PLASMA TREATMENT OF BIO-BASED AND RECYCLED FIBRES TO IMPROVE FIBRE-MATRIX INTERFACIAL ADHESION IN COMPOSITES

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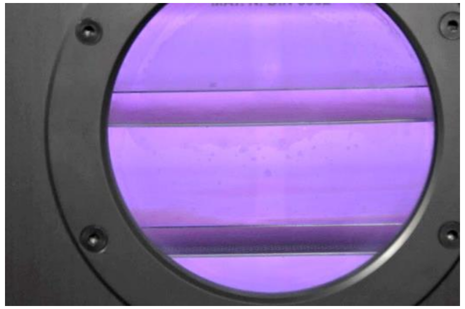
Introduction

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

SOLID → LIQUID → GAS → PLASMA

Atmospheric pressure plasma

Low pressure plasma



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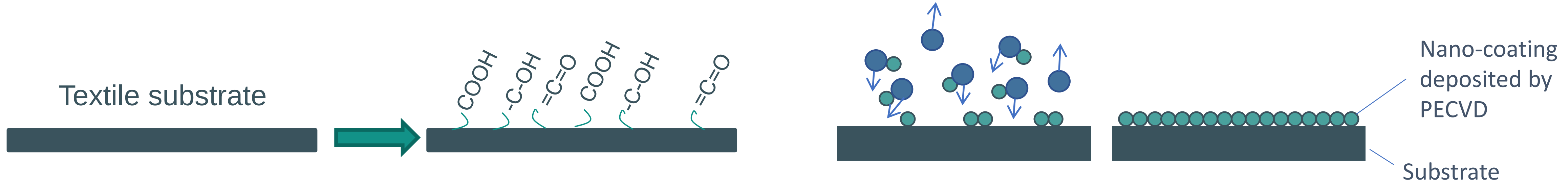
Introduction

Plasma technology is used for **surface functionalization** of different materials. The reactive species interact with the first nanometers of the material surface, without affecting the bulk properties.

Functionalization by Plasma Treatment

- He, Ar, Air, O_2
  Non-polymerizable gases
- Polymerizable monomer/precursors



PECVD: Plasma-Enhanced Chemical Vapour Deposition

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Introduction

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 resin
- Deposition of functional nano-coatings as sizing

Advantages of plasma technology

No water consumption

No wastewater effluents

Well-controlled and reproducible technique

Very low or null chemicals consumption

No drying and curing processes

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Leitat expertise in plasma technology

ECO-COMPASS: Plasma treatments applied to eco-composites

H2020-MG, 2016-2019.

REPAIR3D: Plasma onto chopped and continuous rCF for smart recycling in AM applications

H2020-NMBP, 2019-2022.

BIOCON-CO2: Plasma treatments for promoting adhesion and growth of catalytic biofilms, *H2020-Biotech, 2018-2021.*

GREEN-INSTRUCT: Surface modification of recycled fibers for composites,

H2020-EeB, 2016-2019.

ELSAH: Plasma treatments for improving adhesion and homogeneity of printed inks

H2020-ICT, 2019-2022.

PRESTIGE: Plasma treatments for printed functional materials into consumer goods

H2020-NMBP, 2017-2019.

APOLO: Plasma treatments for smart and printed Perovskite Solar Cells

H2020-LCE, 2018-2020.

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ECO-COMPASS project

The main objective of ECO-COMPASS is to develop and assess multifunctional and ecologically improved composites from bio-sourced and recycled materials for application in aircraft secondary structures and interior.

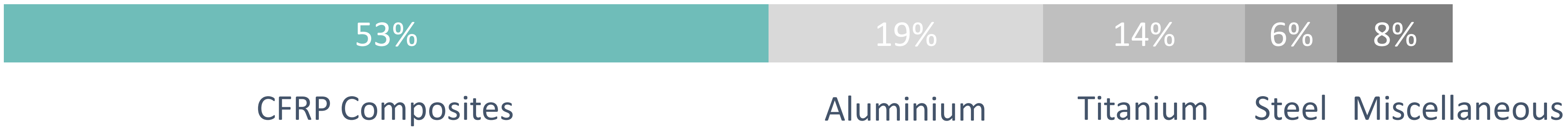
Composites used in aviation today are mainly:

- **Carbon-fibre** Reinforced Plastics (CFRP) for fuselage, wings, etc.
- **Glass-fibre** Reinforced Plastics (GFRP) for interior.

} Man-made

Energy-intensive in production

Materials used in an airframe of a modern aircraft, the Airbus A350:



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LEiTaT managing technologies

CUSTOMISIZE

ECO-COMPASS project

The consortium

Clean Sky 2

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ECO-COMPASS project

Recycled and **bio-fibres** have been studied for the development of ecological improved composites. However, the adhesion between fibres and matrix is lower.

CARBON FIBRES

- Highest specific modulus and strength;
- High temperature resistance, chemical inertness and high damping.

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

FLAX FIBRES

- High tensile strength;
- Good specific stiffness, comparable to glass-fibres;
- Acoustic and thermal damping.

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

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ECO-COMPASS project

The process

1

Loose fibres

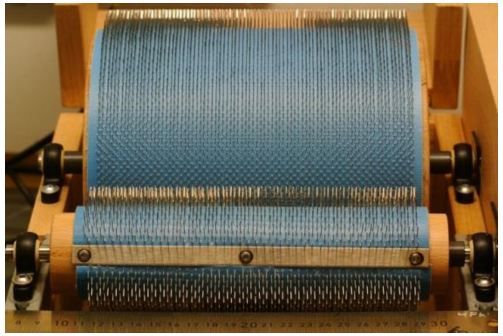
vCF with sizing

rCF without sizing

Flax fibres

2

Nonwoven manufacturing



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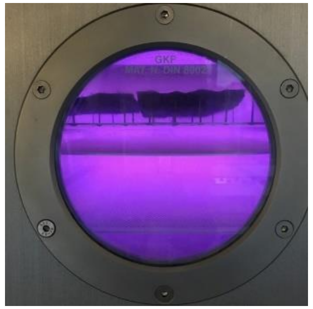
Plasma treatment



- Low pressure plasma.
- Air or oxygen.
- 300-900W.
- 5-10 min.
- Maximum sample size: 205x300 mm

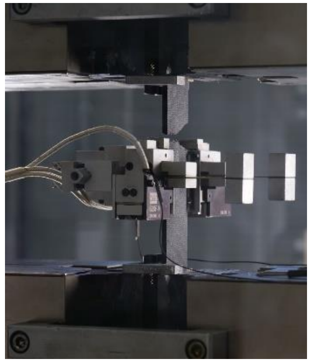
4

Composite manufacturing

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

5

Mechanical testing



CUSTOMISIZE

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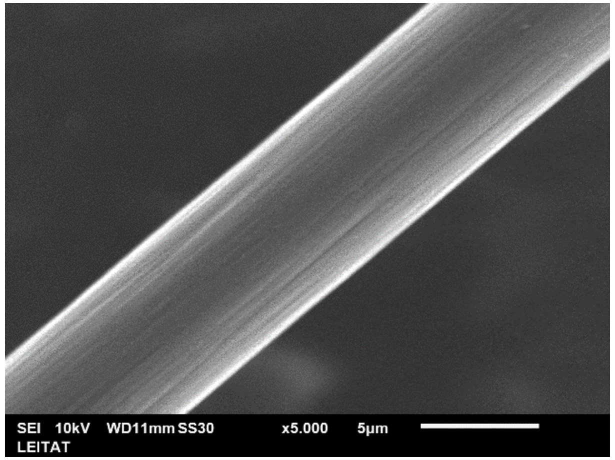
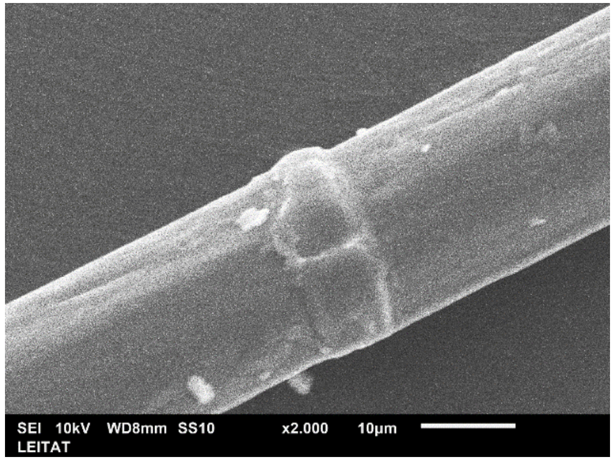
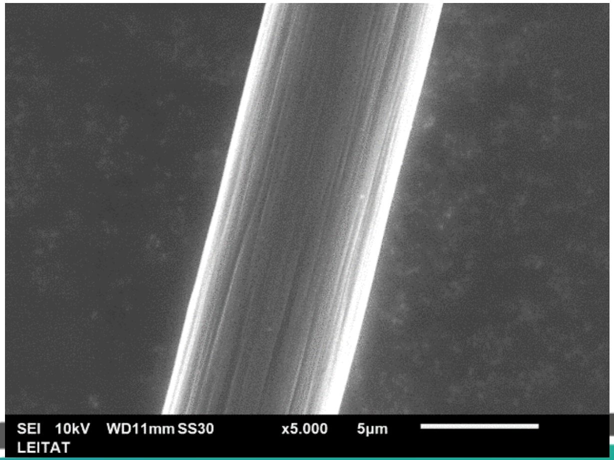
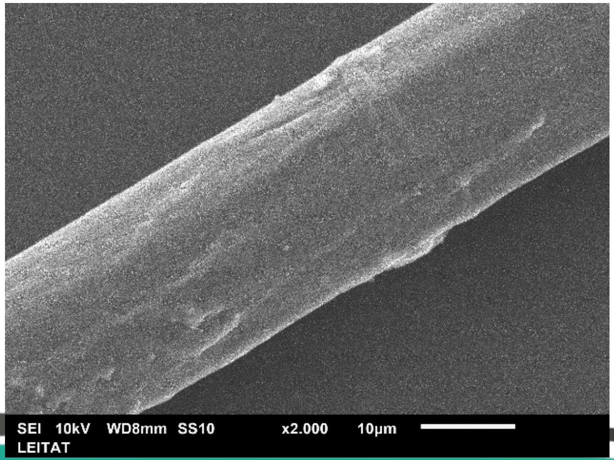
ECO-COMPASS project

The results

Scanning Electron Microscopy (SEM)

	rCF without sizing	Flax fibres
Untreated fibres		
Plasma treated fibres		

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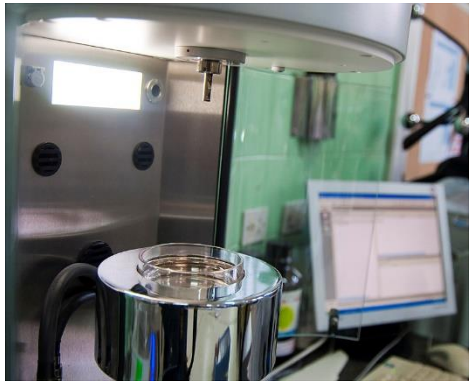
ECO-COMPASS project

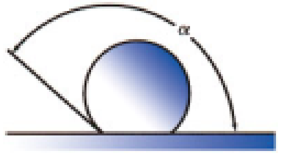
The results

Contact angle (CA)

Krüss K100 MK2 tensiometer



Good wetting



Bad wetting

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

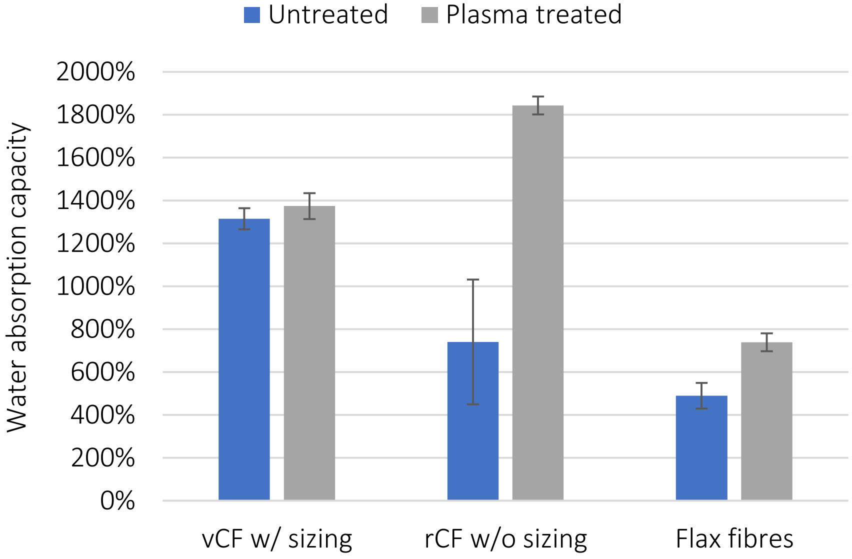
Water absorption capacity (WAC)

UNE EN ISO 9073-6

1 minute submerged in water

2 minutes of draining

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



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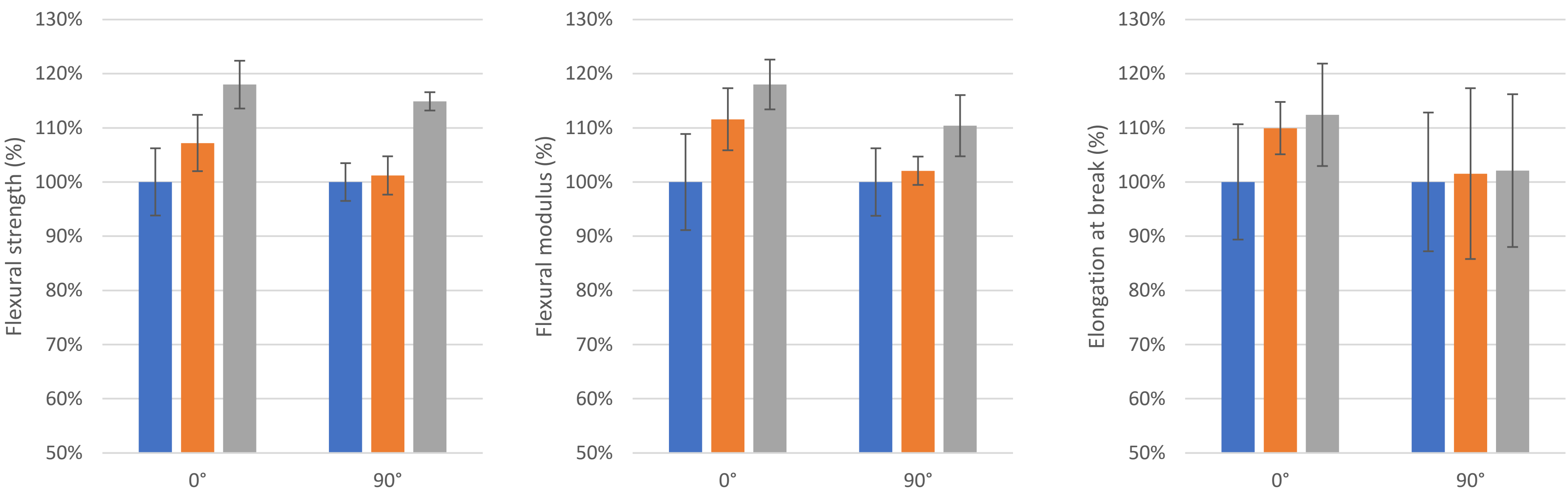
ECO-COMPASS project

The results

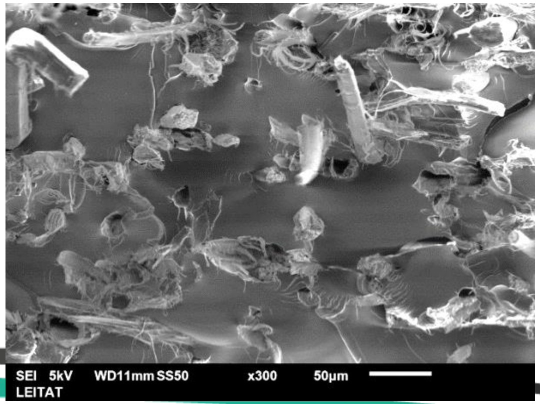
Flax fibres

3-point bending test (UNE EN ISO 14125)



Flax fibres
Flax fibres + plasma (low power)
Flax fibres + plasma (high power)

Fracture Surface of FF-reinforced composite



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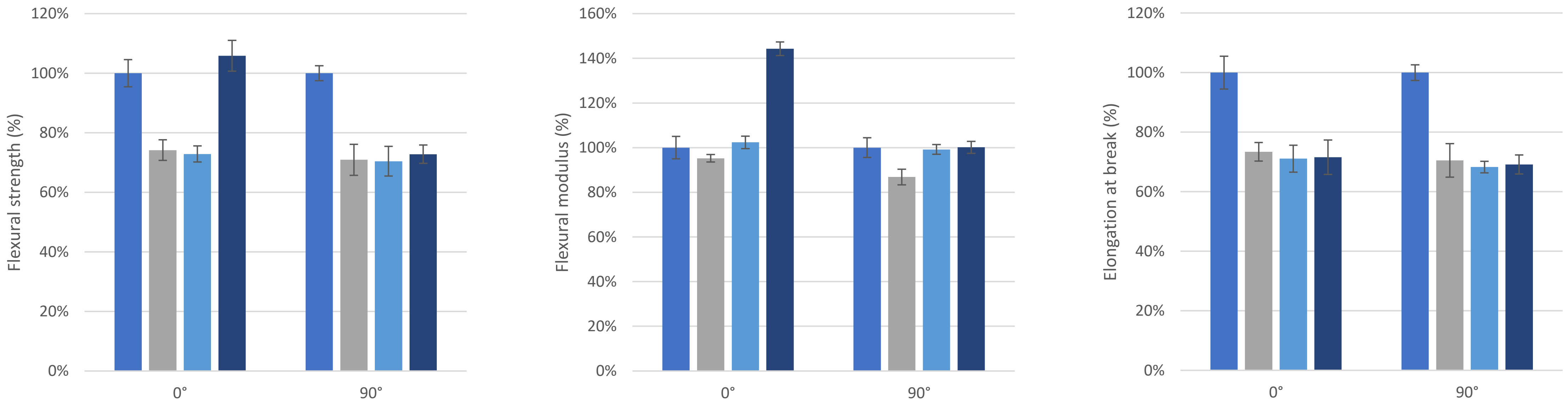
managing technologies

ECO-COMPASS project

The results

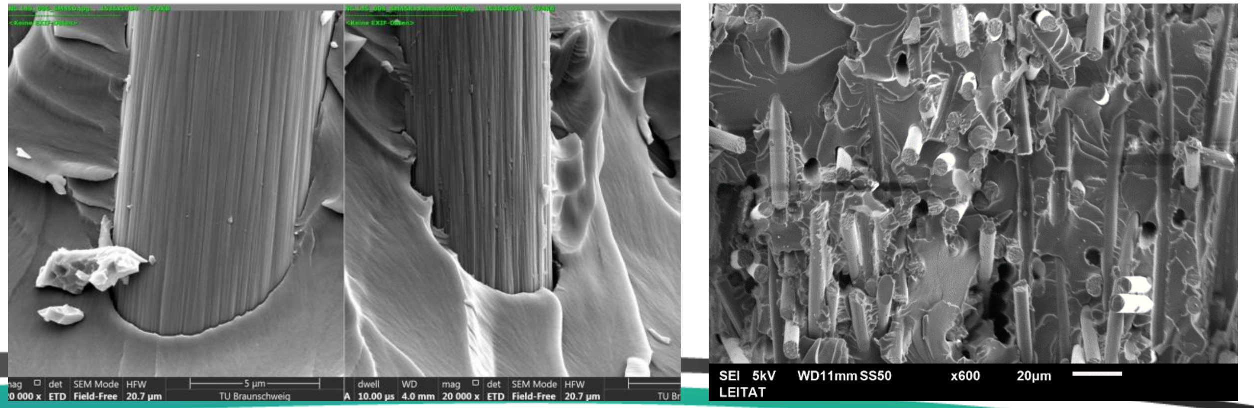
Carbon fibres

3-point bending test (UNE EN ISO 14125)



- vCF with sizing
- rCF without sizing
- rCF without sizing + plasma (low power)
- rCF without sizing + plasma (high power)

Fracture surface of CF-reinforced composite



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Conclusion

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

Carbon Fibres

- The original sizing improves the compatibility with the epoxy resin;
- The recycled fibres without sizing were meant to improve their 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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