Nanoscale characterization of interphase and their impact on the performance of natural fiber reinforced polymer composites

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Agenda

- ☐ Introduction
- ☐ Literature Review
- ☐ Problem Statement
- ☐ Objective
- ☐ Methodology
- ☐ Results and discussion
- ☐ Conclusions

Introduction

NFRPC

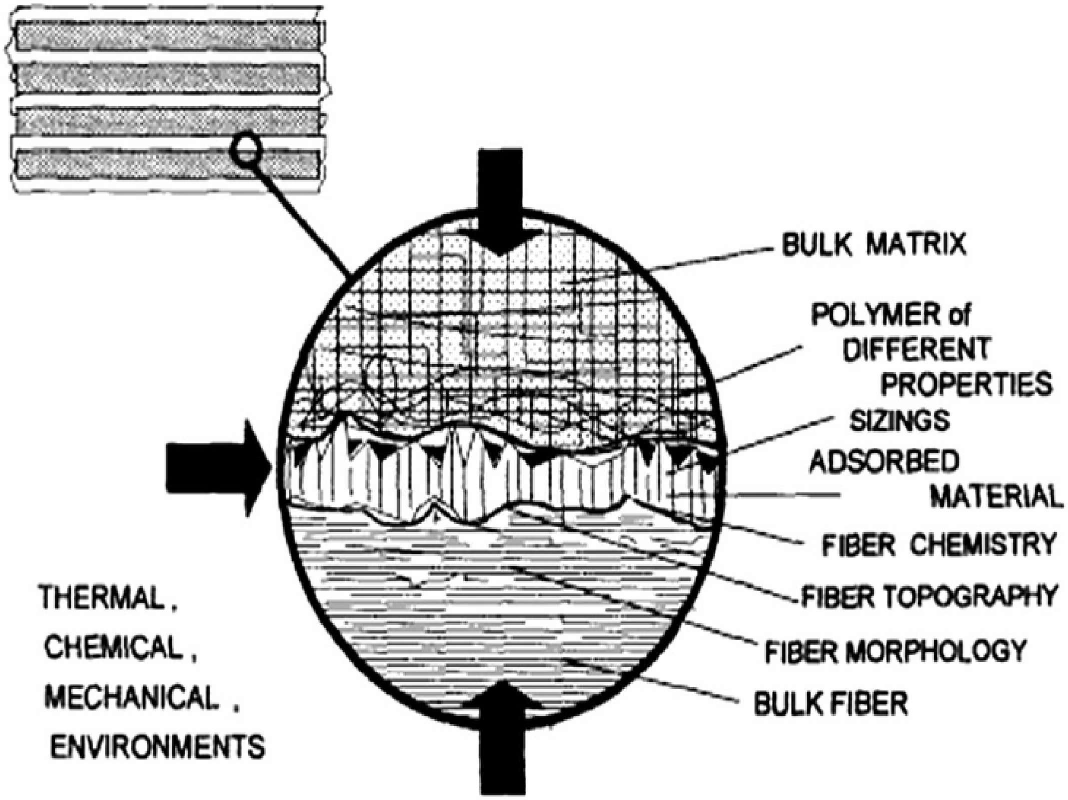
Applications in automotive and building industries

Advantages-Reductions in weight, cost, carbon dioxide, less reliance on foreign oil resources, recyclability.

Disadvantages- High moisture absorption, poor microbial resistance, low thermal resistance, anisotropic properties.

Natural fibers are hydrophilic while that of the polymer matrix are hydrophobic in nature leads to a weak adhesion at the interphase.

Introduction

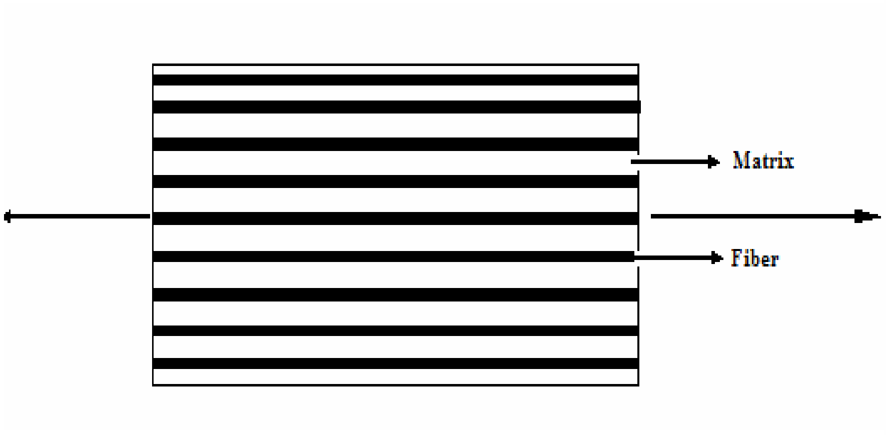


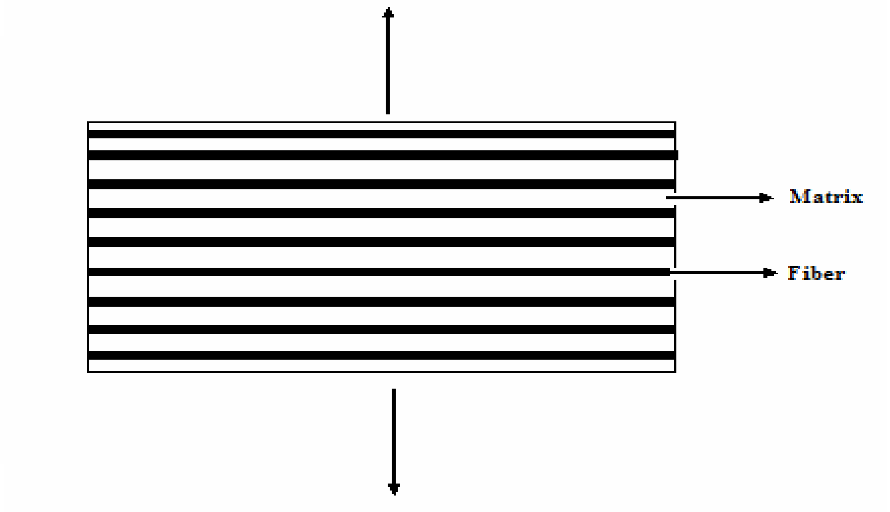
FIBER-MATRIX INTERPHASE

Interphase

Transition region that neither posses the properties of fiber nor the matrix

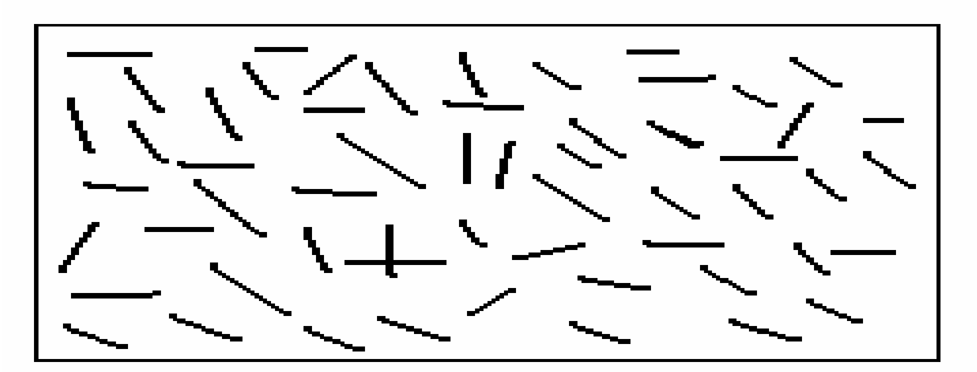
Introduction





A. Force parallel to fiber axis - Interphase not sensitive

B. Force perpendicular to fiber axis – Local stress at interphase comparable to load – interphase sensitive



C. Force on both directions – interphase sensitive

Literature Review

Different stages involved during stress transfer between the matrix and fibers in short-fiber composite materials

- Elastic stress transfer from matrix to fiber
- Deforming matrix adjacent to the bonded interphase may yield and become plastic
- Debonding occurring at the interphase, leads to sliding of matrix over fiber (frictional stress transfer)
- Cracks occur from the debonded fiber ends.
- These processes leads to fiber pull out and these cracks propagate to the neighboring fibers by fiber fragmentation and subsequently leads to composite material fracture (Goh *et al*. 2004).

Literature Review

Characterization of interphase

Previous NFRPC research- mainly used SEM for examining fracture surfaces

Nanoindentaion, nanoscratching , AFM were also used for characterizing interphase

NMR and FTIR for characterizing the elements and bonds respectively.

Major defects

Nanoindentaion, nanoscratching – mainly destructive, only on micro and sub micrometer scales due to limit imposed by indenter tip.

AFM – lack of quantitative measurements.

NMR and FTIR information on the chemical characterization – No much information on the mechanical properties.

Major Questions?

A. What are the mechanical properties within the interphase needed for the efficient transfer of stress?
B. Does the interphase thickness and mechanical property vary with different concentration levels of modifiers?
C. What are the effects of interphase on the bulk properties of composites?

Objective

To demonstrate a new method for characterizing interphase and getting quantitative mechanical measurements at each position within the interphase and their impact on the performance of natural fiber reinforced polymer

Methodology

Discontinuous and randomly oriented fibers

Materials

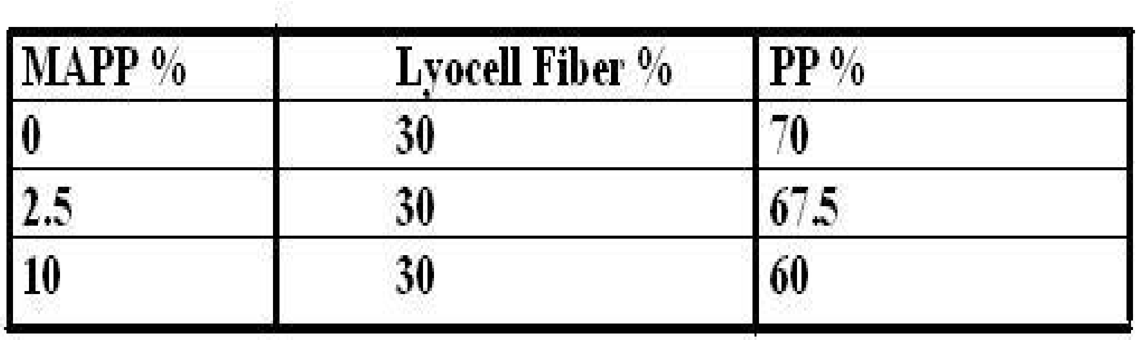
Lyocell fiber
Linear density – 1.5-1.9 dtex
Diameter – 12 µm
Length – 3 mm

Polypropylene
MFI – 3.5g/10min

Maleic anhydride-grafted PP(MAPP)

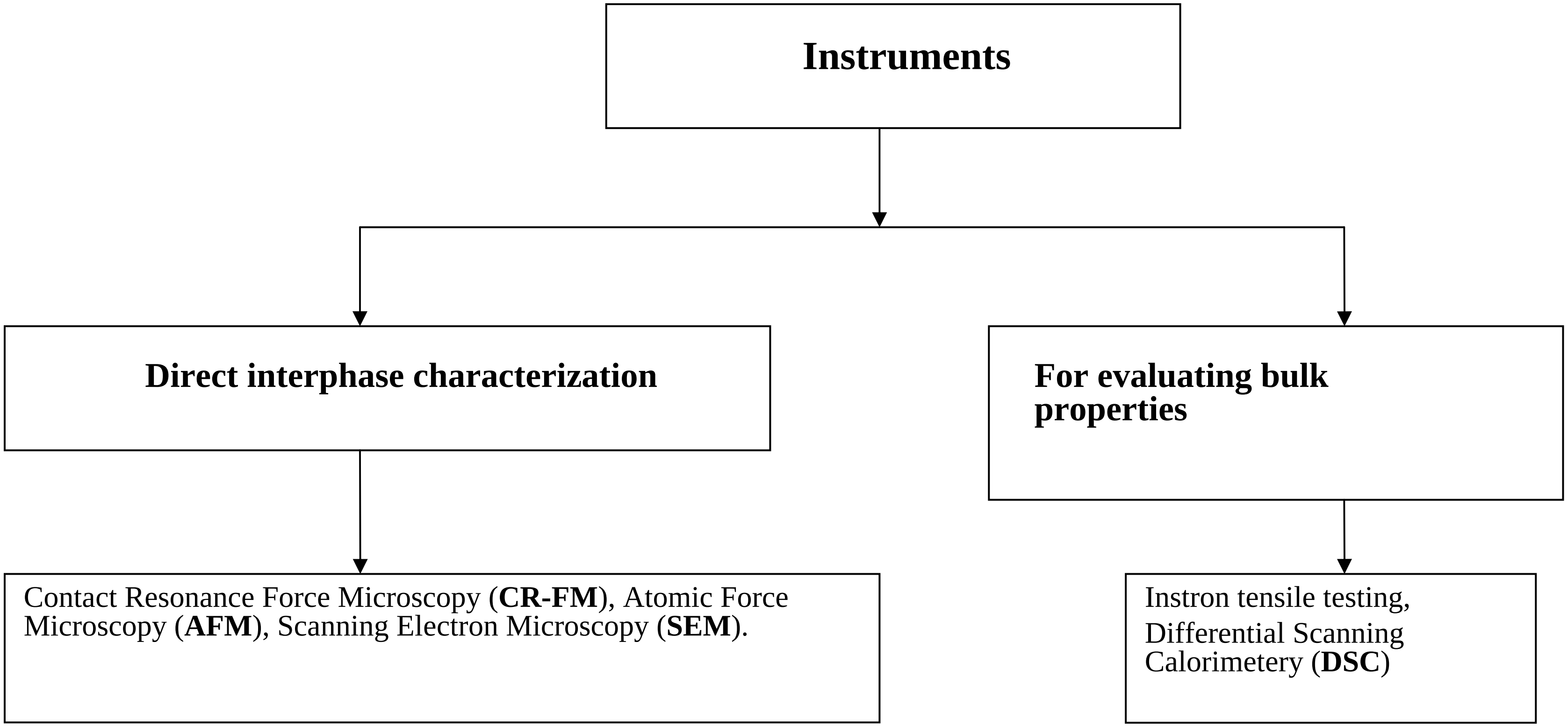
Methodology

Composite types based on modification



MAPP %	Lyocell Fiber %	PP %
0	30	70
2.5	30	67.5
10	30	60

Methodology



Instruments

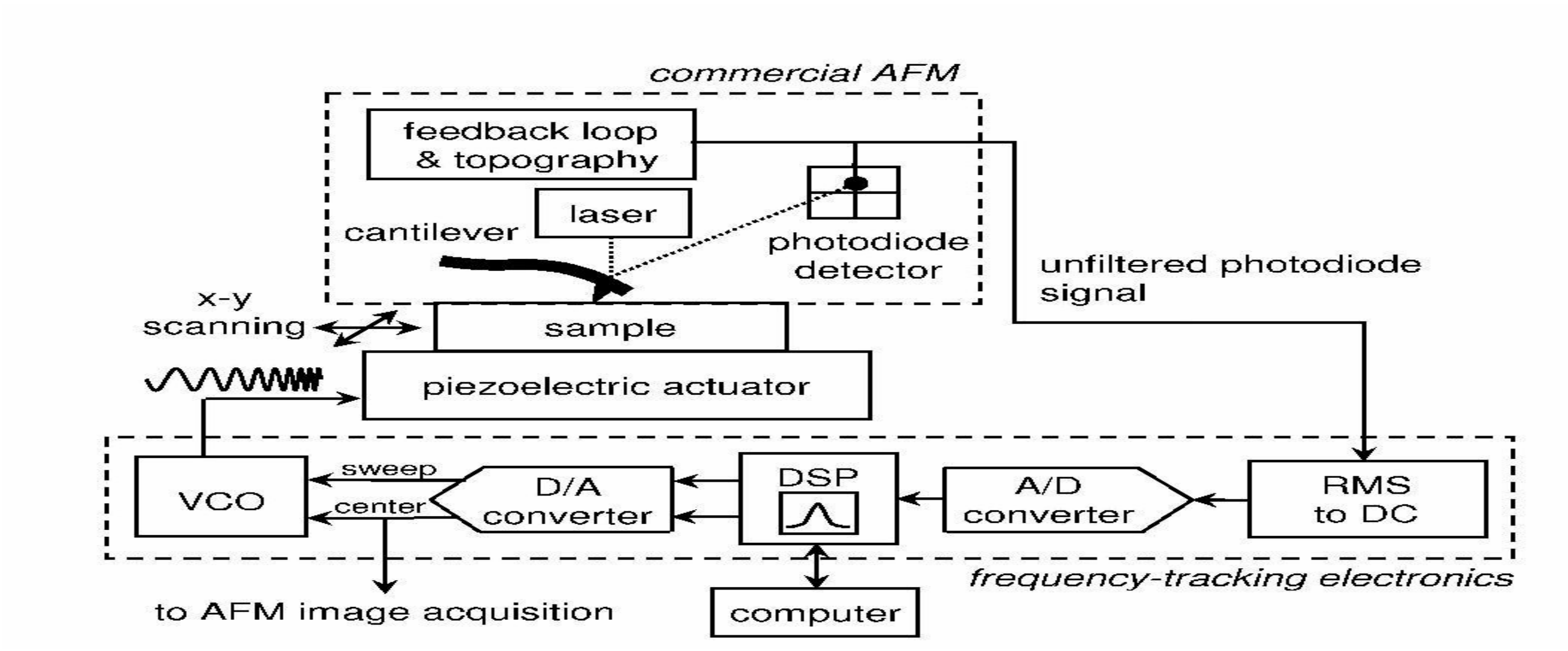
Direct interphase characterization

For evaluating bulk properties

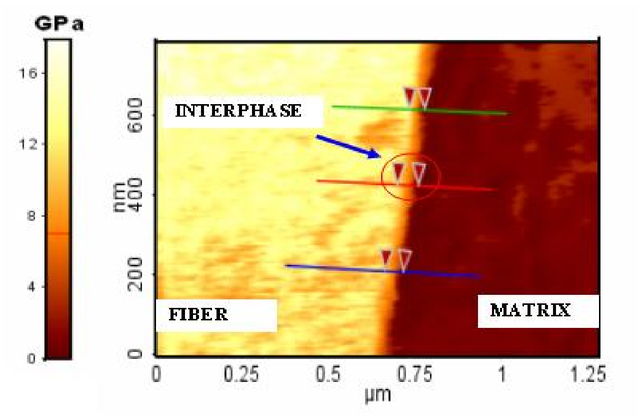
Contact Resonance Force Microscopy (**CR-FM**), Atomic Force Microscopy (**AFM**), Scanning Electron Microscopy (**SEM**).

Instron tensile testing,
Differential Scanning Calorimetery (**DSC**)

Results and discussion

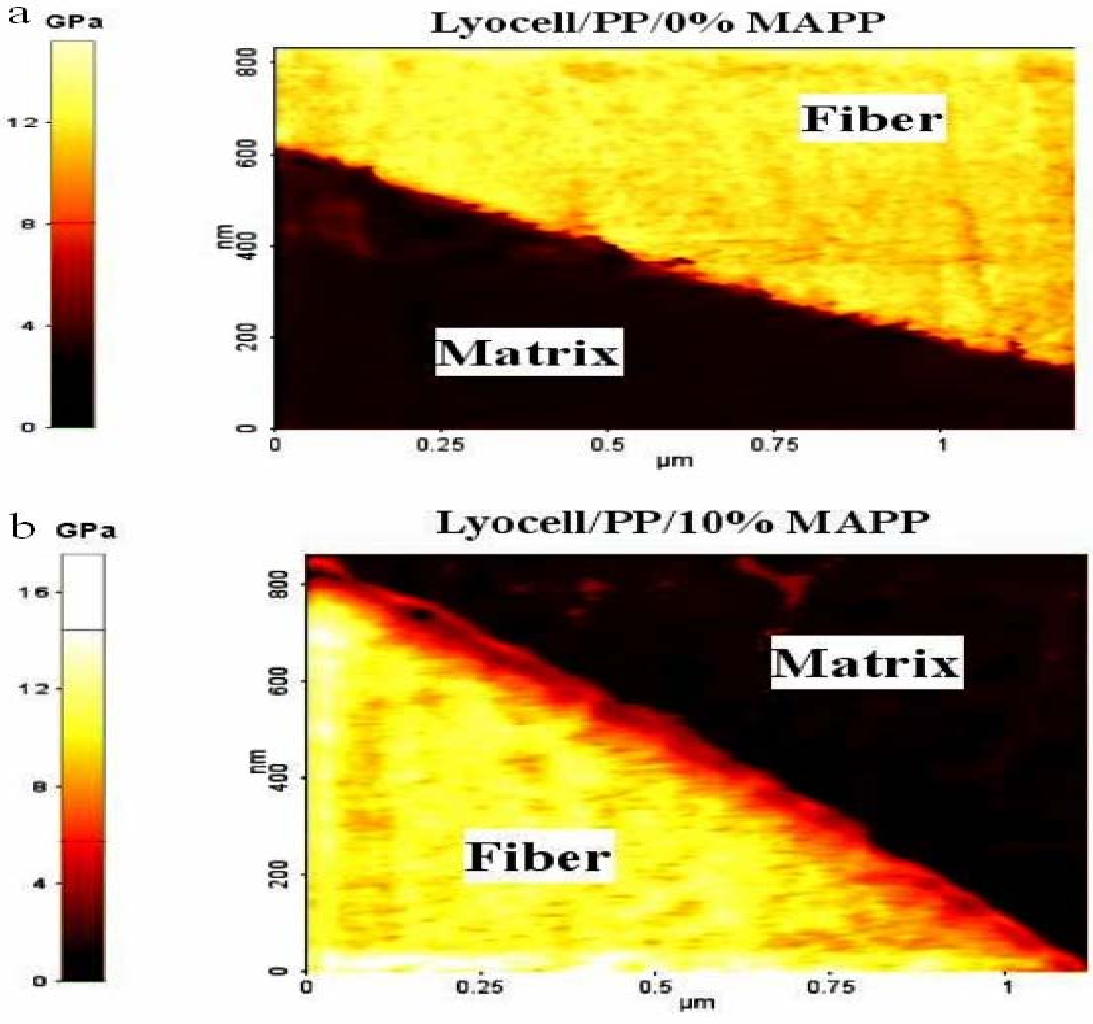


Schematic representation of CR-FM apparatus for modulus mapping

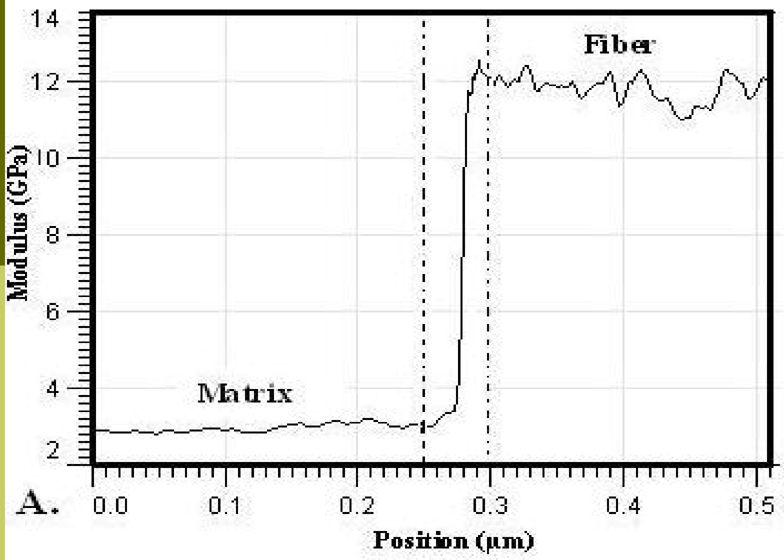


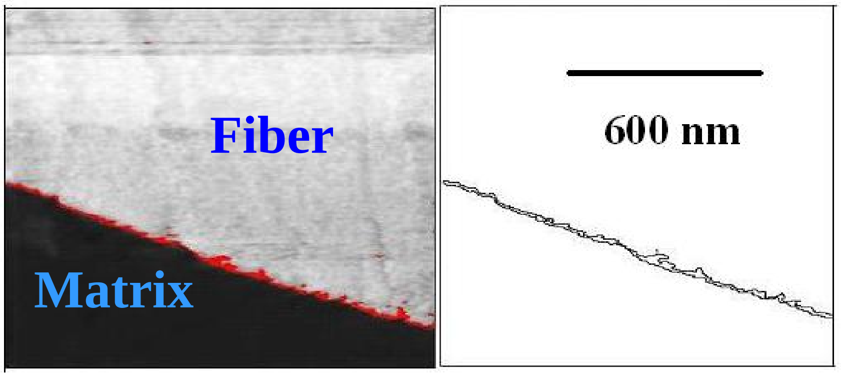
→ **CR-FM Image**

Results and discussion

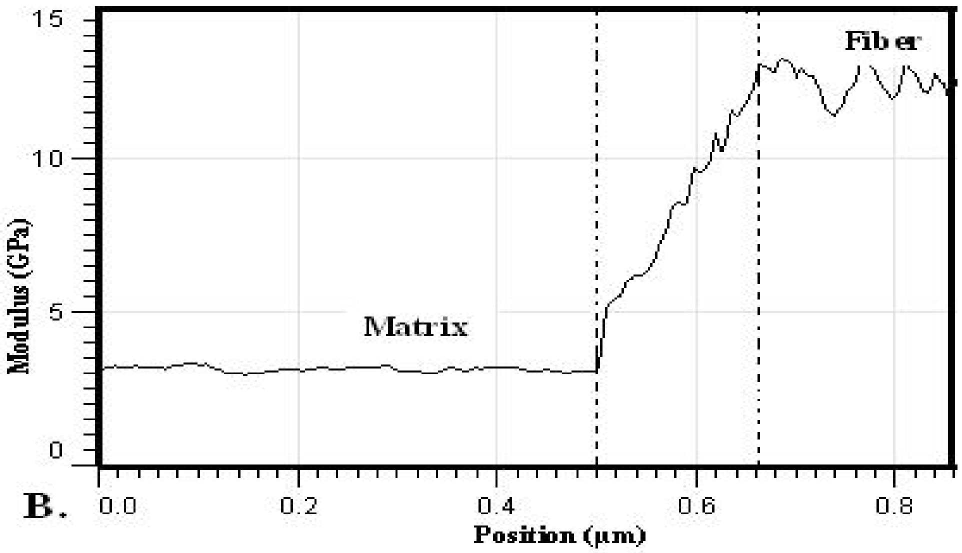


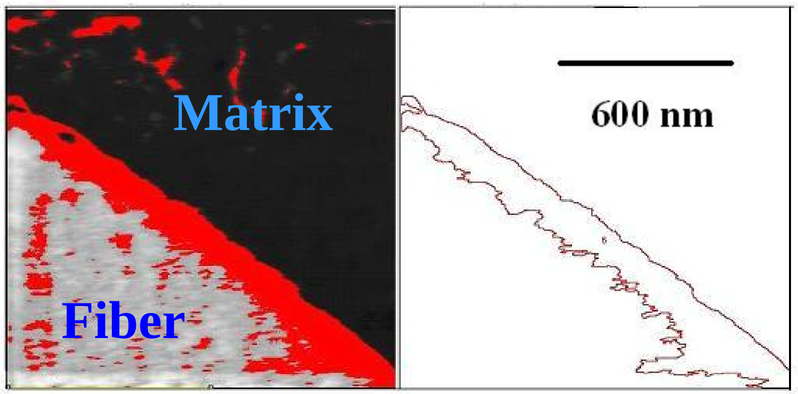
PP/0 % MAPP composites





PP/10 % MAPP composites.

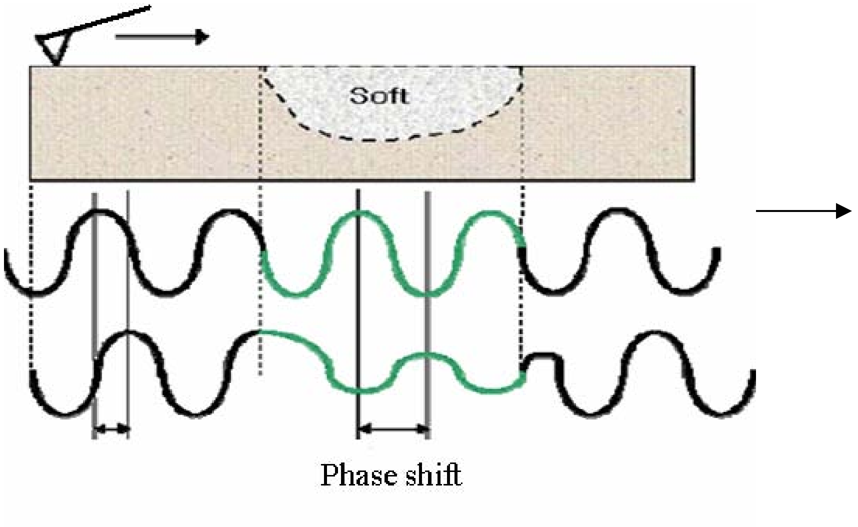


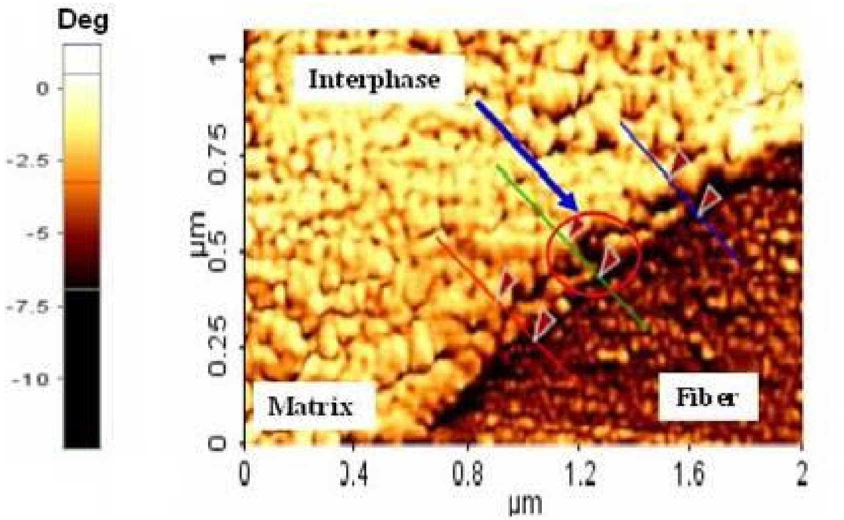


Results and discussion

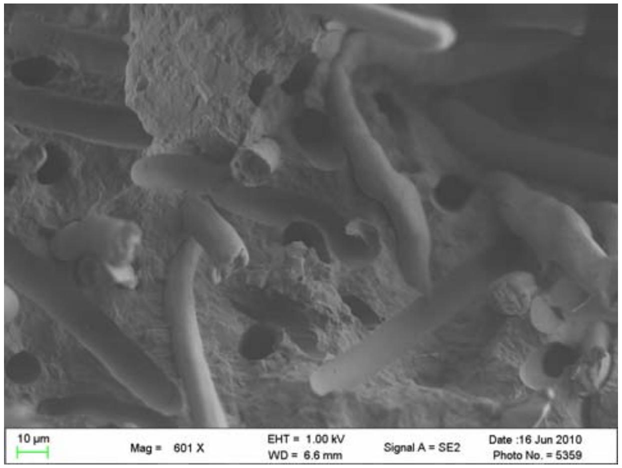
Composite Treatment (polymer, fiber)	Measured interphase width (nm)
0%MAPP	46 ± 5
2.5%MAPP	80 ± 11
10%MAPP	140 ± 15

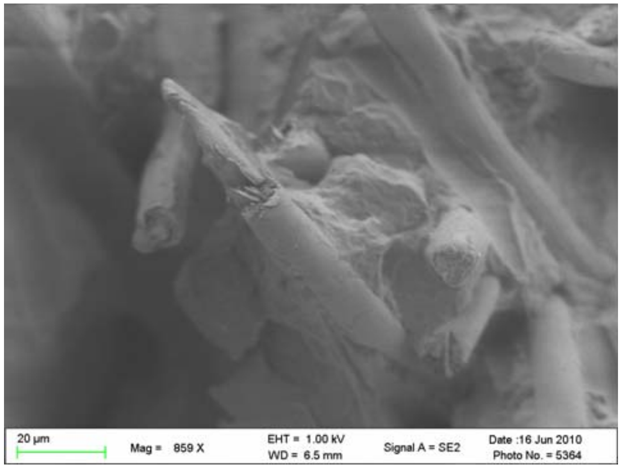
AFM –Phase image





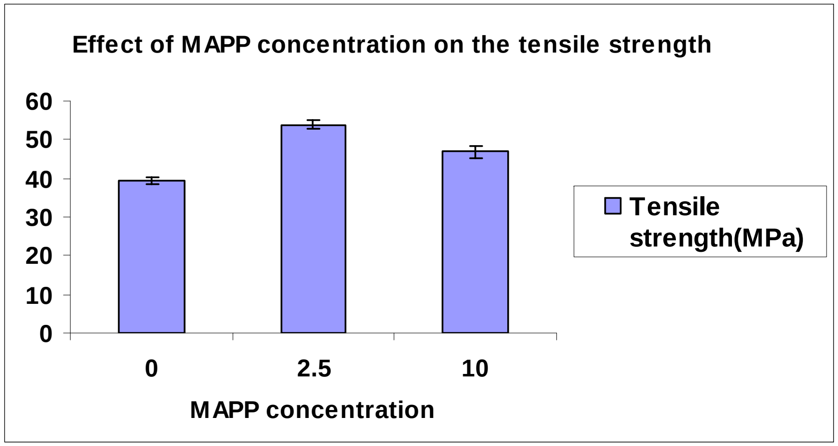
Lyocell/PP/10 % MAPP

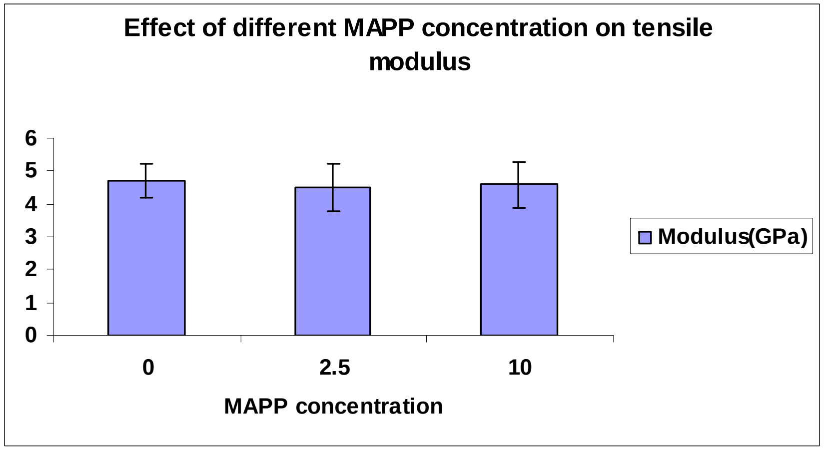




SEM images

Results and discussion





Thermal properties →

Composite Treatment (polymer, fiber)	Crystallization temperature (T_c)	Percentage of crystallinity (K_α)
0 % MAPP	119.74	40.32
2.5 % MAPP	116.21	41.12
10 % MAPP	116.18	40.04

Conclusions

- The average interphase width was found to increase with the increase in amount of MAPP;
- Composites with 2.5% MAPP was found to show higher tensile strength than composites treated with 10 % MAPP ;
- CR-FM is a useful tool for accurately measuring the thickness and evaluating the nanoscale mechanical properties of very narrow interphases. The information about interphases obtained from this technique will be valuable for the optimum design of FRPC products.

Future works

- Impact on the viscoelastic properties
- Chemical quantification
- Applying these techniques for various other treatments (different types of interphase)
- Develop micromechanical models
- Applying these techniques for various nanocomposites.

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Thank you