THERM-A-GAP™ GEL 8010 Reliability Test Report

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Test Report Number:

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1. Thermal Gel 8010 Thermal Interface Material is designed for use in high performance devices requiring minimum thermal resistance for maximum thermal performance and component reliability. **GEL 8010** is specially formulated for use in high performance devices requiring minimum thermal resistance for maximum thermal performance and component reliability. GEL 8010 is a compliant material that requires low compression force to conform over irregular interfaces and can be applied to single devices at minimum bond-line thickness as well as to multiple devices with variable z-axis tolerances. The cross-linked gel structure provides superior long term thermal stability and reliable performance over conventional greases.

   1.1. Major reliability targets of Gel 8010 are good End of Life performance with shelf life more than 18 months GEL 8010 has demonstrated reliable thermal performance during temperature cycling, humidity, long term thermal aging and power cycling tests. It was developed for next generation Intel microprocessors.

   1.2. Gel 8010 is a chemically crosslinked product that is highly conformable at device operating temperatures and pressures resulting in "grease-like" performance. This gel material incorporates a crosslinked polymer system to maximize thermo-oxidative stability and minimize low mass loss. It shows weight loss less than 1% after 3hrs at 150 °C (Figure 1-a) and good thermal stability up to 400°C (Figure 1-b) based on TGA (thermo gravimetric analysis).

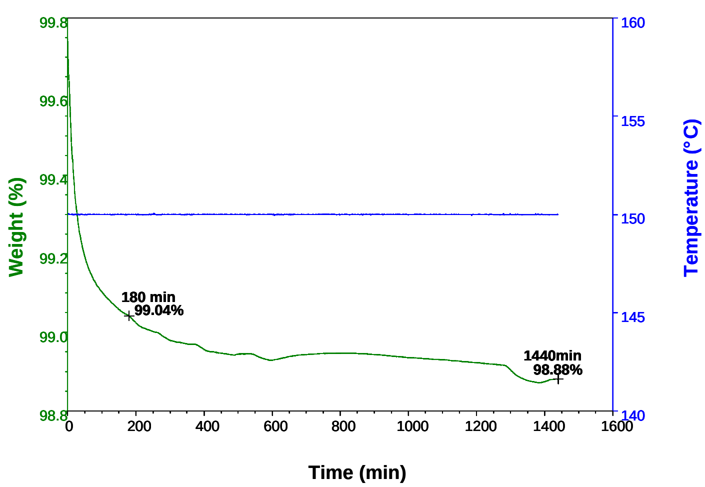


Figure 1-a

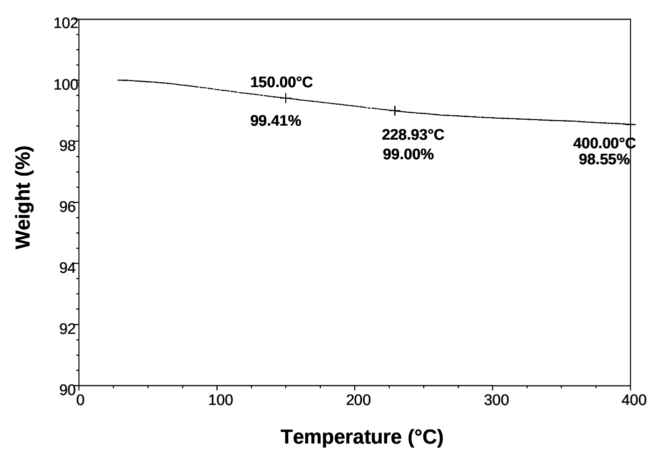


Figure 1-b

Summary

1. The long term reliability of Gel 8010 was evaluated. Thermal resistance was measured after exposing to high temperature baking and HAST conditions.

   1.1. Thermal aging: baking up to 1000 hours at two different temperatures: 95°C and 125°C

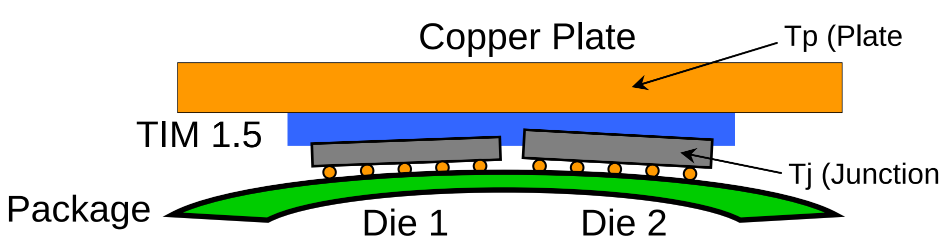
   1.2. Thermal/ humidity aging: 500 hours at 85°C/85% relative humidity

   1.3. Thermal cycling: 800 cycles between 0°C and 125°C

   1.4. Power cycling: 800 cycles at 50 watts with 6 min intervals

2. Random production samples of Thermal Gel 8010 were subjected to various environmental conditions and tested for thermal performance. The thermal performance of Gel 8010 can be investigated using two methods. One method is based on traditional ASTM D5470 Guard Heater Method based on steady heat flux condition. ASTM D5470 tester is a convenient standard tool to measure and compare TIM performance but it requires highly controlled flat co-planar surfaces with uniform temperatures only. Furthermore, it is almost impossible to expose a TIM sample within the instrument in order to have high temperature baking or humidity tests.

   2.1. The other method utilized is an application oriented mobile TIM test method measuring a temperature difference between two interfaces (junction and integrated heat spreader in which a sample was placed. Figure 2, a simplified diagram for the test set-up is shown. A heat source is two bare die chip microprocessors which generate controlled power output and heating type individually. T type thermocouples were used to measure the temperatures of the heat plate, heat sink and ambient. The junction temperature was measured by the electrical method using the temperature dependence of the voltage of the diode on the die. The mobile TIM testing solution was developed not only to capture real use application but also to allow reliability testing. It consists of different surfaces, e.g. one side silicon die, other side copper plate and different die heights for multi-device packages. Also, non-planar surfaces, e.g. package warp from CTE mismatch and non-uniform heating conditions, e.g. *hot spots* can be evaluated. TIM reliability or degradation was determined by acquiring corresponding accelerated stress conditions. Accelerated stress in short time could be superposed to real stress in long time. TIM performance data were collected under accelerated stress conditions. After developing accelerated stress models, the performance could be determined by extrapolating to real stress condition for long time of usage,



Theta (°C/W) = $(T_j - T_p)$ / Power

Figure 2

3. **Equipment:**

   3.1. Mobile TIM Test Vehicles (TTVs) connected test board. T-type thermocouples
   3.2. Agilent E3634A DC power supplier for TTVs and HY1803D DC power supplier for fans
   3.3. Fluke NetDAQ Data logger

3.4. Integrated Cupper Heat Plate with two Pin Fin heat sinks, attached with screws

4. Fixture Assemble Procedure: (see Figure 3)

4.1. A mobile test vehicle (with microprocessor on) is inserted to the socket on the test board. A pin connecter is connected to the edge connector of the board. The pin connecter is used for connections with a data logger and power supplies.

4.2. Gel 8010 is applied to an integrated Cu-heat spreader by spreading the gel with about 6mil thickness stencil. The printed gel can be stored at room temperature for up to 4 weeks before the assembly.

4.3. Let the Cu-heat spreader evenly rest on the top of the die and tighten each screw until resistance is felt, then repeat the 1-3-2-4 sequence. The applied pressured by spring-screwed would be around 50psi.

4.4. Three holes have been machined on Cu heat spreader. Total three thermocouples are used; one for each hole at left and right side of the plate (under heat sink). The third one is placed at the top of the plate. Make sure all 3 thermocouple are inserted all the way in.

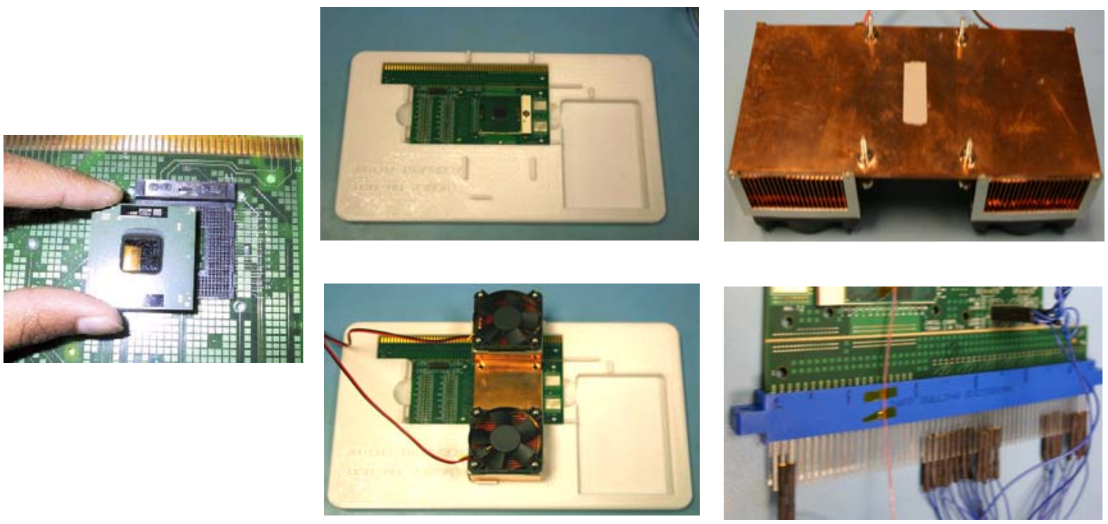


Figure 3

5. Thermal Testing

5.1. Testing starts after assembly is completed. Fans are placed on the top of heat sinks and must be on when the test vehicle (TV) is powered. Power up the fans to an initial 5W.

5.2. The next step is to power up the TV to be about 40W depending on the heating conditions and application conditions. The testing conditions would be either Uniform Heating or Core Heating. The uniform heating has the entire bare die (microprocessor) heated uniformly and junction temperature measures in the center of the die. The core heating only heats the top right quadrant and its junction temperature is measured in the center of the quadrant.

5.3. The testing usually lasts about 20 minutes which would be enough to reach stable measurement system. Each baking conditions have 3-5 different test vehicles.

6. Exposure Methods

6.1. Pre-Assembly Shelf Life measurements

Apparatus: Mobile Thermal Test Vehicles

Procedure: Gel 8010 was stencil applied to several heat spreaders. Each heat spreaders were placed in a controlled room temperature environment. Loose caps were placed on heat spreaders to prevent possible dusts from landing on TIM area. At specific time intervals (1, 2, and 4 weeks), the spreaders were assembled with TTVs. Each assembled TTV fixtures were measured to collect Beginning of Life (time zero) thermal resistance values.

6.2. Heat Baking exposure of 1000 hours at 95°C and 125°C

Apparatus: A forced convection oven was set at 95°C and 125°C. Temperature uniformity was +/- 5°C within oven. This test was conducted at Intel India.

Procedure: Test vehicle Fixtures were placed in a forced convection hot air oven maintained at baking temperatures for 1000 hours. At specific time intervals, the fixtures were removed from the oven, allowed to acclimate to room temperature for two hours minimum, powered up and tested. The thermal resistance (°C/W) between die and plate was calculated by measuring die junction temperature and plate temperature and power.

6.3. High Temperature/Humidity exposure 1000 hours, 85°C, 85% RH.

Apparatus: A Cincinnati Sub-Zero humidity cabinet chamber maintained at 85°C (+/-2°C) at a relative humidity of 85% (+/- 5%)

Procedure: Fixtures were placed in a chamber and fully exposed with no attempt made to protect surfaces. At specific time intervals, the fixtures were removed from the oven, allowed to acclimate to room temperature for two hours minimum, powered up and tested. As before, the thermal resistance (°C/W) between die and plate was calculated by measuring die junction temperature, plate temperature and power.

6.4. Thermal Cycling exposure 750 cycles between 0°C and 125°C

Apparatus: A thermal cycling chamber from Sun Electronic System was used for thermal cycling between 0°C and 125°C.

Procedure: Fixtures were placed in a chamber and fully exposed with no attempt made to protect surfaces. After every 250 cycles or so up to 750 cycles, fixture samples were removed and allowed to acclimate to room temperature for two hours minimum before testing. The thermal cycling was scheduled to stay at lower and upper temperature set points (0°C and 125°C respectively) for 10minutes with a ramp rate of 10°C/minute. As before, the thermal resistance (°C/W) between die and plate was calculated by measuring die junction temperature, plate temperature and power.

6.5. Power Cycling exposure 800 cycle, 6min power-on and 6min power-off

Apparatus: Intel Confidential

Procedure: Fixtures were placed in a chamber and fully exposed with no attempt made to protect surfaces. The power cycling was scheduled to have 6 min power-on and 6 minutes power-off. After every 100 hours or so up to 500 hours, fixture samples were removed and allowed to acclimate to room temperature for two hours minimum before testing. As before, the thermal resistance (°C/W) between die and plate was calculated by measuring die junction temperature, plate temperature and power.

7. Results

7.1. Pre-Assembly Shelf Life

7.2. Thermal Performance: The thermal impedance of Gel 8010 at Beginning of Life was collected. As shown in Figure 4, Gel 8010 showed very similar time zero thermal impedance values regardless of different pre-assembly shelf life periods. It indicates that Gel 8010 does not get dried out at room temperature environment unlike typical grease-type TIMs which tend to be dried out even before fixture assembly.

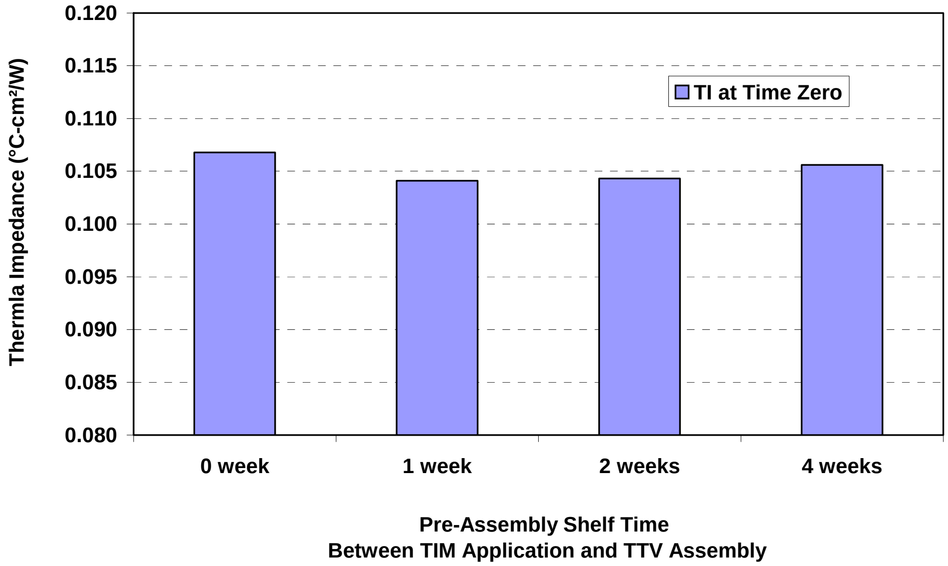


Figure 4

7.3. Heat Baking exposure of 1000 hours at 95°C and 125°C

7.4. Thermal Performance: The initial and heat bake conditioning thermal resistance was collected. The junction resistance (°C/W) between die junction and plate could be calculated by measuring junction die temperatures, plate temperatures and power. The junction to plate resistance values can be converted to TIM resistance (°C-cm²/W) by using test vehicle correlation equations. The correlation varies based on the location of sensor on test vehicle and test vehicle itself.

Figures 5-a and b are the plots for Gel 8010 TIM resistance upon core heating of 40 W versus aging time at 95 and 125°C. The initial TIM thermal resistance for core heating is about 0.12 °C-cm²/W. At 95°C, the thermal resistance values did not change much and actually showed slightly decreased values (0.10 °C-cm²/W) thanks to possible better wetting on substrates during the baking. At 125°C baking temperature, the thermal resistance maintained its values (0.11°C-cm²/W) during 1000 hrs baking condition

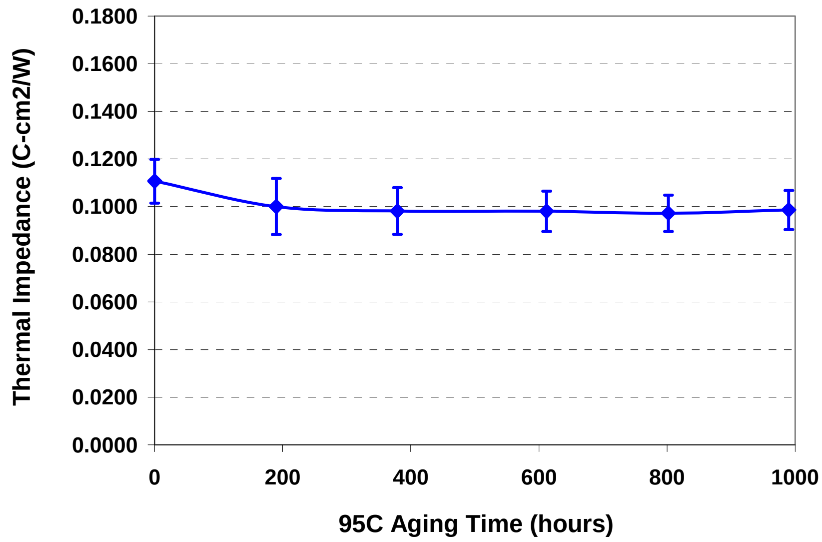


Figure 5-a

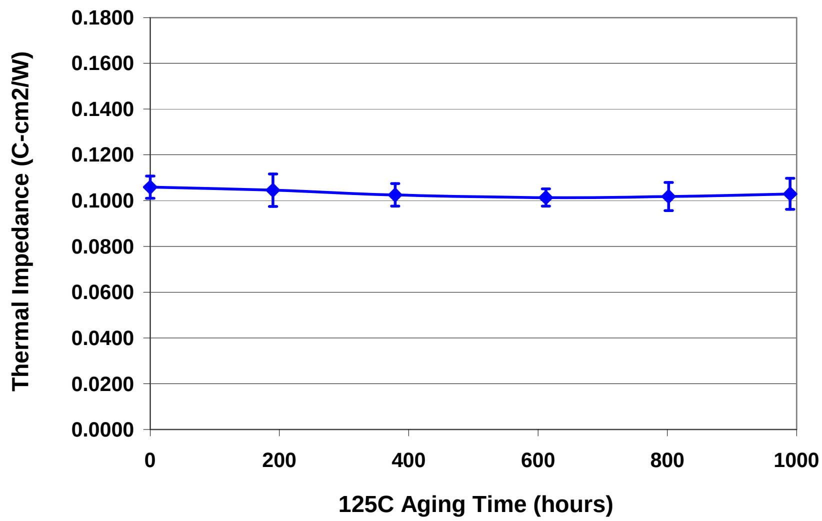


Figure 5-b

7.5. High Humidity Aging @ 85°C / 85% RH, 500 hrs

7.6. Thermal Performance: The initial and humidity aging conditioning thermal resistances are shown in Figure 6. In order to compare the difference between two dies due to die height and warpage, the junction temperatures of two dies (Die 1 and 2) and each dies corresponding plate temperatures were collected respectively. The thermal resistance of Gel 8010 with core heating of 40W were calculated on two dies (Die 1 and 2) was calculated respectively. The thermal resistance reached its saturated value (0.14 °C-cm²/W) after 500hrs of 85°C/85%R.H.

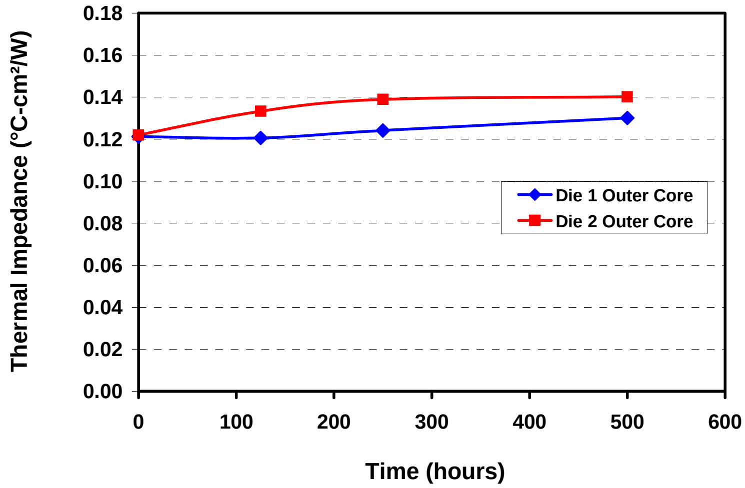


Figure 6

7.7. Temperature Cycling between 0°C and 120°C for 750 cycles

7.8. Thermal Performance: Figure 7 shows the thermal resistance of Gel 8010 for core heating conditions. Thermal cycling did not deteriorate the thermal performance of Gel 8010 as Thermal or Humidity aging. Even after 750 cycles, the values began to show unchanged values. The test results demonstrate the good HAST performance of Gel 8010. In order to compare the difference between two dies due to die height and warpage, the junction temperatures of two dies (Die 1 and 2) and each dies corresponding plate temperatures were collected respectively. The thermal resistance of Gel 8010 with core heating of 40W were calculated on two dies (Die 1 and 2) was calculated respectively.

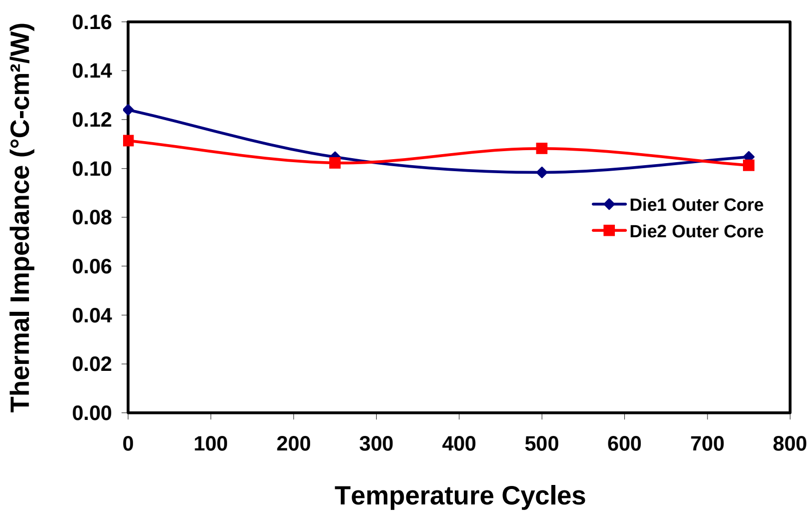


Figure 7

7.9. Power Cycling at 50W for 6min power-on and 6min power-off for 750 cycles

7.10. Thermal Performance: Figure 8 shows the thermal resistance of Gel 8010 for core heating conditions. Power cycling did not deteriorate the thermal performance of Gel 8010 as Thermal or Humidity aging. Even after 750 cycles, the values began to show unchanged values. The test results demonstrate the good HAST performance of Gel 8010.

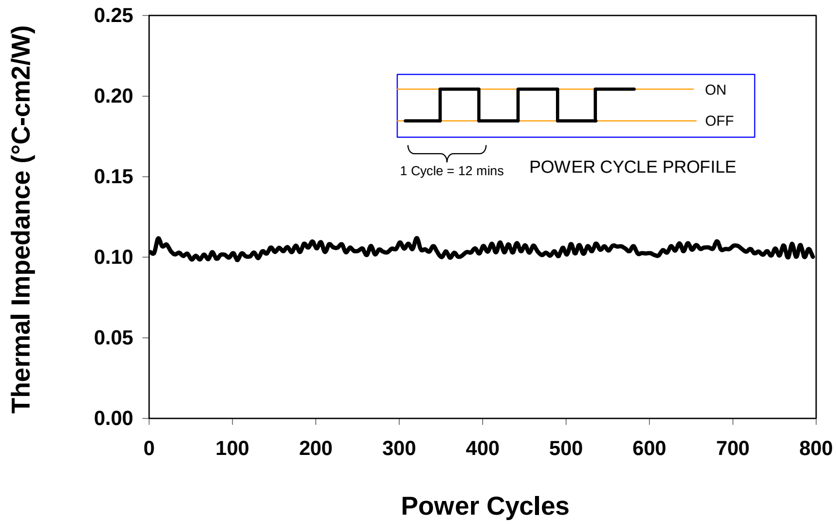


Figure 8

8. Comparison Analysis

8.1. Grease versus Gel 8010 : Power Cycling

8.1.1. The thermal performance of Gel 8010 was compared with a highly used representative thermal grease. The test set-up, test method and exposure method was the same for the grease. Initially, the thermal resistance (0.093 °C-cm²/W) of the grease was slightly lower than that of T777 (0.103 °C-cm²/W). After less than 30 power cycling, the grease began to show higher thermal impedance due to dry-out. The difference between two TIMs became wider as the power cycling went further. Figure 9 shows the similar initial thermal resistance of both TIMs during the power cycling. The thermal resistance of the grease increased more than 2 times compared to that of Gel 8010 maintained the initial values.

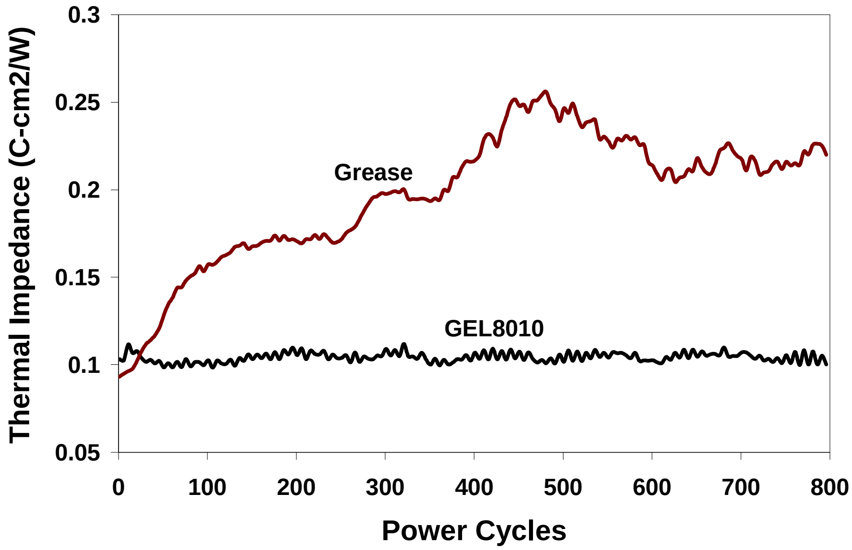

0.3
0.25
0.2
0.15
0.1
0.05
Thermal Impedance (C-cm2/W)
Grease
GEL8010
0
100
200
300
400
500
600
700
800
Power Cycles

Figure 9