PLASMA TREATMENT OF BIO-BASED AND RECYCLED FIBRES TO IMPROVE THEIR ADHESION WITH MATRIX IN ECO-COMPOSITES

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1. INTRODUCTION

- **Composites** are important materials used in aircrafts:
  - Excellent mechanical properties;
  - Relatively low weight.

- Composites are normally reinforced with **carbon fibre** or **glass fibre**:
  - Man-made and energy-intensive in production.

- **Bio-fibres** and **recycled fibres** have been studied for the development of ecological improved composites:
  - The adhesion between fibers and matrix is lower.

- **Plasma treatments** can modify the fiber surface, promoting:
  - Enhanced adhesion between fibers and matrix;
  - Improved mechanical properties.

2. BIOBASED AND RECYCLED FIBRES

Flax Fibres (FF)

- ❑ High tensile strength
- ❑ Good specific stiffness, comparable to glass-fibres
- ❑ Acoustic and thermal damping
- ❑ High variability on the fibre cross-section

The low interfacial adhesion with the resin leads to low mechanical performance.

Loose FF

FF nonwoven (200 g/m^2)

Recycled Carbon Fibres (rCF)

- ❑ Highest specific modulus and strength
- ❑ High temperature resistance, chemical inertness and high damping
- ❑ Uniform cross-section (7 µm)

The production process is complex and energy intensive. Recycled fibres become more and more available, but during the pyrolysis route the sizing is lost.

Loose rCF

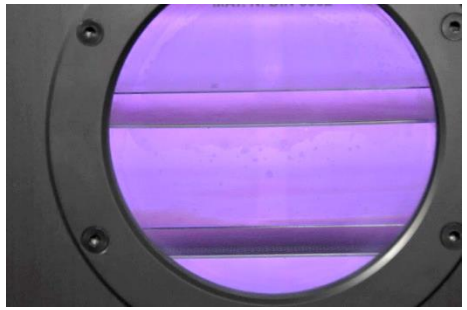
rCF nonwoven (200 g/m^2)

3. PLASMA TECHNOLOGY

Plasma is a partially ionized gas composed of electrons, ions, photons, atoms and molecules, with negative global electric charge

Atmospheric pressure plasma

Low pressure plasma

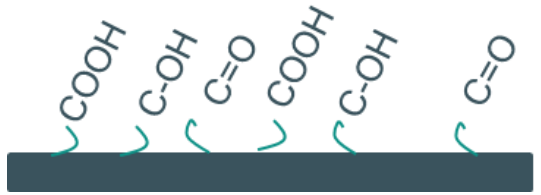


Advantages of plasma technology:

- ❑ Neither water consumption nor wastewater effluents;
- ❑ No chemical consumption;
- ❑ Drying and curing processes are not necessary;
- ❑ Well-controlled and reproducible technique.

Adhesion mechanisms:

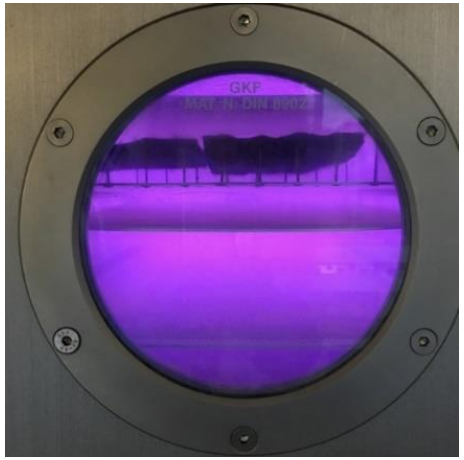
- ❑ Removal of surface contaminants
  - Enhanced fibre-resin contact
- ❑ Increased fibre surface roughness
  - Higher surface area
- ❑ Increased surface energy
  - Promote wetting of fibres by resin
- ❑ Deposition of functional groups onto the fibre surface:
  - Promote covalent bonding between fibre and bio-resin



4. PLASMA TECHNOLOGY AND COMPOSITE MANUFACTURING

Plasma treatment

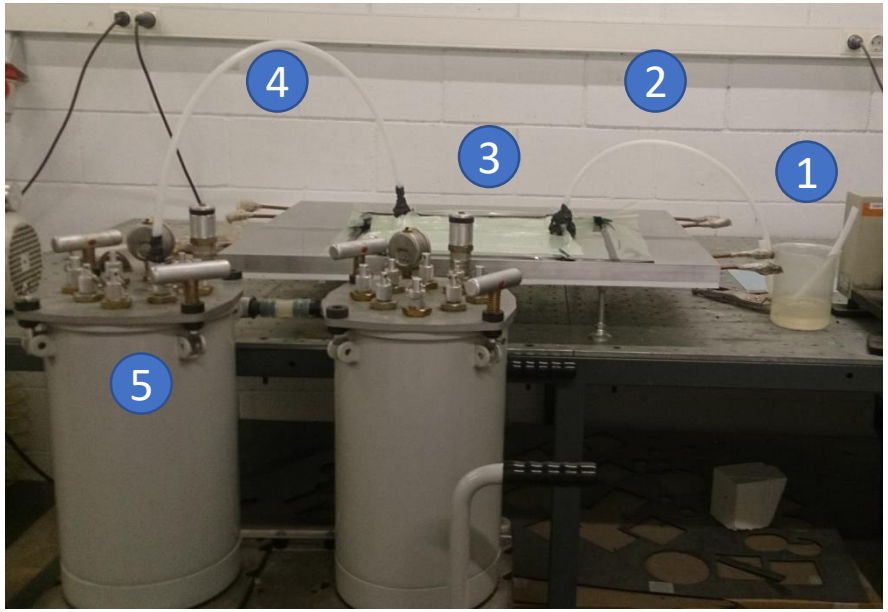
TETRA 30 PC LF (Diener Electronic, GmbH)



- Maximum sample size: 250 x 300 mm
- Gas: Air and Oxygen (10 – 20 cm^3/min)
- Working pressure: 0.25 mbar
- Working power: 300 – 900 W
- Exposure time: 5 – 10 min

Composite manufacturing

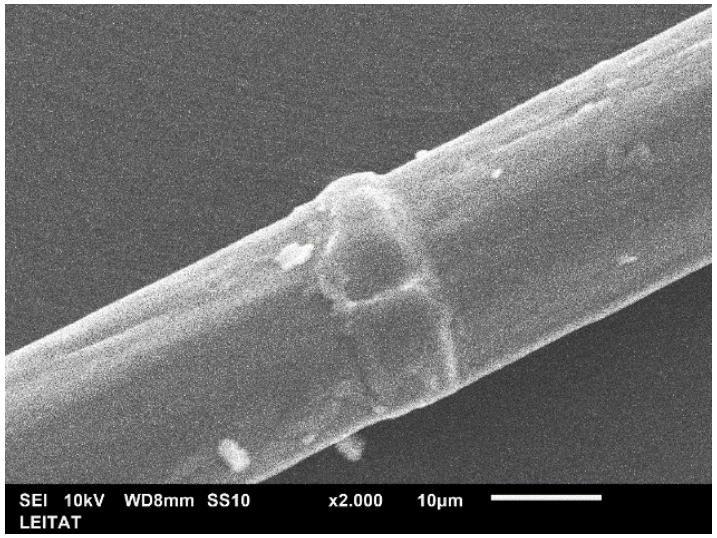
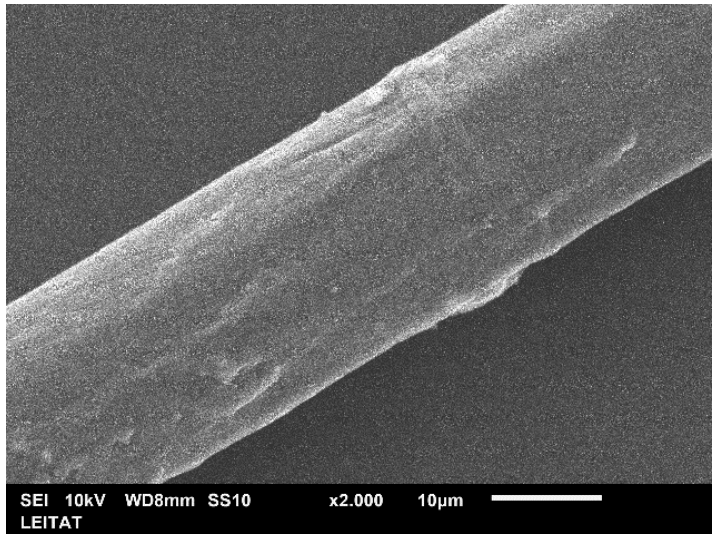
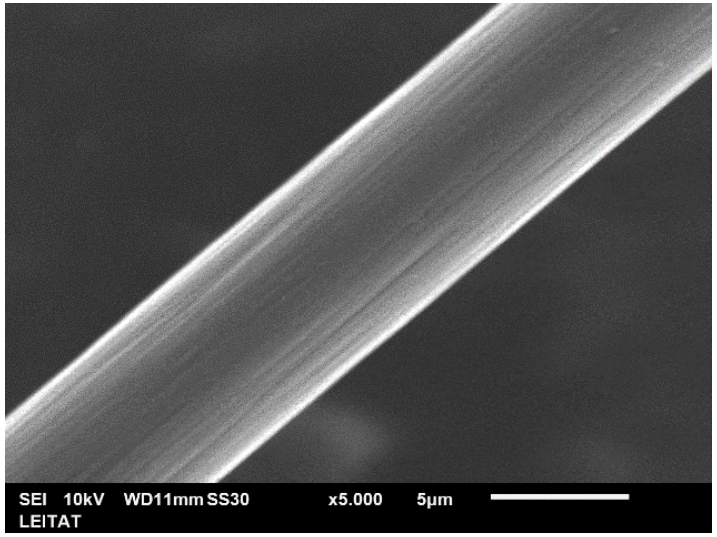
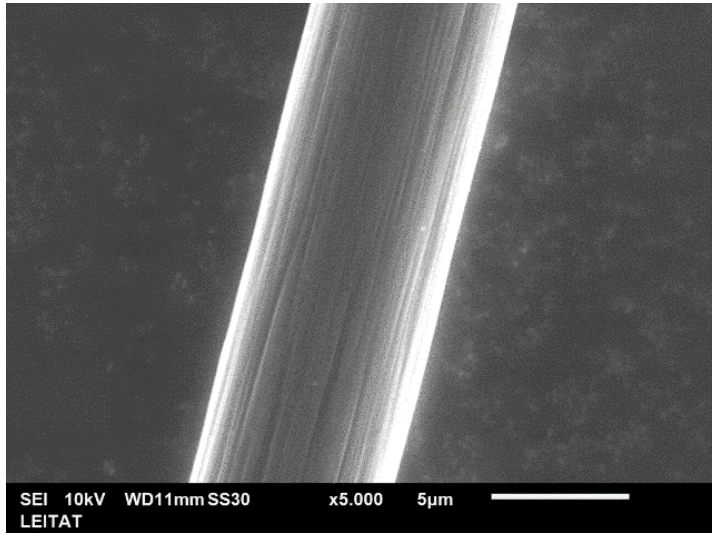
Scheme of the vacuum bagging method



1. *Epoxy resin preparation*
2. *Resin entrance pipeline*
3. *Bag with the nonwovens*
4. *Vacuum pipeline*
5. *Vacuum pump*

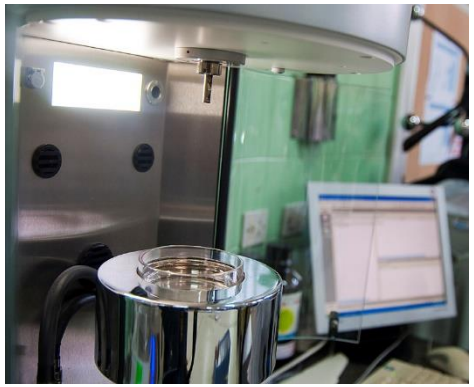
- Vacuum bag technique
- Bio-based epoxy resin
- Number of layers: 6 – 8
- Composite thickness: 3 – 4 mm

Scanning Electron Microscopy (SEM)

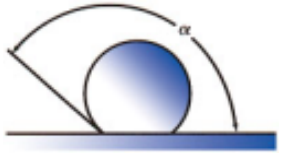
	Untreated	*Plasma treated*
Flax fibres		
Recycled carbon fibres (without sizing)		

Contact angle (untreated fibres)

Krüss K100 MK2 tensiometer



Good wetting



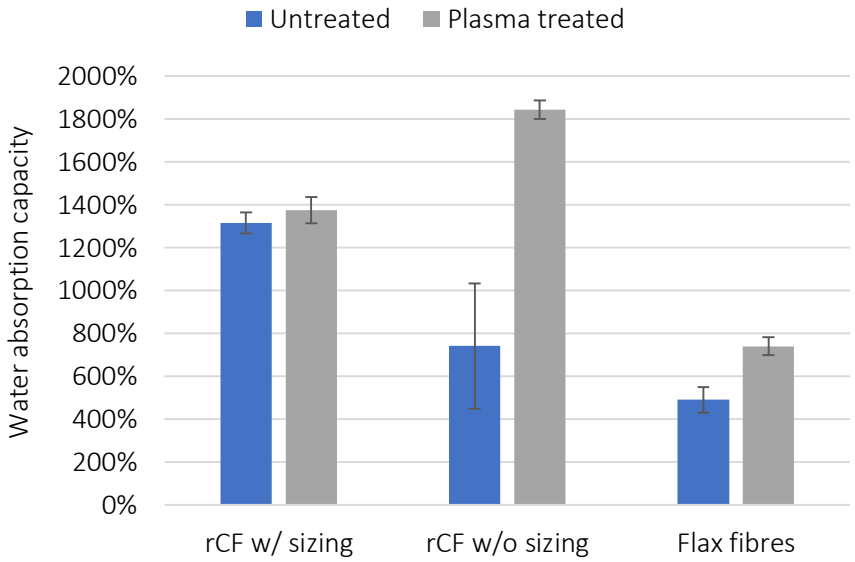
Bad wetting

	Contact angle (º)	
Samples	Water	Epoxy resin
rCF w/ sizing	59,9º	71,6º
rCF w/o sizing	79,1º	82,3º
FF	64º	64,1º

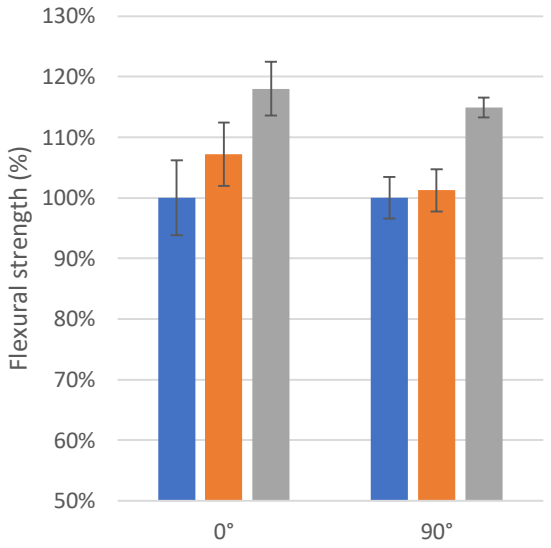
Water absorption capacity (nonwovens)

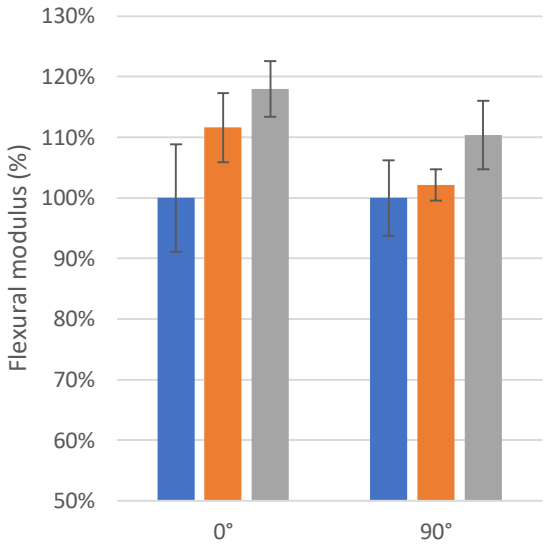
UNE EN ISO 9073-6
1 minute submerged in water
2 minutes of draining

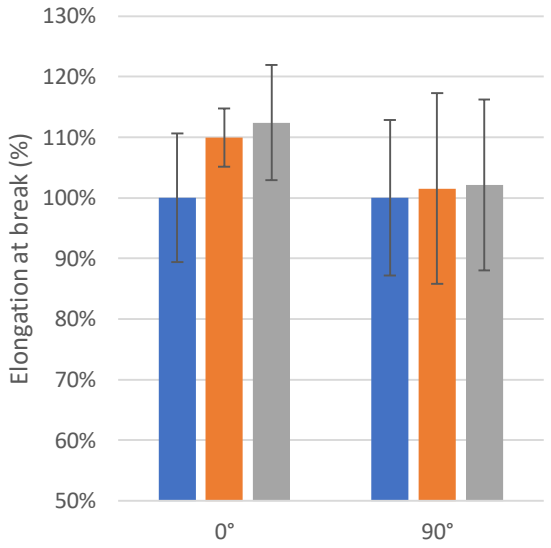
$$WAC(\%) = \frac{(Wet\ weight - Dry\ weight)}{Dry\ weight} \cdot 100$$

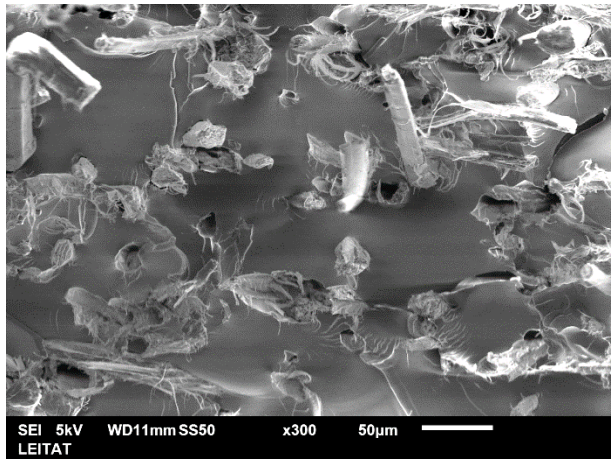


3-point bending test (UNE EN ISO 14125) – Flax fibres







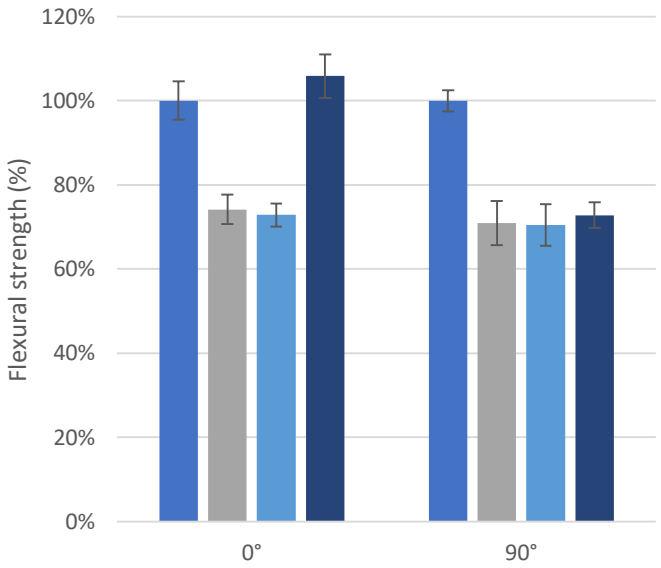


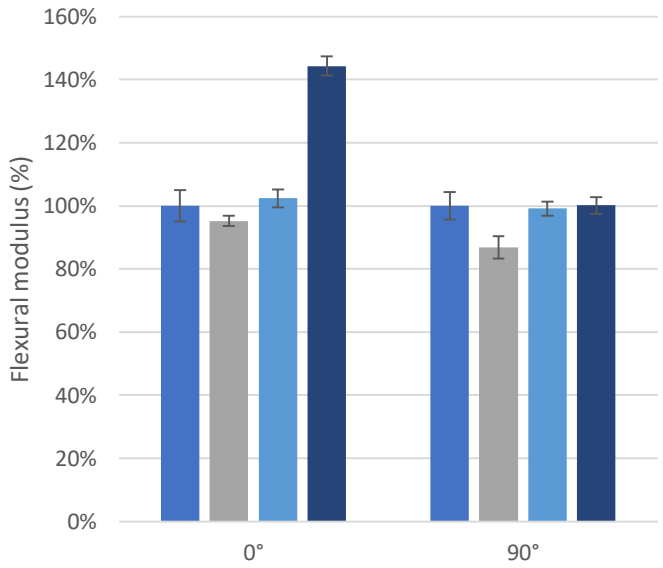
Fracture Surface of FF-reinforced composite

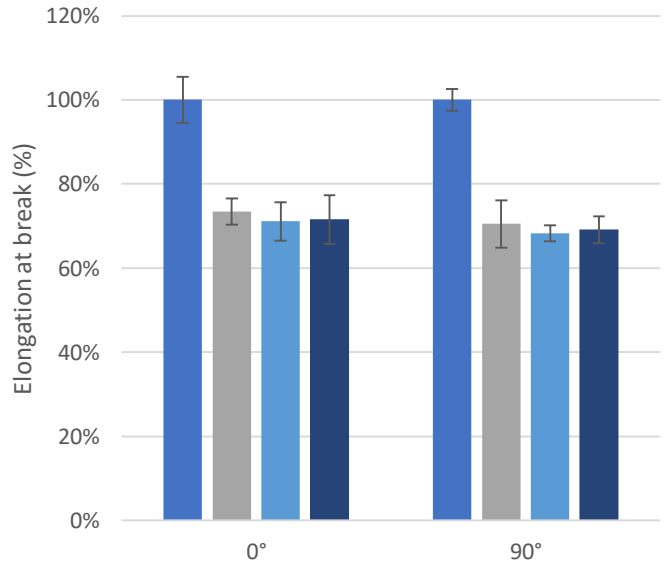
- Flax fibres
- Flax fibres + plasma 300W
- Flax fibres + plasma 600W

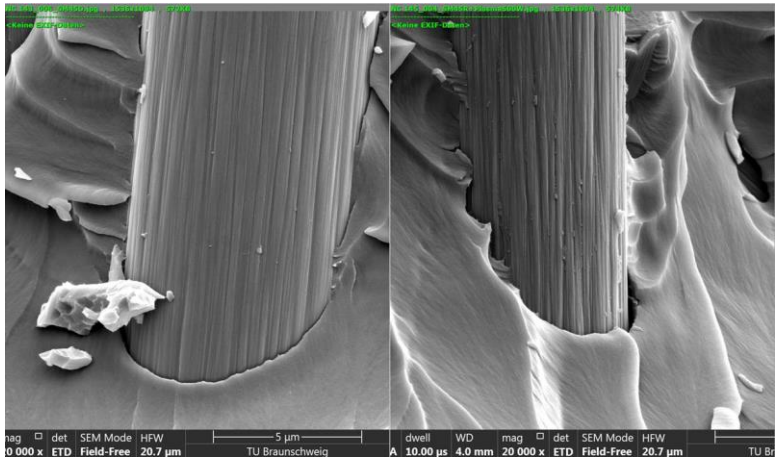
5. RESULTS

3-point bending test (UNE EN ISO 14125) – rCF

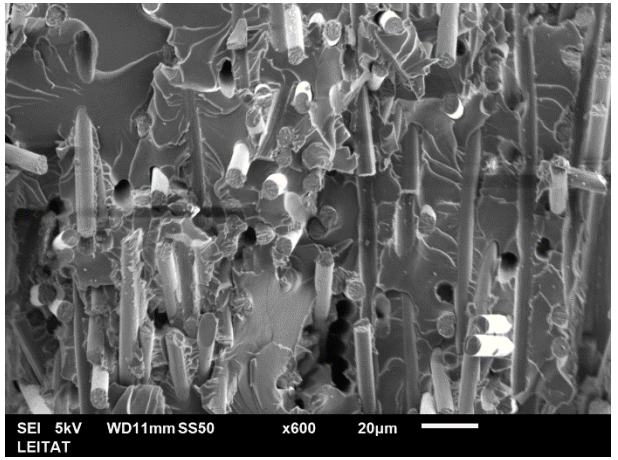








Untreated *Plasma treated*



Fracture surface of rCF-reinforced composite

- rCF with sizing
- rCF without sizing
- rCF without sizing + plasma 300W
- rCF without sizing + plasma 600W

6. CONCLUSIONS

- New eco-composites have been developed by combining bio-fibres and recycled fibres with bio-based resins;
- The effect of plasma treatment between fibre and matrix has been studied:

Recycled Carbon Fibres

- The original sizing improves the compatibility with the epoxy resin;
- The fibre without sizing was meant to improve its mechanical performance by being plasma-treated;
- Plasma treatments have increased significantly the water absorption capacity;
- Plasma treatments have improved the flexural properties of rCF-reinforced composites;
- The conductive nature of CF makes it necessary to avoid any contact point between fibres and electrodes.

Flax Fibres

- The untreated flax fibres already presented good compatibility with the resin;
- Plasma treatments have increased the water absorption capacity;
- Plasma treatments have improved the flexural properties of FF-reinforced composites;
- The moisture content of the fibres negatively affects the effectiveness of plasma treatments, and therefore is necessary to dry the fibres before the treatment.

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Thank you for your attention

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