Thermal characterization of fire-retardant coated green biocomposite

Presented by

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Synopsis

1. Context of the study
2. Research goals
3. Material and methods
4. Results and discussion
5. Conclusion and Perspective

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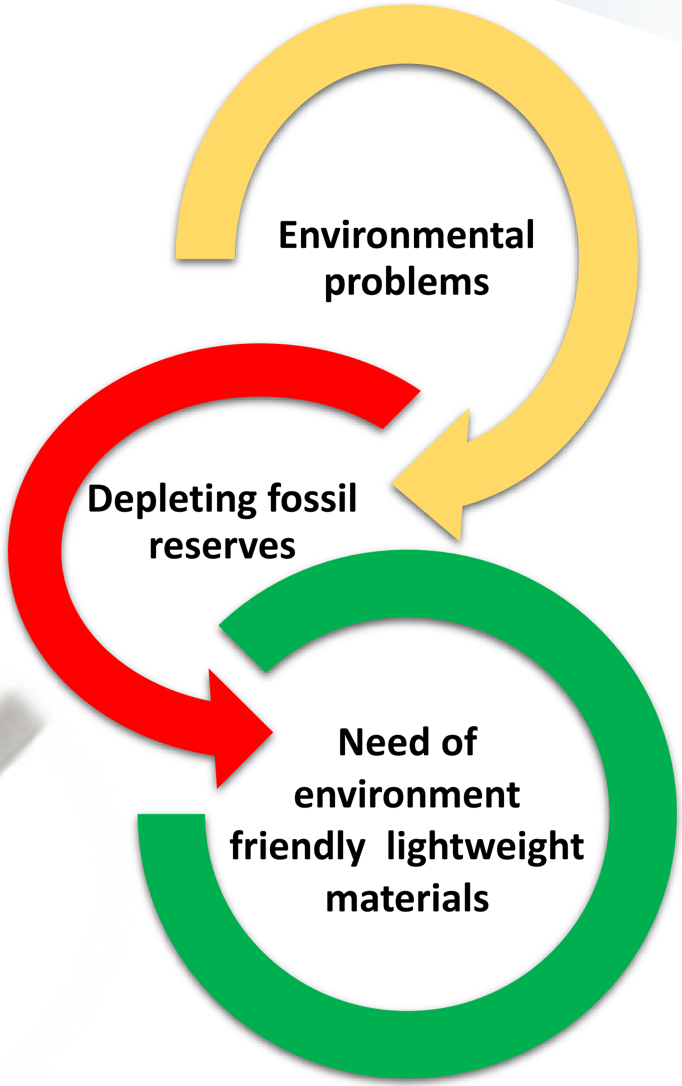
1.1. Context of the study



Synopsis

2. Research Goals

- ✓ Develop new green biocomposite
- ✓ Study their thermal behaviour for reducing flammability to meet the industrial fire safety standards while maintaining their properties

Synopsis

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3.1. Materials & Methods

Materials

Natural Fibre	A balanced 2×2 twill flax fabric of 550 g/m²
Bioepoxy	Infugreen810, a 38 % biobased epoxy
Fire-Retardants	1-Ammonium polyphosphate-tris-2-hydroxyethyl-isocyanurate (APP-THEIC) 2-Boric acid

Methods

Fabrication technique	Vacuum bag resin transfer moulding
Fire-retardant Coating	Brushing
Characterization technique	Thermogravimetric analysis
Morphological analysis	Scanning electron microscopy

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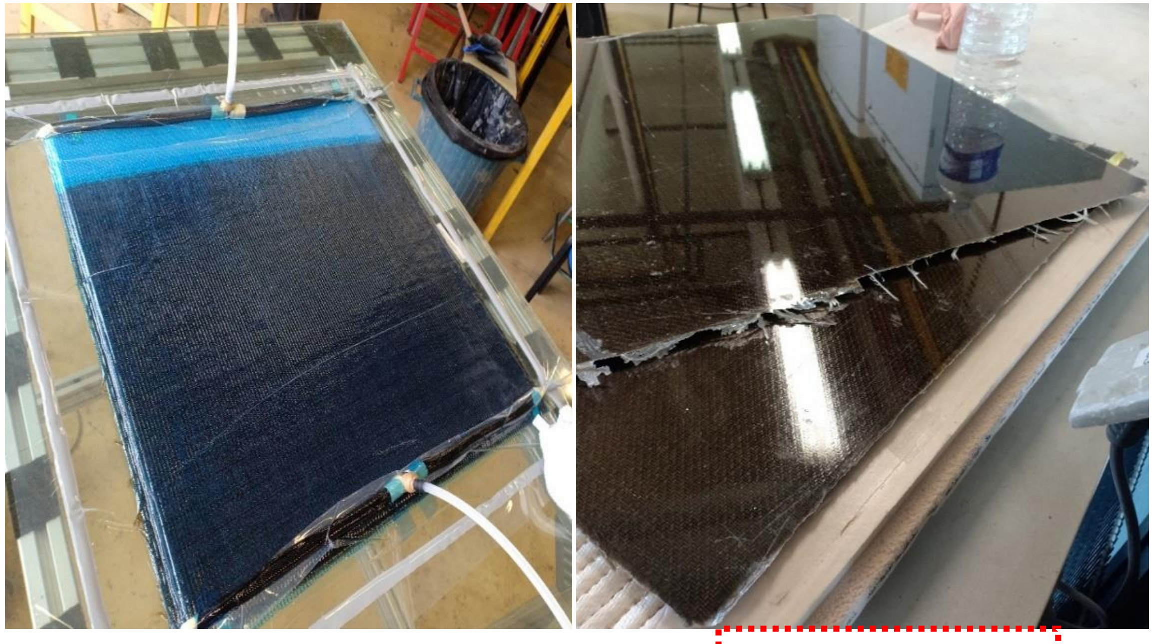
3.2. Fabrication of Green biocomposite & Fire-retardant coating



Flax V_f: 35%
Infugreen V_f:65%

➢ A 38% bio-epoxy was infused in the flax fibres at a vacuum pressure of almost -0.9 bar at room temperature

➢The infused plates were cured for 24 hours at room temperature and post cured in an oven for 16 hours at 60 °C.

➢Fire Retardants coating: Ammonium polyphosphate-THEIC and boric acid were mixed in the resin for 20 minutes at room temperature and pressure by using a mechanical mixture. The hardener (SD 8822) was added for curing purpose and the formulation was mixed for another 15 minutes. The IFR coating was brushed on the specimens having dimension of 2×2×6.5mm The uniformly applied coating was measured to have a thickness of 0.5 ± 0.1mm on each face of the specimen. The prepared specimen were grounded to powdered form to perform TGA.

Formulation	APP-THEIC	BA	Resin	Hardner
E/20APP-TH/10BA	20	10	54	16
E/29APP-TH/1BA	29	1	54	16

3.3. Thermal and Morphological analysis

- Approximately, 8-10 mg of sample was placed in platinum crucibles in a TA instrument SDT Q600 under synthetic air at atmospheric pressure.
- All the experiments were carried out with an airflow rate of 100 ml/min.
- A non-isothermal heating rate of 10°C/min was fixed for a temperature range of 20-1100°C, followed by an isothermal phase of 5 min at the final temperature before the cooling step.

- The SEM analyses were carried out with JEOL JSM 7900 F microscope.
- Sample preparation: the powder is fixed with double-sided carbon tape

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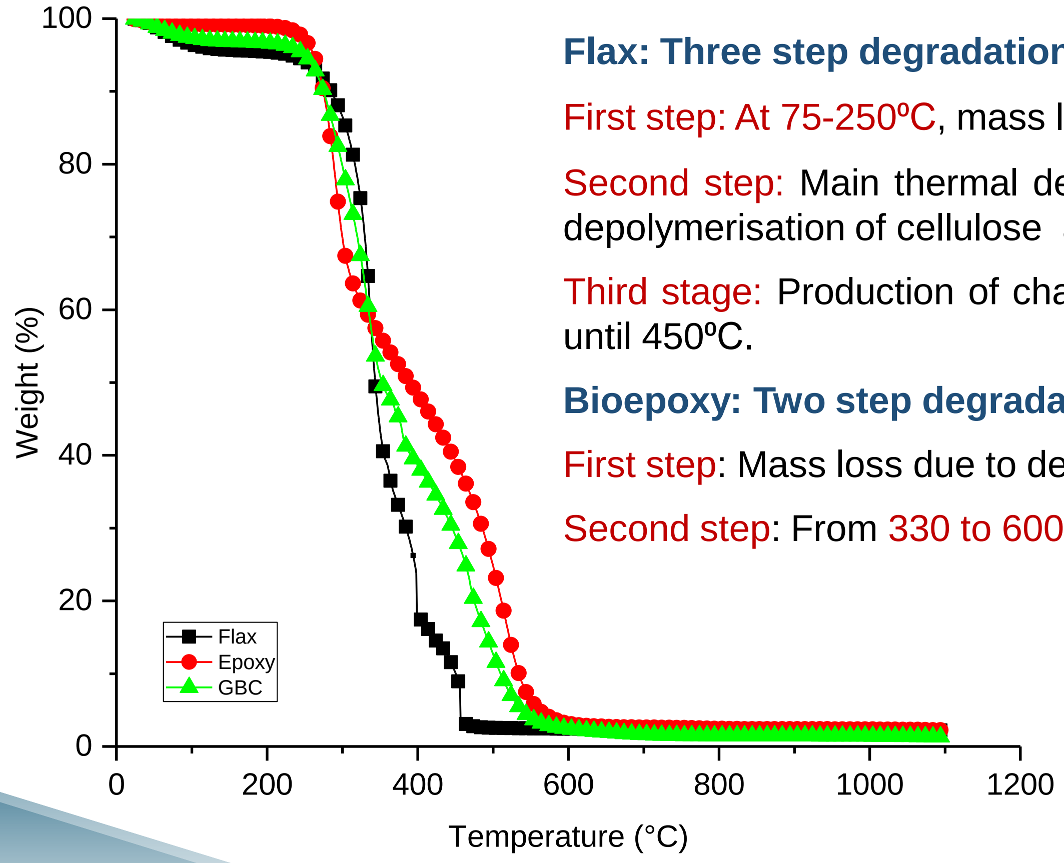
4.1. Thermal degradation profile of the green biocomposite



Flax: Three step degradation process

First step: At 75-250ºC, mass loss due to physical damages e.g. evaporation of water.

Second step: Main thermal degradation between 250-365ºC due to breakage of glyosidic linkages leading to depolymerisation of cellulose and hemicellulose.

Third stage: Production of char above 365ºC, and the process continues by dewatering and charring reaction until 450ºC.

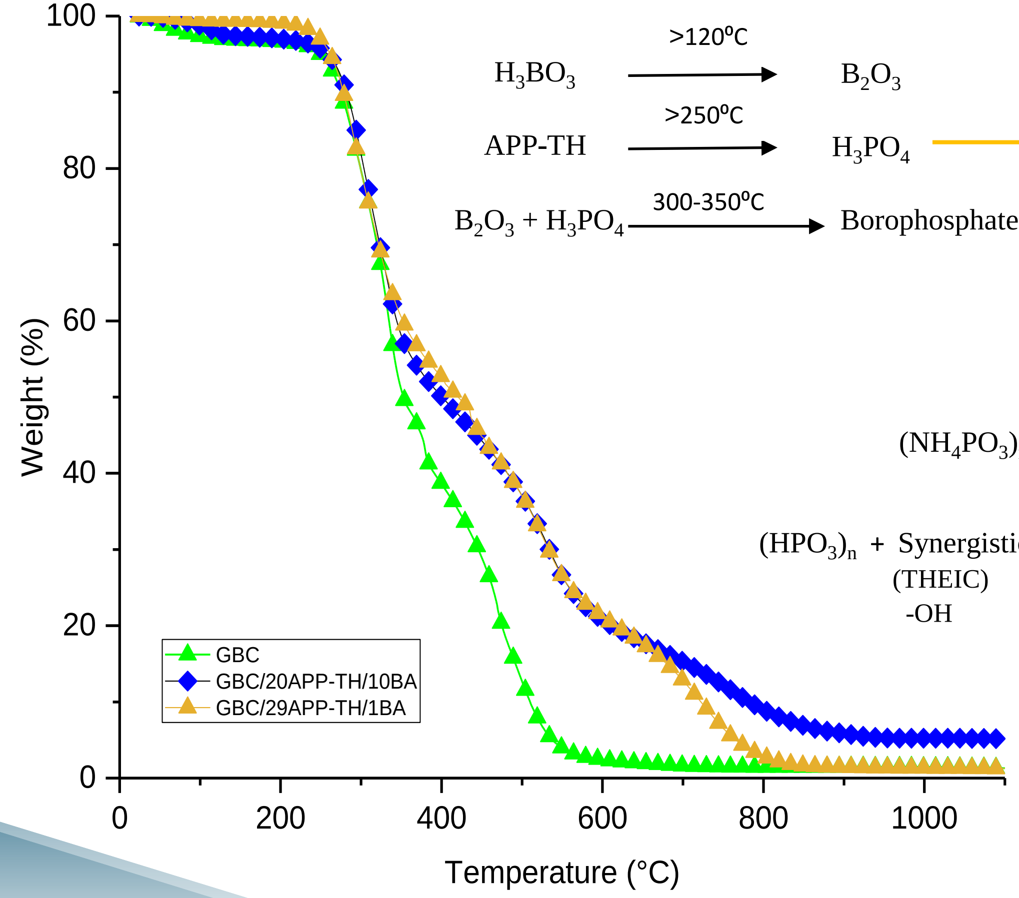
Bioepoxy: Two step degradation process

First step: Mass loss due to dehydration between 225-330ºC.

Second step: From 330 to 600ºC due to release of phenols and cresols

TG curve of green biocomposite (GBC) shows a reduced mass loss rate between 250-350ºC, possibly due to the depolymerisation of the polysaccharides occurring in flax fibre. Once the depolymerisation reaction has completed, the GBC starts to degrade at a faster rate.

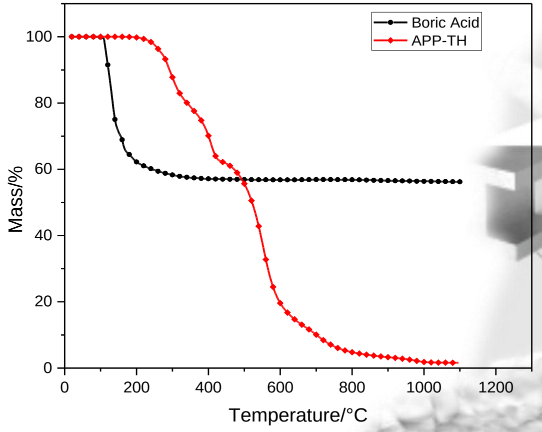
4.2. Thermal degradation profiles of uncoated and fire retardant coated green biocomposite



$$H_3BO_3 \xrightarrow{>120^oC} B_2O_3$$

$$\text{APP-TH} \xrightarrow{>250^oC} H_3PO_4$$

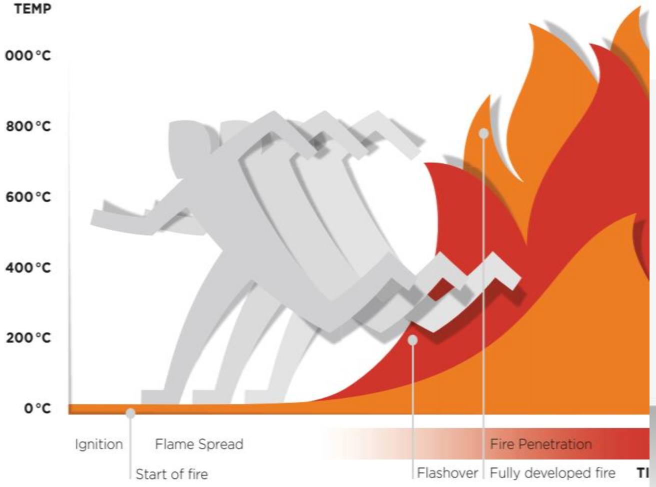
$$B_2O_3 + H_3PO_4 \xrightarrow{300\text{-}350^oC} \text{Borophosphates} + B_2O_3 + \text{Char}$$

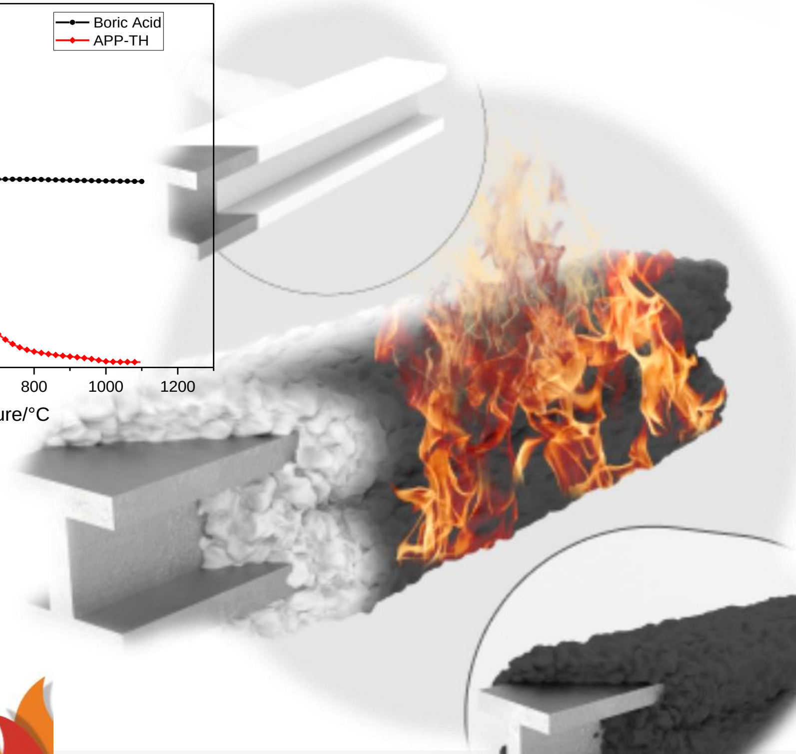


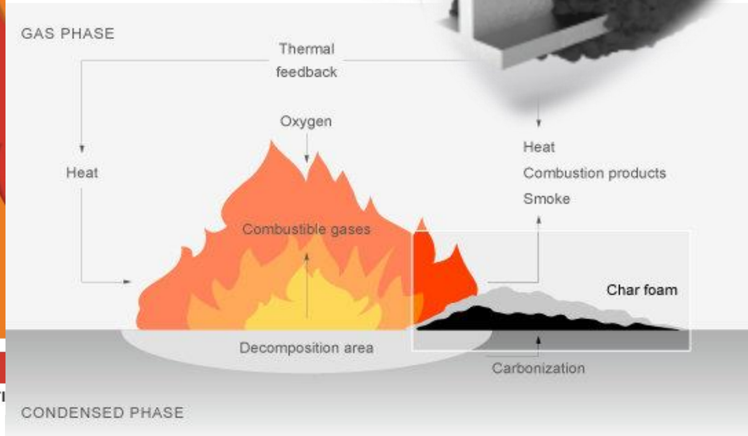
$$(NH_4PO_3)_n \xrightarrow{>250^oC} (HPO_3)_n + n\,NH_3$$

Polyphosphoric acid

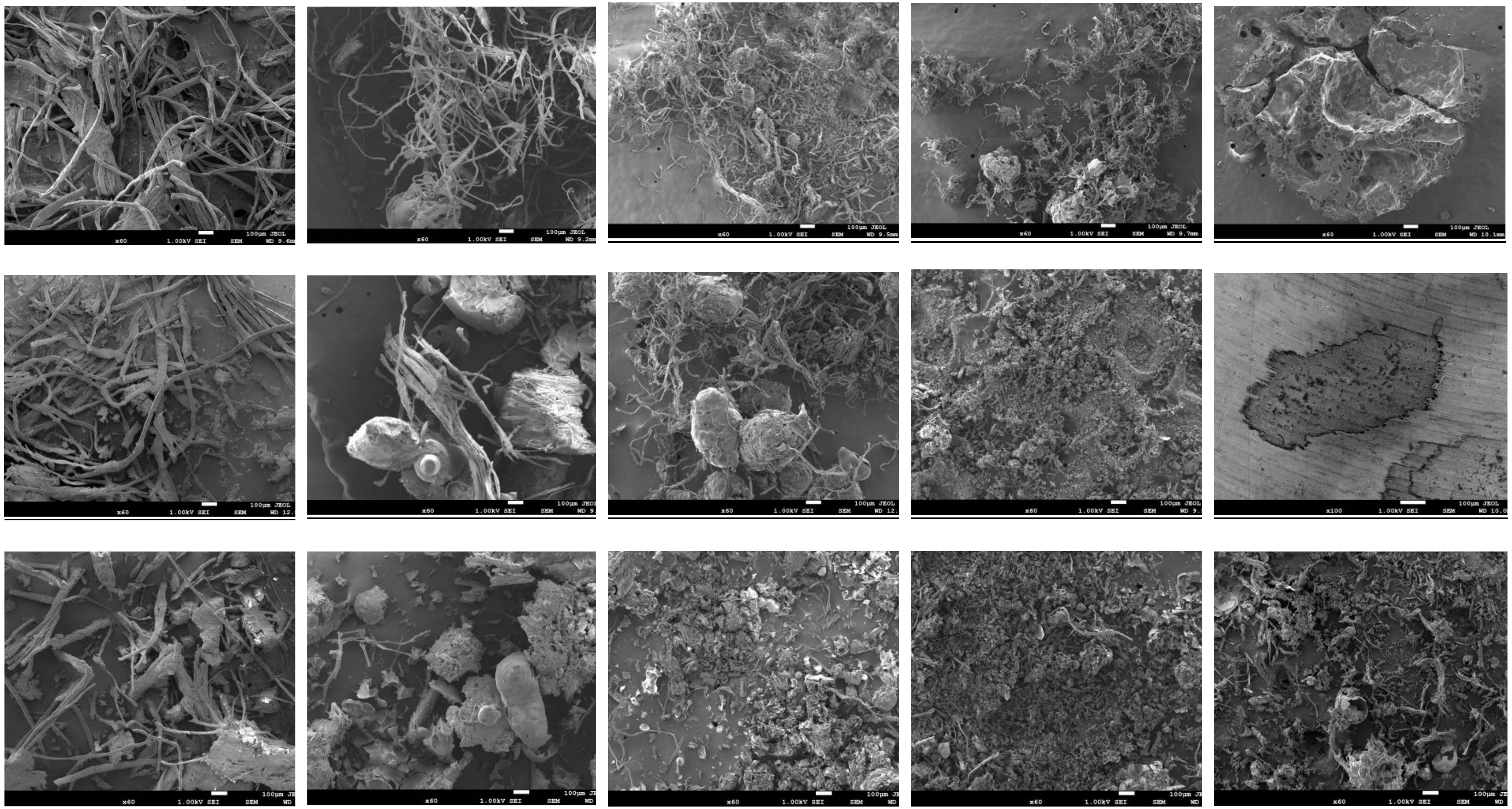
$$(HPO_3)_n + \text{Synergistic (THEIC) -OH} \xrightarrow[\text{Dehydration}]{-H_2O} H_3PO_4 + \text{Char}$$







4.4. Morphological analysis

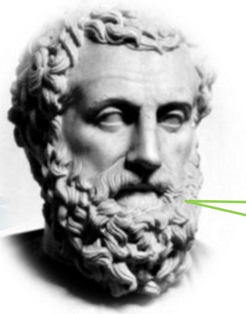


W(%)	Mean at 350ºC	Mean at 550ºC	Mean at 750ºC	Mean at 900ºC
GBC	48.61±1.05	96.57±0.64	98.75±0.26	98.77±0.24
GBC/29APP/1BA	40.81±0.77	73.76±0.45	94.06±0.45	99.09±0.79
GBC/20APP/10BA	42.41±0.47	73.14±1.31	87.62±0.52	94.38±0.28

Synopsis

5.1. Conclusion

- TG curves shows that **the green biocomposite (GBC) fully degrades around 600ºC** with a residual mass of 1.7%.
- **To improve the thermal** degradation of the GBC an **intumescent formulation comprising boric acid and ammonium polyphosphate-THEIC** is coated on the GBC.
- The specimens coated with **GBC/20APP-TH/10BA and GBC/29APP-TH/1BA** follows almost the **same mass loss pattern until 650ºC**, after which **GBC/20APP-TH/10BA shows reduced rate** of decomposition until 800ºC with higher residual mass **as compared to GBC/29APP-TH/1BA**.
- From the mass loss curves, **apparently** it seems that **GBC/20APP-TH/10BA exhibit better performance** against flammability; **however SEM shows** that GBC/29APP-TH/1BA provides more stable fire protective coating.



Aristotle
(384 – 322 B.C.E)

"If one way be better than another, that you may be sure is Nature's way"

5.2. Perspective

- **At present** green biocomposites **lack** to meet the **fire safety** standards for industrial applications; such as transport sector and construction industry due to the **low thermal resistance of natural fibre and biobased epoxies**. Therefore, In order **to realise the full potential** of green biocomposites (GBCs) in general and also as part of the **European green deal 2050 in line with EUs commitments** (Paris Agreement signed in 2019) and resolutions signed in **COP26** regarding New Materials for the Green Industrial Revolution, **further work is required to comply with the stringent fire safety regulations** for industrial applications, such as federal motor vehicle safety standard No. 302 (FMVSS302) and federal aviation regulation (CFAR) 25.853.

Thankyou for your attention

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