

Stratasys DDM Group

Coefficient of Thermal Expansion Test Report

Test House:

NIAR – Wichita Kansas

Contact – Shin Mah

Revision Dates:

<i>Original</i>	<i>2009-12-01</i>	<i>First Release, CTE Data table – ULTEM, PPSF, SR30, PC</i>
<i>Revision A</i>	<i>2011-09-17</i>	<i>Detail procedure with raw test data</i>
<i>Revision B</i>	<i>2011-09-21</i>	<i>Corrected Phase 2 Material Types in test conf table</i>
<i>Revision C</i>	<i>2011-12-20</i>	<i>Added two new materials – SR100 & ABS ESD7</i>

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TABLE OF CONTENTS

Overview.....	3
Test Results Summary.....	3
Test Procedure.....	4
Phase 1 – ISOTROPIC Behavior Assessment	4
Test Table.....	5
Results	5
Findings.....	6
Phase 2 – Material Assessment	7
Test Table.....	7
Results	8
Phase 3 – SR100 & ABS ESD7	9
SR100	9
ABS ESD7.....	10
SMSG Contacts	11
Appendix A – Phase 1 Detail Data	12
Appendix B – Phase 2 Detail Data.....	24
PC.....	24
ULTEM.....	27
SR30	30
Appendix C - Phase 3	33
SR100	33
ABS ESD7.....	42

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OVERVIEW

Fused deposition modeling is being utilized for a variety of tooling and end use parts applications that required elevated temperatures, like composite layup tooling. For these applications users needed to understand the coefficient of thermal expansion (CTE) to appropriately design the tools or parts. This test report provides the data that has been collected and the third party tests houses that were utilized to obtain that data. Only accredited third party test facilities that are recognized in the industry will be included in this report.

TEST RESULTS SUMMARY

Stratasys Product	Test Procedure	Test Facility	$\mu\text{m}/(\text{m}\cdot\text{C}^\circ)$	$\text{in}/(\text{in}\cdot\text{F}^\circ)$	Doc. Rev
PC	ASTM E228	NIAR	79.23	4.46E-05	Original
SR30	ASTM E228	NIAR	115.53	6.50E-05	Original
PPSF	ASTM E228	NIAR	69.83	3.93E-05	Original
ULTEM 9085 Natural	ASTM E228	NIAR	65.27	3.67E-05	Original
SR 100 <End>	ASTM E228	NIAR	98.32 (35°C-100°C)	5.47E-05 (95°F-212°F)	C
			187.6 (100°C-130°C)	10.42E-05 (212°F-266°F)	C
SR 100 <Edge>	ASTM E228	NIAR	84.21 (35°C-105°C)	4.68E-05 (95°F-221°F)	C
ABS ESD7 <End>	ASTM E228	NIAR	80.76 (-40°C-70°C)	4.49E-05 (-40°F-158°F)	C
			389.5 (80°C-105°C)	21.64E-05 (176°F-221°F)	C
ABS ESD7 <Edge>	ASTM E228	NIAR	76.30 (-40°C-60°C)	4.24E-05 (-40°F-140°F)	C

Test Methods

Test Method:	ASTM E228
Test House:	NIAR
Machine:	TA TMA Q400
Test Fixture:	Expansion Probe
Test Method:	Controlled Force 0.05N
Heating Rate:	5°C/min (9°F/min)

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Temperature Range:		
ULTEM	-60°C +170°C	-73°F +338°F
SR30	-60°C +110°C	-73°F +230°F
PC	-60°C +140°C	-73°F +284°F
PPSF	-60°C +200°C	-73°F +392°F
SR 100	35°C +200°C	95°F +392°F
ABS ESD7	-60°C +120°C	-73°F +248°F

TEST PROCEDURE

ASTM E228 Test Procedure was used to assess CTE for Stratasys Materials. Phase 1 investigated how the variety of build orientations and build styles would affect the CTE of an FDM produced part or tool? Because PPSF was the highest temperature material and could be tested to the highest values, it was selected for the initial case study. It was an assumption of the Phase 1 assessment, that higher delta temperatures would accentuate any potential anisotropic behaviors due to FDM processing. In Phase 2, the balance of the FDM materials were evaluated for CTE based on the lessons learned from the Phase 1 Assessment. Phase 3 added two new materials SR100 soluble materials and ABS ESD7 material.

PHASE 1 – ISOTROPIC BEHAVIOR ASSESSMENT

Two factors were investigated to understand their impacts on CTE:

1. Build Orientation
 - a. Edge – both edge and flat were determined to have the same filament orientation so only edge was tested. In this case the coupon was built with its long side lying down on the build table. This configuration effectively tests the CTE in the axis of the extruded filament.
 - b. End – this test sample was built with the long edge of the coupon normal to the build table (standing up). This configuration effectively tests the CTE across the width of the extruded filament.
2. Build Style
 - a. Solid – This sample is built with default setting for a solid part
 - b. Sparse – this sample is built with gaps in the part to determine if localized CTE effects become a factor that changes the overall CTE of the FDM part.

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TEST TABLE

Four configurations (1-4) and three samples (a,b,c) of each configuration were tested.

Sample #	Material	Build Orientation	Fill
Sample 1A	PPSF	End	Solid
Sample 1B	PPSF	End	Solid
Sample 1C	PPSF	End	Solid
Sample 2A	PPSF	End	Sparse
Sample 2B	PPSF	End	Sparse
Sample 2C	PPSF	End	Sparse
Sample 3A	PPSF	Edge	Solid
Sample 3B	PPSF	Edge	Solid
Sample 3C	PPSF	Edge	Solid
Sample 4A	PPSF	Edge	Sparse
Sample 4B	PPSF	Edge	Sparse
Sample 4C	PPSF	Edge	Sparse

RESULTS

Metric

Sample #	Material	Build Orient	Fill	CTE					
				[$\mu\text{m}/(\text{m}\cdot^\circ\text{C})$]					
Sample 1A	PPSF	End	Solid	62.81	Average	65.93	Average	69.83	
Sample 1B	PPSF	End	Solid	71.20					
Sample 1C	PPSF	End	Solid	63.77	St. Dev.	4.59	St. Dev.	3.47	
Sample 2A	PPSF	End	Sparse	74.03	Average	71.74			
Sample 2B	PPSF	End	Sparse	69.13					
Sample 2C	PPSF	End	Sparse	72.07	St. Dev.	2.47			
Sample 3A	PPSF	Edge	Solid	72.13	Average	70.92			
Sample 3B	PPSF	Edge	Solid	70.83					
Sample 3C	PPSF	Edge	Solid	69.81	St. Dev.	1.16			
Sample 4A	PPSF	Edge	Sparse	69.17	Average	70.74			
Sample 4B	PPSF	Edge	Sparse	73.63					
Sample 4C	PPSF	Edge	Sparse	69.43	St. Dev.	2.50			

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English

CTE								
Sample #	Material	Build Orient	Fill	[in/(in·°F)]				
Sample 1A	PPSF	End	Solid	3.54E-05	Avg	3.71E-05	Avg	3.93E-05
Sample 1B	PPSF	End	Solid	4.01E-05				
Sample 1C	PPSF	End	Solid	3.59E-05	St. Dev.	2.58E-06	St. Dev.	1.95E-06
Sample 2A	PPSF	End	Sparse	4.17E-05	Avg	4.04E-05		
Sample 2B	PPSF	End	Sparse	3.89E-05				
Sample 2C	PPSF	End	Sparse	4.06E-05	St. Dev.	1.39E-06		
Sample 3A	PPSF	Edge	Solid	4.06E-05	Avg	3.99E-05		
Sample 3B	PPSF	Edge	Solid	3.99E-05				
Sample 3C	PPSF	Edge	Solid	3.93E-05	St. Dev.	6.55E-07		
Sample 4A	PPSF	Edge	Sparse	3.89E-05	Avg	3.98E-05		
Sample 4B	PPSF	Edge	Sparse	4.14E-05				
Sample 4C	PPSF	Edge	Sparse	3.91E-05	St. Dev.	1.41E-06		

Raw Data is provided in Appendix A

FINDINGS

The CTE values of each of the samples within a configuration were consistent. In addition, the samples across the different configurations were also consistent. Because there were no obvious differences in the test results that indicate any significant difference in CTE based on build orientation or build style, it was determined that a CTE for PPSF could be represented with a single average value of the test samples.

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PHASE 2 – MATERIAL ASSESSMENT

Based on the PPSF Phase 1 finding, it was determined that Phase 2 testing could be conducted on a single build orientation and style. The samples were built on edge with solid build parameters for each of the materials tested.

Three samples for each material were tested and the average value published as the representative CTE value for each material.

TEST TABLE

Sample #	Material	Build Orientation	Fill
Sample 1A	PC	Edge	Solid
Sample 1B	PC	Edge	Solid
Sample 1C	PC	Edge	Solid
Sample 2A	ULTEM	Edge	Solid
Sample 2B	ULTEM	Edge	Solid
Sample 2C	ULTEM	Edge	Solid
Sample 3A	SR30	Edge	Solid
Sample 3B	SR30	Edge	Solid
Sample 3C	SR30	Edge	Solid
Sample 4A	PPSF	Edge	Solid
Sample 4B	PPSF	Edge	Solid
Sample 4C	PPSF	Edge	Solid
Test Parameters:			
Machine: TA TMA Q400			
Test Fixture: Expansion Probe			
Test Method: Controlled Force 0.05N			
Heating Rate: 5°C/min			
Temperature Range:			
-60°C to 140°C (PC)			
-60°C to 170°C (Ultem)			
-60°C to 110°C (SR30)			
-60°C to 200°C (PPSF)			

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RESULTS

Metric

Sample #	Material	Build Orientation	Fill	CTE		
				[$\mu\text{m}/(\text{m}\cdot^{\circ}\text{C})$]		
Sample 1A	PC	Edge	Solid	80.46	Average	79.23
Sample 1B	PC	Edge	Solid	79.57		
Sample 1C	PC	Edge	Solid	77.66	St. Dev.	1.43
Sample 2A	Ultem	Edge	Solid	62.80	Average	65.27
Sample 2B	Ultem	Edge	Solid	67.78		
Sample 2C	Ultem	Edge	Solid	65.22	St. Dev.	2.49
Sample 3A	SR30	Edge	Solid	115.20	Average	115.53
Sample 3B	SR30	Edge	Solid	111.90		
Sample 3C	SR30	Edge	Solid	119.50	St. Dev.	3.81
Sample 4A	PPSF	Edge	Solid	72.13	Average	70.71
Sample 4B	PPSF	Edge	Solid	70.83		
Sample 4C	PPSF	Edge	Solid	69.17	St. Dev.	1.48

English

Sample #	Material	Build Orientation	Fill	CTE		
				[$\text{in}/(\text{in}\cdot^{\circ}\text{F})$]		
Sample 1A	PC	Edge	Solid	4.53E-05	Average	4.46E-05
Sample 1B	PC	Edge	Solid	4.48E-05		
Sample 1C	PC	Edge	Solid	4.37E-05	St. Dev.	8.05E-07
Sample 2A	Ultem	Edge	Solid	3.54E-05	Average	3.67E-05
Sample 2B	Ultem	Edge	Solid	3.82E-05		
Sample 2C	Ultem	Edge	Solid	3.67E-05	St. Dev.	1.40E-06
Sample 3A	SR30	Edge	Solid	6.48E-05	Average	6.50E-05
Sample 3B	SR30	Edge	Solid	6.30E-05		
Sample 3C	SR30	Edge	Solid	6.73E-05	St. Dev.	2.15E-06
Sample 4A	PPSF	Edge	Solid	4.06E-05	Average	3.98E-05
Sample 4B	PPSF	Edge	Solid	3.99E-05		
Sample 4C	PPSF	Edge	Solid	3.89E-05	St. Dev.	8.35E-07

Raw Data is provided in Appendix B

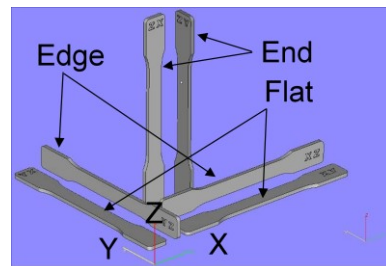
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PHASE 3 – SR100 & ABS ESD7

Both of the Phase 3 materials were found to have anisotropic CTE properties. Therefore, tests were conducted in the End and Edge build styles. Designers should evaluate the operational temperature range for which the materials are being used and account for the CTE growth accordingly. The SR100 material is a soluble material that is not typically used for low temperature part applications so it was not tested at the low temperatures. It is however often used for soluble composite cure tooling and therefore the SR100 was tested over a temperature range from ambient to the Tg of the material.



SR100

Metric

TMA Results								
Stratasys 2011 SR100 CTE Samples								
Sample #	Orientation	Temperature Range (°C)	Coefficient of Thermal Expansion [$\mu\text{m}/(\text{m}\cdot^{\circ}\text{C})$]		Change in CTE from Dimension Change Signal			
					Tg [°C]	Tg [°F]	Tg [°F]	
Sample 1	End	35°C to 100°C 100°C to 130°C 140°C to 155°C	99.85		132.93	271.27	Average	271.97
			195.1				St. Dev.	0.65
			1550					
Sample 2	End	35°C to 100°C 100°C to 130°C 140°C to 155°C	95.86		133.38	272.08	St. Dev.	0.65
			190.9					
			1506					
Sample 3	End	35°C to 100°C 100°C to 130°C 140°C to 155°C	99.26		133.64	272.55		
			176.7					
			1726					
Sample 1	Edge	35°C to 105°C	83.76	Average	84.21			
Sample 2			84.37	St. Dev.	0.40			
Sample 3			84.50					

Raw Data is provided in Appendix C

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ABS ESD7

Metric

TMA Results					
Stratasys 2011 ABS ESD7 CTE Samples					
Sample #	Orientation	Temperature Range (°C)	Coefficient of Thermal Expansion [$\mu\text{m}/(\text{m}\cdot^\circ\text{C})$]		Change in CTE from Dimension Change Signal
					Tg [°C] Tg [°F]
Sample 1	End	-40°C to 70°C N/A	82.59 N/A		N/A N/A
Sample 2	End	-40°C to 70°C 80°C to 105°C	83.38 363.8		79.68 175.42
Sample 3	End	-40°C to 70°C 90°C to 105°C	76.31 416.8		86.38 187.48
Sample 1 Sample 2 Sample 3	Edge	-40°C to 60°C	77.45 76.02 75.44	Average 76.30 St. Dev. 1.03	

Raw Data is provided in Appendix C

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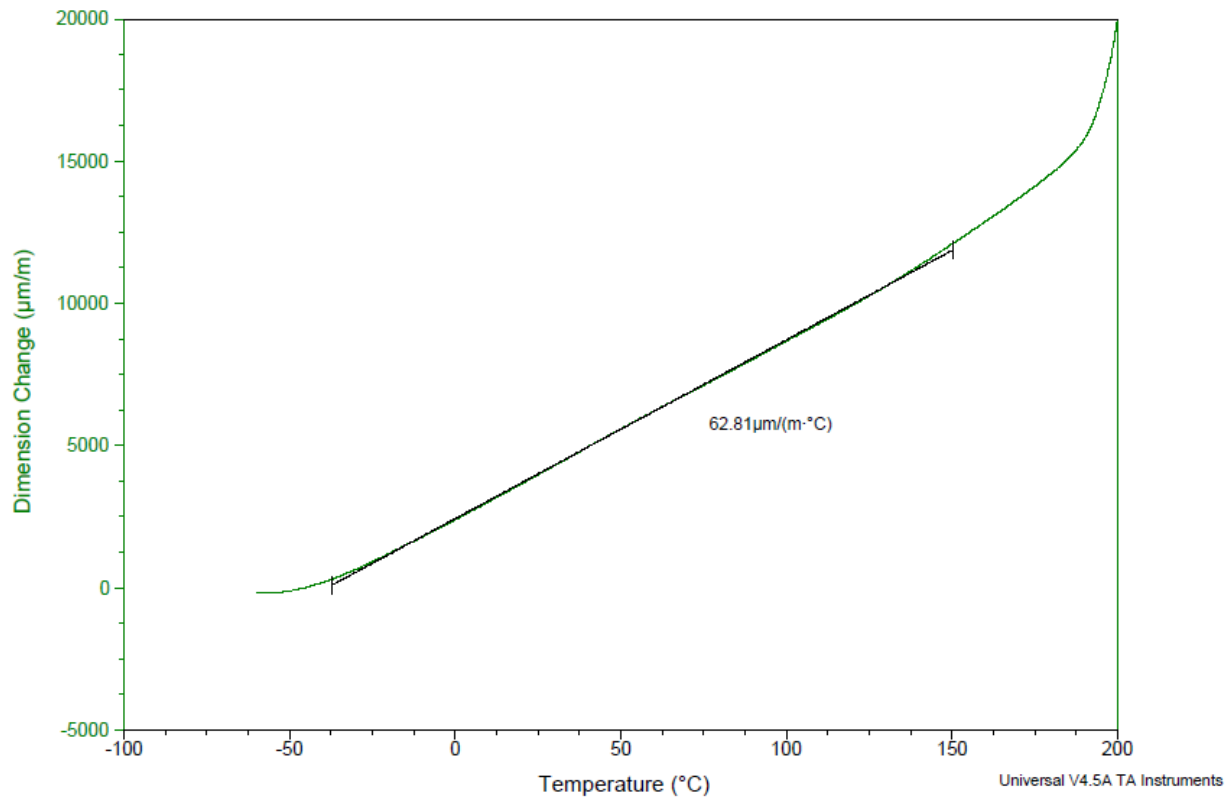


APPENDIX A – PHASE 1 DETAIL DATA

Sample: Sample 1A
Size: 25.7168 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:End Fill:Solid

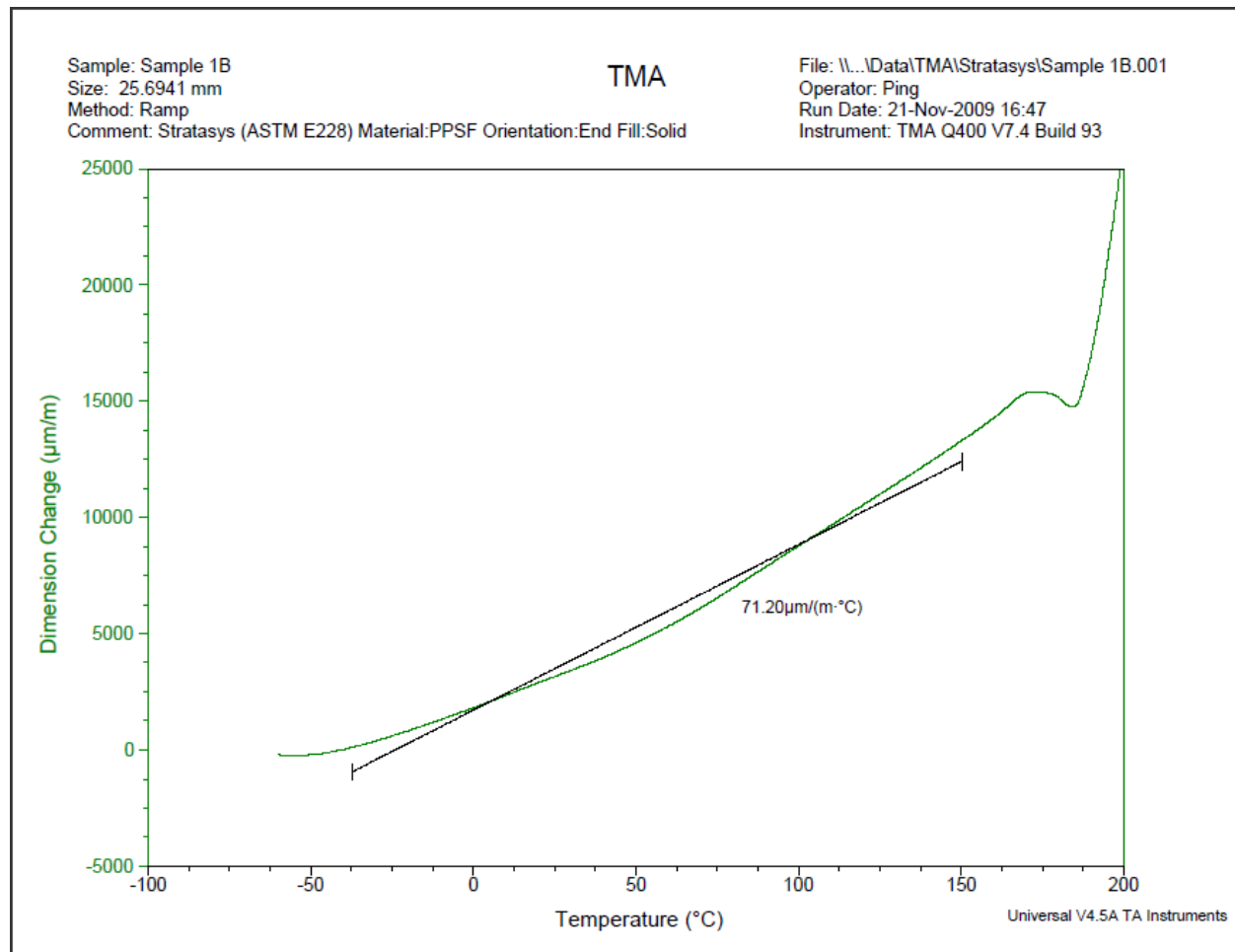
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Operator: Ping
Run Date: 20-Nov-2009 23:59
Instrument: TMA Q400 V7.4 Build 93



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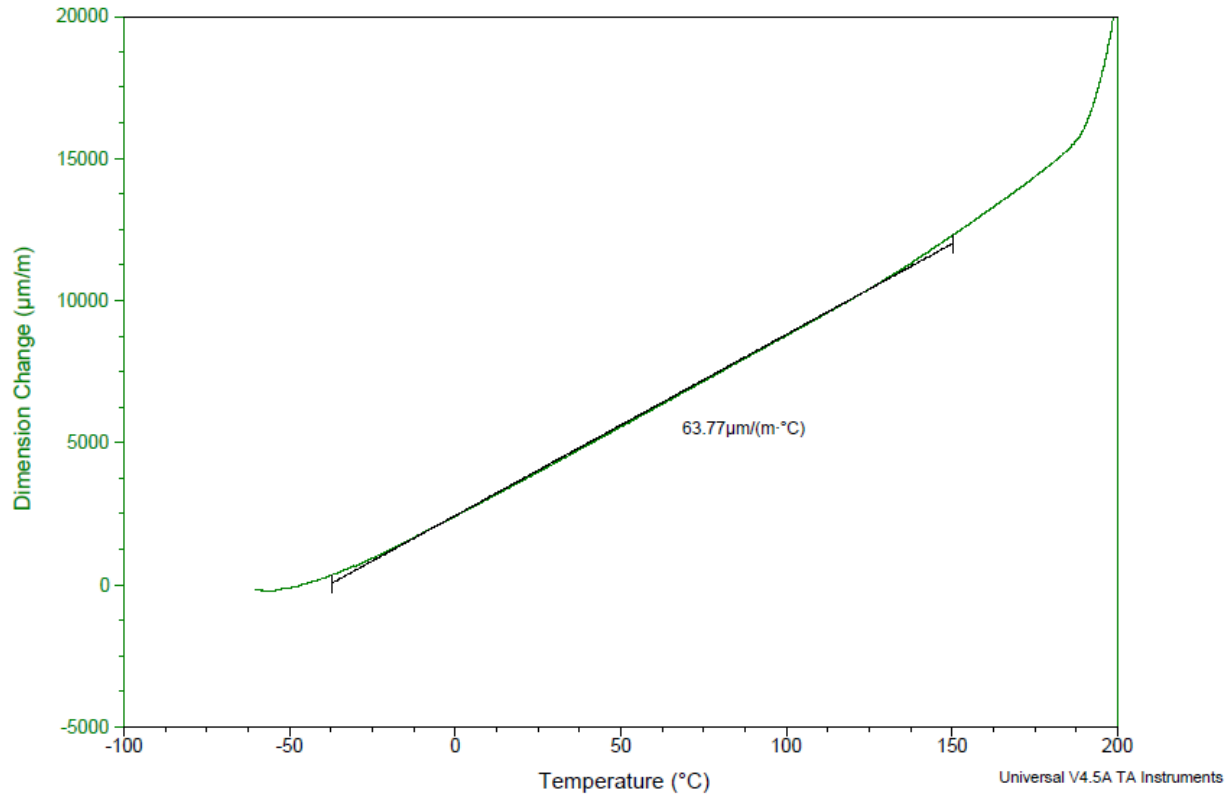
CTE TEST REPORT



Sample: Sample 1C
Size: 25.6613 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:End Fill:Solid

TMA

File: \\...\\Data\\TMA\\Stratasys\\Sample 1C.001
Operator: Ping
Run Date: 21-Nov-2009 18:14
Instrument: TMA Q400 V7.4 Build 93



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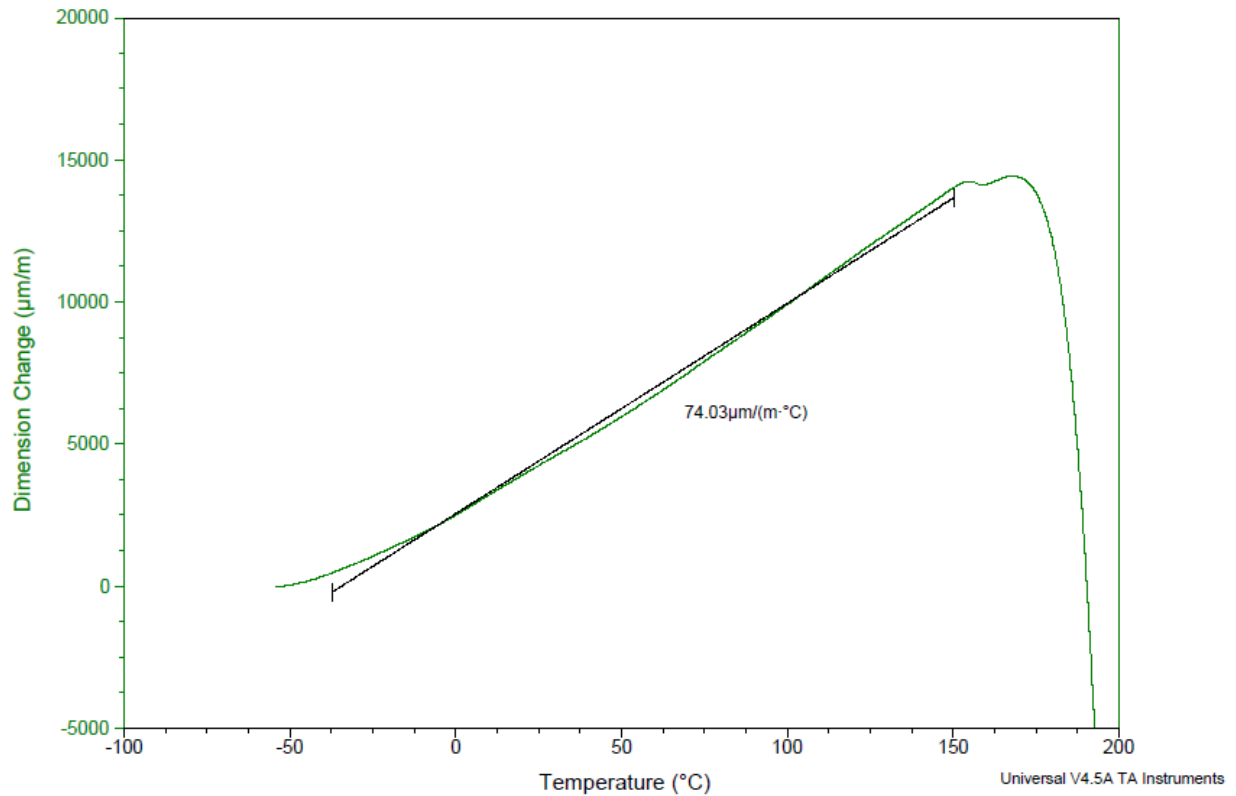
CTE TEST REPORT



Sample: Sample 2A
Size: 25.3086 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:End Fill:Sparse

TMA

File: \\...\\Data\\TMA\\Stratasys\\Sample 2A.001
Operator: Ping
Run Date: 17-Nov-2009 11:49
Instrument: TMA Q400 V7.4 Build 93



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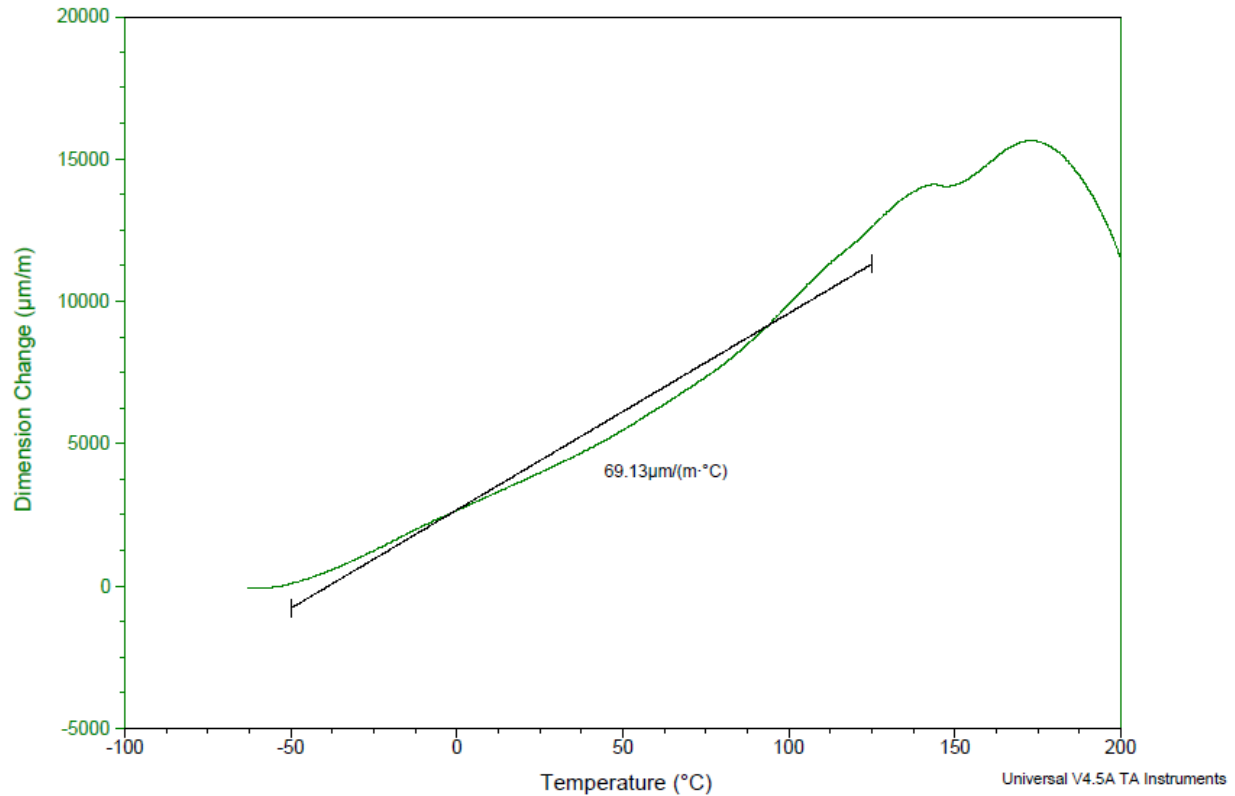
CTE TEST REPORT



Sample: Sample 2B
Size: 25.4084 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:End Fill:Sparse

TMA

File: \\...\\Data\\TMA\\Stratasys\\Sample 2B.001
Operator: Ping
Run Date: 18-Nov-2009 12:18
Instrument: TMA Q400 V7.4 Build 93



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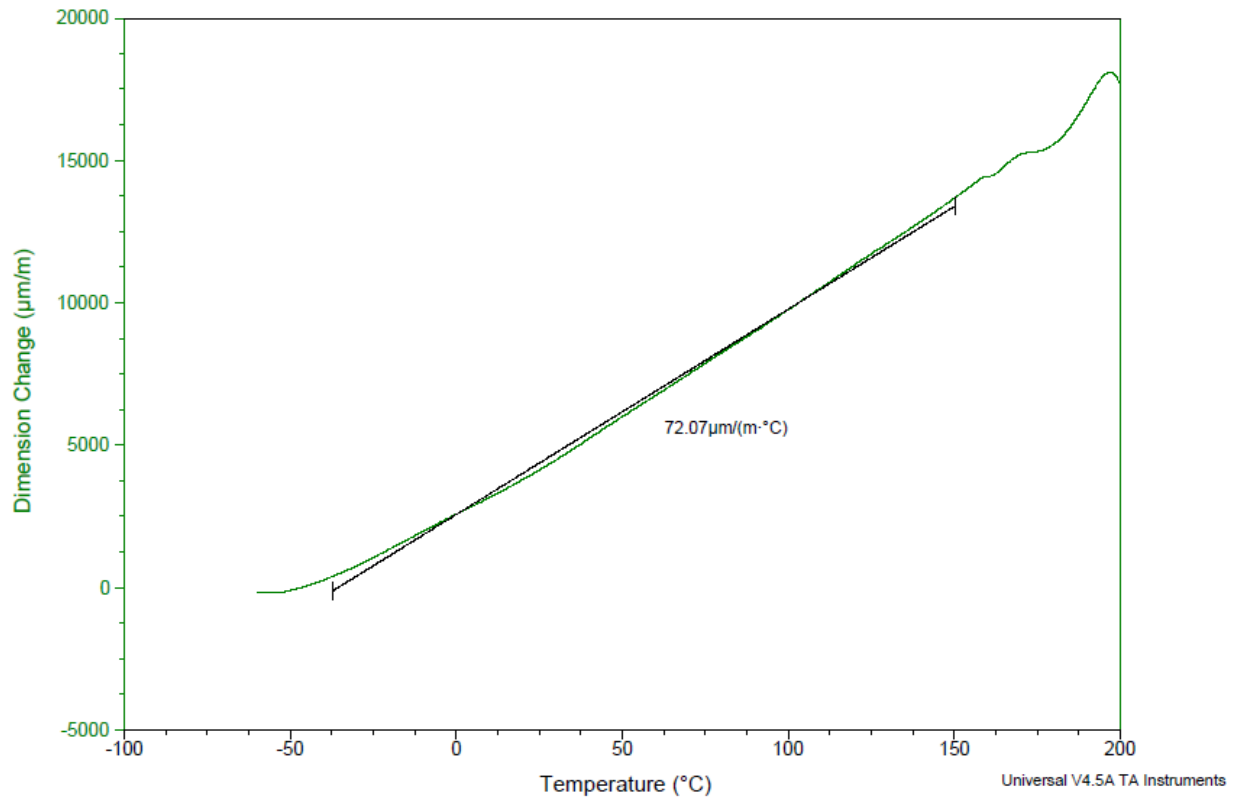
CTE TEST REPORT



Sample: Sample 2C
Size: 25.4790 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:End Fill:Sparse

TMA

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Instrument: TMA Q400 V7.4 Build 93



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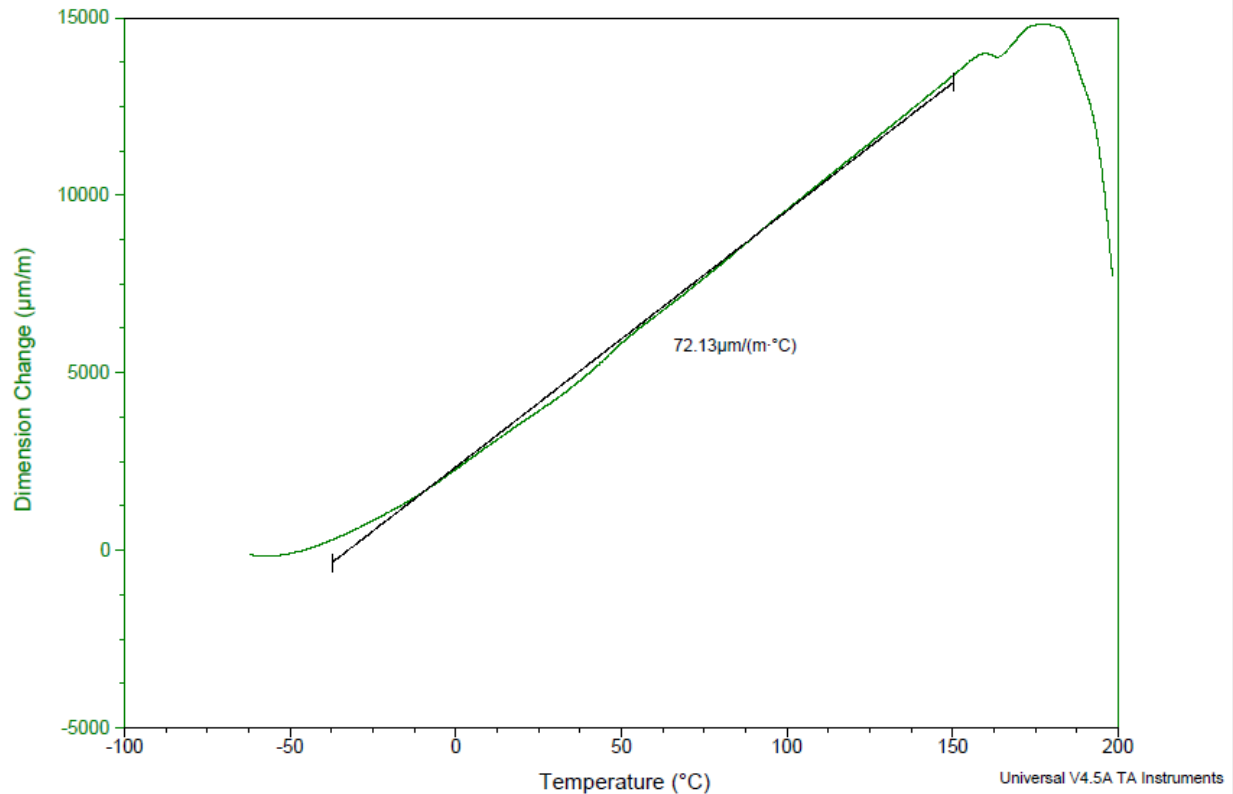
CTE TEST REPORT



Sample: Sample 3A
Size: 25.6393 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:Edge Fill:Solid

TMA

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Operator: Ping
Run Date: 19-Nov-2009 17:29
Instrument: TMA Q400 V7.4 Build 93



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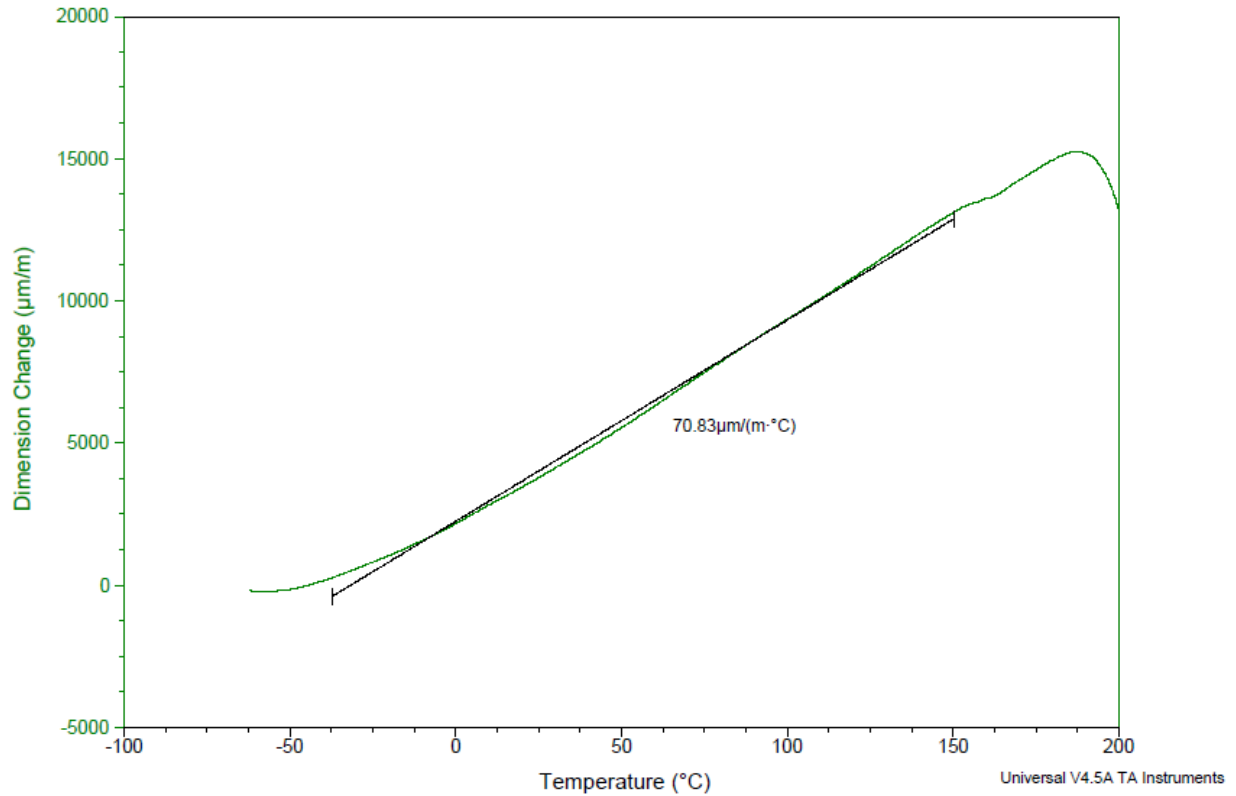
CTE TEST REPORT



Sample: Sample 3B
Size: 25.5030 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:Edge Fill:Solid

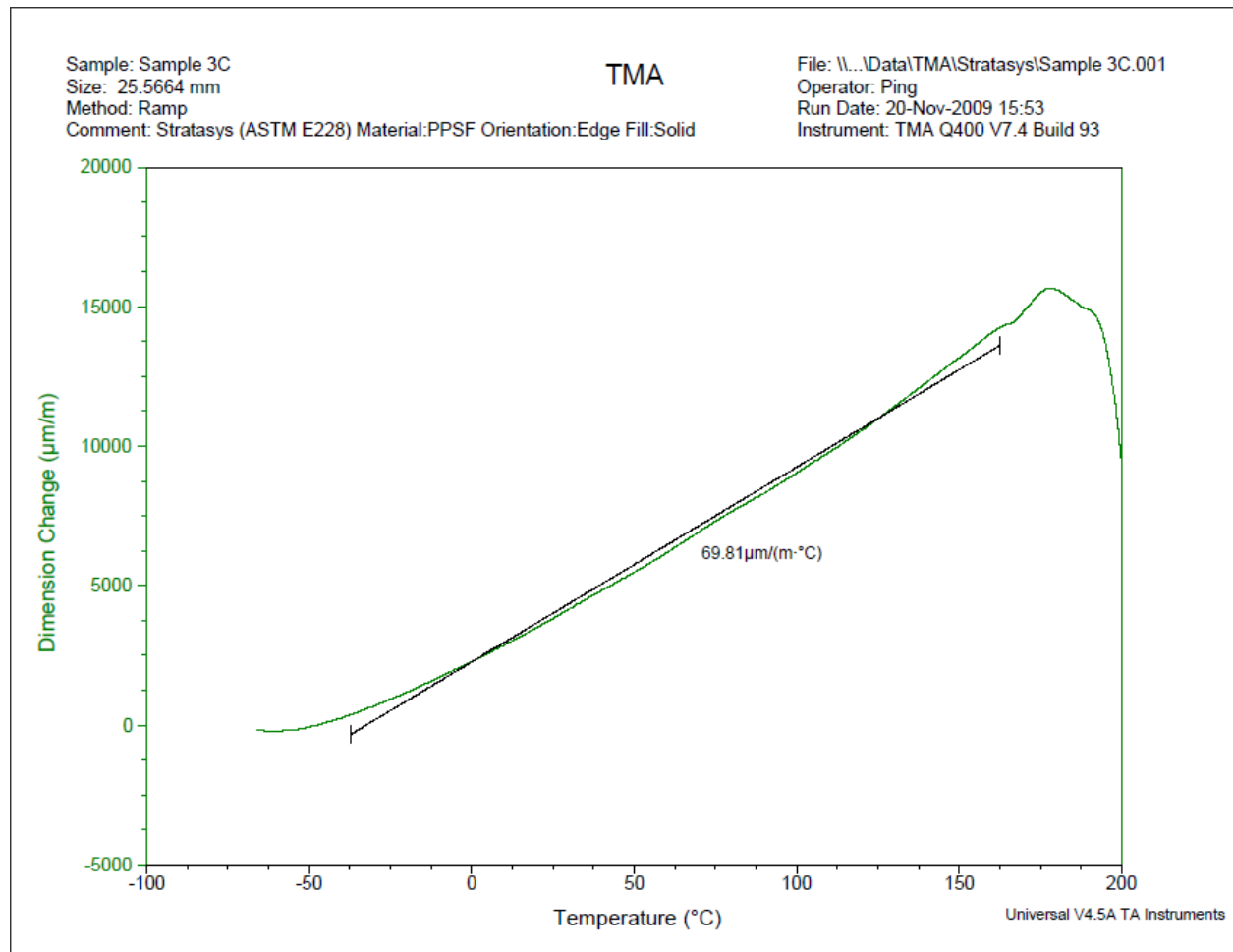
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Operator: Ping
Run Date: 20-Nov-2009 14:29
Instrument: TMA Q400 V7.4 Build 93



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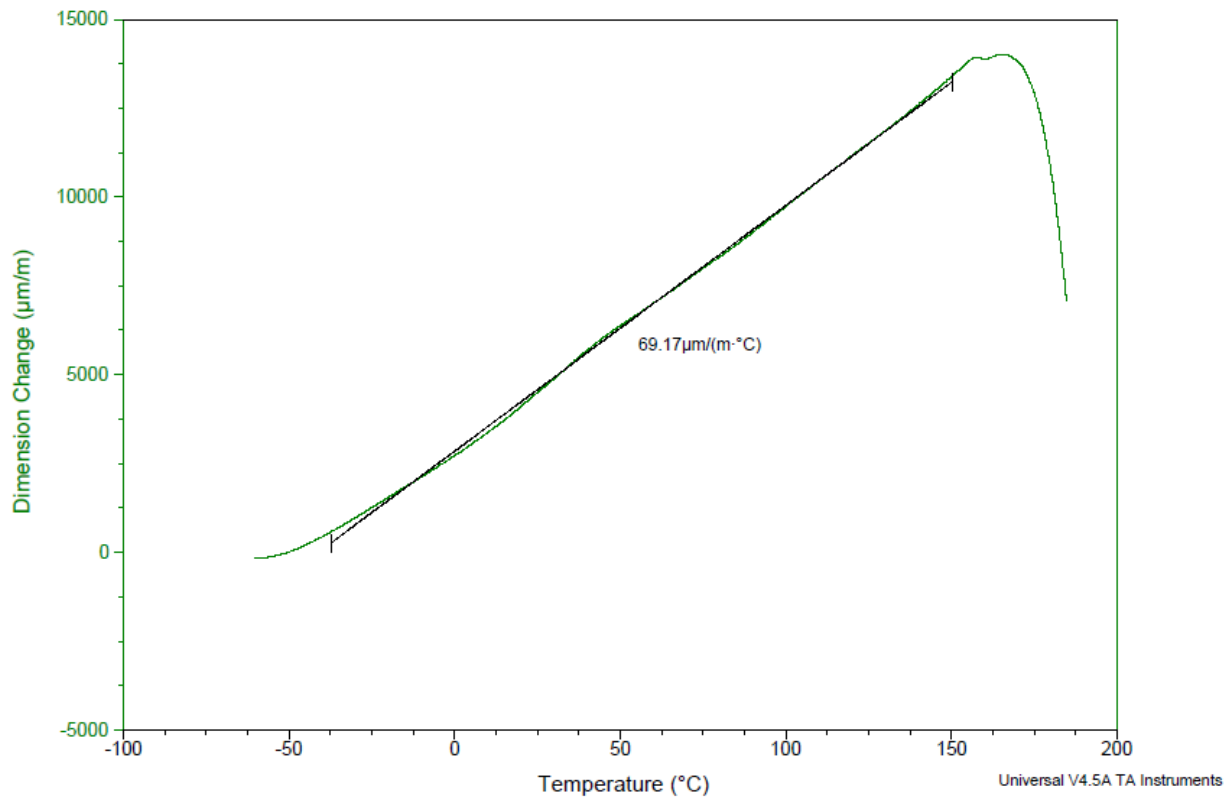
CTE TEST REPORT



Sample: Sample 4A
Size: 25.6738 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:Edge Fill:Spars

TMA

File: \\...\\Data\\TMA\\Stratasys\\Sample 4A.001
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Run Date: 20-Nov-2009 17:16
Instrument: TMA Q400 V7.4 Build 93



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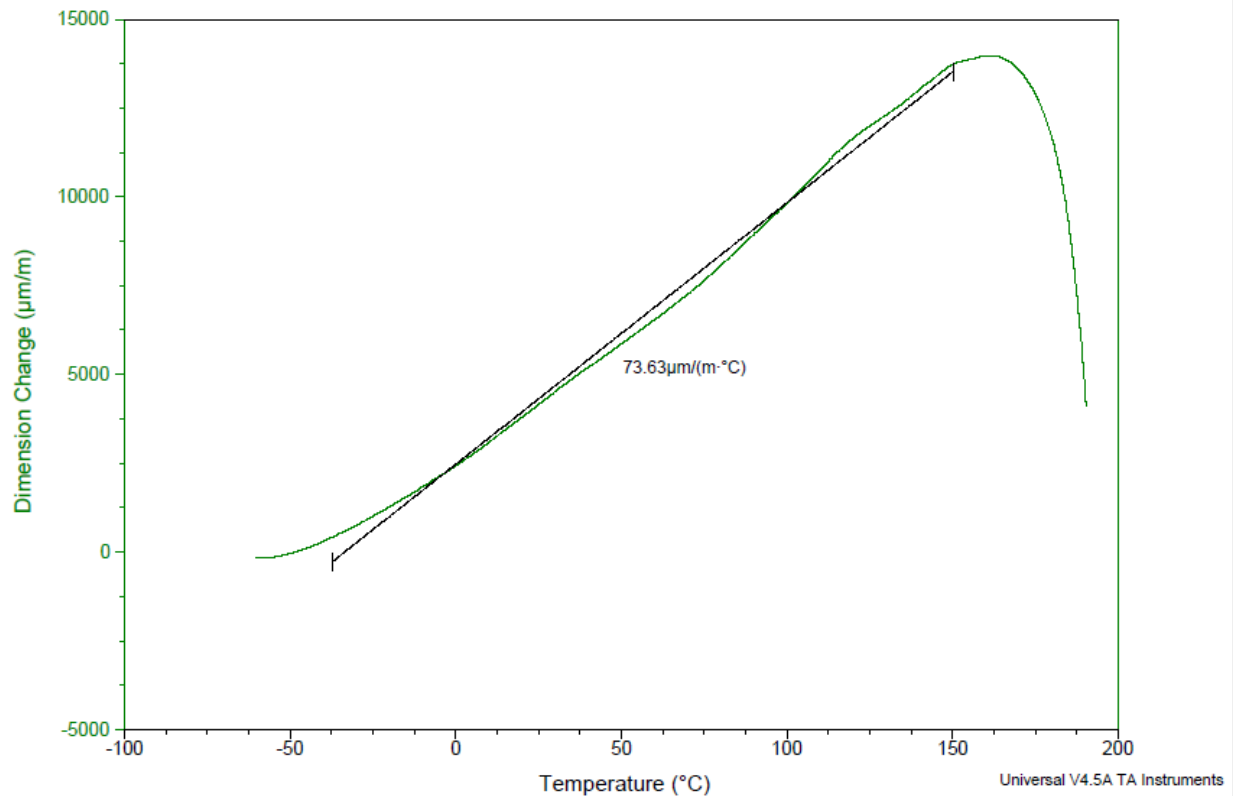
CTE TEST REPORT



Sample: Sample 4B
Size: 25.5650 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:Edge Fill:Spars

TMA

File: \\...\\Data\\TMA\\Stratasys\\Sample 4B.001
Operator: Ping
Run Date: 20-Nov-2009 21:20
Instrument: TMA Q400 V7.4 Build 93



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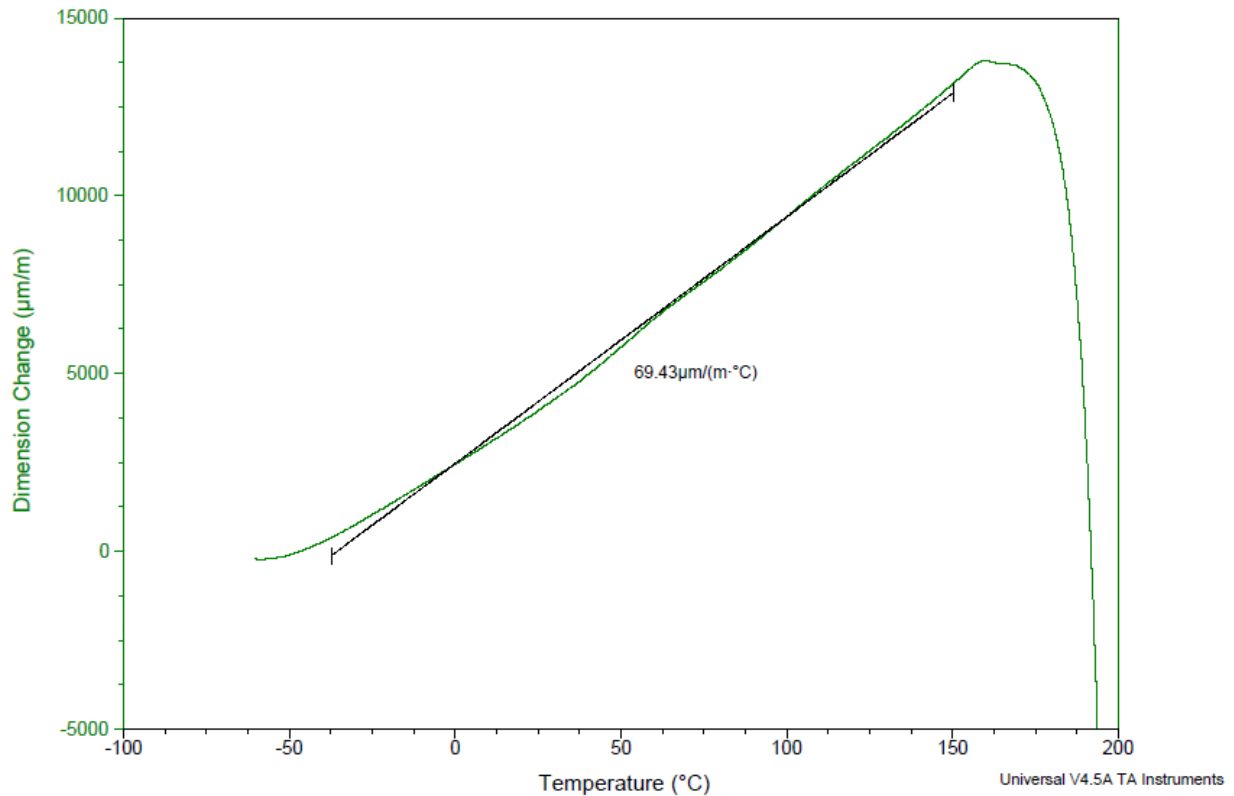
CTE TEST REPORT



Sample: Sample 4C
Size: 25.5595 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PPSF Orientation:Edge Fill:Spars

TMA

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Operator: Ping
Run Date: 20-Nov-2009 22:39
Instrument: TMA Q400 V7.4 Build 93



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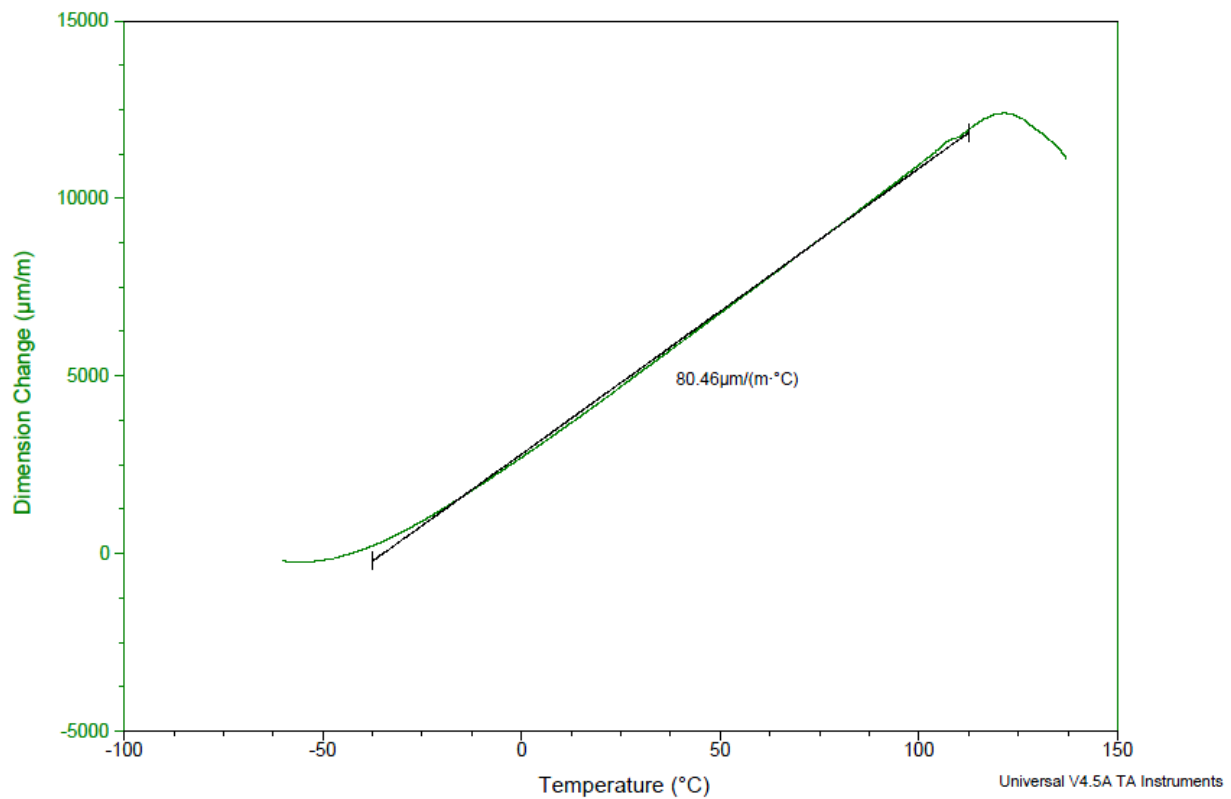
APPENDIX B – PHASE 2 DETAIL DATA

PC

Sample: Sample 1A
Size: 25.5215 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PC Orientation:Edge Fill:Solid

TMA

File: C:\TMA\Stratasys\2010\Sample 1A.001
Operator: Ping
Run Date: 22-Jan-2010 15:07
Instrument: TMA Q400 V7.4 Build 93



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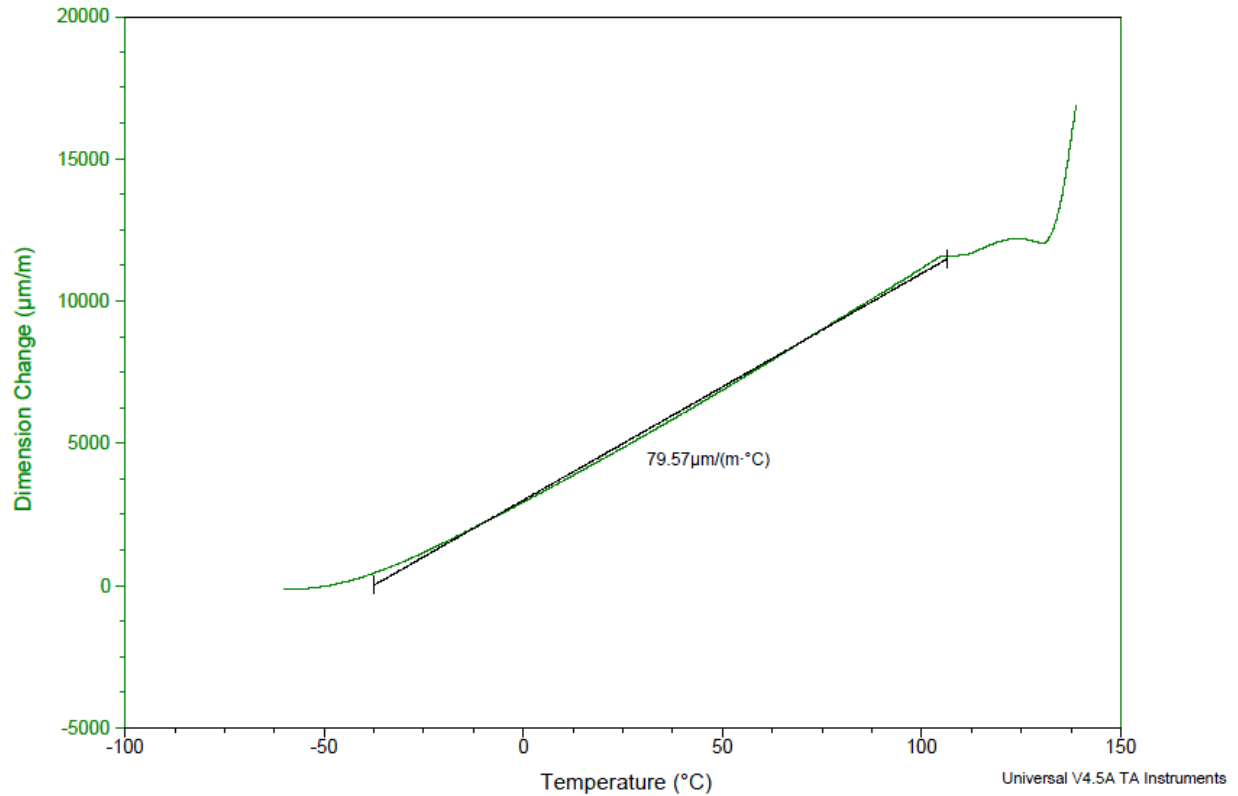
CTE TEST REPORT



Sample: Sample 1B
Size: 25.5506 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PC Orientation:Edge Fill:Solid

TMA

File: C:\TMA\Stratasys\2010\Sample 1B.001
Operator: Ping
Run Date: 22-Jan-2010 16:17
Instrument: TMA Q400 V7.4 Build 93



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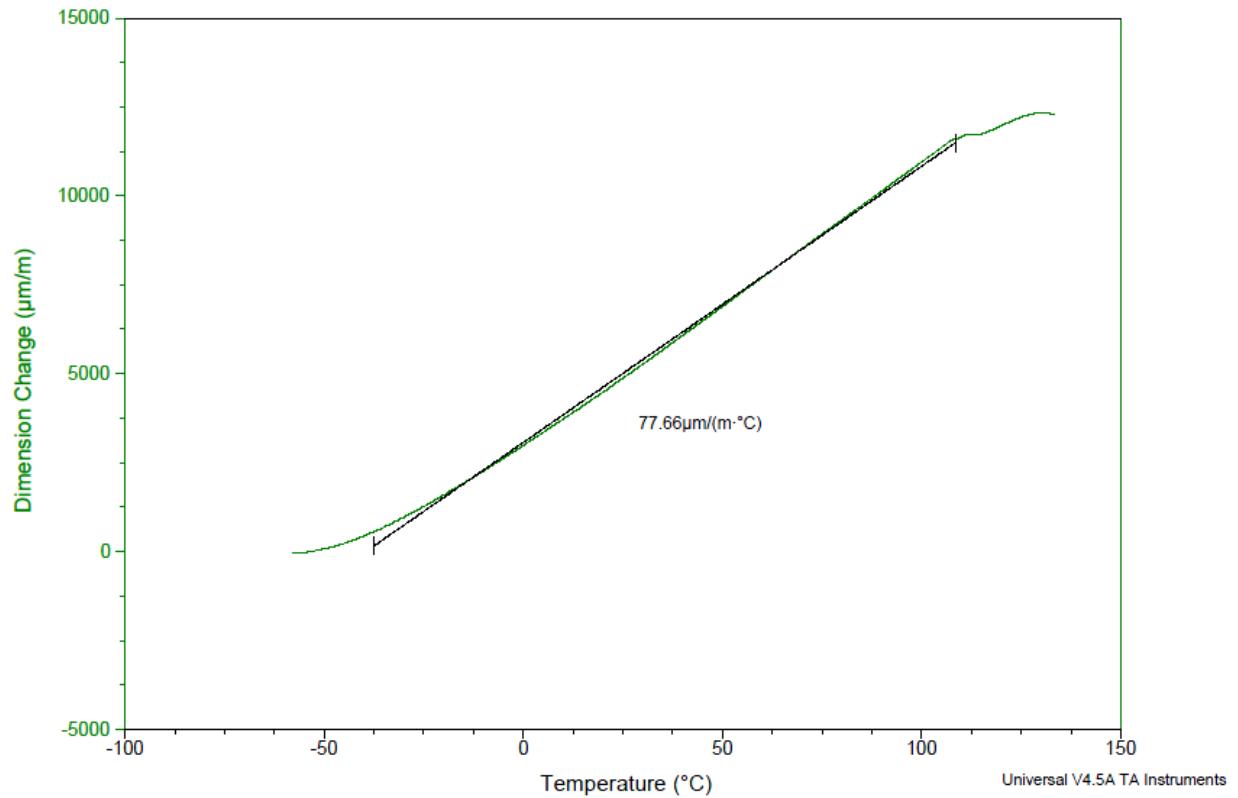
CTE TEST REPORT



Sample: Sample 1C
Size: 25.5447 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:PC Orientation:Edge Fill:Solid

TMA

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Operator: Ping
Run Date: 22-Jan-2010 17:40
Instrument: TMA Q400 V7.4 Build 93



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CTE TEST REPORT

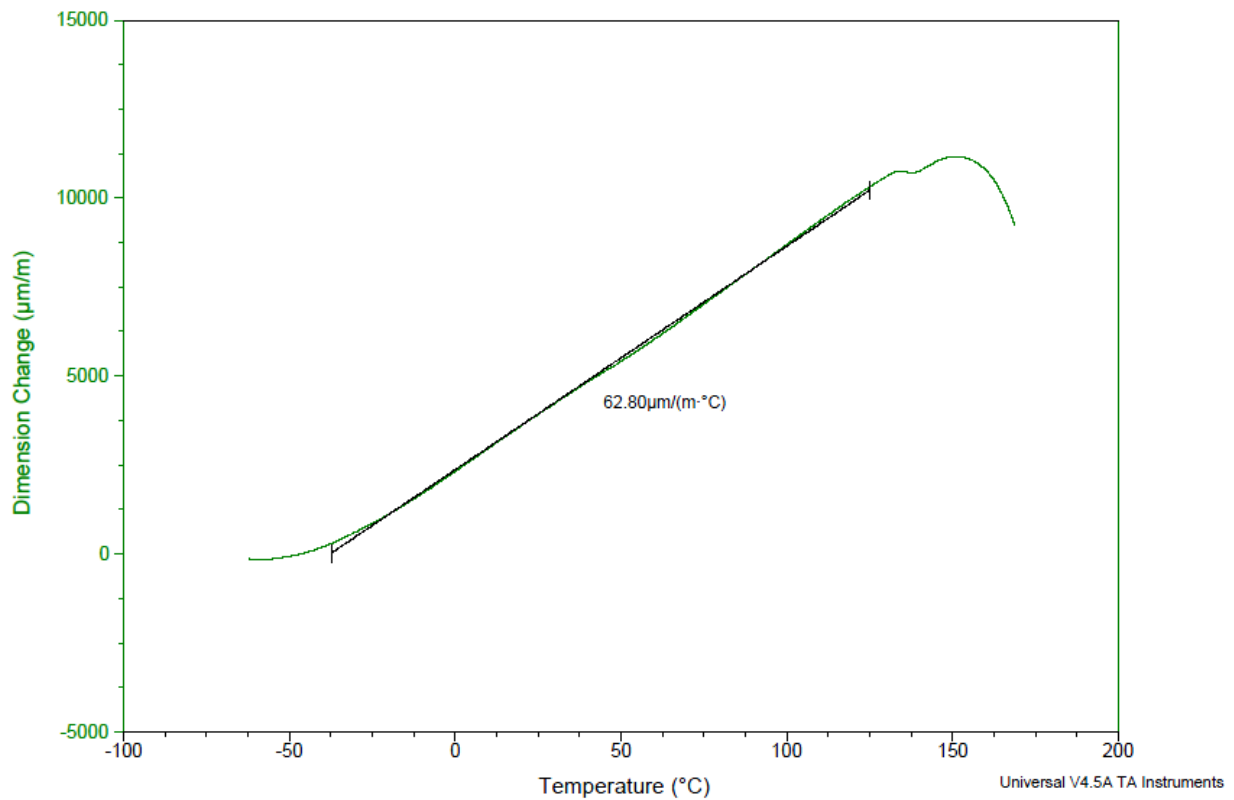


ULTEM

Sample: Sample 2A
Size: 25.6113 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: Ultem Orientation: Edge Fill: Soli

TMA

File: C:\TMA\Stratasys\2010\Sample 2A.001
Operator: Ping
Run Date: 22-Jan-2010 23:06
Instrument: TMA Q400 V7.4 Build 93



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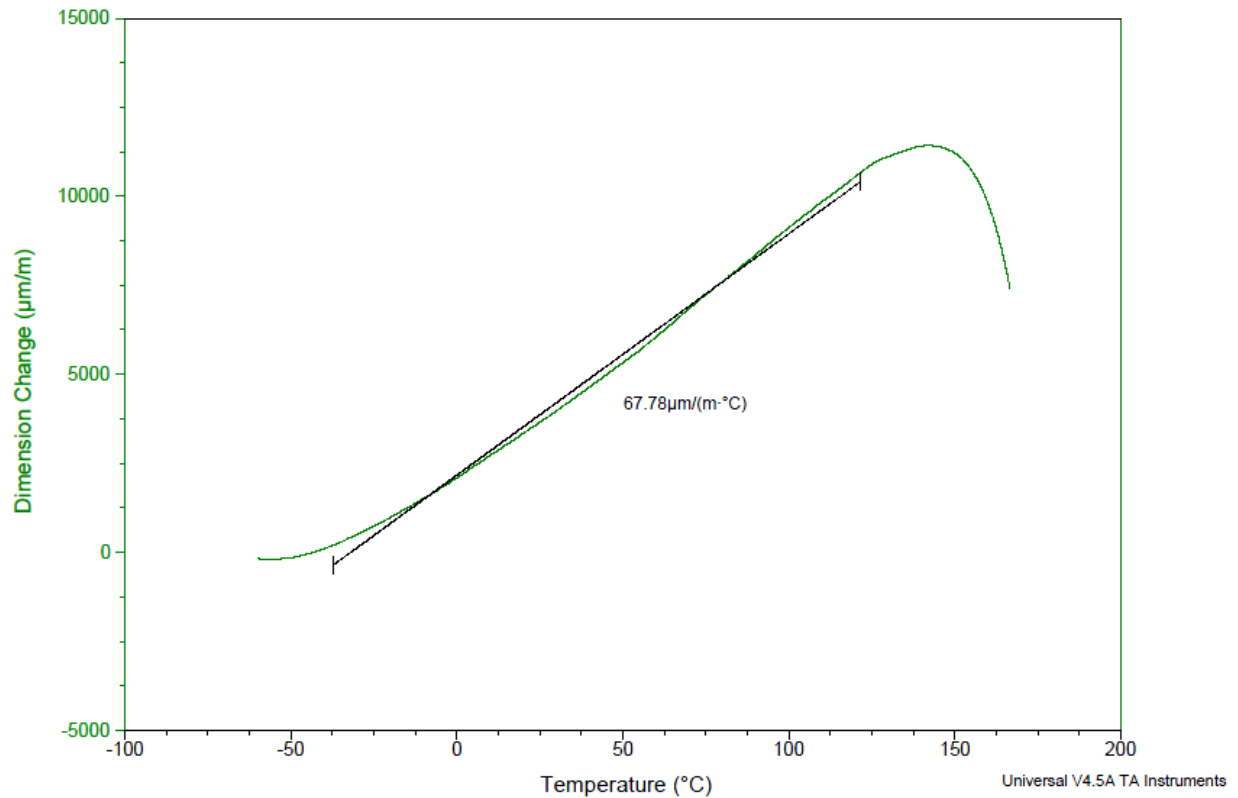
CTE TEST REPORT



Sample: Sample 2B
Size: 25.5845 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: Ultem Orientation: Edge Fill: Soli

TMA

File: C:\TMA\Stratasys\2010\Sample 2B.001
Operator: Ping
Run Date: 23-Jan-2010 00:20
Instrument: TMA Q400 V7.4 Build 93



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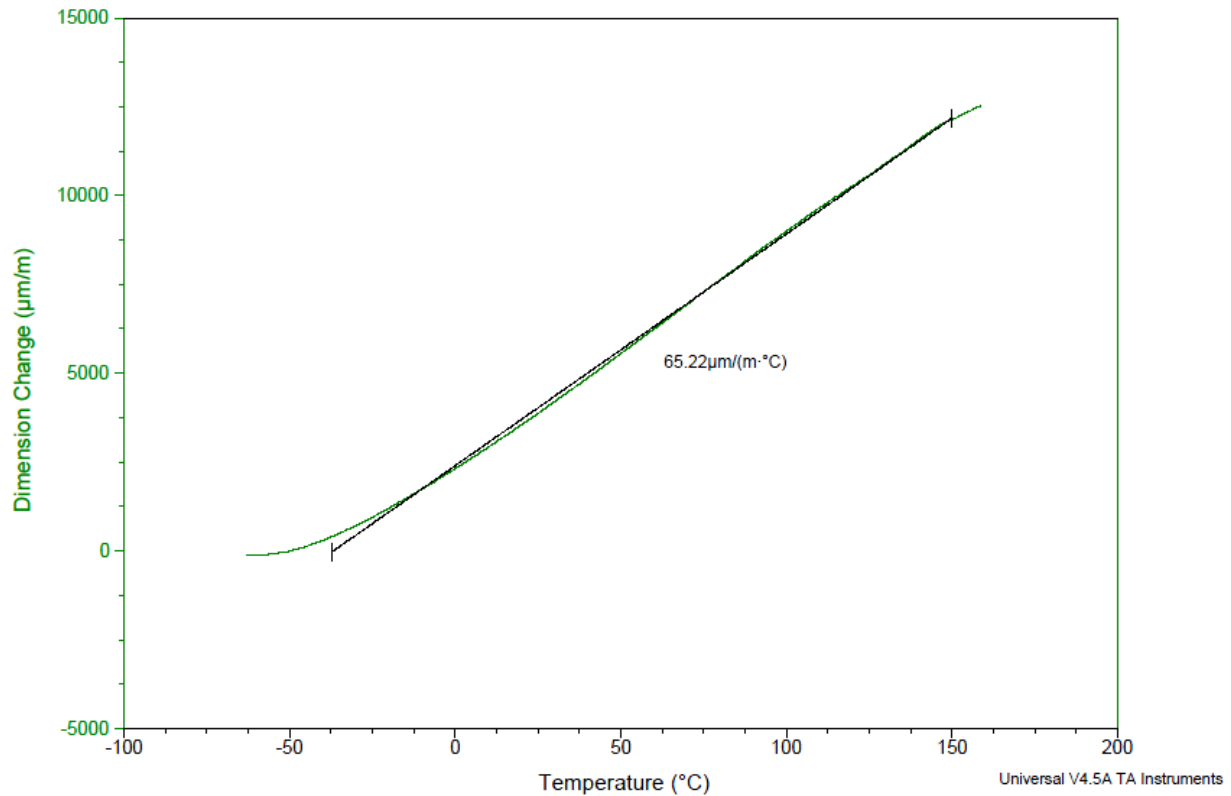
CTE TEST REPORT



Sample: Sample 2C
Size: 25.5938 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:Ultem Orientation:Edge Fill:Soli

TMA

File: C:\TMA\Stratasys\2010\Sample 2C.001
Operator: Ping
Run Date: 23-Jan-2010 01:34
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

CTE TEST REPORT

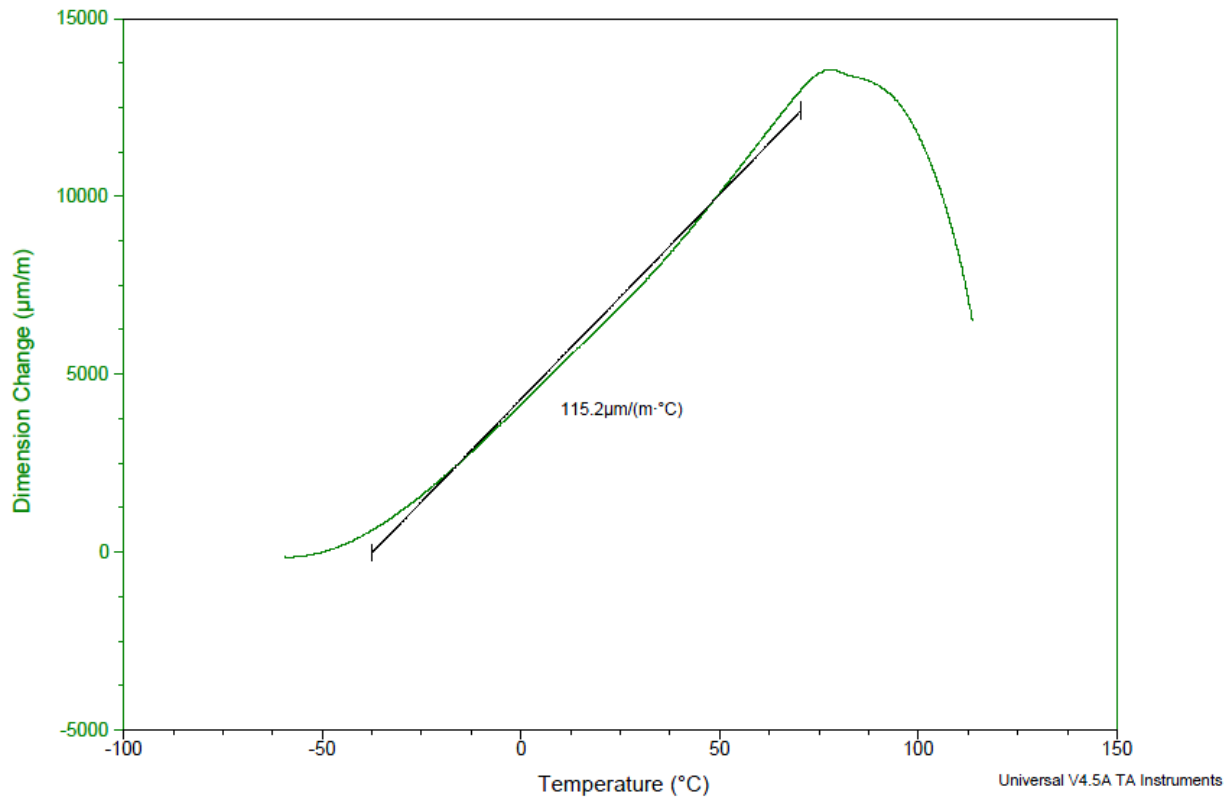


SR30

Sample: Sample 3A
Size: 25.5020 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:SR30 Orientation:Edge Fill:Solid

TMA

File: C:\TMA\Stratasys\2010\Sample 3A.001
Operator: Ping
Run Date: 22-Jan-2010 19:08
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

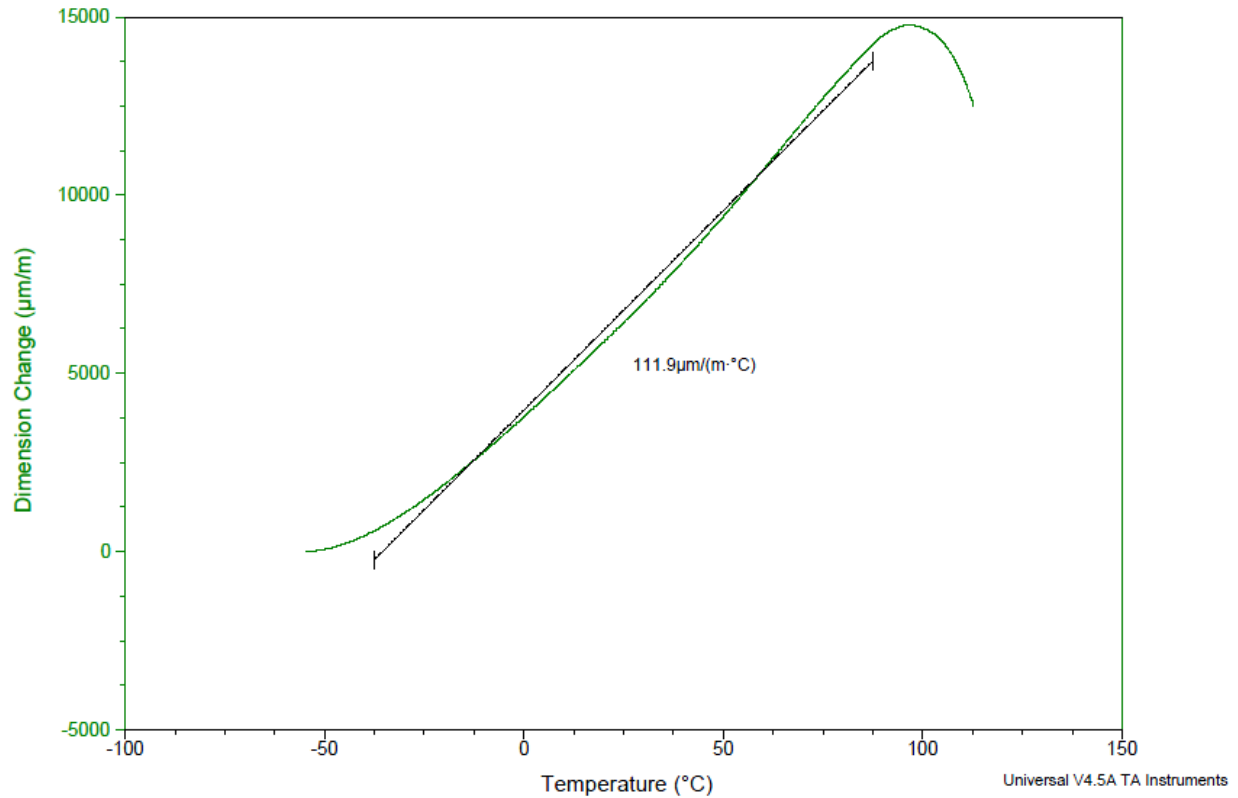
CTE TEST REPORT



Sample: Sample 3B
Size: 25.4000 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:SR30 Orientation:Edge Fill:Solid

TMA

File: C:\TMA\Stratasys\2010\Sample 3B.001
Operator: Ping
Run Date: 22-Jan-2010 20:43
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

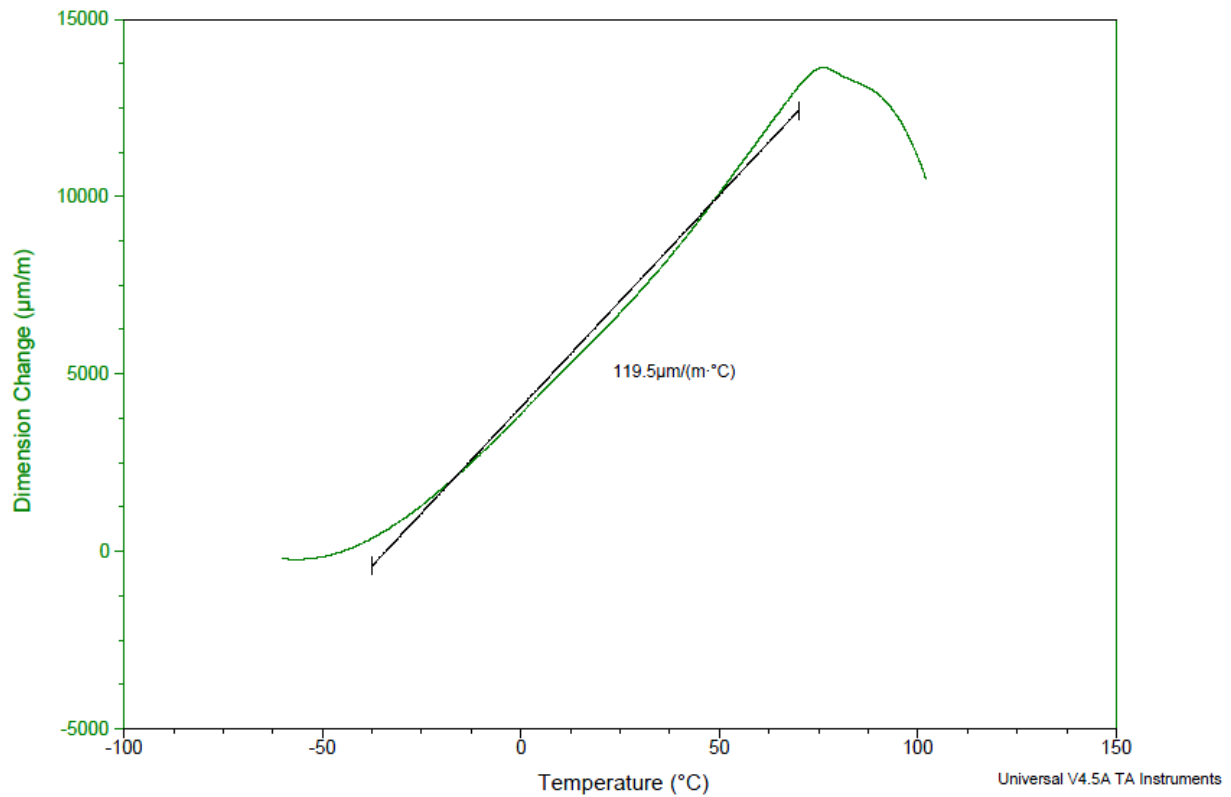
CTE TEST REPORT



Sample: Sample 3C
Size: 25.4943 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material:SR30 Orientation:Edge Fill:Solid

TMA

File: C:\...TMA\Stratasys\2010\Sample 3C.001
Operator: Ping
Run Date: 22-Jan-2010 22:05
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

CTE TEST REPORT



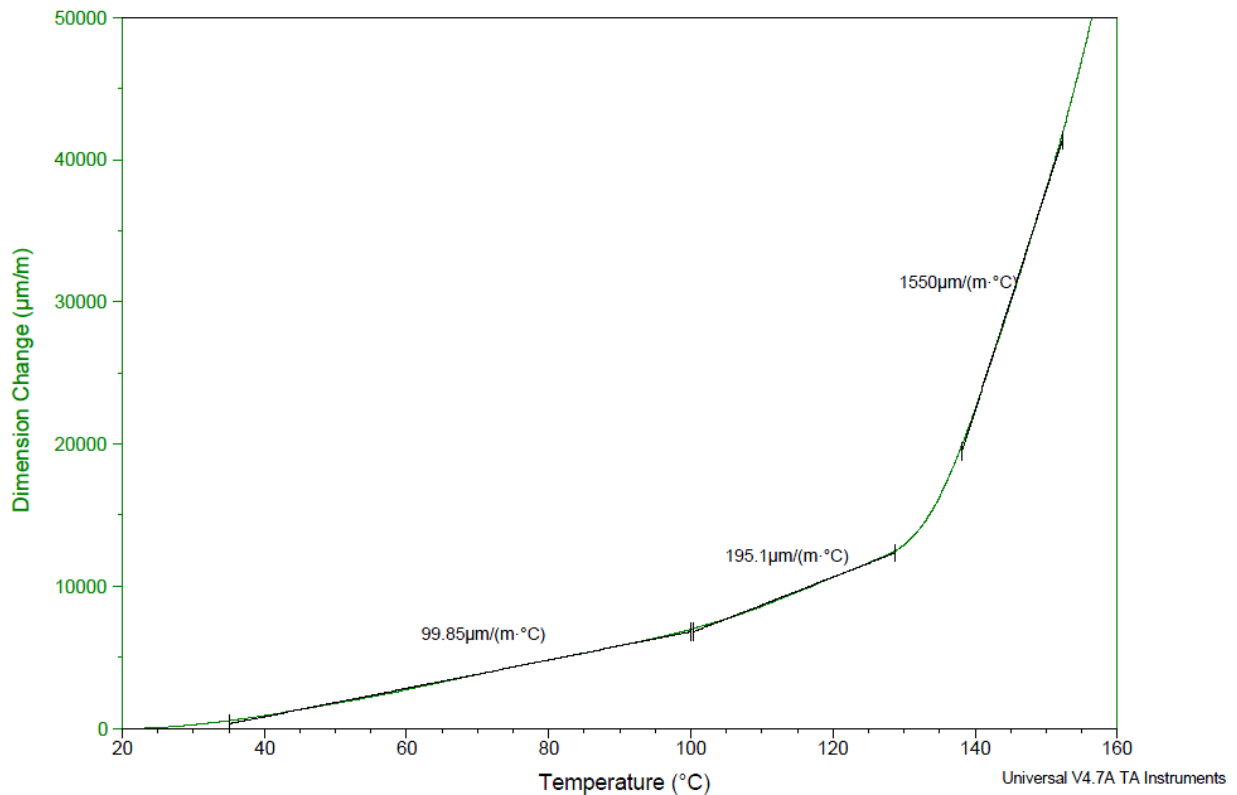
APPENDIX C - PHASE 3

SR100

Sample: Sample 1 (End)
Size: 25.6689 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 1 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 15:06
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

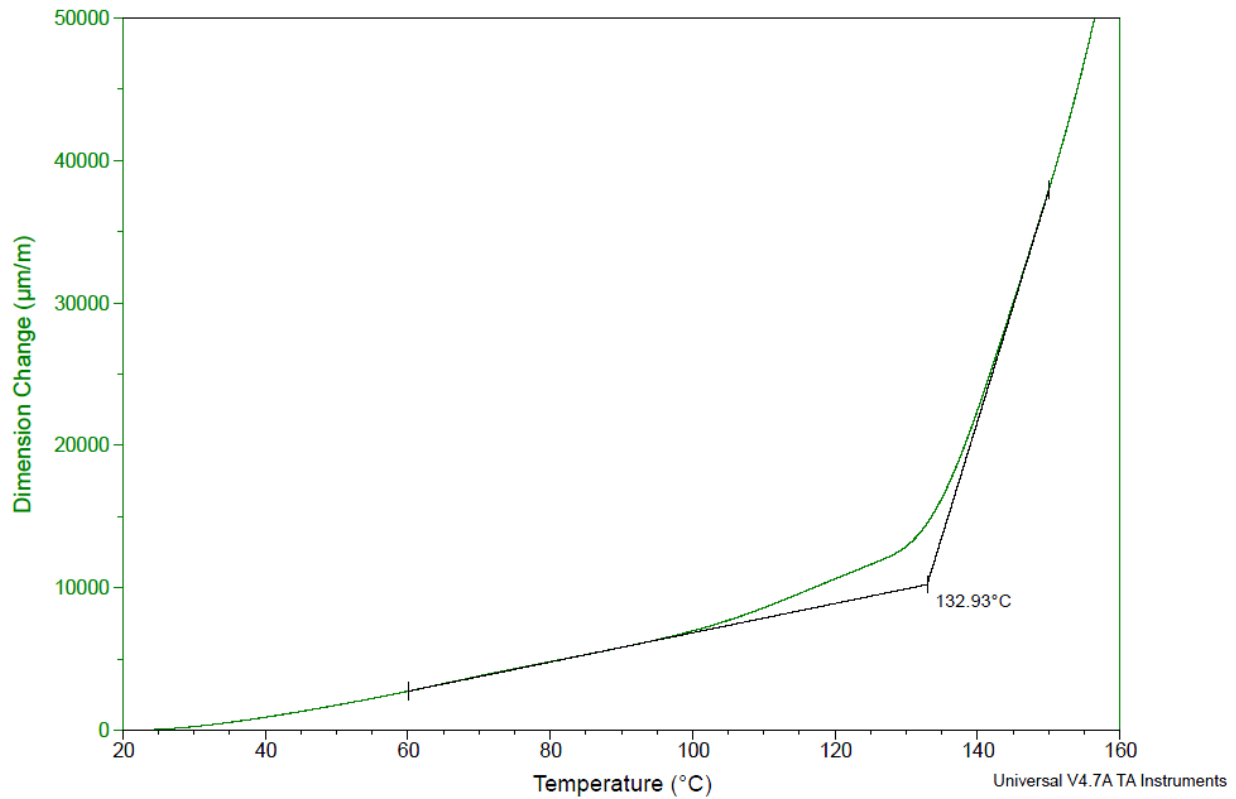
CTE TEST REPORT



Sample: Sample 1 (End)
Size: 25.6689 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 1 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 15:06
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

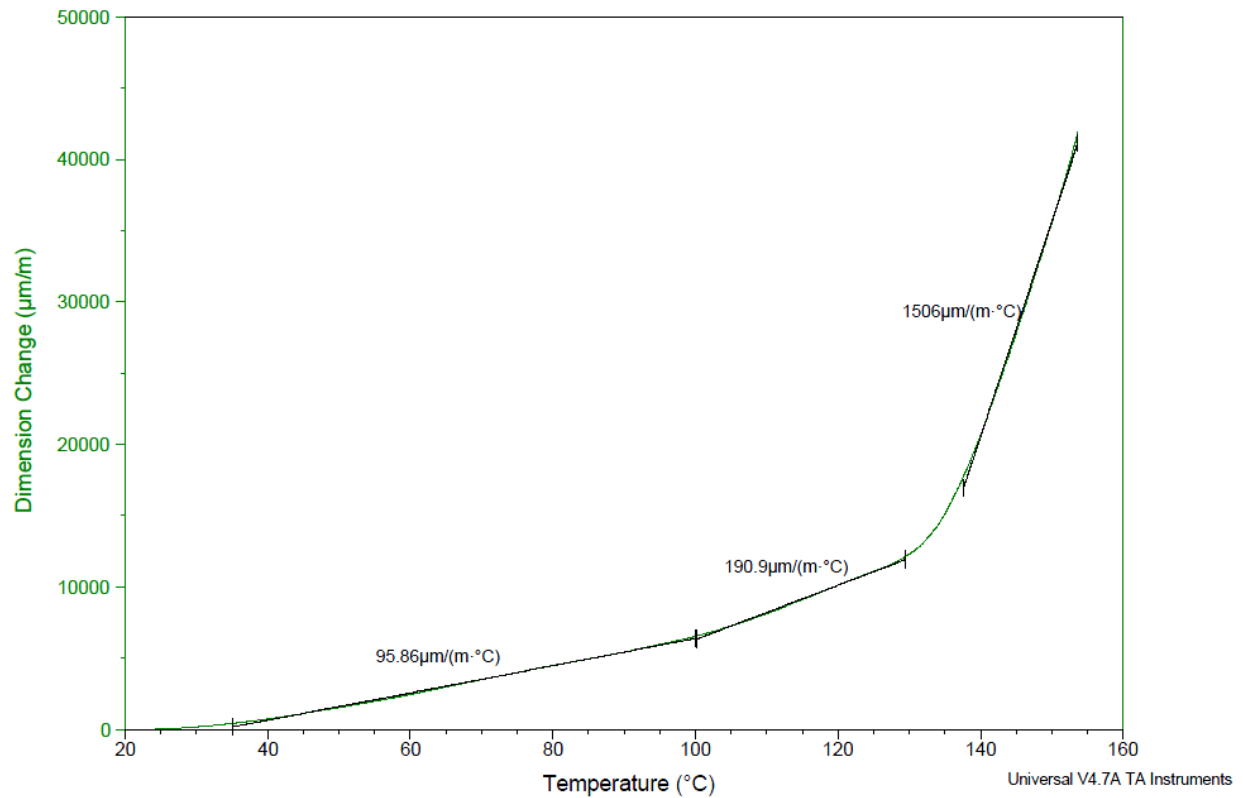
CTE TEST REPORT



Sample: Sample 2 (End)
Size: 25.6156 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 2 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 15:57
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

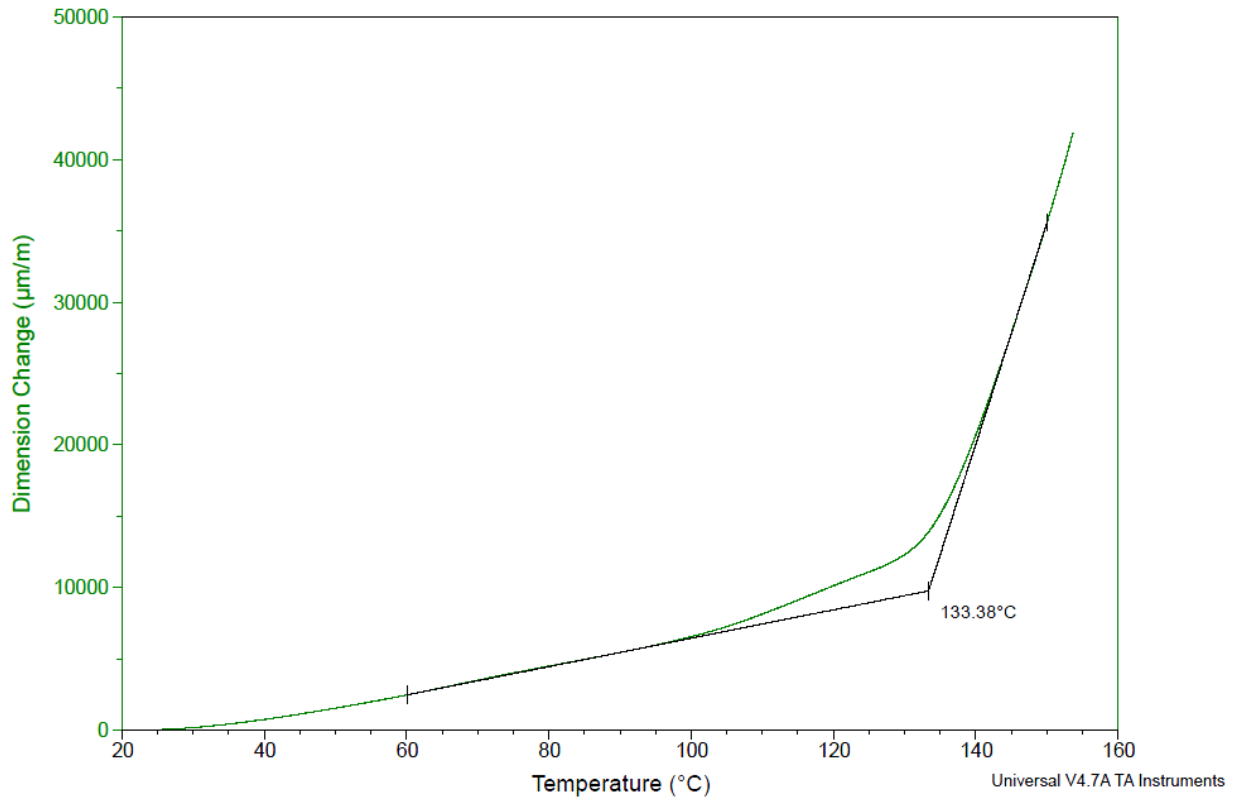
CTE TEST REPORT



Sample: Sample 2 (End)
Size: 25.6156 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 2 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 15:57
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

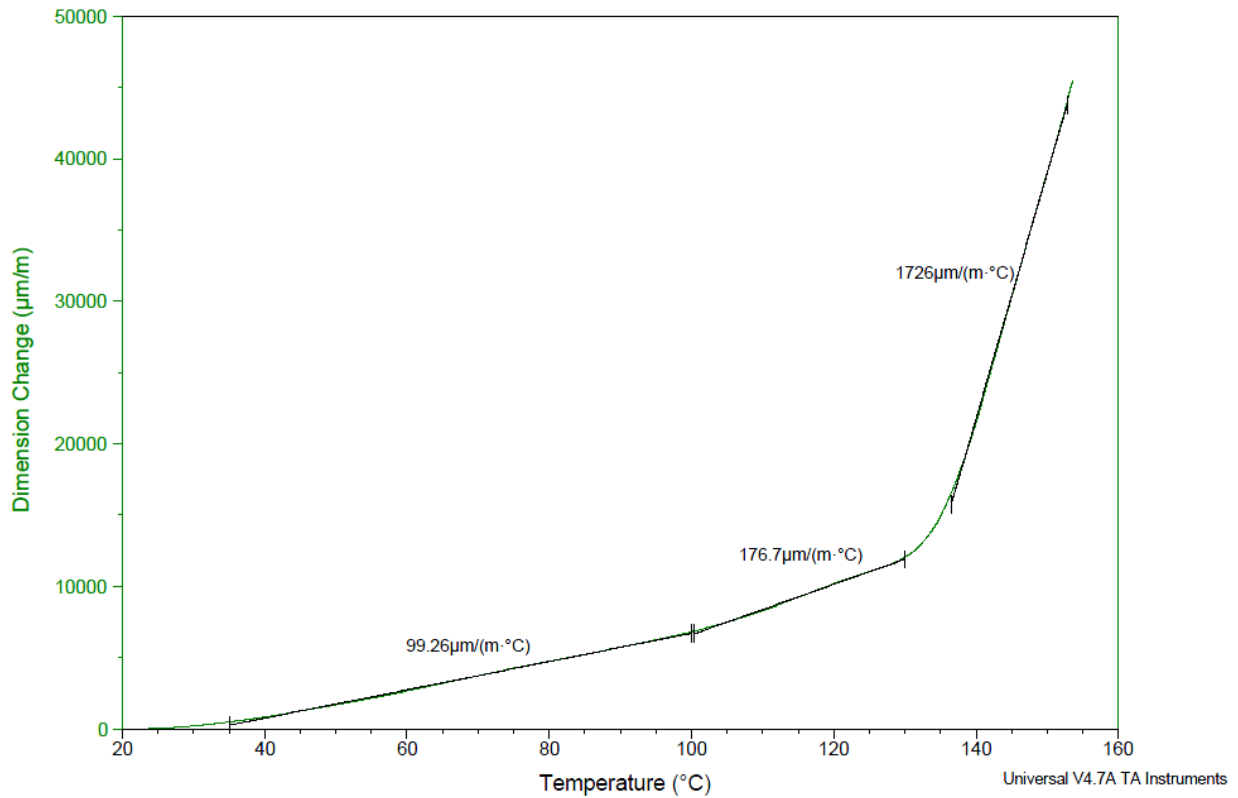
CTE TEST REPORT



Sample: Sample 3 (End)
Size: 25.5157 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 3 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 16:41
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

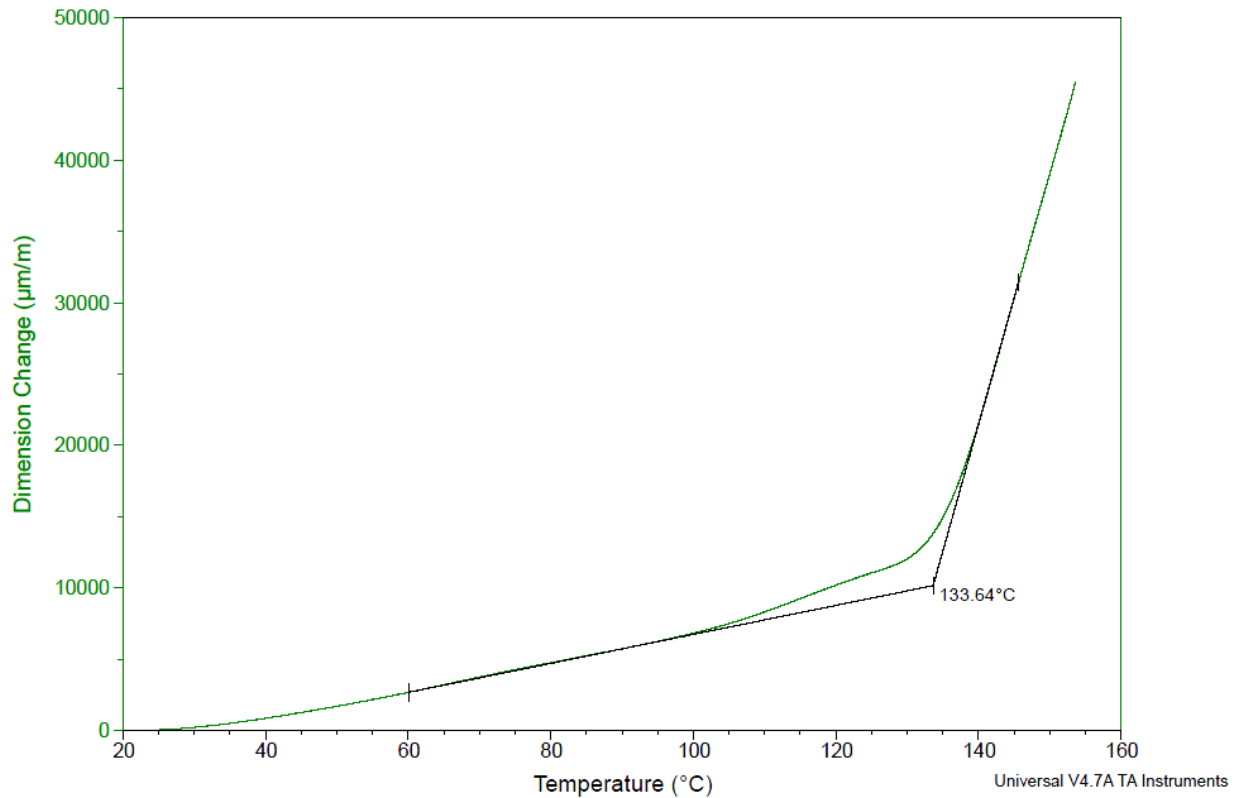
CTE TEST REPORT



Sample: Sample 3 (End)
Size: 25.5157 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: End

TMA

File: C:\2011\SR100\Sample 3 (End).001
Operator: Ping Q400-0227
Run Date: 27-Sep-2011 16:41
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

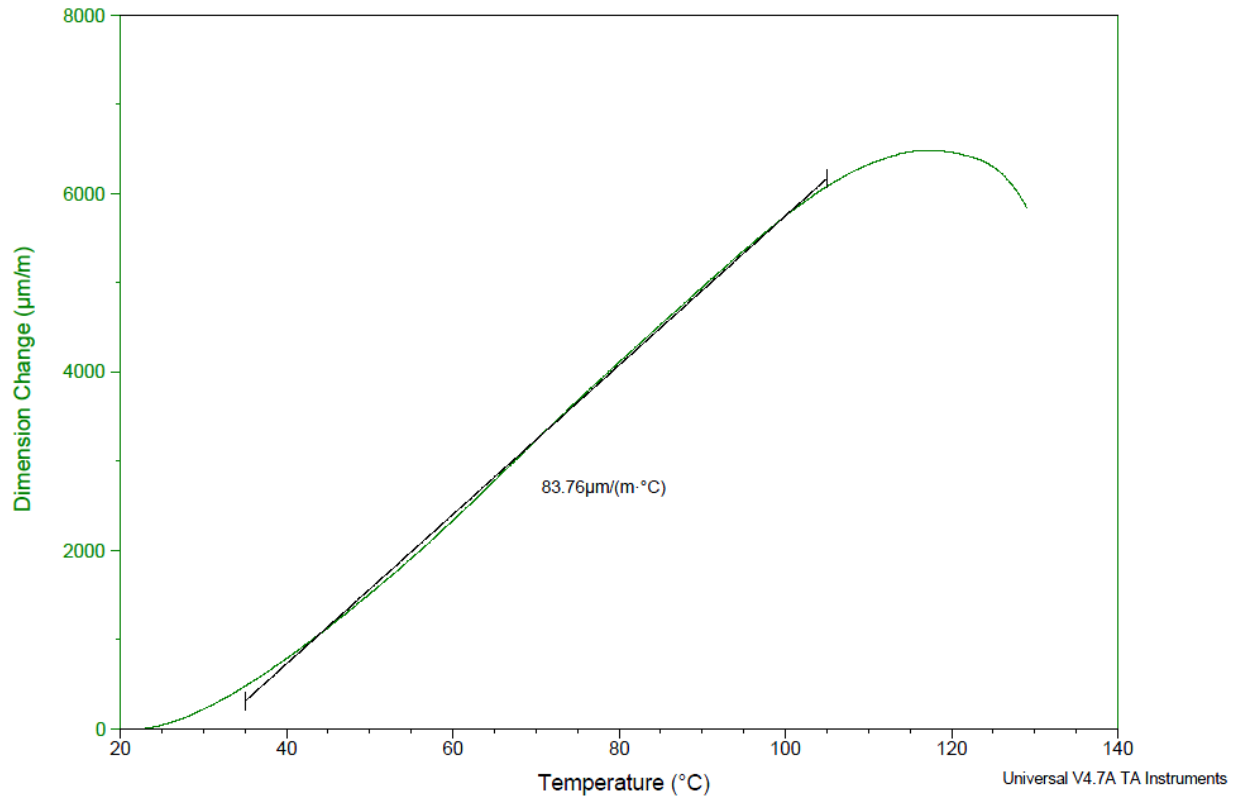
CTE TEST REPORT



Sample: Sample 1 (Edge)
Size: 25.4470 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: Edge

TMA

File: C:\2011\SR100\Sample 1 (Edge).001
Operator: Ping Q400-0227
Run Date: 28-Sep-2011 09:17
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

CTE TEST REPORT



Sample: Sample 2 (Edge)

Size: 25.4842 mm

Method: Ramp

Comment: Stratasys (ASTM E228) Material: SR100 Orientation: Edge

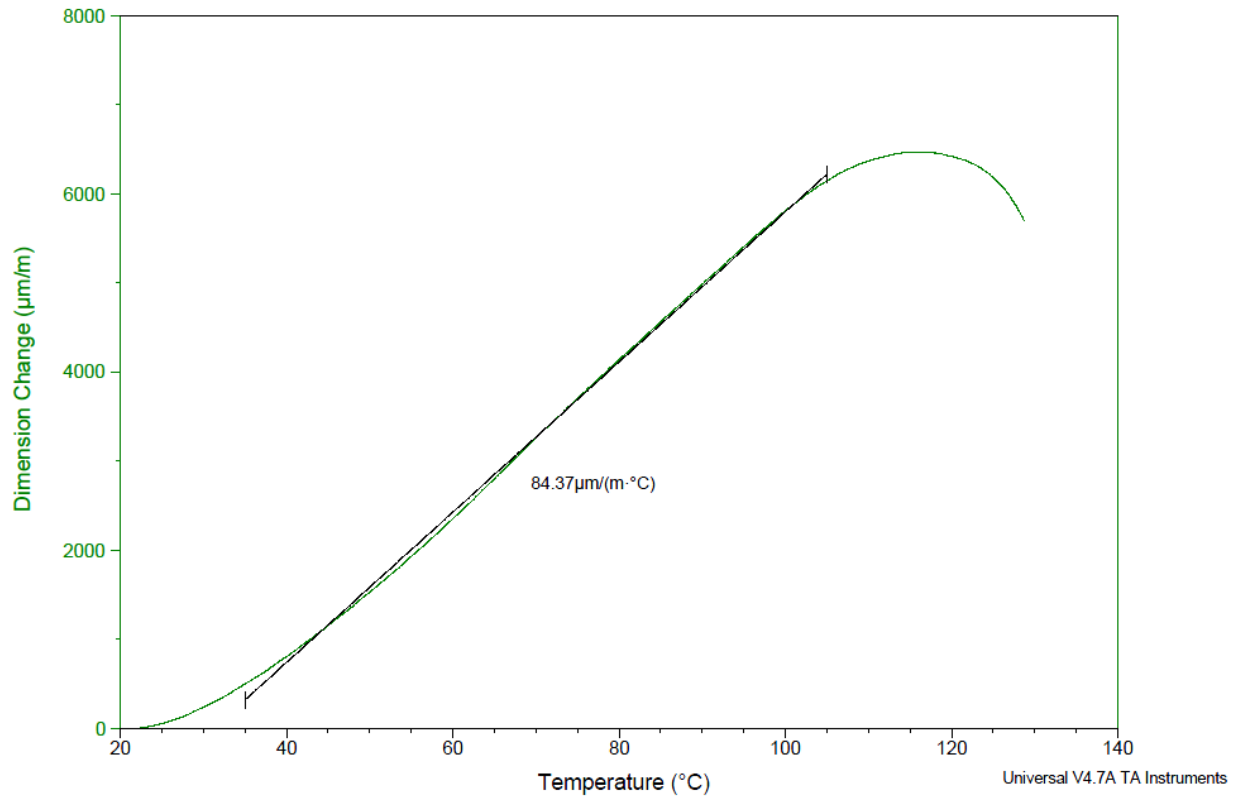
TMA

File: C:\...2011\SR100\Sample 2 (Edge).001

Operator: Ping Q400-0227

Run Date: 28-Sep-2011 10:00

Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

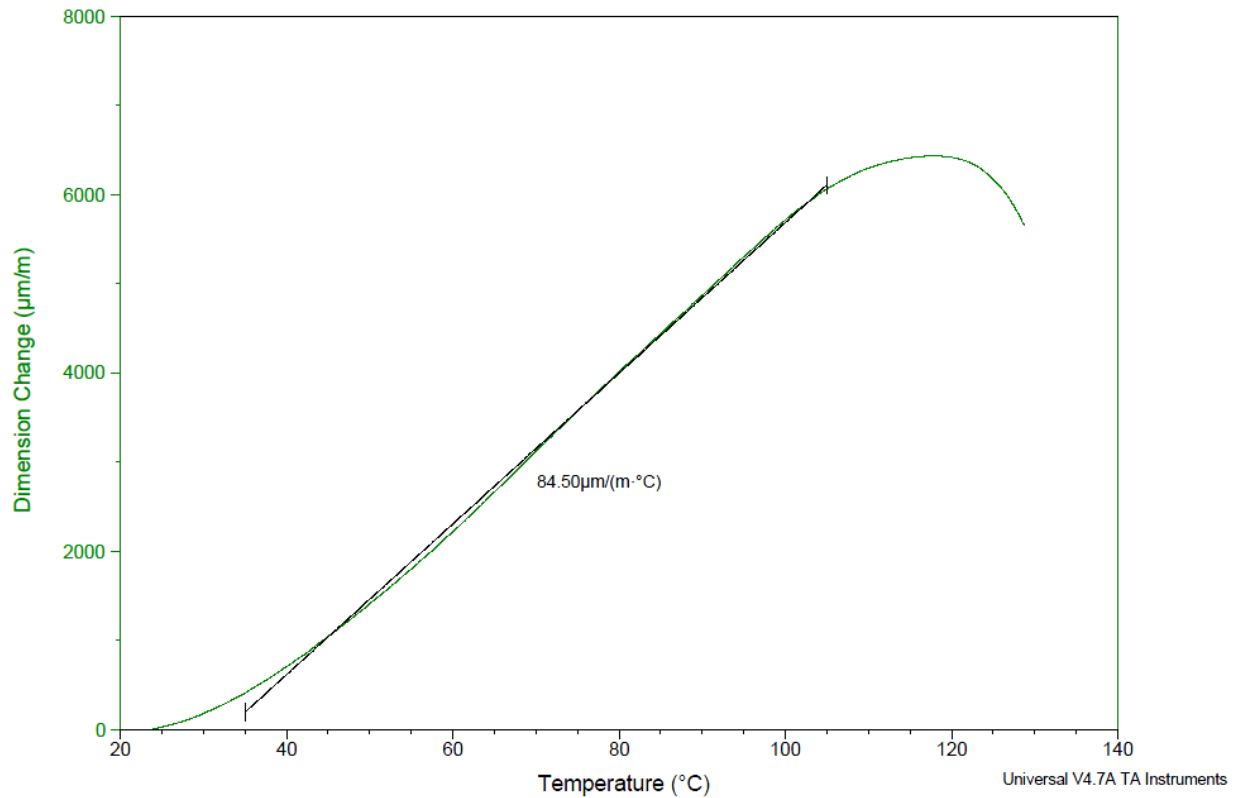
CTE TEST REPORT



Sample: Sample 3 (Edge)
Size: 25.4653 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: SR100 Orientation: Edge

TMA

File: C:\2011\SR100\Sample 3 (Edge).001
Operator: Ping Q400-0227
Run Date: 28-Sep-2011 10:43
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

CTE TEST REPORT

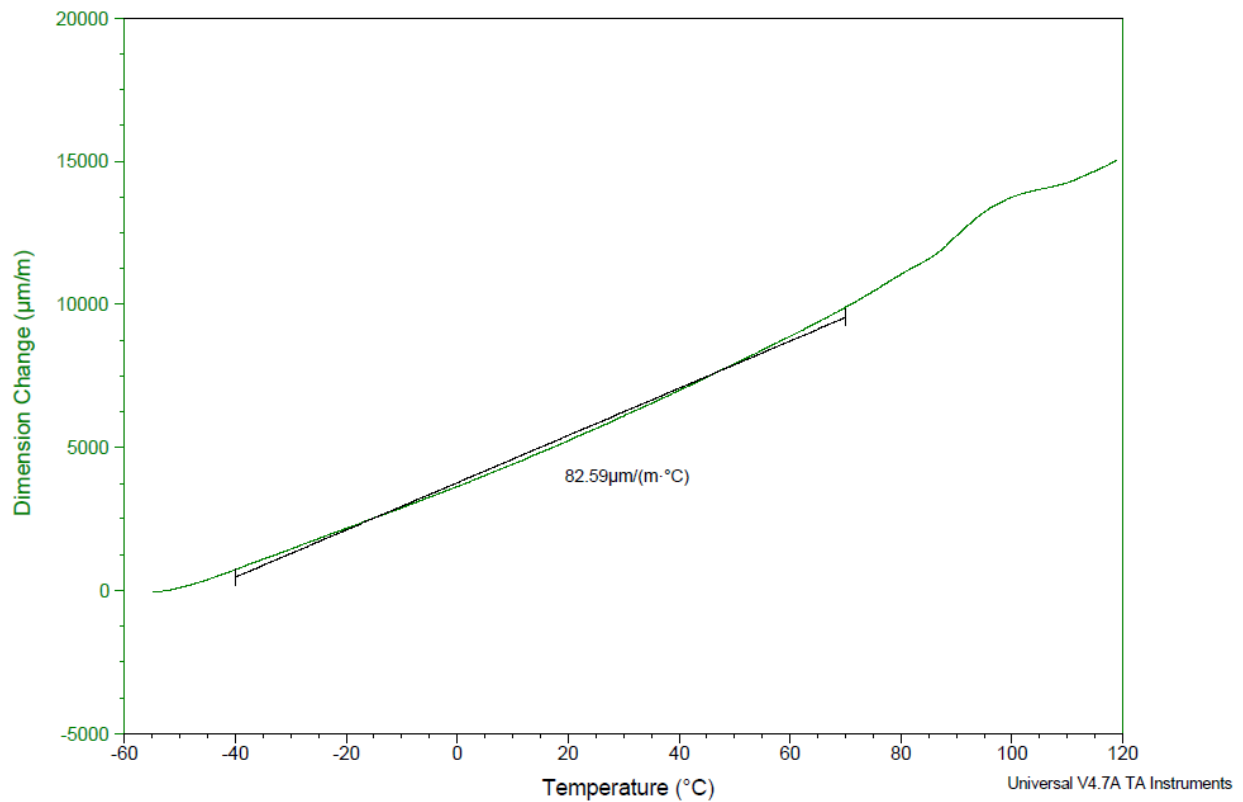


ABS ESD7

Sample: Sample 1 (End)
Size: 14.0523 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: End

TMA

File: C:\2011\ABS ESD7\Sample 1 (End).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 19:16
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

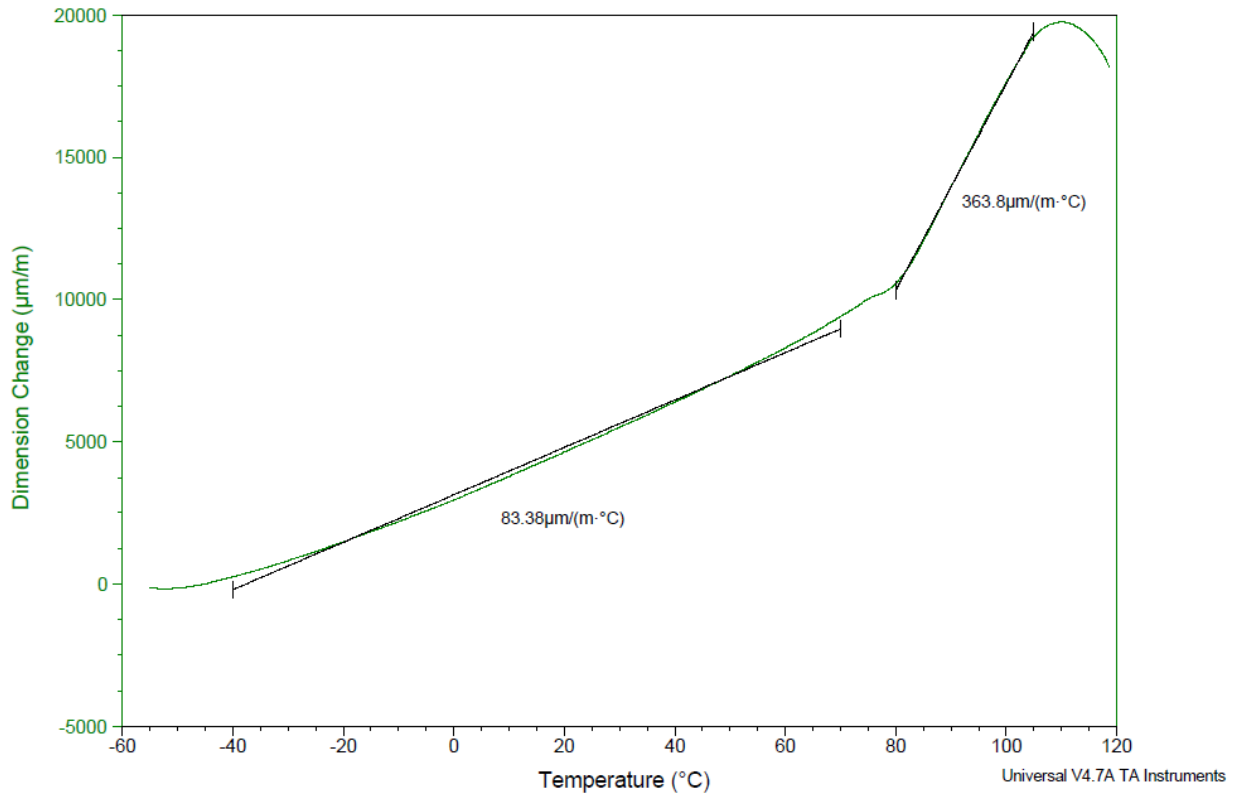
CTE TEST REPORT



Sample: Sample 2 (End)
Size: 25.7829 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: End

TMA

File: C:\2011\ABS ESD7\Sample 2 (End).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 12:35
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

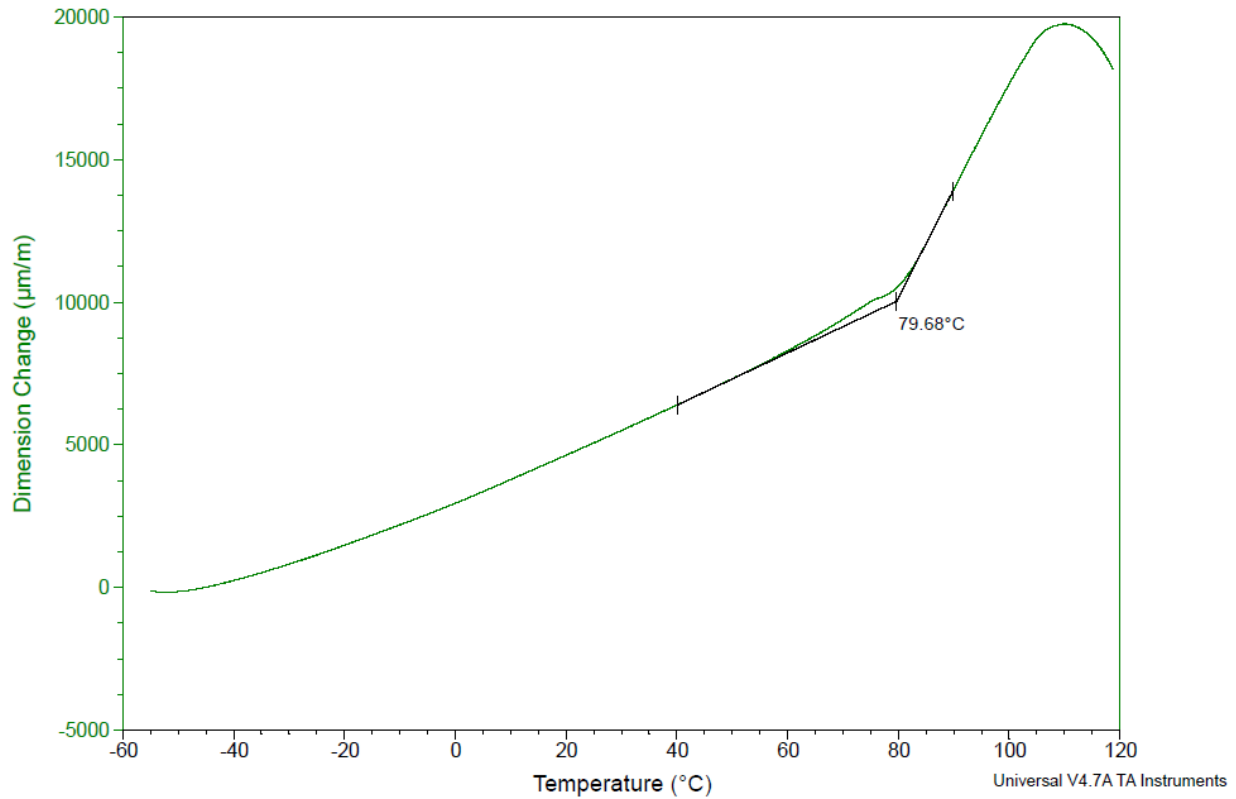
CTE TEST REPORT



Sample: Sample 2 (End)
Size: 25.7829 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: End

TMA

File: C:\2011\ABS ESD7\Sample 2 (End).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 12:35
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

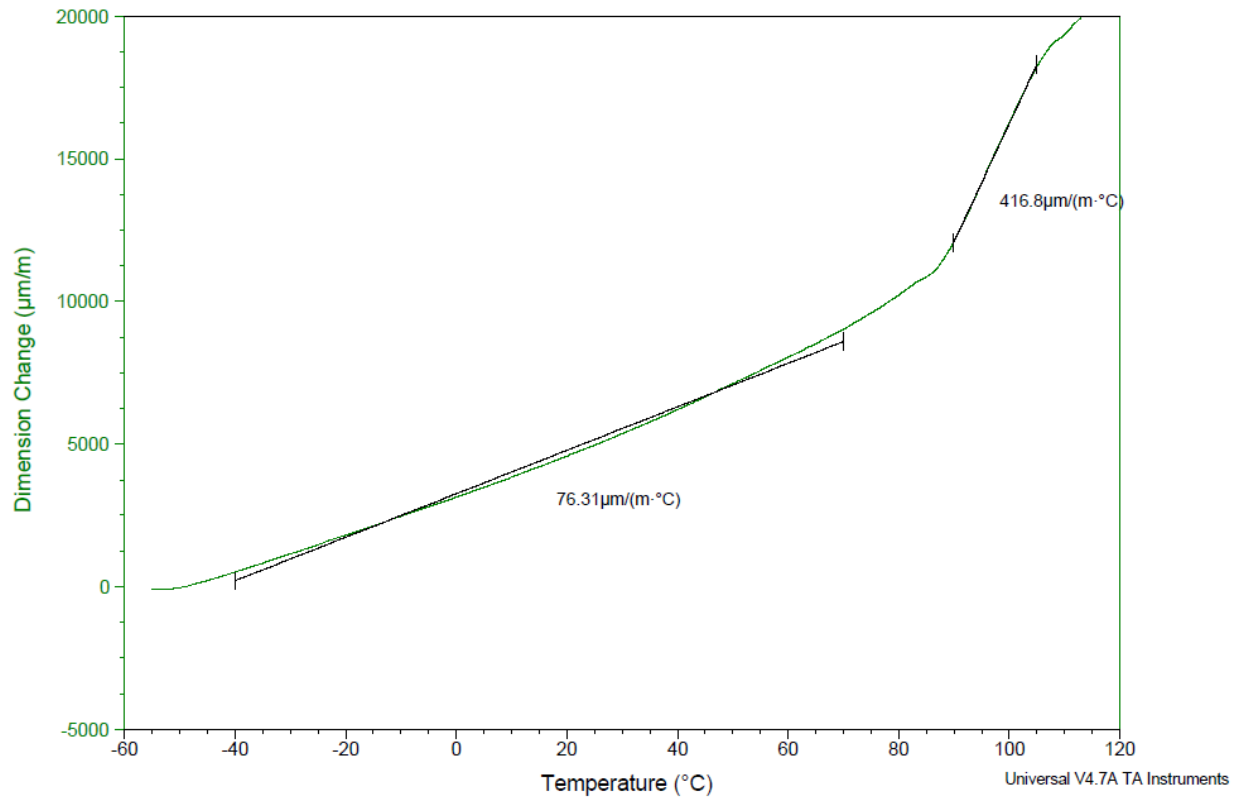
CTE TEST REPORT



Sample: Sample 3 (End)
Size: 25.8125 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: End

TMA

File: C:\2011\ABS ESD7\Sample 3 (End).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 13:36
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

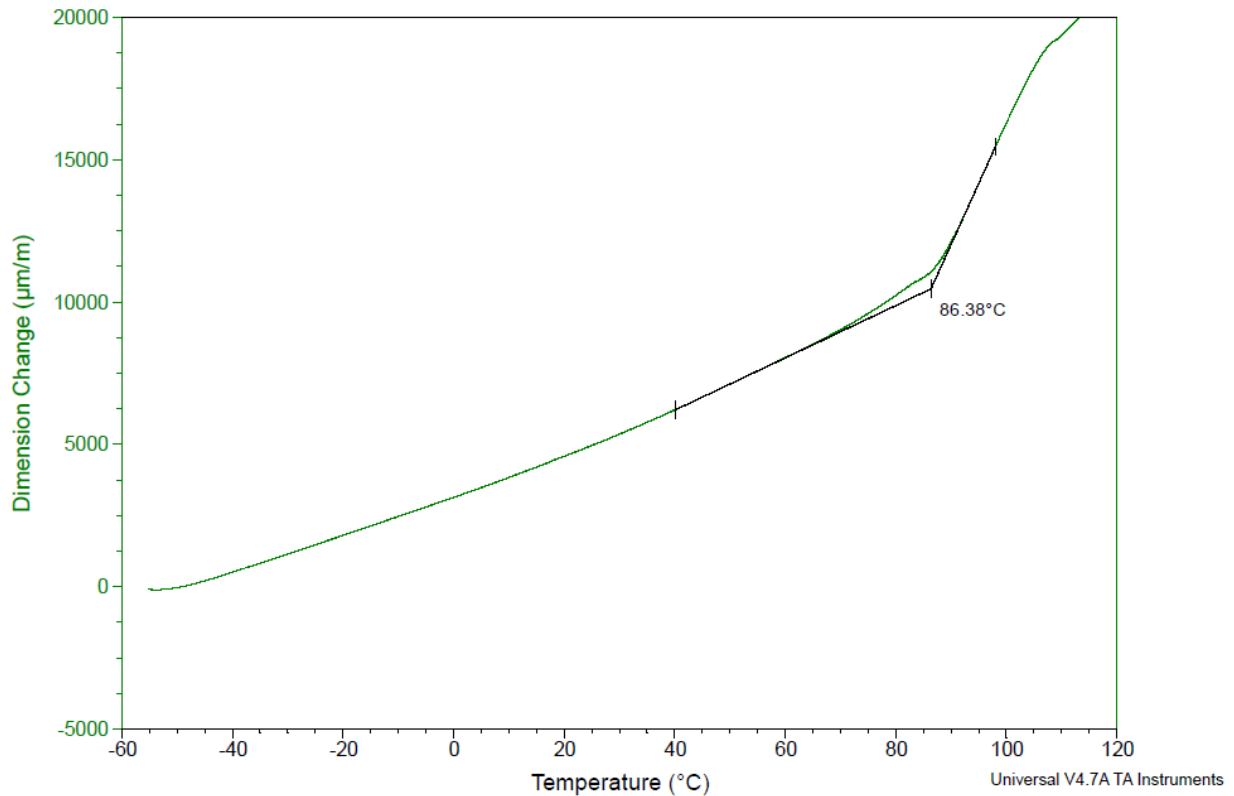
CTE TEST REPORT



Sample: Sample 3 (End)
Size: 25.8125 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: End

TMA

File: C:\2011\ABS ESD7\Sample 3 (End).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 13:36
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

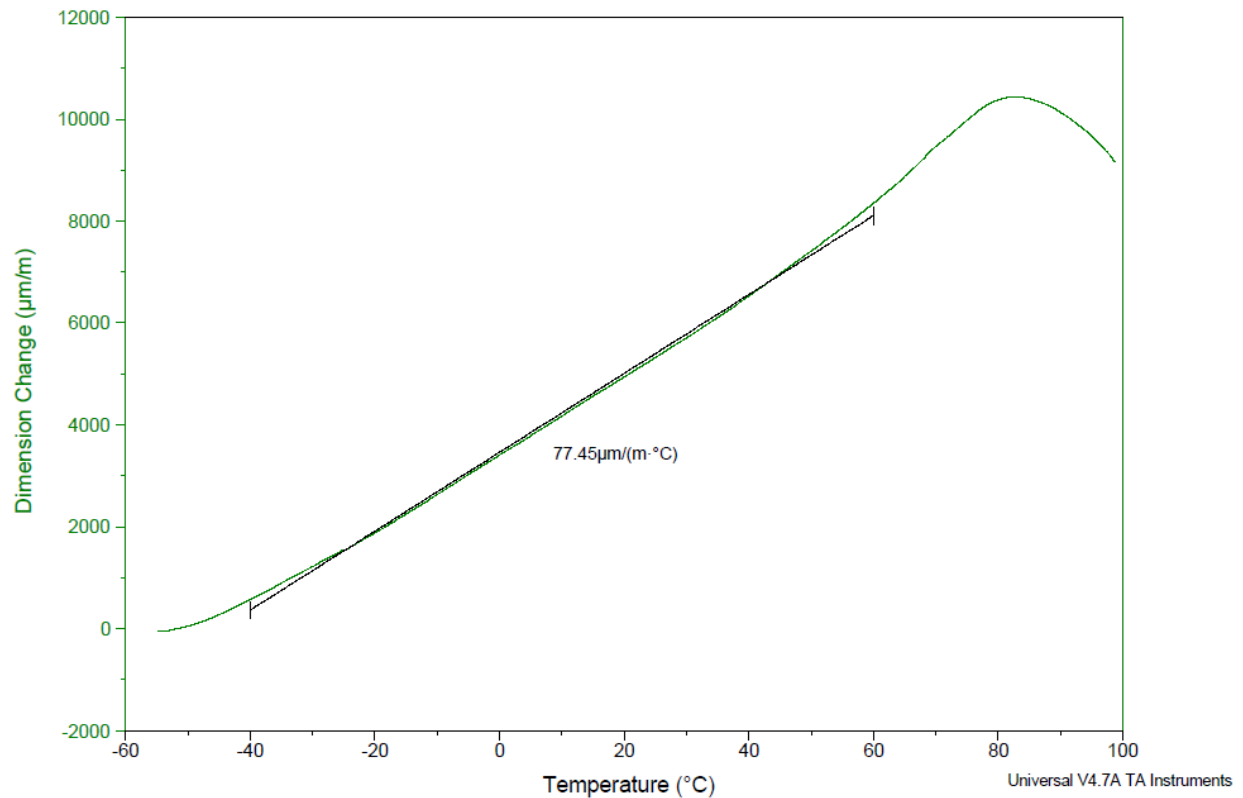
CTE TEST REPORT



Sample: Sample 1 (Edge)
Size: 25.4963 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: Edge

TMA

File: C:\2011\ABS ESD7\Sample 1 (Edge).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 16:31
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

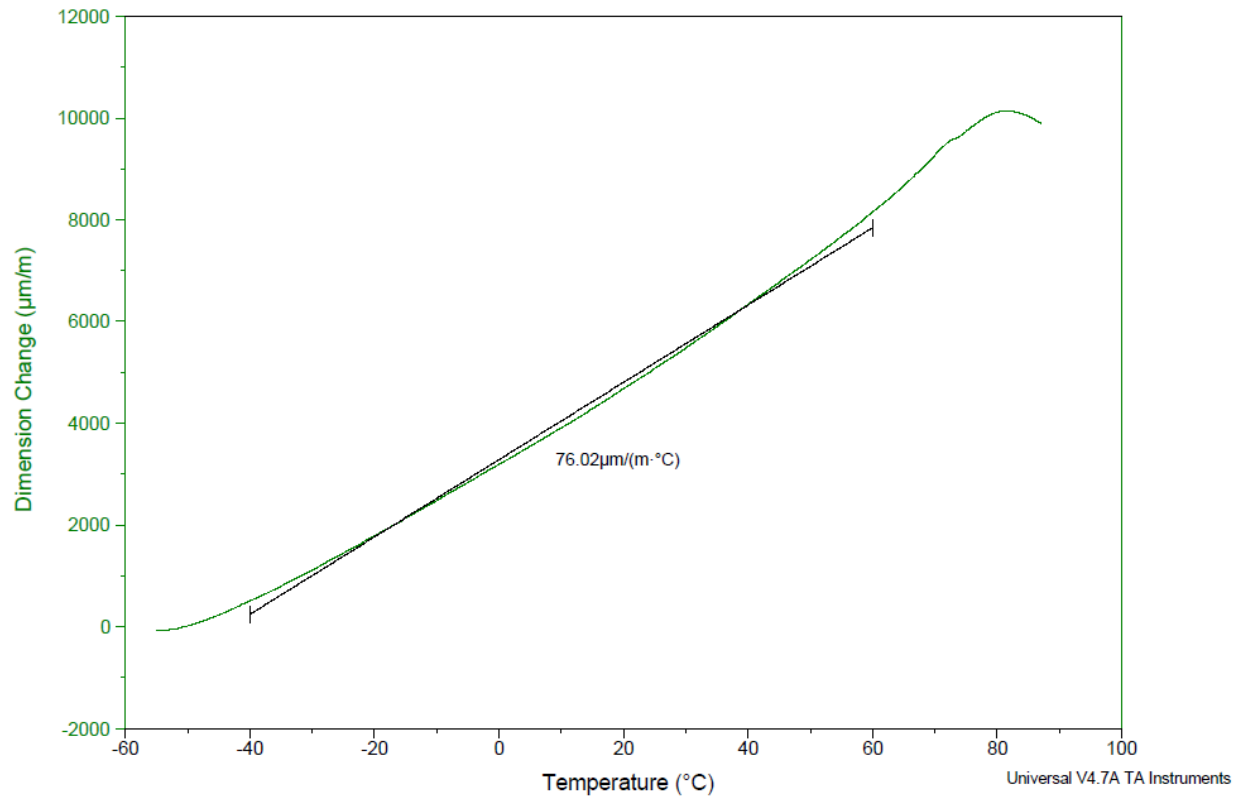
CTE TEST REPORT



Sample: Sample 2 (Edge)
Size: 25.5199 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: Edge

TMA

File: C:\2011\ABS ESD7\Sample 2 (Edge).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 17:29
Instrument: TMA Q400 V7.4 Build 93



STRATASYS MANUFACTURING SOLUTIONS GROUP

CTE TEST REPORT



Sample: Sample 3 (Edge)
Size: 25.5183 mm
Method: Ramp
Comment: Stratasys (ASTM E228) Material: ABS ESD7 Orientation: Edge

TMA

File: C:\2011\ABS ESD7\Sample 3 (Edge).001
Operator: Ping Q400-0227
Run Date: 13-Oct-2011 18:22
Instrument: TMA Q400 V7.4 Build 93

