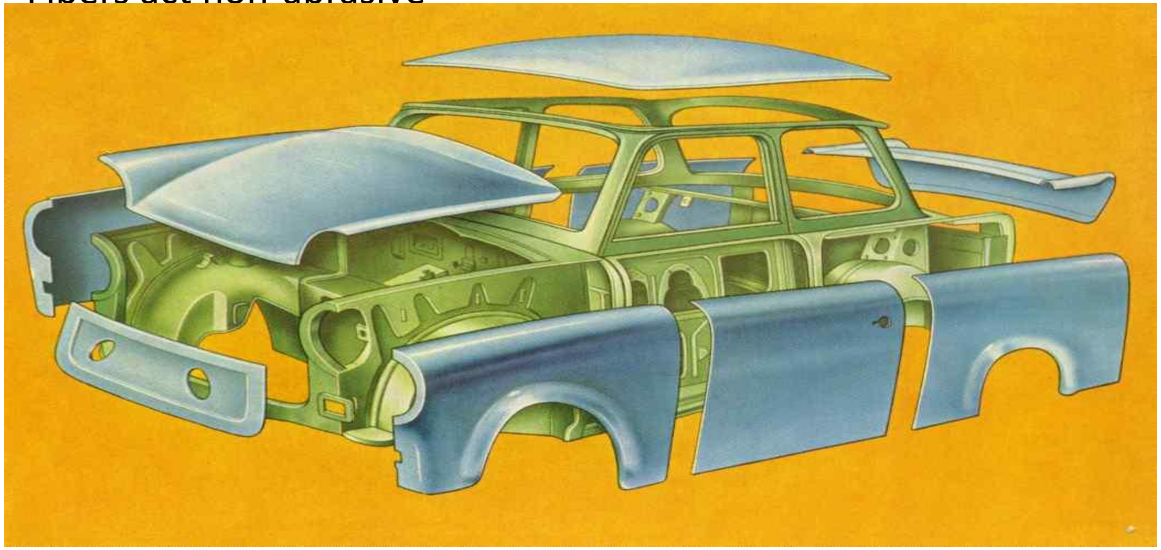
Flax, Ramie, Jute (Bast fibres)



- Front door liners 1.2 to 1.8 kg
- Rear door liners 0.8 to 1.5 kg
- Boot liners 1.5 to 2.5 kg
- Parcel shelves <2 kg
- Seat backs 1.6 to 2.0 kg
- Sunroof interior shields <0.4 kg
- Headrests ~2.5 kg

Replace Glass fibres with Flax, Hemp, etc. - BIOCOMPOSITES

1. Annual growing raw material up to two crops/a
2. Low costs
   0.5 to 1 €/kg compared to 2 €/kg for glass fibers
3. Low density
   1500 kg/m^3, glass 2500 kg/m^3
4. Fibers act non-abrasive



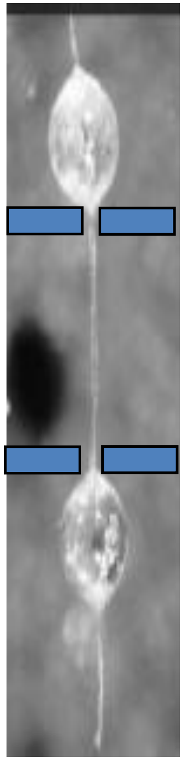
5.
6.
7.
8.
9.

10. Environmental Regulations (end-of-life vehicle regulation ELV)

Money spent to reduce the 1 kilo weight:

Space agencies	25,000 Euro
Aeronautics	250 - 750 Euro
Automobile	0 - 2.5 Euro

Single Fibre testing



Ball and socket method

Direct gripping

Paper frame set-up

•Direct gripping (ASTM D 3822) Standard test method for tensile properties of single textile fibres

- Viscose rayon, Flax, Polyester

• Paper frame set-up (ASTM D 3379-75) Standard method for tensile strength and youngs modulus of single technical fibres

- Glass, Carbon, Aramid

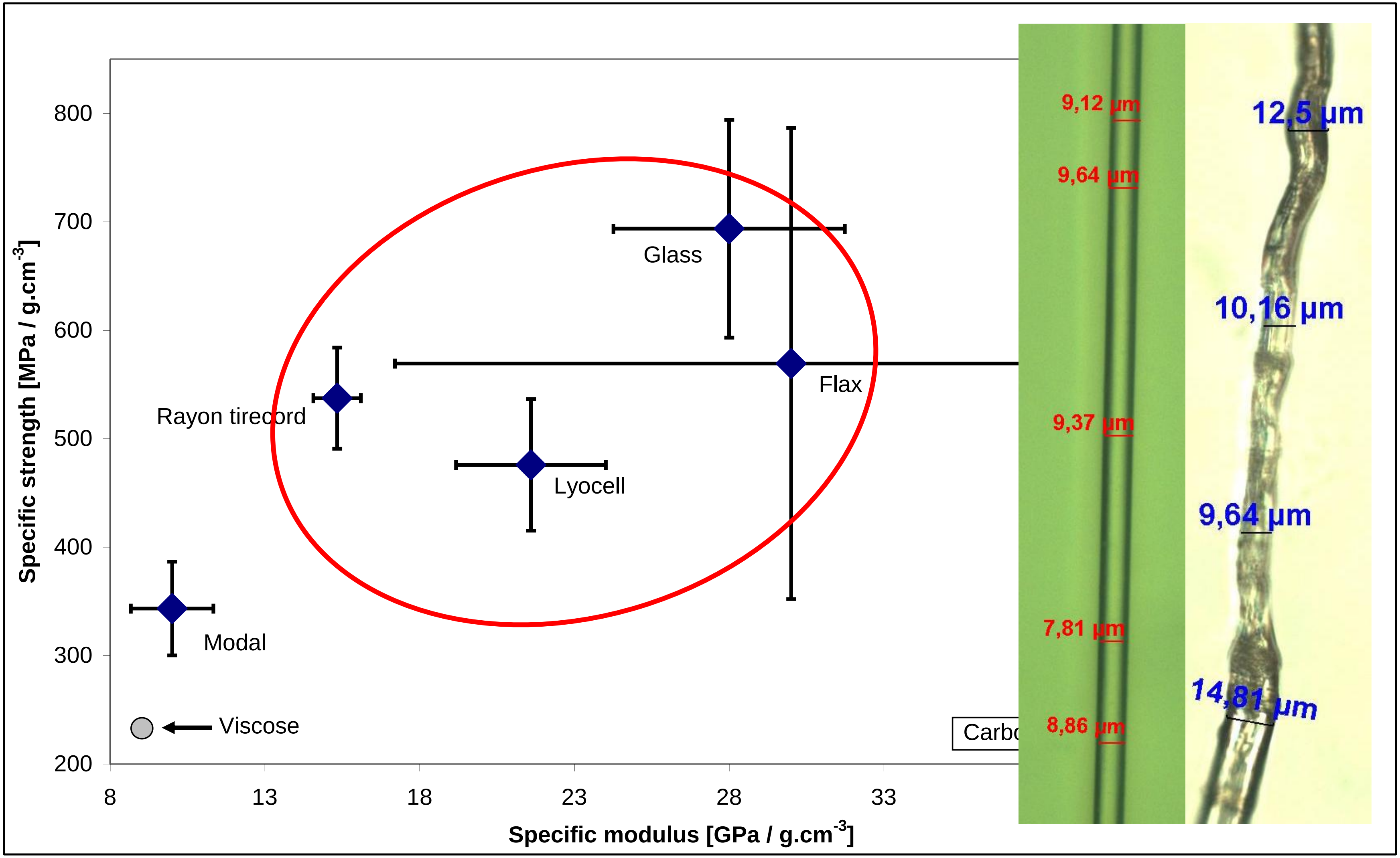
Gauge length 20 mm (Paper frame)

Gauge length 50 mm (Direct gripping)

To avoid the slippage problem and for better accuracy in E-modulus measurement << Paper frame set-up >> is adopted for single pulp fibre testing.

Courtesy: Dr. Navi and Dr. Sedighi-Gilani from EPFL (CH); Prof. Gindl from BOKU (A).

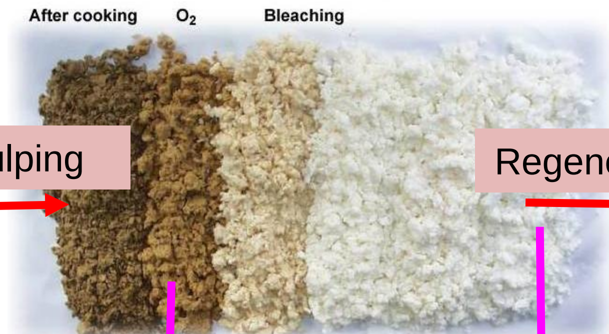
Single fibre tensile properties



Viscose (Rayon) and Lyocell fibres

Pulping / cooking aims to separate cellulose fibers from the wood structure.

Pulping



Regeneration

Raw Cellulose (I) - Unpurified

Regenerated Cellulose (II) - Purifed

Kraft or Chemical pulpin uses NaOH and Na2S, here *Lignin is completel removed*. It accounts for 70 % pulp production.

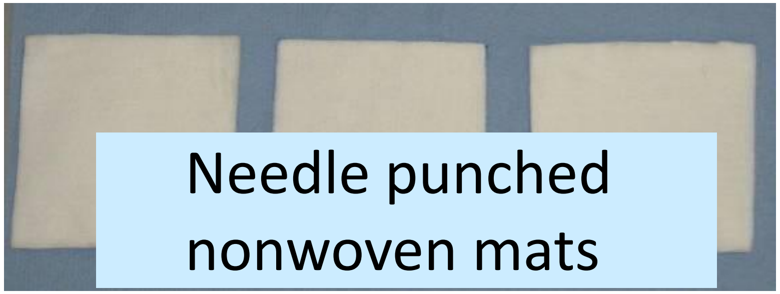
Mechanical properties of

Cellulose (I) >> Cellulose (II)

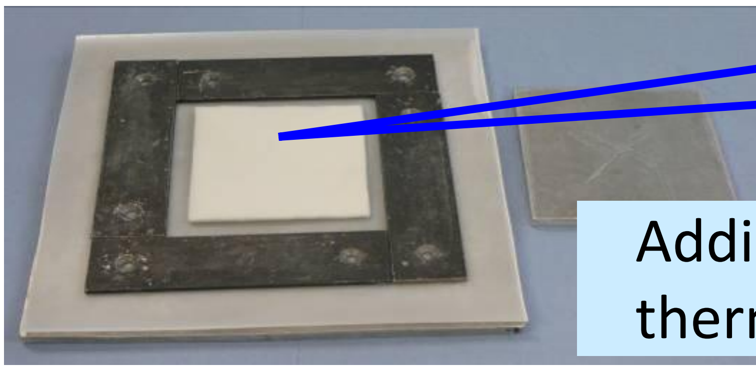
BIRLA Cellulose

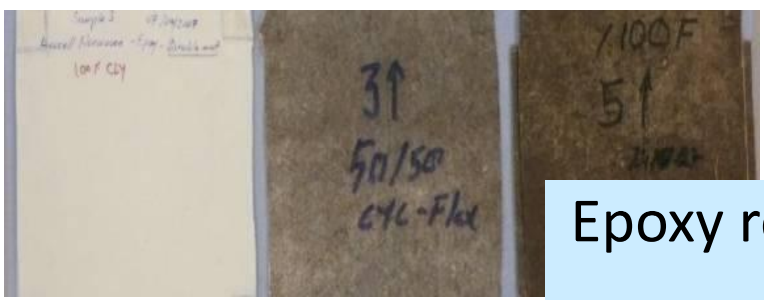
Mechanical pulping involves metal disks which grinds the wood, here lignin is partially removed.

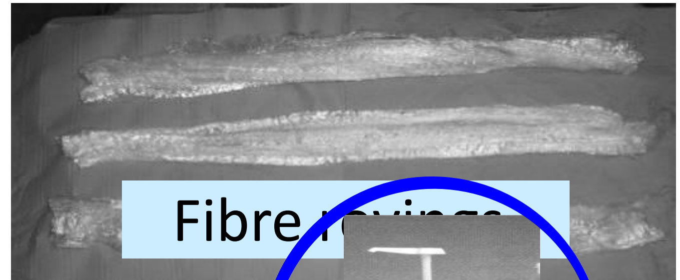
Composite Manufacturing



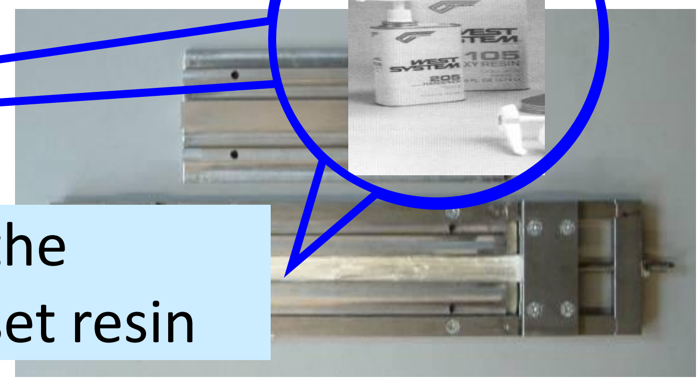
Needle punched nonwoven mats







Fibre rovings



Adding the thermoset resin

Epoxy resin, 80 degrees, 1-2 hours

Fibre volume content - 55 %

Fibre - Matrix adhesion determination

Microlevel — Microbond test

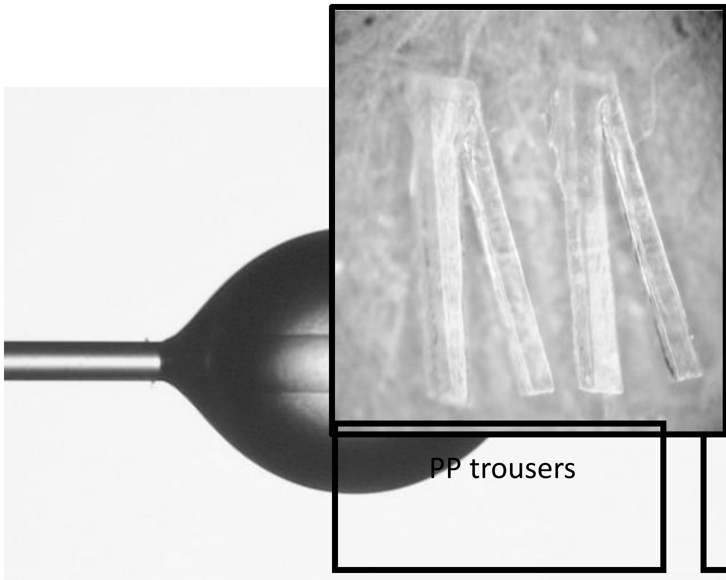
Interfacial shear strength is measured

Macrolevel-1 — Scanning electron mictoscopy

Fibre pull-out is considered

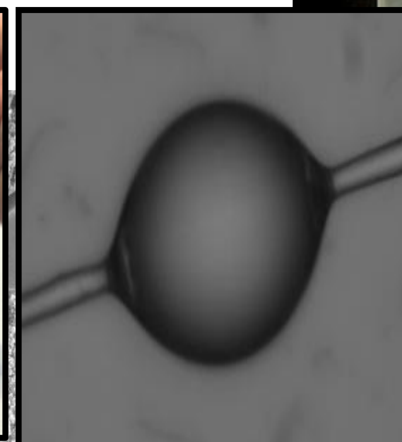
Macrolevel-2 — Double notch shear test

Interlaminar shear strength is measured

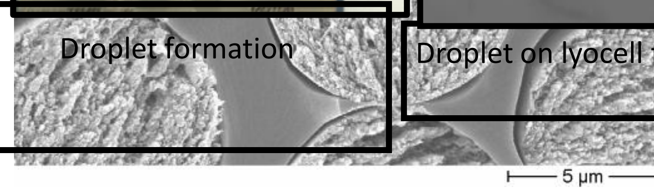


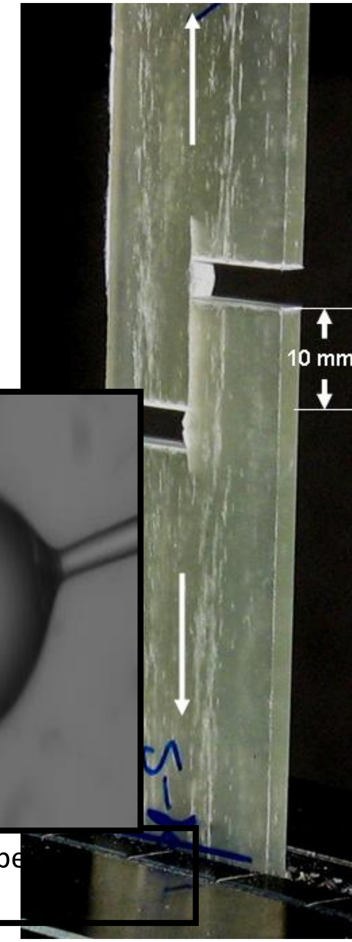
PP trousers

Droplet formation



Droplet on lyocell fibe



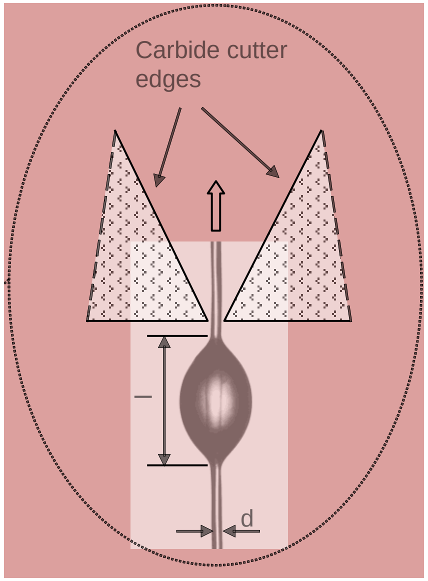


Epoxy droplet on lyocell fibre

SEM fractograph of lyocell-epoxy

Shear test of lyocell-epoxy composite specimen

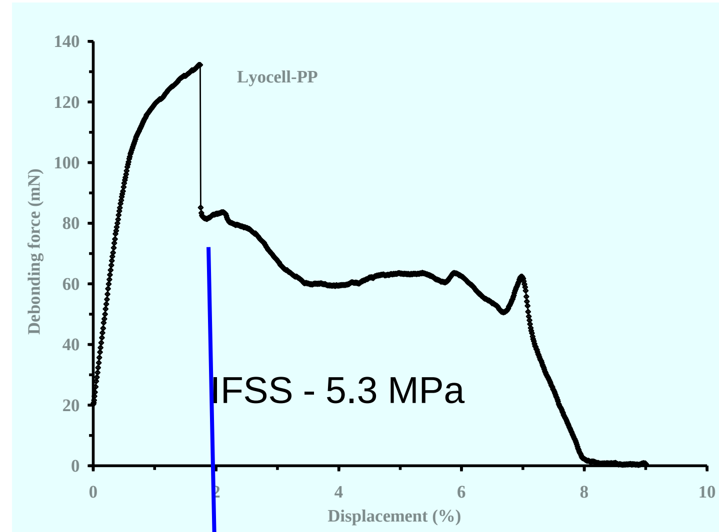
Microbond technique

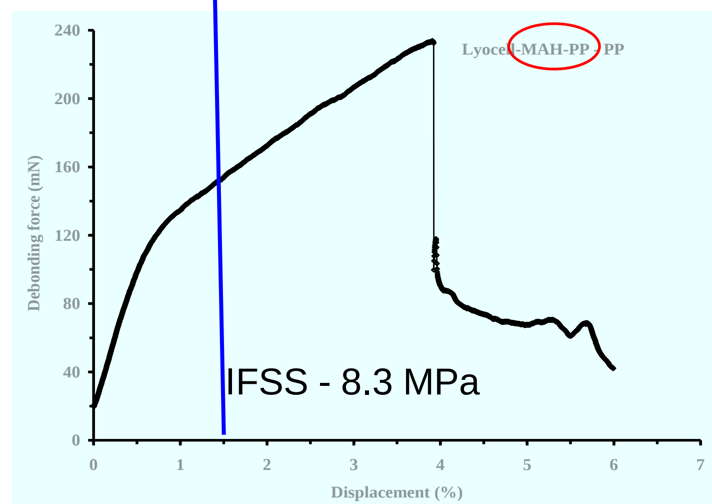


$$\tau = \frac{F}{\pi d l}$$

l / d ratio for lyocell-PP ~ 20

l / d ratio for glass-PP ~ 80

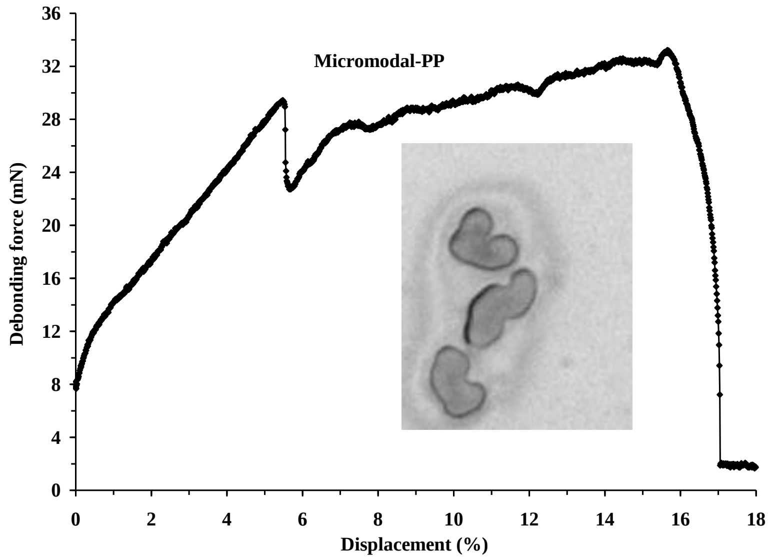


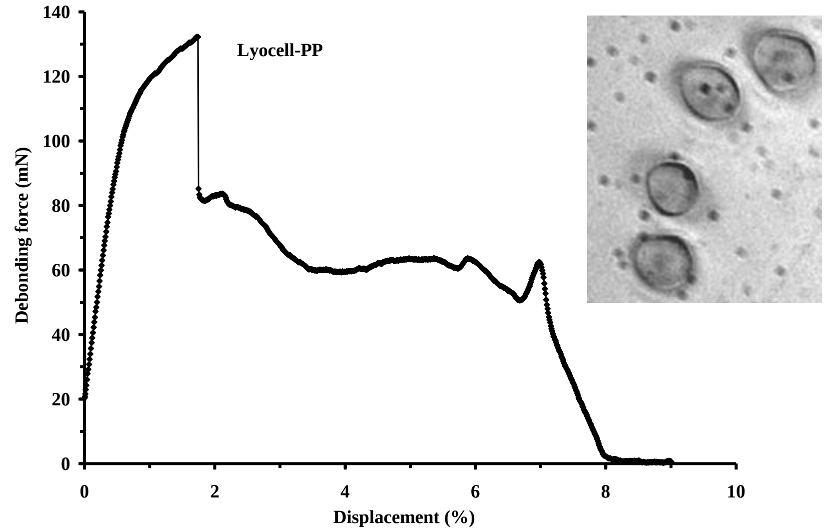


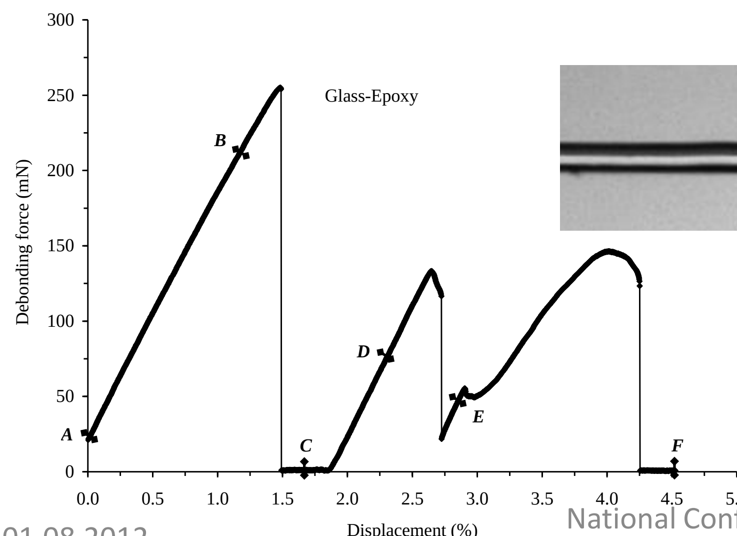
= Interfacial shear strength
F = Maximum load prior to de-bonding
d = fibre diameter
l = fibre embedded length

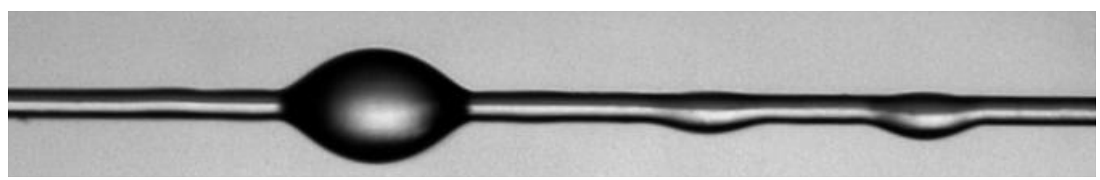
Influence of fibre modification (MAH) is quantitatively observed

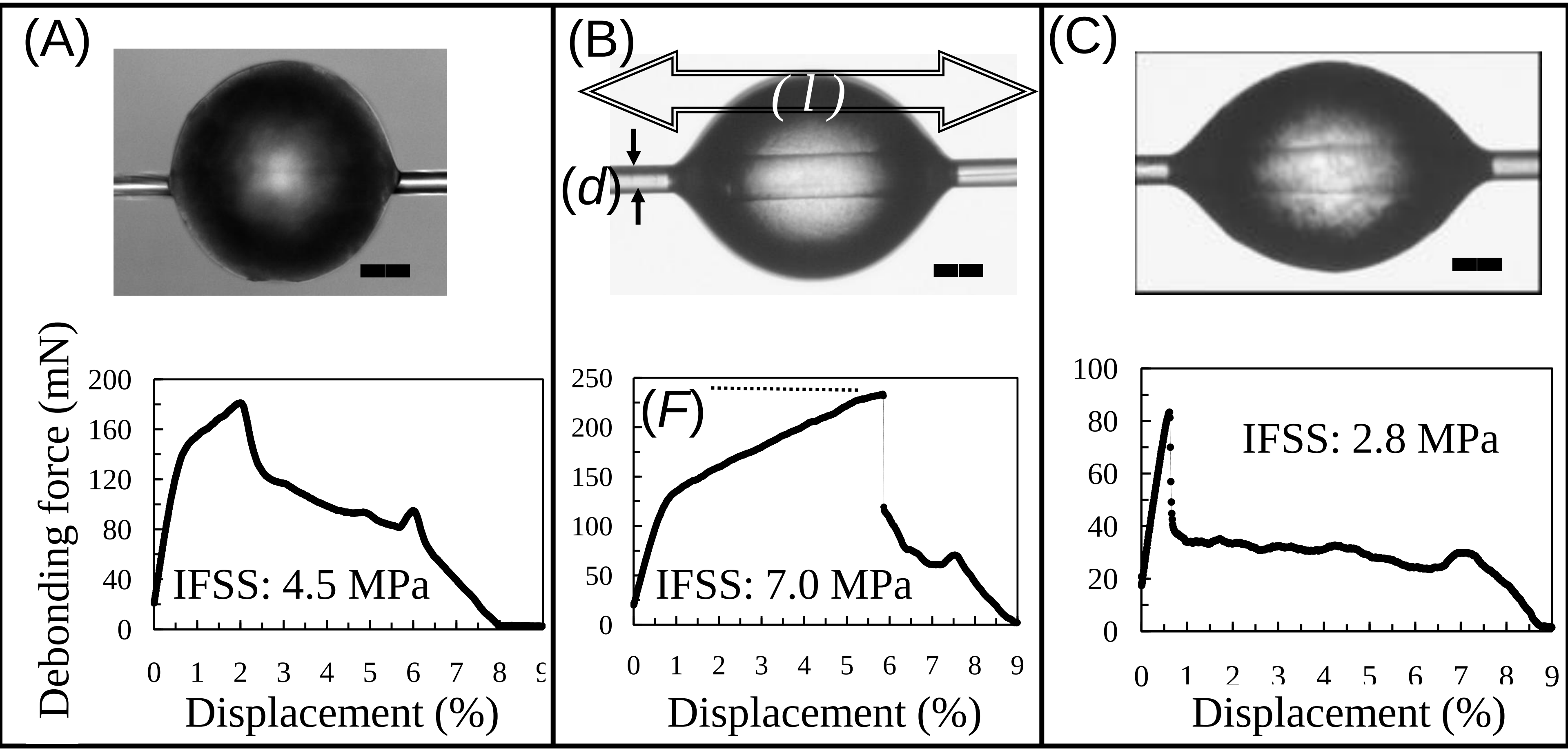
Debonding in Microbond test



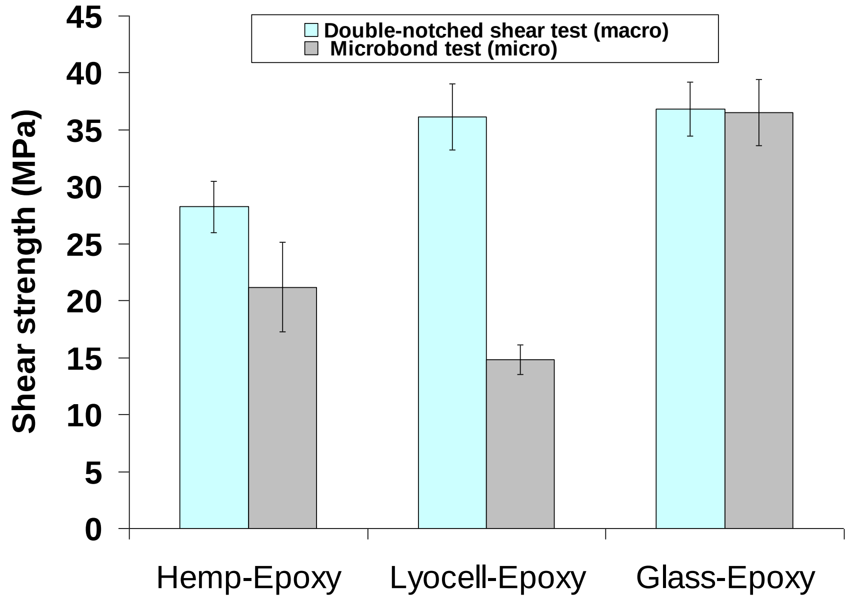






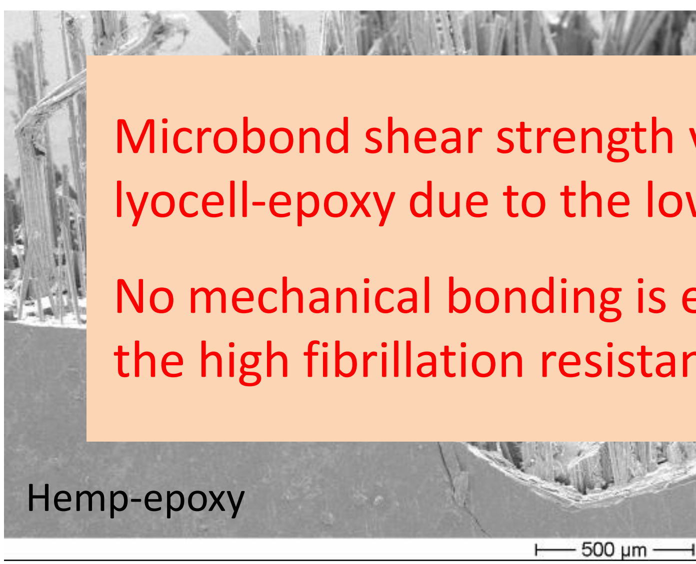

(A)
(B)
(C)
(l)
(d)
(F)
Debonding force (mN)
Displacement (%)
IFSS: 4.5 MPa
IFSS: 7.0 MPa
IFSS: 2.8 MPa

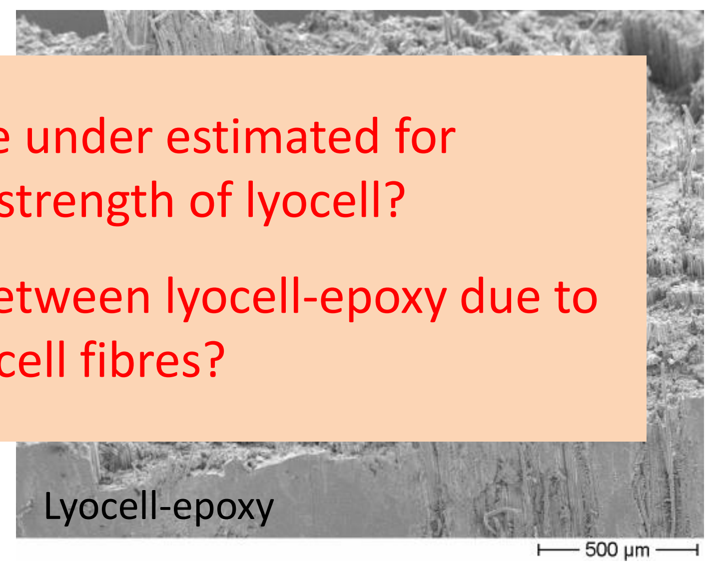
Fibre-Matrix adhesion: comparison



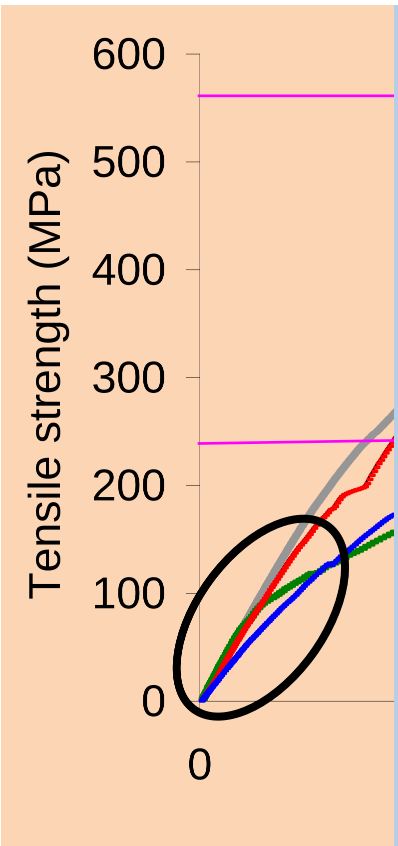
Microbond shear strength values are under estimated for lyocell-epoxy due to the low tensile strength of lyocell?

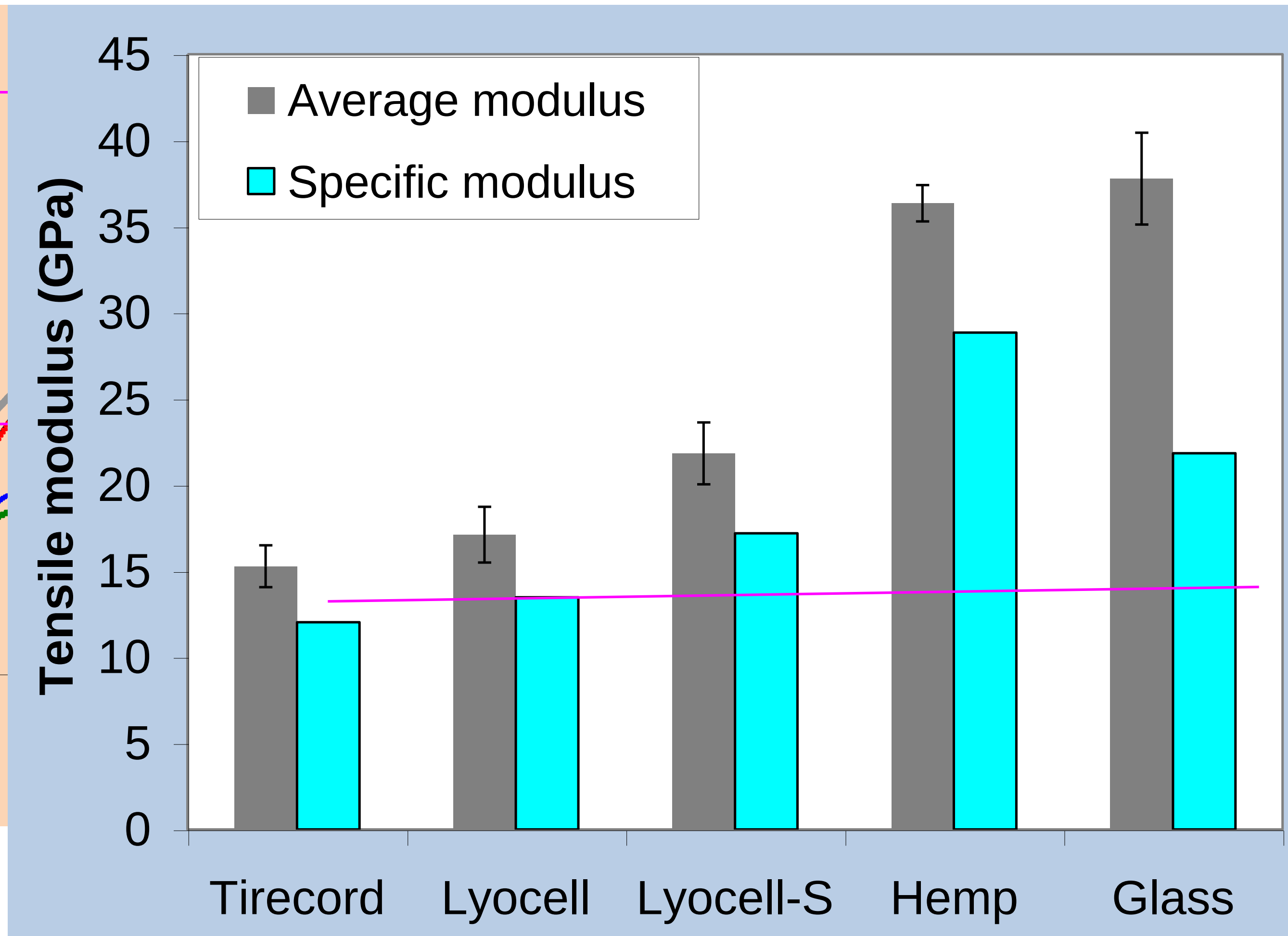
No mechanical bonding is existing between lyocell-epoxy due to the high fibrillation resistance of lyocell fibres?

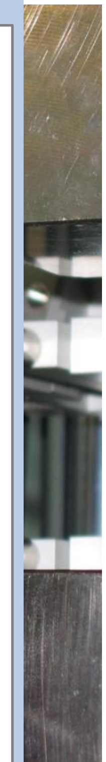




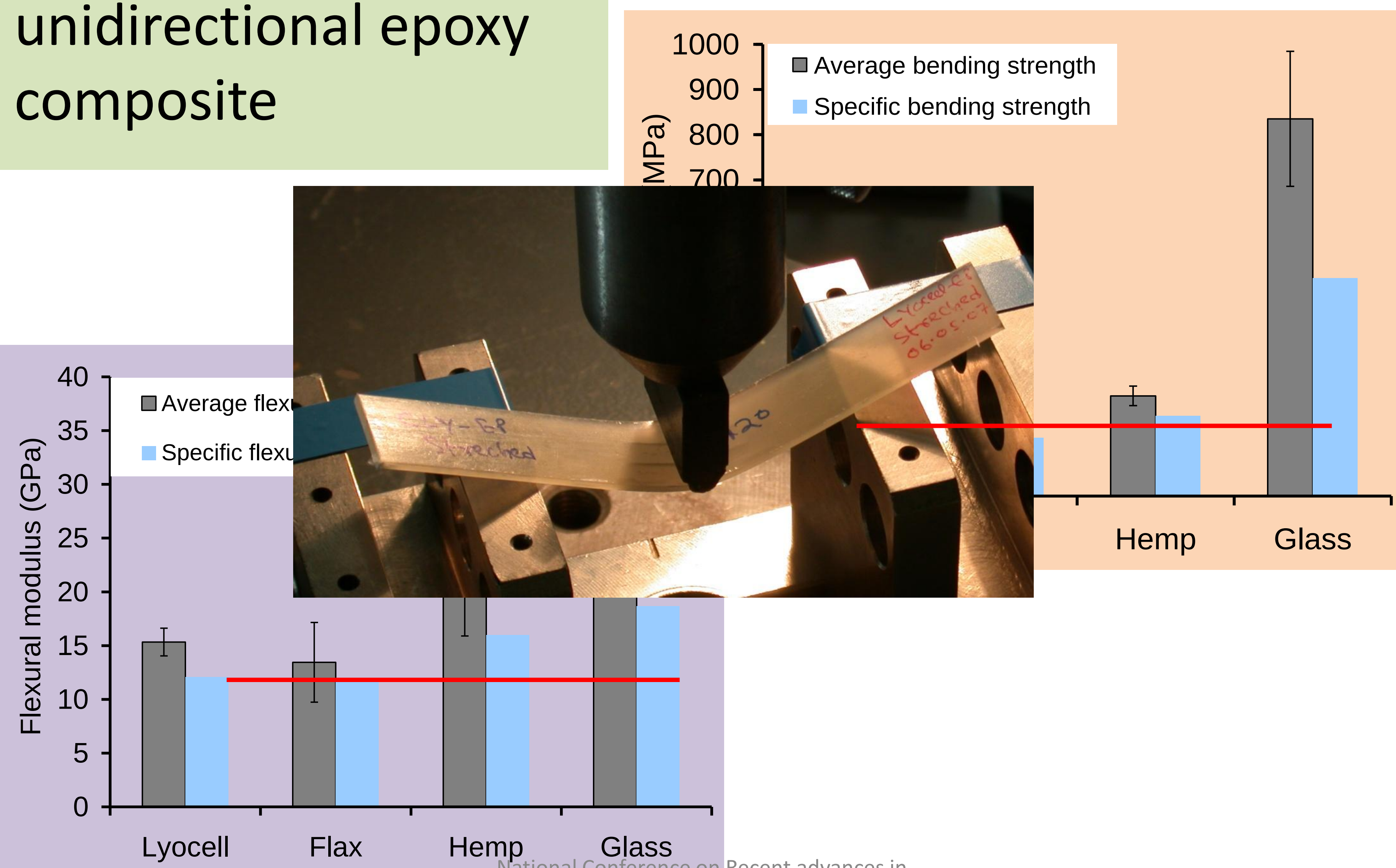
Tensile properties of unidirectional composite



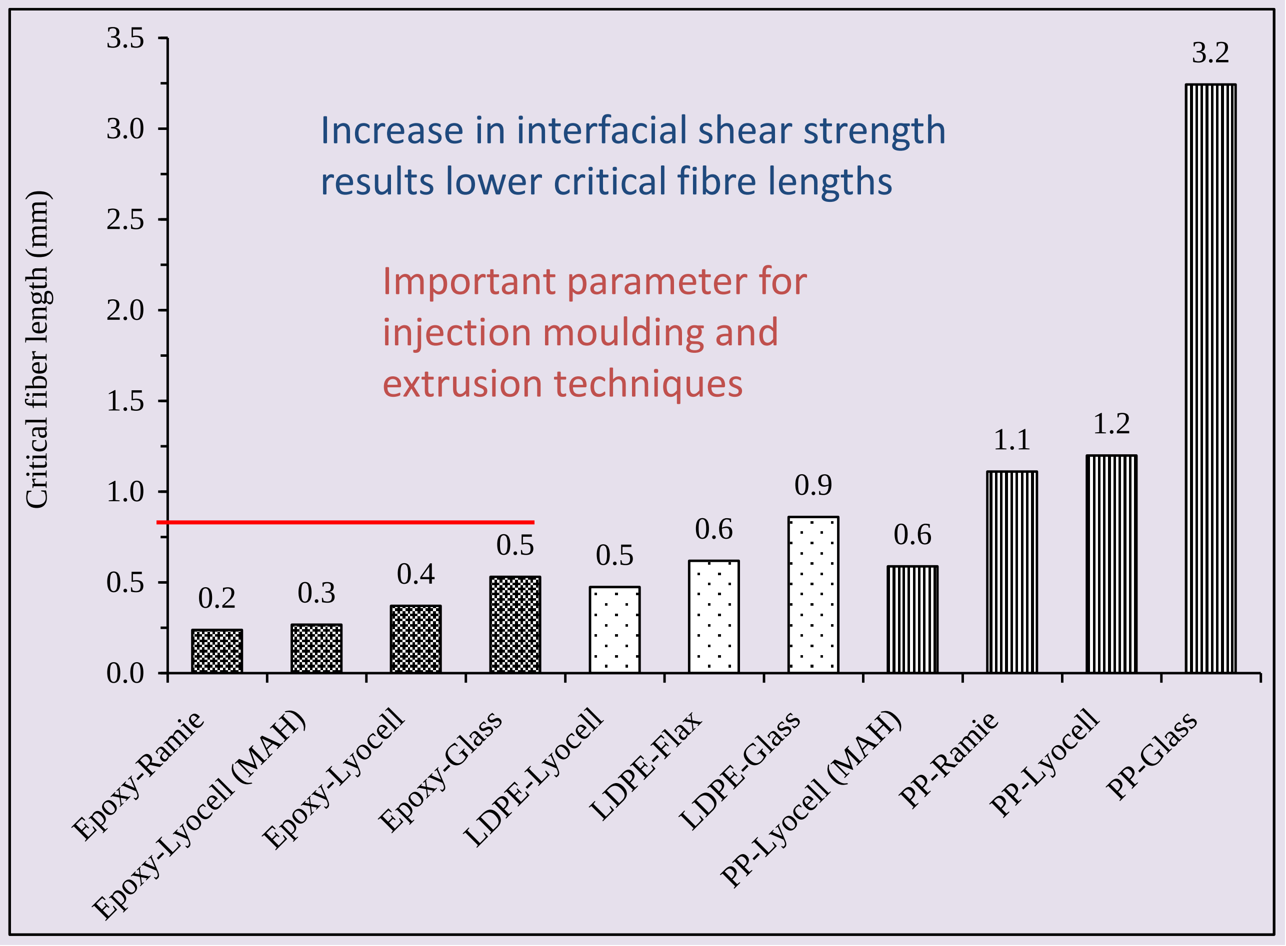


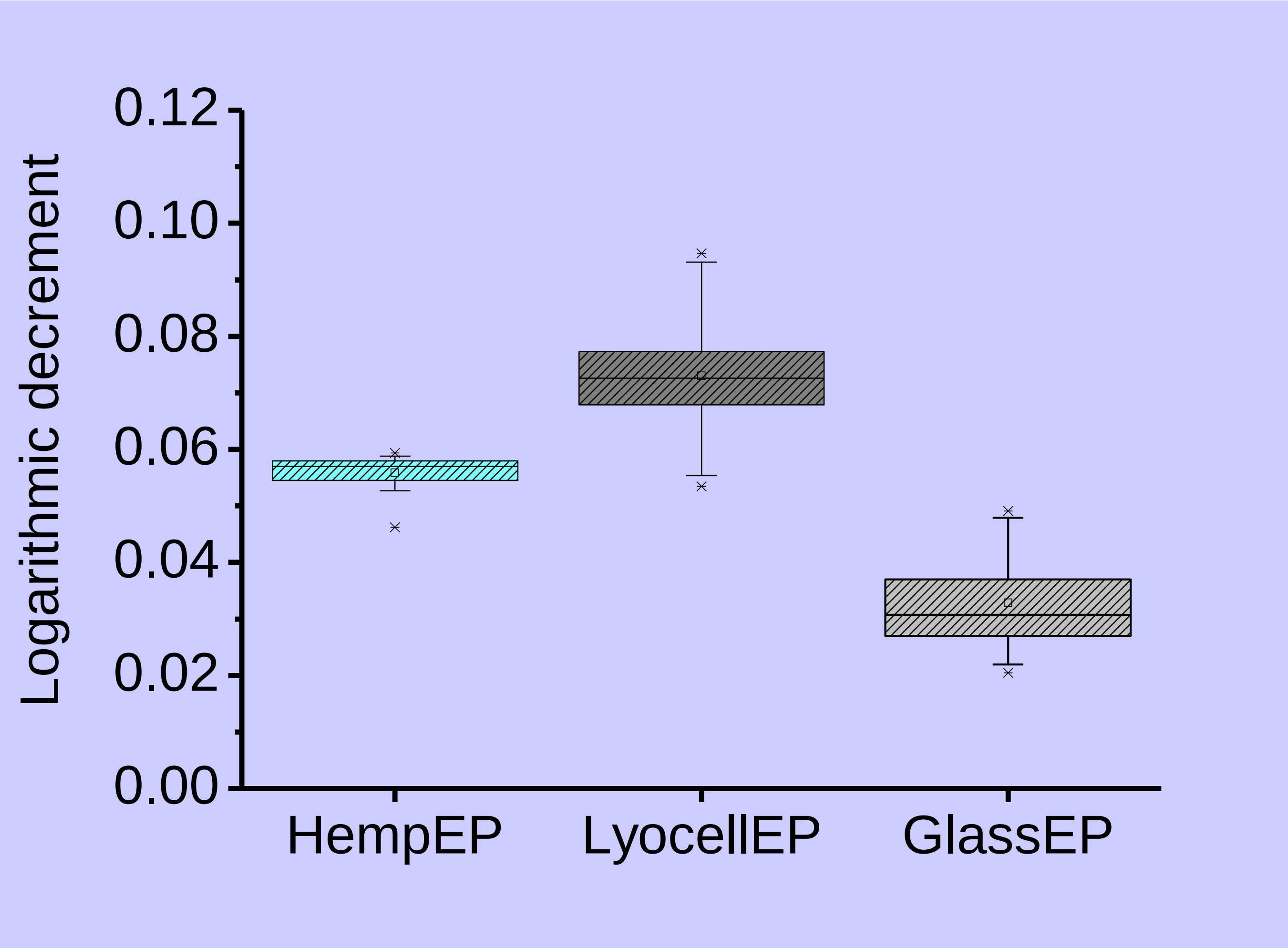


Bending properties of unidirectional epoxy composite

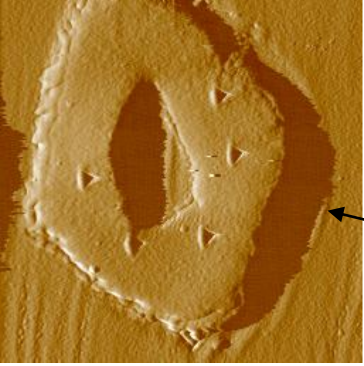


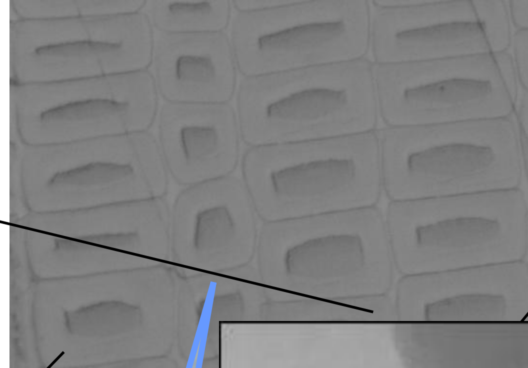
Critical fibre lengths derived from microbond test

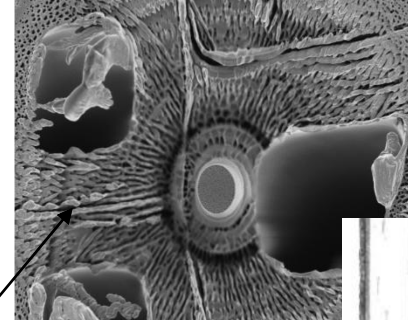


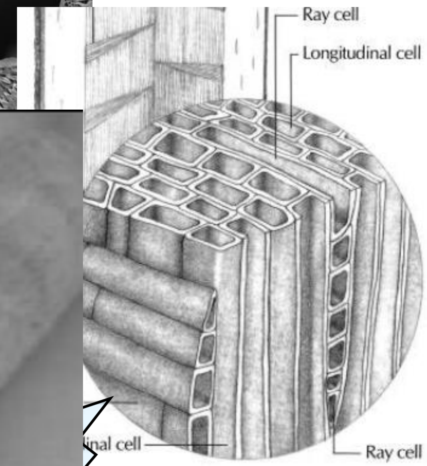


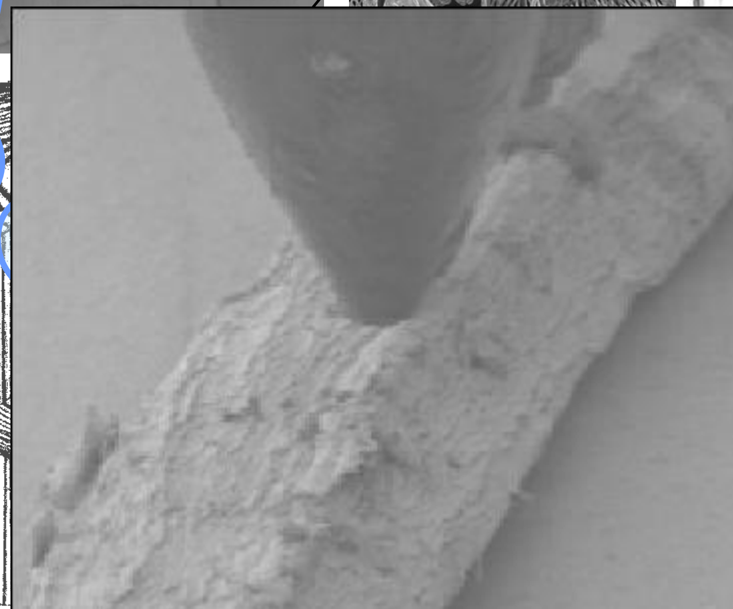
Logarithmic decrement
0.12
0.10
0.08
0.06
0.04
0.02
0.00
HempEP
LyocellEP
GlassEP

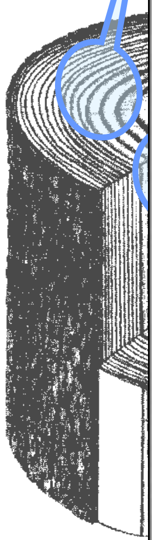


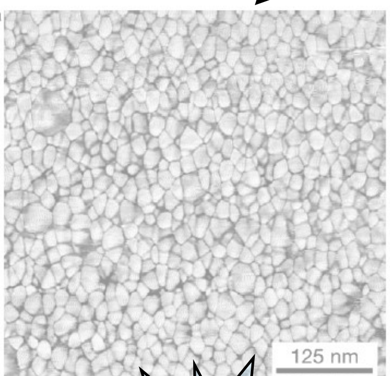


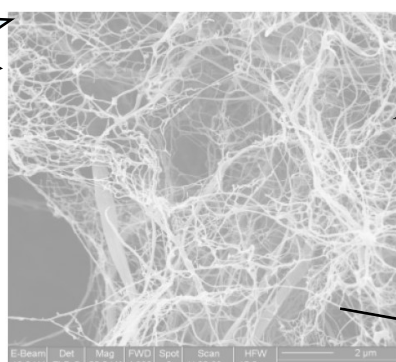


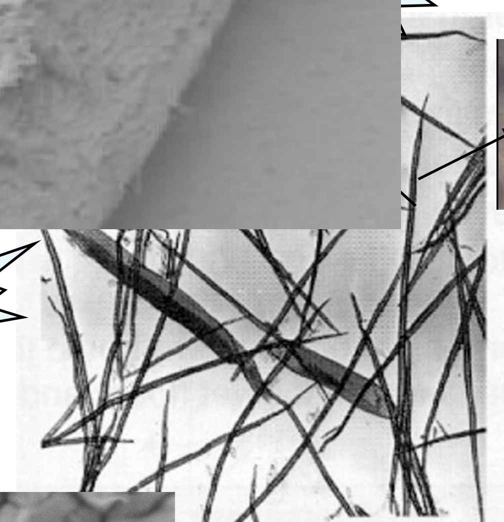


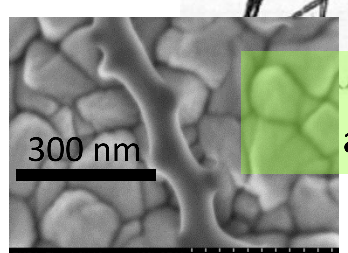












Testing nanofibril 30-40 nm diameter and 1 μm length still remains a challenge!

Conferences and publications

1. Presented a *poster* at “Zellcheming 2006”, Wiesbaden, Germany
2. Presented *poster* at 2nd “Wiener Biomaterial sympoisum”, 2006, TU Vienna, Austria
3. Presented a *poster* at “9th International conference on Wood and Natural fibre reinforced composite”, 2007, Madison, USA.
4. Given a talk at “European Conference on Composite Materials” (ECCM 12) 2006, Biarritz, France

1. Single fibre characterisation of Viscose, Lyocell, Flax and Glass fibres. Proceedings ECCM-12, Biarritz, France, Sept. 2006.
2. Tensile Testing of Single Regenerated Cellulose fibres, Macromolecular symposia 2006;244;83-88.
3. Mechanical Properties of Regenerated Cellulose fibres for Composites, Macromolecular symposia 2006;244;119-125.
4. Anisotropy of the modulus of elasticity in regenerated cellulose fibres related to molecular orientation, Polymer 2008;49;792-799.
5. Differences in the molecular orientation and mechanical properties of uncrimped and crimped regenerated cellulose fibres. Cellulose
6. Determining the interfacial shear strength between man-made cellulose fibres and polymer matrices by means of the microbond technique. Journal of Composite Materials
7. Evalution of experimental parameter in microbond technique with regard to cellulose fibres. Journal of Reinforced Plastics and Composites.


THANK YOU VERY MUCH