Experiment Proposal

Experiment number GP2024019

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Experiment title	Space aging of shape memory polymer composites for non-explosive actuators	
MRF Instrument	**SEM with correlative AFM**	**Days requested:** 4
Access Route	Direct Access	**Previous GP Number:** No
Science Areas	Engineering, Materials, Physics	**DOI:** -
Sponsored Grant	None	**Sponsor:** -
Grant Title	-	**Grant Number:** -
Start Date	-	**Finish Date:** -
Similar Submission?	-	
Industrial Links	-	

Non-Technical Abstract

The study aims to support designing, manufacturing and testing new-concept non-explosive actuators for self-deploying space structure such as antennas, solar sails, and panels. Non EXplosive Shape memory Actuators (NEXSAs) are based on shape memory polymer composites (SMPCs) which are smart materials with the ability of freezing a non-equilibrium shape after a thermo-mechanical cycle and recovering the initial equilibrium shape by heating in absence of constraints. SMPC samples have been exposed in open space environment by the NASA MISSE (Materials International Space Station Experiment) platform in MISSE9 campaign. In particular the SMPC samples from the MISSE 9 experiment have shown some unexpected behaviours.
As such, in the present proposal we wish to measure the morphology and chemical composition of MISSE-FF flight and backup samples by means of SEM-EDX to complete the characterization of these samples already studied by means optical microscopy, DSC, FTIR and mechanical test.

Publications

L. Santo, F. Quadrini, A.G. Accettura, W. Villadei, Shape memory composites for self-deployable structures in aerospace applications, Procedia Engineering 88C (2014) 42-47.

F. Quadrini, L. Santo L, E.A. Squeo, Shape memory epoxy foams for space applications, Materials Letters 69 (2012) 20-23.

L. Santo et al., Behavior of shape memory epoxy foams in microgravity: experimental results of STS-134 mission. Microgravity Science and Technology 24 (2012) 287-296.

ISIS neutron and muon source — **E-platform:** No

Instruments		**Days Requested:**
Access Route		**Previous RB Number:**
Science Areas		**DOI:**
Sponsored Grant		**Sponsor:**
Grant Title		**Grant Number:**
Start Date		**Finish Date:**
Similar Submission?		
Industrial Links		

ISIS@MACH ITALIA

ISIS Neutron and Muon Source

Science and Technology Facilities Council

Sample record sheet

Principal contact Dr Triestino Minniti, University of Rome Tor Vergata, ITALY

MRF Instrument **SEM with correlative AFM** **Days Requested:** 4

Special requirements:

SAMPLE

Material	Composite	-	-
Formula	-	-	-
Forms	Solid		
Volume	cc		
Weight	0.39 g		
Container or substrate	-	-	-
Storage Requirements	-	-	-

SAMPLE ENVIROMENT

Temperature Range	- K	-	-
Pressure Range	- mbar	-	-
Magnetic field range	- T	-	-
Standard equipment	-	-	-
Special equipment	-	-	-

SAFETY

Prep lab needed	Yes	-	-
Sample Prep Hazards	-	-	-
Special equip. reqs	-	-	-
Sensitivity to air	No	-	-
Sensitivity to vapour	No	-	-
Experiment Hazards	-	-	-
Equipment Hazards	-	-	-
Biological hazards	No	-	-
Radioactive Hazards	-	-	-
Additional Hazards	-	-	-
Additional Details	-	-	-
Sample will be	Disposed by IS	-	-

1. Background and Context

The study aims to support designing, manufacturing and testing new-concept non-explosive actuators for self-deploying space structure such as antennas, solar sails, and panels. Non EXplosive Shape memory Actuators (NEXSAs) are based on *shape memory polymer composites* (SMPCs) which are smart materials with the ability of freezing a non-equilibrium shape after a thermo-mechanical cycle and recovering the initial equilibrium shape by heating in absence of constraints. NEXSA booms are light, and their actuation is intrinsically slow-rate, low-energy, and low-load, thus reducing risks of structure breaking or blocking during deployment. Moreover, the energy for the deployment is mainly stored into the smart material and not provided by stiff springs or explosive charges. A small amount of energy is necessary only for material transition and is provided by heating. A power lower than 10 W is sufficient to deploy booms of any length. SMPCs have been studied for non-explosive actuators (NEA) in space experiments from 2013 (in BION-M1 Soyuz-2 Module). SMPC samples have been exposed in open space environment by the NASA MISSE (Materials International Space Station Experiment) platform in MISSE9, MISSE10, MISSE12 and MISSE13 campaigns. Recently, samples from MISSE campaigns have been recovered and are under testing. In particular the SMPC samples from the MISSE 9 experiment have shown some unexpected behaviours. The typical shape of a sample to be exposed in the MISSE-FF facility is a disk with a maximum diameter of 1 inch (25.4 mm). Design and manufacturing of the SMPC samples is shown in Figure 1. The SMPC laminate consisted of 2 plies of CFR prepreg with 100 µm of SM epoxy resin interlayer. Two disks were trimmed from the prepreg (HexPly M49/42%/200T2X2/CHS-3K supplied by Hexcel) and some cuts were made to allow successive opening of a window into the composite laminate. The SM epoxy resin (3M Scotchkote 206 N) was deposited as free powder during lamination and co-cured with the CFR plies in a metallic mold. Laminate cure was performed on a heat plate at a temperature of 150°C for 30 min with applied pressure of 70 kPa. The internal window was opened by means of a successive thermo-mechanical cycle with a proper shaping mold (Figure 1). The sample was heated over 150°C and a punch was used to open the window. Subsequently the entire assembly was left to cool in air, and the deformed SMPC sample was extracted.

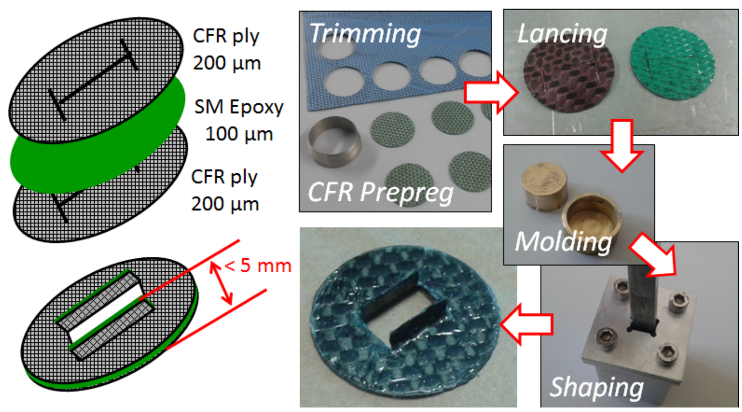

Figure 1 – Design and manufacturing of SMPC samples for long-term exposure to Space environment in LEO

The flight samples were positioned in different orientations on the MISSE-FF platform: M9W-C10F was flown in the wake orientation, which is parallel to the ISS trajectory but in the opposite direction, and M9Z-C17F was flown in the zenith orientation, which is normal to the ISS trajectory and opposite to the Earth. The MISSE-FF and MISSE-9 experiments were launched on the SpaceX-14 mission on April 2, 2018. The MISSE-9 carriers were installed in the MISSE-FF platform and deployed on April 19, 2018, thus exposing the samples to the space environment. The zenith and wake samples were retrieved on April 26, 2019, and returned to Earth with the SpaceX-17 mission on June 3, 2019. The samples were exposed to space vacuum for 1.07 years and were directly exposed to the LEO space environment for 0.54 years.

2. Proposed experiment
In the present proposal we wish to measure the morphology and chemical composition of MISSE-FF flight and backup samples by means of SEM-EDX to complete the characterization of these samples already studied by means optical microscopy, DSC, FTIR and mechanical tests. To this end, we wish to use the SEM with correlative AFM instrument operating at the University of Rome Tor Vergata Unit. Results from SEM image and EDX spectra measured in this experiment will be compared with results of the characterization already performed by the proponents.

3. Summary of previous experimental proposals or characterisation
Microscopy, DSC, FTIR and mechanical tests were carried out on flight and backup samples. Results show that flight samples behaved differently, because of their different orientation on MISSE-FF. The applied deformed shape was partially recovered on the sample with zenith orientation during its exposure, but both flight samples did not show any additional shape recovery on-Earth. The other sample, with wake orientation, froze the non-equilibrium shape permanently.

4. Justification of experimental time requested
MISSE-FF flight and backup samples will be measured by SEM, EDX scans using a field of view and magnification which depends on the size of eventual damage. We predict n. 10 images per sample to cover the 25.4 mm maximum diameter. Hence, after discussion with the instrument scientist, we request 4 days of instrument time including set-up and calibration time.

5. References

[1] L. Santo, F. Quadrini, A.G. Accettura, W. Villadei, Shape memory composites for self-deployable structures in aerospace applications, Procedia Engineering 88C (2014) 42-47.

[2] L. Santo, F. Quadrini, L. De Chiffre, Forming of shape memory composite structures, Key Engineering Materials 554-557 (2013) 1930-1937.

[3] L. Santo, F. Quadrini, E.A. Squeo, F. Dolce, G. Mascetti, D. Bertolotto, W. Villadei, P.L. Ganga, V. Zolesi, Behavior of shape memory epoxy foams in microgravity: experimental results of STS-134 mission. Microgravity Science and Technology 24 (2012) 287-296.

[4] F. Quadrini, L. Santo L, E.A. Squeo, Shape memory epoxy foams for space applications, Materials Letters 69 (2012) 20-23.

[5] L. Santo, F. Quadrini, P.L. Ganga, V. Zolesi, Mission BION-M1: results of Ribes/Foam2 experiment on shape memory polymer foams and composites, Aerospace Science and Technology 40 (2015) 109-114.