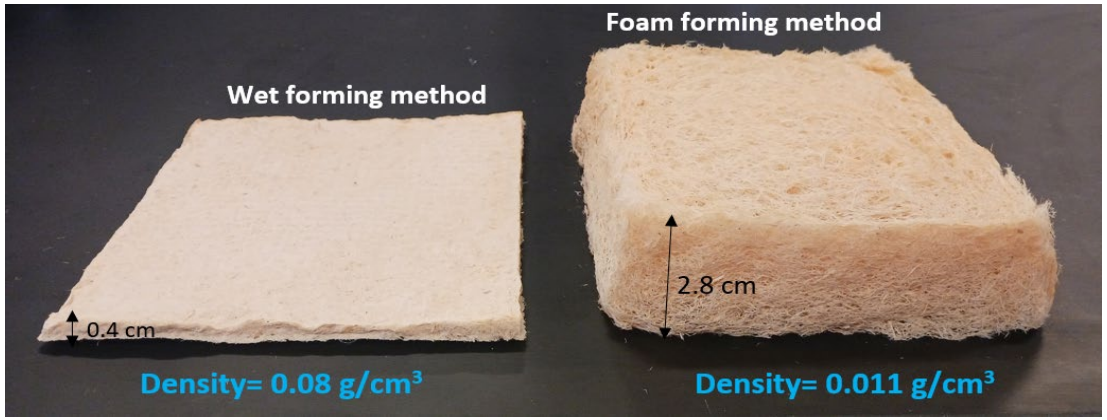
06-15-2023

Preparation of low-density foamed lignocellulosic structures enabled by cellulose nanofibrils (CNFs)



Maryam El Hajam, Wenjing Sun, Islam Hafez, Caitlin Howell, Mehdi Tajvidi

Education and Background

Baccalaureate

Major: Life and Earth Sciences

June 2011

2011–2014

Bachelor's Degree

Major: Chemical Engineering

Master's Degree

Major: Materials and Processes Engineering

2014–2016

2016 –2022

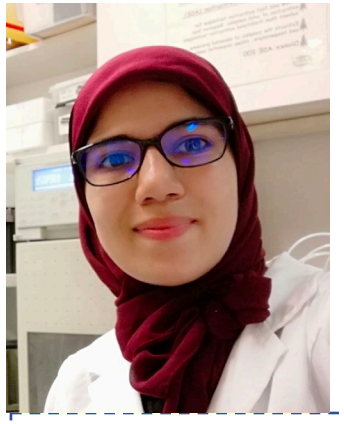
PhD Degree

Major: Sciences and Engineering of Materials and Processes

Postdoctoral research associate

Since Oct 2022

All Biobased (lignocellulosic - mycelium) insulation products for building and packaging applications



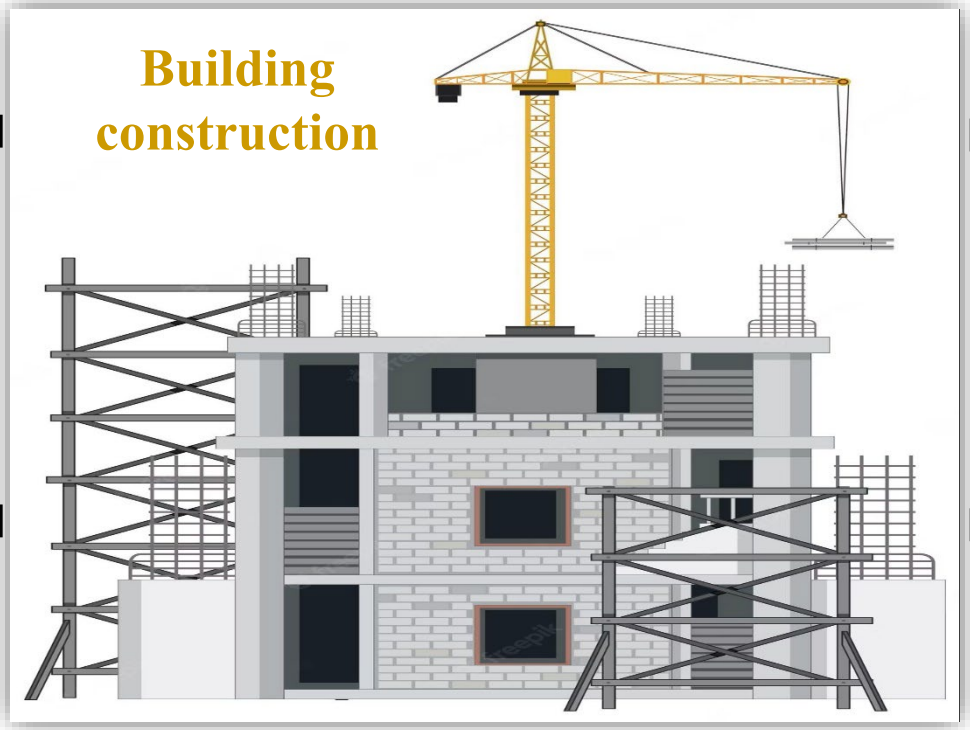
Well-insulated building

=

Cost/Energy-efficiency

Contribute to 1/3 of the total greenhouse gas emissions

Building construction



Consume around 37% of the total final energy

Reduction of heat exchange through the house envelope

A substantial amount of heat is lost or gained through the wall system

20%

Energy cost savings

Petrochemical materials

Glass wool
Mineral wool
Expanded polystyrene (EPS)
Extruded polystyrene (XPS)
Polyurethane
Polyisocyanurate

\+ **Excellent thermo-mechanical properties for thermal insulation applications**

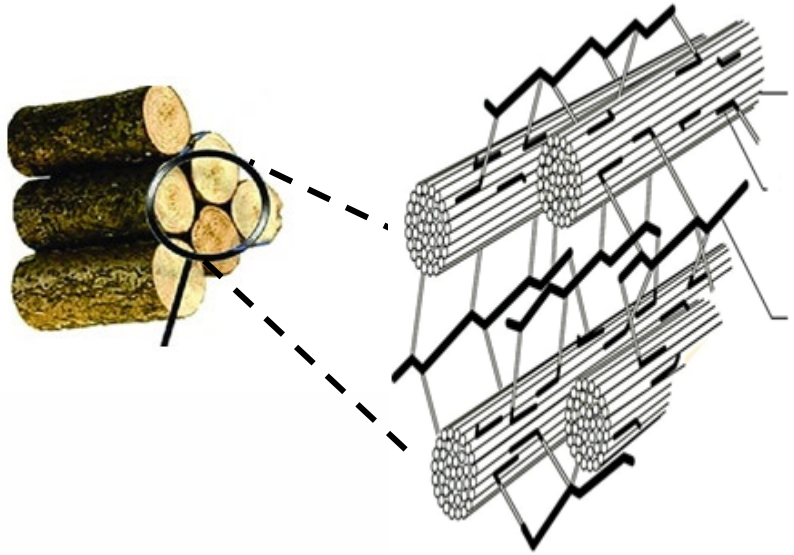
− **Non-biodegradable**
Non-renewable
Non-recyclable

Lignocellulosic-based composites
Using fungal mycelium as a binder

Eco-friendly, Non-toxic, Renewable, and Recyclable

Lignocellulosic materials

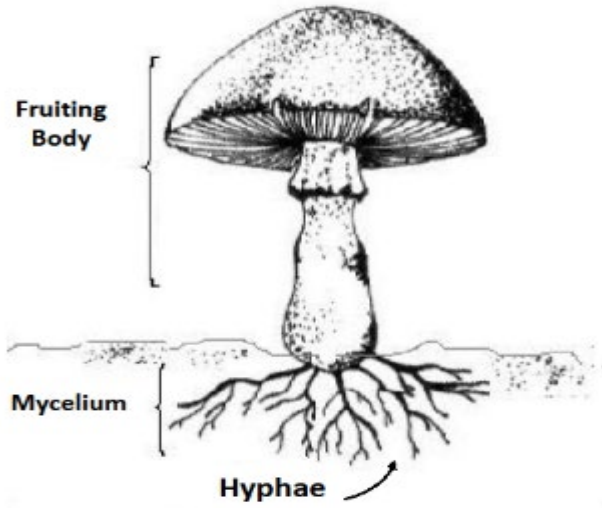
Fungal mycelium



Cellulose

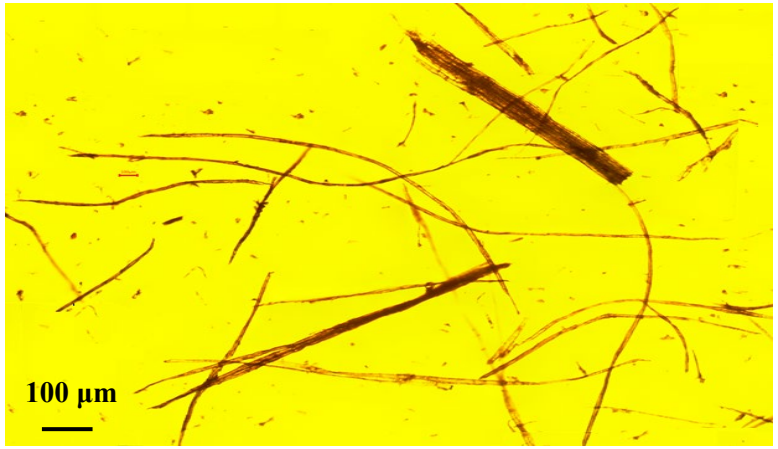
Hemicellulose

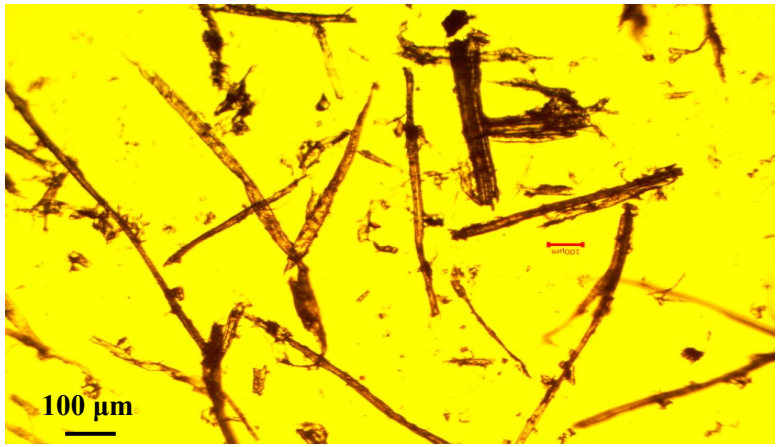
Lignin

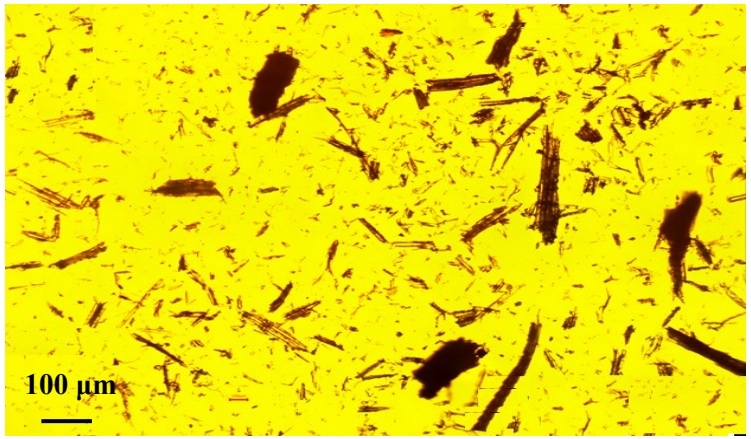


Lignocellulosic substrate sources:

Particle size distribution







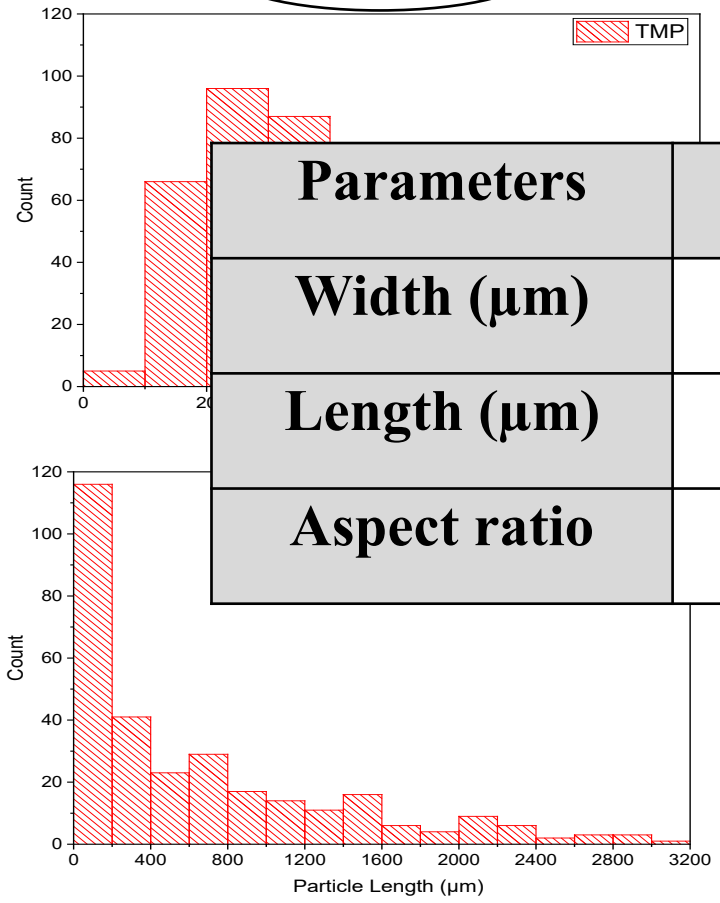
Width and length distribution of TMP, PF and RWP

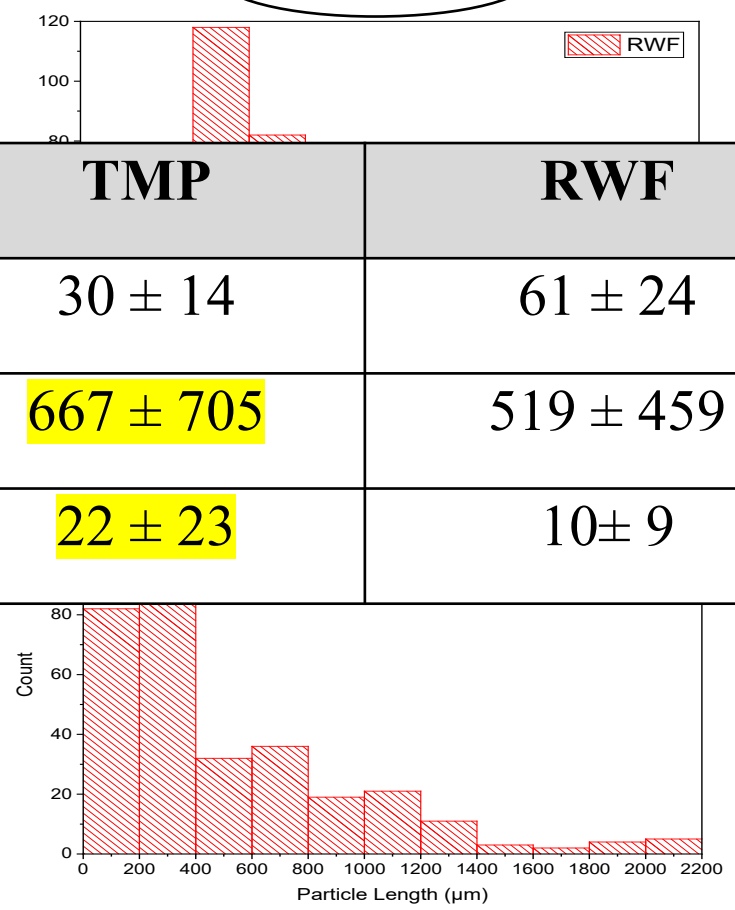
TMP

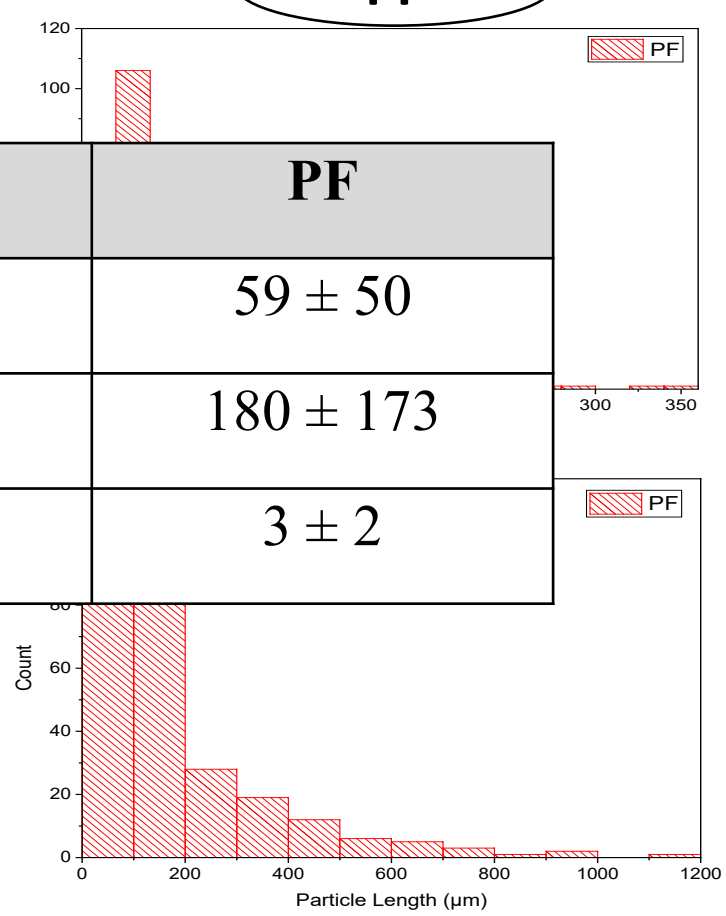
RWP

PF

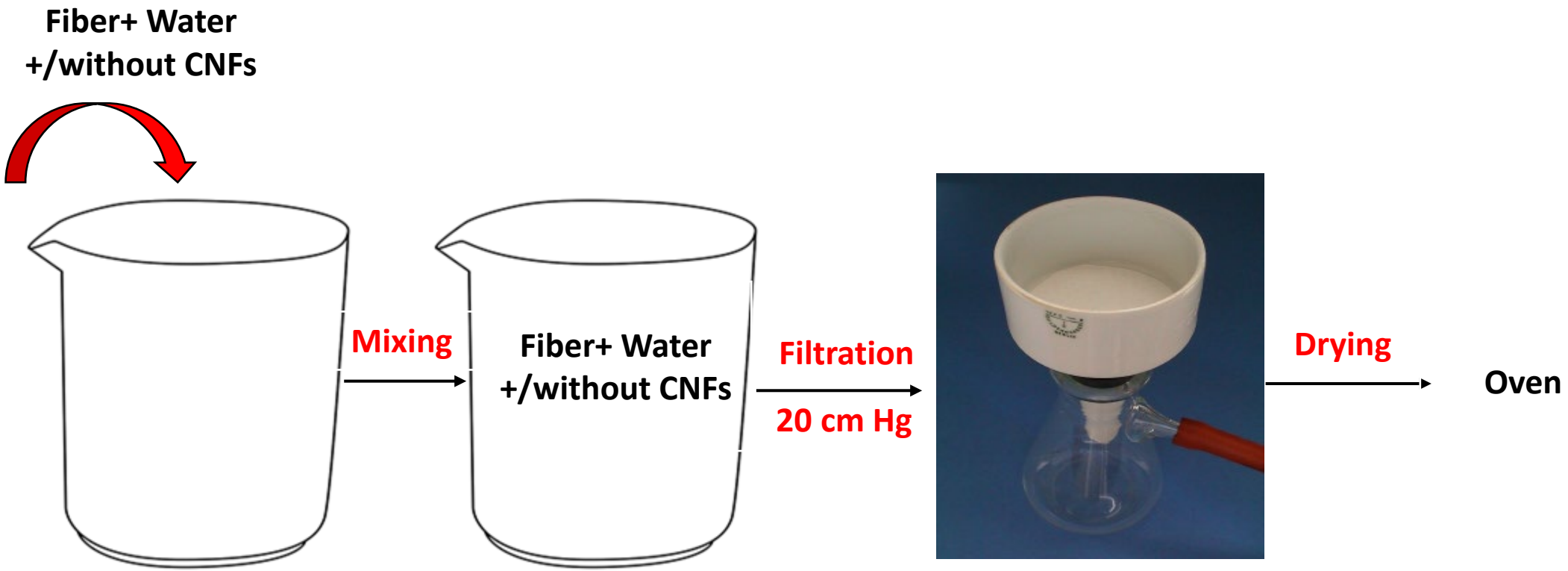
Parameters	TMP	RWF	PF
Width (µm)	30 ± 14	61 ± 24	59 ± 50
Length (µm)	667 ± 705	519 ± 459	180 ± 173
Aspect ratio	22 ± 23	10± 9	3 ± 2







Wet forming method/Filtration



Foam forming method

What is it?

Technology that utilises air bubbles containing aqueous foam as a carrier fluid for the raw materials.

In foam forming, **a high air content is present (50–65%)** and since the fibers inside the **foam are mostly trapped between the foam bubbles**, the formed materials are **highly porous, thick with an excellent homogeneity.**

Foaming agents: Sodium Dodecyl Sulfate (SDS) (anionic) and Cetyltrimethyl ammonium bromide (CTAB) (cationic)

Foam forming method

SDS/CTAB

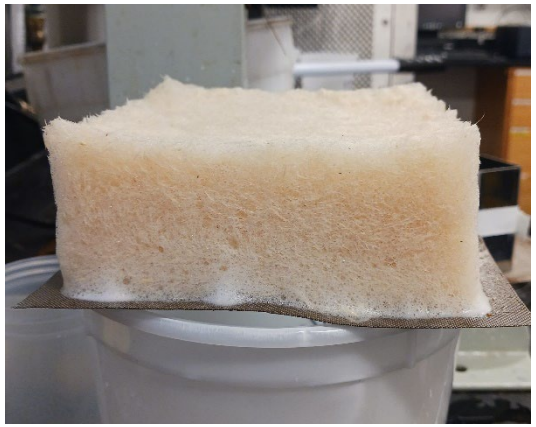
+

CNFs

5000 rpm
for 5 min

Fibers

5000 rpm
for 5 min



Substrate packing: Filtration method

TMP

RWF

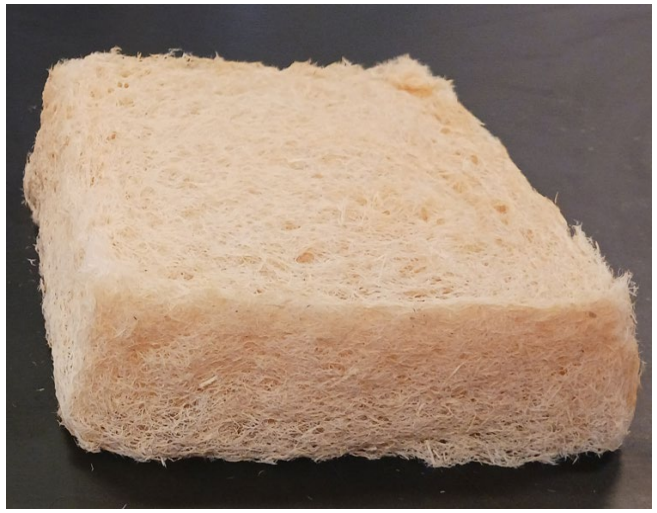
PF

	Thickness (cm)	Density (g/cm^3)
Vacuum pressure : 20 cm Hg		
TMP 100 %	2.2	0.082
TMP+1% CNF	2	0.092
TMP+2% CNF	1.7	0.109
RWP 100 %	1.6	0.122
RWP+1% CNF	1.5	0.132
RWP+2% CNF	1.3	0.151
PF+1% CNF	0.8	0.232
PF+2% CNF	0.7	0.276

Substrate packing: foam forming method

Effect of lignocellulosic sources

TMP



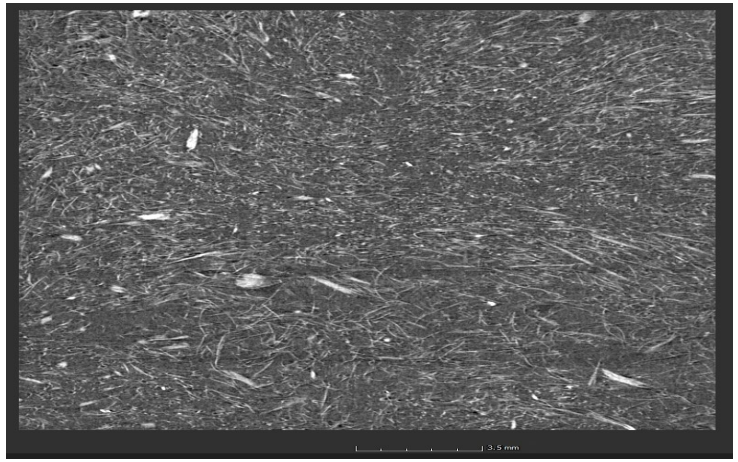
RWF

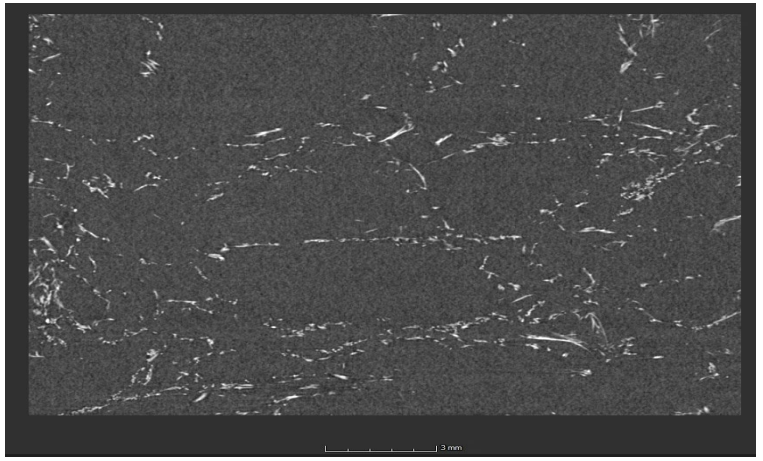
PF

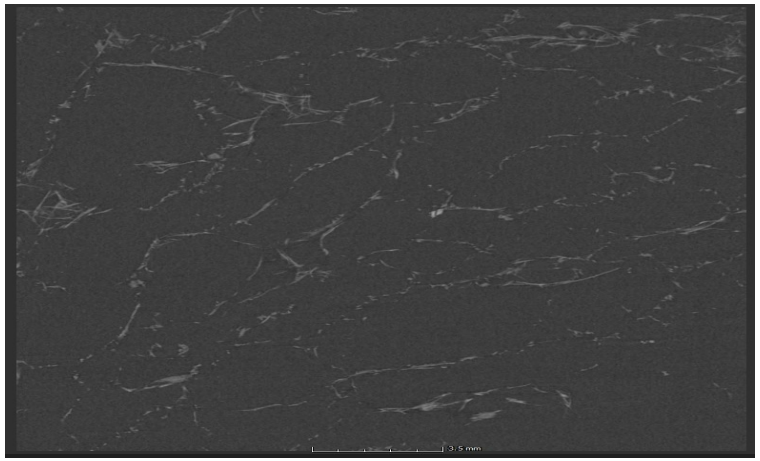
- Effect of surfactants (SDS and CTAB)
- Effect of CNFs content (2, 5 and 10%)
- Effect of solid content (2, 4 and 6%)
- Effect of drying temperature (70 and 105 °C)

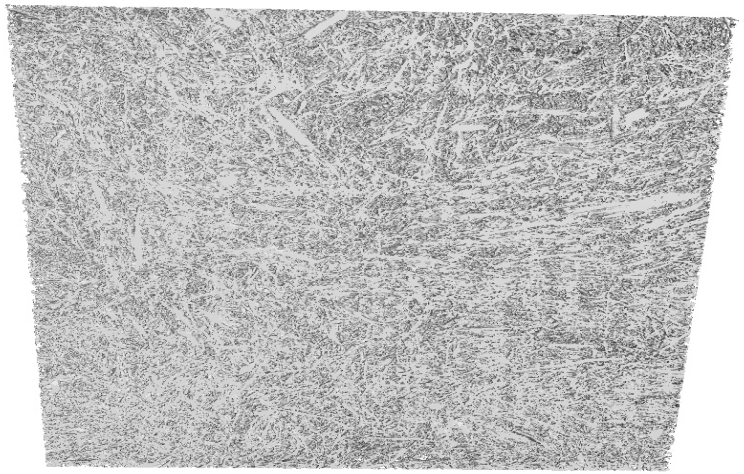
X-ray Tomography

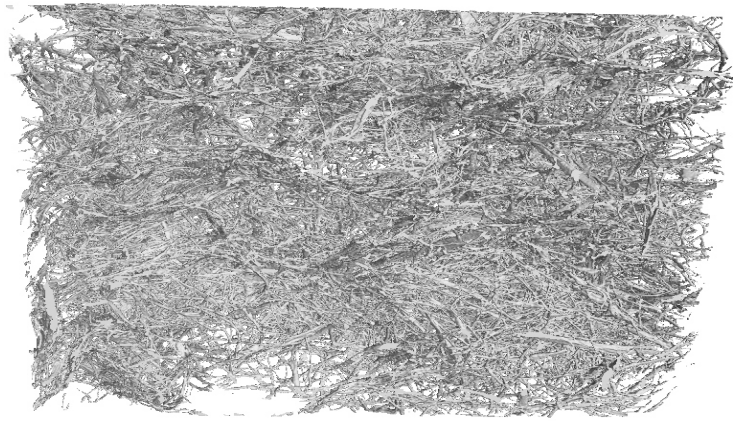
TMP 100%/ Water	TMP 90%/CNF 10%/ SDS 1g/l	TMP 90%/CNF 10%/ CTAB 1g/l





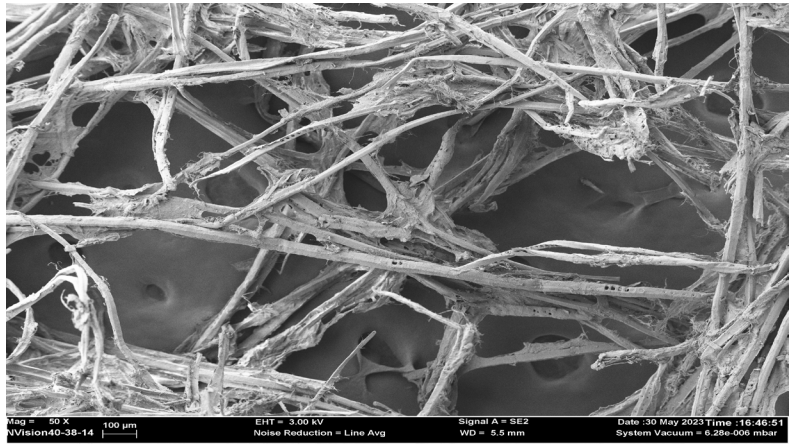




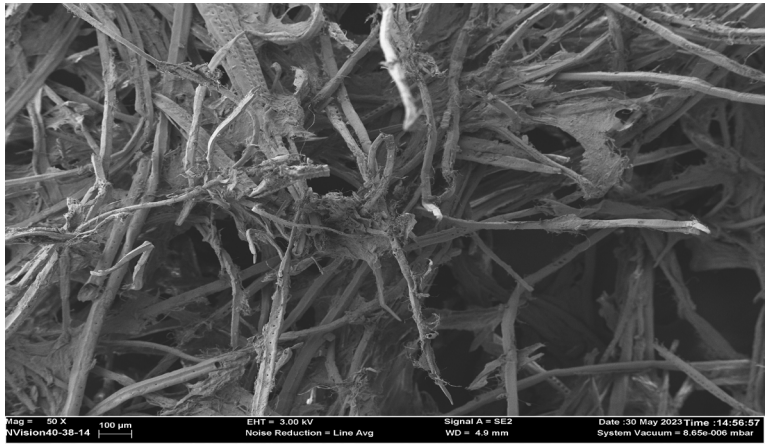


Scanning electron microscopy

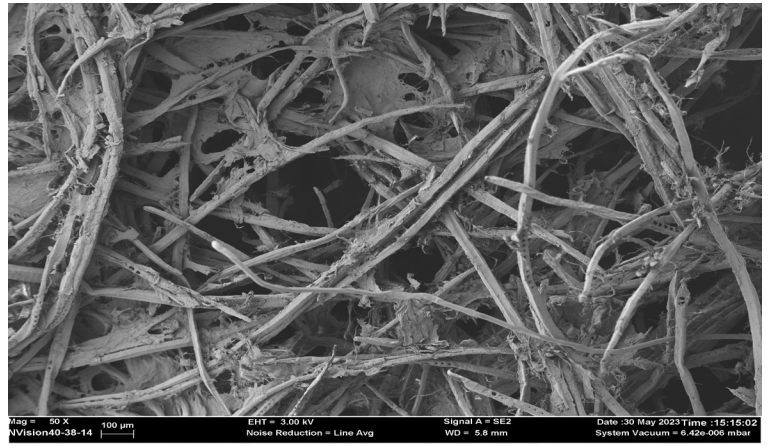
TMP 90%/CNFs 10%/ SDS 1g/l----SC 2%



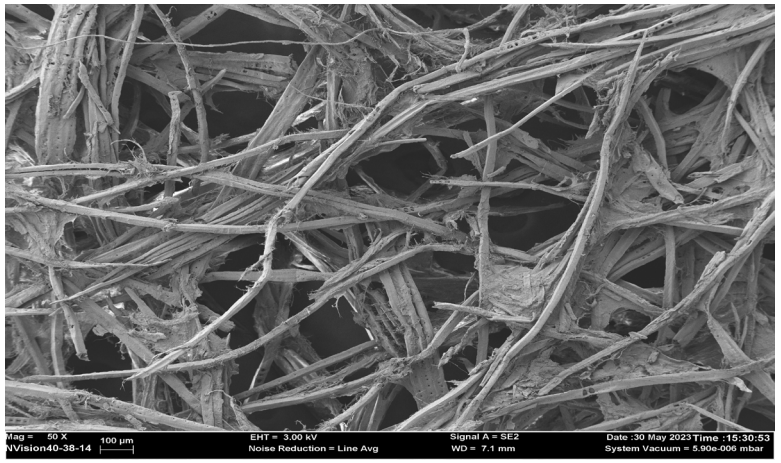
TMP 90%/CNFs 10%/ SDS 1g/l---- SC 4%



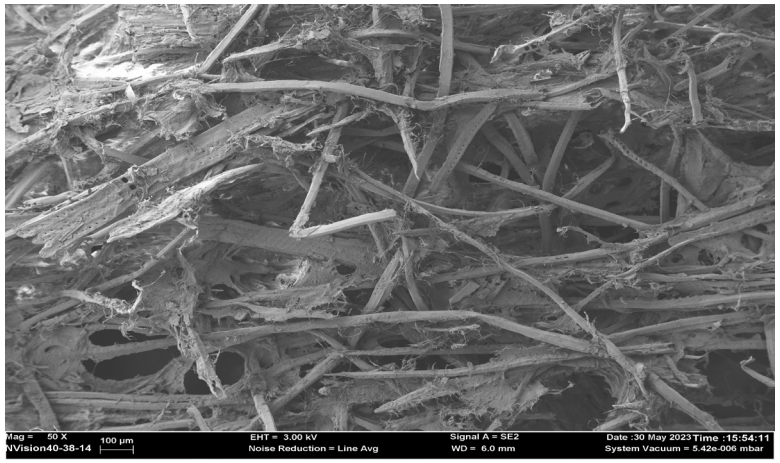
TMP 90%/CNFs 10%/ SDS 1g/l---- SC 6%



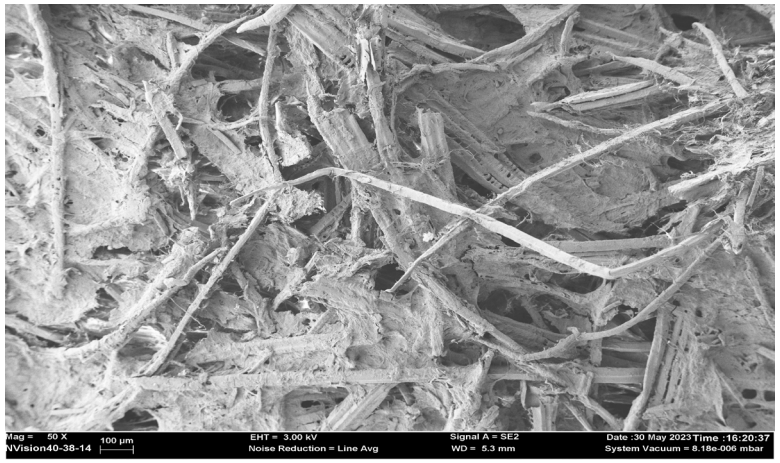
TMP 90%/CNFs 10%/ CTAB 1g/l----SC 2%



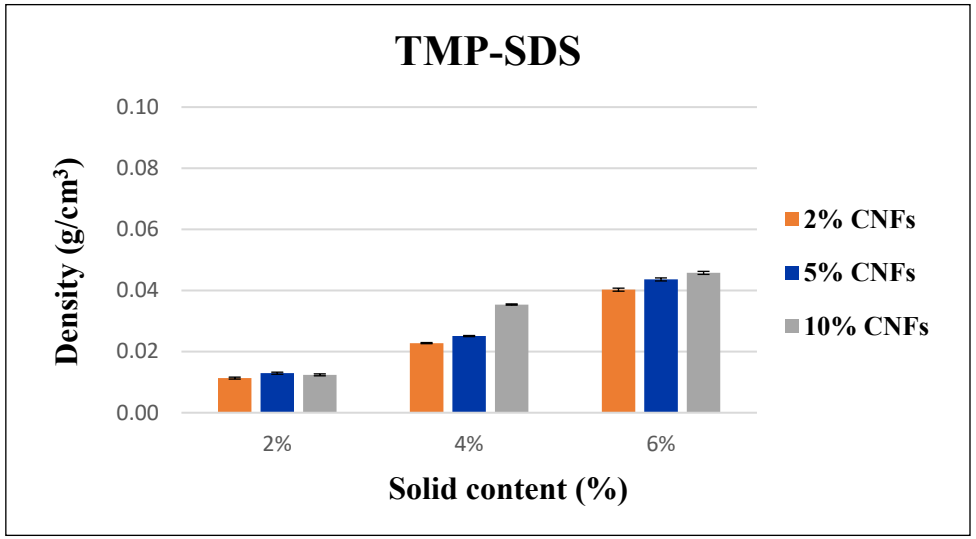
TMP 90%/CNFs 10%/ CTAB 1g/l--- SC 4%

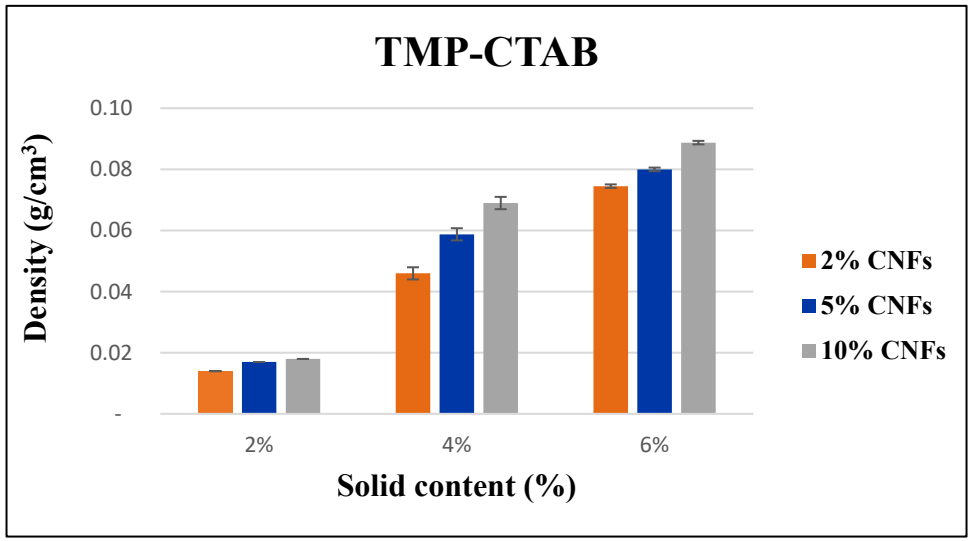


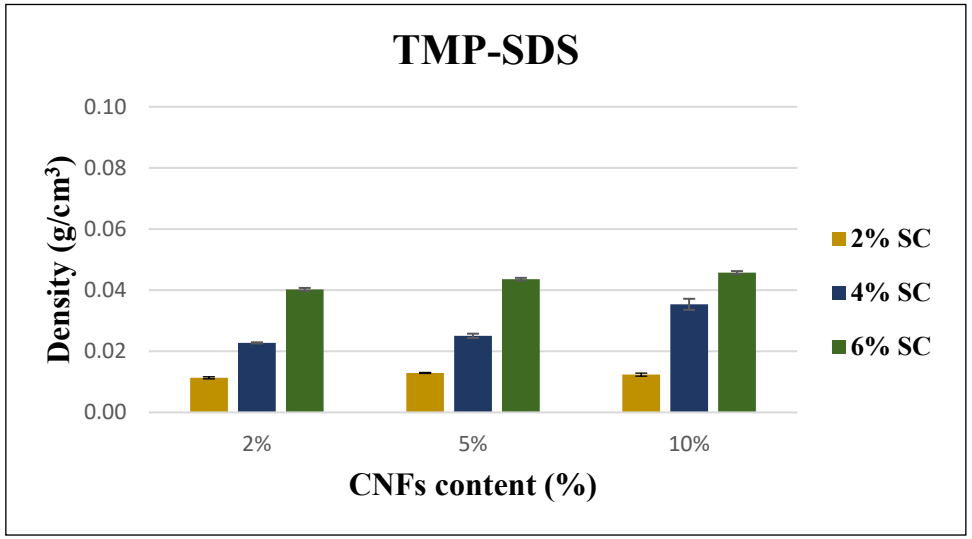
TMP 90%/CNFs 10%/ CTAB 1g/l--- SC 6%

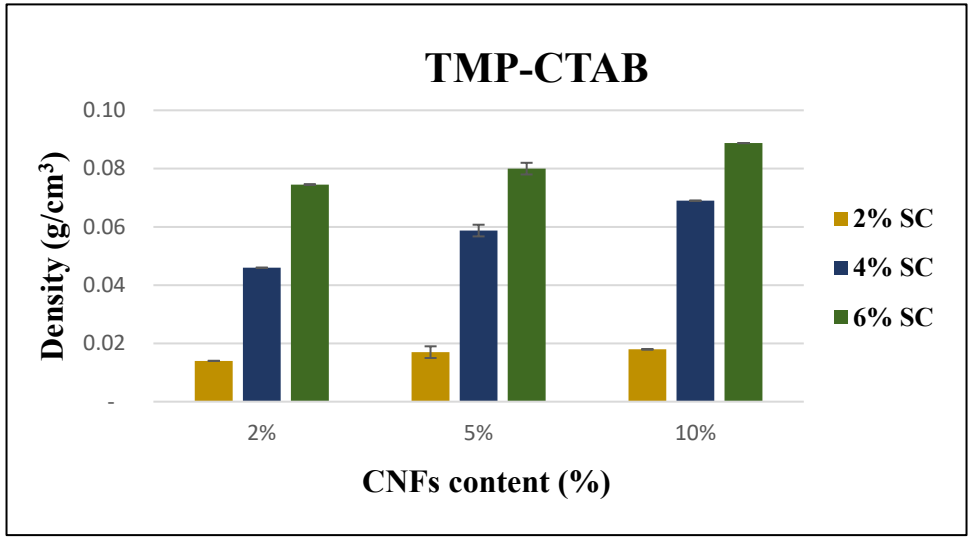


Density

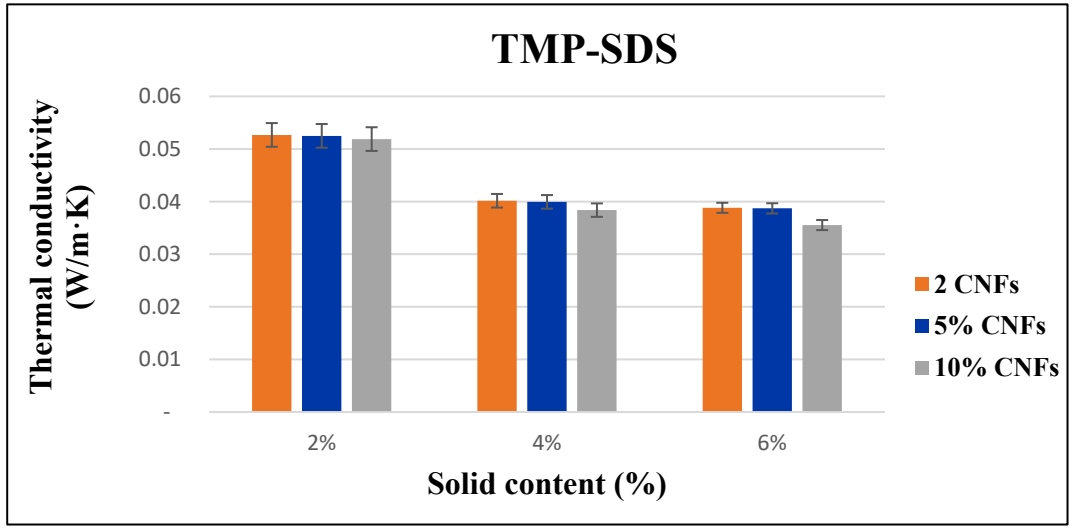

TMP-SDS
Density (g/cm³)
0.10
0.08
0.06
0.04
0.02
0.00
2%
4%
6%
Solid content (%)
2% CNFs
5% CNFs
10% CNFs

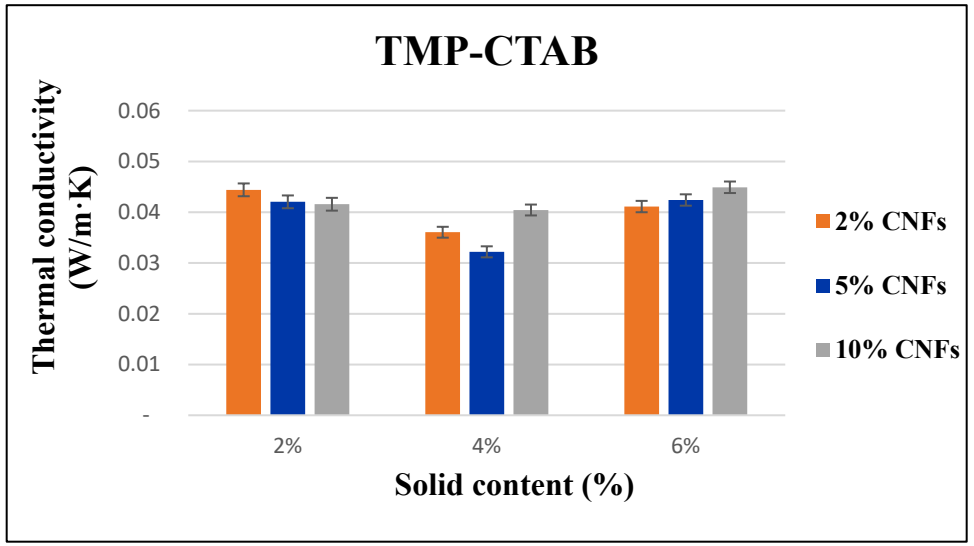

TMP-CTAB
Density (g/cm³)
0.10
0.08
0.06
0.04
0.02
-
2%
4%
6%
Solid content (%)
2% CNFs
5% CNFs
10% CNFs

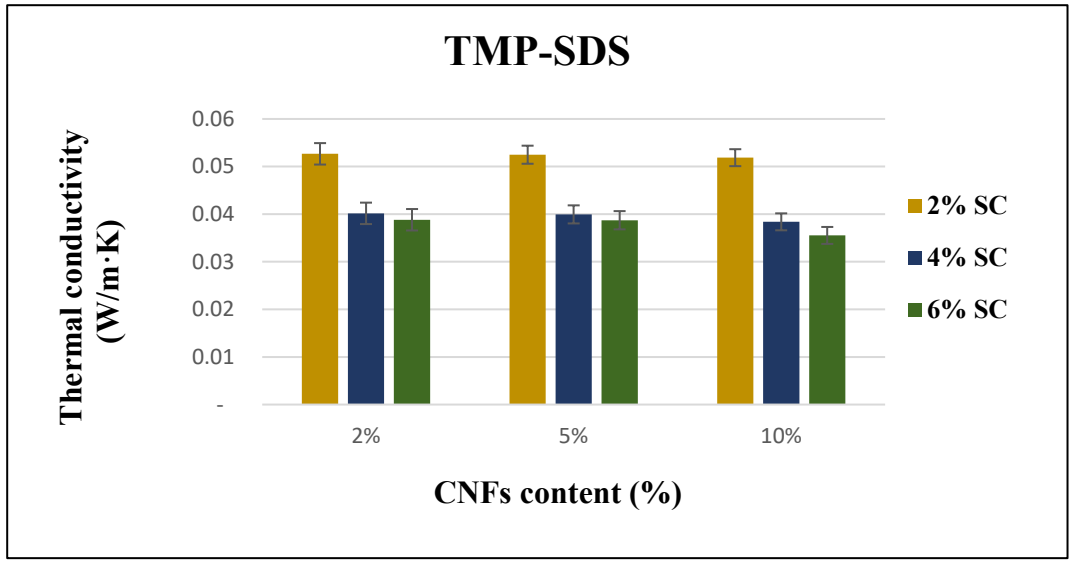

TMP-SDS
Density (g/cm³)
0.10
0.08
0.06
0.04
0.02
0.00
2%
5%
10%
CNFs content (%)
2% SC
4% SC
6% SC

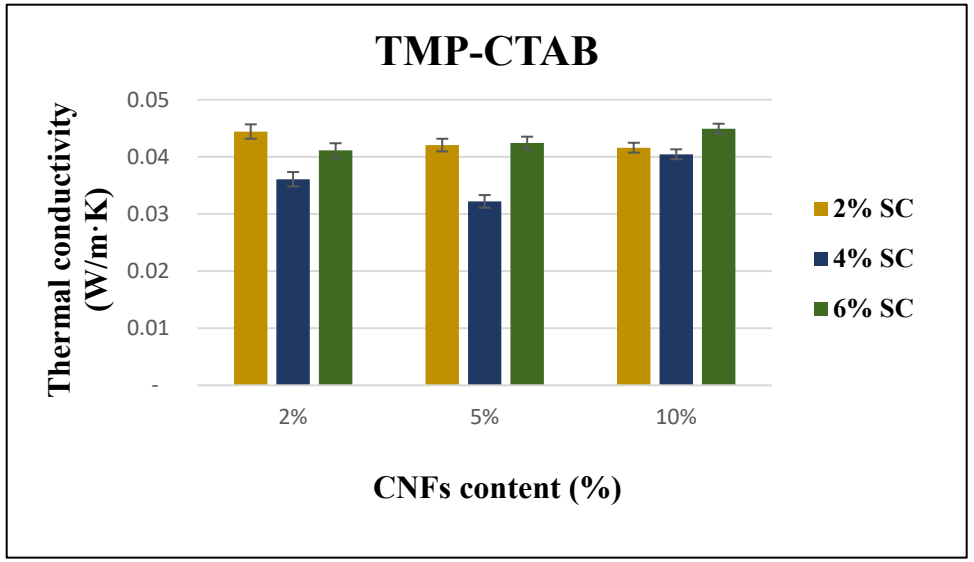

TMP-CTAB
Density (g/cm³)
0.10
0.08
0.06
0.04
0.02
-
2%
5%
10%
CNFs content (%)
2% SC
4% SC
6% SC

Thermal conductivity

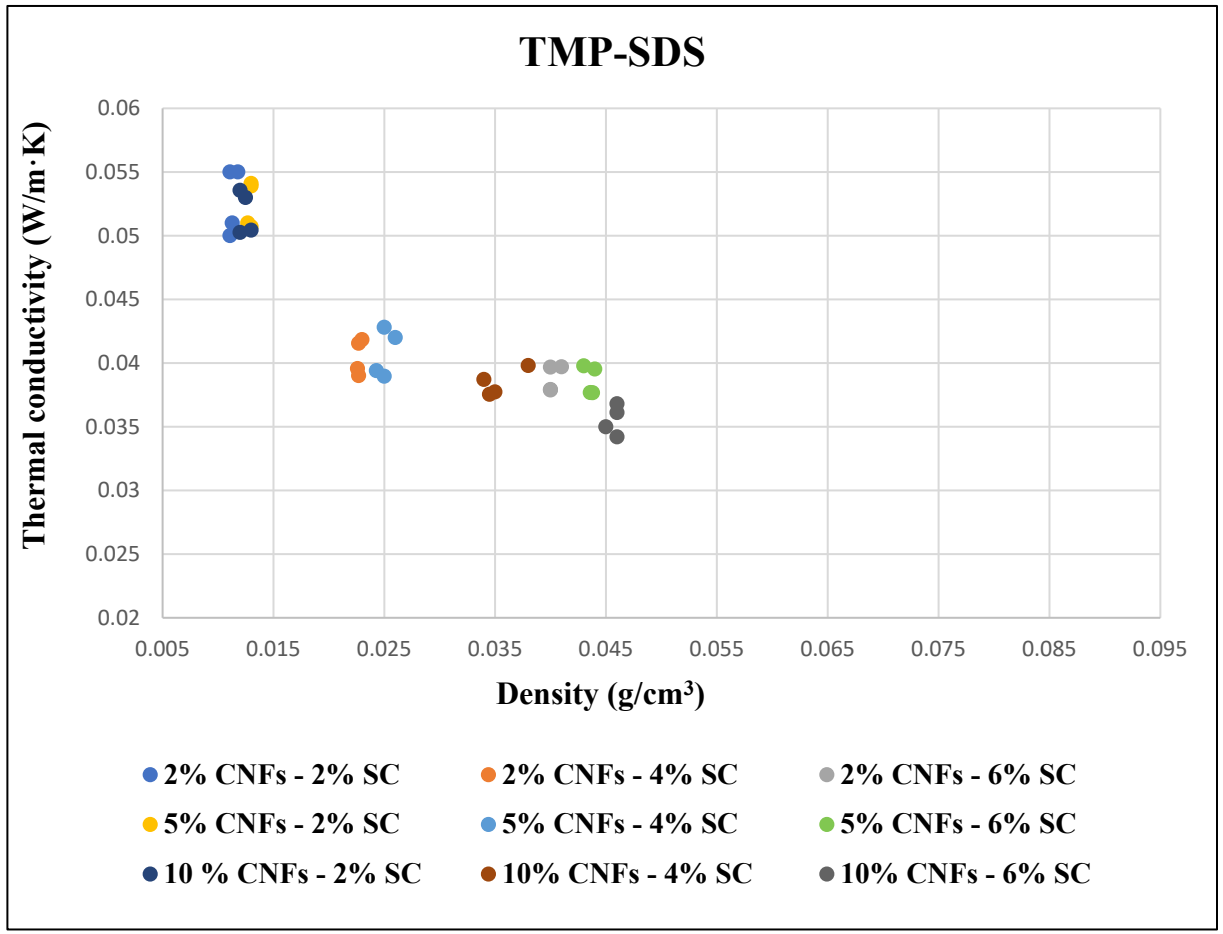


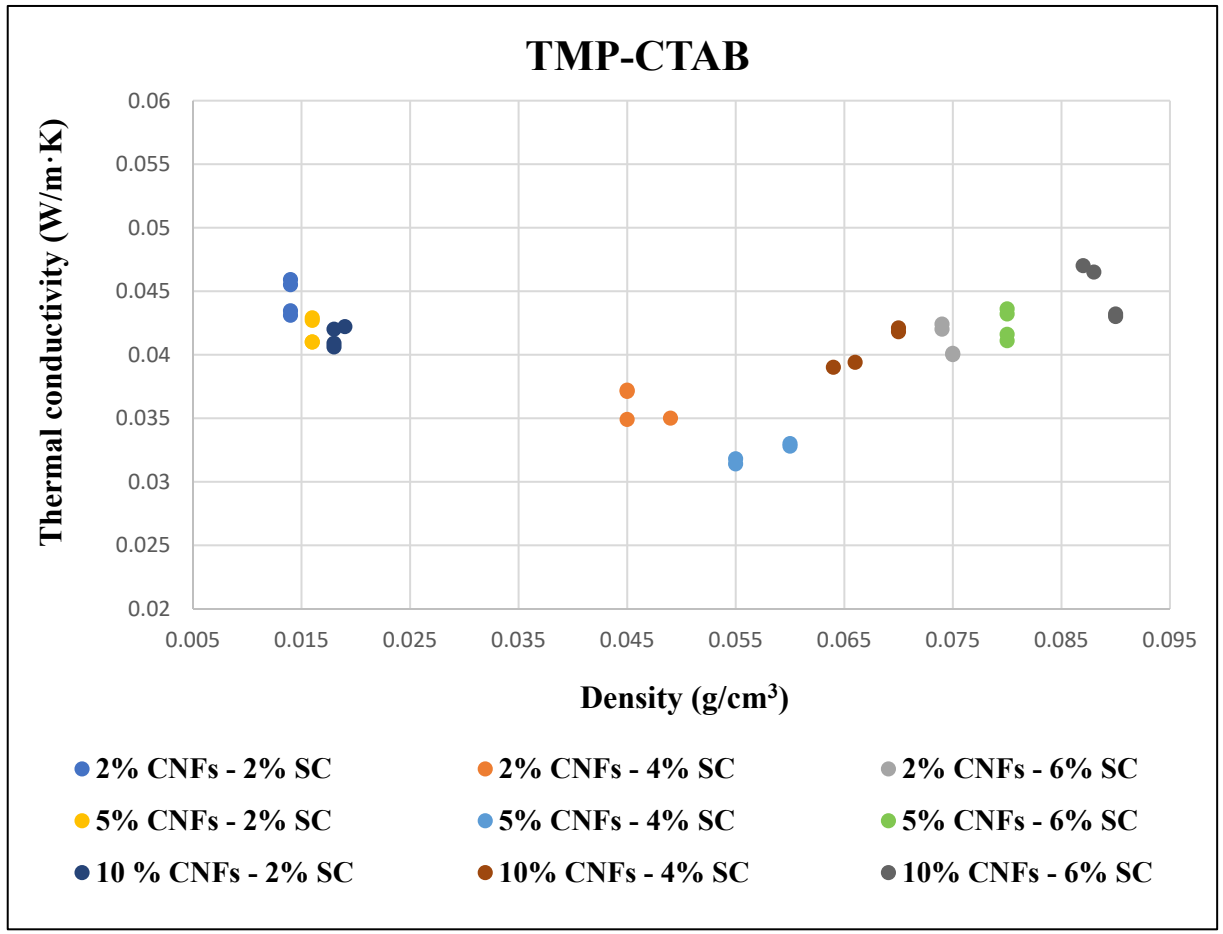




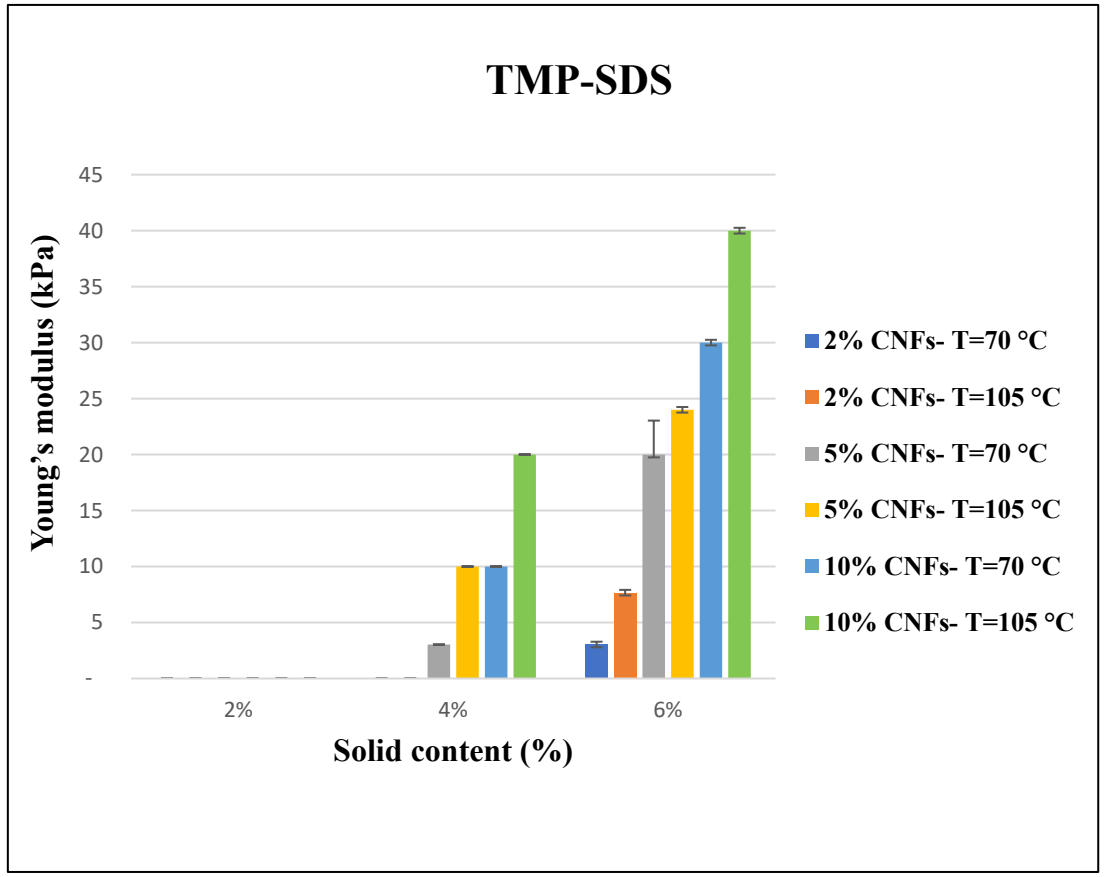


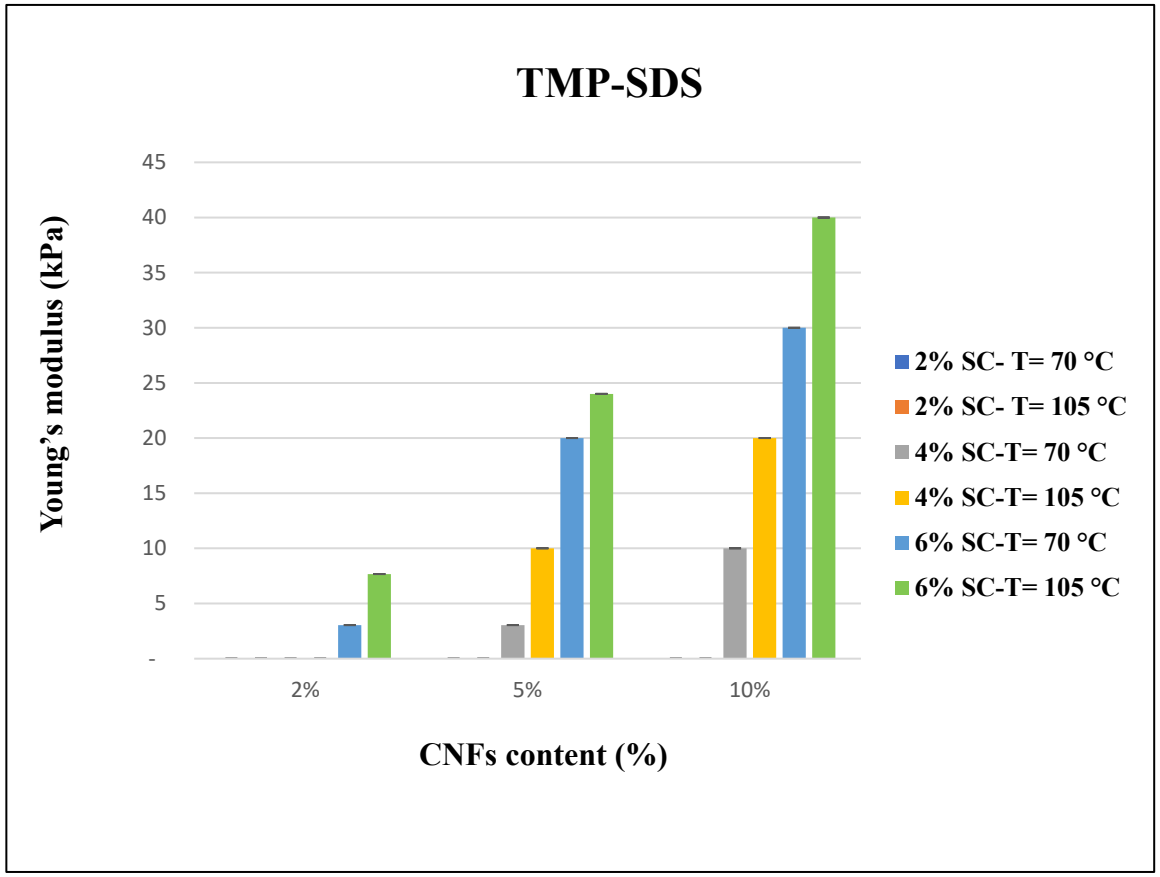
Density and Thermal Conductivity



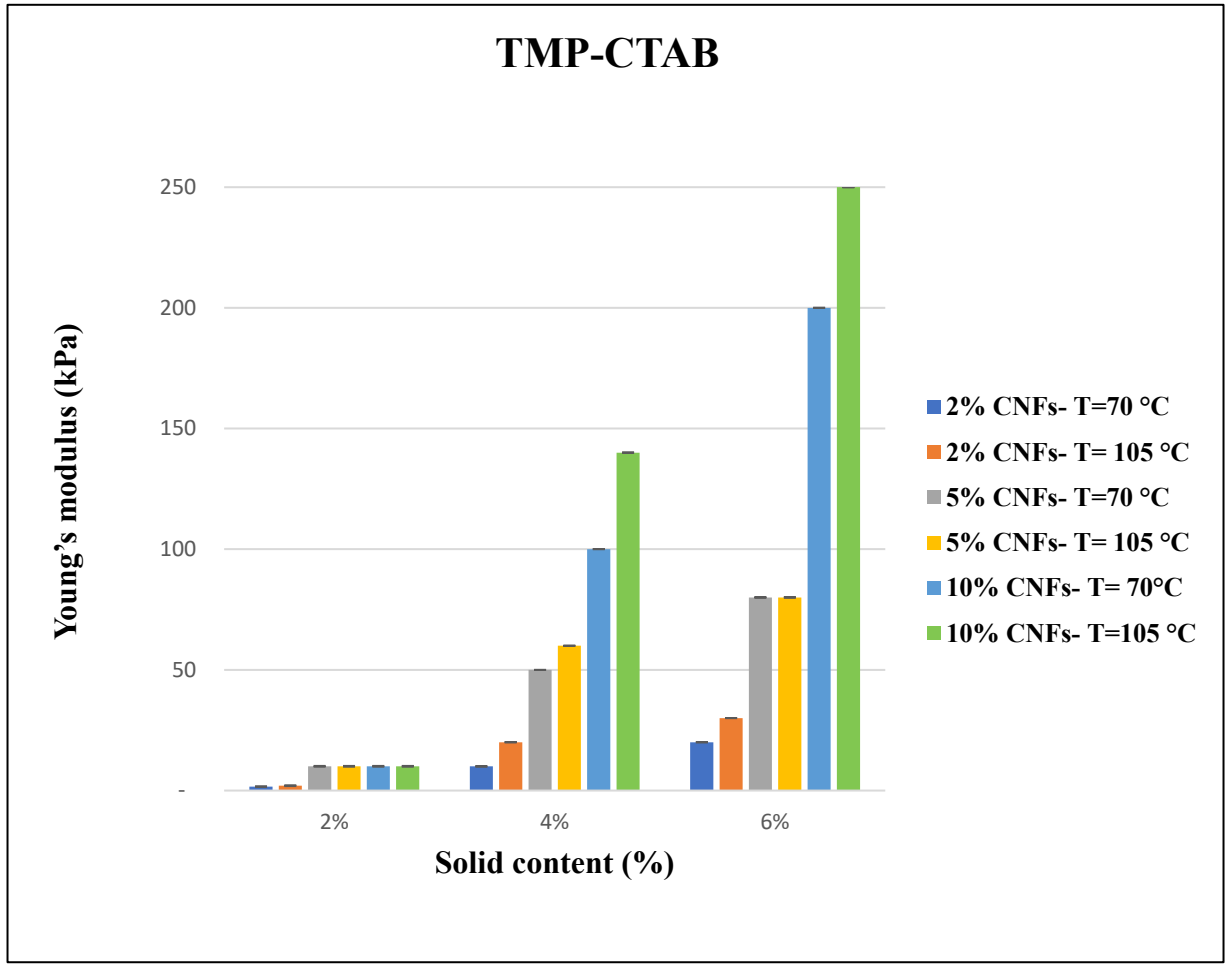


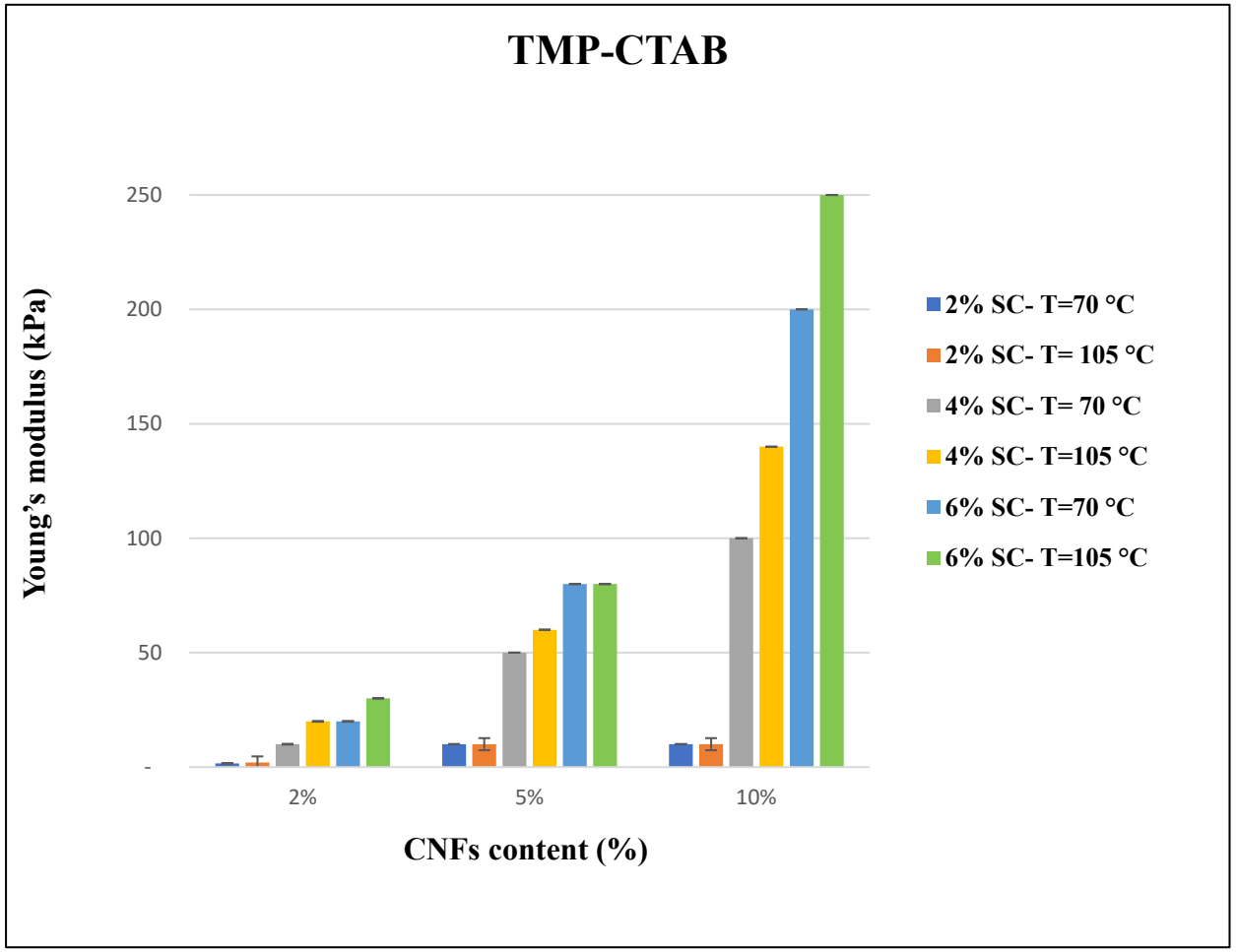
Mechanical properties: compressive Young's modulus



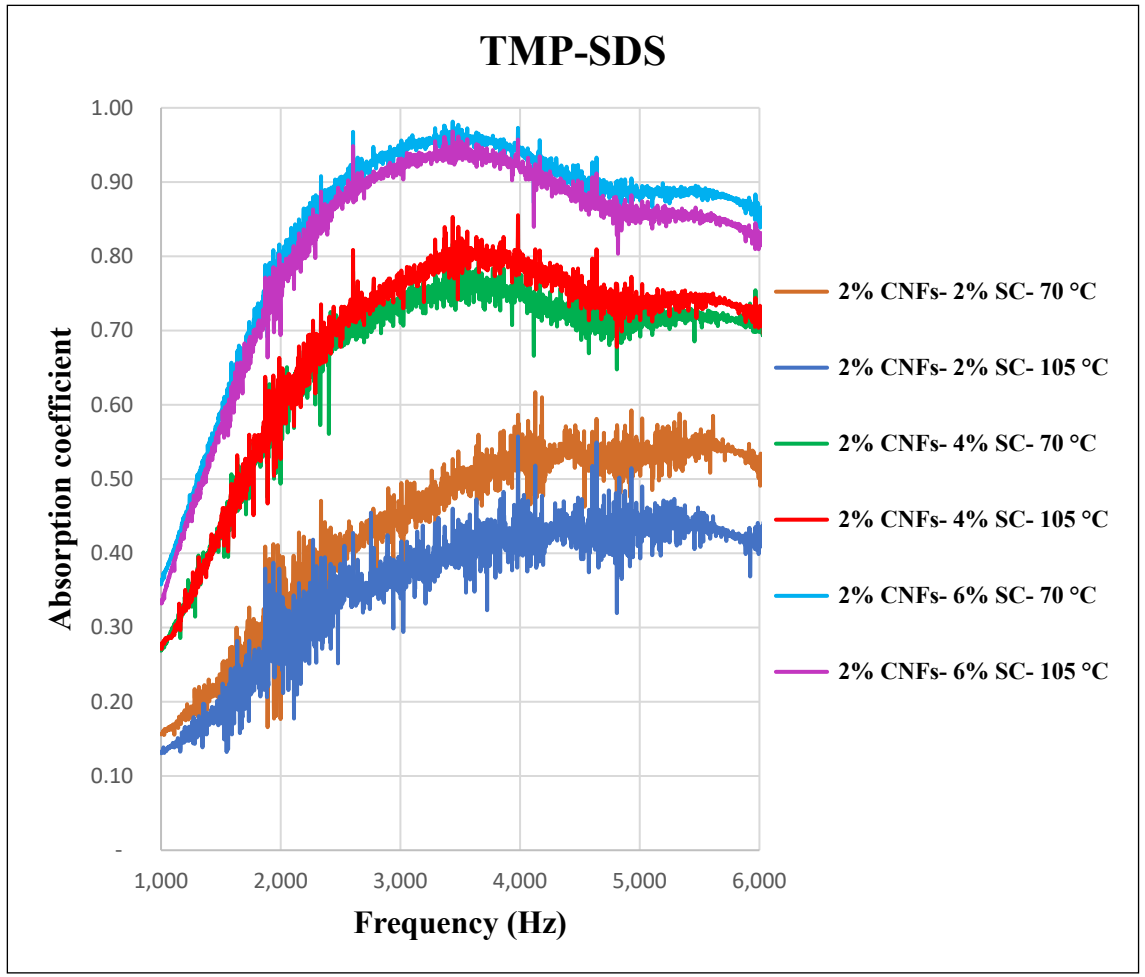


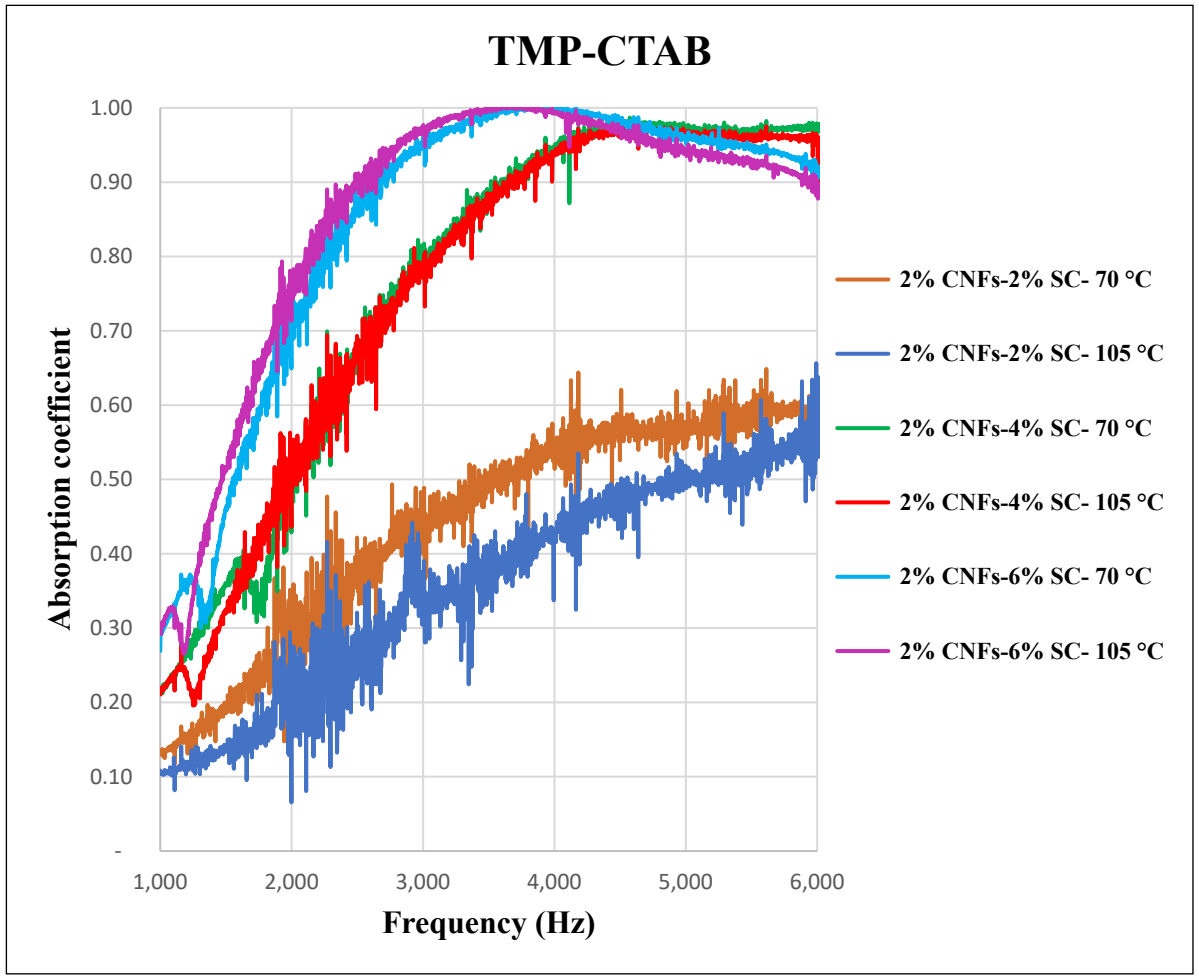
Mechanical properties: compressive Young's modulus



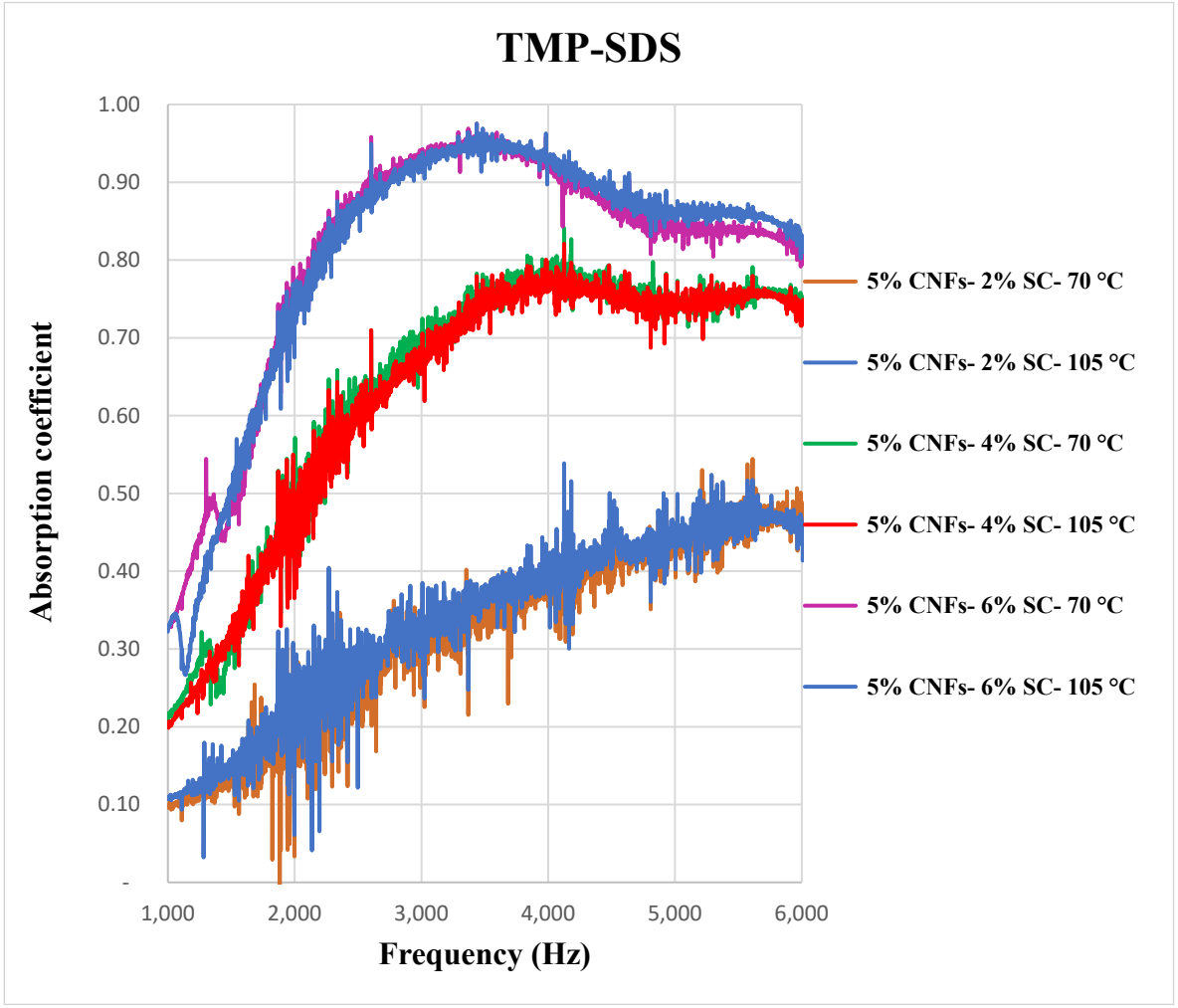


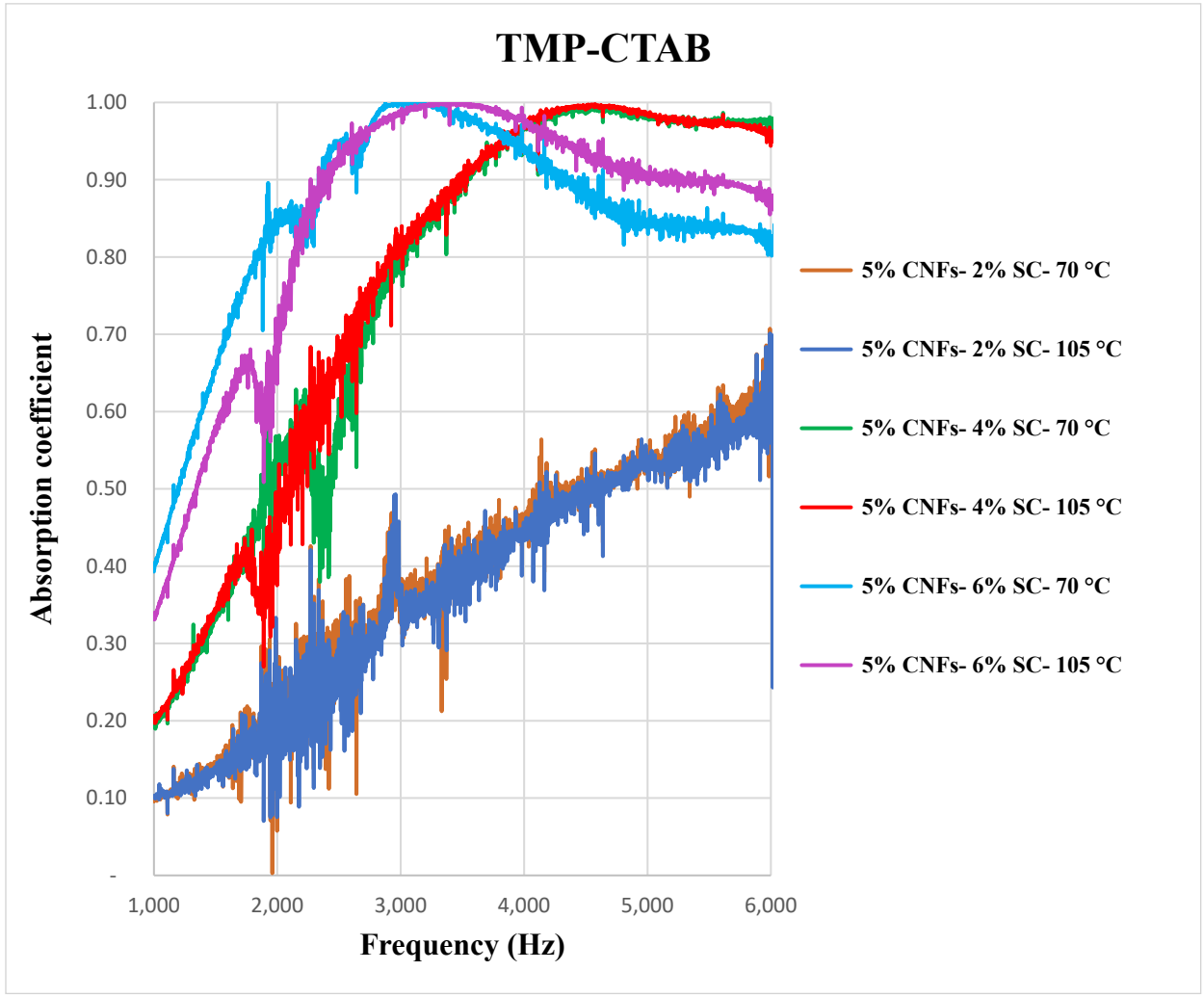
Sound absorption



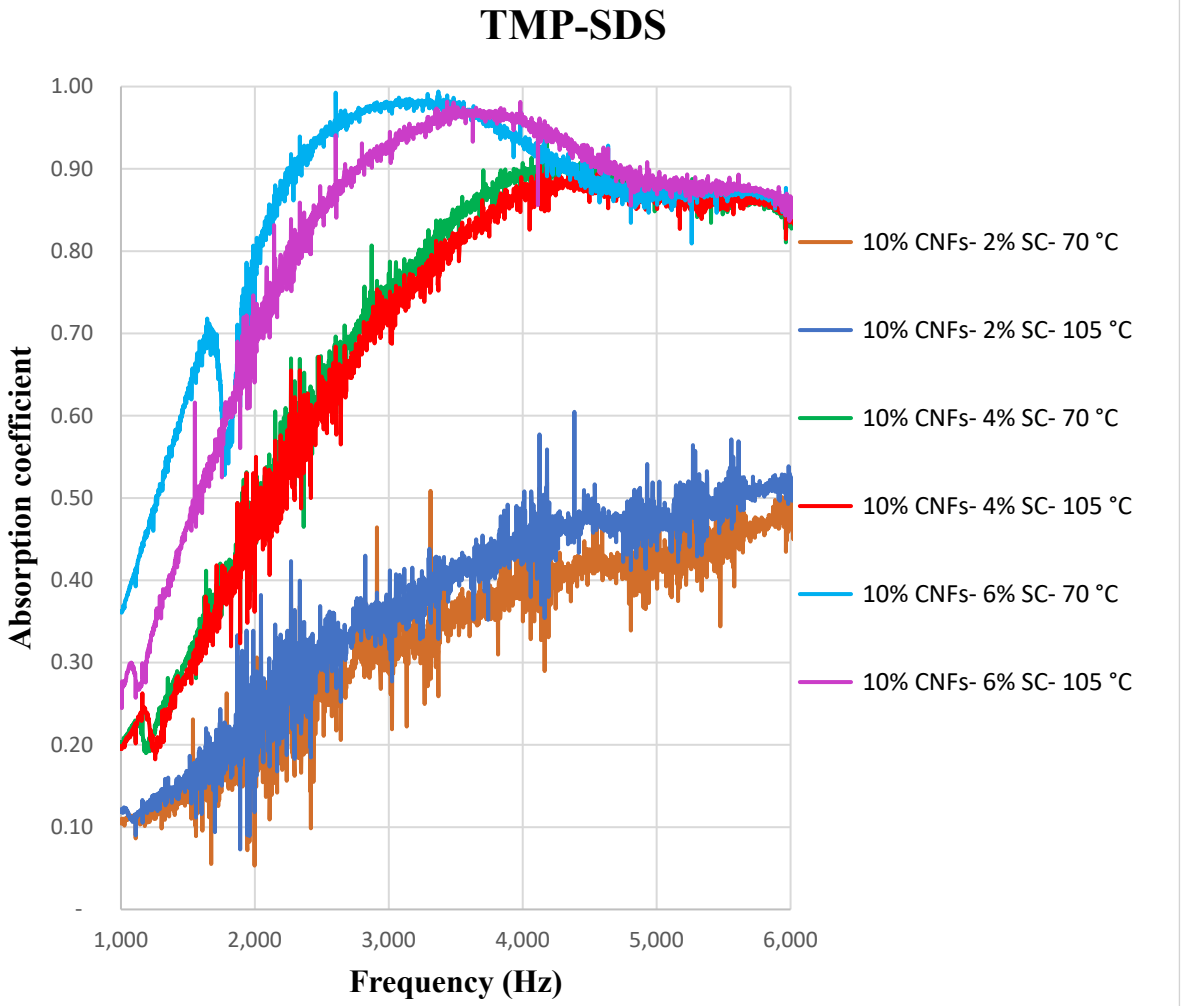


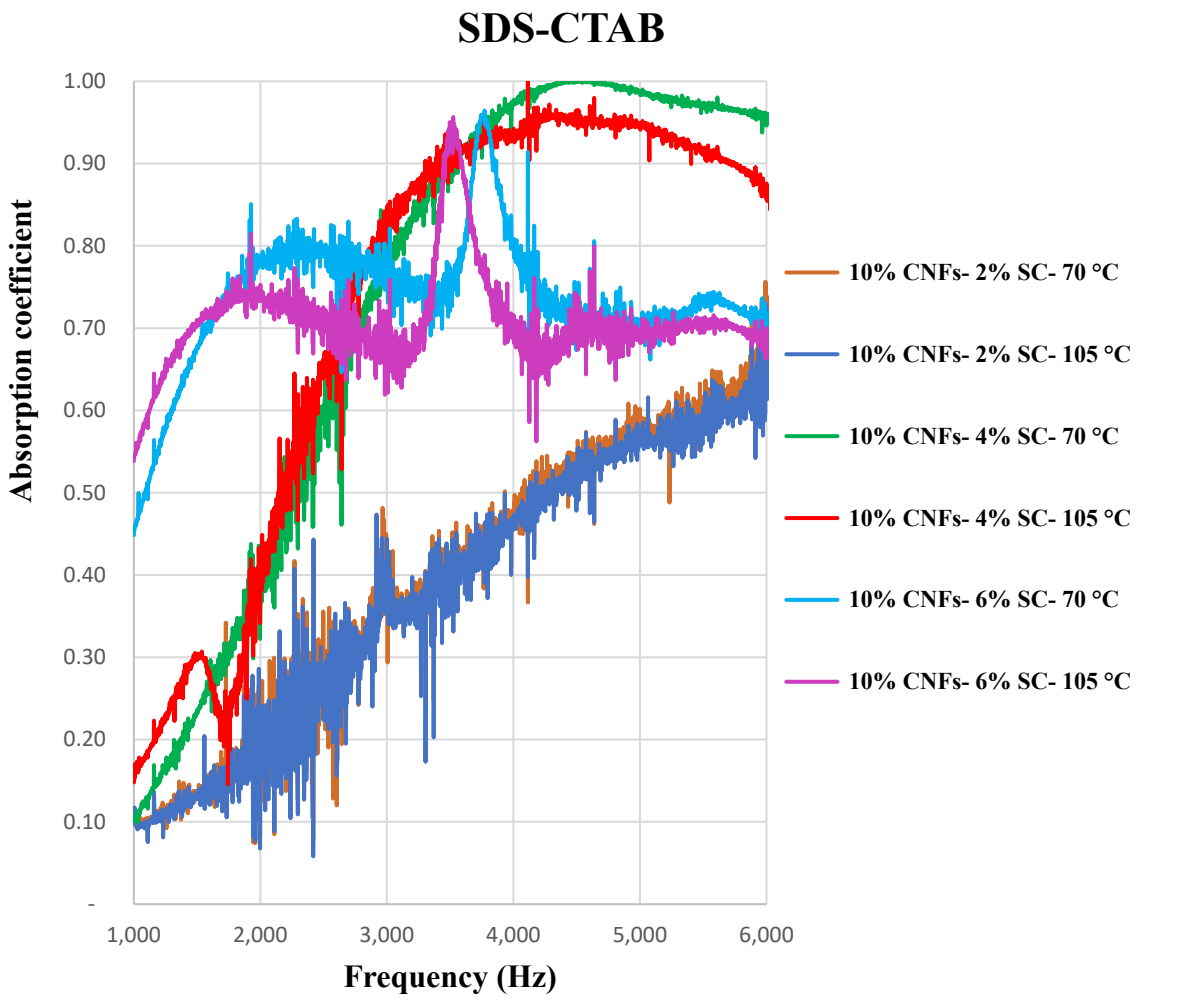
Sound absorption



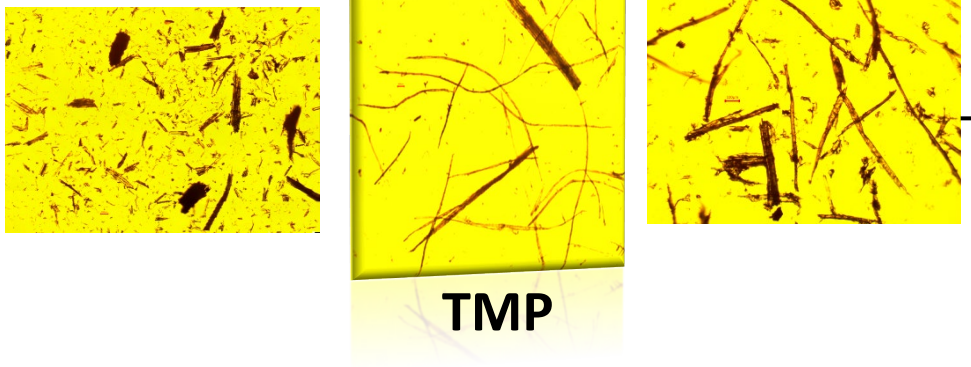


Sound absorption





Lignocellulosic substrate sources



Substrate packing methods

Vacuum Filtration Method

$d>0.08\ g/cm^3$

Foam Forming Method

SDS: $0.01<d<0.04\ g/cm^3$

CTAB: $0.015<d<0.08\ g/cm^3$

Properties

Thermal conductivity: 0.032-0.055 W/Mk

Young's Modulus: 0-40 kPa (SDS)

2-250 kPa (CTAB)

Sound absorption: 0.3-1 at 3000 Hz

How can we improve the mechanical and isolation properties of these materials?

Lignocellulosic-based composites

Using fungal mycelium as a binder

Acknowledgment

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