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NANOCOMPOSITE MATERIALS FOR THE CONSTRUCTION OF SPACE PROBES – AN INVESTIGATION ON FRACTURE TOUGHNESS OF HYBRID INTERFACES

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MOTIVATIONS, OBJECTIVE & METHODS

MOTIVATIONS
- Create robust polymer matrix composites that can sustain thermomechanical loads given the entry of probes into different planetary atmospheres
- Facilitate joining techniques for the composite shell of planetary probes to the TPS

OBJECTIVES

Fracture toughness is one of the most important mechanical properties of a material. It represents the ability of that material to resist fracture when an initial crack is presented in that material. This study is to assess fracture toughness of polymer matrix composite (PMC) and Metal-PMC interfaces with carbon nanotubes (CNT) grown on carbon fabrics (fuzzy fabrics) and Titanium foil (fuzzy Ti) as a function of temperature.

METHODS
- Design and fabricate laminates with hybrid fuzzy interfaces
- Utilize imaging & spectroscopy to verify CNT presence at interfaces
- Test Temperature:
  Room : 25°C High : 110°C
- ThermoGravimetric Analysis (TGA)
- Dynamic Mechanical Analysis (DMA)
- Differential Scanning Calorimetry (DSC)
- Double Cantilever Beam (DCB) & 4 point End Notch Flexure (4ENF)
- Optical Microscopy (OM)
- Scanning Electron Microscopy (SEM)

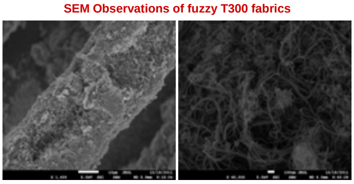
MATERIALS AND OBSERVATIONS

Carbon nanotubes are grown by the chemical vapor deposition method on the surface of
- T650 (8Harness Satin) fabric
- T300 (Plain Weave) fabric
- Titanium foil

Composite panels are fabricated by VARTM method. These panels have Epoxy EPON 862 matrix.

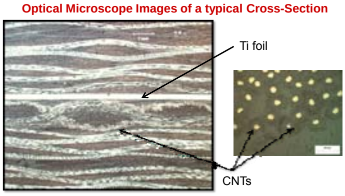
Plain T300 fabric Fuzzy T300 fabric Fuzzy Ti foil

SEM Observations of fuzzy T300 fabrics



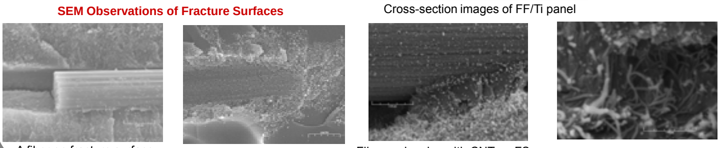
A carbon fiber in T300 fabric CNT network on T300 fabric surface

Optical Microscope Images of a typical Cross-Section



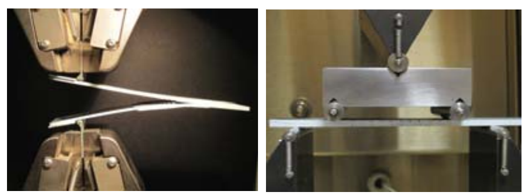
Cross-section images of FF/Ti panel

SEM Observations of Fracture Surfaces



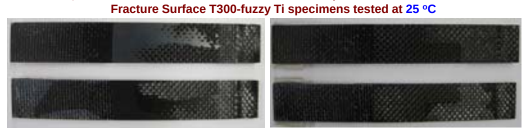
A fiber on fracture surface A fiber imprint on fracture surface Fiber and resins with CNT on FS CNT bundles on fracture surface

FRACTURE TOUGHNESS TESTS



DCB test set up 4ENF test set up

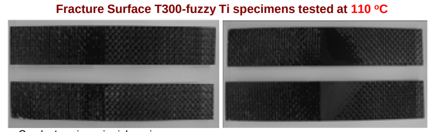
Fracture Surface T300-fuzzy Ti specimens tested at 25 °C



Crack starts on Ti and remains on Ti region → Lowest G values series

Crack starts in resin rich region then migrates to fabrics regions → Highest G values series

Fracture Surface T300-fuzzy Ti specimens tested at 110 °C

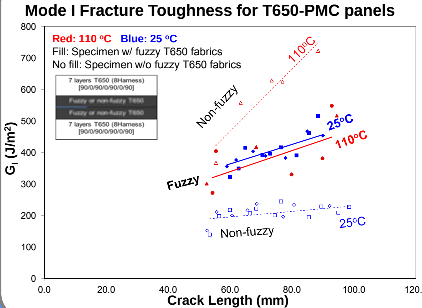


Crack stays in resin rich region → Little variation in G values

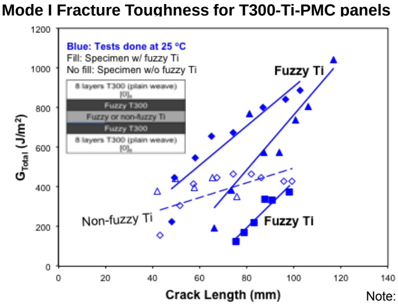
Crack starts on Ti and migrates to resin rich region → Large variation in G values

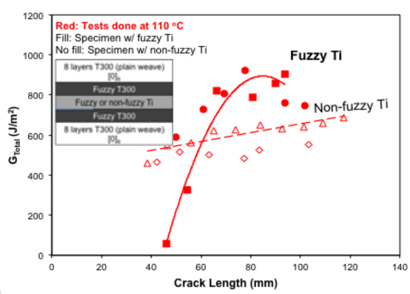
RESULTS

Mode I Fracture Toughness for T650-PMC panels



Mode I Fracture Toughness for T300-Ti-PMC panels





Note: Values calculated based on assumption of uniform crack front across specimen width

CONCLUSIONS

- CNT modified interfaces improve fracture toughness in PMC laminates both at room temperature and high temperature.
- Panels with fuzzy-Ti interface demonstrate higher fracture toughness at high temperature
- Variations in the crack growth path in T300-fuzzy Ti specimens are as follows
  - at Room Temperature (25°C)
    - ✓ starts on Ti and then migrates to resin rich and fuzzy fabric region
    - ✓ starts in resin rich region then migrates to fuzzy fabric region and then to the next fabric layer (accompanied with highest G values)
    - ✓ starts on Ti and remains on Ti (accompanied with lowest G values)
  - at High Temperature (110°C)
    - ✓ starts at Ti face then migrates to resin rich region
    - ✓ starts remains in resin rich region.

This study proposed a system of composite materials that has high resistance to fracture to build the parts of probes that carry heavy mechanical loads. The problem about adhesion and debonding between the TPS and composite shell layers was also addressed here with the study on bimaterial interface between Titanium and composite. To sum up, it is worthwhile to consider composite materials in the design of future planetary probe missions.

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AFOSR-MURI
Functionally Graded Hybrid Composites