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PERFORMANCE OF THERMAL CONTROL TAPE IN THE PROTECTION OF COMPOSITE MATERIALS

Rachel R. Kamenetzky
Ann F. Whitaker
NASA Marshall Space Flight Center
MSFC, Al

INTRODUCTION

The selection of materials for construction of long duration mission spacecraft has presented many challenges to the aerospace design community. After nearly six years in low earth orbit, NASA's Long Duration Exposure Facility (LDEF), retrieved in January of 1990, has provided valuable information on both the nature of the space environment as well as the effects of the space environment on potential spacecraft materials. Composites, long a favorite of the design community because of a high strength-to-weight ratio, were flown in various configurations on LDEF in order to evaluate the effects of radiation, atomic oxygen, vacuum, micrometeoroid debris and thermal variations on their performance. Fiberglass composite samples covered with an aluminum thermal control tape were flown as part of the flight experiment A0171, the Solar Array Materials Passive LDEF Experiment (SAMPLE). Visual observations and test results indicate that the thermal control tape suffered little degradation from the space exposure and proved to be a reliable source of protection from atomic oxygen erosion and UV radiation for the underlying composite material.

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LDEF AO171 EXPOSURE CONDITIONS

The LDEF AO171 tray was located on the leading edge row 8A of the satellite, and was in orbit at an angle of ~38° from the ram vector. Table I shown below summarizes the environmental exposure conditions for the composite samples. Of particular significance in the evaluation of the thermal control tape performance is the high atomic oxygen fluence level and the large number of thermal cycles.

Table I LDEF AO171 Exposure Conditions

High Vacuum	10^{-6} to 10^{-7} Torr (estimated)
UV Radiation	10,471 ESH
Proton Fluence	10^{9} p+/cm^{2} (0.5 to 200 Mev)
Electron Fluence	10^{12} to 10^{8} e^{-}/cm^{2} (0.5 to 3.0 Mev)
Atomic Oxygen	6.93 X 10^{21} atoms/cm^{2}
Micrometeoroid/ Space Debris	2 to 7 impacts per composite,<1mm
Thermal Cycles	~32,000 cycles (Temperature TBD)

COMPOSITE TEST SPECIMENS

Six "S" glass epoxy composite samples, 0.5" x 6" in size, were flown as part of flight experiment AO171, three of which were covered with an aluminum thermal control tape. Additionally, six composite control samples, three with the thermal control tape, remained in the lab for post flight comparison. The composite resin was supplied by Air Logistics and the "S" glass was from Owens Corning S-901 glass. The thermal control tape was a 2 mil aluminum with 2 mil pressure sensitive silicone adhesive SR574. Figure 1 below shows the basic flight configuration for the six plates which made up the AO171 tray experiment. The fiberglass epoxy composites, along with the aluminum covered fiberglass composites, are shown in the post flight condition in the upper right corner of plate III.

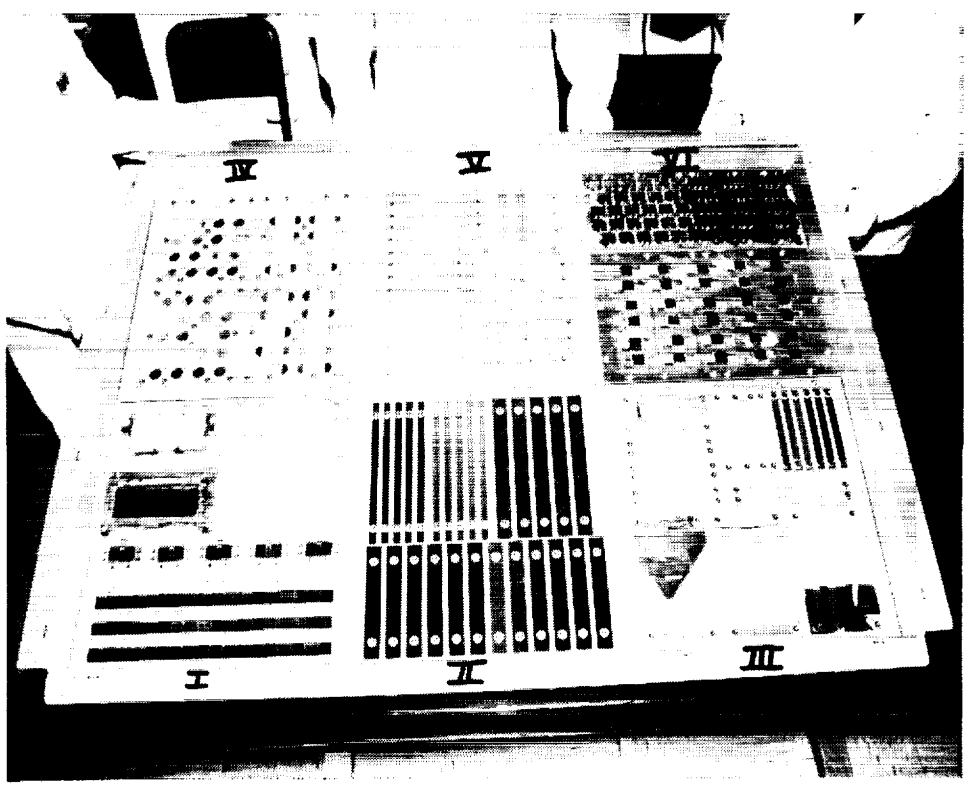


Figure 1. Flight experiment AO171, Solar Array Materials Passive LDEF Experiment (SAMPLE).

VISUAL OBSERVATIONS

In order to evaluate the effects of the space environment on the aluminum thermal control tape, comparative series of visual and mechanical tests were performed on the tape covered flight composite samples and the laboratory tape covered control composite samples. As seen in figure 2 below, no clear visual distinction can be made between the flight exposed samples and the control samples. However, because the tape was applied only to the surface of the composites, the edges of the flight samples were exposed to atomic oxygen and UV radiation. The flight sample edges showed clear signs of resin erosion in the composite matrix. A thin oxide layer was also evident on both the exposed and control tape surface. Further work is needed to better quantify the thickness of this oxide layer.

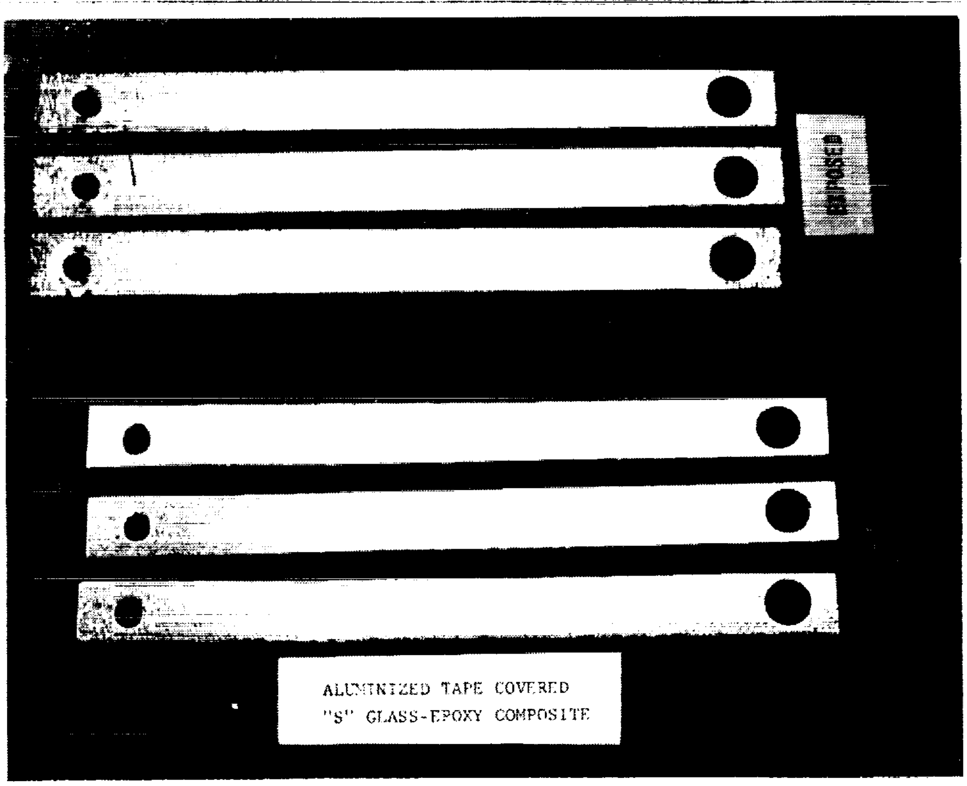


Figure 2. Tape covered fiberglass epoxy composite flight and control specimens.

ALUMINUM THERMAL CONTROL TAPE SEM PHOTOGRAPHS

The thermal control tape surface on the flight and control composite samples was examined using a scanning electric microscope (SEM). Figure 3 shown below compares the SEM photograph taken at 200x magnification for a control sample (left) and for a flight sample (right). Both the control and flight sample photographs show what appears to be fabrication "roll marks". The flight sample SEM photo, however, also shows evidence of a wave-like crest structure projecting from the surface of the tape.

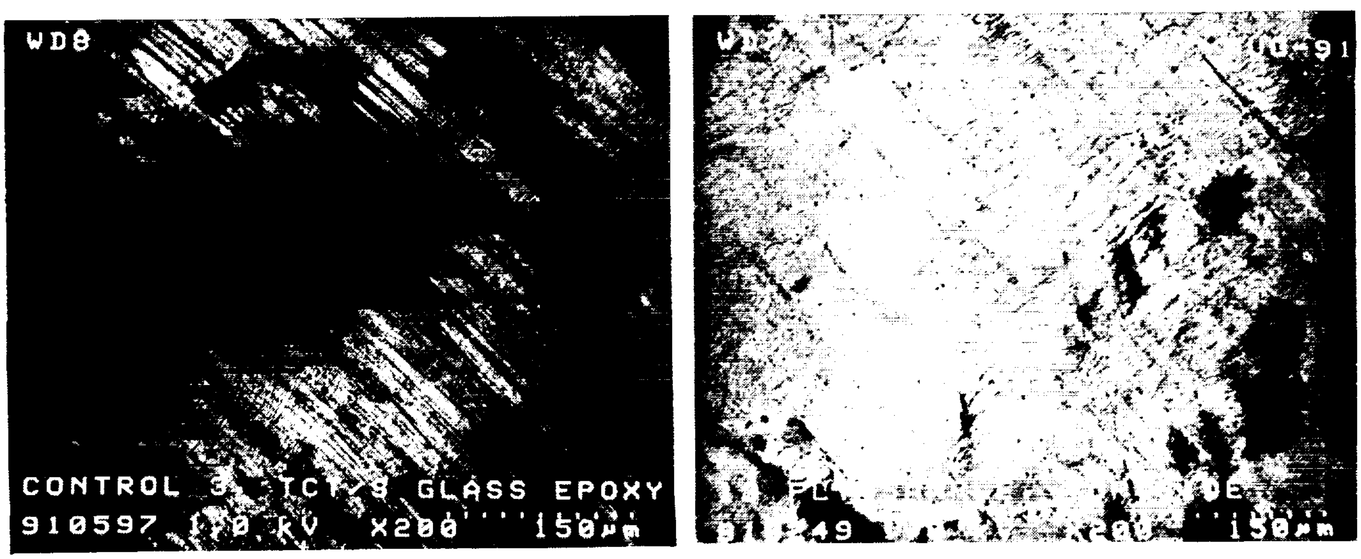


Figure 3. SEM photograph at 200x magnification of control tape surface (left) and flight tape surface (right).

ALUMINUM THERMAL CONTROL TAPE SEM PHOTOGRAPHS (Continued)

Figure 4 shown below compares the SEM photograph taken at 1000x magnification for the same control sample (left) and flight sample (right) as contained in the earlier SEM photos. In this series of photos, a clear difference in the surface structure of the two tape specimens is easily seen. The wave-like structure of the flight tape is reminiscent of Luder's bands, a fatigue phenomena, and may be linked to the high number of thermal cycles that the flight samples underwent. Further analyses are required to confirm this phenomena.

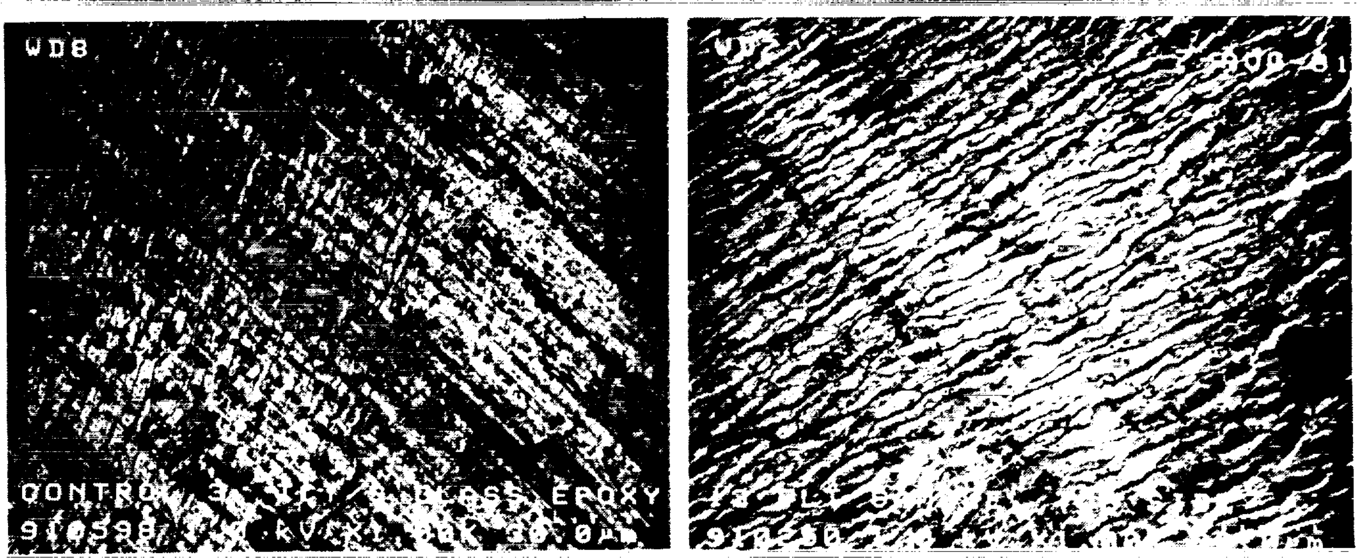
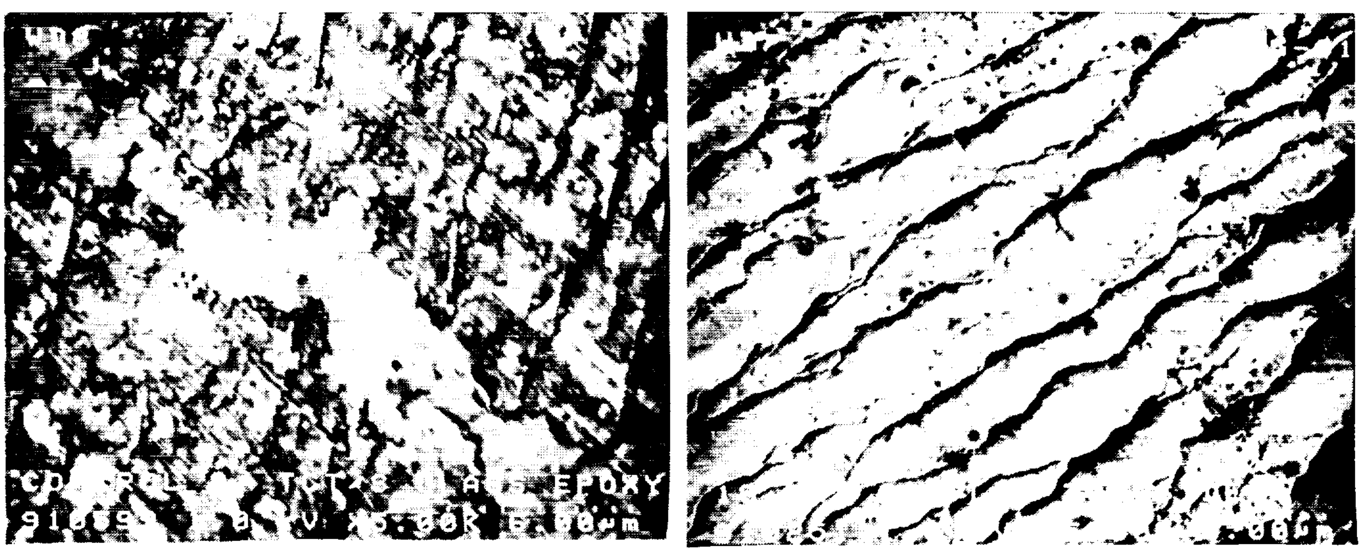


Figure 4. SEM photograph at 1000x magnification of control tape surface (left) and flight tape surface (right).

ALUMINUM THERMAL CONTROL TAPE SEM PHOTOGRAPHS
(Continued)

Finally, figure 5 below compares the SEM photograph taken at 5000x magnification for the control tape sample (left) and for the exposed tape sample (right). The contrast in surface texture between the flight tape and control tape is clearly evident.



Caption: Figure 5. SEM photograph at 5000x magnification of control tape surface (left) and flight tape surface (right).

MICROMETEOROID DEBRIS

Two of the flight taped covered glass epoxy specimens showed evidence of a single impact with micrometeoroid/space debris, with each impact measuring less than 1mm in diameter. While the thermal control tape was able to prevent damage to the composite substrate on one flight sample, the impact on the second sample did penetrate through to the composite substrate causing damage to the underlying fibers. Figure 6 shown below is the SEM photographs of the impact area for the non-penetrating impact (left) and for the penetrating impact (right).

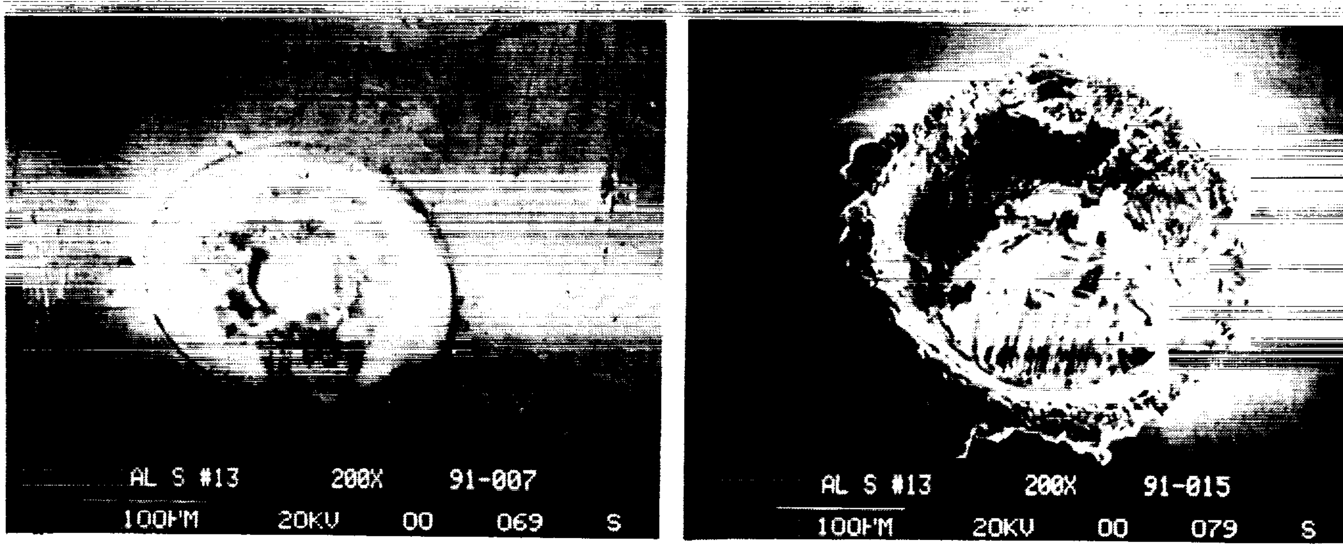


Figure 6. SEM photograph at 200x magnification of debris impacts on flight exposed tape covered fiberglass composites.

MECHANICAL AND OPTICAL PROPERTIES

Deterioration of composite materials by atomic oxygen/UV radiation is of considerable concern to the aerospace designer. Erosion of the composite matrix resin can lead to degradation in material mechanical strength. The thermal control tape proved successful in protecting the underlying composite from the atomic oxygen/UV radiation resin erosion as evident in the mass loss data. The mass loss for the "bare" composite was four times greater than for the tape covered composite. The small degree of mass loss on the tape covered specimens was due to erosion along the specimen edges where the composite was exposed. The tape silicone adhesive also proved to withstand the rigors of the environment, with the flight specimens showing an increase in peel strength over the control by a factor greater than 2 to 1. This increase in peel strength is again probably due to thermal cycling effects. Difficulties in conducting the peel tests on the flight tape specimens also suggested that the flight tape had become embrittled by the space exposure. This tape embrittlement theory is currently under investigation. The solar absorptance and IR emittance on the tape covered specimens showed little change between the flight and control specimens, with the differences in recorded values considered to be in the noise range of the portable instruments used to measure the properties. Table II below summarizes the mechanical and optical properties for the "bare" composite, control and flight, and for the aluminum tape covered composites, control and flight.

Table II Mechanical and Optical Properties

	Peel Strength (lb./in)	Mass Loss (mg/cm^2)	Solar α (avg.)	IR ϵ (avg.)
Bare <u>Composite</u>				
✓ Control	******	******	0.723	0.894
✓ Flight	******	2.40	0.787	0.895
Tape Covered <u>Composite</u>				
✓ Control	1.9	******	0.140	0.025
✓ Flight	4.6	0.59	0.103	0.020

CONCLUSION

The aluminum thermal control tape proved effective in protecting the underlying fiberglass epoxy composite from the rigors of the low earth orbit space exposure. Although SEM photos revealed morphology changes in the flight exposed tape surface, due at least in part to thermal cycling effects, the overall tape performance was not compromised. Mass loss data from the flight tape covered composite samples and "bare" composite samples clearly indicate that the aluminum tape prevented atomic oxygen/UV erosion of the composite matrix resin. The average peel strength for the flight exposed tapes increased by a factor of nearly 2.5 over the average ground based control tapes. Solar absorptance and IR emittance data on the aluminum tape varied little between flight exposed samples and control samples. The tape did not however provide complete protection from micrometeoroid/debris. One debris hit did penetrate the protective tape, causing damage to the composite substrate, while a second impact, originating most probably from a shuttle fluid dump, was unable to penetrate the tape.