Development and Testing of Thermal Materials to be Used on the Hubble Space Telescope

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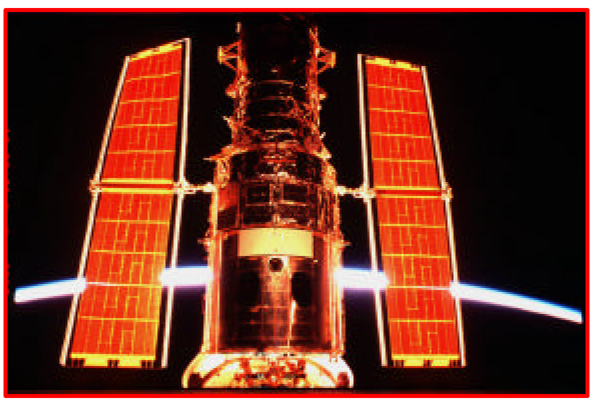
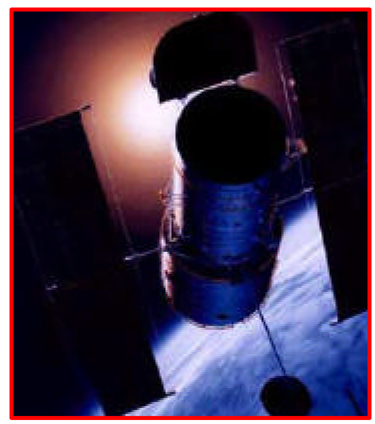
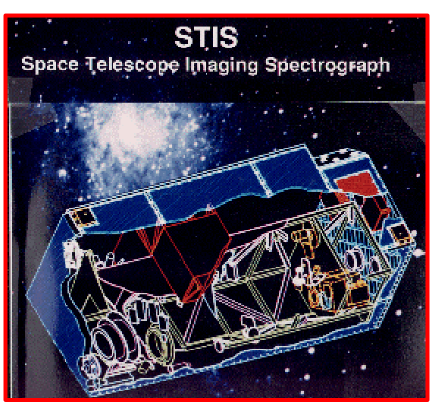
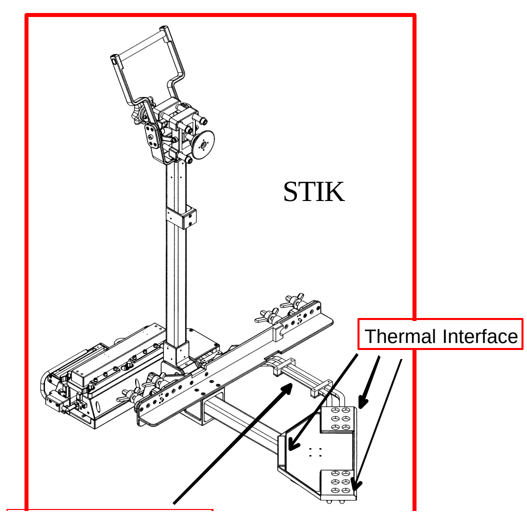




MOTIVATION

- Improve the operating temperature of STIS
- Attach STIK device to STIS during Servicing Mission 4
- Need material that will enhance thermal interface between STIS radiator and STIK





STIS - Space Telescope Imaging Spectrograph
STIK- STIS Thermal Interface Kit

Goals and Milestones

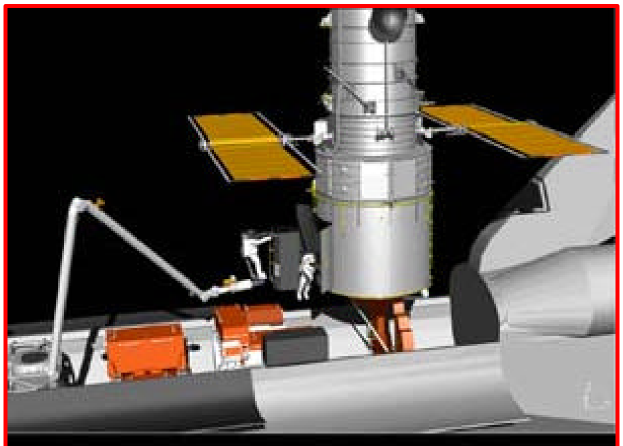
- Develop a material that
    - Will permit heat to be conducted from STIS at acceptable rate
    - Will be operationally friendly to EVA crews installing STIK
- Conduct testing to justify the first application of CNTs in space

Thermal Contact

- ♦ Conductance is directly proportional to material conductivity and contact area.
- ♦ Contact is needed that will permit the interface to have a conductance of at least .45 W/(in^2K).
- ♦ Material(s) must conform to STIK radiator (high area) but also have high conductivity.

Challenges

- ♦ Surface conditions of the STIS copper radiator are unknown, as it is in orbit.
- ♦ Radiator is mechanically tied to the optical bench, therefore only 3.7 psi of pressure can be applied to the thermal interface.
- ♦ Only few materials may be considered because of STIS Requirements.
    - High electrical insulation
    - High thermal conductivity
    - EVA friendly
    - Abrasion Resistant
    - No Particulation
    - Removable
    - No silicones or materials that could contaminate optics



Astronauts will have to attach the STIK assembly with no visibility of the thermal interface as well as being encumbered by their EMUs.

Actions

- Develop low modulus, ReedPad, to account for variations in STIS radiator plate.
- Implement carbon nanotubes to conform to the radiator material on the smallest scale.
- Test graphite based thermal interface materials for feasibility.
- Test combinations of materials for best solution. Figure 1.

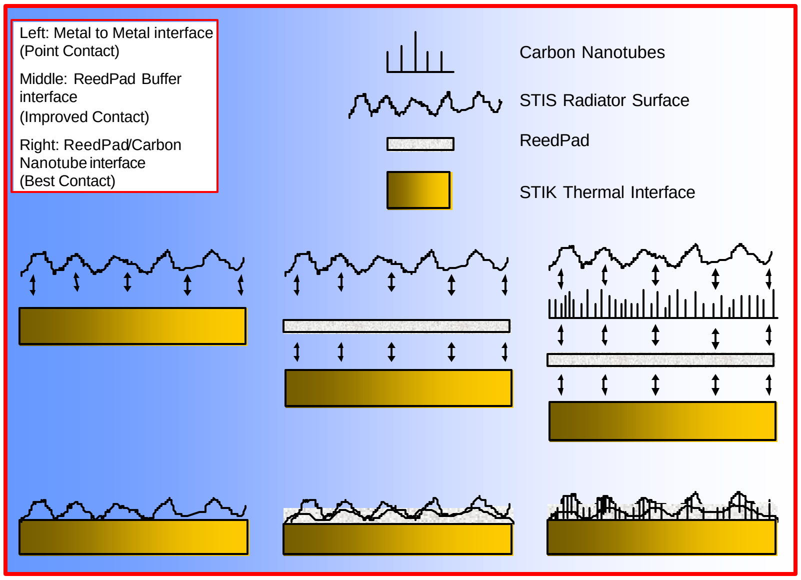
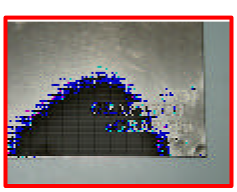


Figure 1: Examples of different types of thermal contact from different materials.

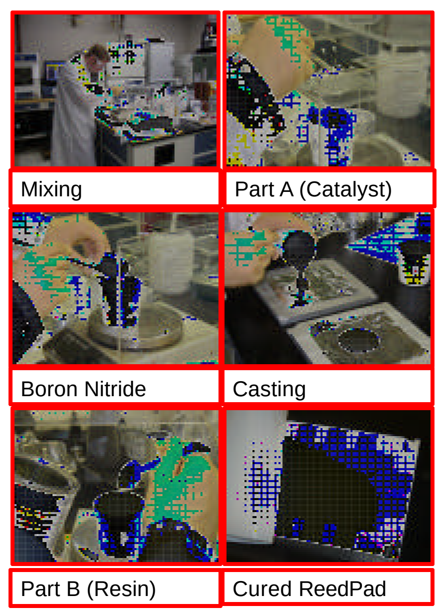
Materials:

ReedPad - a polyurethane derivative of Uralane 5750. The cross-link density of the polymer matrix is altered by changing the amount of catalyst and cure time. This leads to a change in modulus and the ability of the material to adapt to different surfaces. The modulus needs to be high enough that the material has a characteristic strength and can be managed during EVAs. If the modulus is too high, the material will not be able to conform to the surface of the STIS radiator. Conductivity of the material can be changed by adding different amounts of Boron Nitride, but adding more Boron Nitride with increase the modulus.

eGraph - Graphite thermal interface material designed for applications requiring low contact resistance and high thermal conductivity.

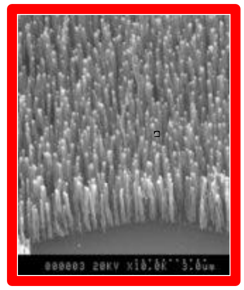


Example 2 (left): eGraph 720 is shown



Example 1 (above): Formulation and Preparation of ReedPad

Carbon Nanotubes - supplied by the Applied Physics Laboratory at John's Hopkins University. These tubes can be grown in "forests" of chemically aligned arrays with high conductivity in axial direction. They are expected to help adjust to irregularities in roughness on thermal surfaces. Carbon nanotubes can be grown in three configurations (top to bottom in the right illustration): 1.) Armchair (exhibiting metallic properties), 2.) Zig Zag and 3.) Chiral (both exhibiting semi-metallic properties. They exist in single wall form, where each individual tube has 1 layer of atoms or multi-wall form, where tubes are located inside each other. Although not available in bulk quantities, a single multi-wall carbon nanotube can have 10x the conductance of copper (3000 W/mK) with the theoretical limits of single wall carbon nanotubes, although not yet measures experimentally) approaching 8000 to 37,000 W/mK.



Example 3: Forests of CNTs.

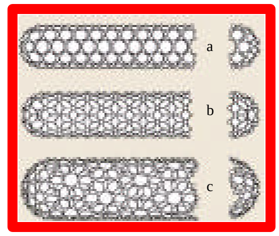
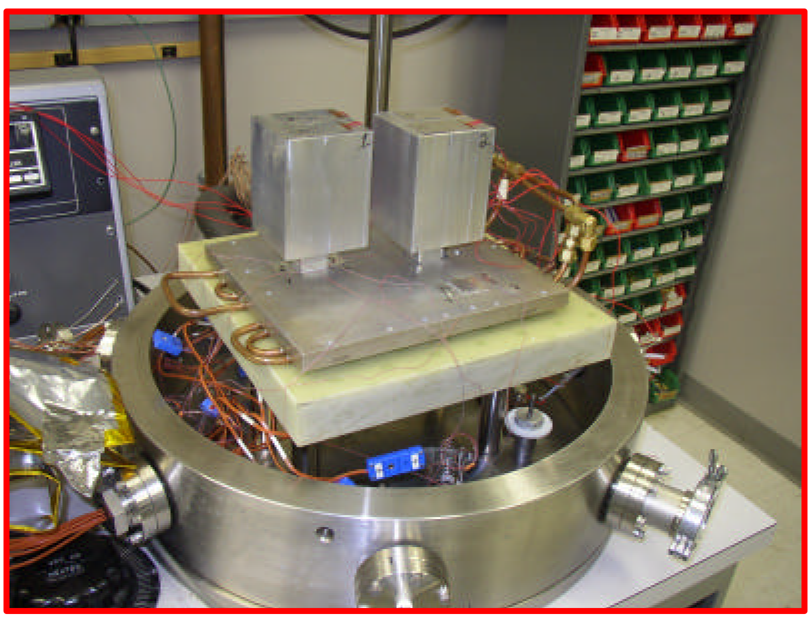


Figure 2: Different configurations of Carbon Nanotubes: a. Armchair, b. Zig-zag, c. Chiral

Thermal Testing

- Material is placed between two metal substrates
- Upper substrate
- Applies 3.7 psi pressure
- Designed contact area of 1 in^2
- Heated with 2, 70 ohm resistive heaters
- Lower substrate is maintained at 0^oC
- Apparatus enclosed in thermal vacuum chamber
- Temperature gradient is measured through material at different power levels
- Conductance is calculated for each material tested



Example 4: Thermal Test Apparatus in Materials Engineering Branch

Accomplishments

- ♦ Designed and implemented thermal testing apparatus for use in existing test cell
- ♦ Made improvements to procedure for formulation and preparation of ReedPad
- ♦ Tested eGraph materials and various formulations of ReedPad for conductance

Thermal Conductance of Some Materials Tested	Trial 1 Thermal Conductance (W/in^2K)	Trial 2 Thermal Conductance (W/in^2K)	Power (Watts)
ReedPad (10/100, catalyst/resin and 50% Boron Nitride)	0.36	0.43	0.72
	0.36	0.42	1.12
	0.36	0.41	1.61
ReedPad (10/100, catalyst/resin and 50% Boron Nitride, Heat Cured*)	0.48	0.41	0.72
	0.50	0.45	1.61
ReedPad (11/100, catalyst/resin and 60% Boron Nitride, Heat Cured*)	0.32	0.27	0.71
	0.35	0.23	1.12
eGraph 720	1.01	0.80	0.71
	1.01	0.80	1.12
	0.87	0.73	1.61

* 4 hours at 100°C

Figure 3: Preliminary joint conductance data for various materials

Future Work

- ♦ Test Carbon Nanotubes for conductance
- ♦ Automate conductance testing procedure
- ♦ Continue to optimize ReedPad
- ♦ Thermal Interface Material Ready by HST Servicing Mission 4