Advenit MAKAYA
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HPS High Performance Space Structure Systems GmbH GERMANY

Carbon Nanotube Technology and Material Engineering for Various Space Applications (NATAP)

Executive Summary, NATAP-HPS-RP-100, issue 1

(ESA/ESTEC Contract N° 4000116757/16/NL/LvH/fg)

Prime Contractor:

HPS GmbH (DE)

Subcontractors / Major External Services

FutureCarbon GmbH (DE), TOSEDA s.r.o, Czech Republic (CZ), INVENT GmbH (DE), INEGI (PT), HPS Lda (PT), AAC GmbH (AT)

Carbon nano-materials embedded in composite materials like CFRP can improve specific performance characteristics such as electrical conductivity, resistance to mechanical fatigue and crack propagation, structural damping, PIM reduction, EMC shielding, re-machining and coating capabilities. Some of these improvements were investigated and demonstrated in the GSTP projects "NACO-1" and "NACO-2" performed between 2007 and 2013, as well as in several other TRP- and ARTES-activities. Those activities allowed the contractors and ESA to gain experience in the handling and processing of carbon nanotubes (CNT) for composites, as well as in the characterization of the obtained materials.

The ranking of space applications potentially benefiting of CNT-technology have been changed throughout all activities. The NATAP activity in contract to ESA aimed at finally selecting two applications with highest potential for performance improvements, taking into account all knowledge gained so far, followed by the development and testing of two demonstrators. Applications under trade-off included:

- Satellite Panels (structural improvements through increased ILSS)
- Bonds (electrical and thermal conductivity improvements)
- Electrical grounding paths (for secondary and tertiary structures)
- Feed horns (RF improvements through surface el. conductivity)
- Optical baffles (conductive black paint)
- Optical benches (low CTE with lightweight materials)
- Optical mirrors (surface accuracy)
- Interface plates (e.g. for heatpipes and radiators)
- Thermal heaters (via conductive resin)
- EMC shielding paint (e.g. for electronic box).

Out of this list, the following two demonstrators have been realized.

1.) An optical mirror bear the improvement in very lightweight constructions with comparable characteristics of conventional Zerodur-based mirrors. The realised demonstrator (28 cm diameter) consists of a sandwich structure, composed of CFRP honeycomb, CFRP facesheet and an infiltrated CNT buckypaper, which serves as a “grindable surface” for highest accuracy. This surface was finally coated with a metal layer (by vapor deposition of Al coating and top protective SiO/SiO2 coating layer) for optical reflectivity in the appropriate wavelength.

2.) A radar feed horn for Earth Observation applications was realised out of CFRP with an integrated CNT-coating of a high electric conductivity. Two horns have been manufactured (24 cm diameter, 55 cm length, max. diameter tolerance: 0.8 mm): one with a pure CNT RF-reflective surface and one with an additional aluminum coating (plus Silicon Dioxide layer) on top of the CNT layer. The integrated CNT-coating consists of a high concentration of CNT/graphene applied by spray-technology.

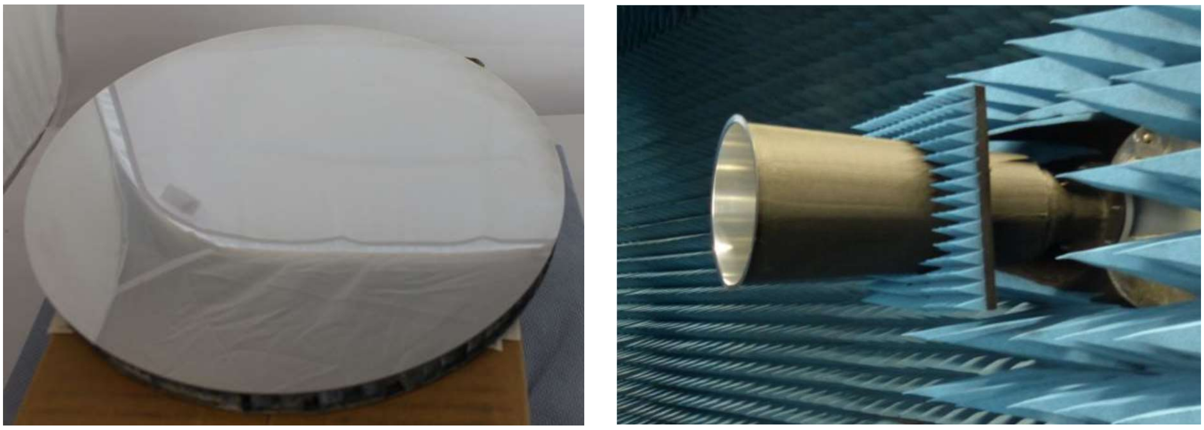

Figure 1: NATAP demonstrators: optical mirror (left), feed horn (right)

The intensive material characterization campaign and the final demonstrator test campaign gave the following major results and conclusions. The last columns show the level of improvement in comparison to conventional solutions (--, -, 0, +, ++):

Optical Mirror		
Mass	More than 20% mass saving in relation to a conventional optical mirror can be achieved. The mirror demonstrator's mass was only 270 gr.	++
CTE	-0.706 x10^{-6}/K in X/Y-direction (requ.: < +/- 1x10^{-6} /K)	++
Thermal conduct.	0.84 W/(m*K), better than required (>0.75 W/(m*K))	+
Specific heat	0.73 J/(kg*°C) acceptable in relation to Zerodur 0.85 J/(kg*°C)	- (can be improved)
Surface accuracy	0.135 µm has been reached, not far away from requirements (<0,1µm)	- (can be improved)
Surface quality	Not reached, many cracks, but ideas for getting rid of the cracks have been identified	-- (can be improved)

Reflectivity	0.7 (after cycling), required value (>0.93) not reached due to cracks in surface	-- (can be improved)
Temperature range	-120 °C - +100 °C	0
Conclusion	The principle of producing a highly accurate optical mirror in CFRP-CNT technology is rated as promising. Mass can be significantly improved at very good thermo-elastic distortion values. Unfortunately many cracks have been detected after thermal cycling, but the team has identified potential solutions to overcome these non-compliances. TRL 3-4 have been reached, starting from 2-3	

Feed Horn		
Mass	Less than 50% of conventional feed horns can be achieved. The horn demonstrator's mass was only 520 gr.	++
CTE	< 1/10 of conventional aluminum solutions	++
Peak Gain	> 16.1 dBi (for the metallised horn, not fully achieved for the horn with just CNT layer)	0
Cross-pol.	< -25 dB (achieved for both horns)	0
Appl. Temperatures	± 150 °C	0
Manufacturability	Is well possible; some aspects are more difficult, but especially for large horns some aspects are less difficult.	0
Conclusion	With a CNT/CFRP feed horn tremendous mass savings can be reached with very high in-orbit thermo-elastic stability. The metal coating sticked very well on the CNT-layer with no print-throughs from CFRP. TRL 4-5 has been reached, starting from 3.	

At the end of the activity a development plan has been proposed for both applications necessary to lift the technology up to TRL 8.

The activity has been performed under contract to ESA between April 2016 and July 2018 by HPS Germany (applications, design of demonstrators, test specification, horn RF test) as prime contractor with the following subcontractors: FutureCarbon Germany (CNT buckypaper and CNT spray), TOSEDA Czech Republic (prepreg for mirror and metallization of mirror and horn), INVENT Germany (Feed Horn Demonstrator manufacturing), INEGI Portugal (buckypaper/resin technology), HPS Portugal (Optical Mirror Demonstrator manufacturing), AAC Austria (sample characterisation and demonstrator testing).

Munich, 24.07.2018