

Flax Reinforced Thermoset Composites from Polyfurfuryl Alcohol

Rakesh Kumar and Rajesh Anandjiwala

*CSIR Materials Science and Manufacturing, Nonwovens and
Composites Group, Port Elizabeth*

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Furfural Production



Sucrose + Bagasse



Hydrolysis
(H^+ , H_2O)

Cyclodehydration
(H^+ , $-3H_2O$)

Steam Distillation

Separation
(H_2O /Furfural)

Purification



Furfural

- Furfural is produced in a
- ✓ digester under high-pressure steam
 - ✓ recovered by steam distillation
 - ✓ water-furfural separation
 - ✓ purification

Preparation of Polyfurfuryl Alcohol

Furfural



*Furfuryl
Alcohol (FA)*

*Polyfurfuryl
Alcohol (PFA)*

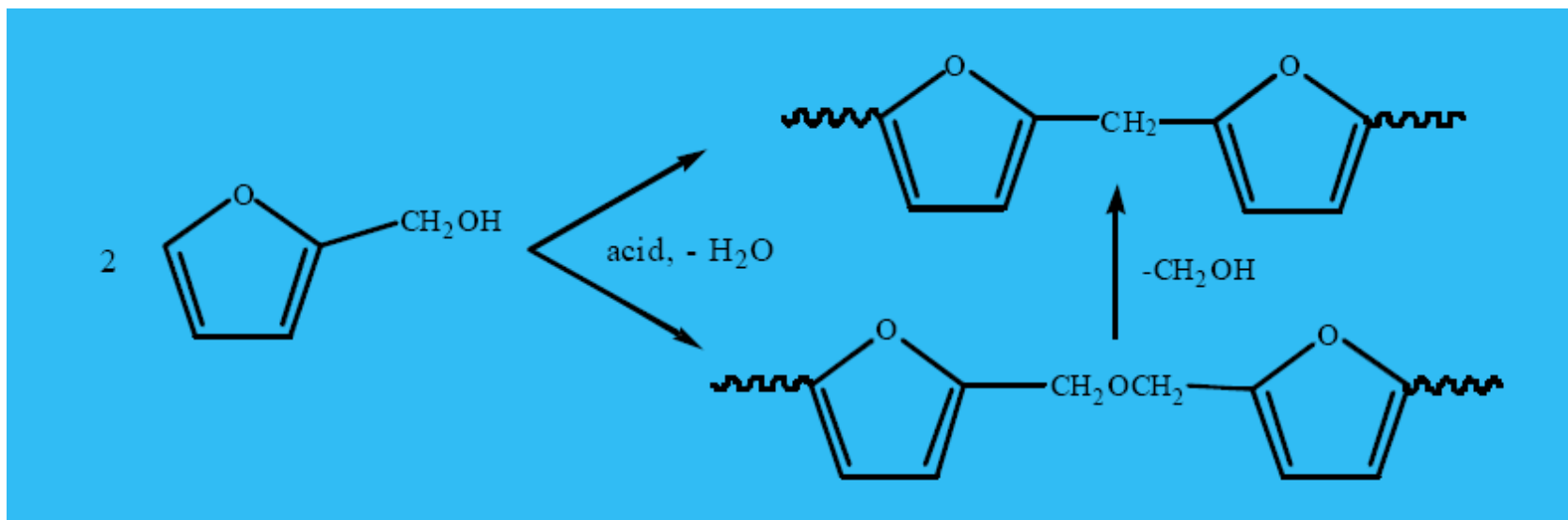
Catalysts Used for Polymerization

1. *Triethylamine Macromolecules 1996, 29, 3839-3850*
2. *Hexamethylenetetramine Chem. Mater. 1999, 11, 384-391*
3. *p-toluene sulfonic acid (PTSA) Composites Manufacturing 1995, 6, 45-52*
4. *Iodine in methylene chloride Ind. Eng. Chem. Res. 2006, 45, 6393-6404*



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Polymerization Process



The reaction pathway is simple but it is not so simple as PFA is black in colour which indicates generation of some chromophoric groups.

Polymerization of Furfuryl Alcohol

✓ *Under mechanical stirring*

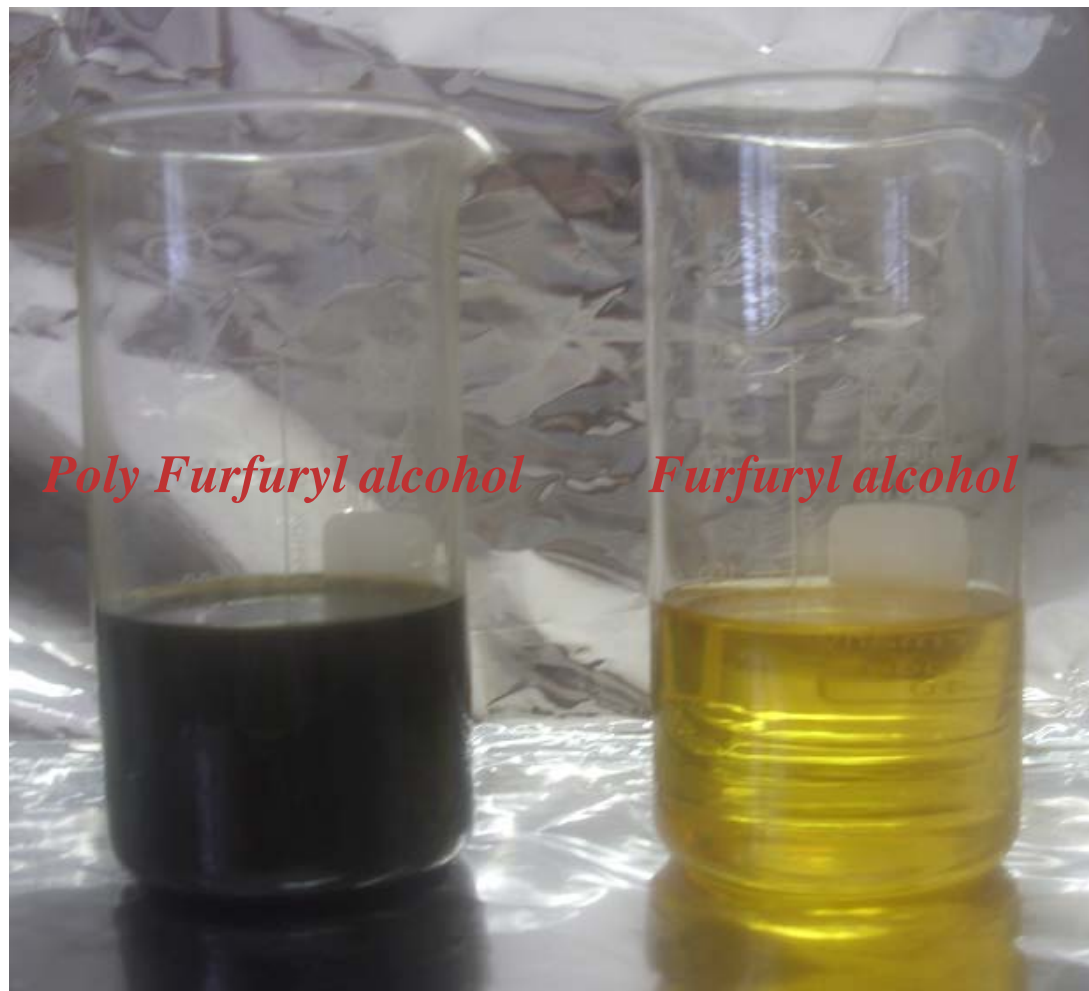
✓ *using p-toulene sulphonic acid (0.3 and 0.6 phr)*

✓ *45-50°C*

✓ *30 min*

Designation: PFA-3 and PFA-6 represents PFA with 0.3 and 0.6 phr of acid catalyst. FA represents furfuryl alcohol.

Appearance and Viscosity



Poly Furfuryl alcohol

Furfuryl alcohol

At 25°C

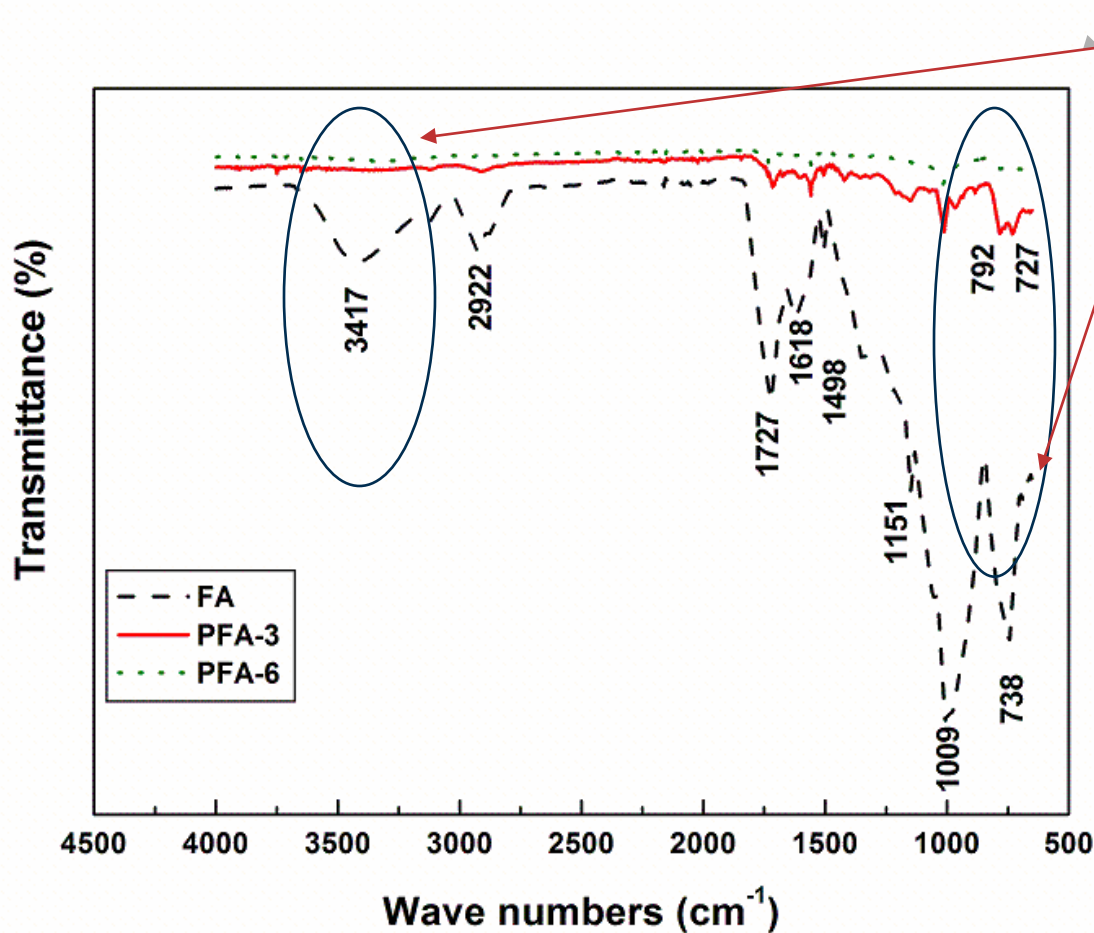
FA - 6.9-7.0 cts

PFA 3 - 560± 10 cts

PFA 6 - 711668 ± 10 cts

Characterization of FA and PFA

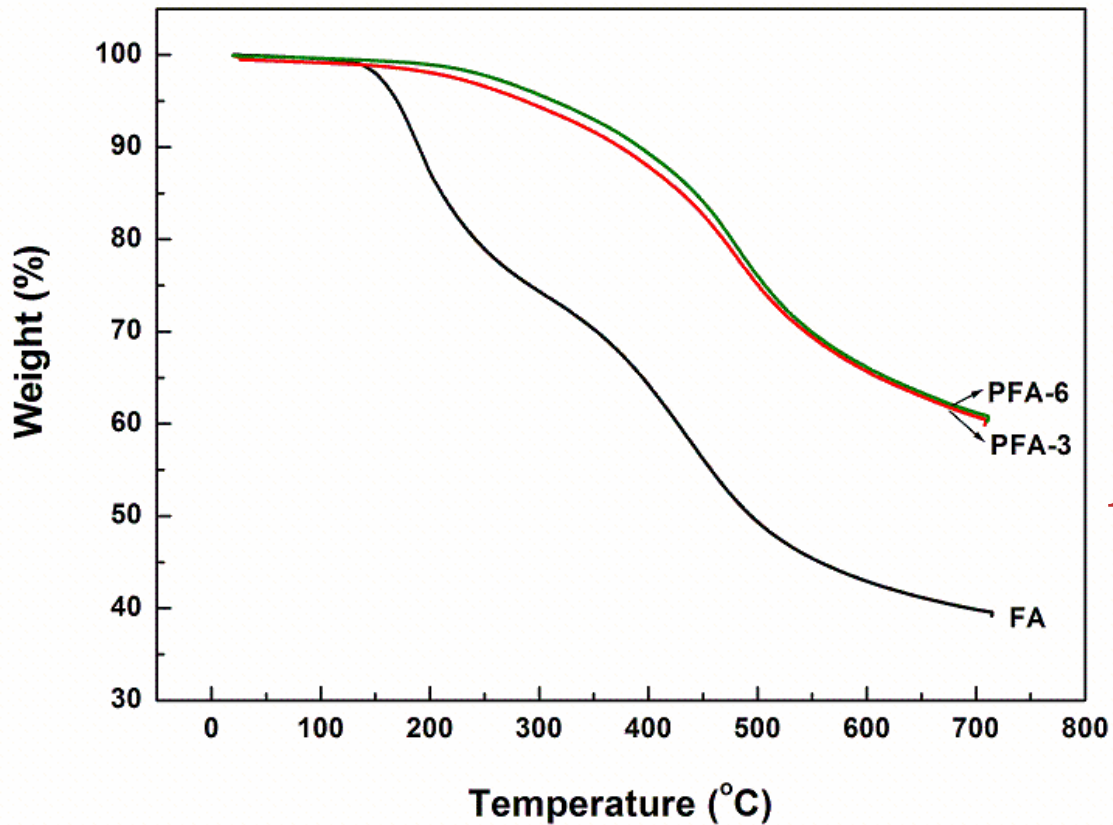
FTIR of FA and PFA



a substantial decrease of the -OH band around 3417 cm⁻¹

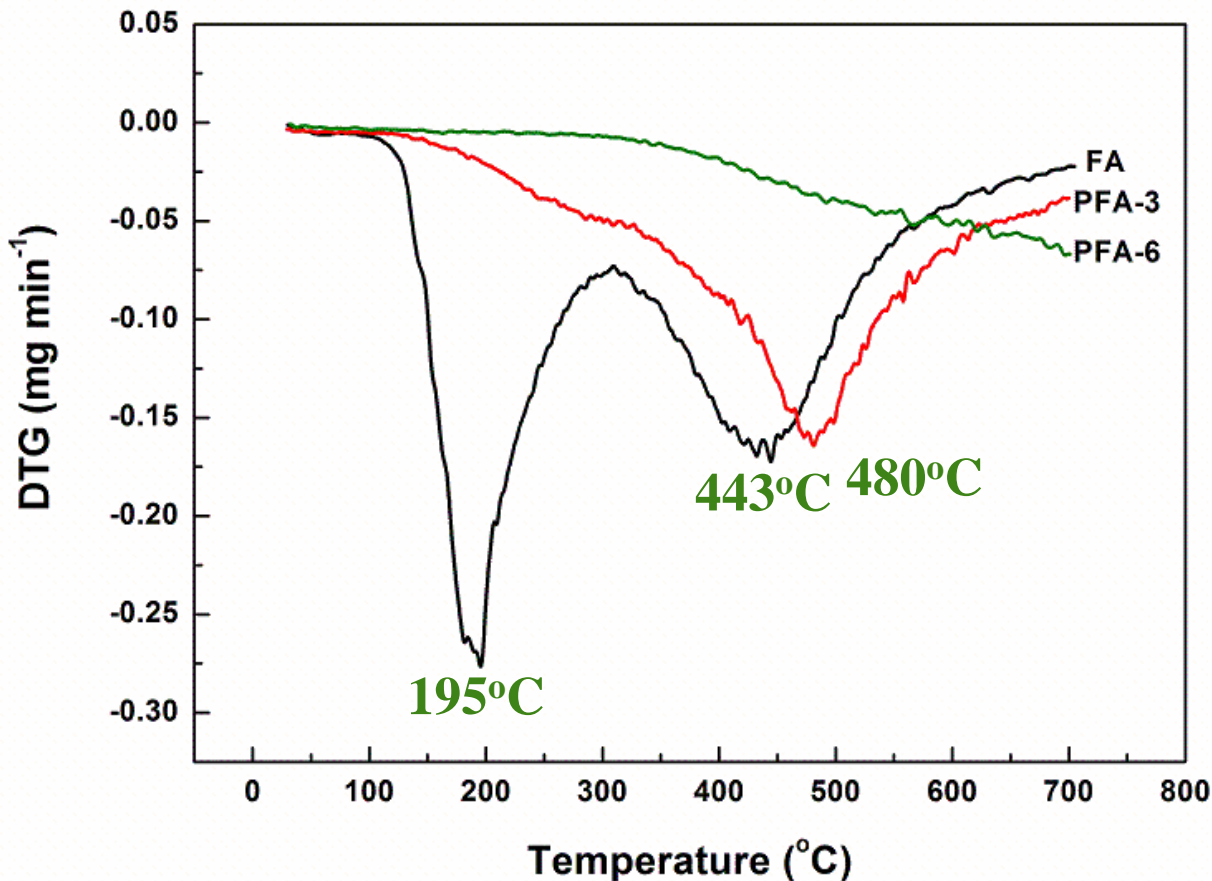
the presence of a band at 792 cm⁻¹ characteristic of 2,5-disubstituted furan rings

TGA of FA and PFA



Remaining mass is 60-65% which is same as that of phenolics

DTG of FA and PFA



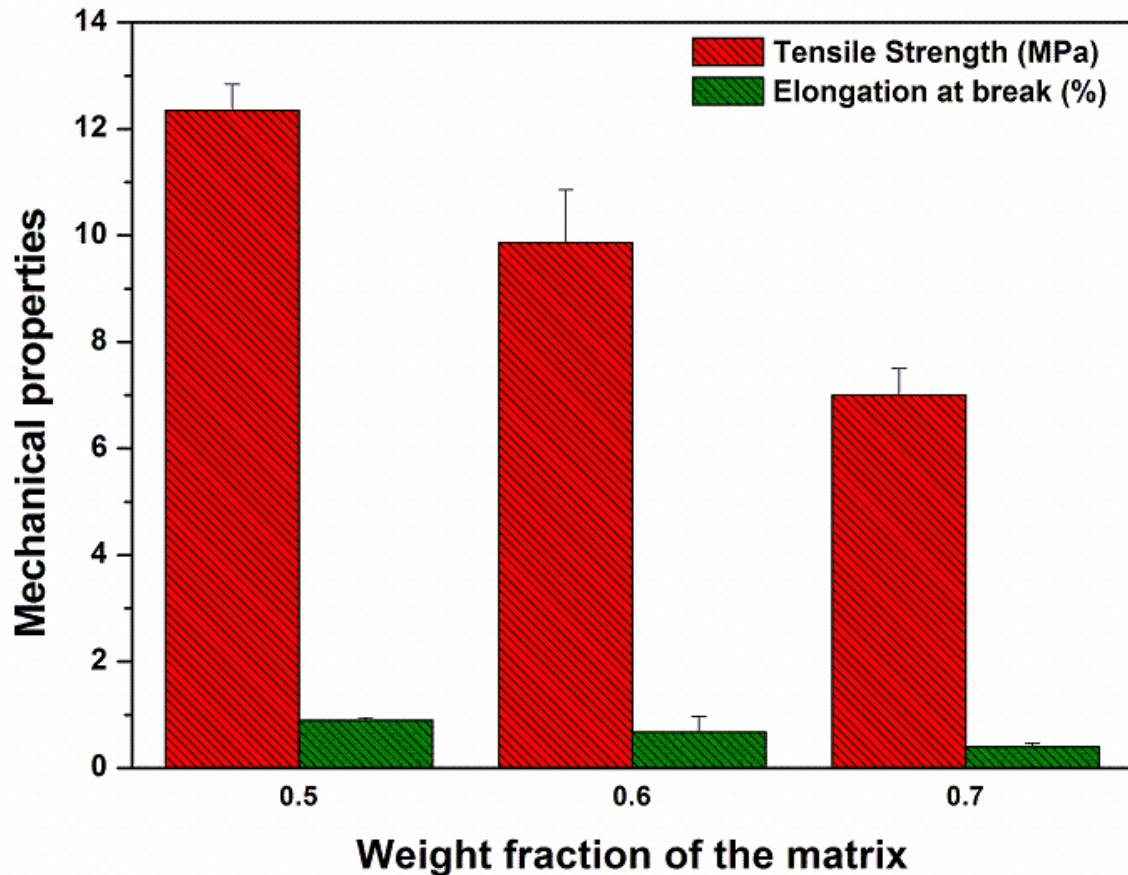
T_{max} at lower temperature is absent in PFA indicating higher thermal stability of PFA.

Characterization of PFA based composites

Composites Preparation

- ✓ *Woven flax fabric (180 g/m²) with warp (19 threads/cm) and weft (21 threads/cm)*
- ✓ *Known weight fraction (0.5, 0.6, 0.7) of PFA-3 was spread homogeneously on the fabric*
- ✓ *Composites cured in oven at 190°C for 30 minutes*

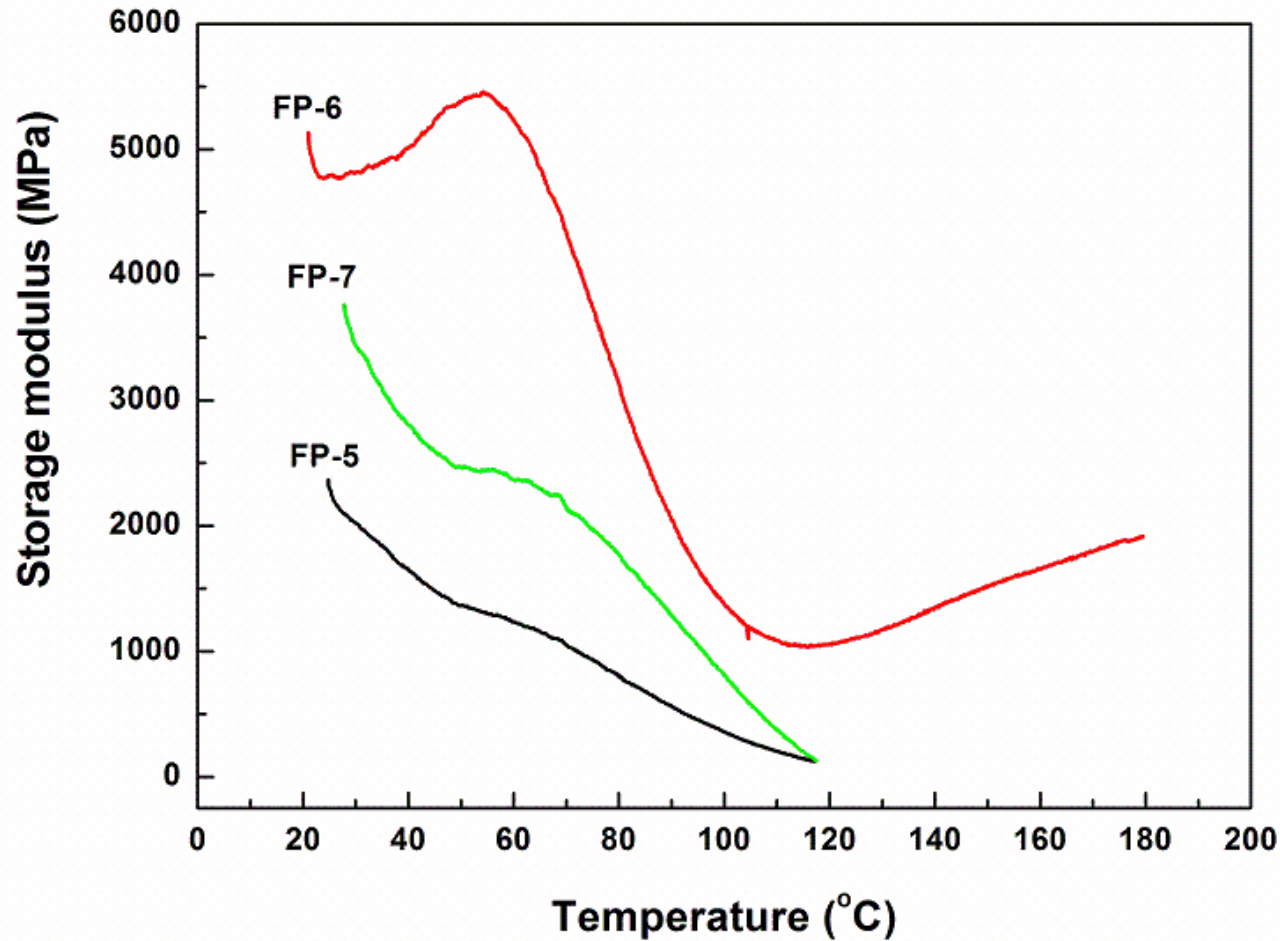
Mechanical Properties



Increase in weight fraction of the matrix resulted in decrease in tensile strength as well as percentage elongation at break.

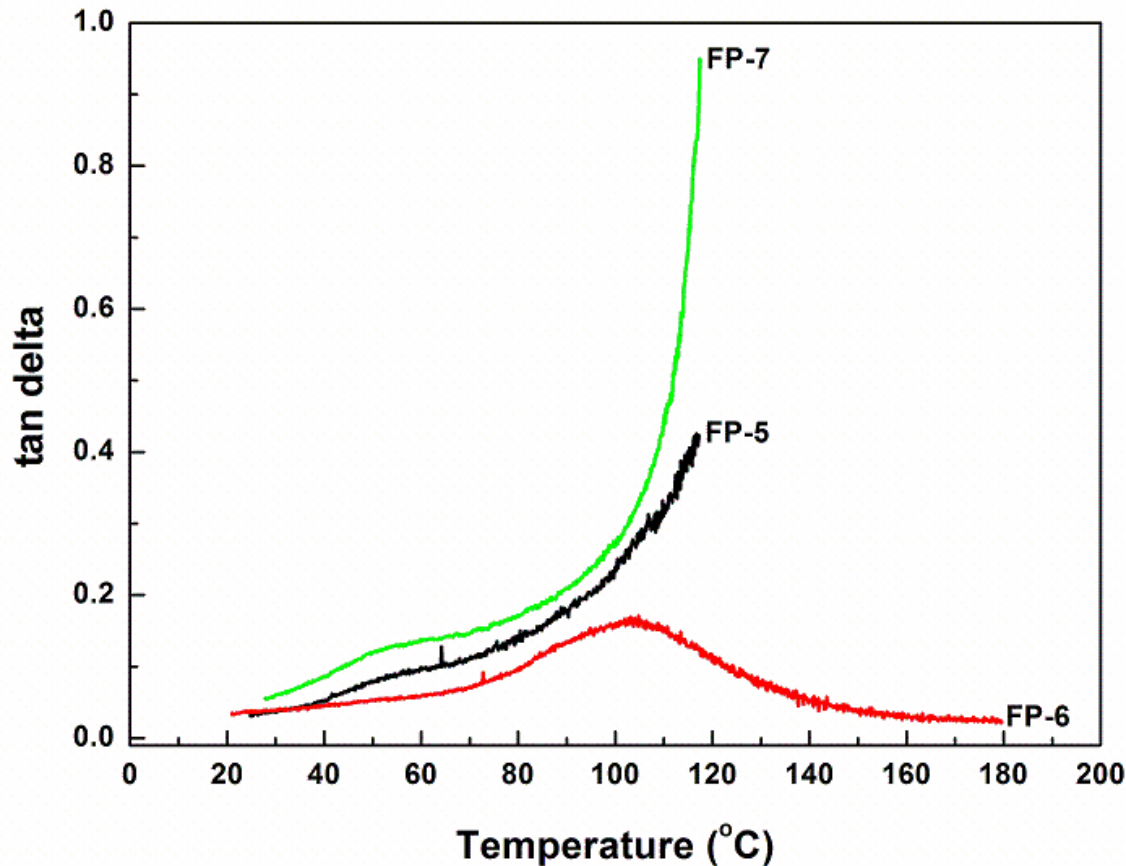
PLA based nowoven flax fiber at 0.7 weight fraction of matrix has tensile strength of 21 ± 1 MPa

Storage Modulus



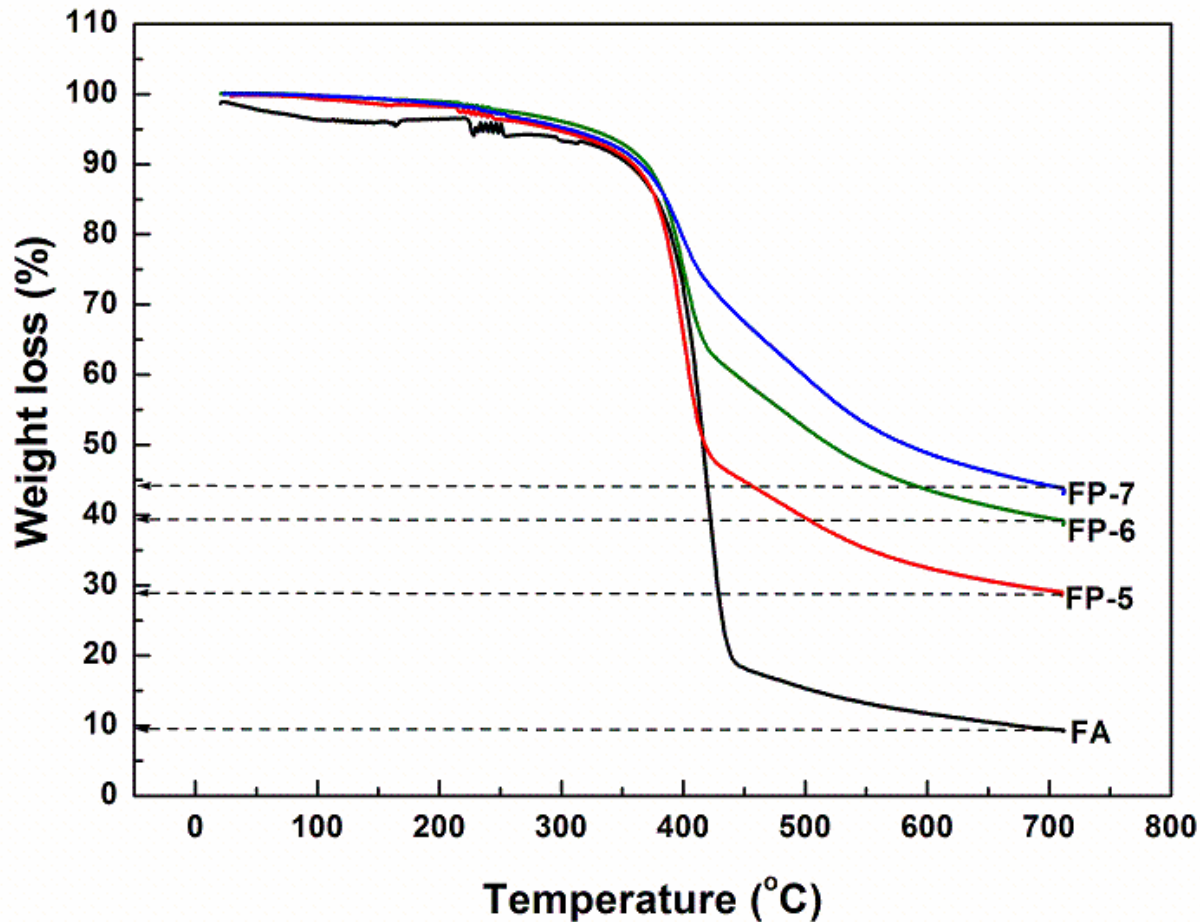
At 0.6 weight fraction of the matrix storage modulus was highest.

tan δ Curves of Composites



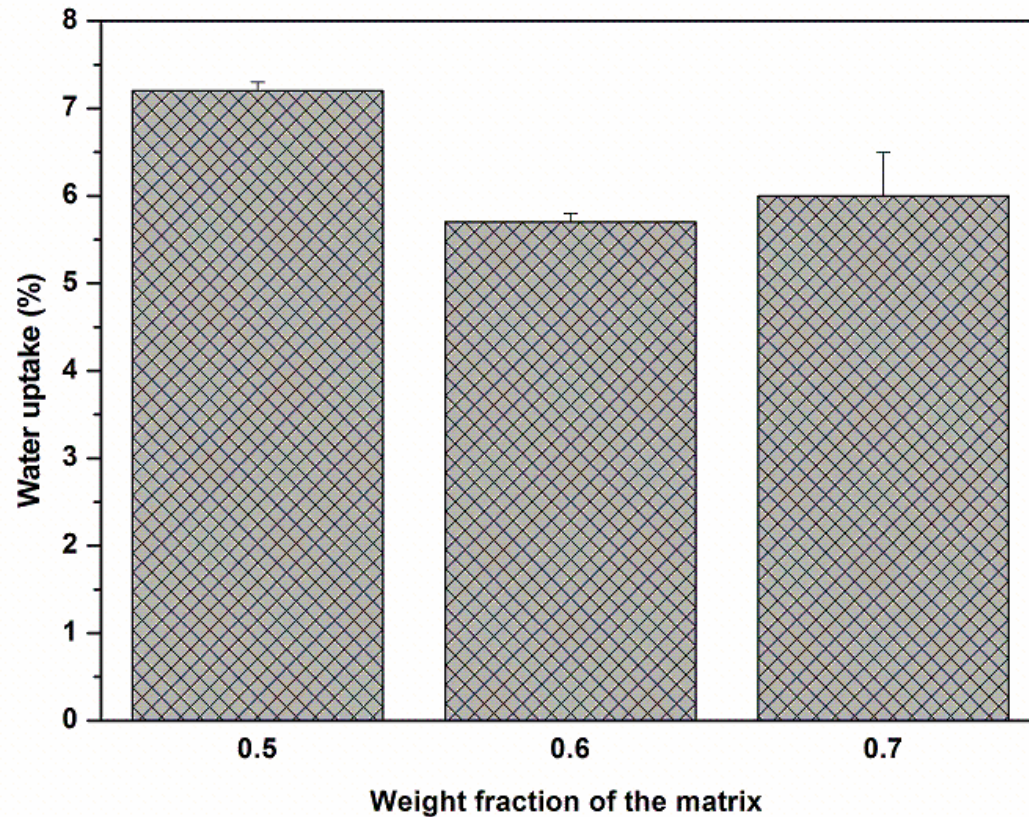
The lower damping factor at 0.6 weight fraction of the matrix indicates good compatibility of matrix with fibers.

TGA of Thermoset Composites



The increase in weight fraction of the matrix increased the thermal stability with higher char yield.

Water Uptake



Water uptake of the composite was lowest at 0.6 weight fraction of the matrix which indirectly states higher water resistance. PLA based nowoven flax fiber at 0.7 weight fraction of matrix has water uptake of 9.8 %.

Conclusions

✓ The high water resistance and low cost of PFA make it a good candidate for thermoset biopolymer with a chance to compete with phenolics.

✓ PFA based composites with high thermal stability can be used in interior of aircraft cabins, internal fittings for buildings, rail carriages, in built environment applications.

Thanks For Your Attention