



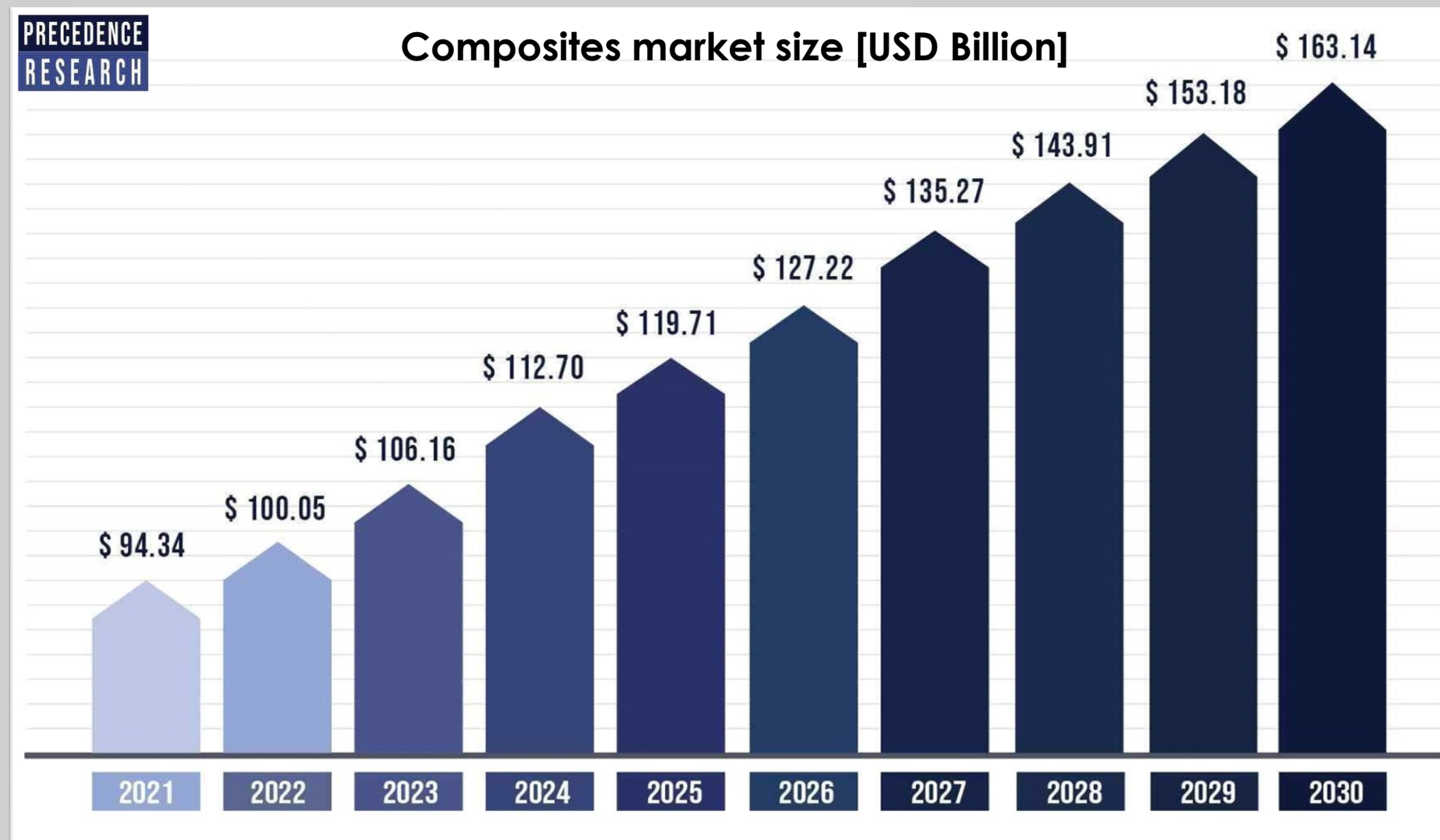
# Epoxy/cyclic olefin copolymer/carbon structural composite with electro- activated self-healing properties

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WHY COMPOSITE  
MATERIALS ARE SO  
IMPORTANT?





# Introduction

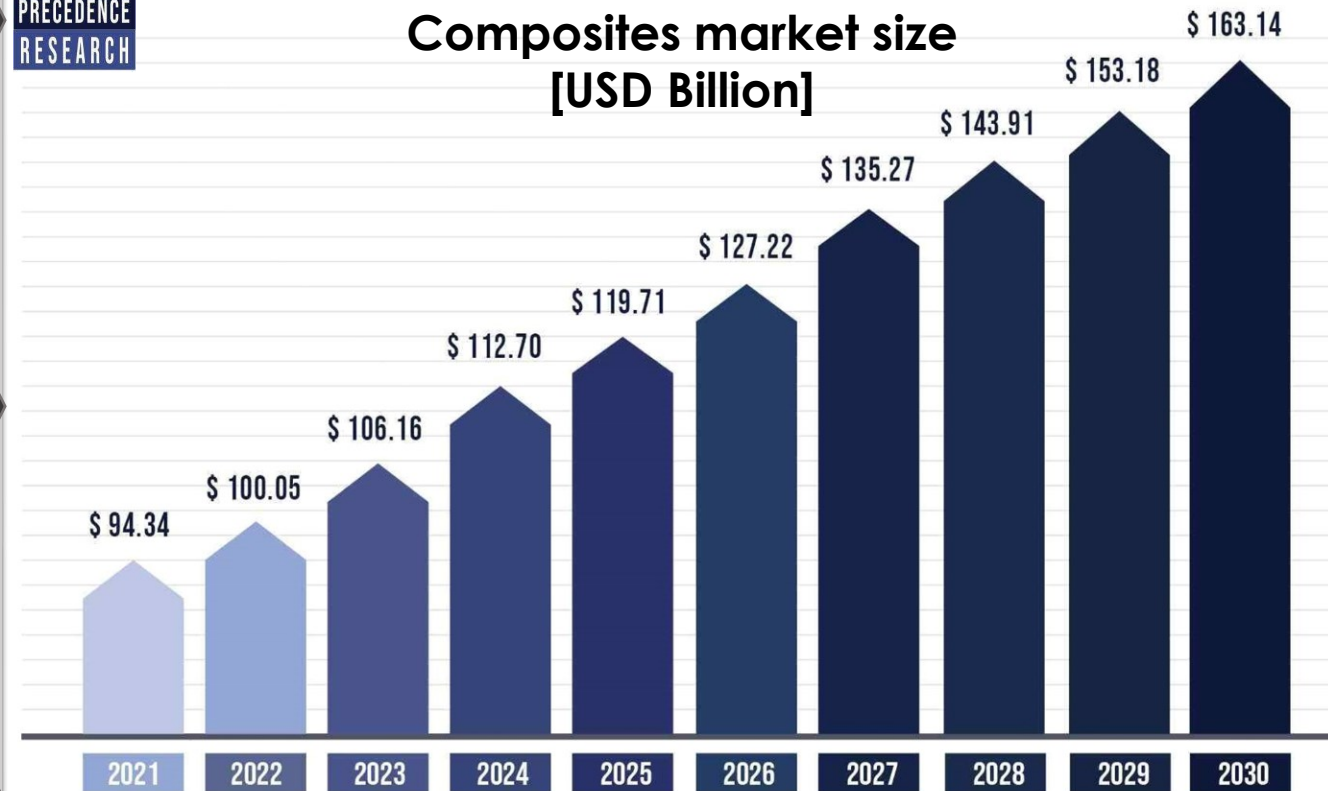
High strength-  
to-weight ratio

High stiffness-  
to-weight ratio

High fatigue  
resistance

PRECEDENCE  
RESEARCH

**Composites market size  
[USD Billion]**



High thermal  
stability

Design  
flexibility

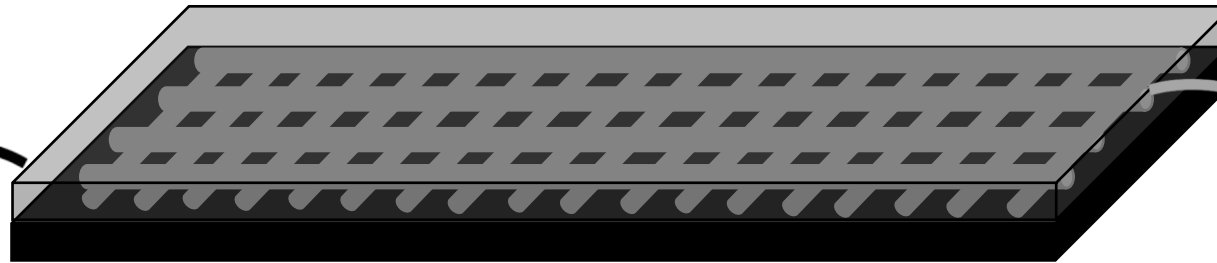
High durability

# Introduction

## Self healing composite



Self-healing composite aims at the restoration of a lost functionality in a specific application in order to extend the service life of the whole system



### Matrix

High mechanical properties  
Stable at high temperature

### Healing agent

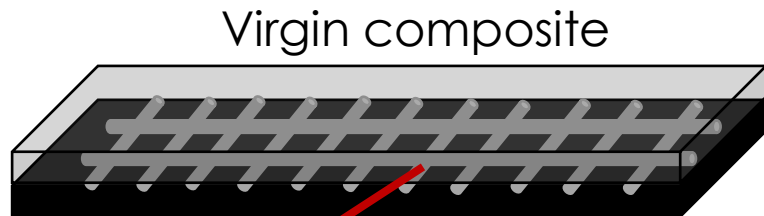
Low melting or softening point  
High flowability

# Aim of the work

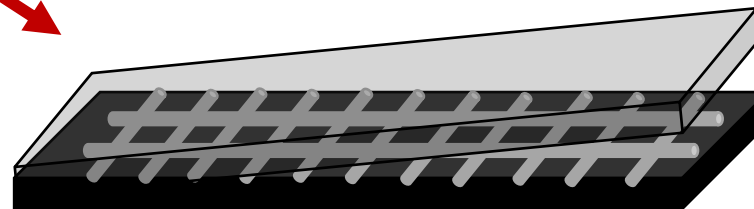
Self-healing carbon fiber epoxy composite



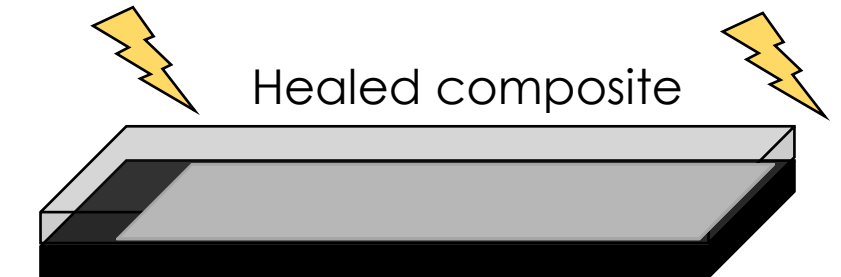
Healing agent deposited through Jet spinning



Healing agent



Interlaminar fracture  
toughness tests

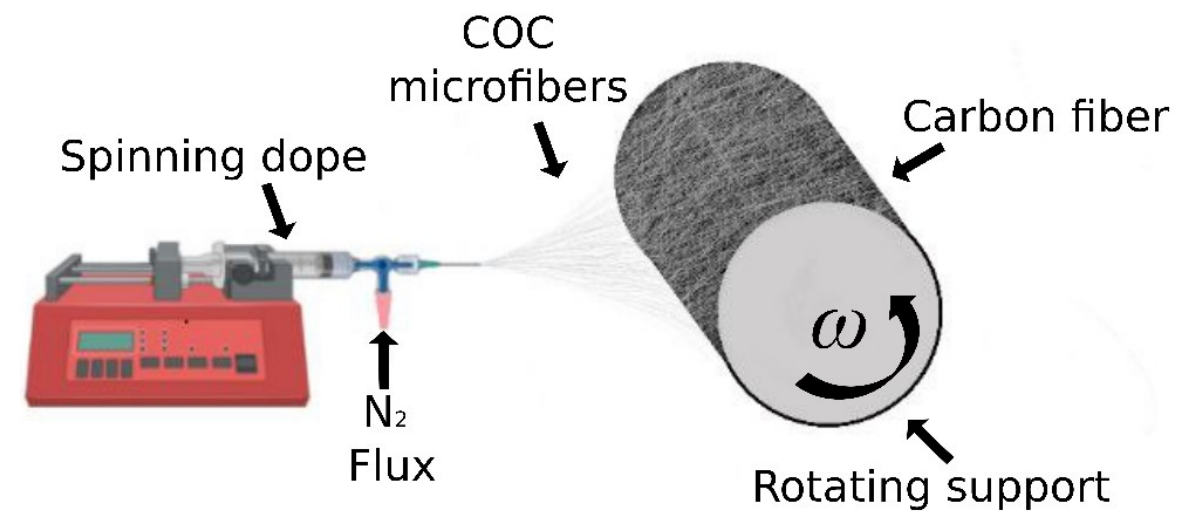


Healed composite

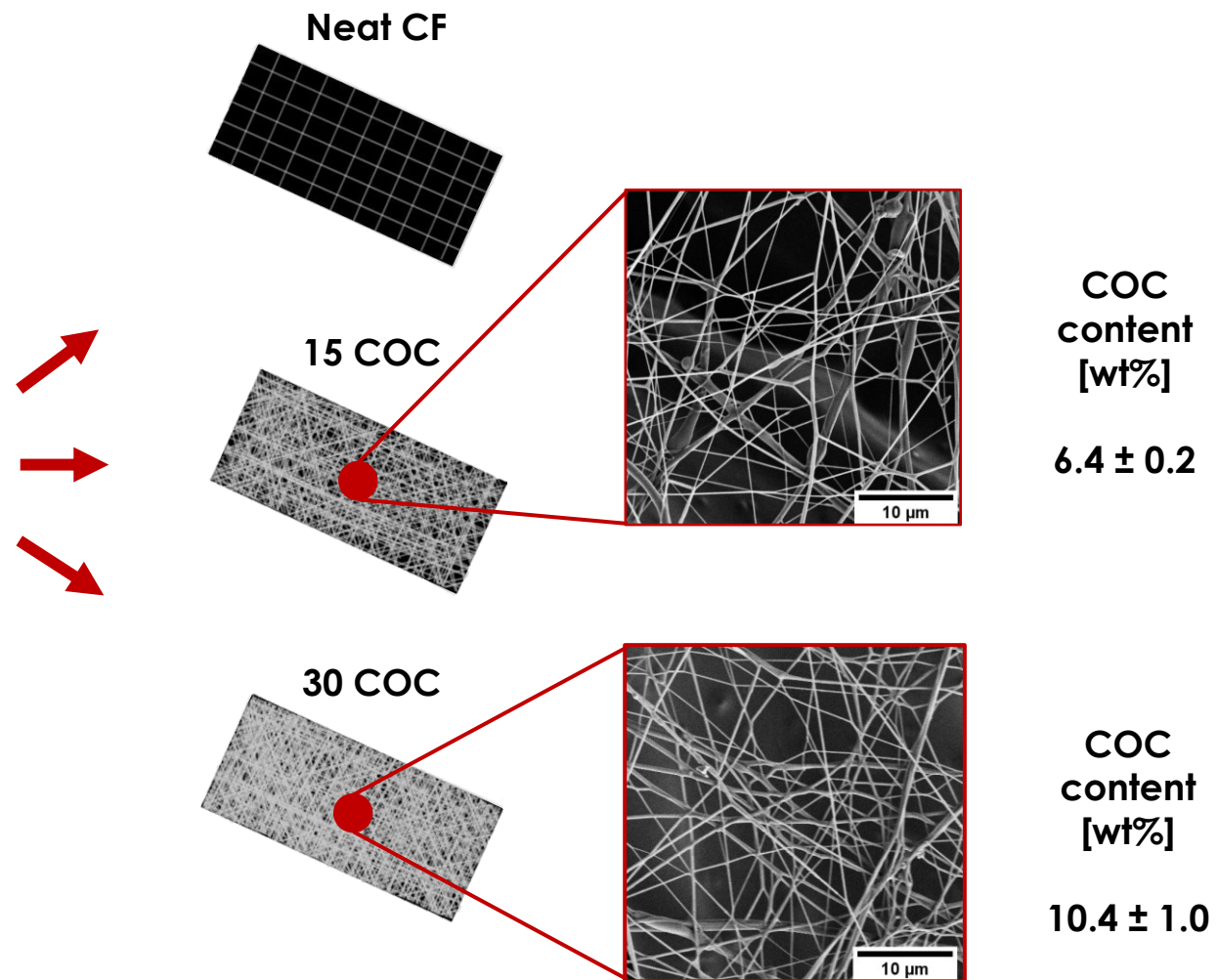


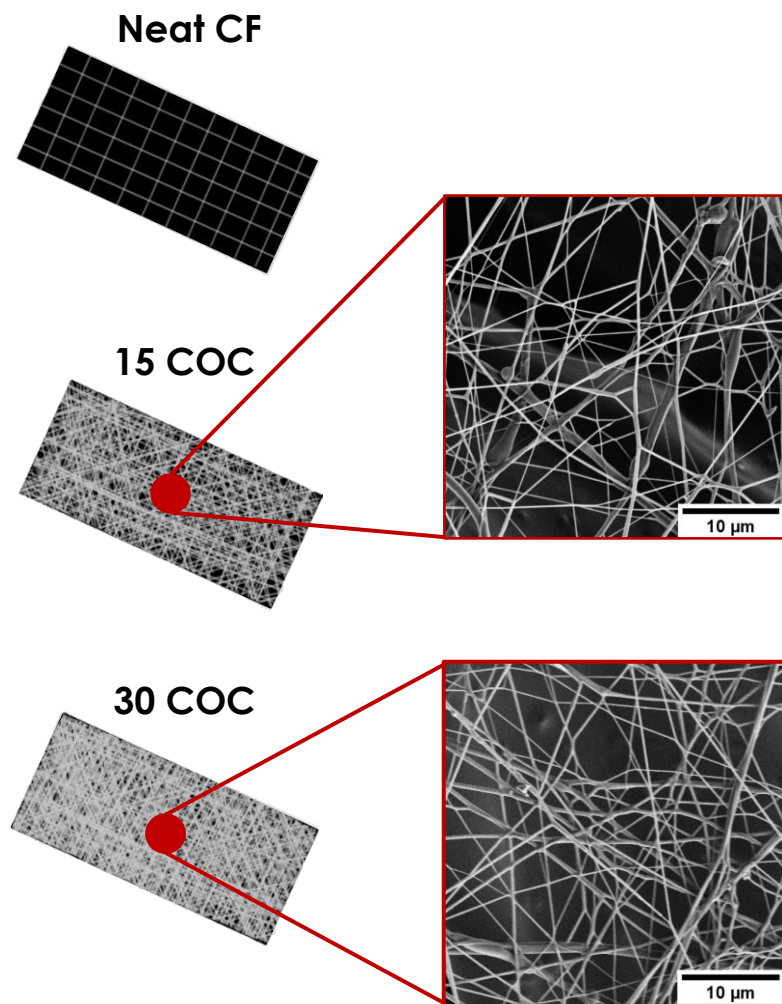


# Deposition of the healing agent



Cyclic olefinic Copolymer (COC)  
 TOPAS 9506F-500  
 COC dissolved in p-xylene (0.15 g/ml)  
 $N_2$  flux = 100 ml/min



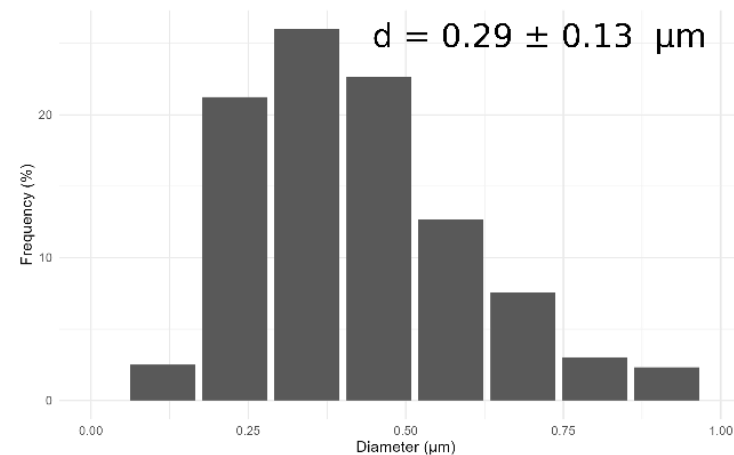
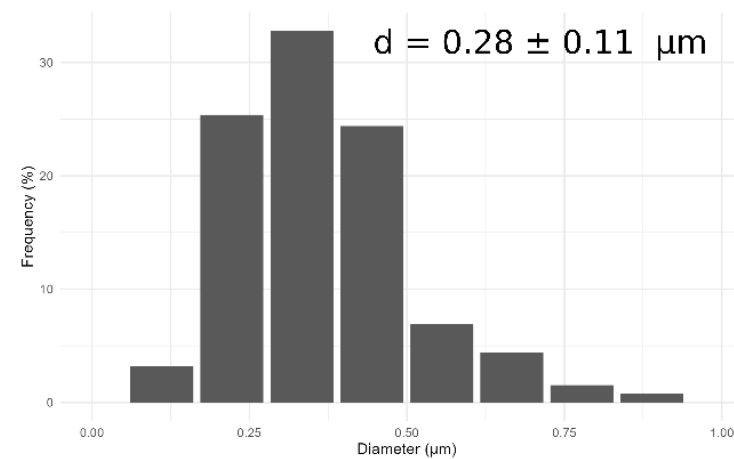


**COC  
content  
[wt%]**

**$6.4 \pm 0.2$**

**COC  
content  
[wt%]**

**$10.4 \pm 1.0$**



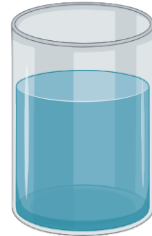


# Composite production

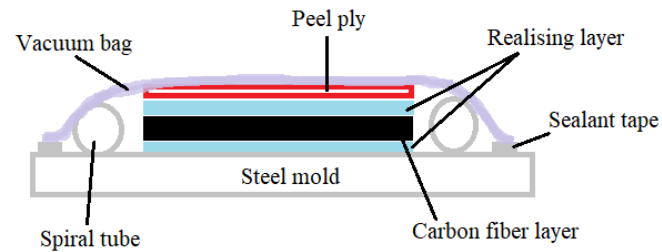
Elan-tech® EC 157.1  
resin

Elan-tech® W 342  
hardener

100:30

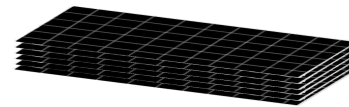


## Vacuum Assisted Resin Transfer Molding

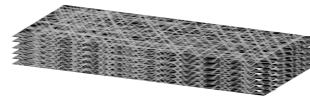


Curing 8 h RT + 15 h 60 °C

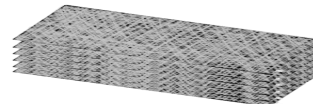
EP-CF



EP-4COC-CF



EP-8COC-CF



Flexural tests



ILSS



$G_{IC}$



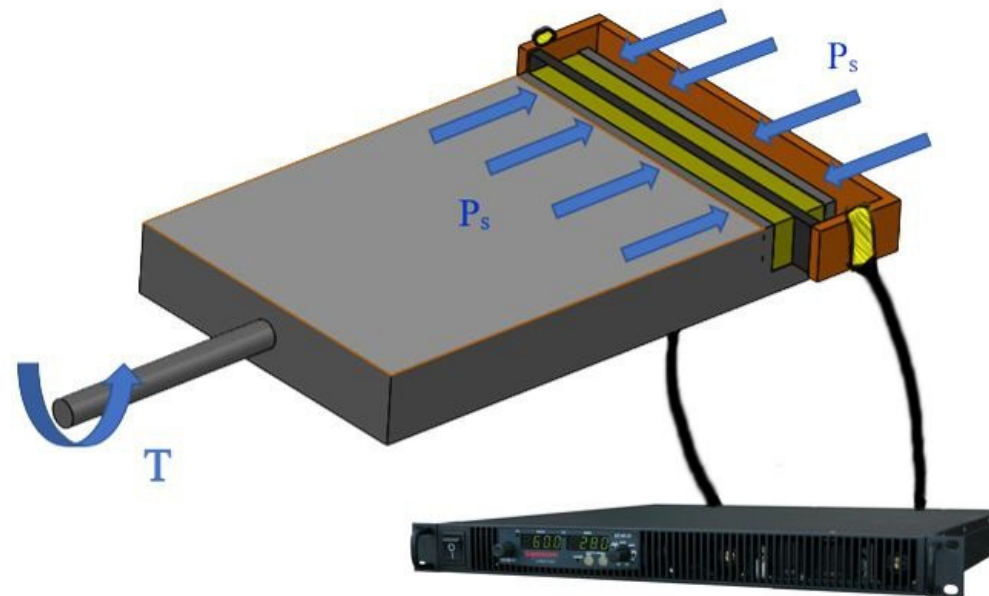
# Healing Process

**Healing process** performed at **110 °C**

through **Joule effect**

**Applied Pressure: 0.5 MPa**

**Time: 20 min**

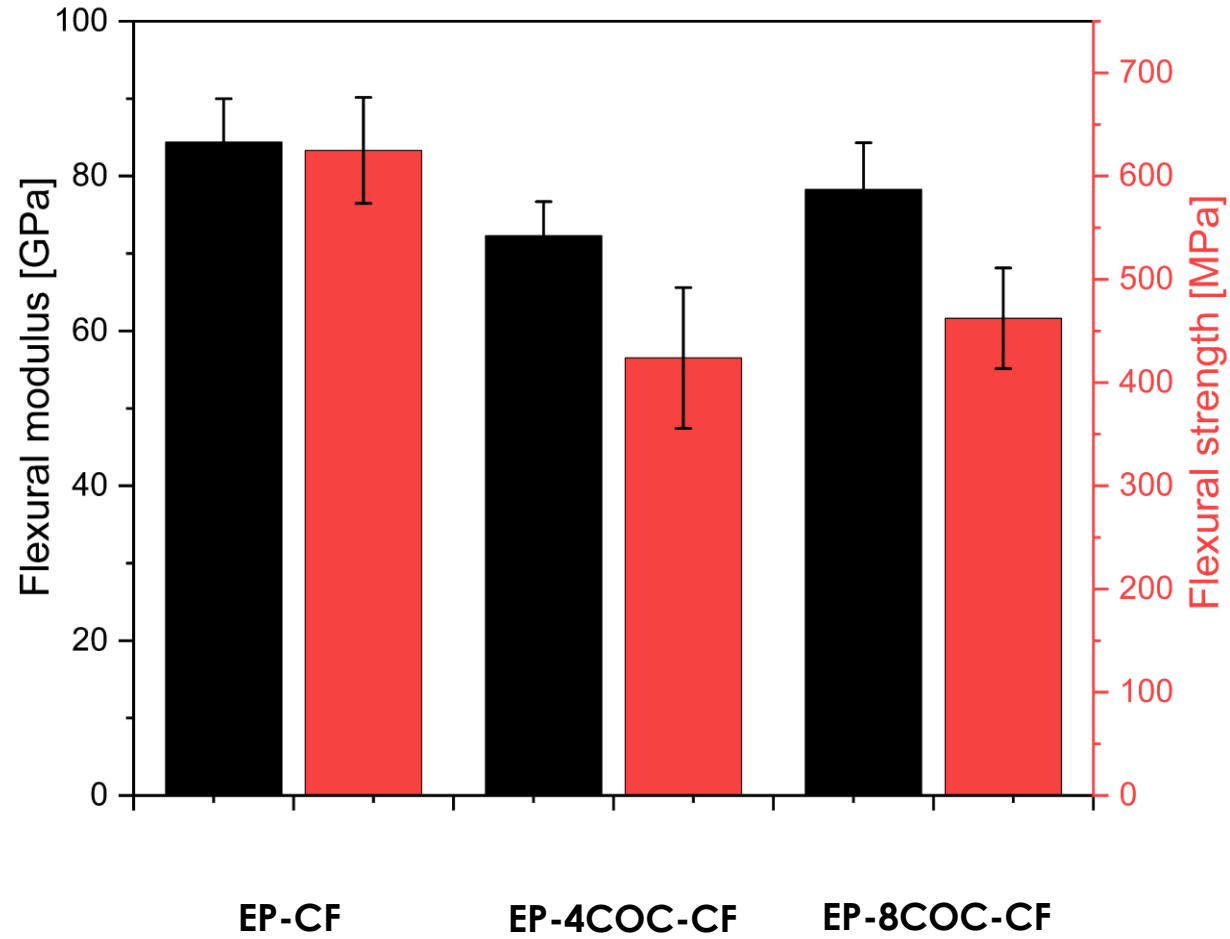


$$\text{Healing Efficiency } (\eta_{GI}) = \frac{G_{I,Healed}}{G_{I,Virgin}} \cdot 100 [\%]$$

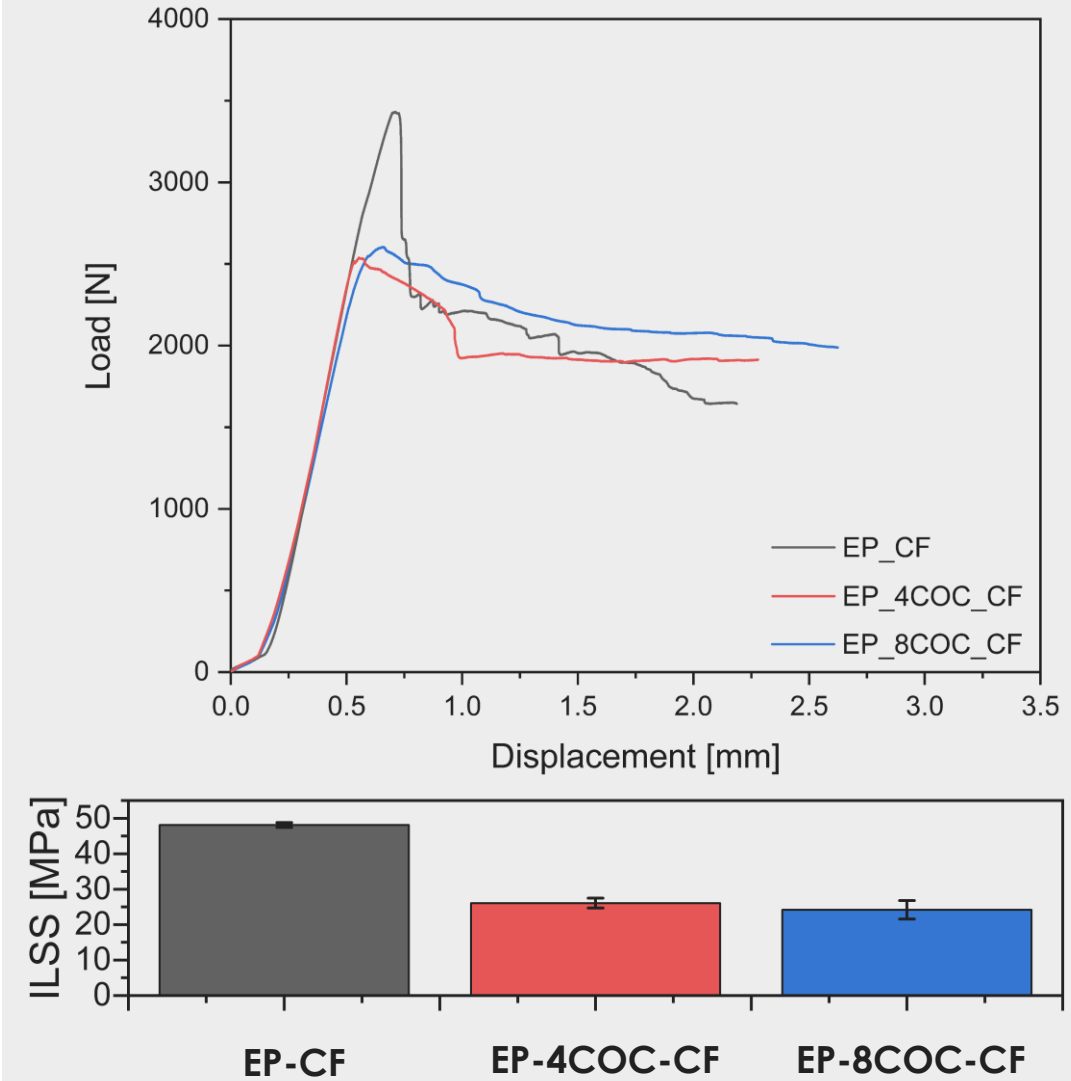
$$\text{Healing Efficiency } (\eta_P) = \frac{P_{Healed}}{P_{Virgin}} \cdot 100 [\%]$$

# Results and Discussions

Flexural properties  
ASTM D790, Instron® 5969, 50 kN

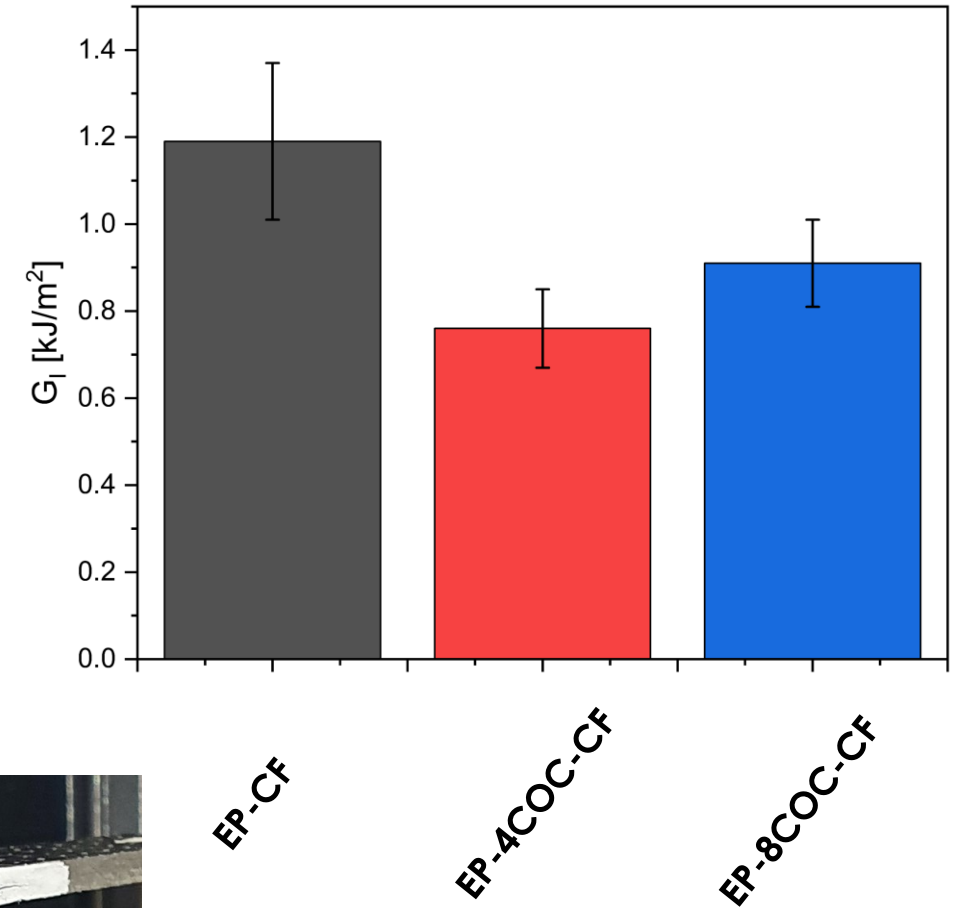
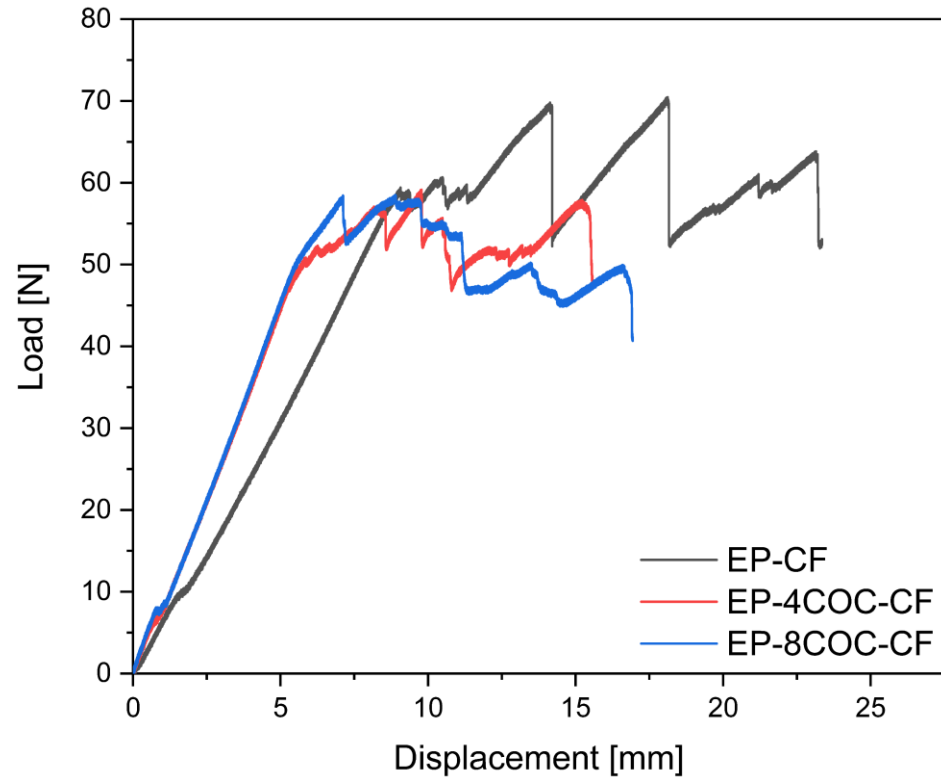


Interlaminar shear strength  
ASTM D2344, Instron® 5969, 50 kN, 1 mm/min

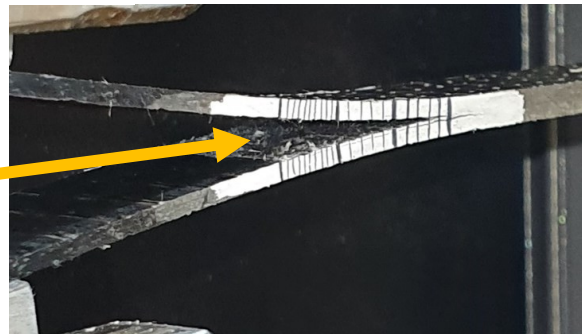


# Results and Discussions

Interlaminar fracture toughness  
ASTM D5528-21, Instron® 5969, 1 kN

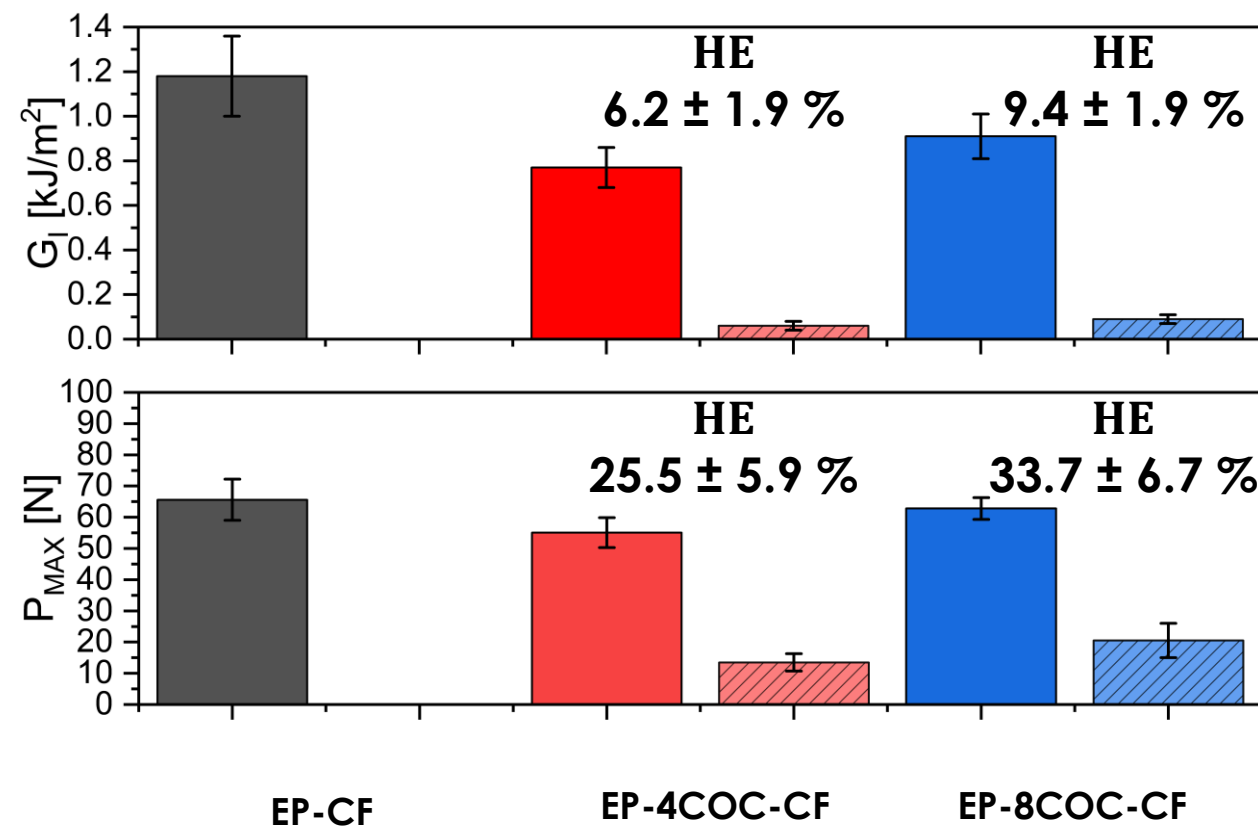
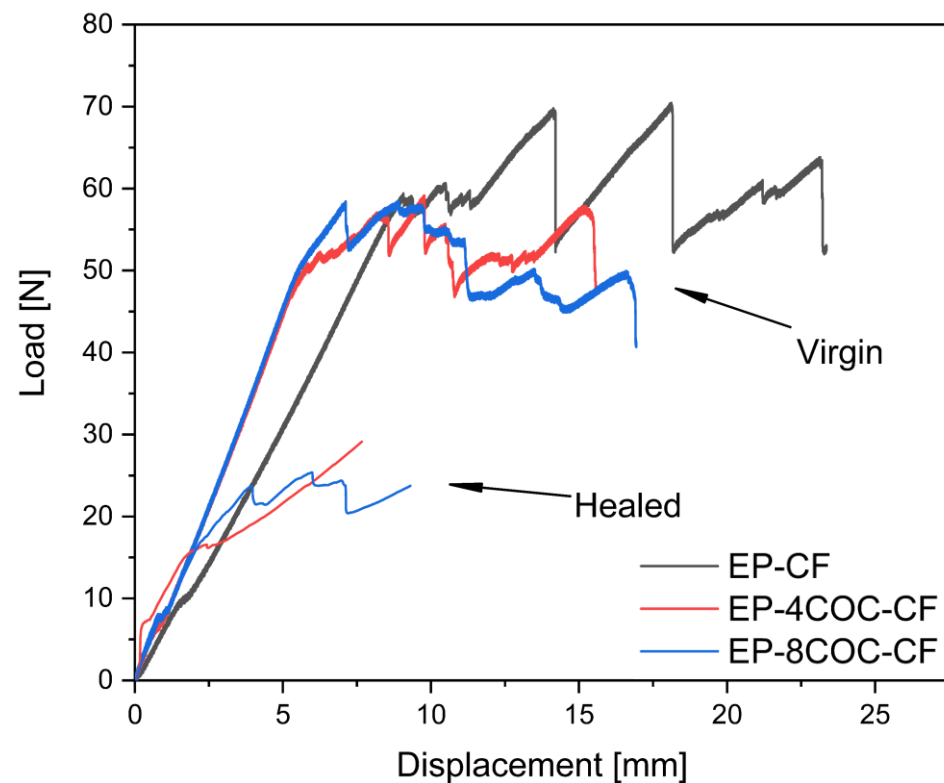


Healing agent



# Results and Discussions

Interlaminar fracture toughness  
ASTM D5528-21, Instron® 5969, 1 kN



Partial recovery of the mechanical properties

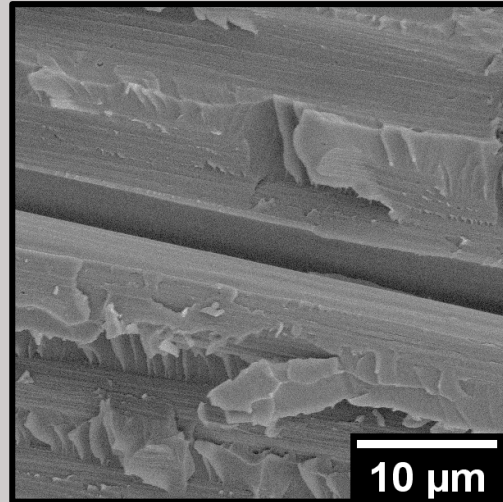


# Results and Discussions

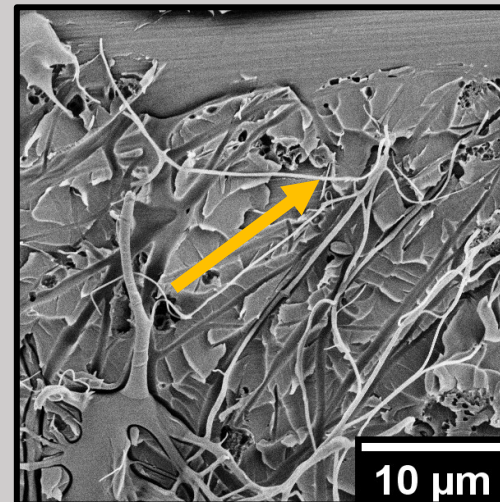
Scanning Electron  
Microscope  
**Zeiss - SUPRA®40**  
Fractured Surfaces  
Voltage = 3.5 kV  
Pt:Pd (80:20)

Before  
healing

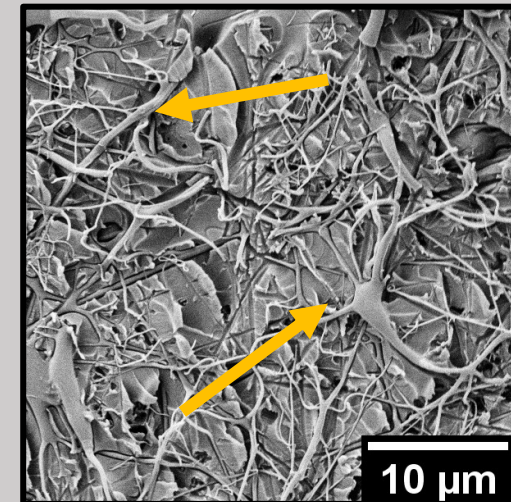
EP-CF



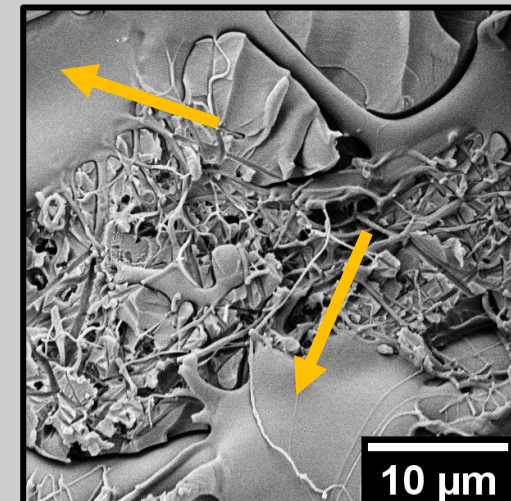
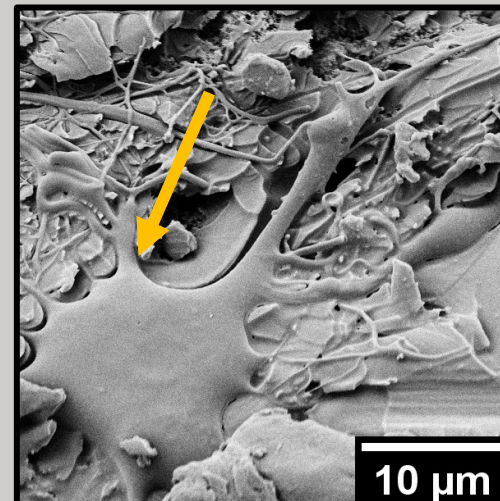
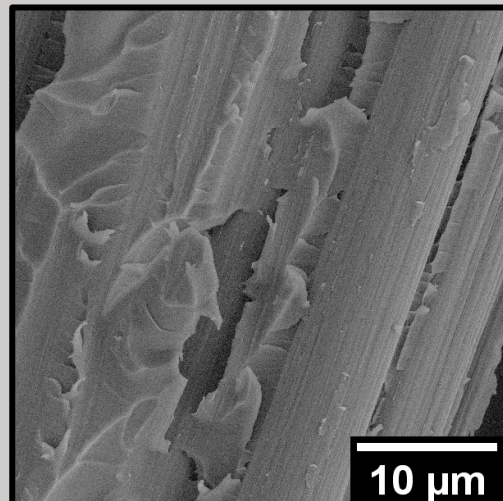
EP-4COC-CF



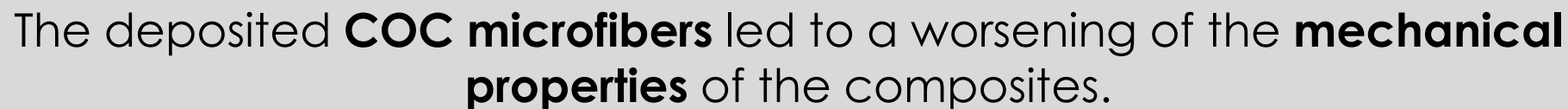
EP-8COC-CF



After  
healing







# Future perspective



Production of **intrinsic self-healing** thermosetting composites by directly 3D printing the healing agents on top of the fibers



Design of a **melt electro writing** process for improving of the overall mechanical properties of the **self-healing composites**



Study of the **interfacial adhesion** between the **healing agent** and the **fiber**



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