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**Figures and tables for summary description of the project context
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Figure 1: different functionalities integrated in a single load-bearing material

Multifunctionality and synergy concept

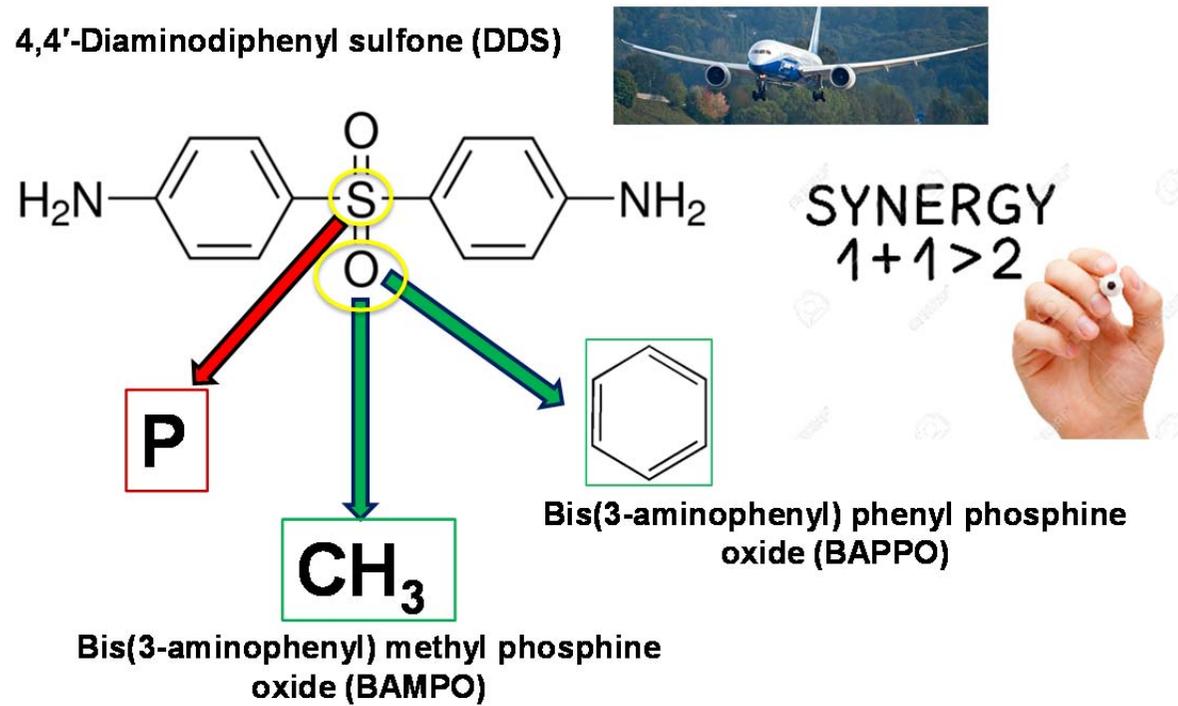


Figure 2: multifunctionality and synergy concept

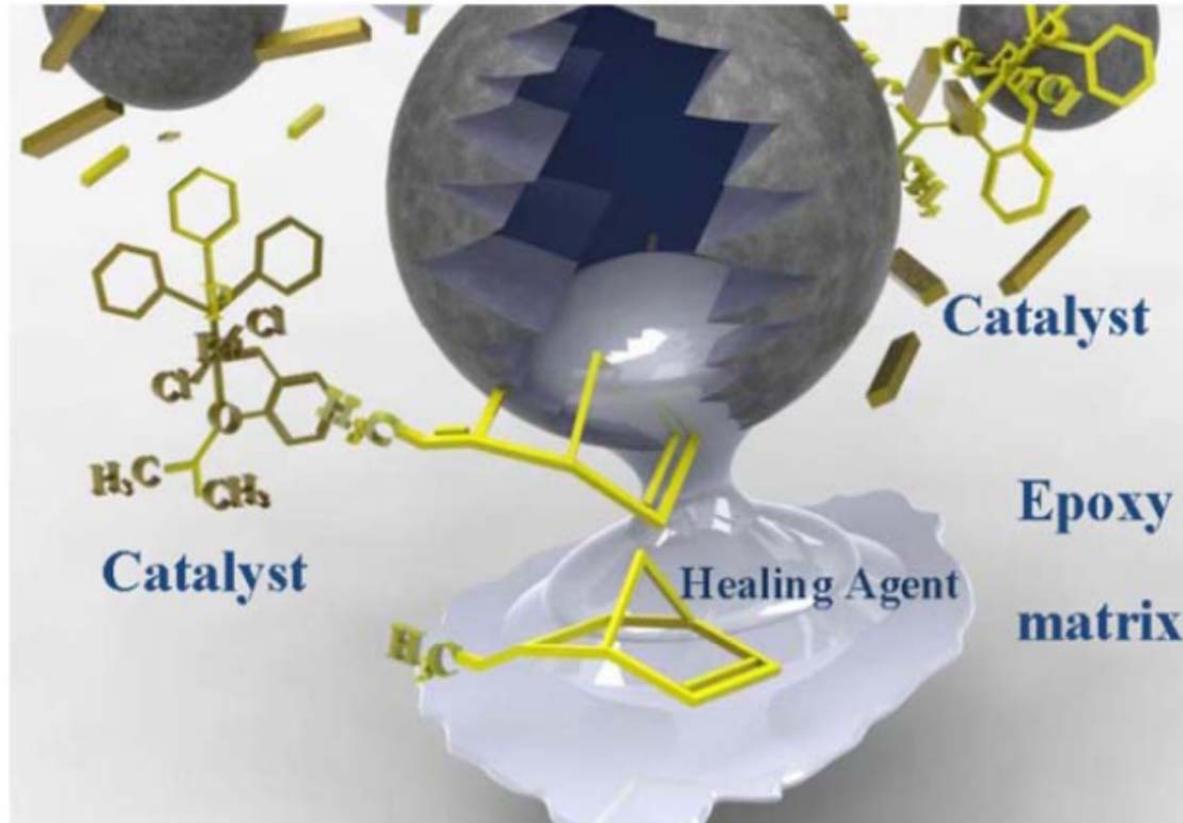


Figure 3: self-healing materials based on the “microencapsulation” concept

Functionalization of Carbon nanotubes with catalysts active in ROMP reactions

Electrical conductivity and self-healing functionality

Grubbs catalyst 2nd generation (G2) and Hoveyda-Grubbs catalysts covalently bonded on the wall of MWCNTs.

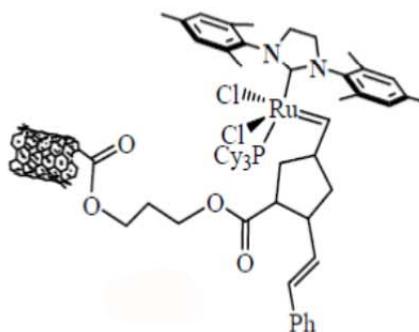


Figure. Carbon nanotube functionalized with Grubbs catalyst 2nd generation (MWCNT-G2_{pr}).

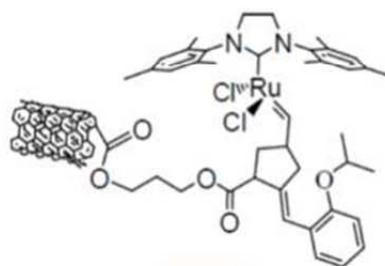


Figure. Carbon nanotube functionalized with Hoveyda-Grubbs catalyst 2nd generation (HG2).

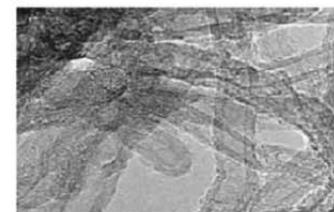
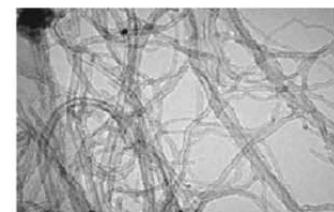
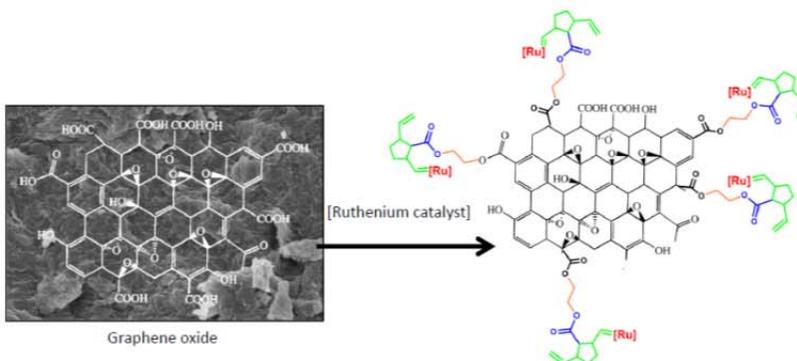


Figure. High resolution transmission electron microscope images of the MWCNTs

Figure 4: Catalysts for ROMP reactions covalently bonded to the walls of CNTs

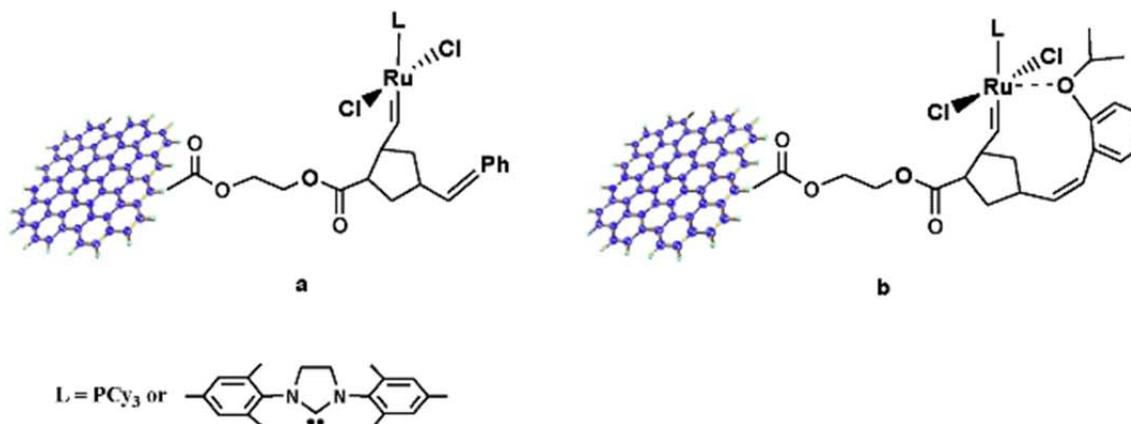
Auto-repair function – design and research strategy

Graphene sheets



Catalysts for ROMP polymerization were covalently bonded to graphene sheets.

The catalyst activities were tested in reactions of ring opening metathesis polymerization (ROMP) of 2-norbornene and 5-ethylidene-2-norbornene.



This work started with the preparation of graphite oxide (GO) followed by the functionalization with ruthenium catalysts.

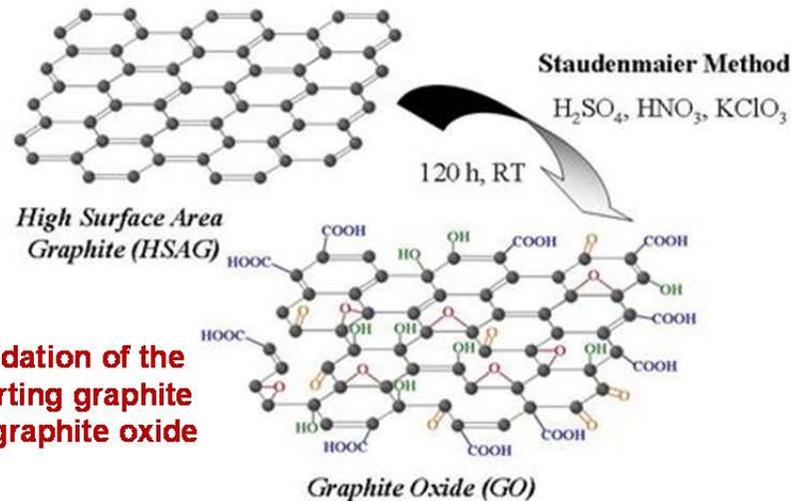
Figure 5: Catalysts for ROMP reactions covalently bonded to graphene sheets

Auto-repair function – design and research strategy

Modified Graphene

Preparation of Graphite oxide (GO)

The starting graphite (G) is a high surface area graphite (trade name Synthetic Graphite 8427) from Asbury Graphite Mills Inc., with a minimum carbon wt % of 99.8 and a surface area of 330 m²/g.



Oxidation of the starting graphite to graphite oxide

Graphite oxide was prepared by Staudenmaier's method,² from the high surface area graphite (HSAG).

2) Staudenmaier, L. Ber. Dtsch. Chem. Ges. 1898, 31, 1481–1487.

Characterization

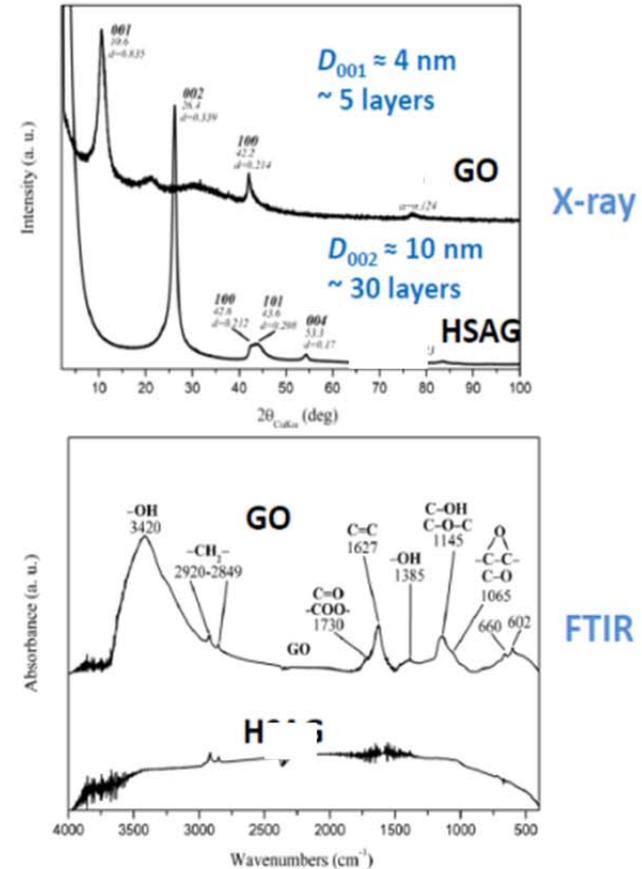
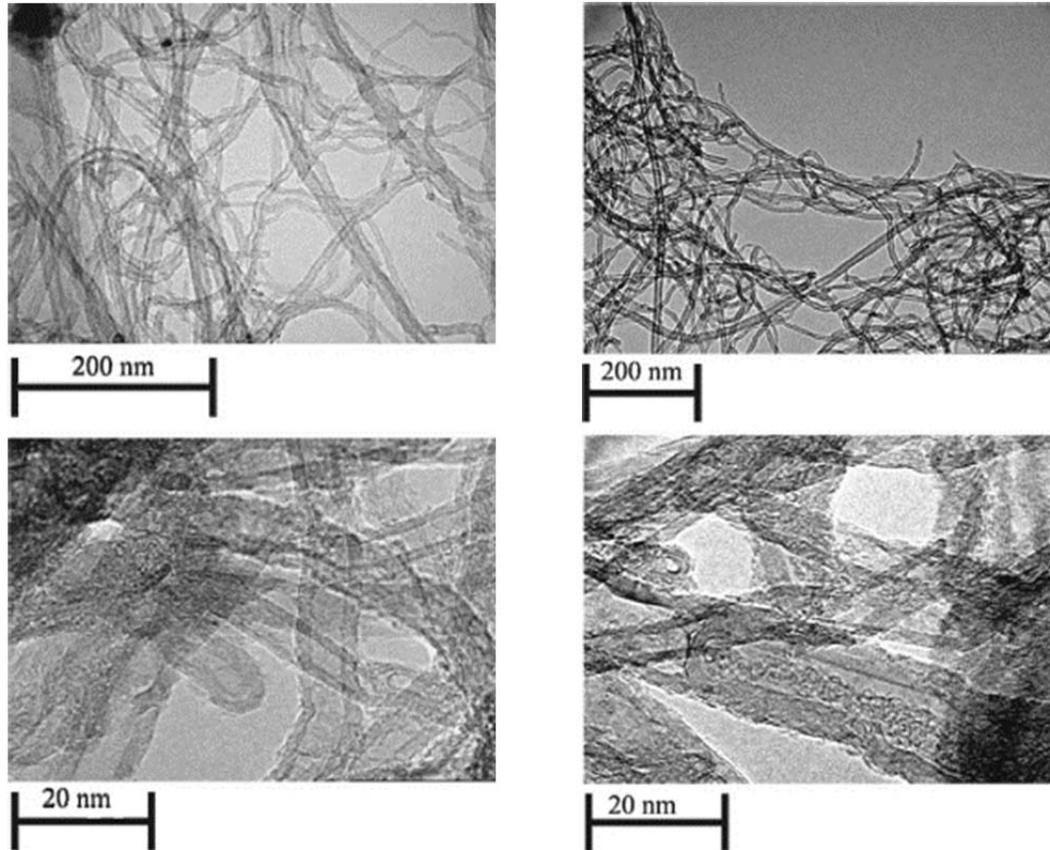


Figure 6: preparation of the graphite oxide used for the functionalization of ROMP catalysts

Electrical conductivity function : design and research strategy

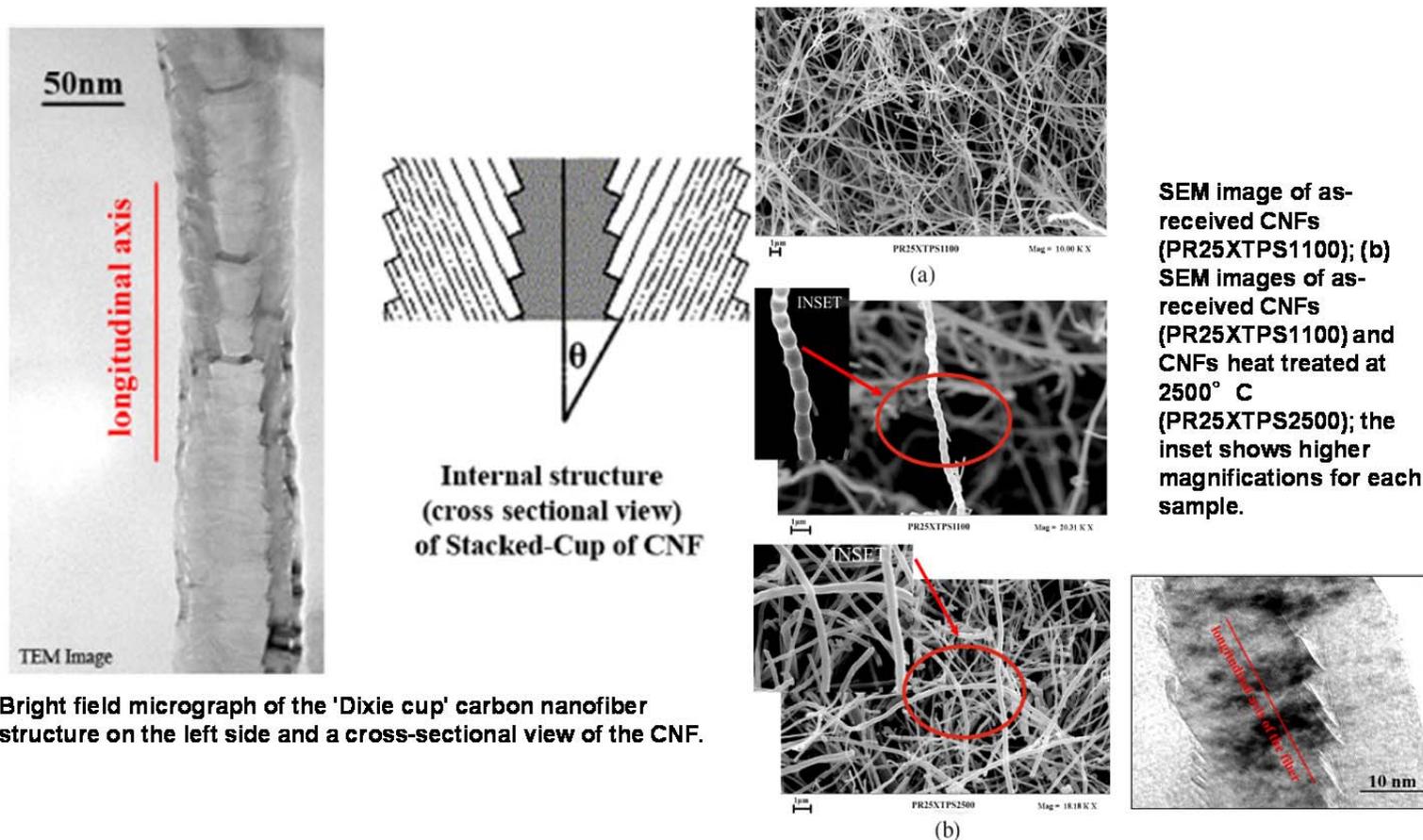


Images of unfunctionalized MWCNTs

Images of functionalized MWCNTs

Figure 7: unfunctionalized and functionalized used as electrical conductive filler in IASS resins

Electrical conductivity function: design and research strategy



Bright field micrograph of the 'Dixie cup' carbon nanofiber structure on the left side and a cross-sectional view of the CNF.

Figure 8: untreated and heat-treated CNFs used as electrical conductive filler in IASS resins

Electrical conductivity function: design and research strategy

Graphene sheets

Three samples of graphene-based nanoparticles have been analyzed:

- 1) partially exfoliated graphite (pEG);
- 2) carboxylated partially exfoliated graphite (CpEG);
- 3) fully exfoliated graphite (SL).

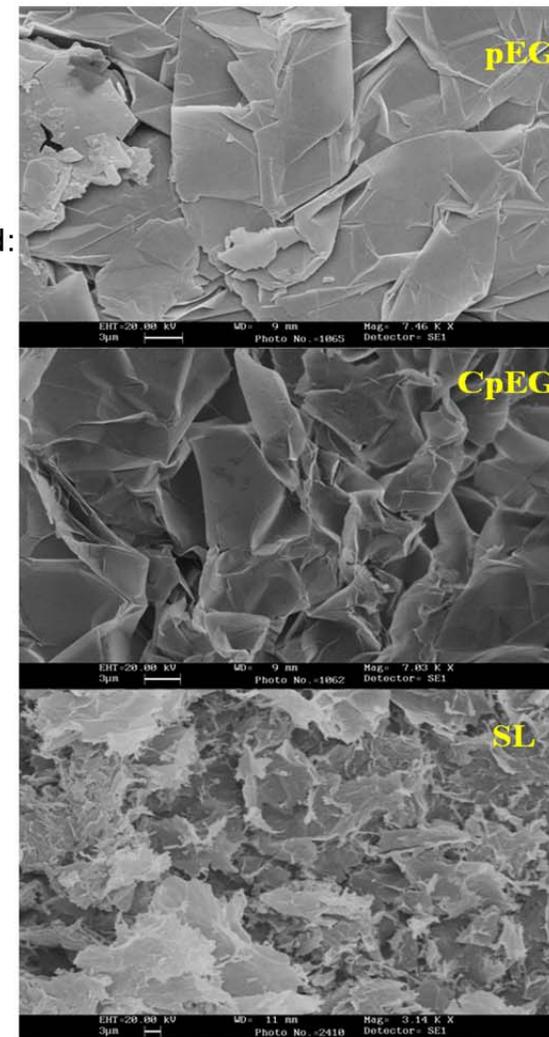
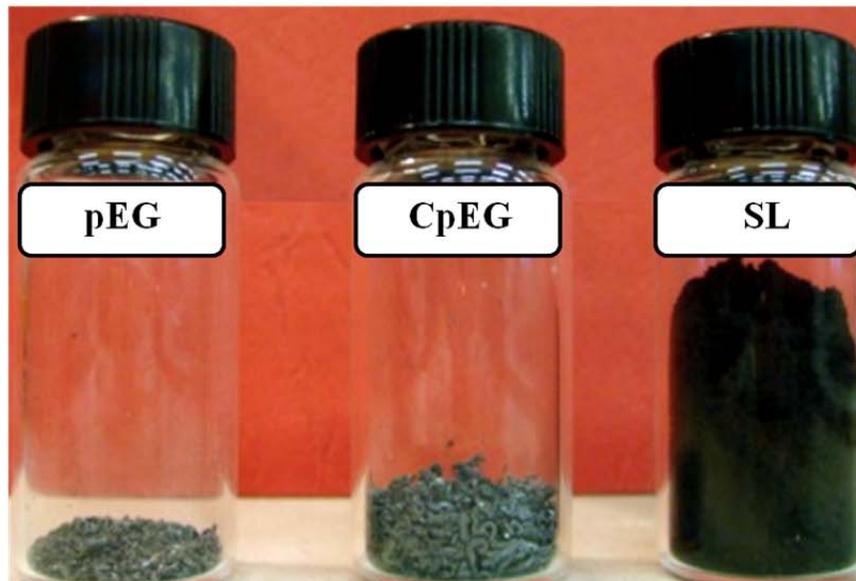


Figure 9: graphene-based nanoparticles used as electrical conductive filler in IASS resins

Enhanced flame resistance function : design and research strategy

- **Identification and Synthesis of new Hardener Agents**
 - *Bis(3-aminophenyl)methylphosphine oxide (BAMPO)*
 - *Bis(3-aminophenyl)phenylphosphine oxide (DAPPO)*

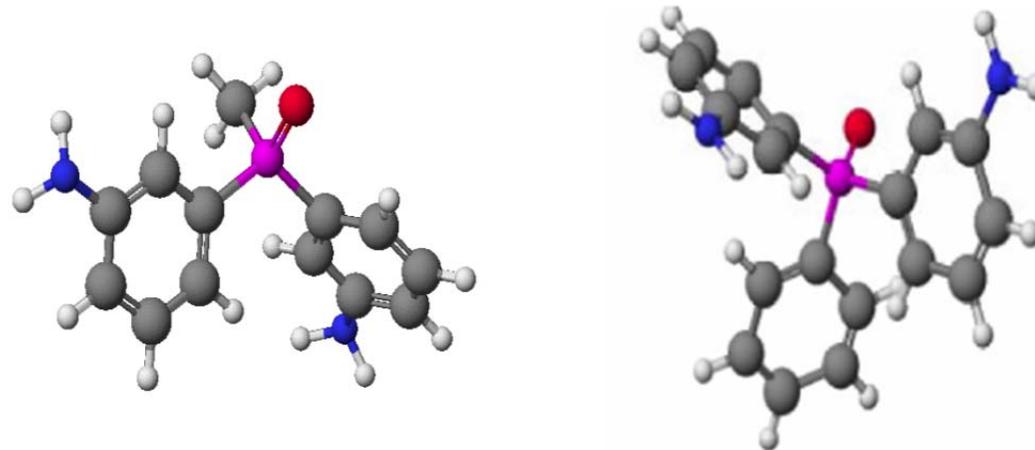


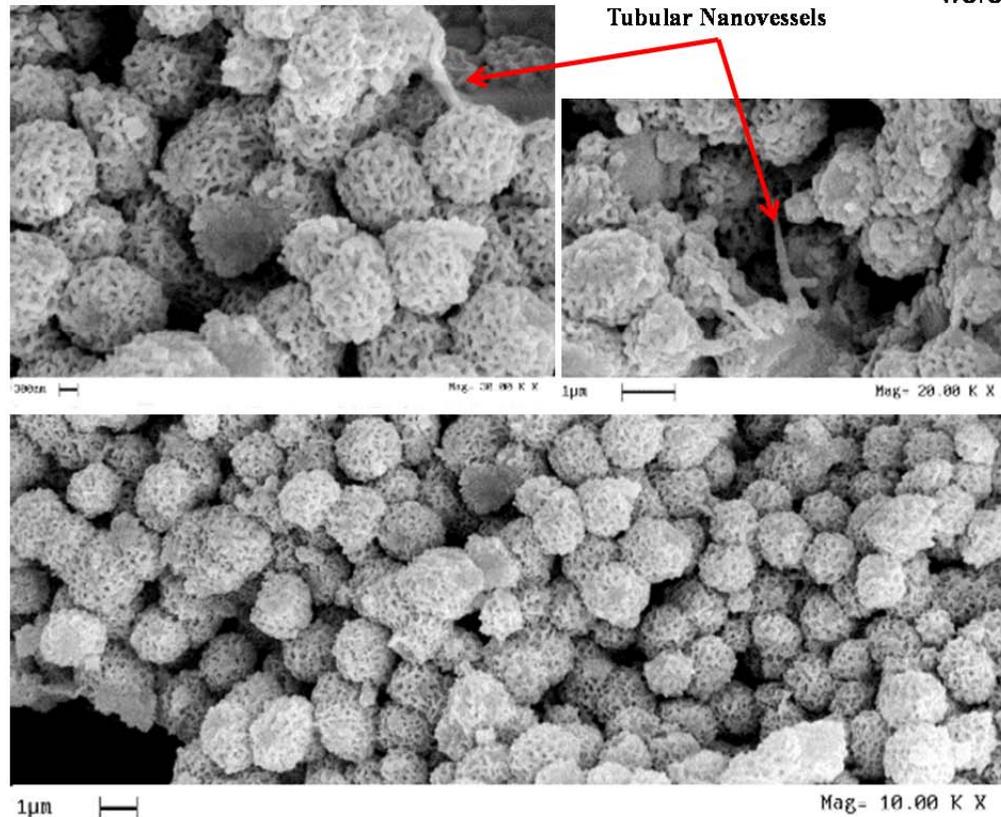
Figure 10: new hardeners agent (curing agents) synthesized to produce flame resistant composites



Figures and tables for **description of the project context**
and the main objectives

Auto-repair function: Main Results

ENB/DCPD-filled microcapsules were synthesized and analyzed



SEM images at different magnifications of the synthesized microcapsules in the form of spherical snarls. Red arrows highlight the tubular nanovessels which constitute the spherical snarls

Figure 11: ENB/DCPD-filled microcapsules (in the form of spherical snarls)

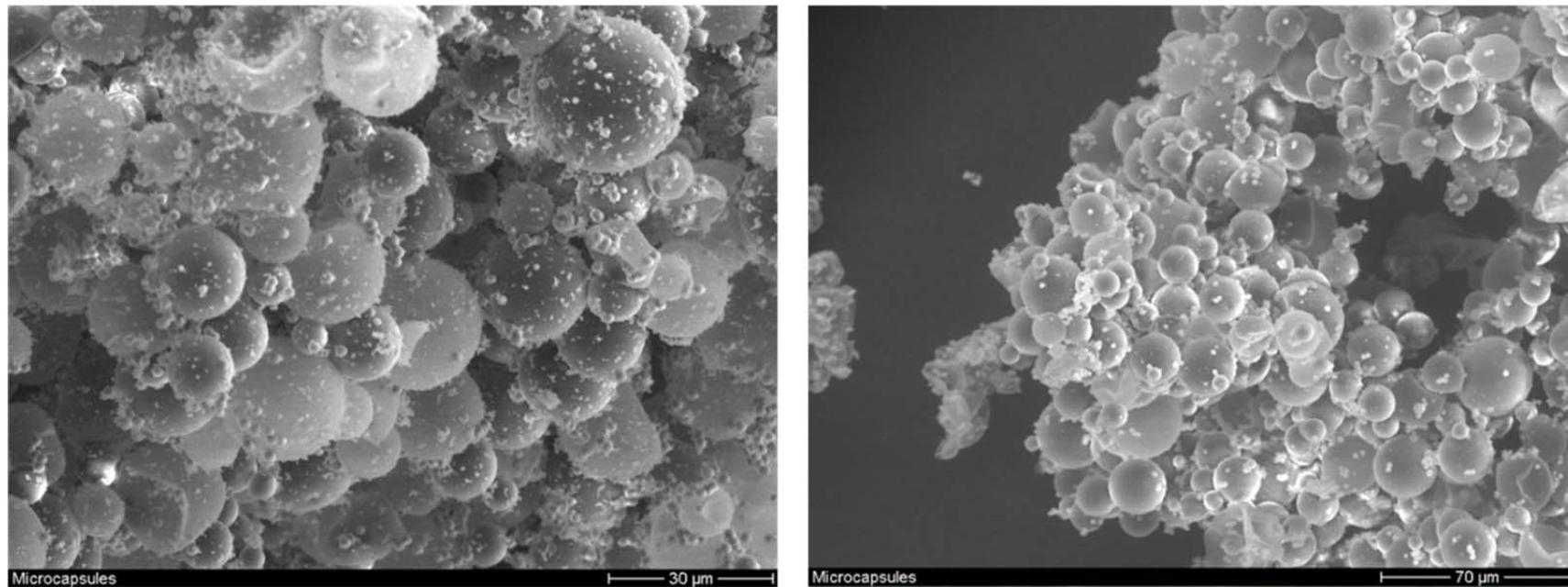


Figure 12: ENB/DCPD-filled microcapsules (in the form of spherical microcapsules)

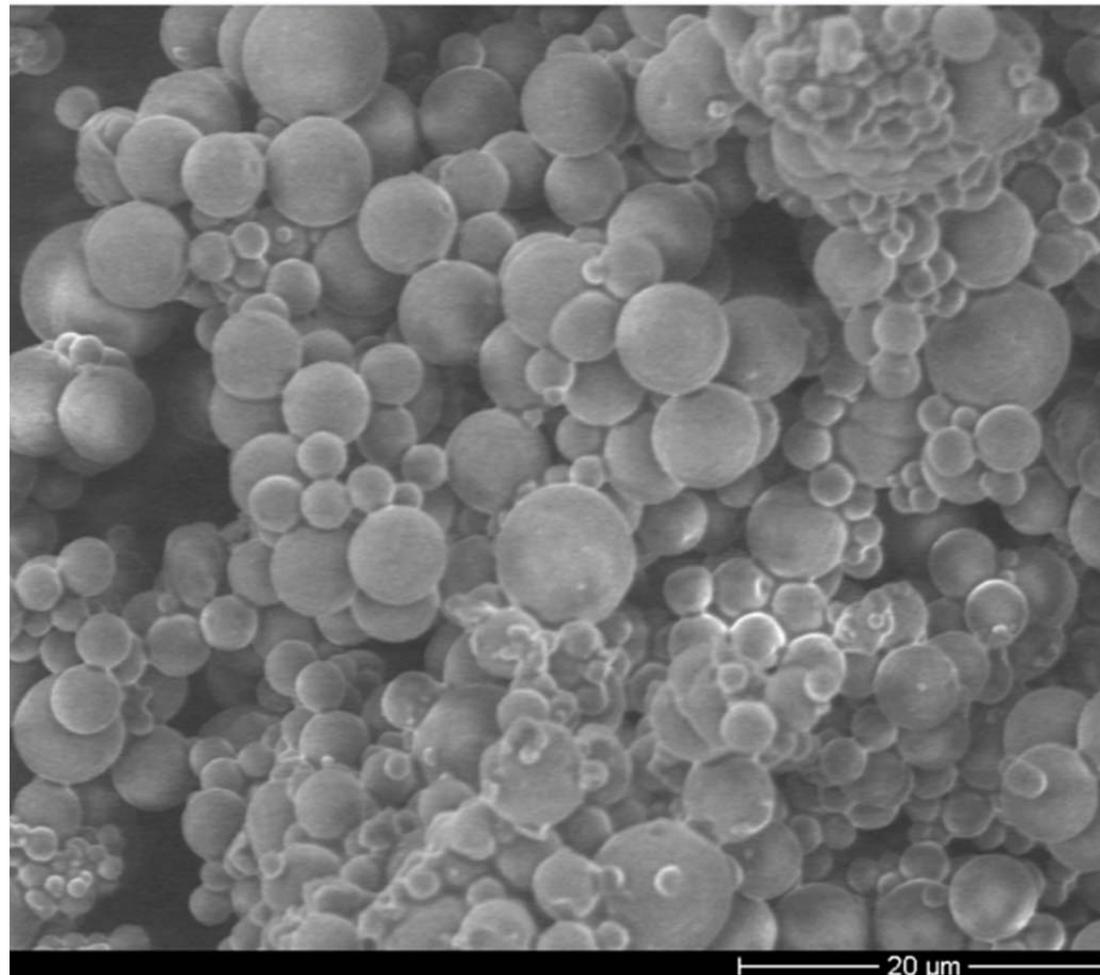


Figure 13: FE-SEM images of microcapsules containing Tri-Az-Ac

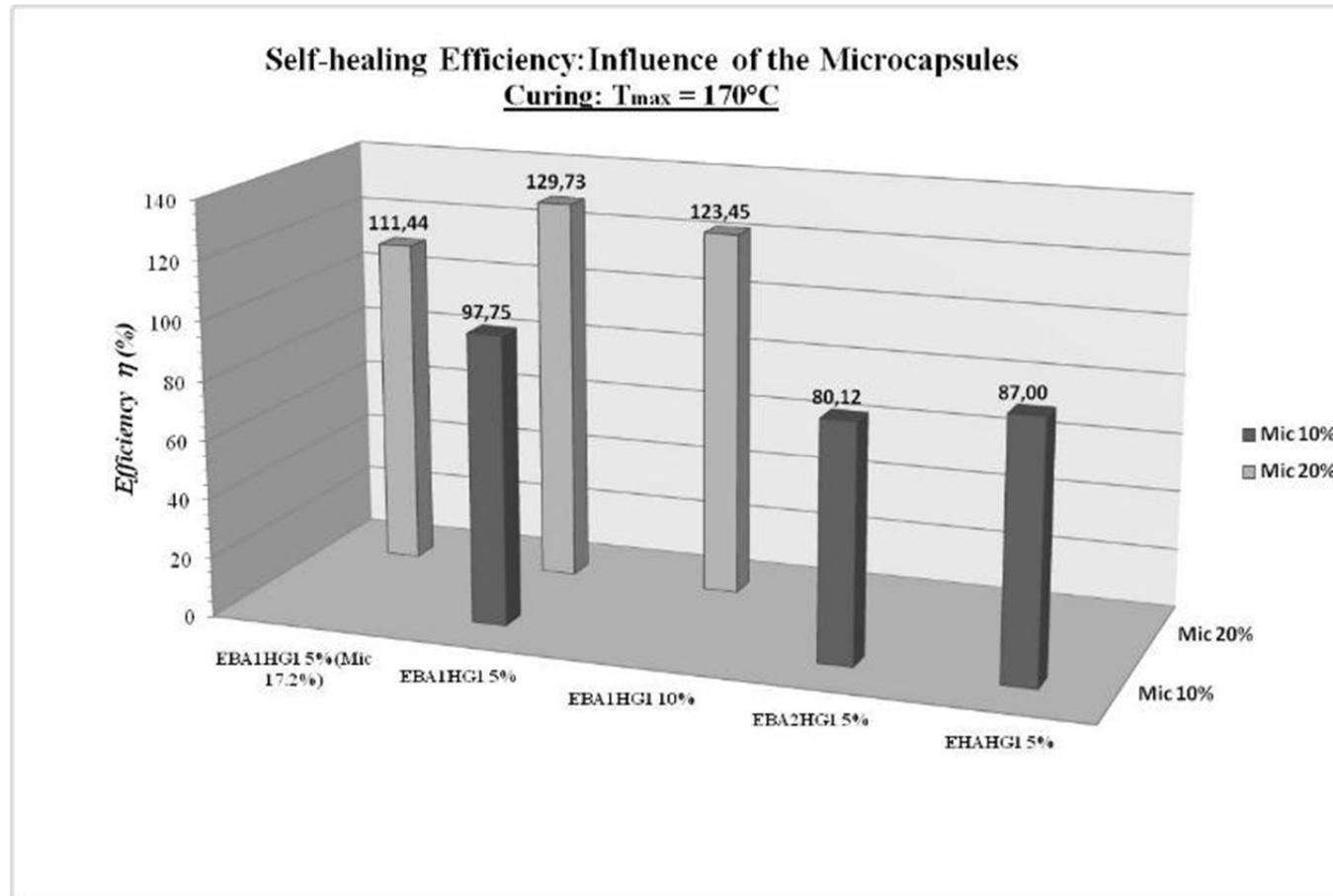


Figure 14: Self-healing efficiency-Influence of the microcapsules amount

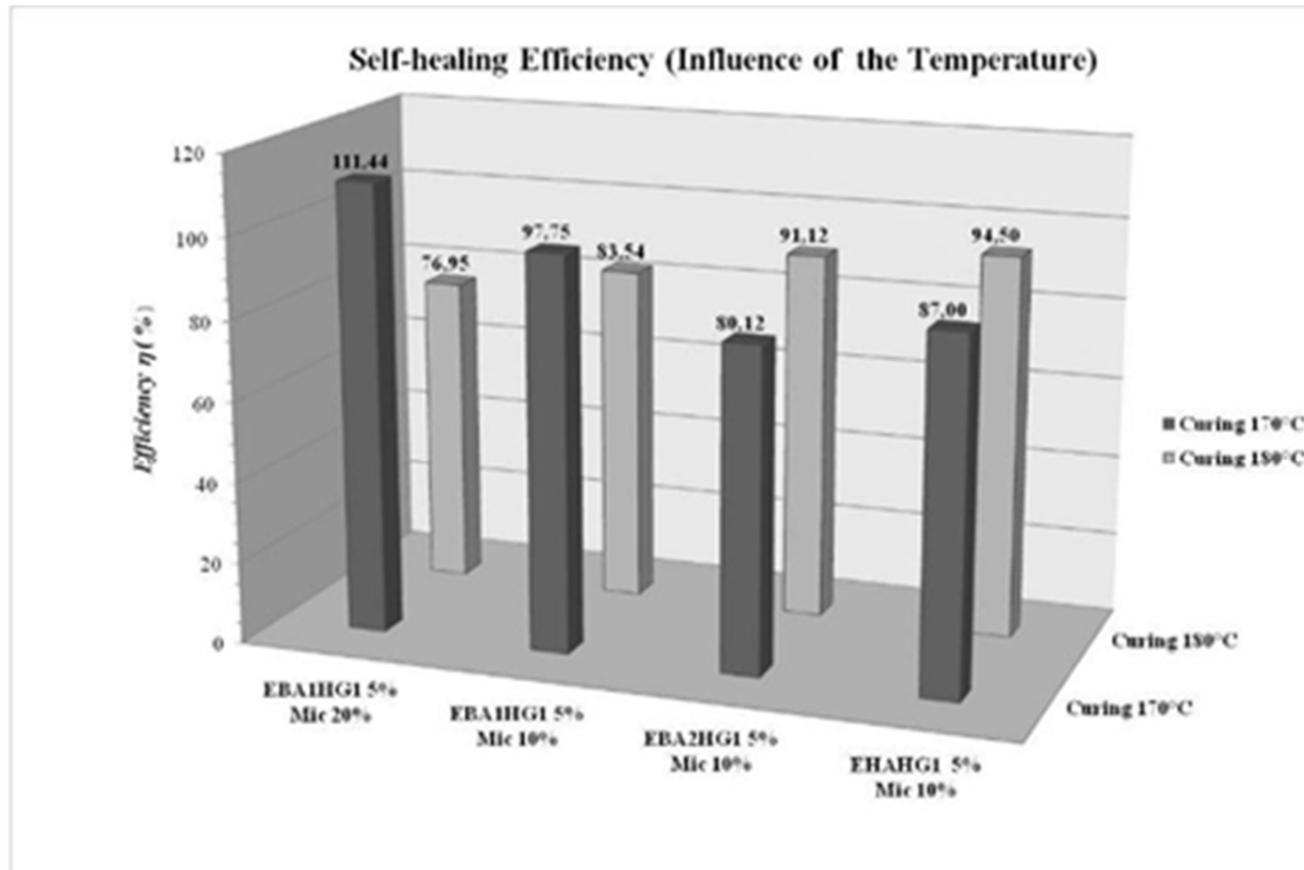


Figure 15: Self-healing efficiency-Influence of the curing temperature

Auto-repair function: RESULTS



Figure 16: different composition of self-healing systems

MATERIAL AND PROCESS REQUIREMENTS (ALA)

T_g (°C)	T_{cure} (°C)	$T_{service}$ (°C)
150	180	-55 to 80

Diagram showing evaluation of requirements:

- T_g (150°C): **NO** (indicated by a red 'X' over an upward arrow)
- T_{cure} (180°C): **OK** (indicated by an upward arrow)
- $T_{service}$ (-55 to 80°C): **OK** (indicated by an upward arrow)

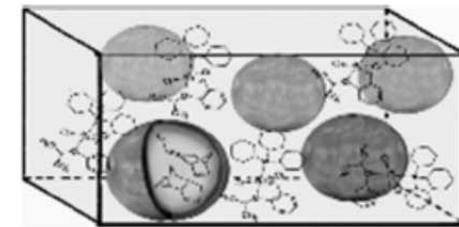


Figure 17: some of the mechanical requirements suggested by Alenia



Figure 18: scheme of the analyzed solutions

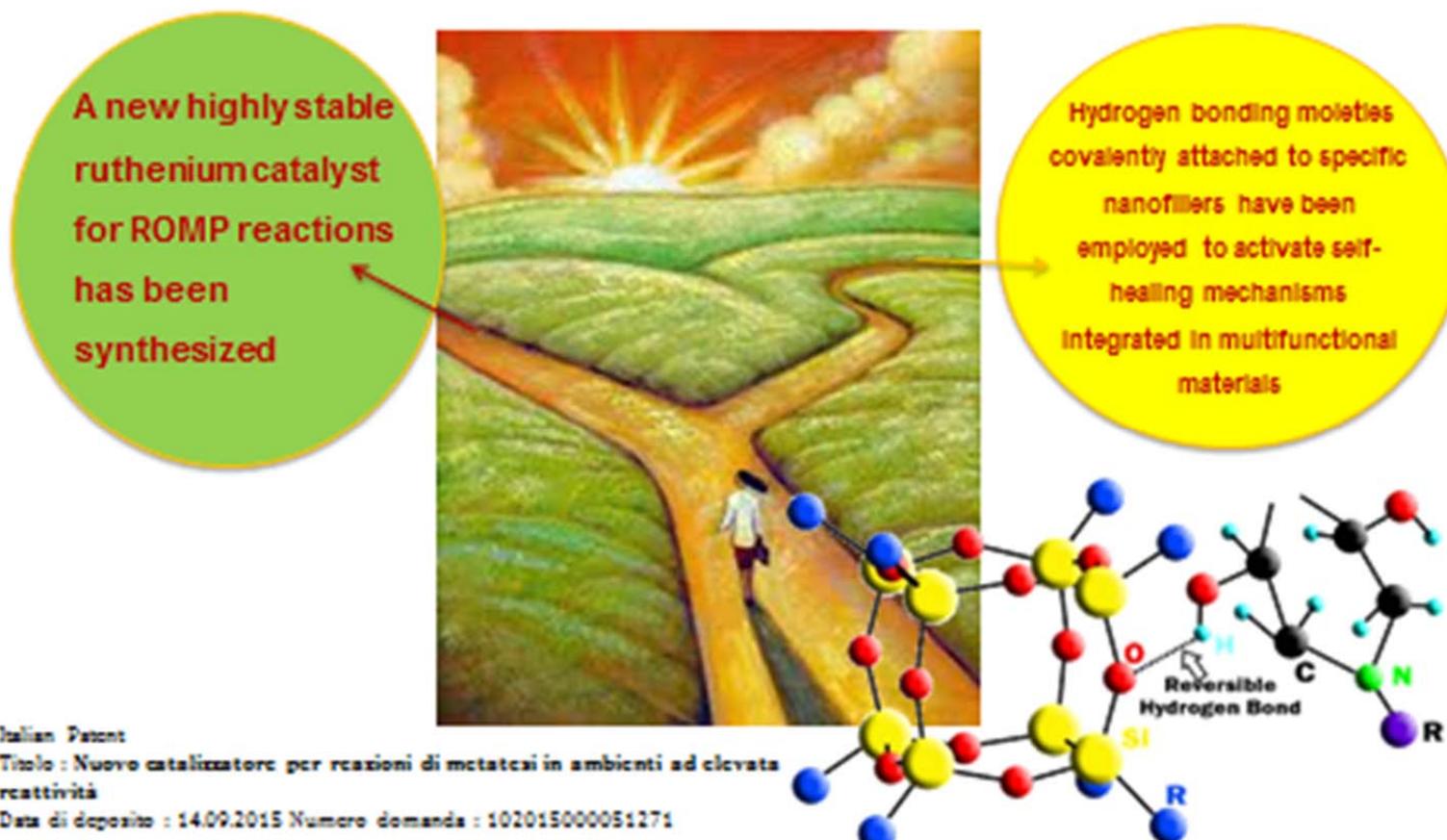


Figure 19: The main results on the self-healing functionalities

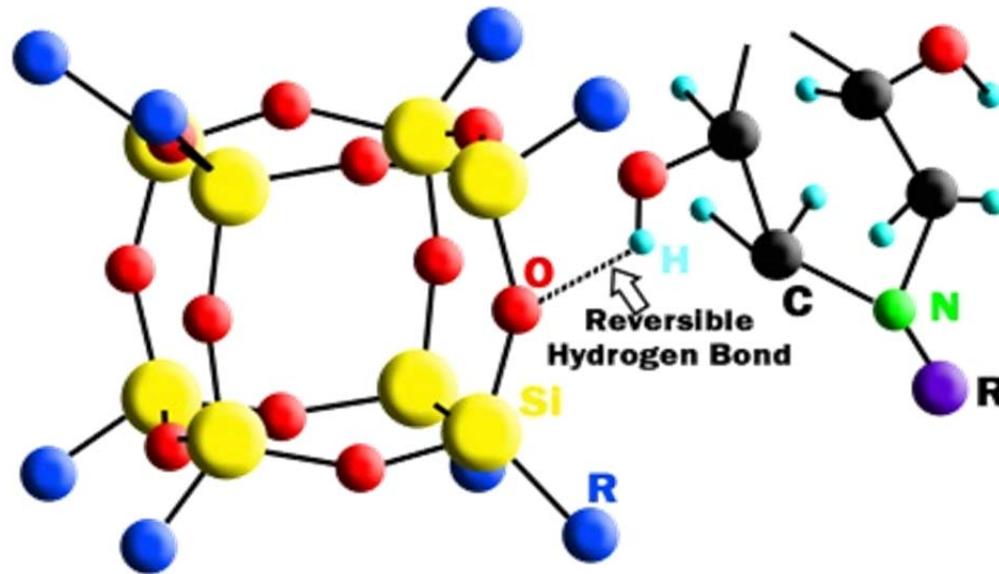


Figure 20. Attractive reversible Hydrogen bonding forces between the nanocages of POSS and chemical groups of the epoxy precursors.

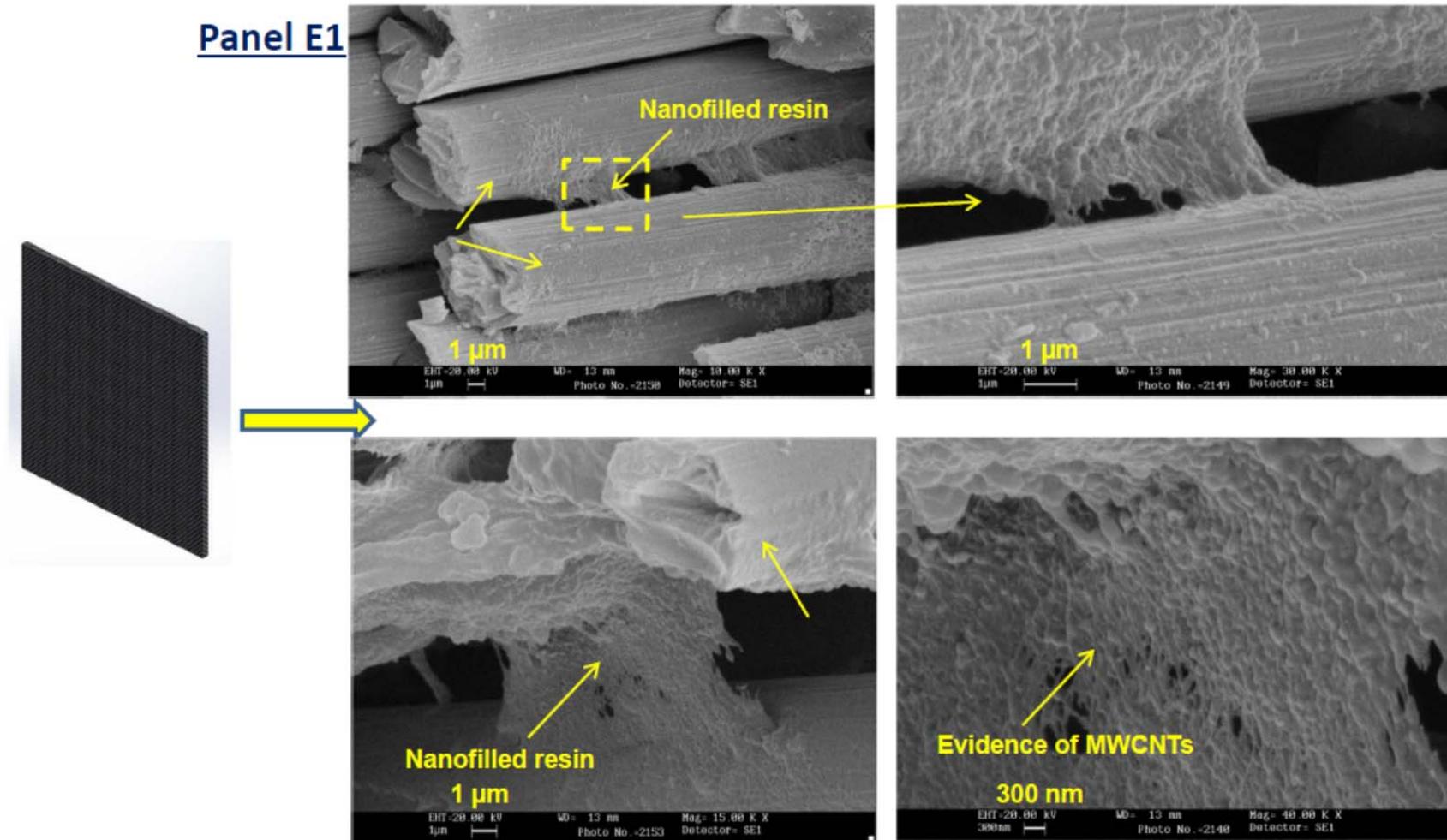
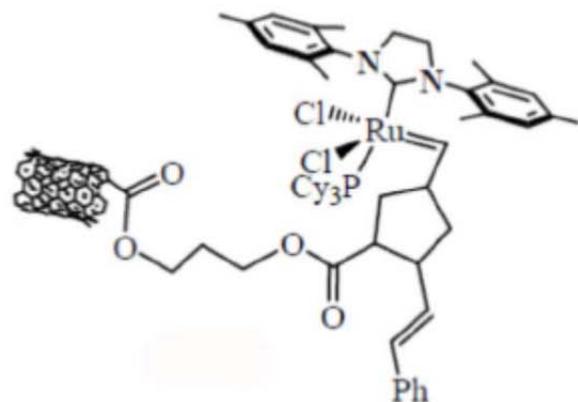
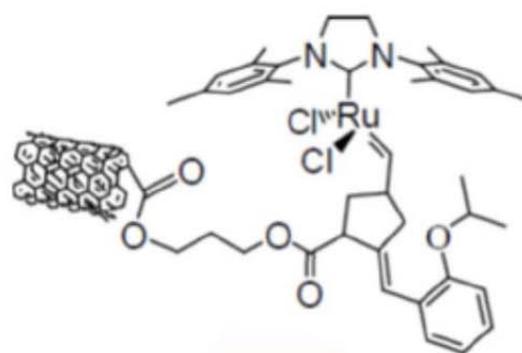


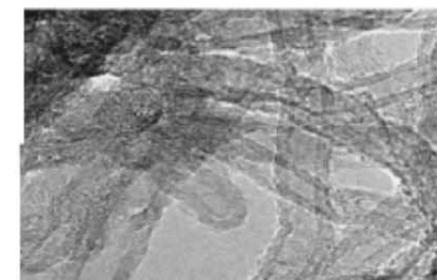
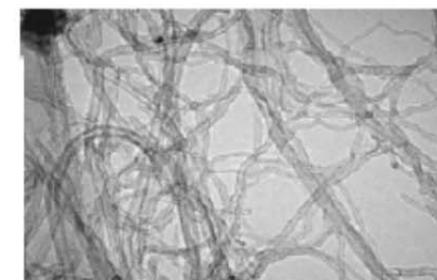
Figure 21: CFRPs manufactured using the developed multifunctional resin.



Carbon nanotube functionalized with Grubbs catalyst 2nd generation (MWCNT-G2_{pr}).



Carbon nanotube functionalized with Hoveyda-Grubbs catalyst 2nd generation (HG2).



High resolution transmission electron microscope images of the MWCNTs

Figure 22: Scheme of the Grubbs catalyst 2nd generation (G2) and Hoveyda-Grubbs catalyst 2nd generation (HG2) covalently bonded on the wall of MWCNTs.



Table 1: List of Panels manufactured with formulation 1

<i>Label</i>	<i>Composition</i>		<i>Manufactured via</i>
	<i>Matrix</i>	<i>Fillers wt/wt %</i>	
<i>First period</i>			
<i>Sample A</i>	<i>T25BD-90DDS</i>	<i>No Filler</i>	<i>LIQUID INFUSION</i>
<i>Sample B</i>	<i>T20BD</i>	<i>No Filler</i>	<i>LIQUID INFUSION</i>
<i>Sample C</i>	<i>T20BD</i>	<i>0.5% CNT</i>	<i>LIQUID INFUSION</i>
<i>Sample D</i>	<i>T20BD</i>	<i>0.5% CNT</i>	<i>BULK INFUSION</i>
<i>Sample E1</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (7 plies)</i>
<i>Sample E2</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (14 plies)</i>
<i>Sample F</i>	<i>T25BD</i>	<i>No Filler</i>	<i>BULK INFUSION (14 plies)</i>
<i>Second period</i>			
<i>Sample E2</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (14 plies)</i>
<i>Sample E3 (5C)</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (24 plies) Con foglio di PEEK 10 micron per DCB specimens</i>
<i>Sample F2 (4B)</i>	<i>T25BD</i>	<i>No filler</i>	<i>BULK INFUSION (24 plies) Con foglio di PEEK 10 micron per DCB specimens</i>
<i>Sample E4</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (24 plies)</i>
<i>Sample E4 (6C)</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS</i>	<i>BULK INFUSION (24 plies)</i>
<i>Sample F3 (5B)</i>	<i>T25BD (Master batch nano4)</i>	<i>No filler</i>	<i>BULK INFUSION (24 plies)</i>
<i>Sample LS1</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS+Flame retardant</i>	<i>BULK INFUSION (8 plies)</i>
<i>Sample G</i>	<i>80%w DGEBA (Epon828) + 20%w BDE) + 10% w of (Epon+BDE) Ankamine 54</i>	<i>No filler</i>	<i>BULK INFUSION (24 plies)</i>
<i>Sample LS2</i>	<i>T25BD</i>	<i>0.5% CNT 5% GPOSS+Flame retardant</i>	<i>BULK INFUSION (8 plies)</i>



<u>Sample E5</u>	<u>T25BD</u>	<u>0.5% CNT</u> <u>5% GPOSS</u>	<u>BULK INFUSION (24 plies) Con foglio di PEEK 10 micron per DCB specimens</u>
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Figure 24: Simple Panels

Figures and tables for final report

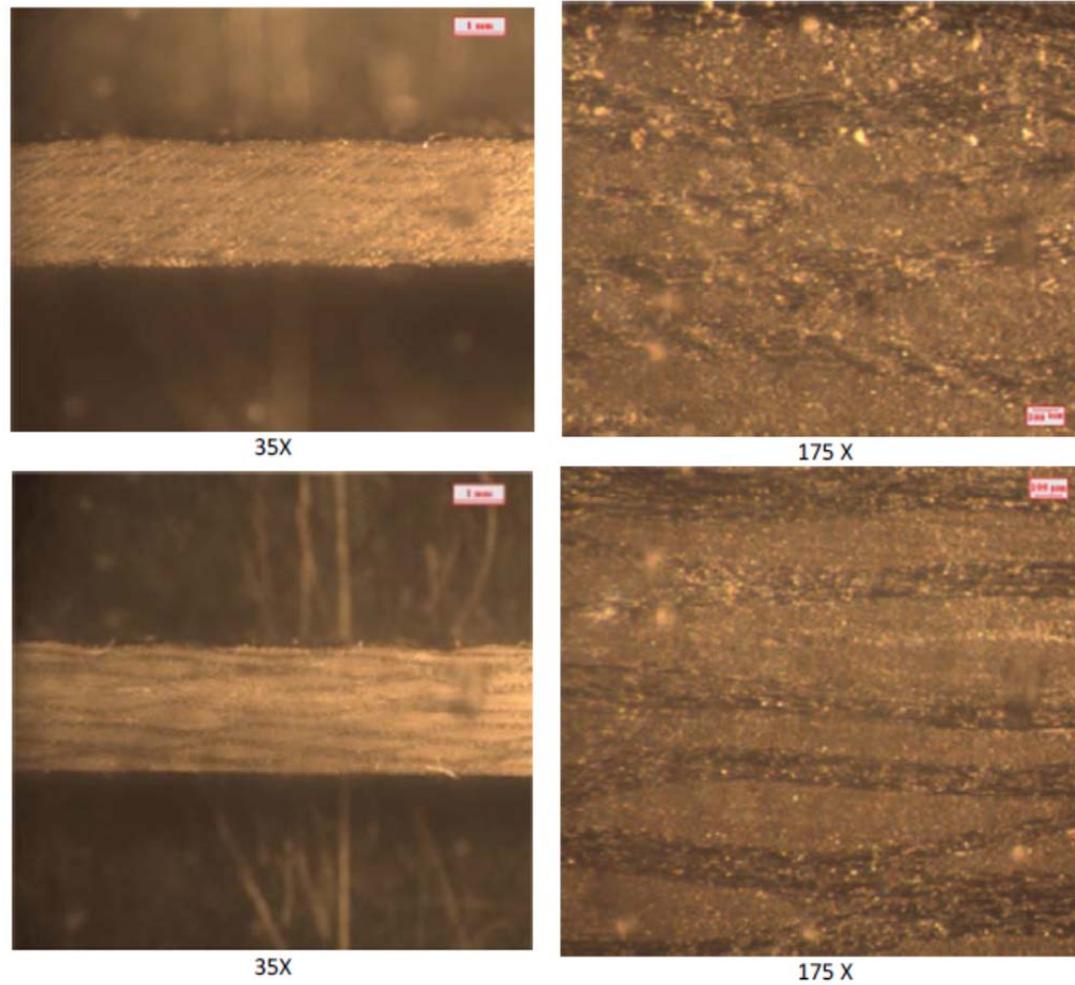


Figure 25: Microscope Inspections

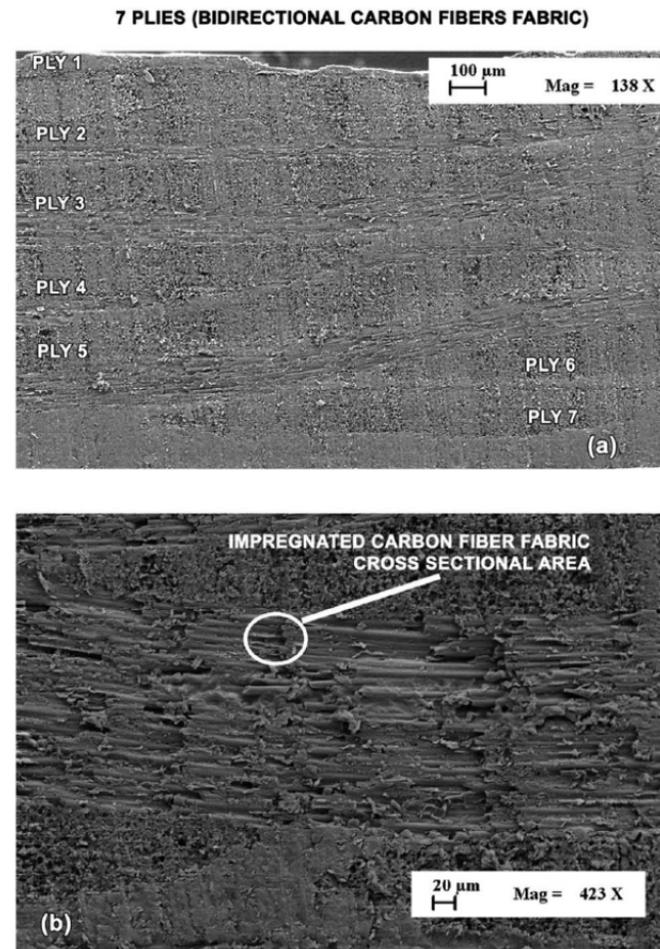


Figure 26: SEM images, at two different magnification, of the cross sectional area of the manufactured panels (7 plies)



Figure 27: Preliminary panels with microcapsules



Figure 28: Panel with microcapsules and reference panels

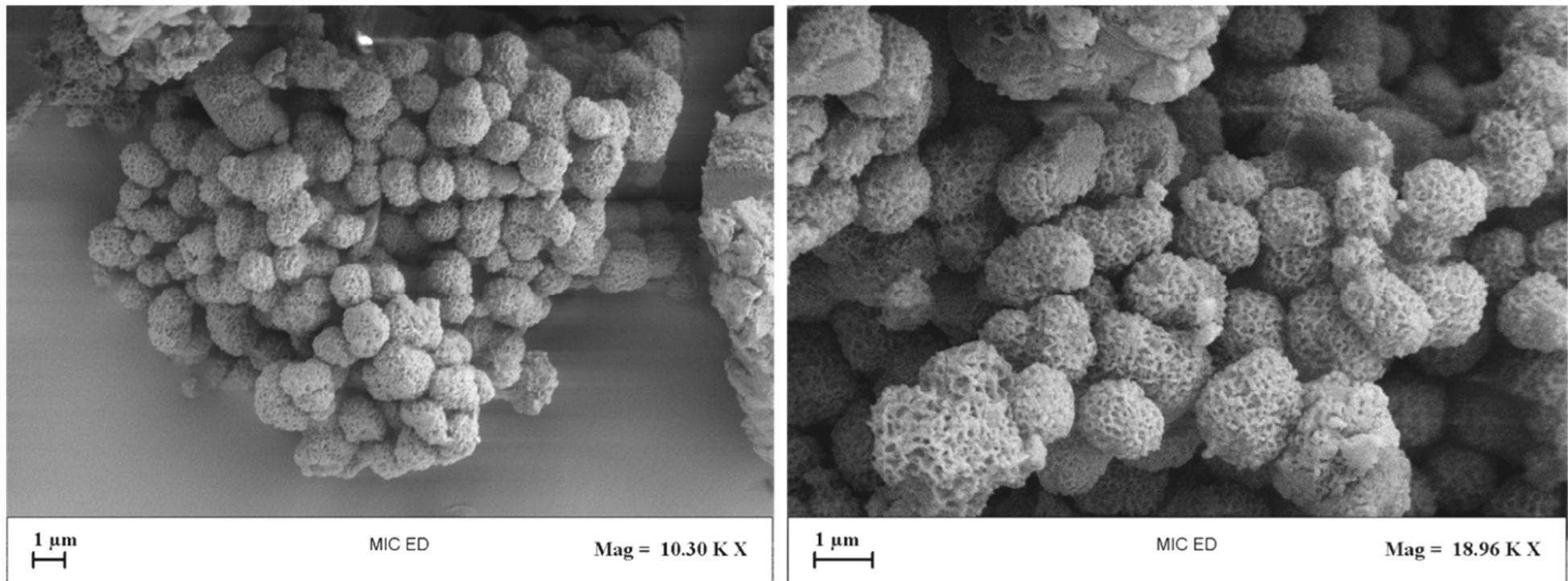


Figure 29: FESEM images of the ENB/DCPD microcapsules used to manufacture panels.

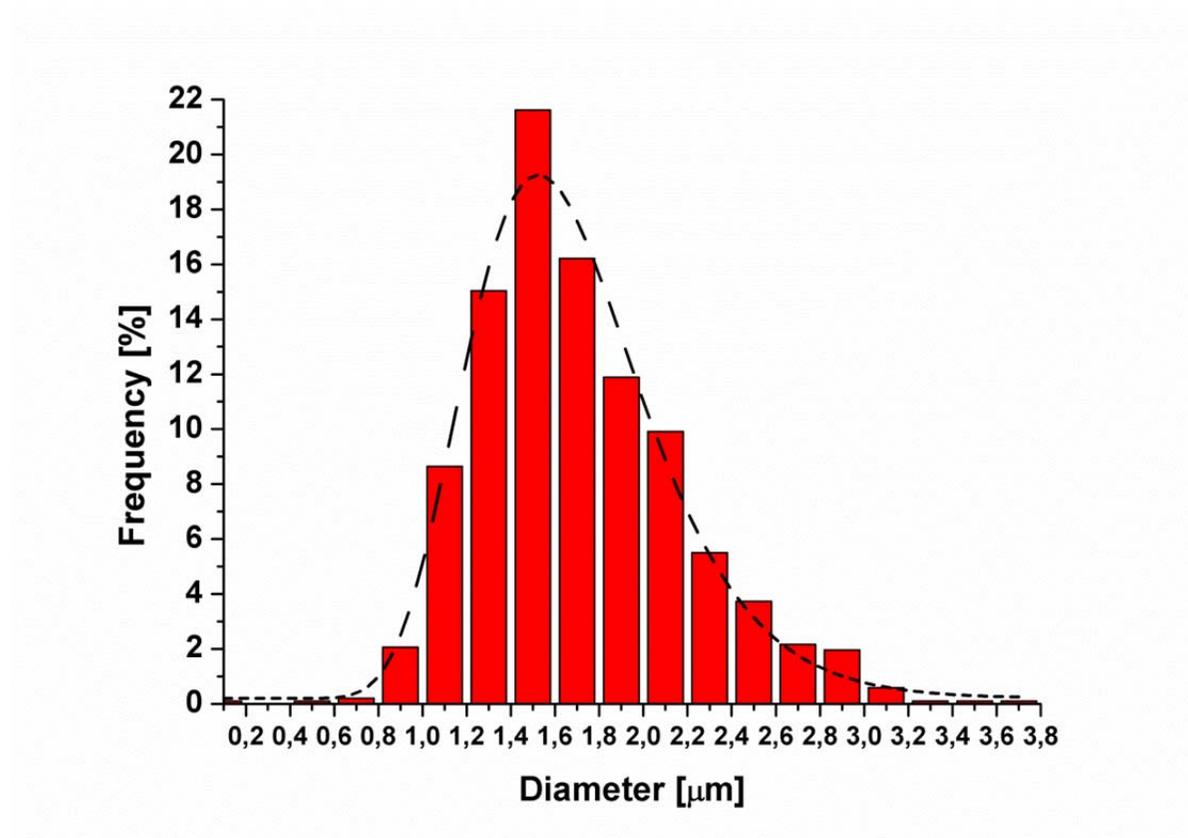


Figure 30: Histogram of the microcapsule diameter

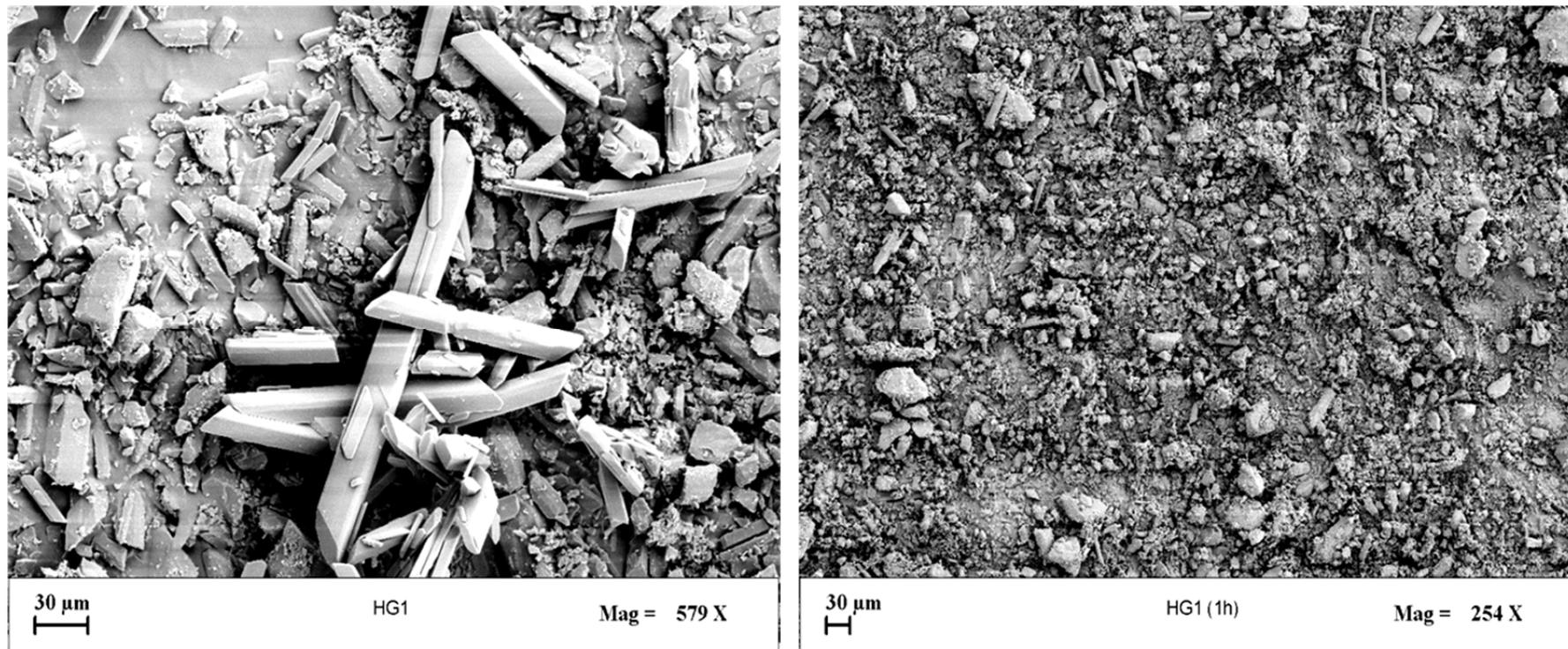


Figure 31: FESEM images of HG1 catalyst before (see on the left) and after (see on the right) pulverization

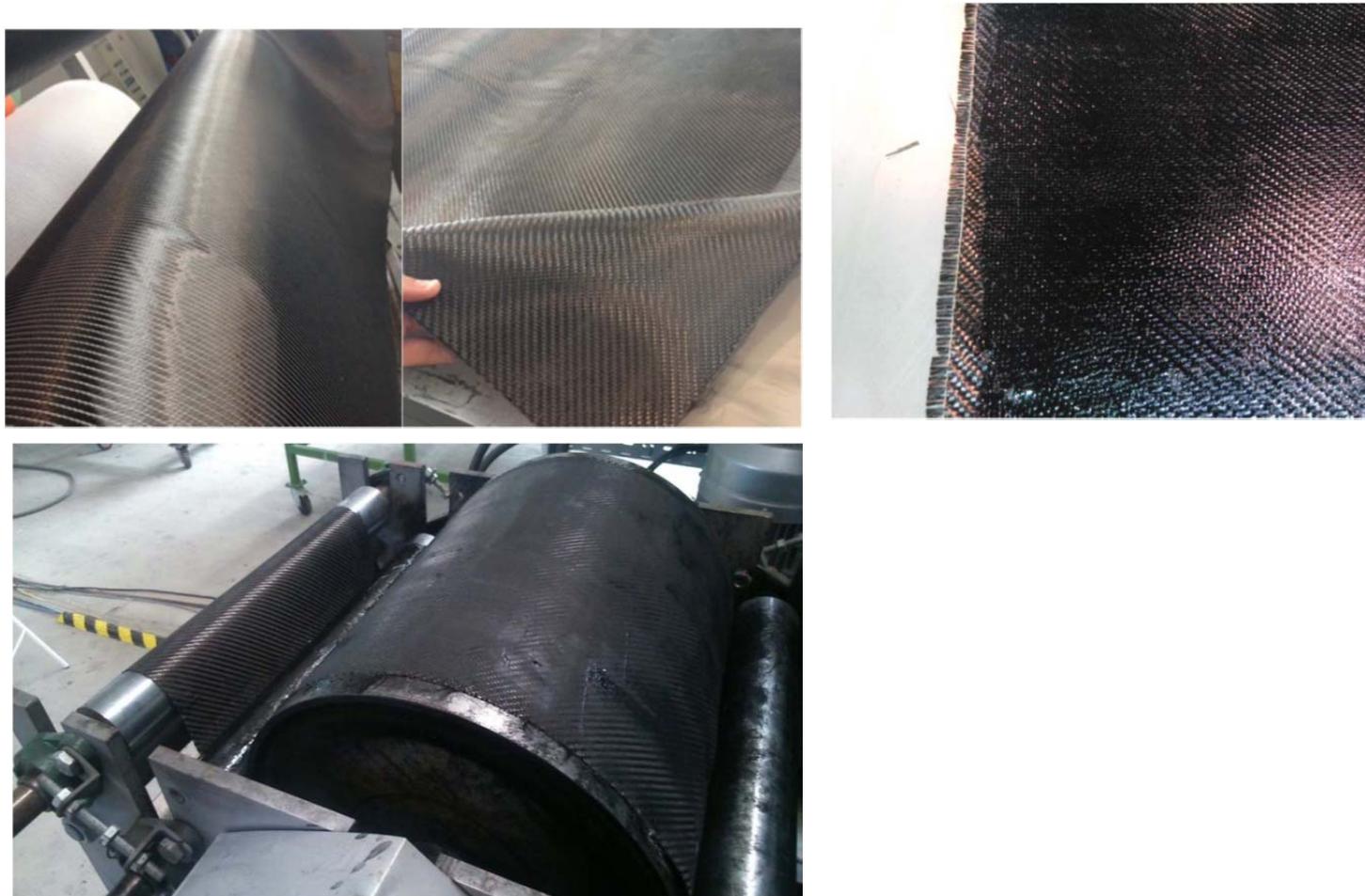


Figure 32: Phases of the manufacturing of prepreg with nanocharged resin

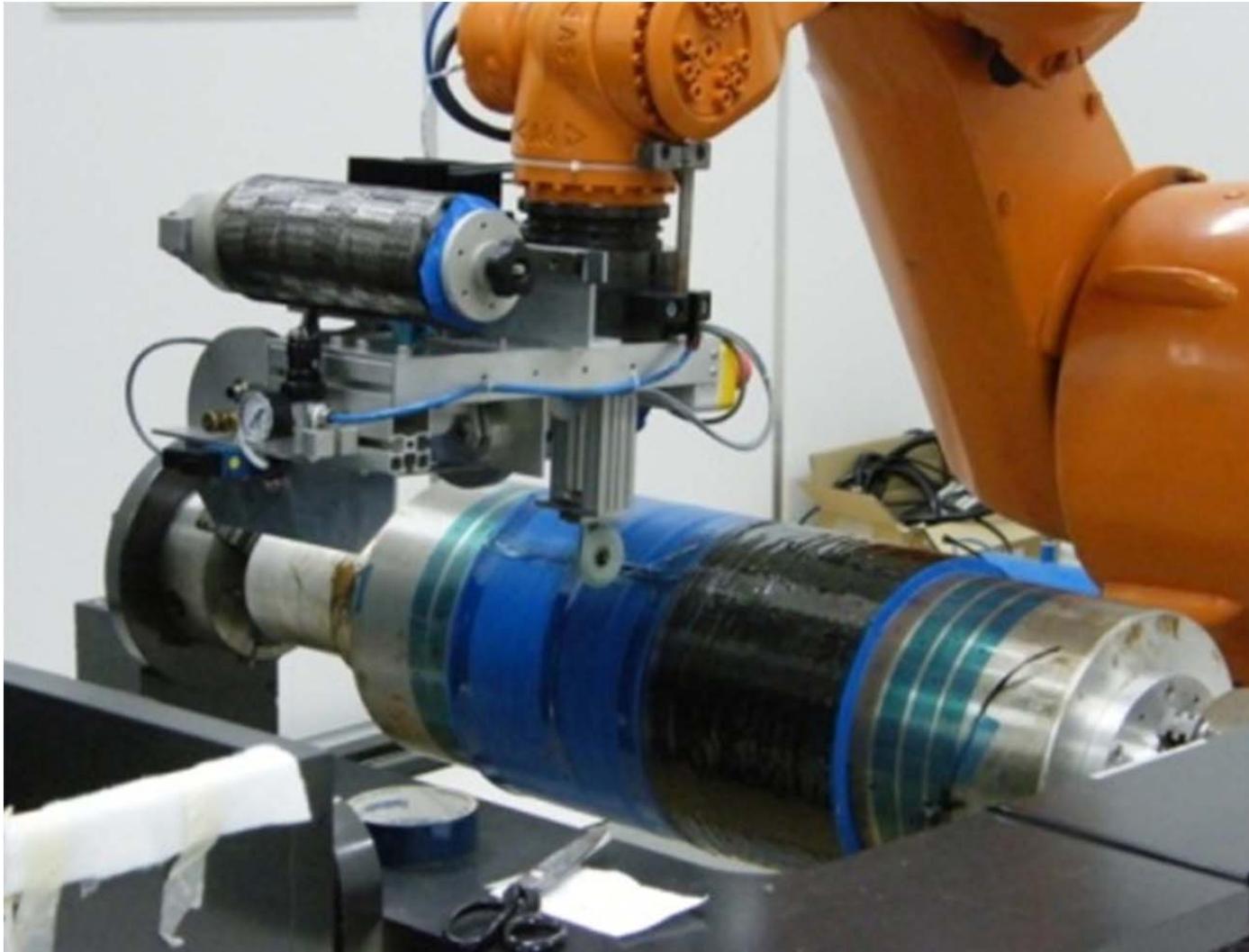


Figure 33: Automated head for wet winding



Figure 34: Wounded cylinder and rings

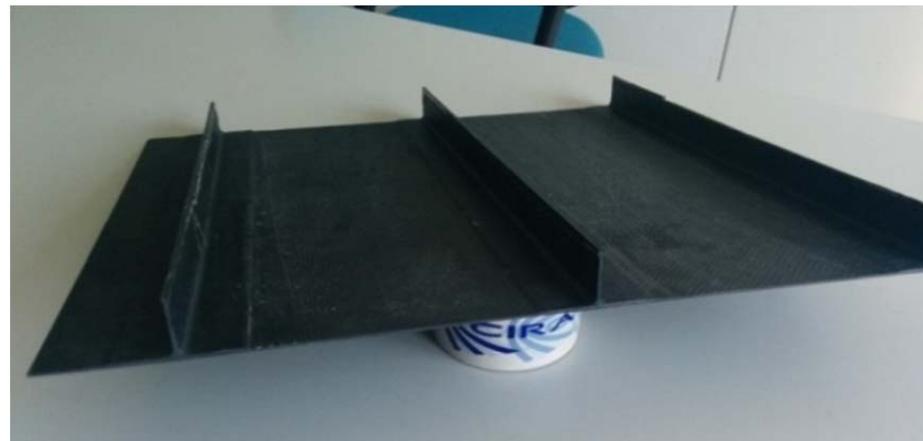


Figure 35: Demonstrator Panel produced by infusio

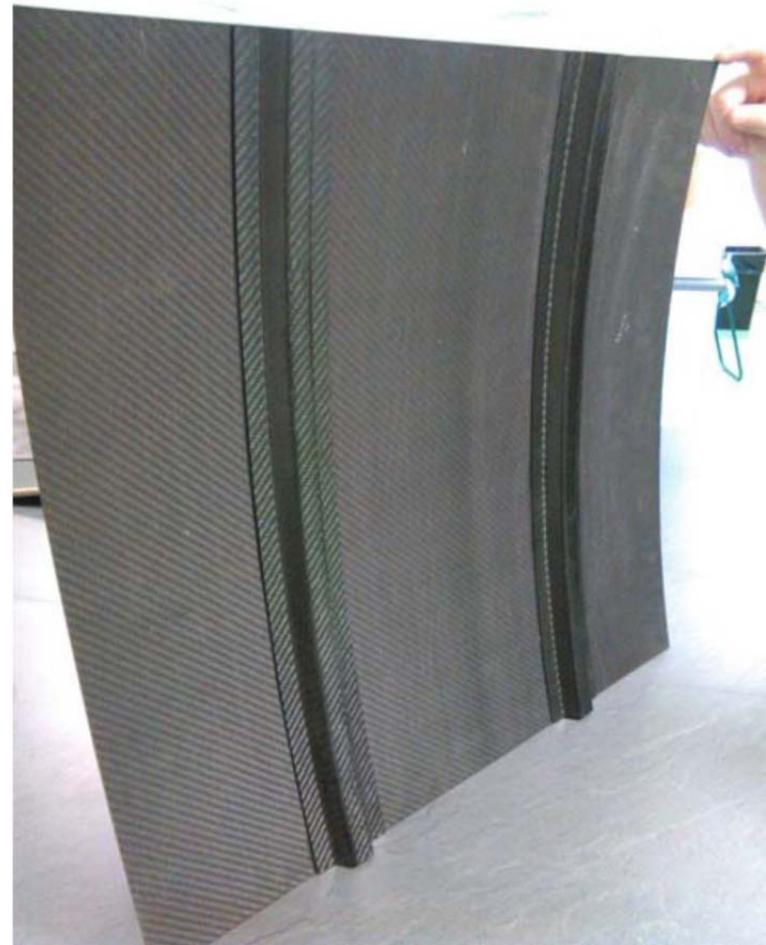
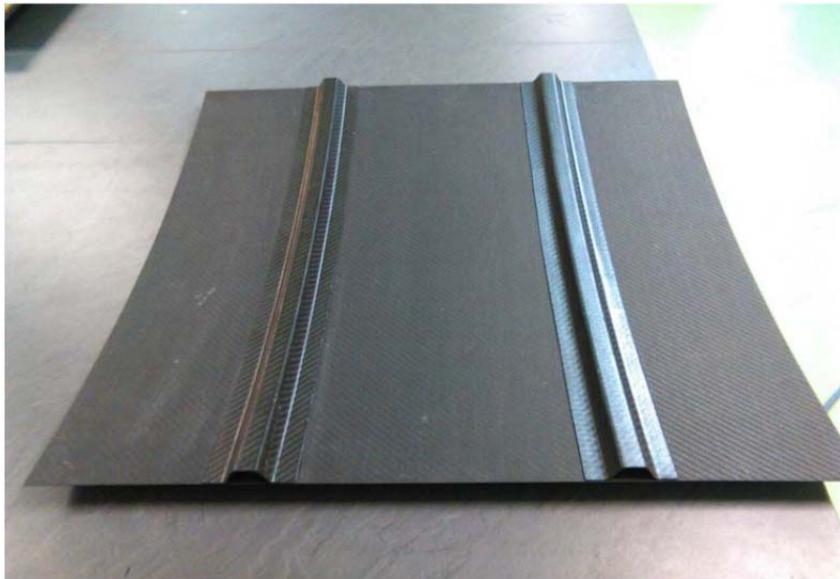


Figure 36: Demonstrator Panel by prepregging.



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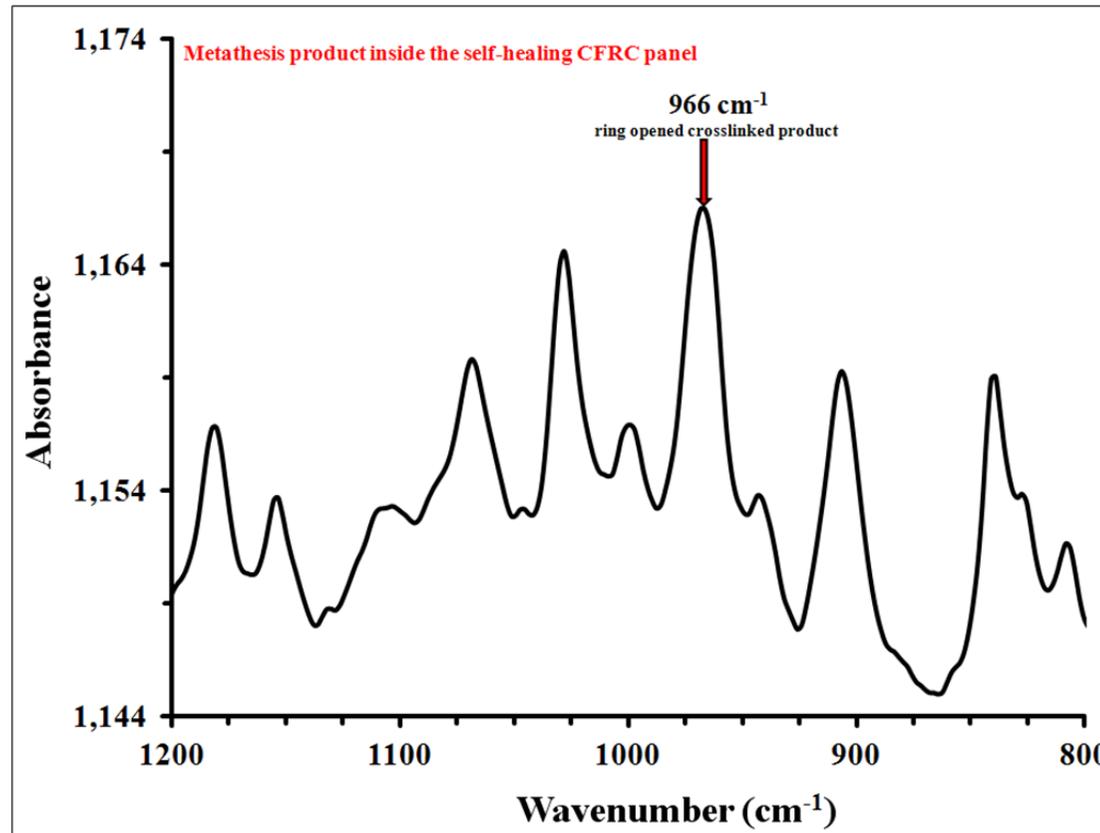


Figure 37. FTIR spectrum of self-healing panel (SH1) powder treated with ENB. The highlighted peak at 966 cm⁻¹ is characteristic of ring-opened poly(ENB)

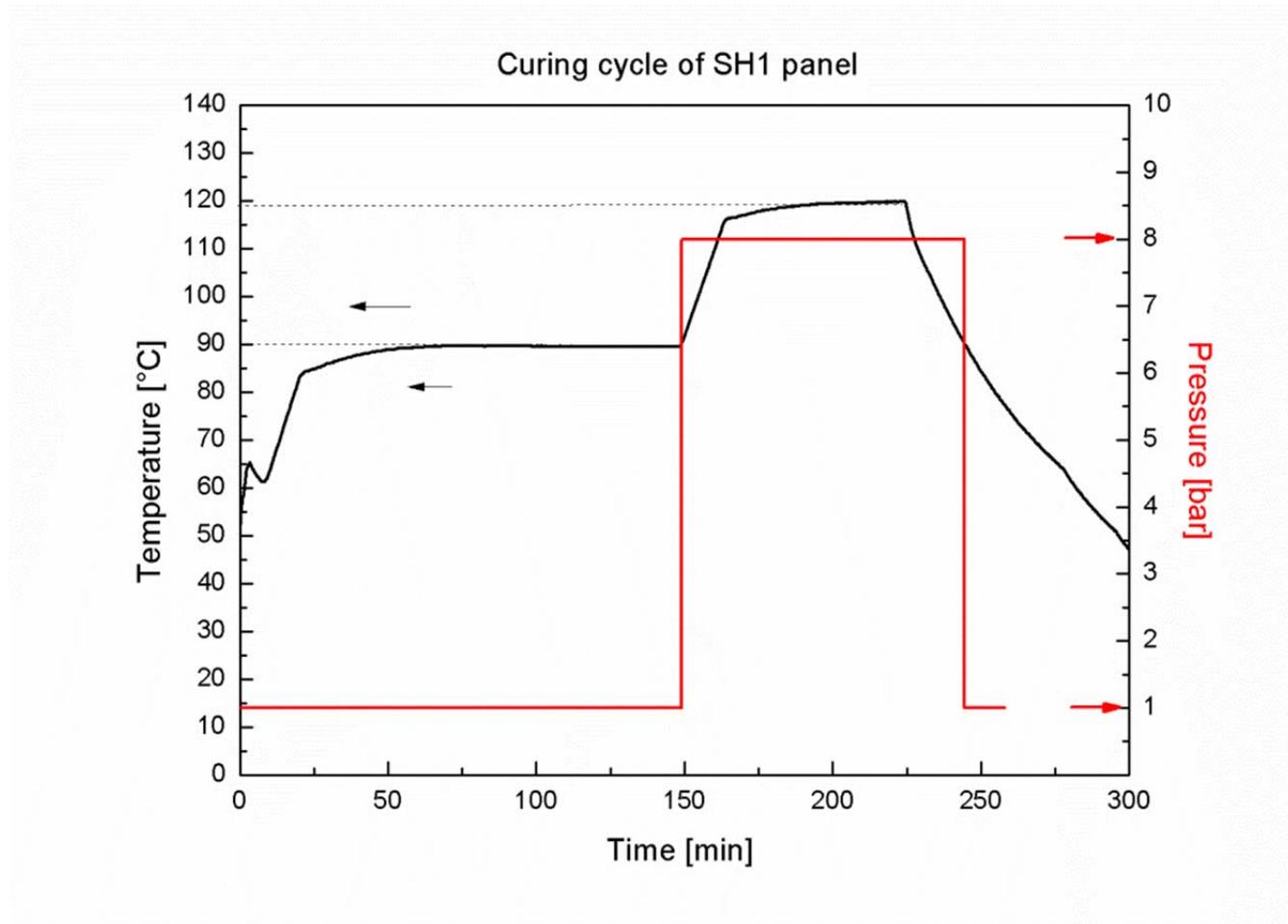


Figure 38. Curing cycle and pressure for the impregnation process

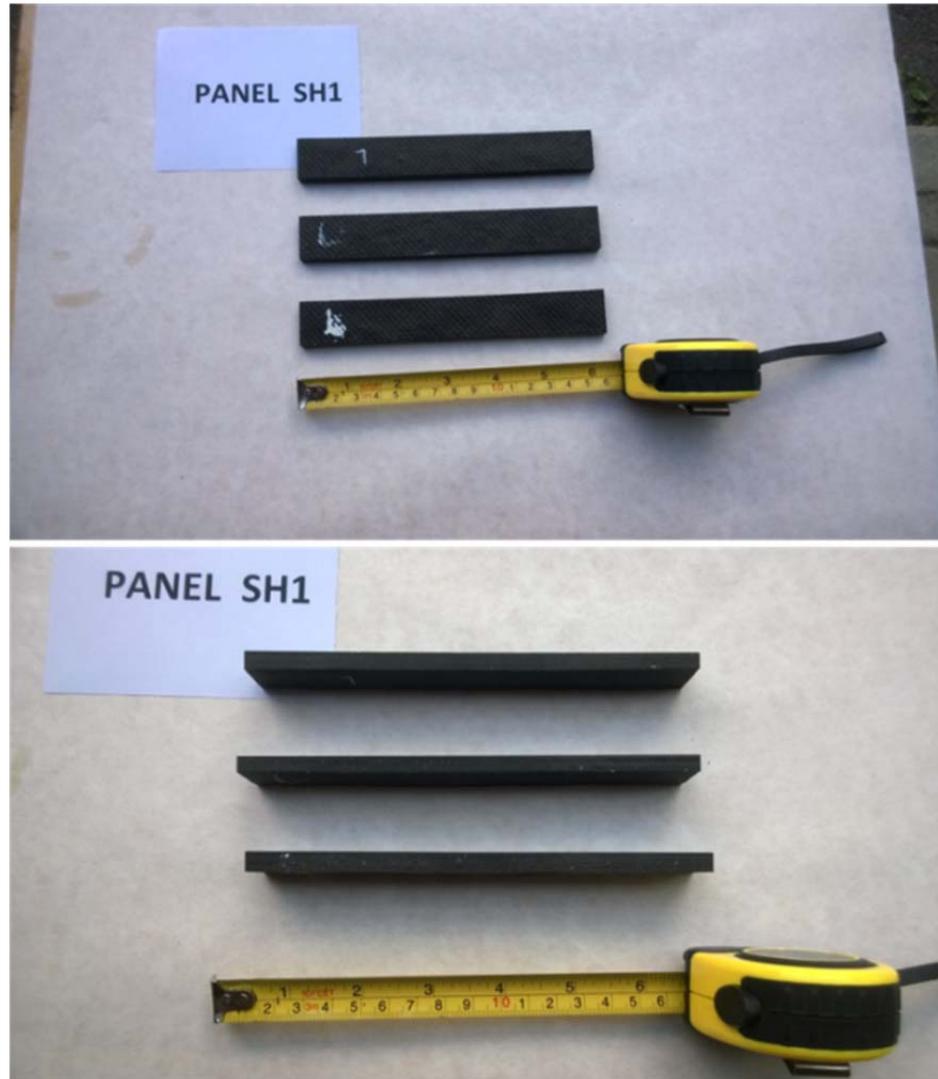


Figure 39. Coupons extracted from self-healing panels

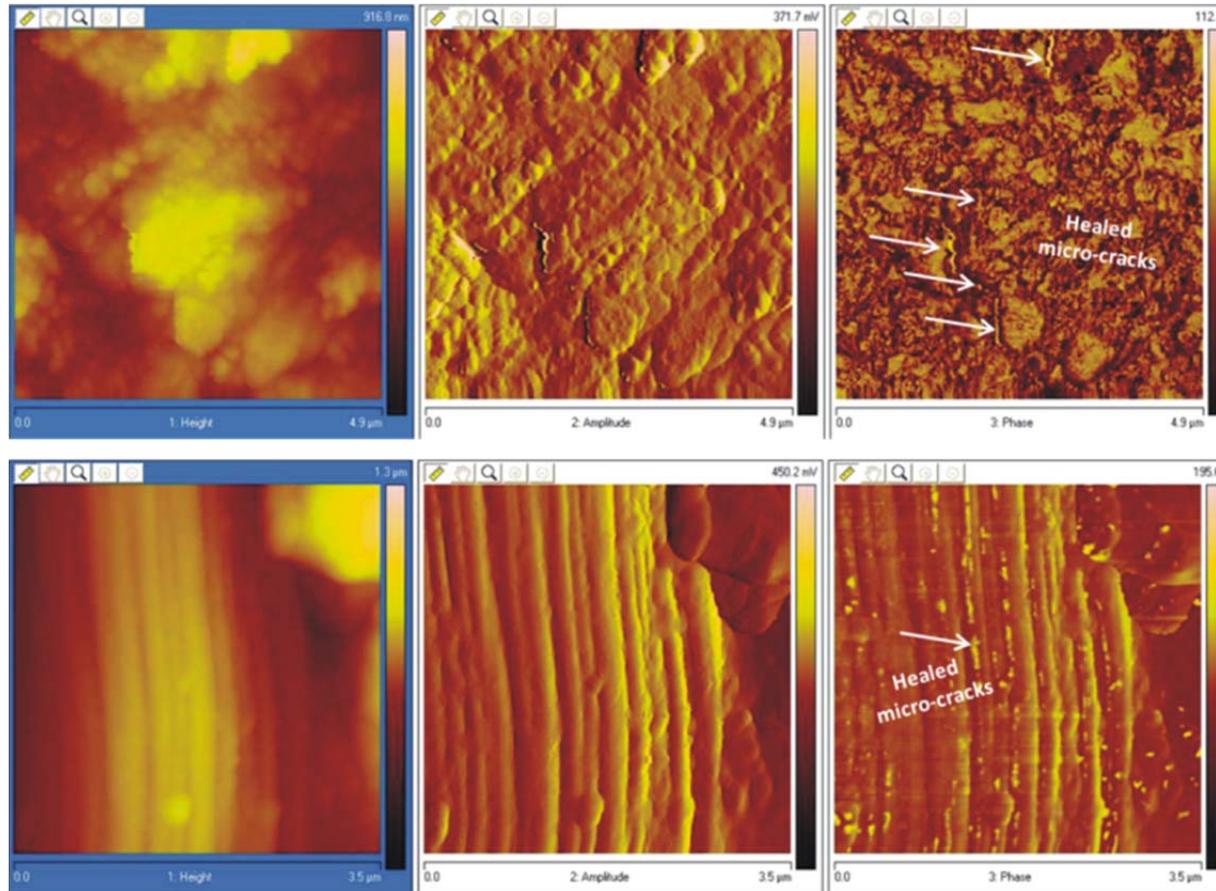


Figure 40. AFM images of fracture surface of the self-healing panel with healed micro-cracks



Figures for description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.

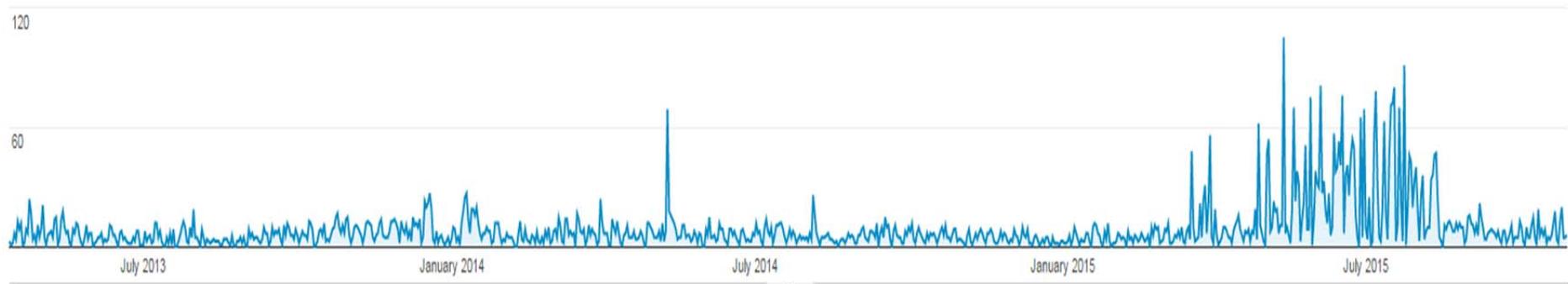


Figure 41: IASS website users, April 2013-October 2015

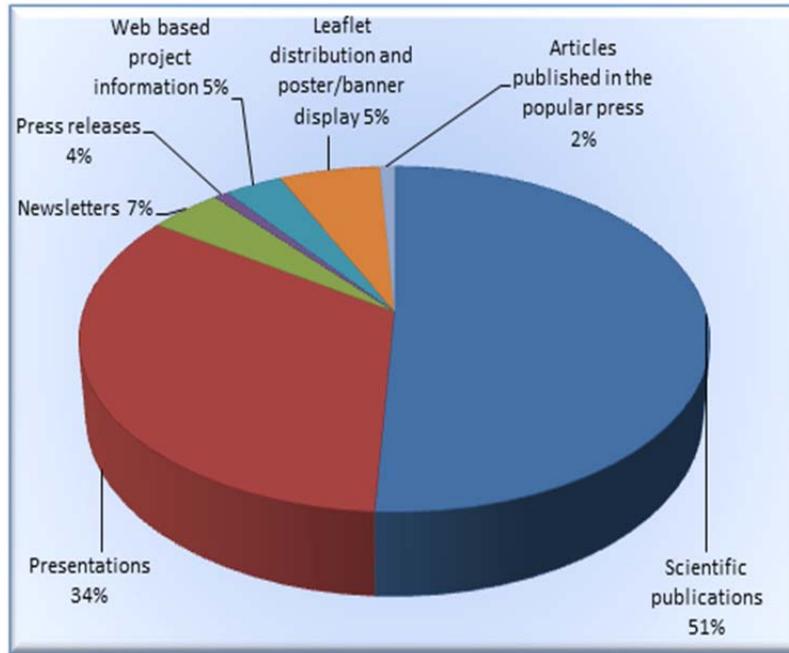


Figure 42: IASS related performed Dissemination Activities

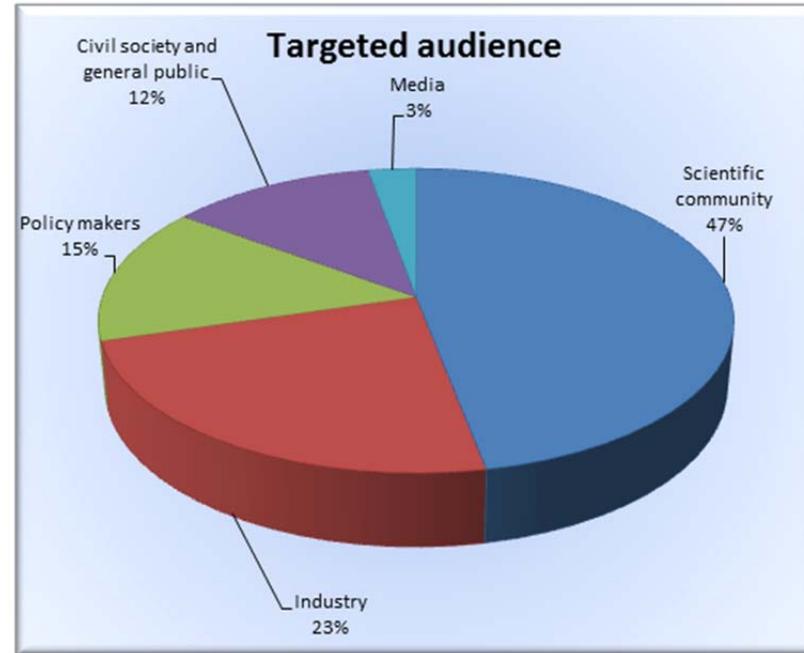


Figure 43: Target groups reached through the dissemination activities realized during the project's second period



Figure 44: Geographic coverage of the performed dissemination activities

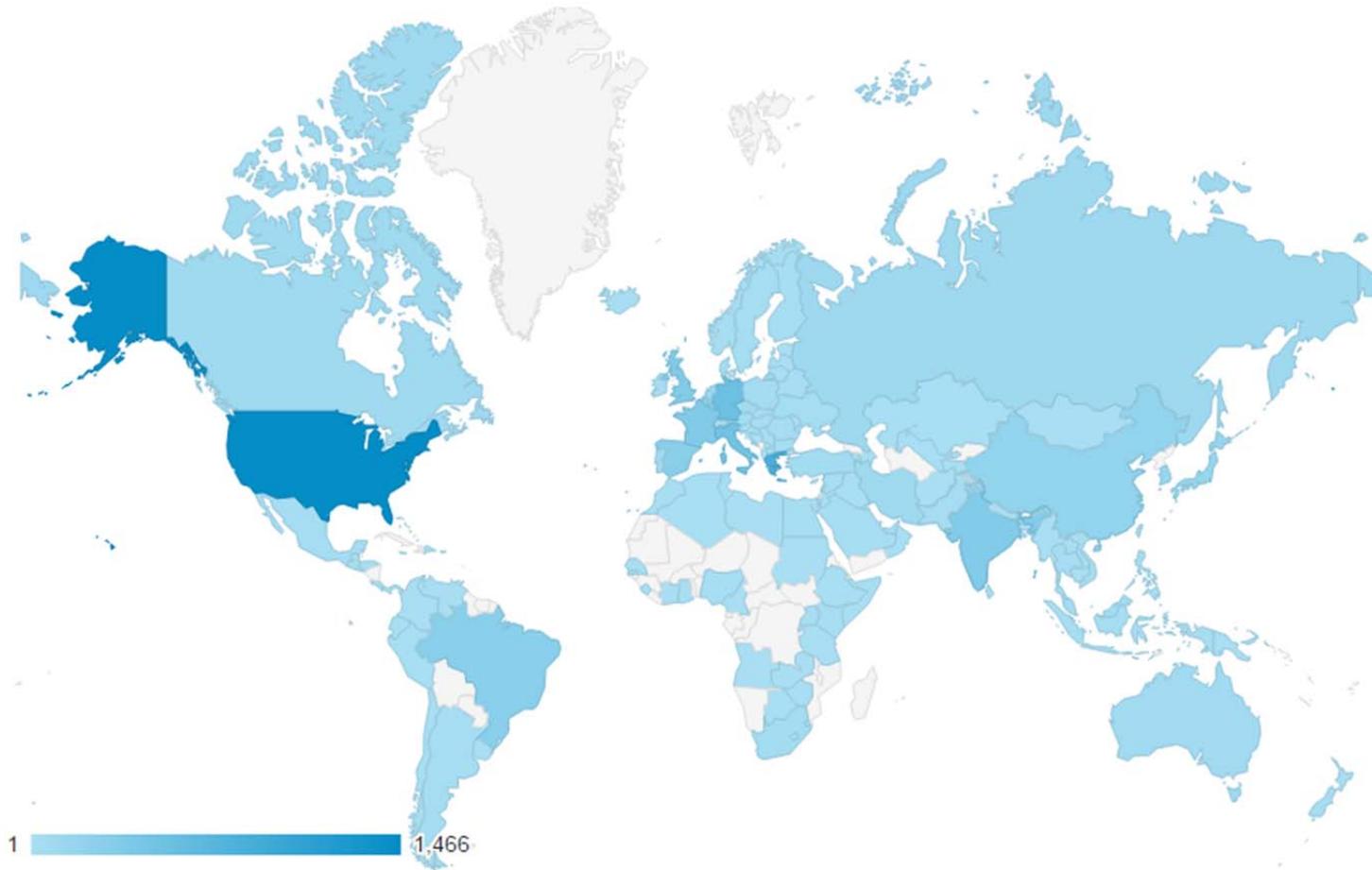


Figure 45: Geographic coverage of the IASS website visitors