TEST REPORT

Ttape 1000A Thermal Reliability

Purpose

This report focuses on Ttape 1000A with regards to the thermal conductivity, 90° peel strength, and lap shear strength performances over the course of thermal cycling from -40°C to +125°C. The films exhibited no degradation in performance over these cycling conditions.

Samples and Specimen

Ttape 1075A = 3 mil thermally Conductive Pressure Sensitive Adhesive

Exposure Methods

Exposure condition: Samples were subjected to temperature cycling of -40°C to +125°C for up to 400 cycles. Each cycle lasts 105 min, consisting of a 15 min dwell time at -40°C, heating to +125°C at 5.5°C/min, a 15 min dwell time at +125°C, and cooling to -40°C @ 3.7°C/min.

Equipment: Thermotron SM-32-3800

Procedure: Samples were placed in the Thermotron for up to 400 cycles and were removed for measurement at these specific intervals, cycle # 19, 73, 125, 208, 304, and 400. A control set was tested prior to any thermal cycling and is labeled with cycle # 0. The samples were allowed to acclimate to room temperature before testing. Lap shear and 90° peel testing are destructive tests; samples cannot be re-used from one cycle test to another. Thermal conductivity measurement is a non-destructive test and samples can be re-used.

Measurement Methods

Samples were subjected to three primary measurements as follows:

1. Lap Shear

Description: Lap shear was measured per the ASTM D1002 standard.

Specimen: Lap shear specimen consist of 1” x 3” x 1/8” (width x length x height) borosilicate glass and the following:

Ttape 1075A = The product does not consist of a core to provide additional mechanical rigidity other than the PSA's cohesive property. A secondary borosilicate glass was used to attach to the first with a $1in^2$ overlap area.

A pressure of 20psi was applied to each specimen for 5 minutes at room temperature.

Equipment: Instru-Met model 1123 with 50lb or 200lb tension load cell

Procedure: The extended portions of the specimen were placed into the upper and lower grip of the MTS mechanical tester. Crosshead speed was set at 1.3mm/min to shear the film from the substrate. Five specimens were tested for each scheduled thermal cycle.

2. 90° Peel – German Wheel

Description: The 90° peel test was performed using a circular wheel known as the German wheel, with the specimen adhered to aluminum foil that is adhered to the perimeter of the wheel. A MTS mechanical tester was used to peel the specimen from the foil. The test was performed per ASTM D3330.

Figure 1 – Picture of a German Wheel peel setup

Specimen: Strips of Ttape 1075A with dimensions of 0.5" x 8" were attached to the smooth side of ULHIVAC aluminum foil (glossy side, Ra ~130nm) of dimension of 1" x 9". Since the Ttape has no core film to provide reinforced mechanical rigidity, Kapton® polyimide was applied onto the second side of the PSA to supply the reinforcement. Samples were dwelled for 1 hour prior to peel in a 23°C 50% RH environment.

Equipment: Instru-Met model 1123 with 2kg tensile load cell

Procedure: The aluminum foil side of the specimen was attached to the German wheel using double sided tape (Nitto P-02). The German wheel is anchored to the bottom of the MTS. A 1 inch free section of Ttape was held by the MTS upper grip to enable the initiation of the peel. Crosshead speed was set at 12 inches/min with the force measured in tension mode. The measured force is a direct measurement of the bond strength of the adhesive to the aluminum. Each tested thermal cycle involves an average of five specimens.

3. Thermal conductivity

Description: Thermal conductivity was measured per the ASTM D5470 standard using the Analysis Tech TIM Tester 1400 instrument through the linear fit relationship between thermal impedance and thickness for a specific material. Each thickness of the material yields a certain thermal impedance value. With multiple thicknesses, a plot of thermal impedance and thickness can be obtained. The inverse of the slope of linear fit curve is the thermal conductivity of the tested material.

Specimen: Each specimen has a diameter of 33mm. There are five specimens to cover five thicknesses, which are built by putting on an additional layer of the same film; essentially, ranging from one layer to five layers. On the two exterior sides of the specimen, a 3 mil copper foil is applied to enable the thermal conductivity testing of the films.

Equipment: Analysis Tech TIM Tester 1400, Ono Sokki EG-225 micrometer

Procedure: Silicone oil, acting as a coupling agent, is lightly applied to the surfaces of the specimen and the TIM Tester 1400 platens. The specimen is placed in between the platens and is subjected to 300kPa of pressure. After the measurement, the thickness of the specimen is measured using the Ono Sokki micrometer. The five specimen are then placed back into the cycling chamber until removal per the next required testing cycle. The same five specimens are used during the entire study.

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Results

Thermal Conductivity

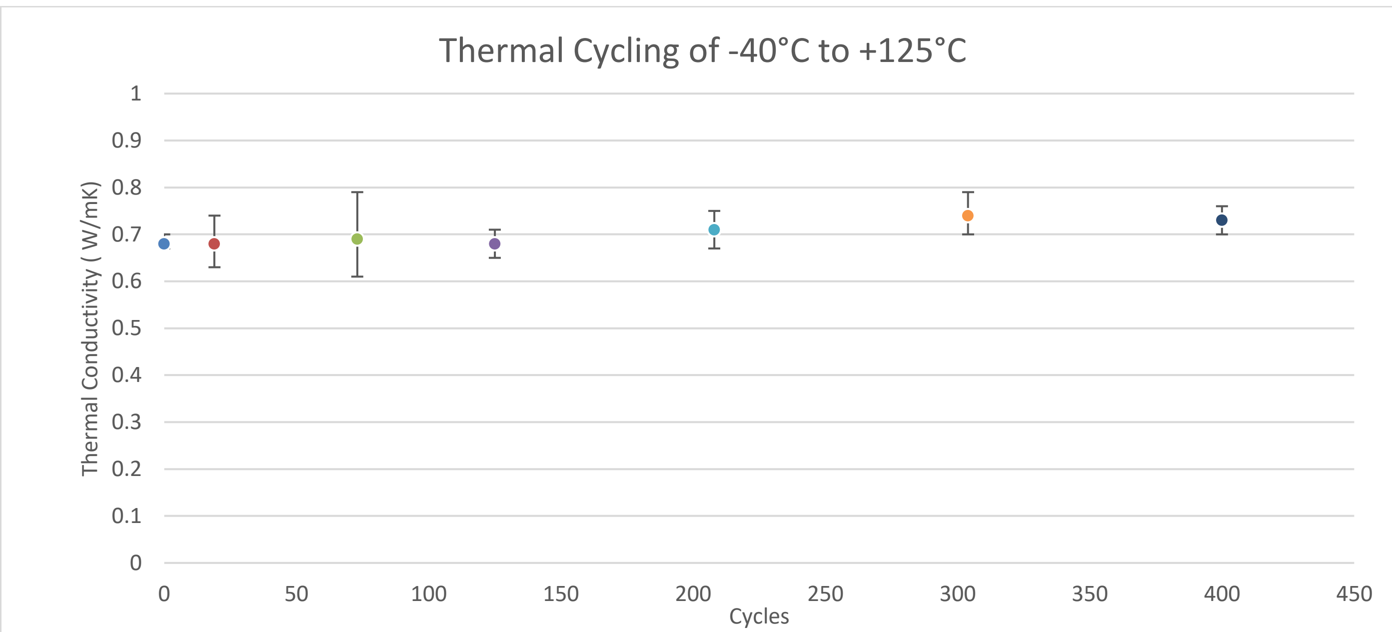

Figure 2 - Effect on thermal conductivity with thermal cycling

Table 1 - Thermal conductivity averages, min, and max for Ttape 1075A

	Cycle Number						
Ttape 1075A	0	19	73	125	208	304	400
W/mK avg	0.68	0.68	0.69	0.68	0.71	0.74	0.73
W/mK min	0.67	0.63	0.61	0.65	0.67	0.70	0.70
W/mK max	0.70	0.74	0.79	0.71	0.75	0.79	0.76

The thermal conductivity of the AT07075 and EIF-XA05002S000 do not change under these thermal cycling conditions. There is an outlier data point on the 208th cycle for the EIF film that caused the confidence interval to be much wider.

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90° Peel – German Wheel

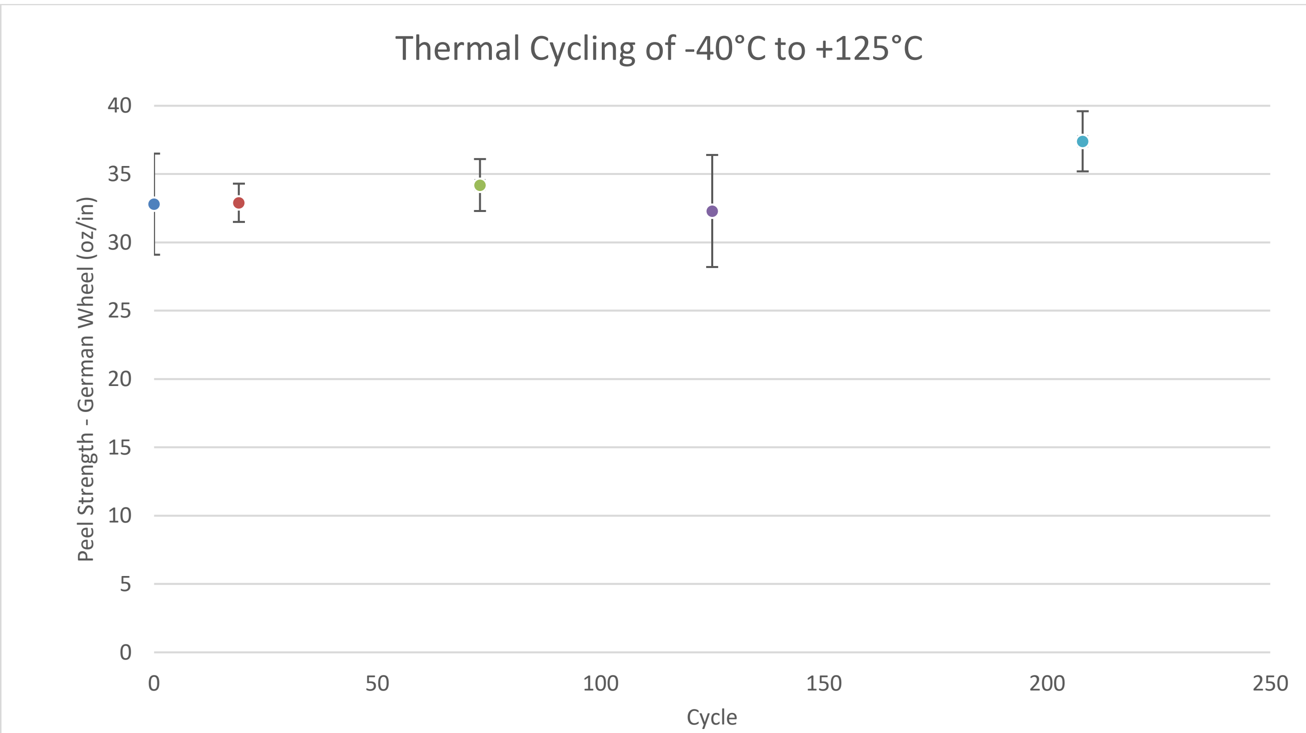

Figure 3 - Effect on 90° peel with thermal cycling

Table 2 – 90° peel strength averages and standard deviation

	Cycle Number				
Film: AT07075	0	19	73	125	208
Average [oz/in]	32.8	32.9	34.2	32.3	37.4
Std Dev [oz/in]	3.7	1.4	1.9	4.1	2.2

Taking into account of the standard deviation, there is no statistical significance of the changes in the averages over the course of the study. In other words, the 90° German Wheel peel strength does not change over these thermal cycling conditions. Observationally, both films cleanly peel and separated from the aluminum foil they were adhered on.

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Lap Shear

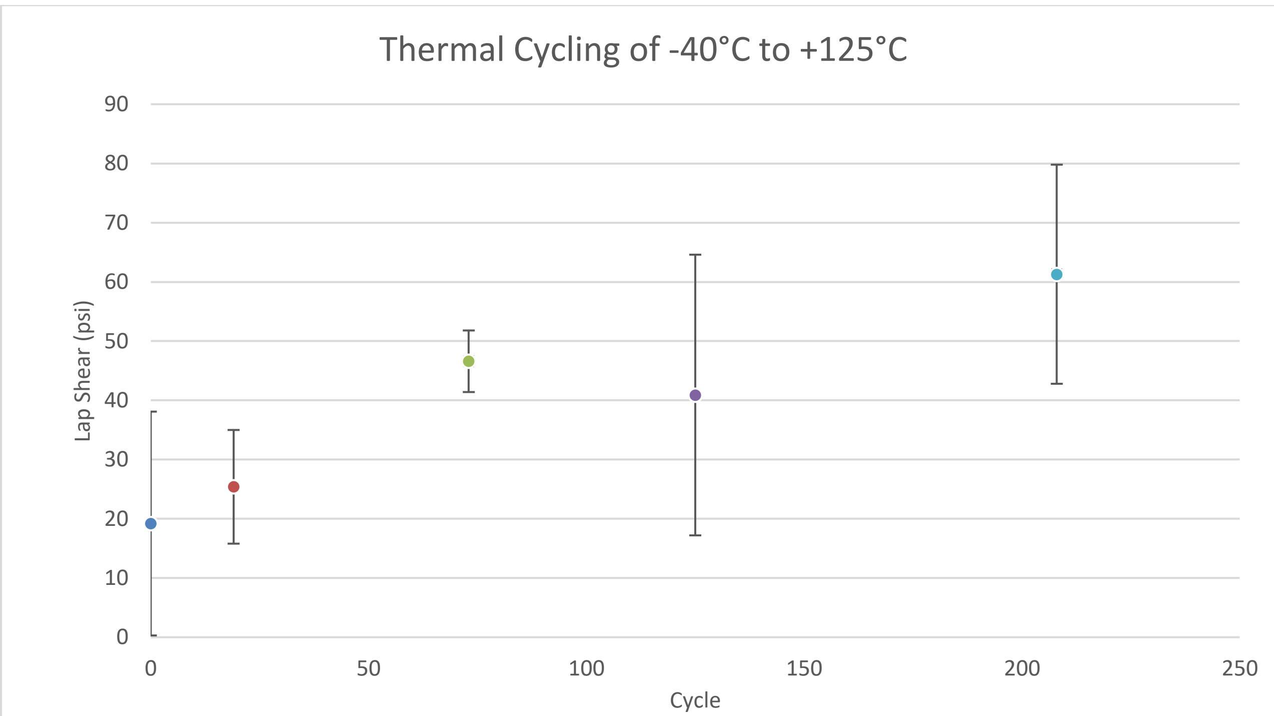

Figure 4 - Effect on lap shear with thermal cycling

Table 3 – Average and standard deviation of lap shear strength

	Cycle Number				
Film: AT07075	0	19	73	125	208
Average [psi]	19.2	25.4	46.6	40.9	61.3
Std Dev [psi]	18.9	9.6	5.2	23.7	18.5

There has been a significant increase of lap shear strength over the course of the study. This is most likely due to additional wetting to the glass substrates with time and cyclical heating. This study showed that there is no degradation of the adhesive shear strength.

For this particular study, on the lap shear measurement, the mating substrates for the pressure sensitive adhesive coating was glass. Inaccurate comparisons and conclusions can be drawn by comparing these values to those that are generated with a different substrate material, such as aluminum, because the surface energy of the substrate is a factor in the overall adhesive and shear strength of the adhesive.