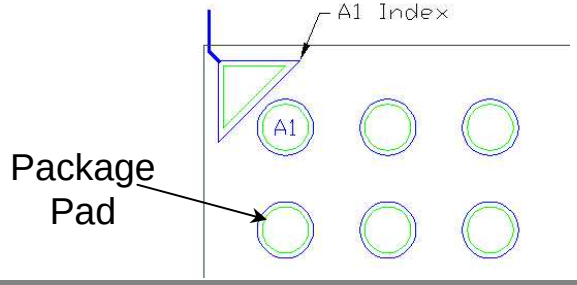
Freescale Semiconductor Tape Ball Grid Array (TBGA) Overview

Table of Freescale TBGA Configurations

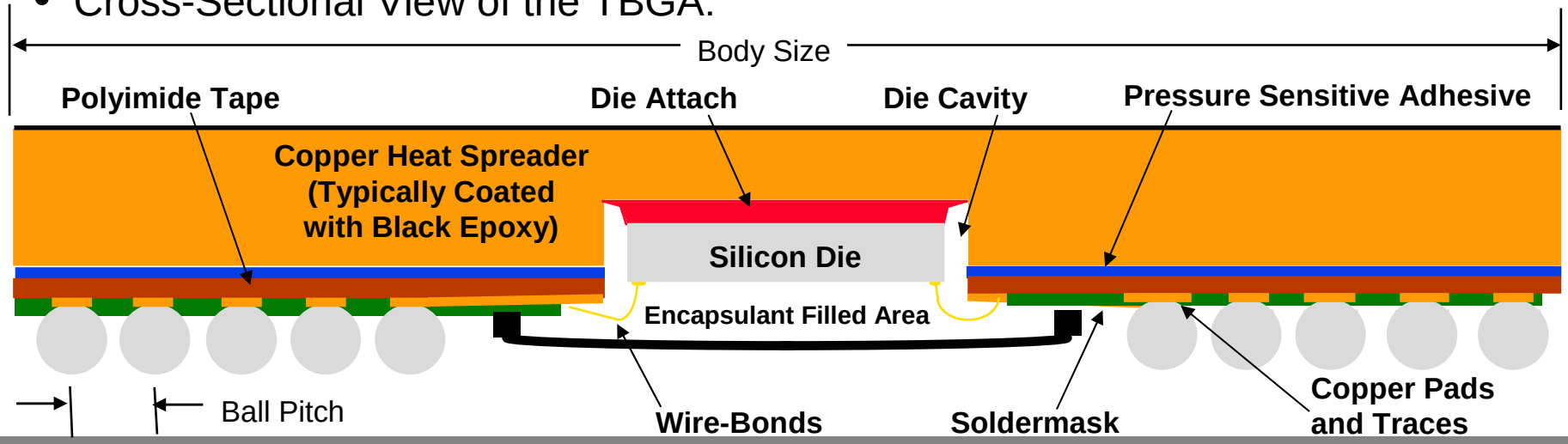
Body Size (mm)	Ball Pitch (mm)	Ball Count	Number of Perimeter Rows	Pkg Pad Diameter (mm)
31 x 31	1.00	500	5P	0.50
35 x 35	1.00	672	6P	0.45
37.5 x 37.5	1.00	740	6P	0.45
31 x 31	1.27	304	4P	0.60
35 x 35	1.27	352	4P	0.60
37.5 x 37.5	1.27	480	5P	0.60

- Information is based on products currently in production and is subject to change.
- Customer is recommended to contact Freescale for details on specific products.



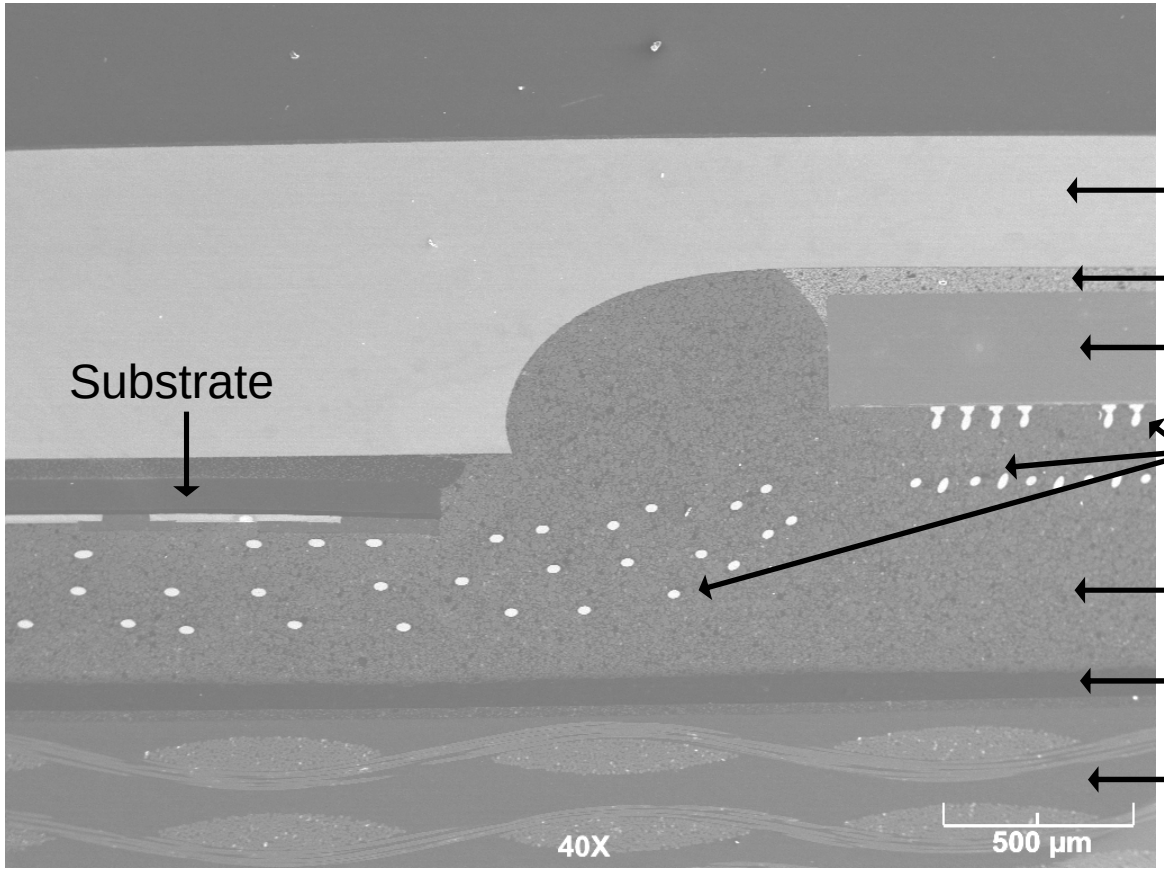
TBGA Construction

- Several TBGA packages currently in production, including:
  - 1.27 mm BGA pitch
    - > 31 x 31 mm body, 304 TBGA
    - > 35 x 35 mm body, 352 TBGA
    - > 37.5 x 37.5 mm body, 480 TBGA
  - 1.0 mm BGA pitch
    - > 31 x 31 mm body, mm body, 500 TBGA
    - > 35 x 35 mm body, 672 TBGA
    - > 37.5 x 37.5 mm body, 740 TBGA
- Cross-Sectional View of the TBGA:



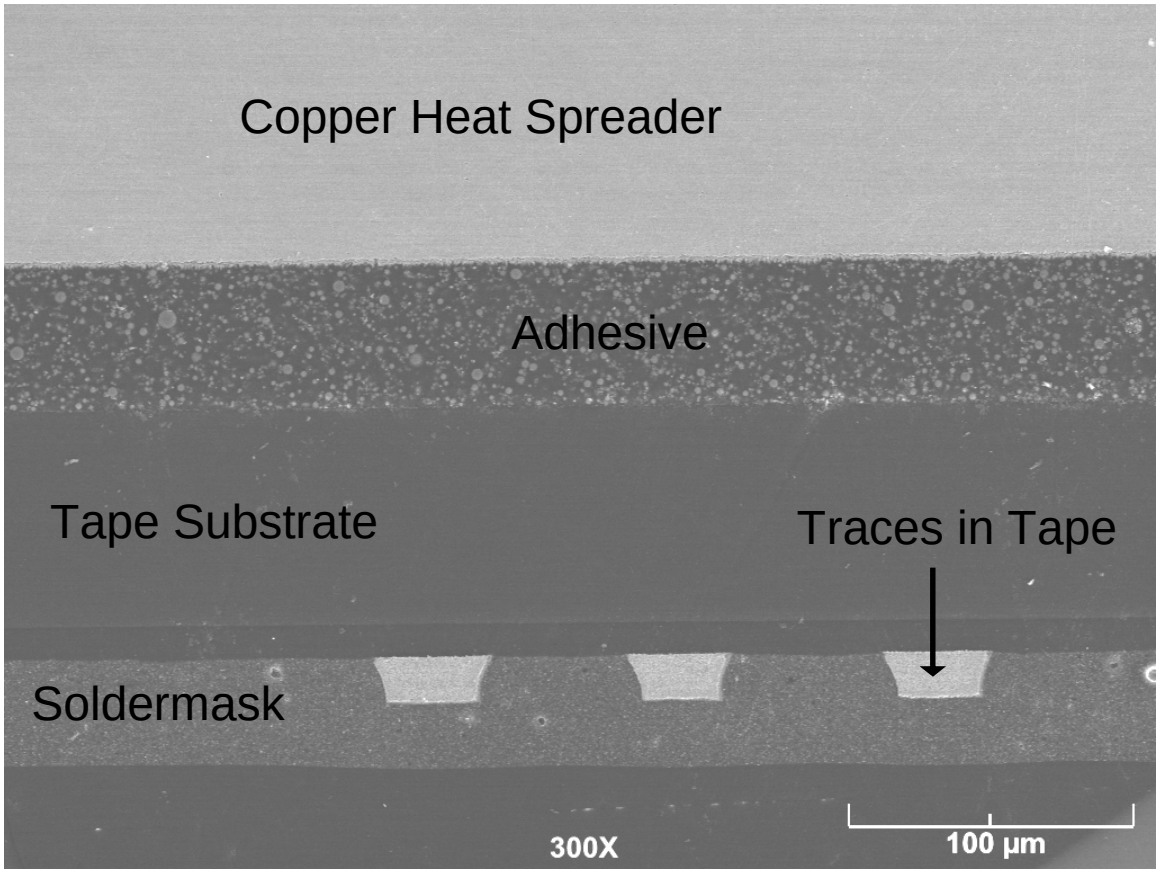
TBGA Construction (Cont.)

TBGA Cross-Section near Die Region



TBGA Construction (Cont.)

TBGA Cross-Section of Substrate Layers



TBGA Advantages

- Increased thermal dissipation
- Excellent board-level reliability
- Very flat / planar over a wide temperature range
- Finer substrate lines and spacing compared to laminate-based wire-bond PBGA substrates

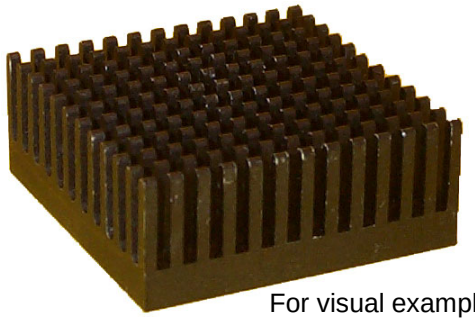
TBGA Thermal Measurements

Four TBGAs evaluated for thermal performance in wind tunnel per JEDEC 51-6

- 352 TBGA
  - Die Size: 8.74 x 7.32 mm (thermal die)
  - Substrate: 35 x 35 mm
- 480 TBGA
  - Die Size: 10.16 x 10.16 mm (thermal die)
  - Substrate: 37.5 x 37.5 mm
- 672 TBGA
  - Die Size: 6.73 x 7.06 mm (thermal die)
  - Substrate: 35 x 35 mm
- 740 TBGA
  - Die Size: 8.21 x 8.85 mm (thermal die)
  - Substrate: 37.5 x 37.5 mm

Thermal Measurements (cont.)

- Heat Sinks Evaluated
  - “A”: Thermalloy 2330B, 37.9x38.2x16.3 mm, cross cut extrusion pin fin
  - “B”:Thermalloy 2332B, 41.3x43.3x16.3 mm, cross cut extrusion pin fin
  - “C”: Wakefield 698100AB, 53.8x53.1x24.7 mm, cross cut extrusion pin fin



For visual example only

- Note
  - Measurements taken in open flow
  - Heat sinks tested are examples of commercially available heat sinks. Many other heat sinks are available and may be more appropriate for the customer application.

Thermal Measurements (cont.)

No Heat Sink

Air Flow (ft/min)	Internal Planes	352 TBGA Theta JA (C/W)	480 TBGA Theta JA (C/W)
0	0	**15.1**	**13.1**
100	0	**12.4**	**10.7**
200	0	**11.1**	**9.6**
400	0	**9.8**	**8.2**
800	0	**8.0**	**6.4**
0	2	**11.7**	**10.5**
100	2	**9.7**	**8.6**
200	2	**8.8**	**7.8**
400	2	**7.9**	**6.9**
800	2	**6.8**	**5.5**

352 TBGA		480 TBGA	
Theta JB (C/W)	Theta JC (C/W)	Theta JB (C/W)	Theta JC (C/W)
4.4	**1.6**	**3.3**	**1.1**

With Heat Sink

Air Flow (ft/min)	Internal Planes	352 TBGA Theta JA (C/W)			480 TBGA Theta JA (C/W)		
		A	B	C	A	B	C
0	0	**10.2**	**9.6**	**7.1**	**9.0**	**8.6**	**6.4**
100	0	**7.4**	**6.9**	**5.0**	**6.4**	**6.0**	**4.5**
200	0	**5.6**	**5.3**	**3.8**	**4.8**	**4.6**	**3.2**
400	0	**4.3**	**4.1**	**3.1**	**3.5**	**3.4**	**2.6**
800	0	**3.3**	**3.1**	**2.5**	**2.6**	**2.5**	**2.0**

Internal planes are the copper layers within the test board. All boards have a top and bottom layer. Ref JESD51-9
Results will vary by die size.

Thermal Measurements (cont.)

No Heat Sink

Air flow (ft/min)	Internal Planes	672 TBGA Theta-JA	740 TBGA Theta-JA
0	0	**14.4**	**13.7**
100	0	**11.9**	**11.2**
200	0	**10.7**	**10.0**
400	0	**9.4**	**8.7**
800	0	**7.7**	**7.1**
0	2	**10.8**	**10.5**
100	2	**9.0**	**8.6**
200	2	**8.2**	**7.8**
400	2	**7.4**	**7.0**
800	2	**6.2**	**5.9**

672 TBGA		740 TBGA	
Theta-JB (C/W)	Theta-JC (C/W)	Theta-JB (C/W)	Theta-JC (C/W)
3.8	**1.7**	**3.6**	**1.6**

With Heat Sink

Air flow (ft/min)	Internal Planes	672 TBGA Theta JA (C/W)			740 TBGA Theta JA (C/W)		
		A	B	C	A	B	C
0	0	**10.3**	**9.9**	**7.4**	**9.3**	**9.1**	**6.5**
100	0	**7.5**	**7.1**	**5.2**	**6.9**	**6.8**	**4.9**
200	0	**5.8**	**5.6**	**4.0**	**5.4**	**5.2**	**3.7**
400	0	**4.3**	**4.2**	**3.3**	**4.1**	**4.0**	**3.0**
800	0	**3.2**	**3.2**	**2.7**	**3.0**	**3.0**	**2.4**

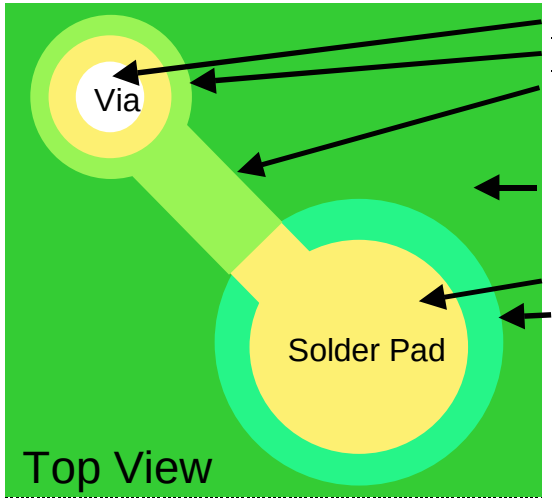
Internal planes are the copper layers within the test board. All boards have a top and bottom layer. Ref JESD51-9
Results will vary by die size.

Motherboard Pad Design for TBGA

- Motherboard solder pad diameters:
  - In general, motherboard pad solderable diameter should match the package pad diameter
    > See **table on Slide 3** for package pad diameters
  - When required for routing, motherboard pad diameter may be decreased by up to 10% versus the package pad
- Solder pad configurations:
  - Soldermask Defined (SMD) pads:
    > Added strength provided by the soldermask overlap
    > Used on the TBGA package substrate
  - Non-Soldermask Defined (NSMD) pads:
    > Most common type of motherboard pad in the industry
    > Typically results in the most consistent solderability, especially with hot air solder leveled (HASL) surface finish
    > However, may be more likely to fail by pad lifting / trace cracking during bending, high ramp rate thermal cycling or rework
  - NSMD motherboard pads recommended for most applications

1.27 mm Pitch TBGA NSMD Motherboard Solder Pad Geometry

- Recommended non-soldermask defined (NSMD) motherboard pad dimns
  - 0.60 mm solder pad diameter
    > Matches 1.27 mm pitch TBGA pad diameters
  - Surface finish may be any consistently solderable surface such as organic solderability protectant (OSP), HASL, electroless or electrolytic nickel/gold or immersion silver

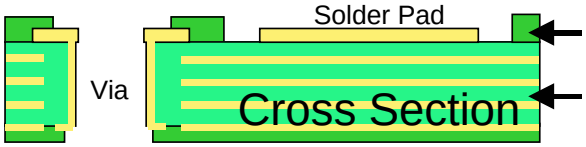


≥ 0.30 mm (12 mil) Finished Plated Through Hole (Adjustable)
≥ 0.65 mm (25 mil) Annual Pad (Adjustable)
0.30+ mm (12+ mil) Wide Line Between Pads (For added strength)

Soldermask

0.60 ± 0.037 mm (23.6 ± 1.5 mil) Copper Pad Diameter

0.075 ± 0.025 mm (3 ± 1 mil) Clearance Between Copper Pad and Soldermask (Adjustable Depending on Supplier Capability)

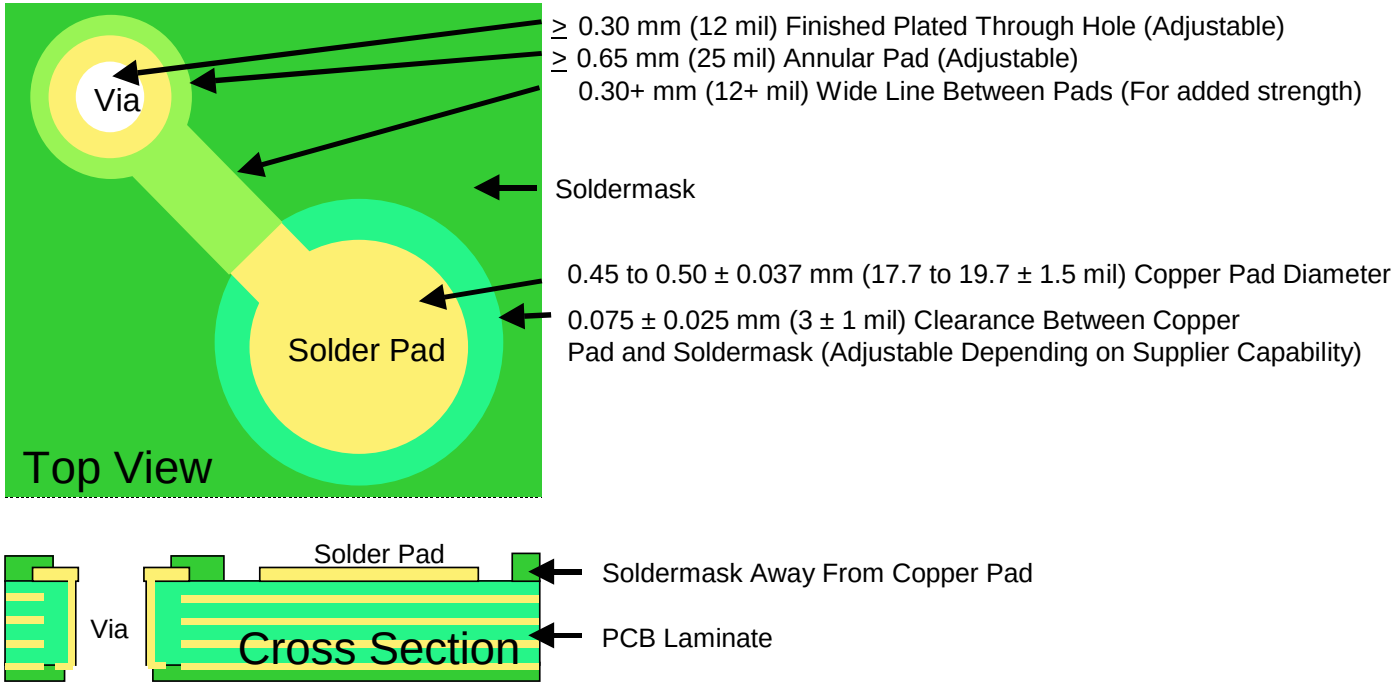


Soldermask Away From Copper Pad

PCB Laminate

1.00 mm Pitch TBGA NSMD Motherboard Solder Pad Geometry

- Recommended non-soldermask defined (NSMD) motherboard pad dimns
  - 0.45 to 0.50 mm solder pad diameter
    > Should match 1.00 mm pitch TBGA pad diameter
  - Surface finish may be any consistently solderable surface such as organic solderability protectant (OSP), HASL, electroless or electrolytic nickel/gold or immersion silver



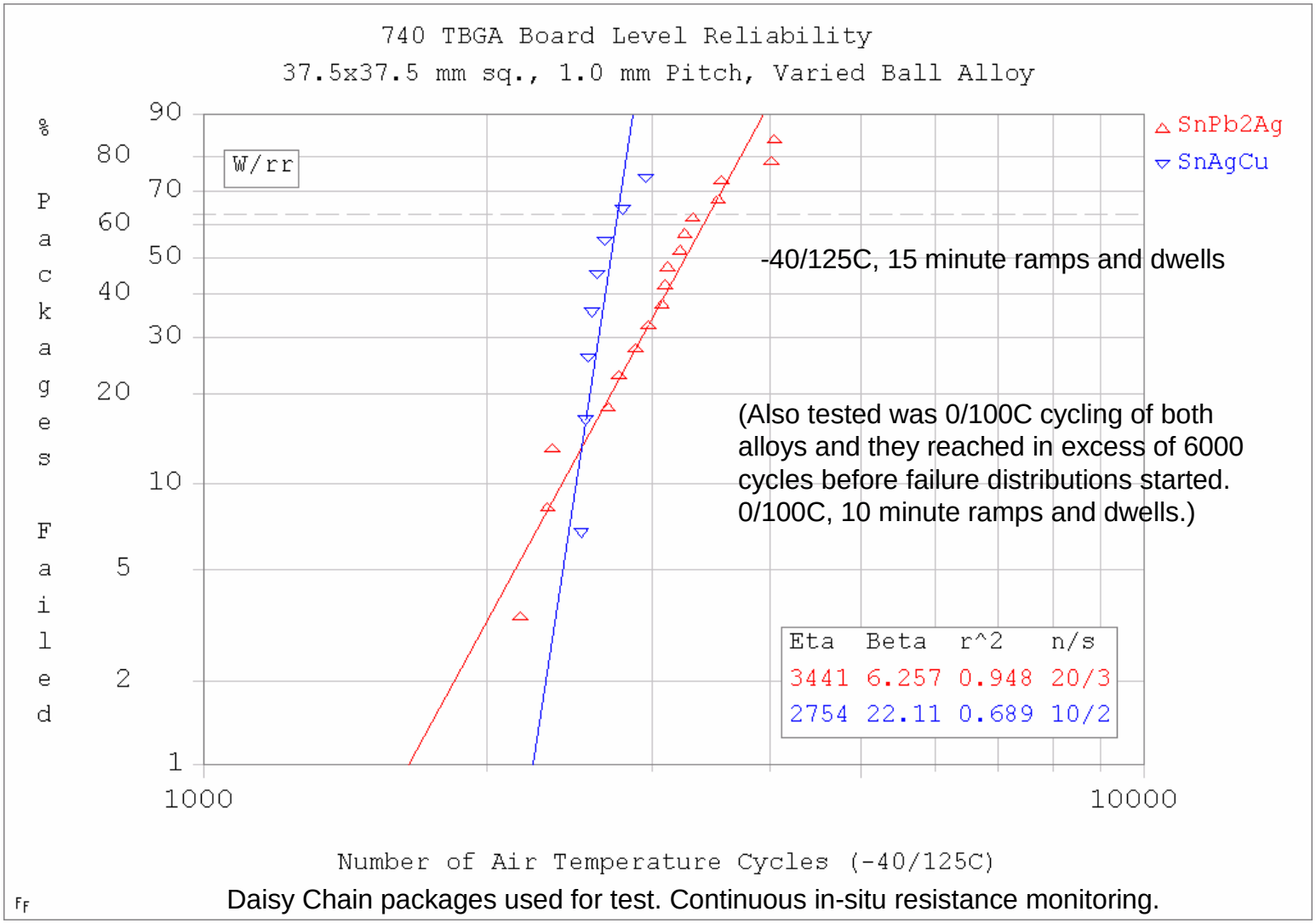
Surface Mount Assembly of TBGA

- No minimum solder paste volume is typically required since the solder ball melts during reflow
- TBGA can have a high thermal mass relative to other components and should be carefully profiled with a thermocouple in a corner and inner sphere on a fully populated profile PCB
- SnPb TBGA qualified to a maximum reflow temperature of 220°C and Pb-free TBGA is qualified to 260°C
- Soldering profiles are solder paste dependent, but here are some guidelines that can be used:
  - SnPb soldering:
    - > Raise temperature of the joints to 100°C at between 1.5 and 3.0°C/sec
    - > Peak component temperature typically between 205 and 220°C
    - > Desirable dwell time above 183°C between 50 and 80 secs
  - Pb-free soldering:
    - > Raise temperature of the joints to 100°C at between 1.5 and 3.0°C/sec
    - > Peak component temperature typically between 235 and 245°C
    - > Desirable dwell time above 217°C between 50 and 80 secs

TBGA CTE Analysis

- Composite CTE measurements have been taken on 352 35mm x 35mm TBGA using Moiré Analysis
  - Backside (Cu heat spreader): 17.5 ppm/°C
  - Frontside (BGA and cavity side): 17.2-18.0 ppm/°C
- Package well matched to most epoxy/glass motherboards which have a CTE of 16 to 22 ppm/ºC resulting in outstanding board level reliability

740 TBGA Weibull Plot of ATC – Board Level Reliablity



FF

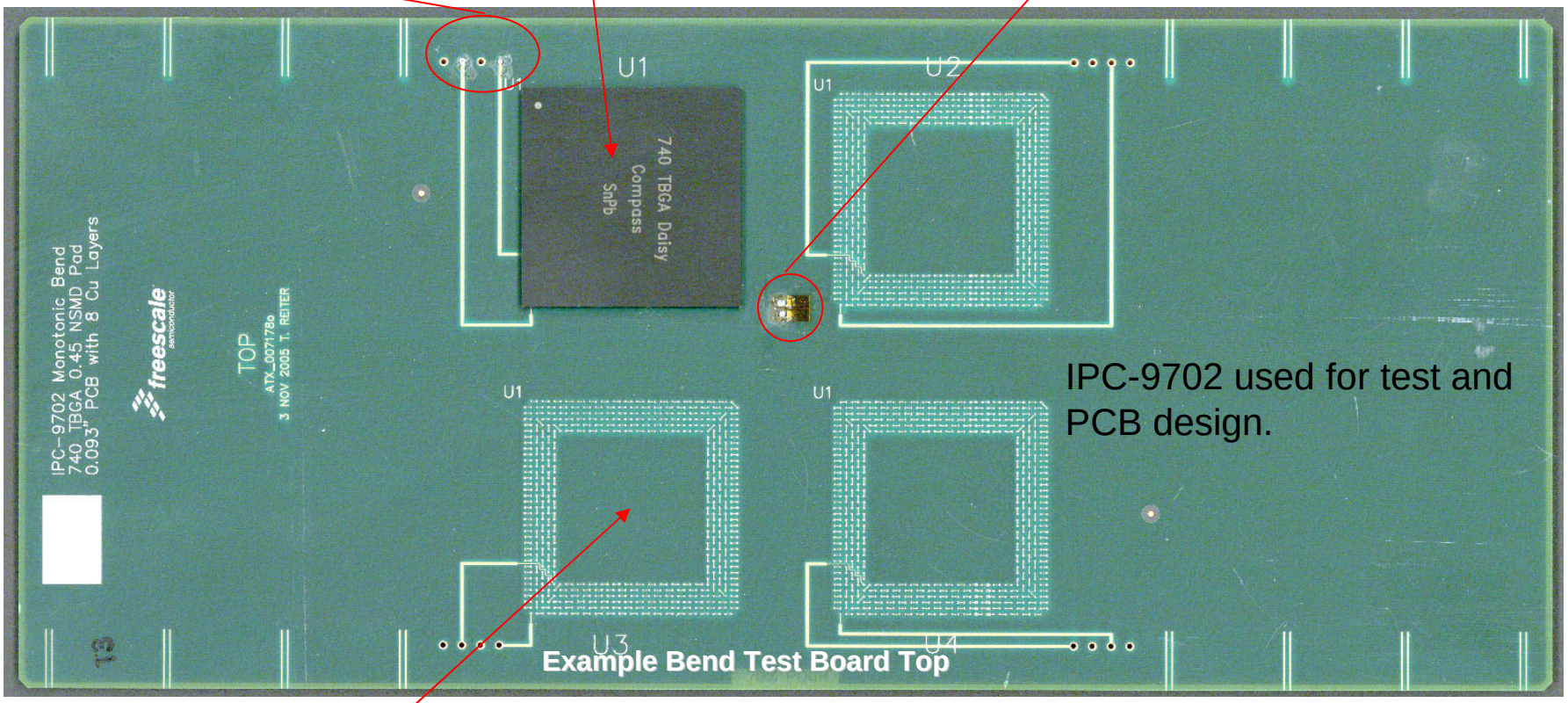
Daisy Chain packages used for test. Continuous in-situ resistance monitoring.

Bend Test

Connections to monitor daisy chain net

Daisy chain package mounted to PCB

Strain gage 1 cm from part edge, global strain value

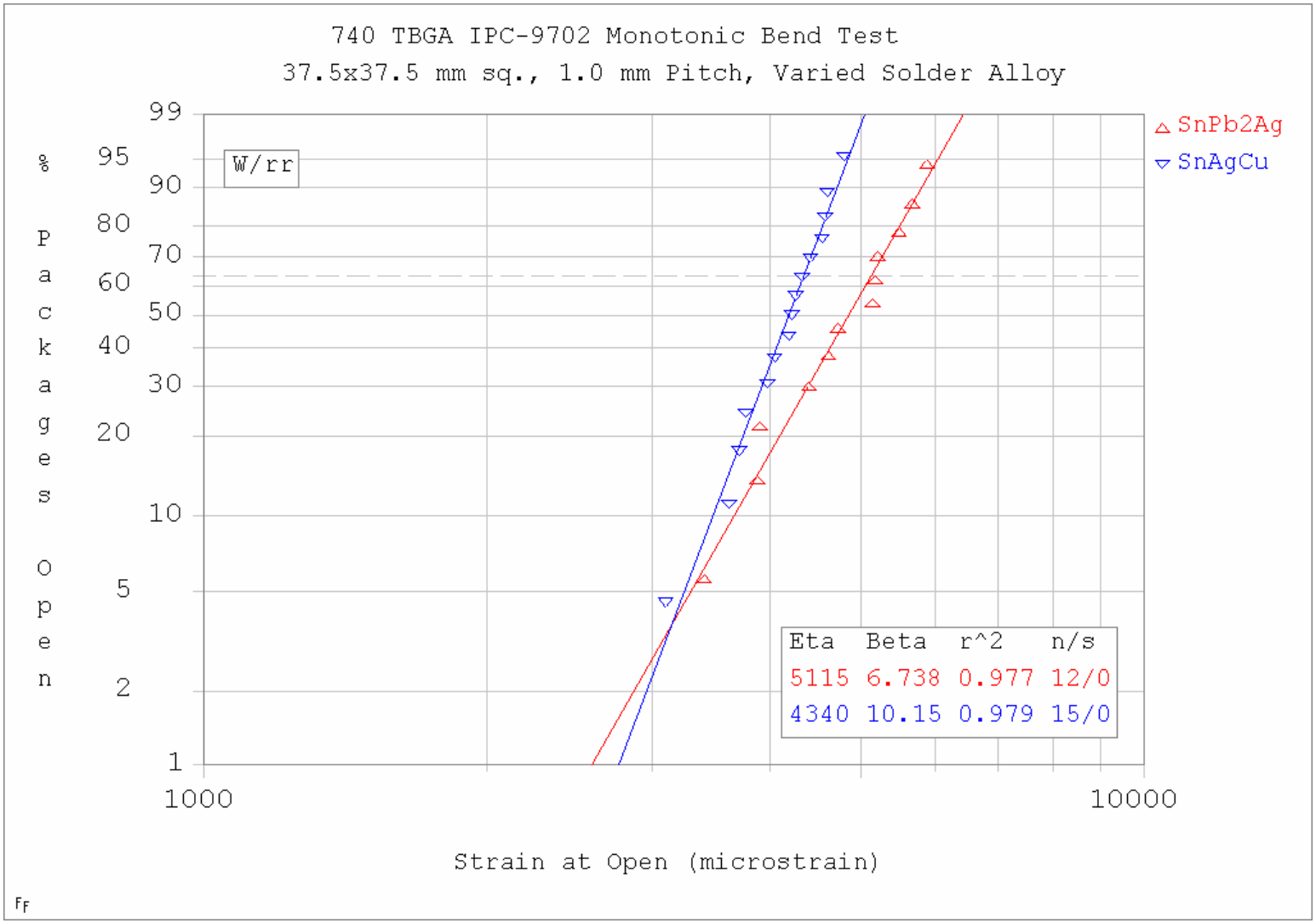


IPC-9702 used for test and PCB design.

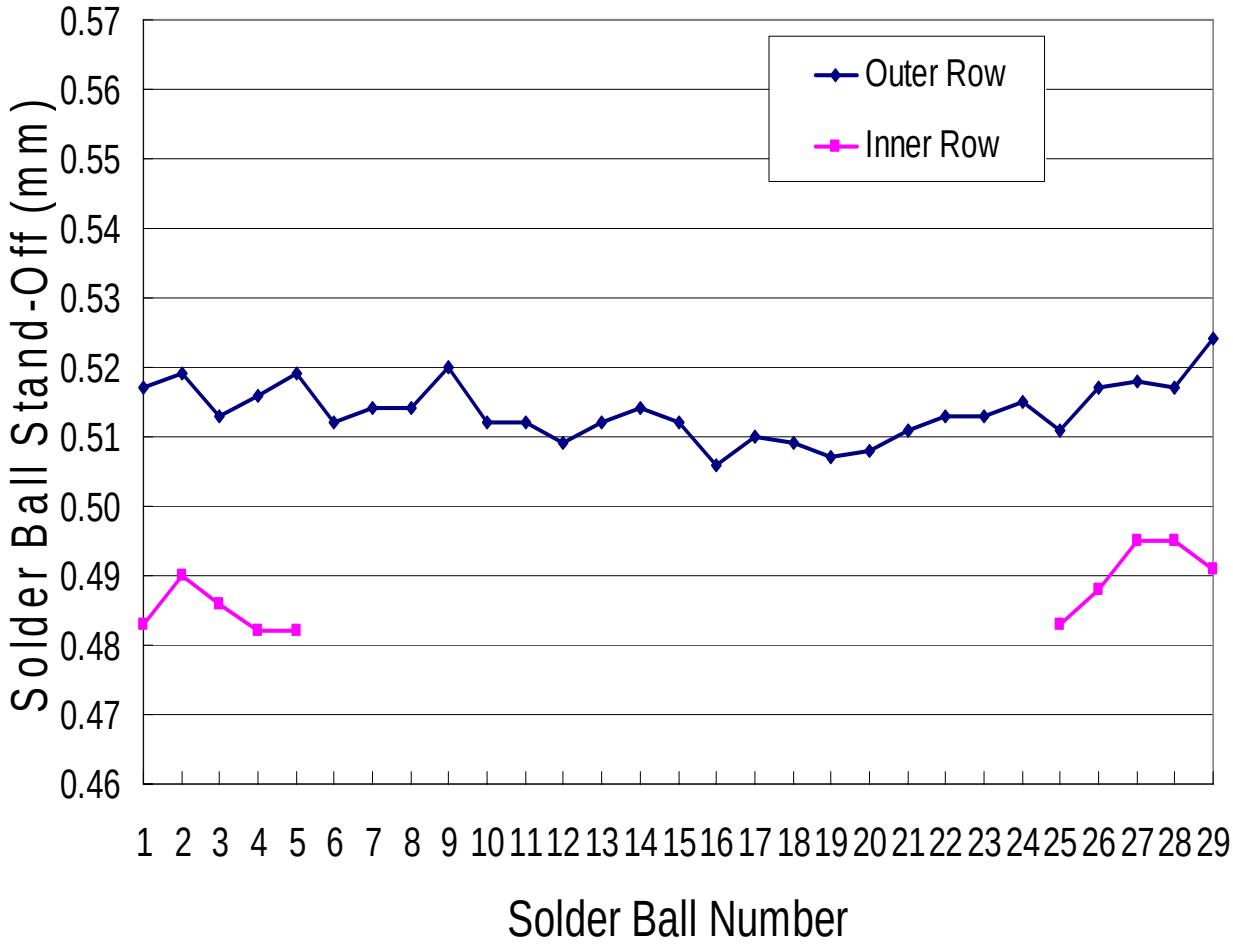
4 point bend anvils centered to package

Unpopulated package site

740 TBGA Weibull Plot of Break Strain – Bend Test



480 37.5 x 37.5 TBGA Board-Mounted Solder Joint Stand-Off

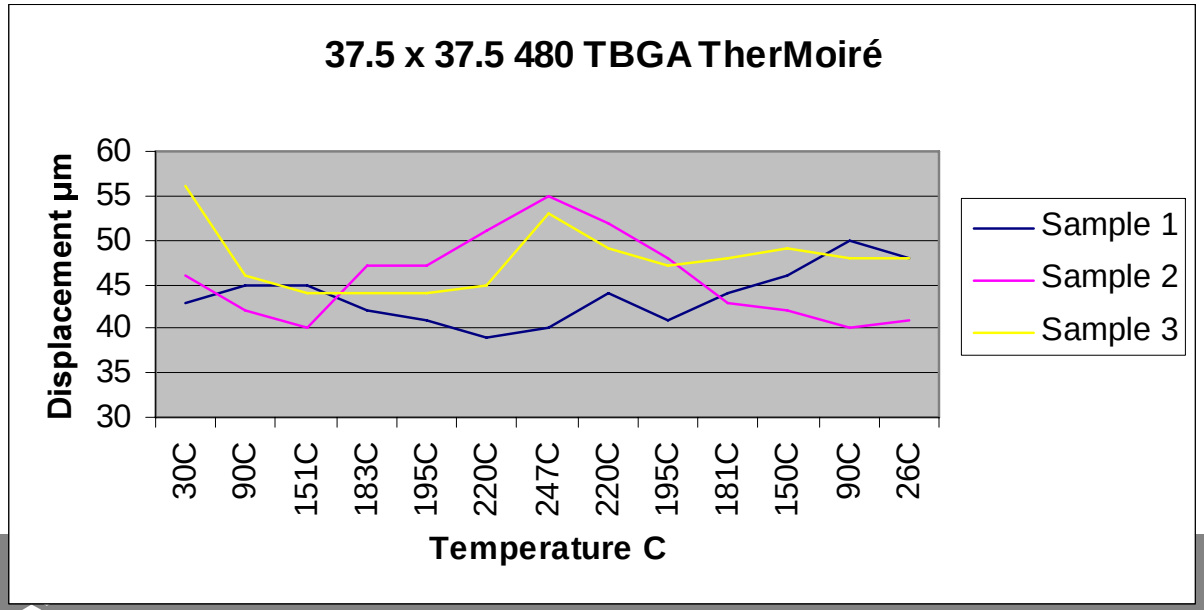


Notes:

- **Package very flat with 0.05 mm (2.0 mil) variation across entire 37.5 mm package.**
- **Overall mean stand-off height is 0.507 mm (20.0 mils).**
- **0.15 mm thick solder paste stencil with 0.58 mm apertures.**
- **0.635 mm SMD package pads.**
- **0.58 mm NSMD test board pads.**
- **OSP surface finish on test boards.**

37.5 x 37.5 480 TBGA TherMoire Analysis

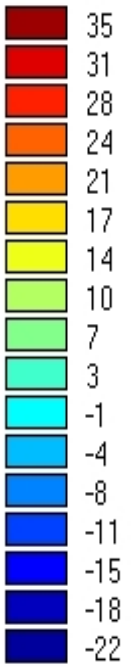
	TherMoiré Warpage (um) at Temperature Read Points												
Profile	Heating						Peak	Cooling					
Temperature	30C	90C	151C	183C	195C	220C	247C	220C	195C	181C	151C	90C	26C
Sample 1	43	45	45	42	41	39	40	44	41	44	46	50	48
Sample 2	46	42	40	47	47	51	55	52	48	43	42	40	41
Sample 3	56	46	44	44	44	45	53	49	47	48	49	48	48
Minimum	**43**	**42**	**40**	**42**	**41**	**39**	**40**	**44**	**41**	**43**	**42**	**40**	**41**
Maximum	**56**	**46**	**45**	**47**	**47**	**51**	**55**	**52**	**48**	**48**	**49**	**50**	**48**
Average	**48.3**	**44.3**	**43.0**	**44.3**	**44.0**	**45.0**	**49.3**	**48.3**	**45.3**	**45.0**	**45.7**	**46.0**	**45.7**



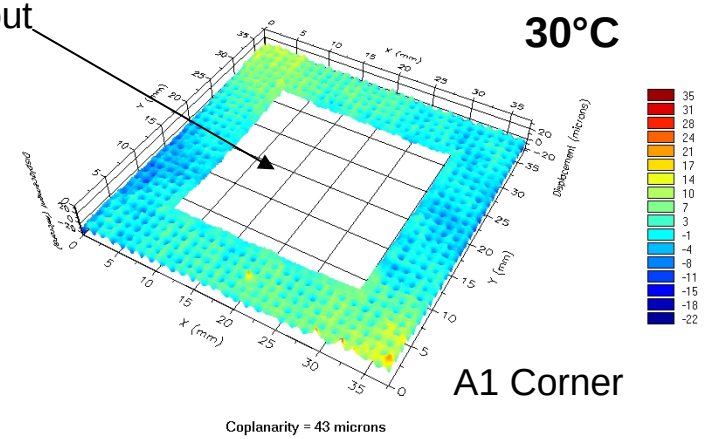
Peak temperature is 247C
Data was taken from the sphere side of the package
Samples were baked, spheres removed, and painted prior to TherMoiré
The mold cap in the center was masked out for a more accurate measurement

TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 1 - Heating

Mold cap area masked out



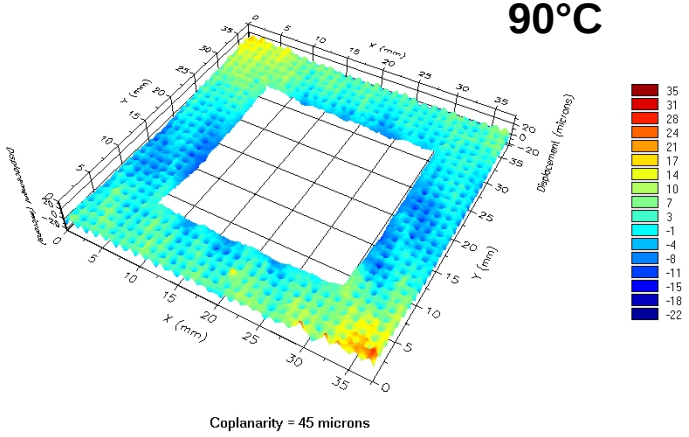
30°C



A1 Corner

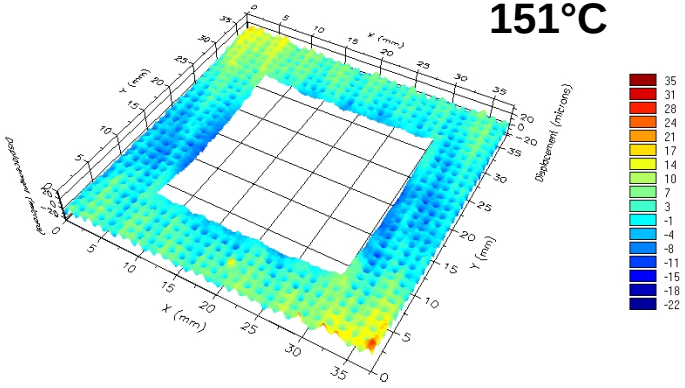
Coplanarity = 43 microns

90°C



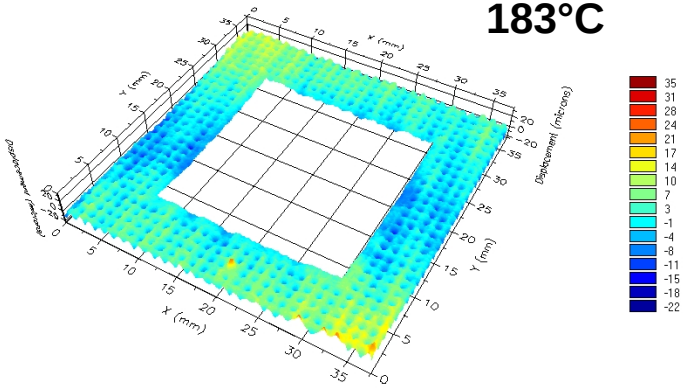
Coplanarity = 45 microns

151°C



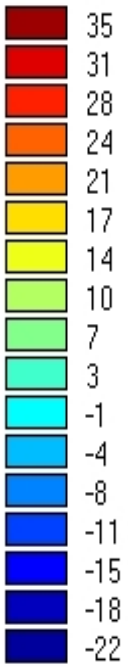
Coplanarity = 45 microns

183°C

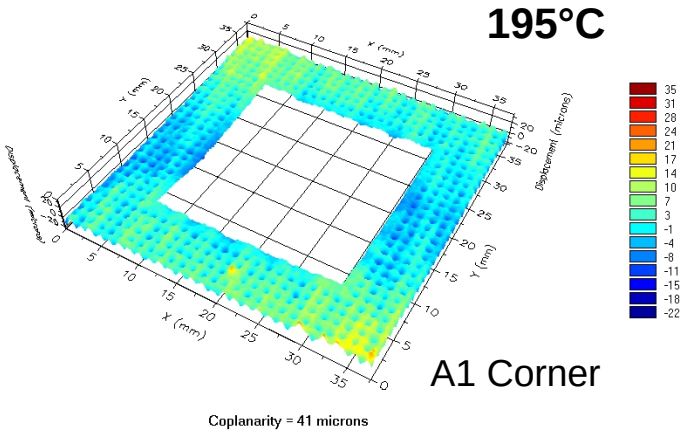


Coplanarity = 42 microns

TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 1 - Heating



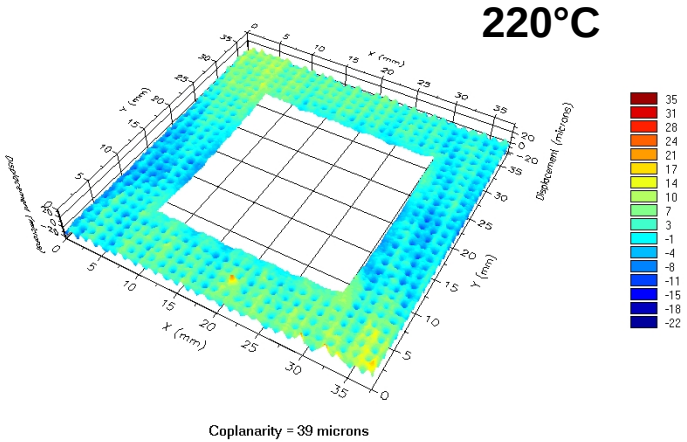
195°C



A1 Corner

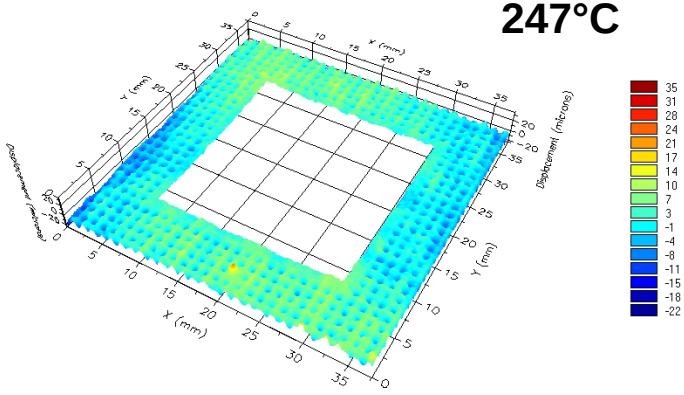
Coplanarity = 41 microns

220°C



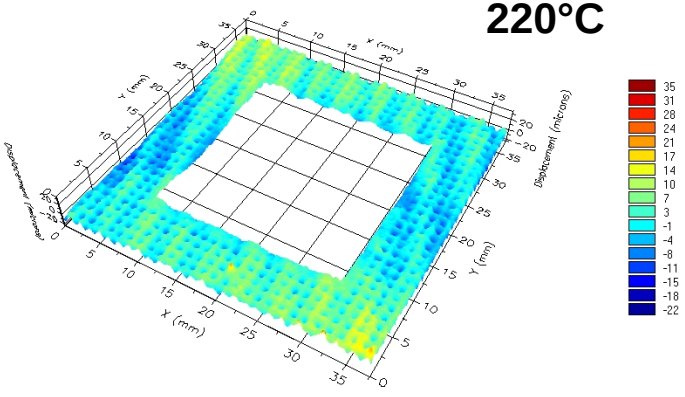
Coplanarity = 39 microns

247°C



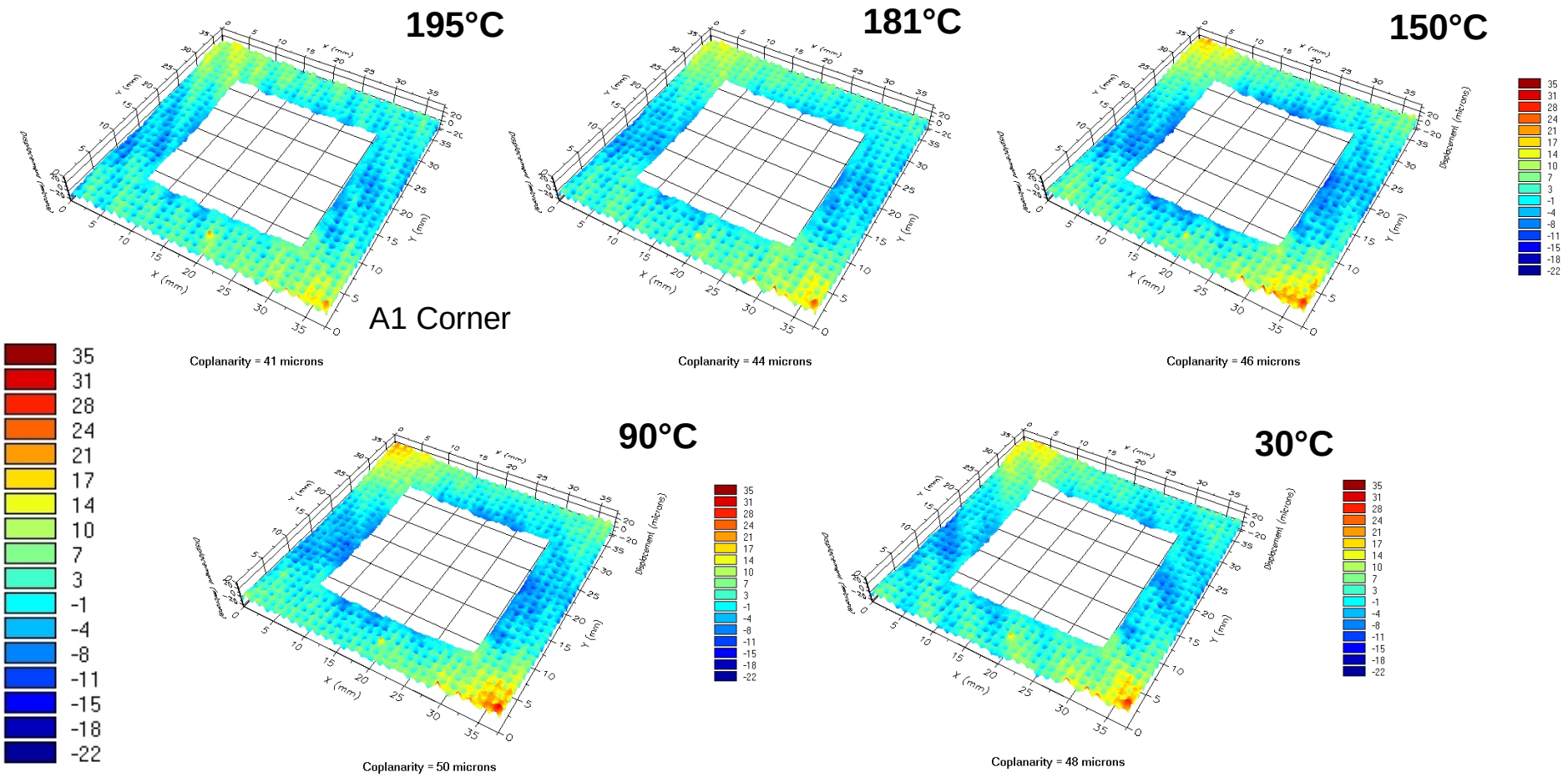
Coplanarity = 40 microns

220°C

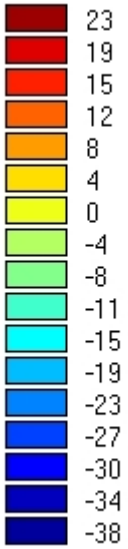


Coplanarity = 44 microns

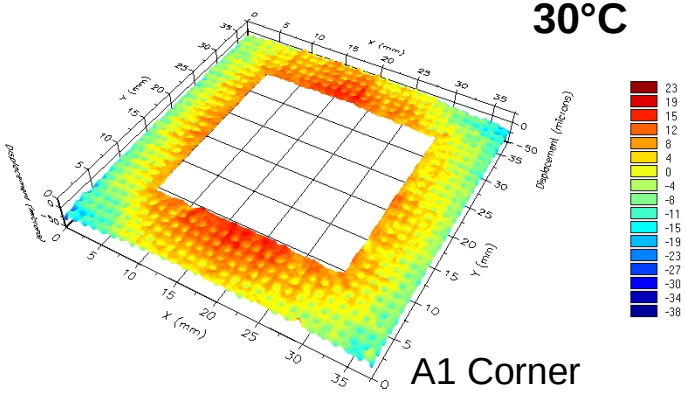
TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 1 - Cooling



TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 2 - Heating

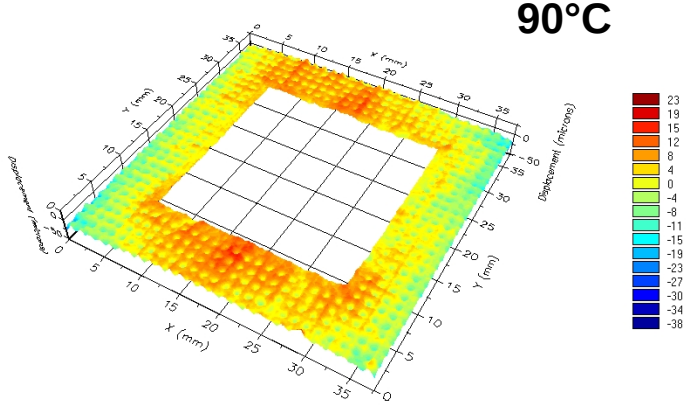


30°C



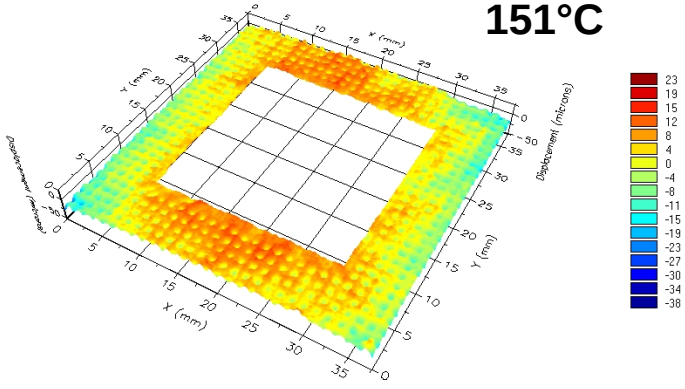
Coplanarity = 46 microns

90°C



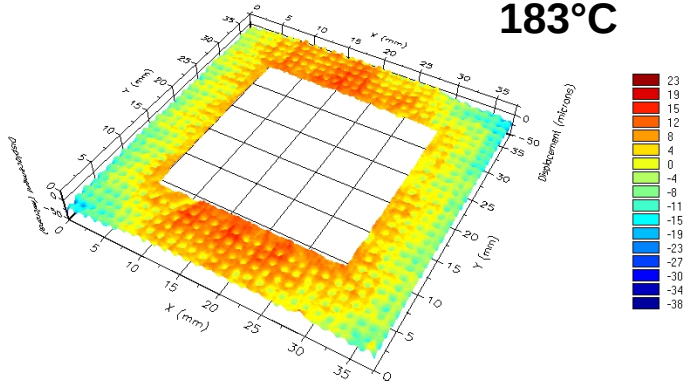
Coplanarity = 42 microns

151°C



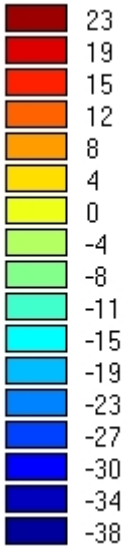
Coplanarity = 40 microns

183°C

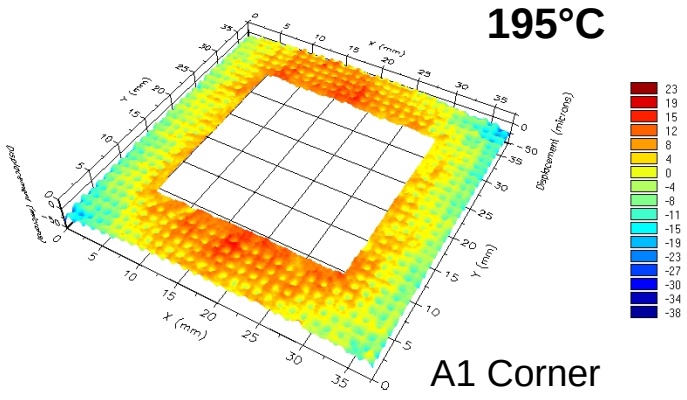


Coplanarity = 47 microns

TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 2 - Heating



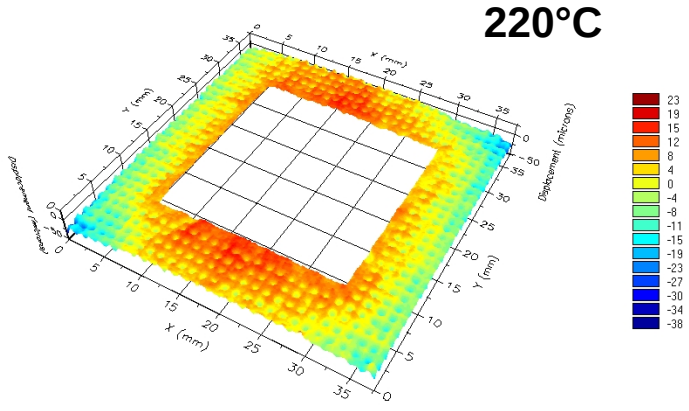
195°C



A1 Corner

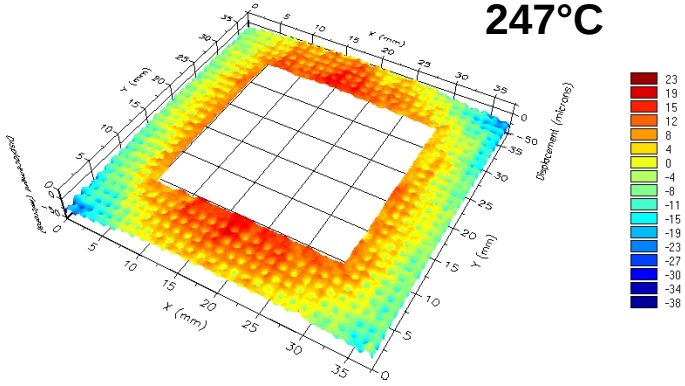
Coplanarity = 47 microns

220°C



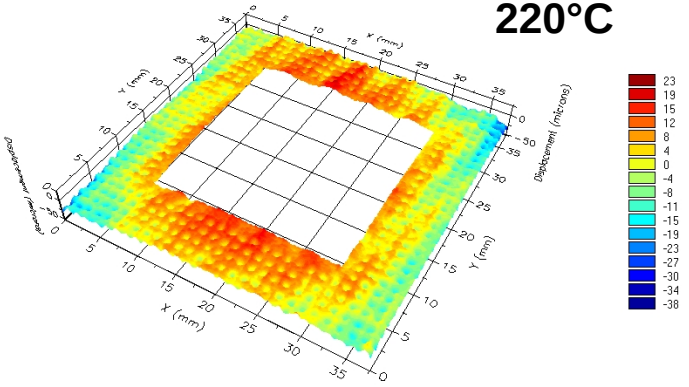
Coplanarity = 51 microns

247°C



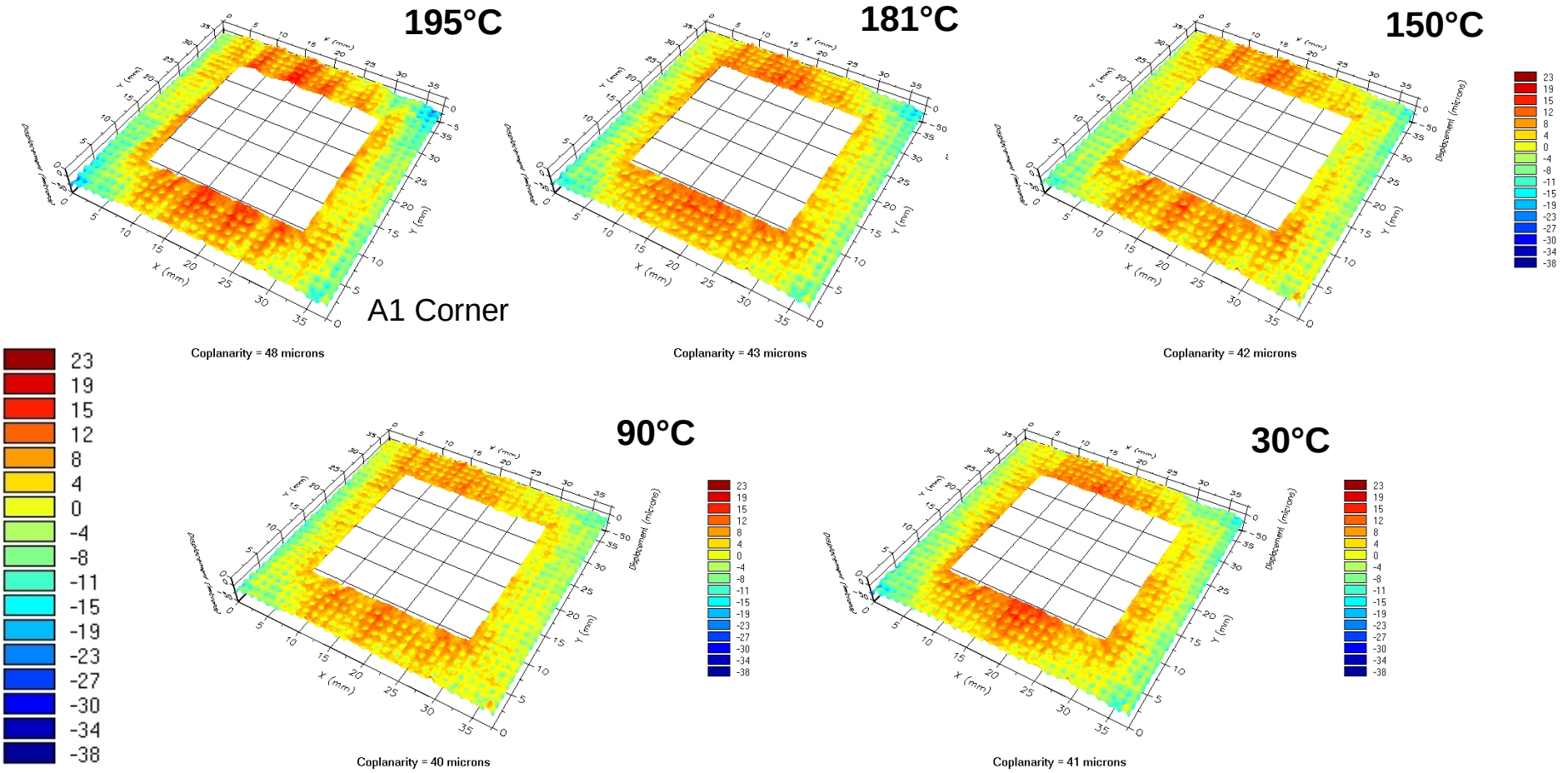
Coplanarity = 55 microns

220°C

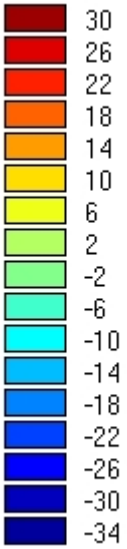


Coplanarity = 52 microns

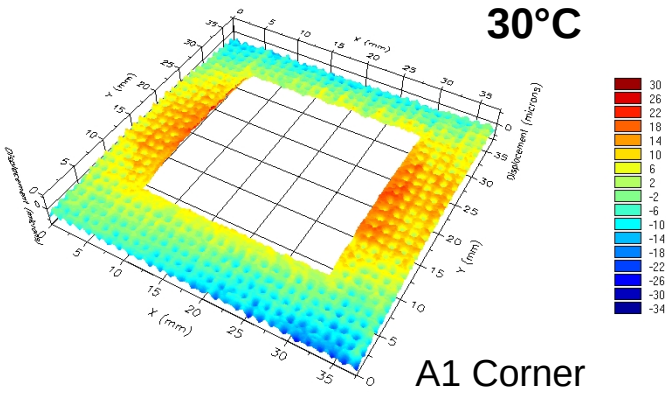
TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 2 - Cooling



TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 3 - Heating



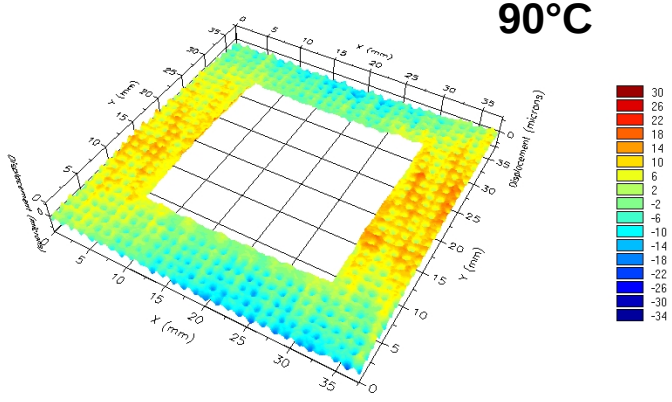
30°C



A1 Corner

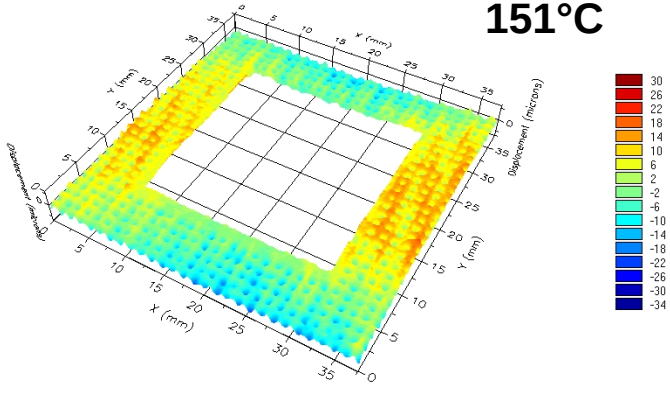
Coplanarity = 56 microns

90°C



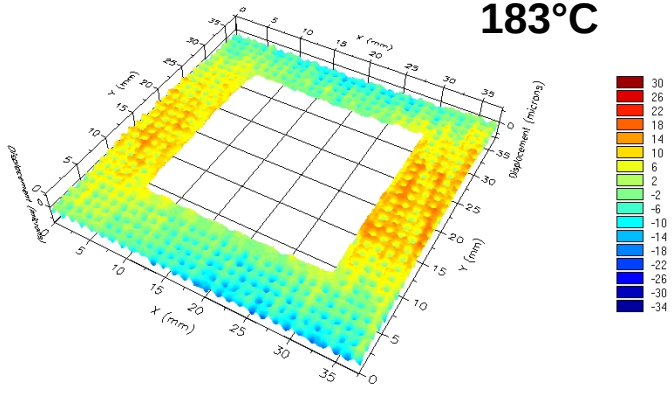
Coplanarity = 46 microns

151°C



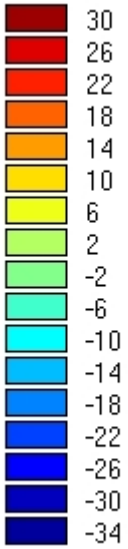
Coplanarity = 44 microns

183°C

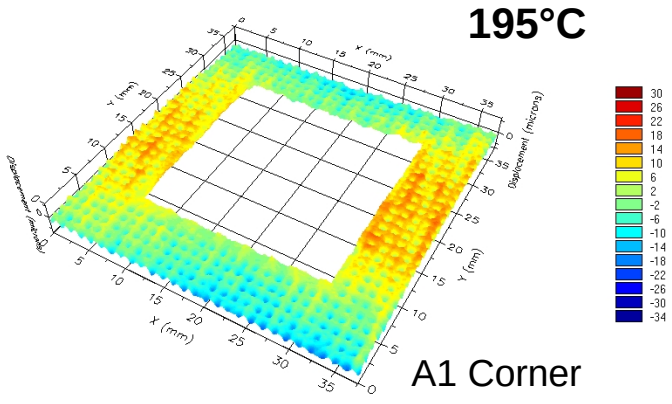


Coplanarity = 44 microns

TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 3 - Heating



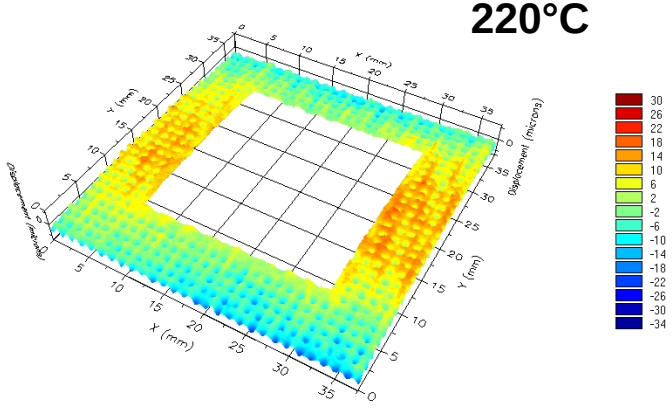
195°C



A1 Corner

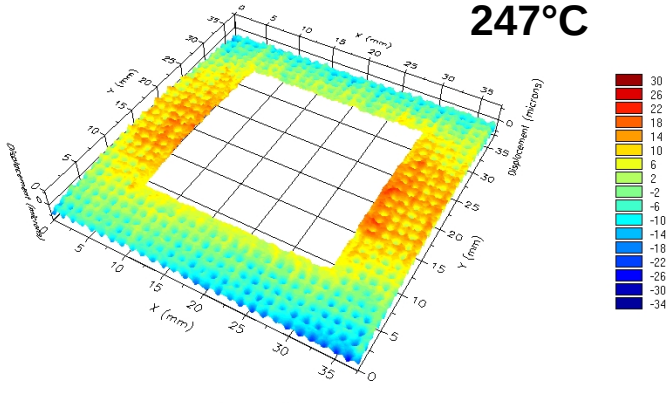
Coplanarity = 44 microns

220°C



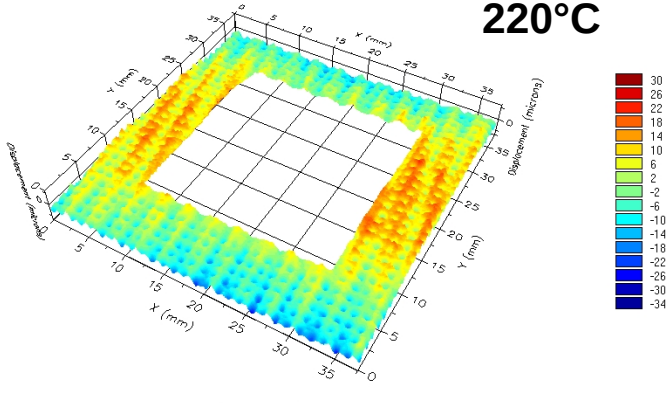
Coplanarity = 45 microns

247°C



Coplanarity = 53 microns

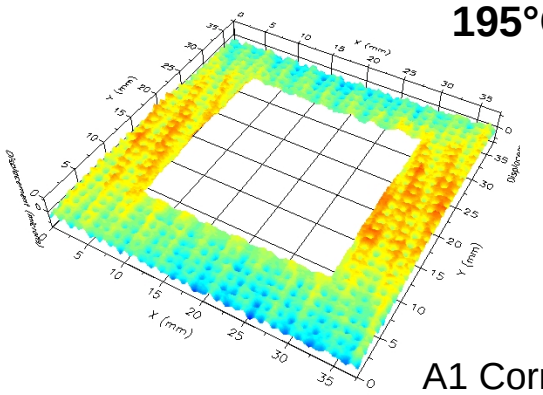
220°C



Coplanarity = 49 microns

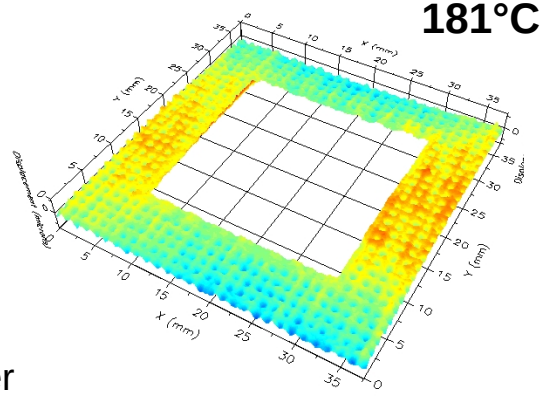
TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 3 - Cooling

195°C



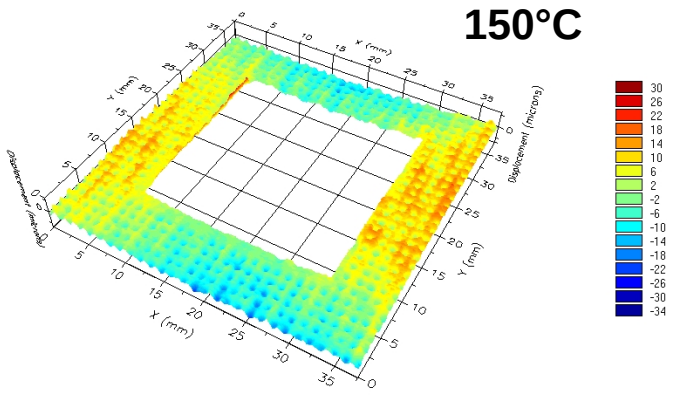
Coplanarity = 47 microns

181°C



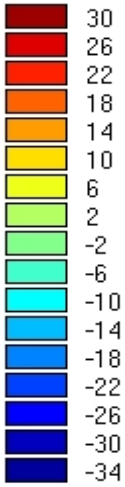
Coplanarity = 48 microns

150°C

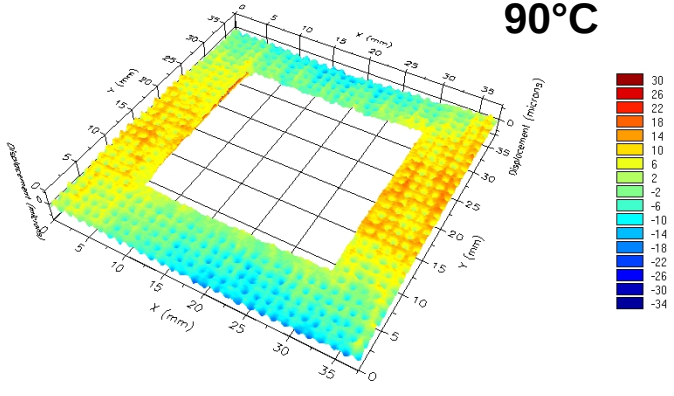


Coplanarity = 49 microns

A1 Corner

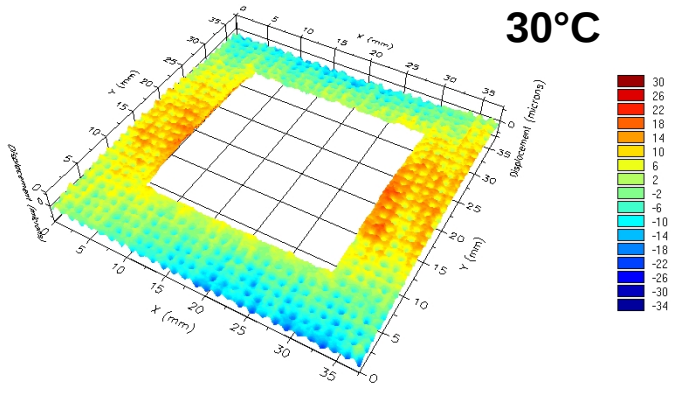


90°C



Coplanarity = 48 microns

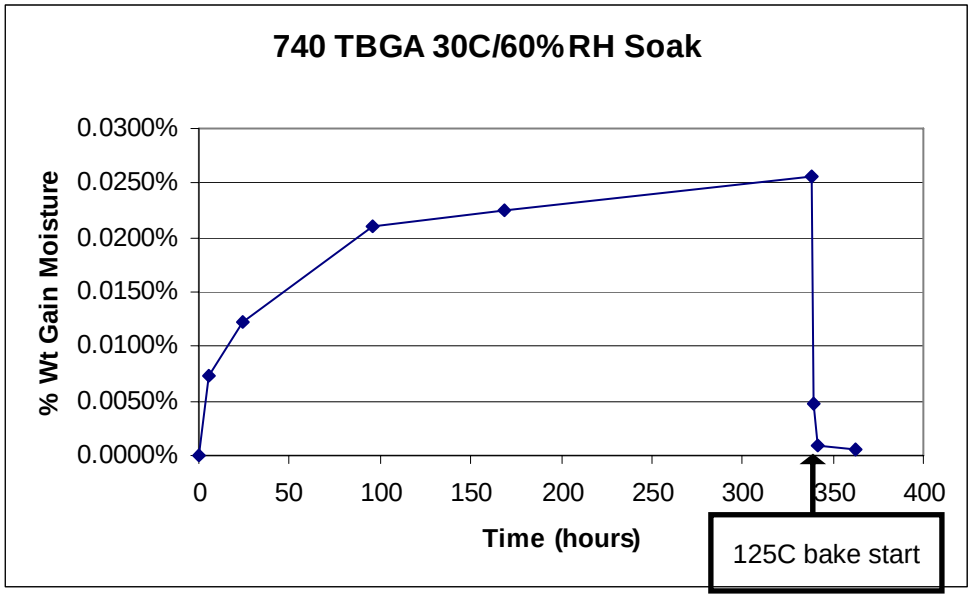
30°C

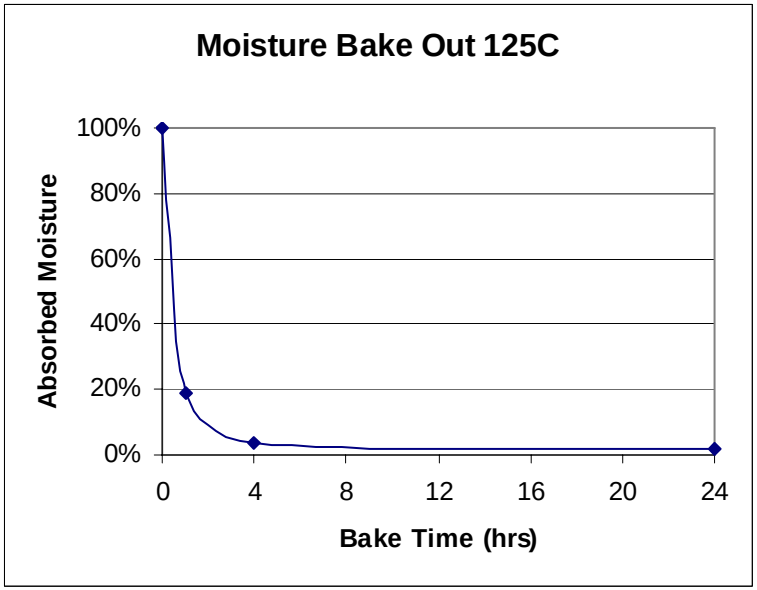


Coplanarity = 48 microns

TBGA Moisture Study

- 740 pin TBGA
  - Weight gain in 338 hours of 30°C/60%RH soak
  - Weight loss in 125°C bake-out
  - Industry standard 24 hour bake





Note: FSL recommends to bake parts for 24 hours at 125degC.