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Science and Technology Facilities Council
ISIS Neutron and Muon Source

Experiment Proposal

Experiment number GP2024021

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Experiment title	DMA characterization of CNT-based surface composites for sensors applications
MRF Instrument	**Dynamic Mechanical Analyzer**
Access Route	Direct Access
Science Areas	Materials, Medicine
Sponsored Grant	None
Grant Title	-
Start Date	-
Similar Submission?	-
Industrial Links	-

Days requested: 3
Previous GP Number: GP2023008
DOI: -
Sponsor: -
Grant Number: -
Finish Date: -

Non-Technical Abstract

Surface composite made of polymer films and carbon nanotubes (CNTs) are a promising class of composite materials that can be used in innovative stretchable sensors. Electrical and mechanical properties can be tuned by properly choosing the polymer substrate, thus making them suitable for different applications. Analysis of the mechanisms of the grafting process of CNTs on the polymer substrates and of the interactions between the two components have been carried out by SEM and Confocal Raman Microscopy the occurring of different processes for thermoplastic and thermosetting polymers. We here propose to complement the characterization studying two CNT deposited on a two different polymer substrates chosen as representative examples of the two different classes of polymers (i.e. thermoplastic thermosetting ones), by means of Dynamic Mechanical Analysis (DMA), to better understand the material response to stress and the possible consequences on their functional behaviour.

Publications

Fazi, Laura, et al. "Characterization of conductive carbon nanotubes/polymer composites for stretchable sensors and transducers." Molecules 28.4 (2023): 1764.

Sample record sheet

Principal contact Dr Laura Fazi, University of Rome Tor Vergata, ITALY
MRF Instrument **Dynamic Mechanical Analyzer** **Days Requested:** 3
Special requirements:

SAMPLE

Material	polymer CNT composite	-	-
Formula	polymer CNT composite	-	-
Forms	Solid		
Volume	5 cc		
Weight	5 g		
Container or substrate	-	-	-
Storage Requirements	-	-	-

SAMPLE ENVIROMENT

Temperature Range	300 - 400 K	-	-
Pressure Range	1000 - 1000 mbar	-	-
Magnetic field range	- T	-	-
Standard equipment	None	-	-
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	-	-	-
Radioactive Hazards	-	-	-
Additional Hazards	-	-	-
Additional Details	-	-	-
Sample will be	Disposed by IS	-	-

DMA characterization of CNT-based surface composites for sensors applications

1. Scientific Background

Surface composites made of polymer films and carbon nanotubes (CNTs) are a promising class of composite materials that can be used in innovative stretchable sensors [1]. In fact, they couple the elasticity and plasticity of polymer films with the electrical properties of CNTs. By properly choosing the polymer substrate, one can obtain different electrical and mechanical behaviours, making them suitable to different applications ranging from biomedical devices to actuators [2]. Beyond the choice of the material, the composite materials need to be characterized in terms of the grafting mechanisms of the CNTs on the polymer substrates, because from them follow the electrical and mechanical properties [3,4]. To better understand such mechanisms, many investigations have been made with microscopy techniques such as conventional Scanning Electron Microscopy and Confocal Raman Microscopy to try to clarify the interaction between the CNTs below the polymer surfaces. To understand how the consequences of these interactions influence the mechanical behaviour a dynamic mechanical characterization must be made on the composite material.

2. Previous Characterizations

Previous characterizations, using the Small Research Facilities available at the ISIS@MACH ITALIA laboratories of the unit at University of Rome Tor Vergata (GP2022008), have produced some major estimation of the grafting mechanisms and the penetration depths of CNTs inside the polymer. In particular, SEM images (shown in Figure 1), have provided evidence suggesting the “soaking” of CNTs bundles in the polymeric substrate. We performed a cold cut in liquid nitrogen in order to leave unchanged the structure of the composite interface, but this method does not give us information on the grafting dynamics of carbon nanotubes in the polymer nor on their penetration depth.
With Confocal Raman Microscopy some estimations of the depth of penetration of the CNTs inside the polymers have been obtained but the resolution allowed by this technique (from 5 to 15 micron, depending on the depth), does not allow to obtain unambiguous and trustworthy results, especially with substrates with thickness around 20-30 microns.

3. Proposed Experiment

We propose a mechanical characterization of a set of polymer-CNT samples to assess the mechanical properties of these composite materials, to benchmark their suitability to the end application and the related mechanical stresses. To do this, we plan to perform a Dynamic mechanical analysis experiment in the 300 - 400 K temperature range using the Dynamic Mechanical Analyzer instrument at the Tor Vergata unit of IM@IT. Samples of composite material films will be prepared with the dimension compatible with the instrument request: 100 microns thickness; 5 mm large; and 20 mm long. Samples will include polypropylene, polyethylene, Polydimethylsiloxane (PDMS), and polyisoprene.

4. Justification of time requested

Samples from 4 different polymers, both as blank and as CNT-containing composite, will be measured for about 3 hours. Considering 3 hours per sample, for a total of 8 samples, we request 3 instrument days of the Dynamic Mechanical Analyzer MRF.

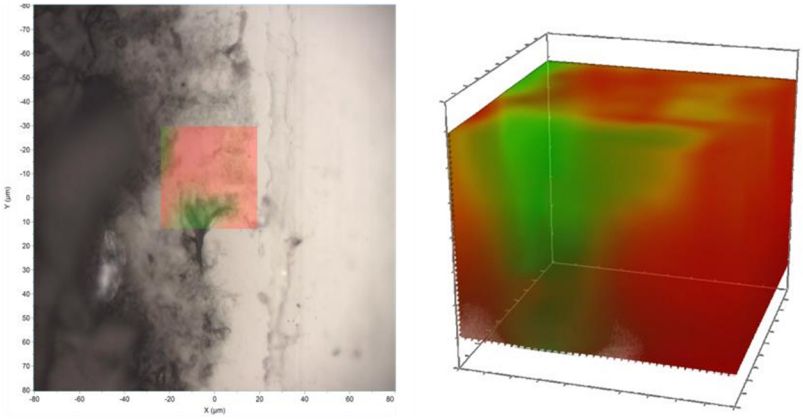

Figure 1 – Raman confocal 3D map that show the carbon nanotube penetration (green signal) into the polymer substrate (red signal).

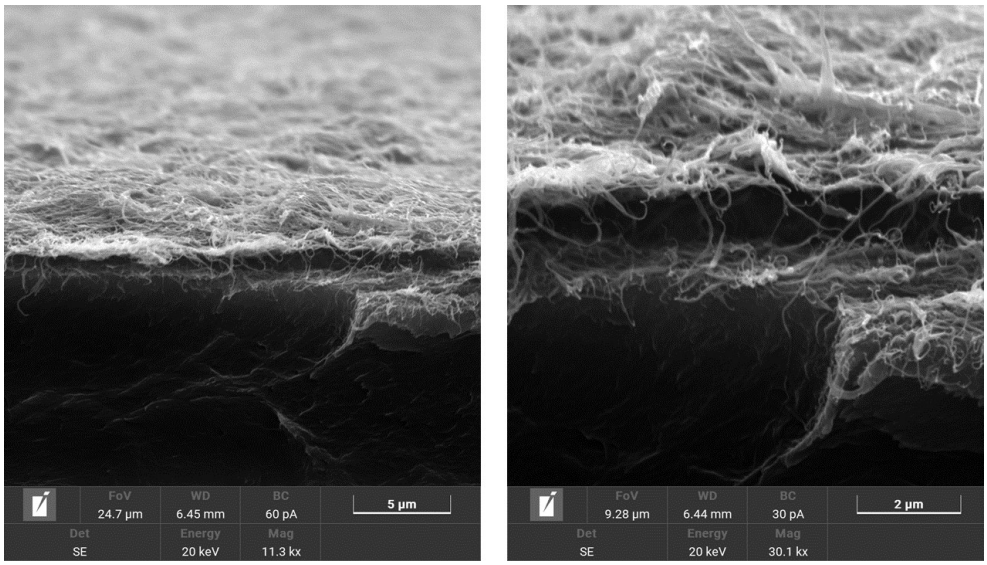

Figure 2 – SEM images of the interface after cold cutting in liquid nitrogen: on the top the carbon nanotube layer and on the bottom the polymer substrate. The left image shows the SWCNTs anchor sites into the substrate.

References

[1] Morales, Piero, et al. "Self-grafting carbon nanotubes on polymers for stretchable electronics." *The European Physical Journal Plus* 133.6 (2018): 1-11.

[2] Pavone, Luigi, et al. "Chronic neural interfacing with cerebral cortex using single-walled carbon nanotube-polymer grids." *Journal of neural engineering* 17.3 (2020): 036032.

[3] Fazi, Laura, et al. "Carbon Nanotube-Based Stretchable Hybrid Material Film for Electronic Devices and Applications." *Journal of Nanoscience and Nanotechnology* 20.7 (2020): 4549-4556.

[4] Fazi, L., et al. "Stretchable conductors made of single wall carbon nanotubes self-grafted on polymer films." Journal of Physics: Conference Series. Vol. 1548. No. 1. IOP Publishing, 2020.