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Evaluation of New Bio-Based Hybrid Composite Materials Reinforced with Basalt Fiber and Recycled Carbon Fiber

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INTRODUCTION & AIM

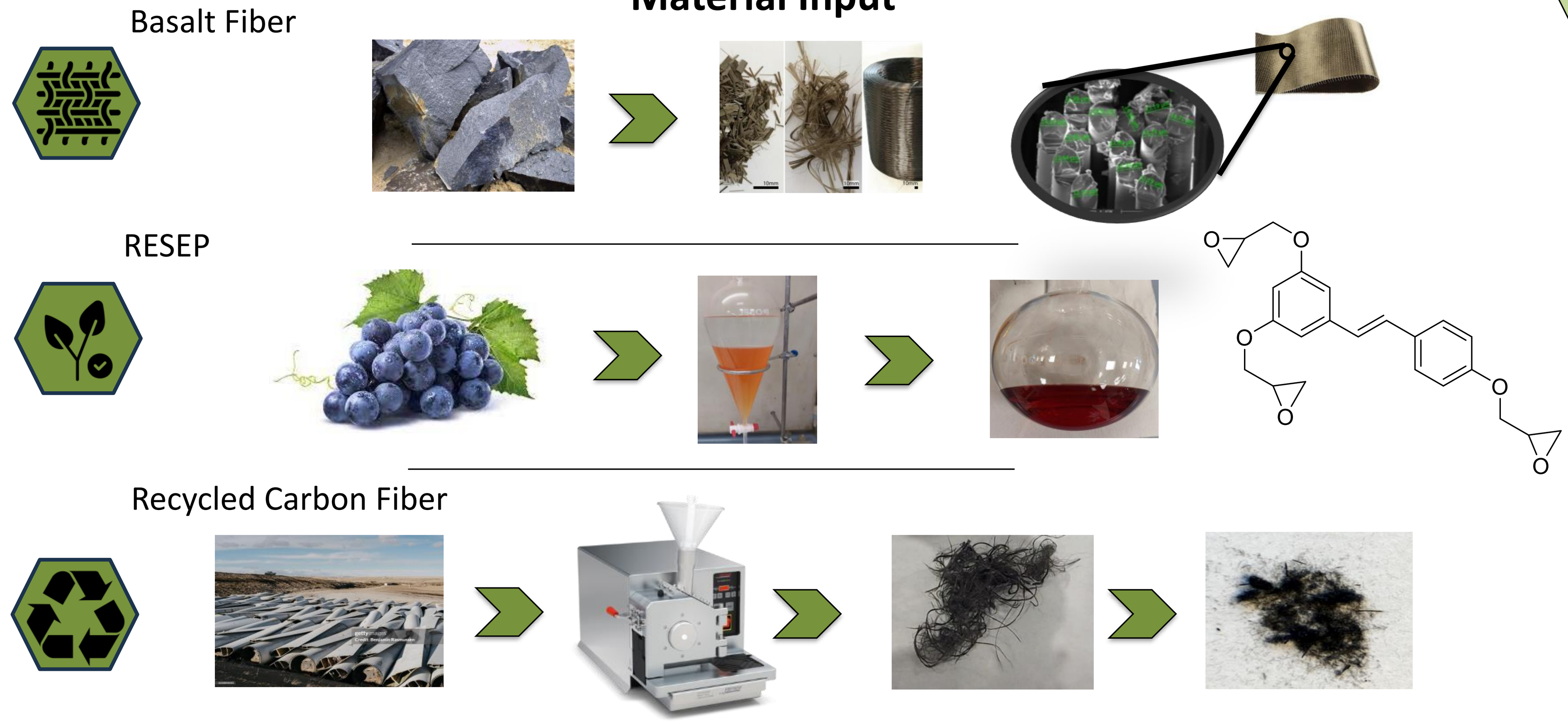
Developing green materials is essential for advancing more sustainable engineering solutions. Among these materials, biopolymers and their composites are promising alternatives to petroleum-based polymers due to their lower toxicity and potential cost efficiency, particularly when derived from waste resources.

In this work, we investigate the feasibility of using a bio-based resin, epoxidized resveratrol (RESEP), reinforced with continuous basalt fibers to create a sustainable composite suitable for non-structural components, that can be used in the transportation or energy industry, among others.

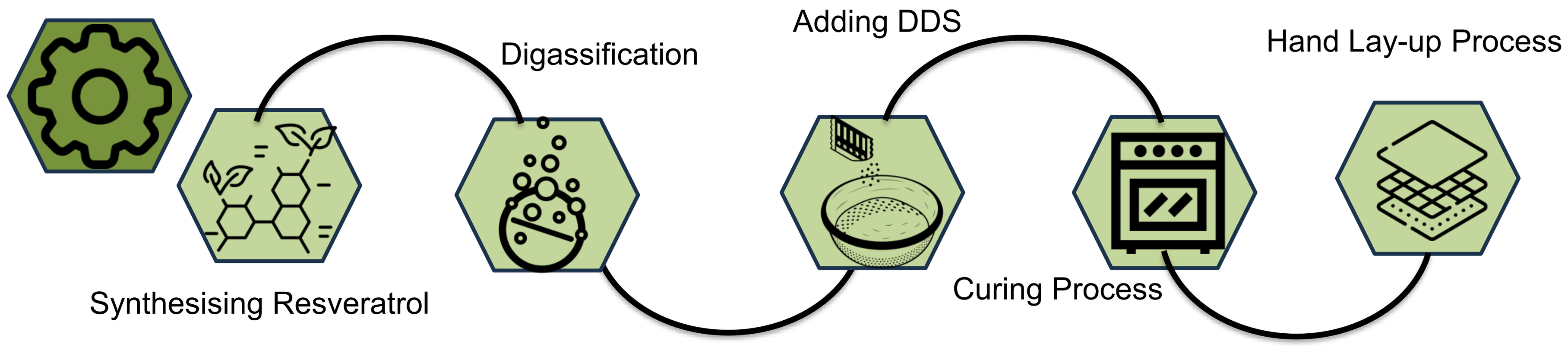
A baseline composite consisting solely of RESEP and basalt fibers is compared with a DOPO-modified version for improved flame resistance, as well as with a variant containing mechanically recycled carbon fibers to create electrically conductive, smart composites.

METHOD

Material Input

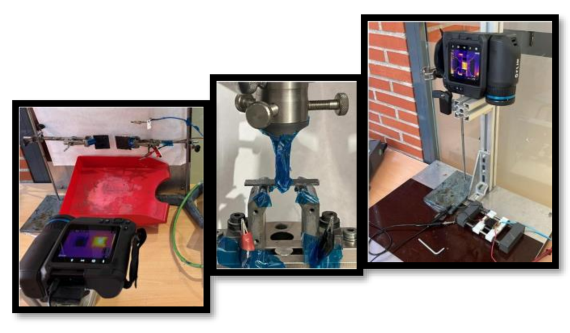


Manufacturing Process



Characterization

- DMTA
- SEM
- Joule Heating
- De-icing Test
- Electrical conductivity
- Structural Health Monitoring (SHM) in 3PB and ILSS



RESULTS & DISCUSSION

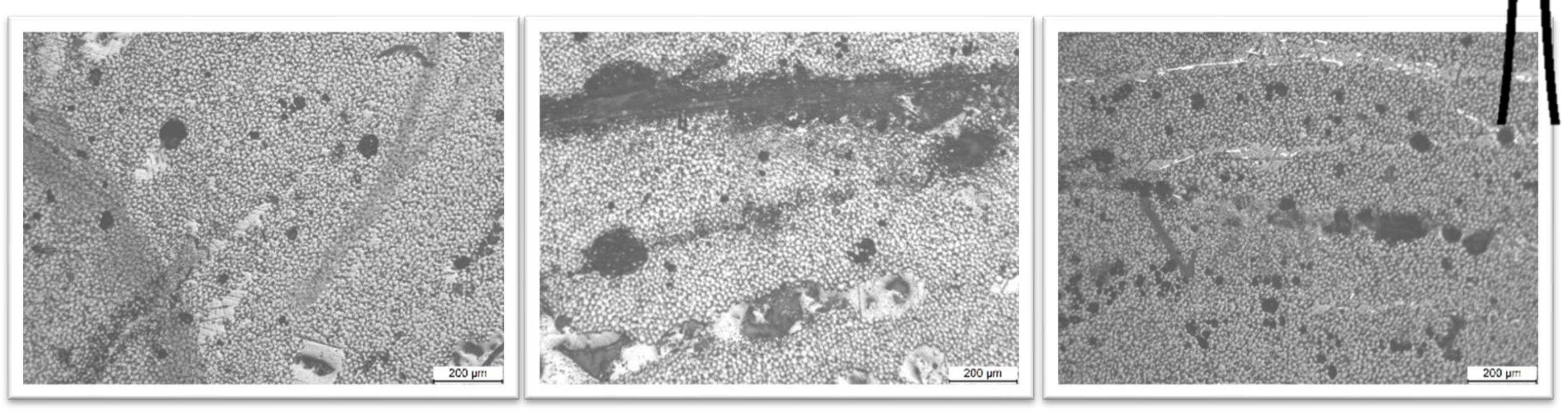
Electrical Conductivity and DMTA Analysis

Electrical Conductivity = $1.42 \cdot 10^2$ S/m → structural health monitoring or resistive heating through the Joule effect

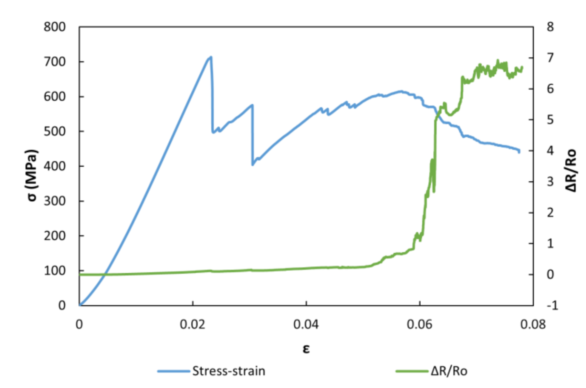
Sample	RESEP - BF	RESEP - BF – 5% DOPO	RESEP - BF - 7.5% RCF
Tg	299.16 ± 6.03 ˚C	299.31 ± 0.42 ˚C	300.57 ± 3.133 ˚C

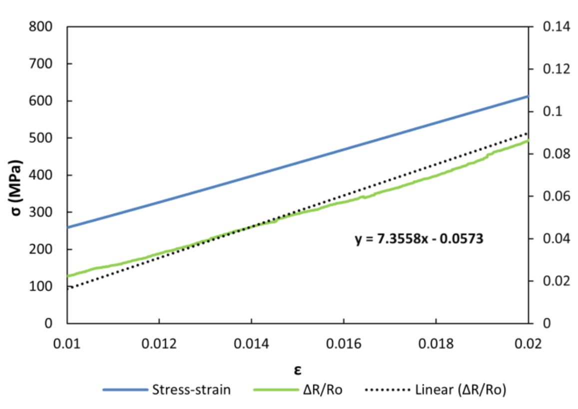
Mechanical and electromechanical properties

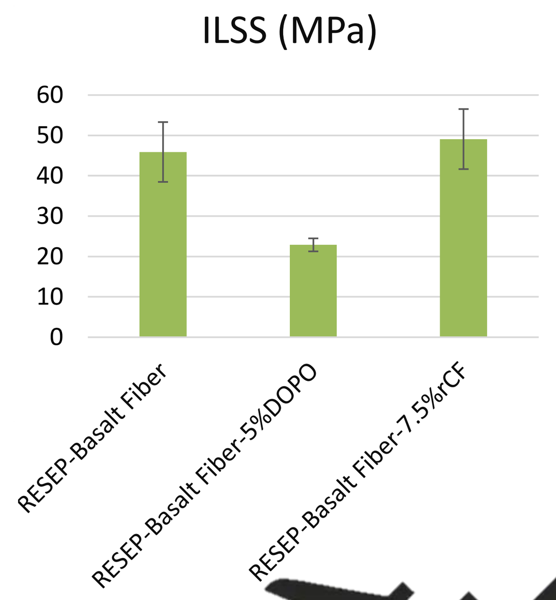
Samples	E_f (GPa)	σ_b (MPa)	ε_b
RESEP + Basalt Fiber	29.81 ± 4.06	926.23 ± 221.81	0.022 ± 0.004
RESEP + Basalt Fiber + 5% DOPO	30.90 ± 3.35	648.00 ± 62.64	0.015 ± 0.001
RESEP + Basalt Fiber + 7.5% RCF	34.00 ± 2.82	870.73 ± 143.50	0.023 ± 0.014



RESEP-BF RESEP-BF-DOPO RESEP-BF-RCF



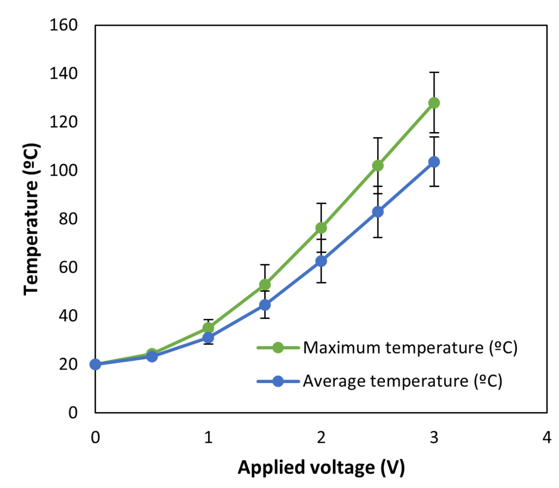




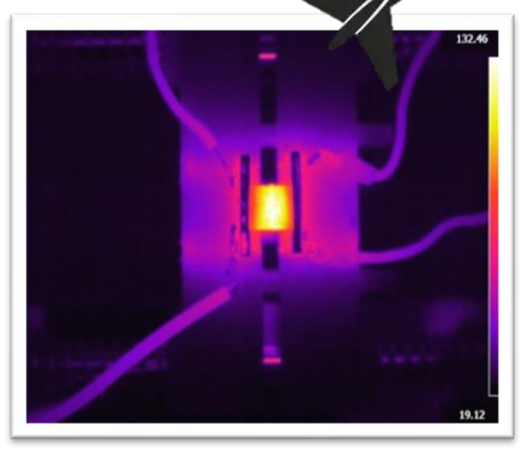
Gauge Factor =7.36

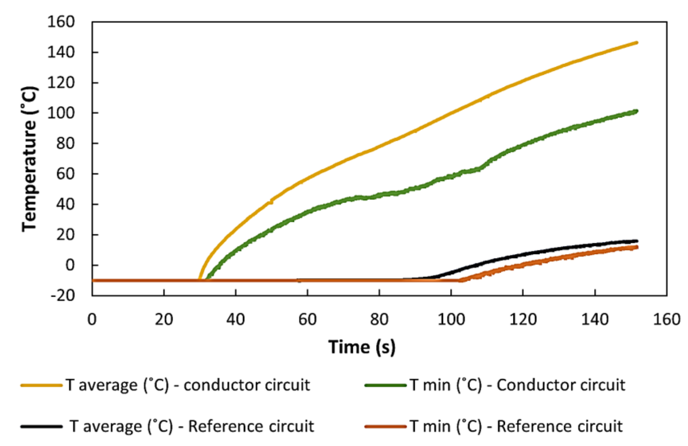
Conventional metallic strain gauges have a gauge factor of around 2

Joule Heating and De-icing tests

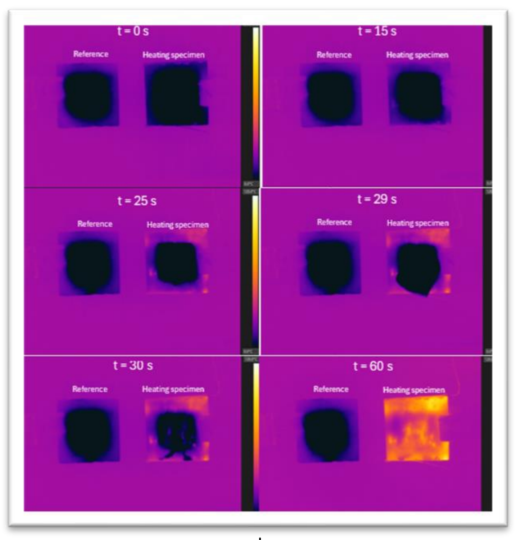


Applying a low voltage of 3 V: maximum temperature of 128 °C, and average temperature of 103.67 °C





At 29 s, the 2.5 mm ice layer begins to slide with a voltage of 8 V



CONCLUSION

- ✓ High glass transition temperature (around 300 °C) sustainable composites were succesfully developed in this work using a bio-based matrix (epoxidized resveratrol), and continuous basalt fibers.
- ✓ The addition of 5% DOPO does not significantly affect stiffness, but reduces flexural strength by 30%, that is due to the increased viscosity, which hinders the impregnation of the fibers during the manufacturing process, leading to a higher void content. 7.5% RCF improves the elastic modulus by 14% and causes only a 6% drop in strength, but this could be improved by optimizing recycling.
- ✓ The quality of the interface between the matrix and the basalt fiber is negatively affected by the addition of 5% DOPO: it reduces the ILSS by 50%, again related to the higher void content, especially located between fiber plies. In contrast, the laminate with 7.5% RCF increases the ILSS by 7% since the RCF reinforcement prevents slippage between layers.
- ✓ The high electrical conductivity reached ($1.42 \cdot 10^2$ S/m) allowed effective and homogeneous Joule heating (over 100 °C on average by aplying just 3 V).
- ✓ The material containing RCF exhibits additional multifunctional properties, serving both as a SHM sensor (gauge factor = 7.36, superior to metallic gauges) and as an efficient de-icing device (2.5 mm ice layer detached at 29 s under 8 V).

FUTURE WORK

- ✓ Manufacturing fully composite with bio-based hardener.

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