PRODUCTION AND PROPERTIES OF A MALEATED CASTOR OIL-POLYSTYRENE POLYMER MATRIX

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OUTLINE

- Introduction to study
- Aim of the study
- Overview on synthesis of matrix and composite
- Mechanical tests and results
- Fracture surface analysis
- SEM (RISE)
- Raman Confocal Microscopy
- TEM
- Conclusions

INTRODUCTION TO STUDY

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"…the supplies used to produce products in accordance to the needs of humans should not be depleted; and
emissions caused by the production or disposal of products should have no negative impact on the environment…" [1]

INTRODUCTION TO STUDY

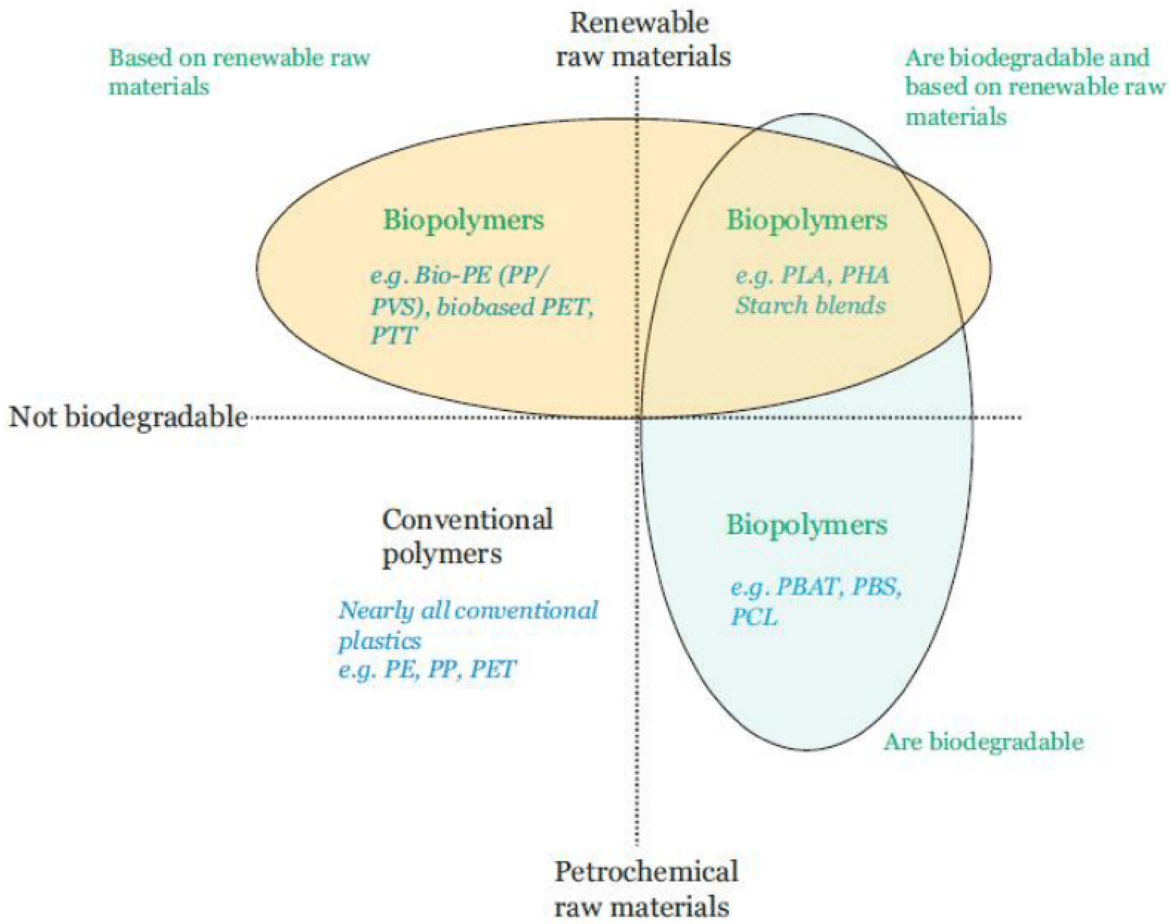
What sets vegetable oil-based polymers apart from conventional polymers?

- More affordable
- Natural resources are readily available
- Properties similar to those of conventional polymers (or better)
- Some are biodegradable, non-toxic
- Low contribution to production of greenhouse gasses

Why castor oil?

- Non-edible
- Contains double bonds and hydroxyl groups = increased reactivity

INTRODUCTION TO STUDY



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AIM OF STUDY

- Conduct research on non-polyurethane biopolymers
- Develop a maleated castor oil/polystyrene (MACO-PS) polymer matrix
- Reinforce the matrix with natural fibres
- Determine the mechanical properties of the matrix as well as the reinforced composite
- Compare these mechanical properties to those of GPPS (general purpose PS) and HIPS (high impact PS)
- Measure biodegradability of MACO-PS matrix

SYNTHESIS OF MATRIX

4-step process:

1. Maleation of castor oil
2. Formation of matrix with styrene (MACO-PS)
3. Hand layup process
4. Thermal curing

RESULTS OF MECHANICAL TESTS AND THERMAL ANALYSIS

Property	MACO-PS	GPPS	HIPS	Reinforced MACO-PS	Standard/ Method
Flexural Properties					
UTS (MPa)	22.1	74.4	27.2	12.2	ASTM D7264-15
Toughness (MPa)	3.94	1.12	3.24	> 2.76	
Strain at break	24.7 %	2.80 %	14.0 %	>31.4%	
Charpy Impact Test					
Impact strength (kJ/m2)	41.5	33.9	58.4	45.0	ASTM D6110
Hardness					
Shore-D hardness	60.5	85.0	76.9	68.0	Durometer

RESULTS OF MECHANICAL TESTS AND THERMAL ANALYSIS

Property	MACO-PS	GPPS	HIPS	Reinforced MACO-PS	Standard/ Method
Tensile Properties					
UTS (MPa)	23	44.8	13.5	13.1	ASTM D638-14
Young's modulus (GPa)	1.0	3.3	1.5	0.3	
Toughness (MPa)	2.53	0.61	3.19	1.0	
Strain at break	12.8 %	1.60 %	25.8 %	11.8 %	
Differential Scanning Calorimetry					
Tg (˚C)	54.9 and 93.2	90-95	-85.2 and 104.3	-	Heating rate of 20˚C/min

MICROSCOPY METHODS

Fracture surfaces

- Leica MZ 8 stereomicroscope

SEM

- WiTec RISE electron microscope
- Backscatter electron analysis
- Low vacuum in presence of small amount of moisture
- 20kV acceleration voltage
- 200x magnification

MICROSCOPY METHODS

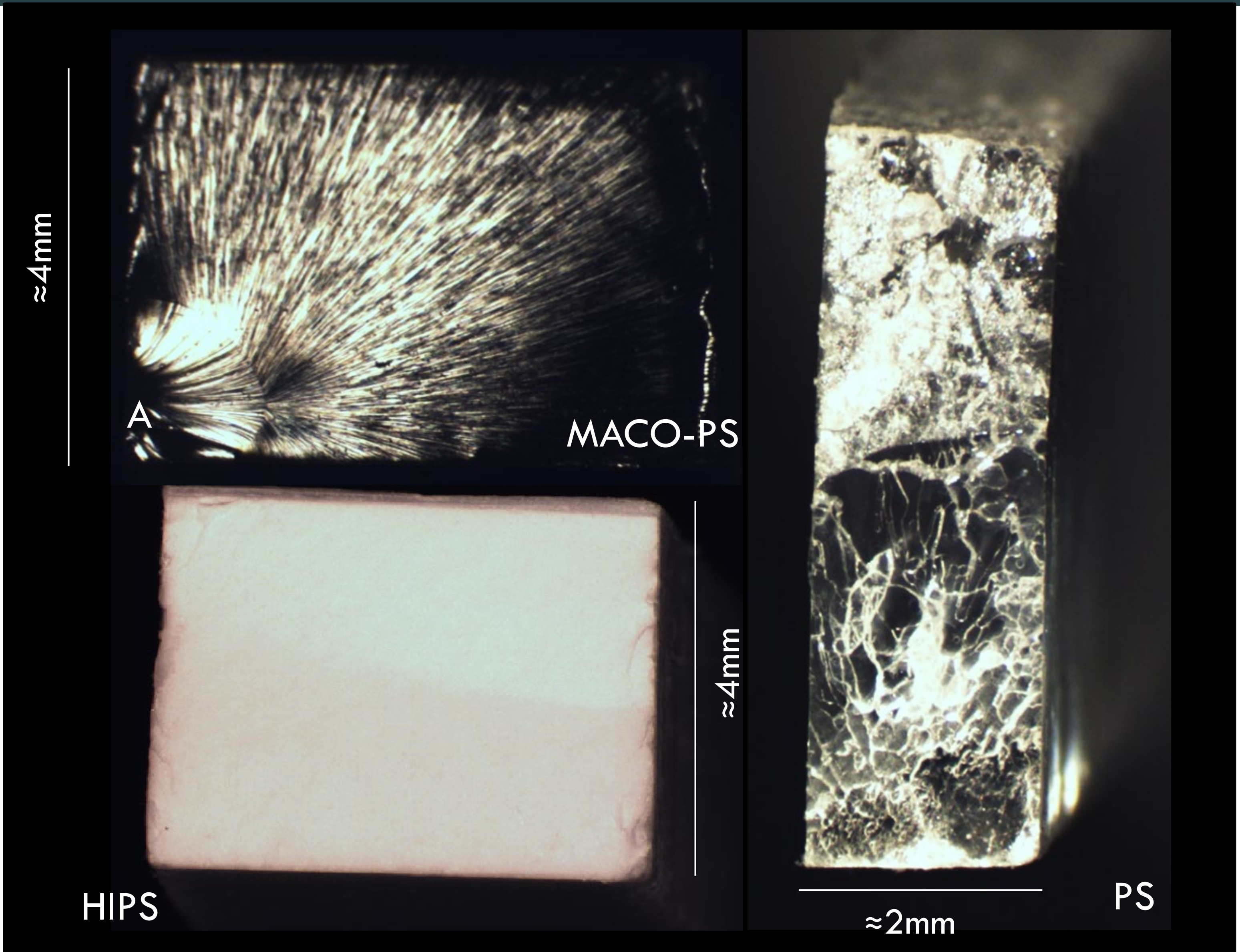
Raman spectroscopy

- WiTec Alpha 300R confocal microscope
- 1-2mW laser power (solids) and 5mW (liquids)
- Integration time was 1.19s for spectra and 0.25s for maps

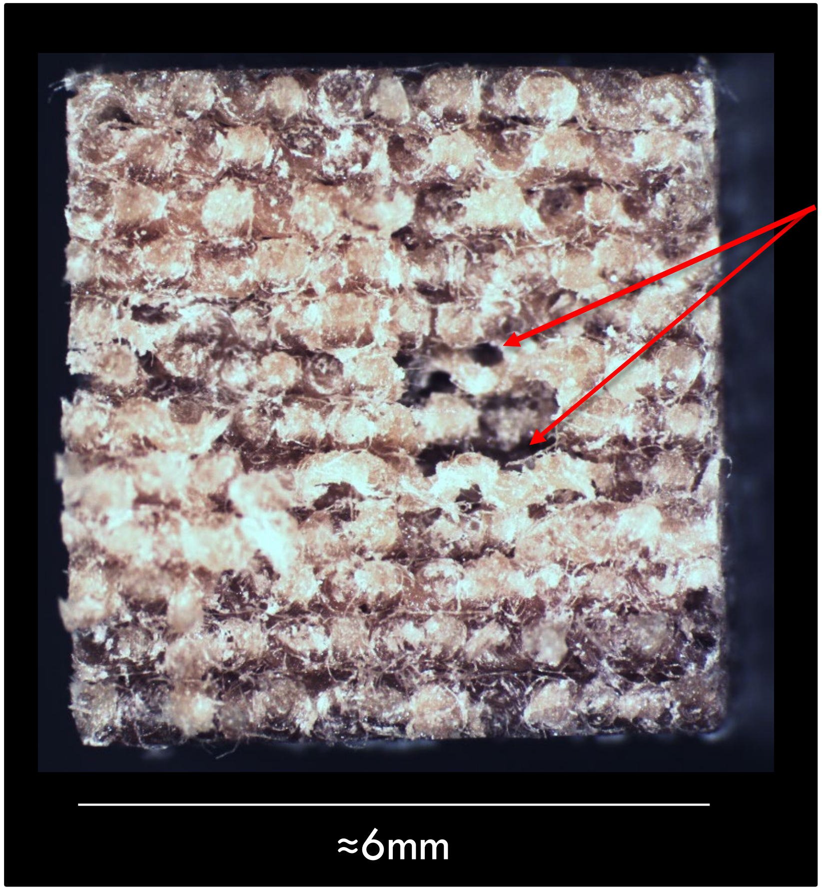
TEM

- Samples cut using Leica Reichert Ultracut S with a diamond blade (100nm sample thickness)
- Samples were vapour stained with 2% OsO_4 solution for 1hr and 16hrs; 0.6% RuO_4 for 30min
- FEI Tecnai G2 F20 X-Twin transmission electron microscope
- Operated at 200kV

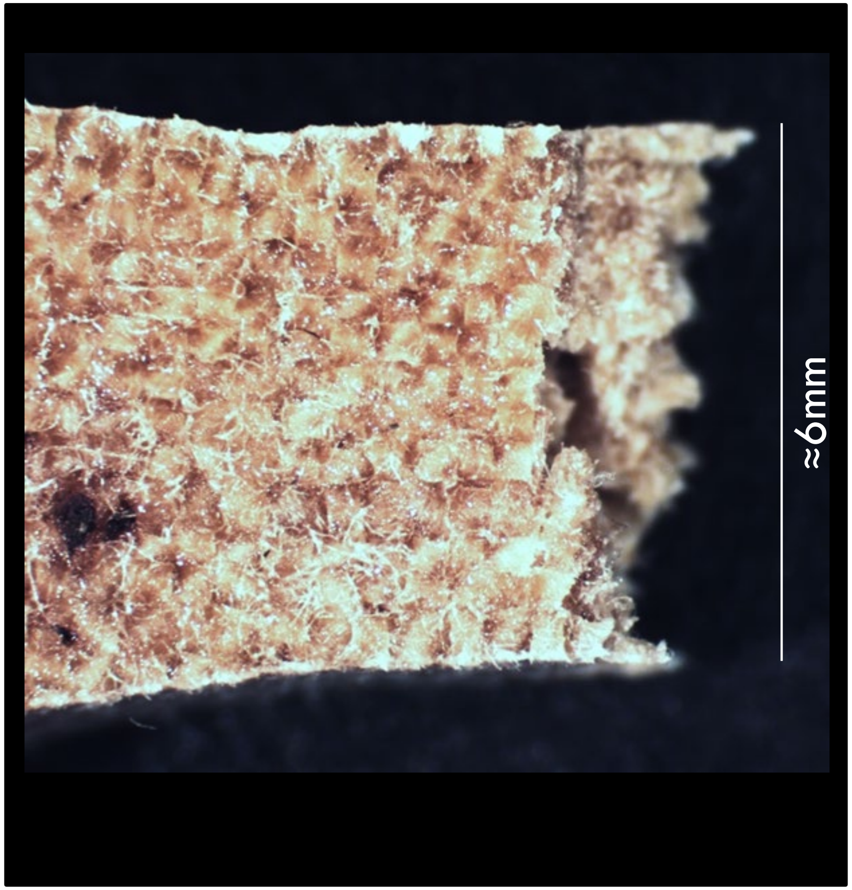
FRACTURE SURFACES



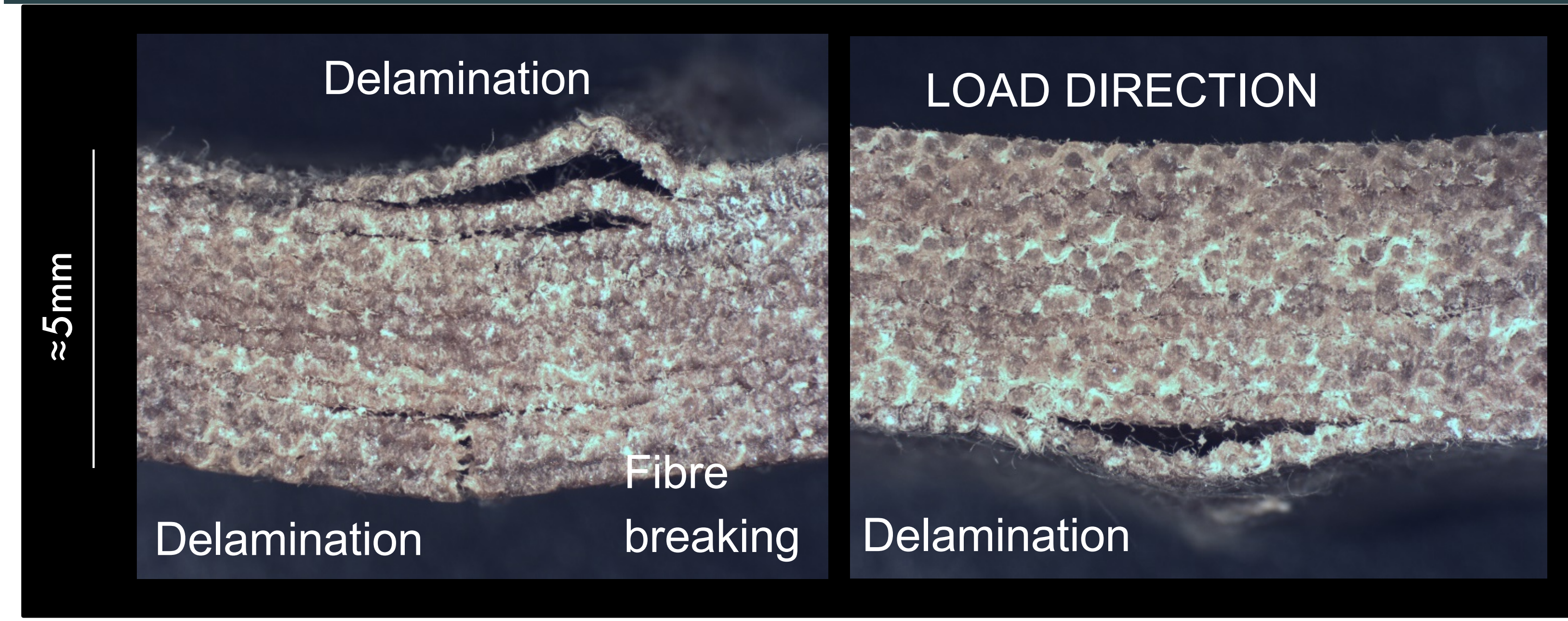
FRACTURE SURFACES

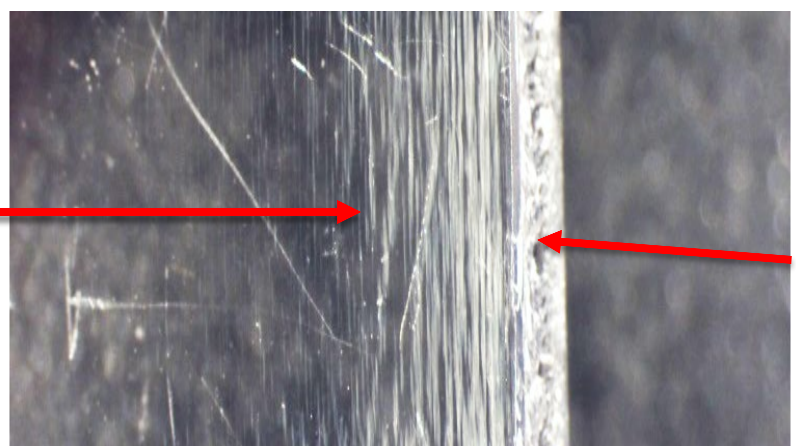


Voids caused by absence of matrix

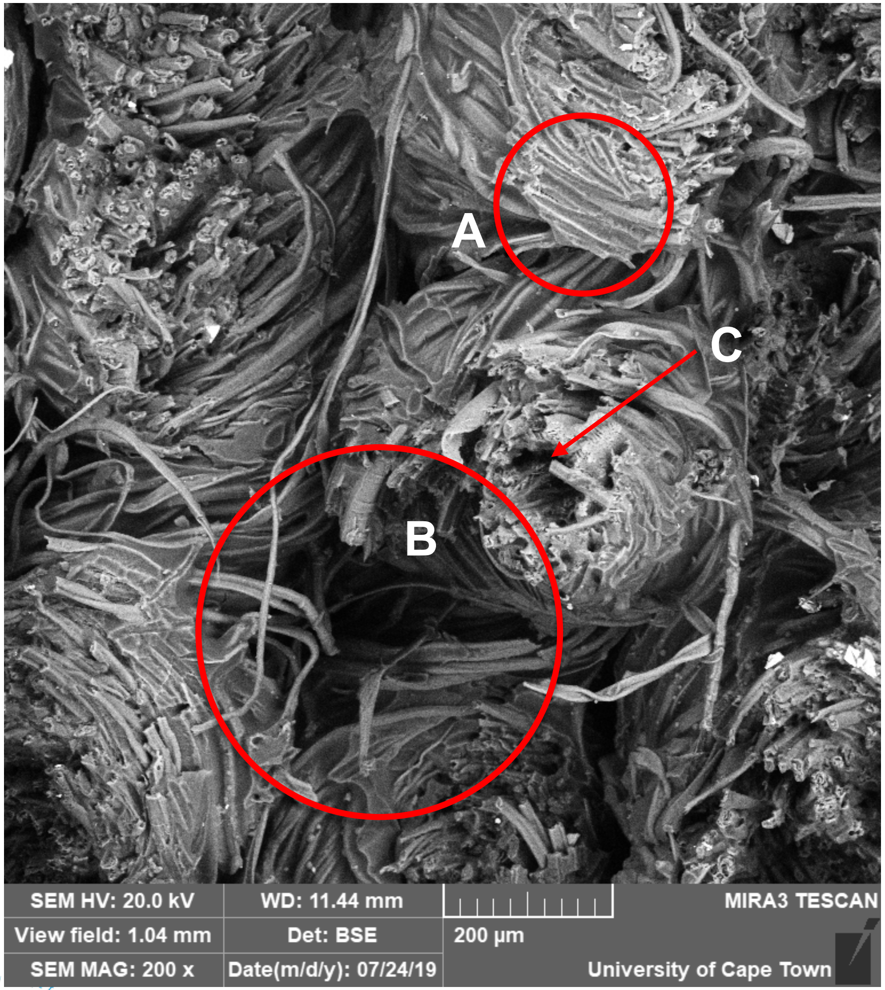


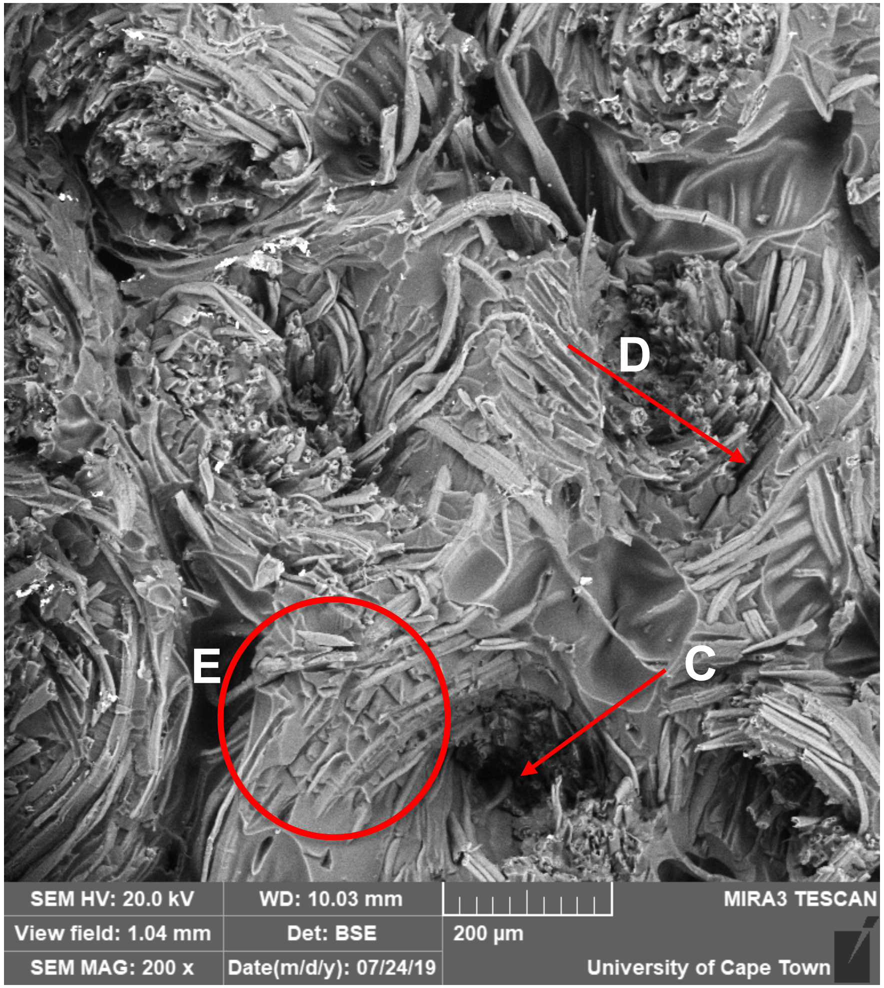
FRACTURE SURFACES



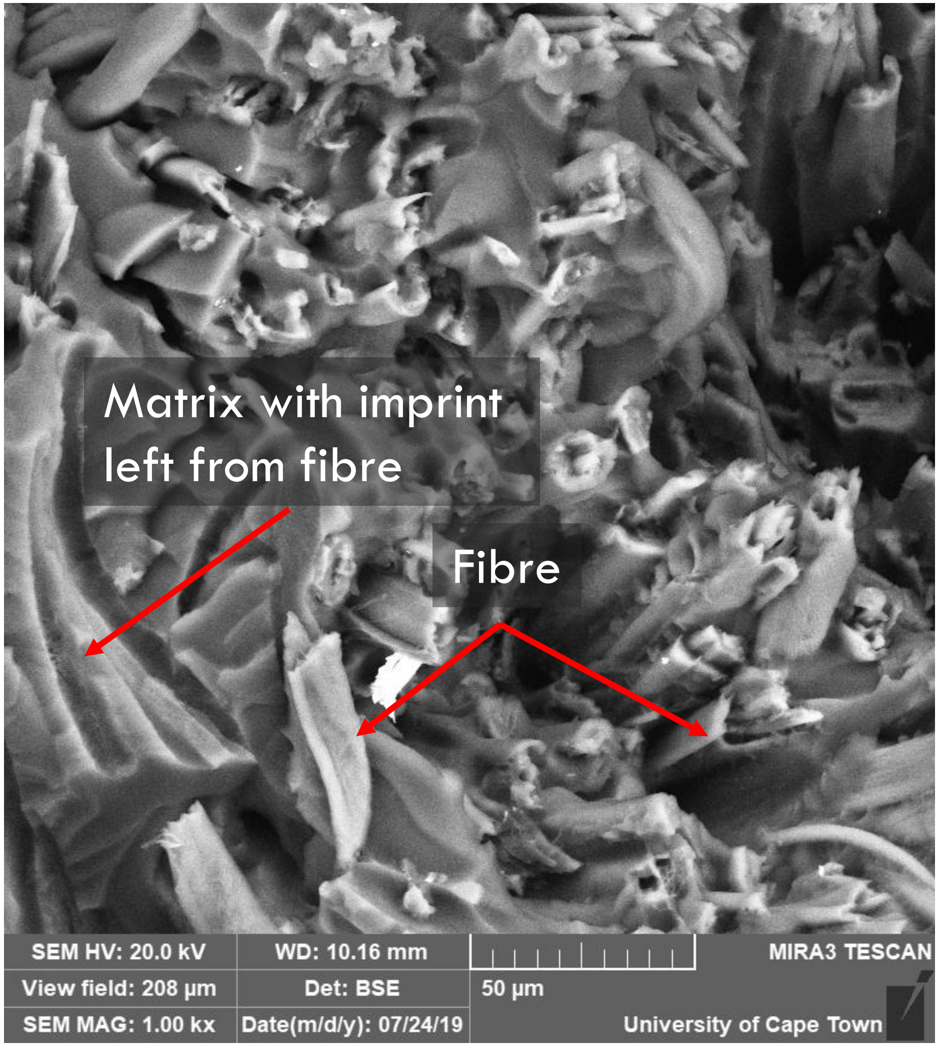


SEM

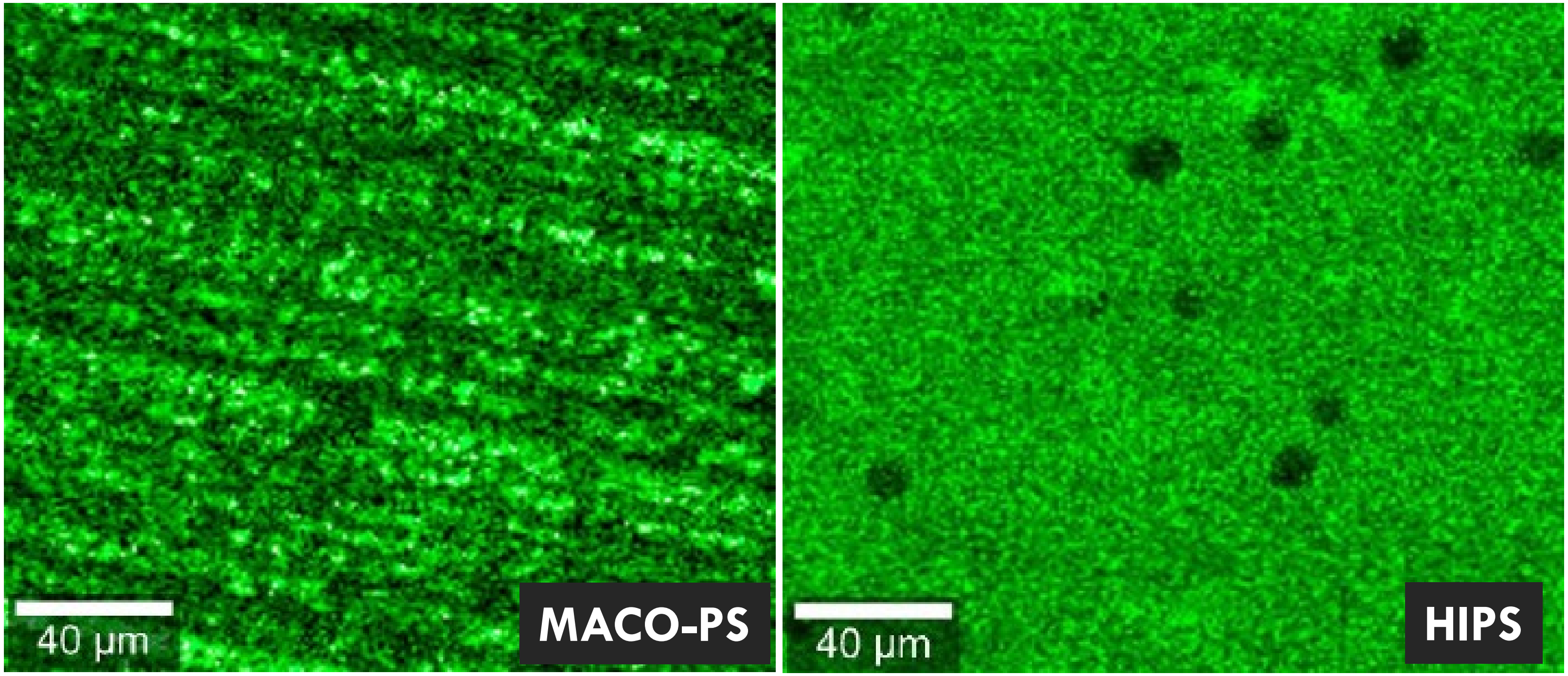

A
B
C
SEM HV: 20.0 kV
WD: 11.44 mm
MIRA3 TESCAN
View field: 1.04 mm
Det: BSE
200 µm
SEM MAG: 200 x
Date(m/d/y): 07/24/19
University of Cape Town


D
E
C
SEM HV: 20.0 kV
WD: 10.03 mm
MIRA3 TESCAN
View field: 1.04 mm
Det: BSE
200 µm
SEM MAG: 200 x
Date(m/d/y): 07/24/19
University of Cape Town

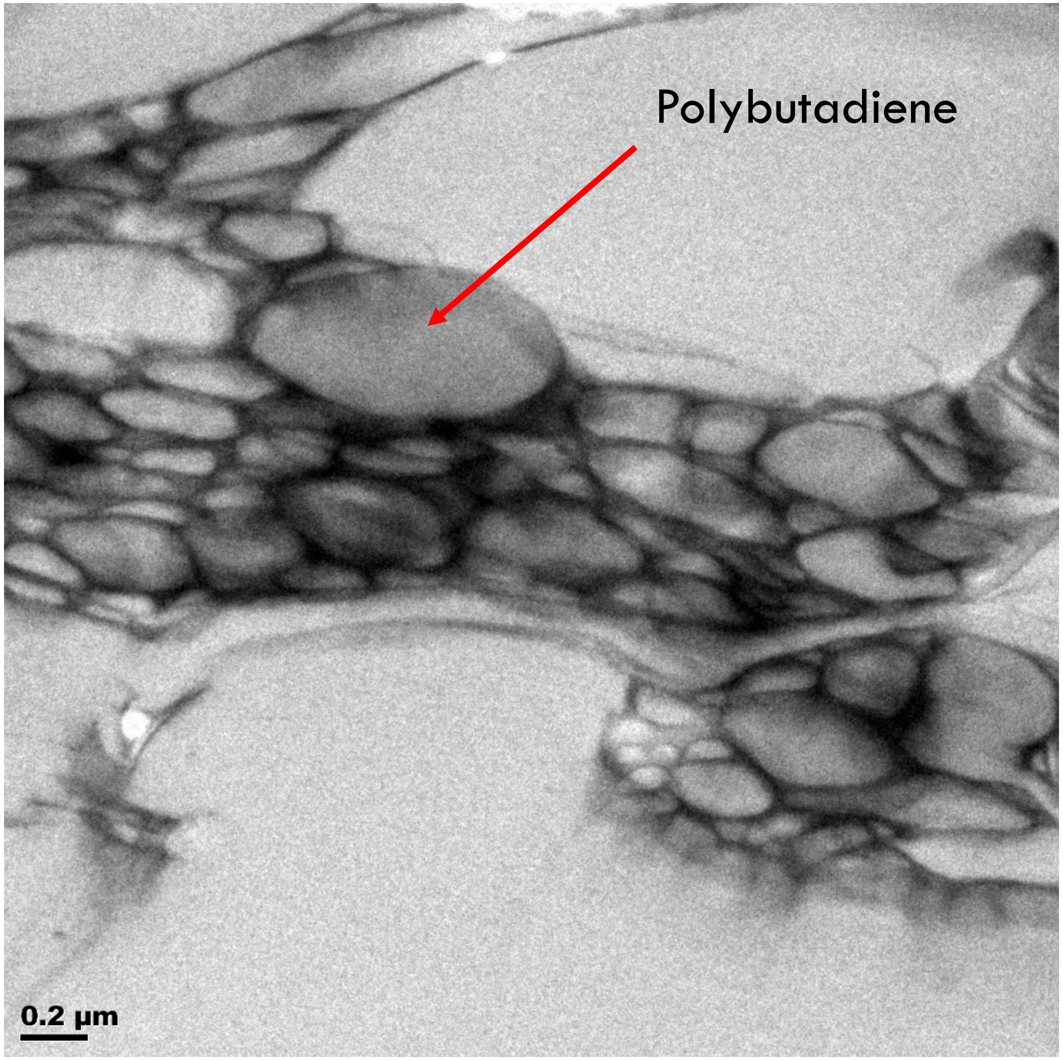
SEM


Matrix with imprint left from fibre
Fibre
SEM HV: 20.0 kV
WD: 10.16 mm
MIRA3 TESCAN
View field: 208 μm
Det: BSE
50 μm
SEM MAG: 1.00 kx
Date(m/d/y): 07/24/19
University of Cape Town

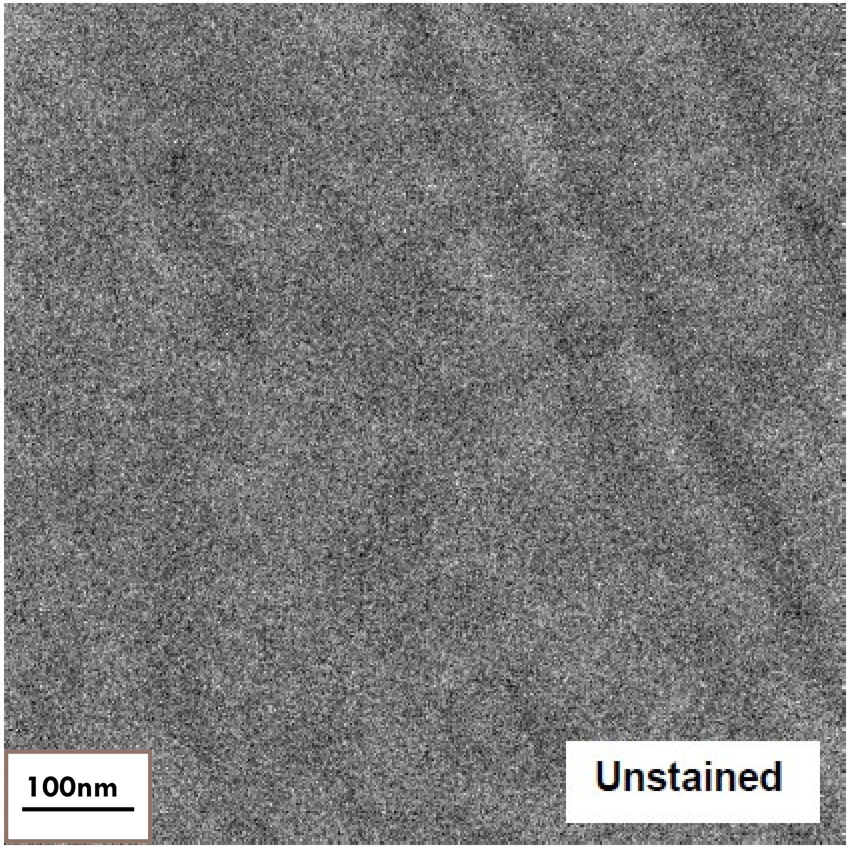
RAMAN MAPPING

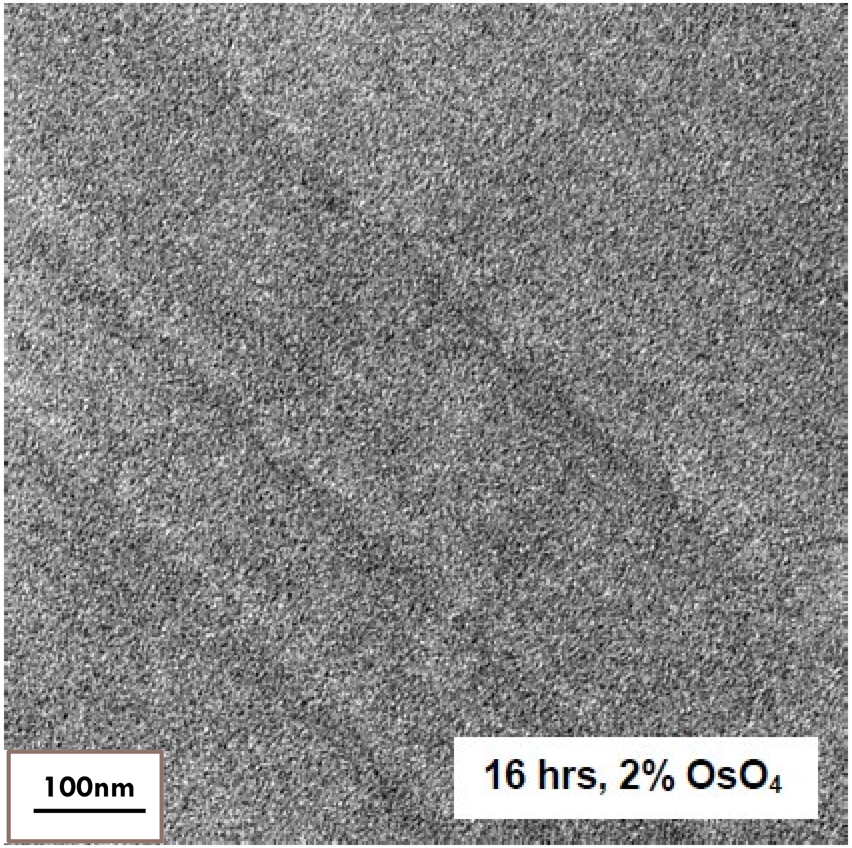


TEM



TEM





CONCLUSIONS

- The mechanical properties of the green MACO-PS matrix corresponds to those found for HIPS
- Fracture surfaces found for the tested materials backed the mechanical test results
- SEM was successfully used to identify the cause for weak mechanical properties of the reinforced composite
- Raman mapping together with TEM confirmed the morphology of the matrix to be either a random co-polymer or an interpenetrating polymer network

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Questions?