Reliability Solder Columns for Extreme Cold

Martin Hart

TopLine®

Braided Column

U.S. Pat 10,477,698

Thanks and Appreciation to:

Reza Ghaffarian

Jet Propulsion Laboratory
California Institute of Technology

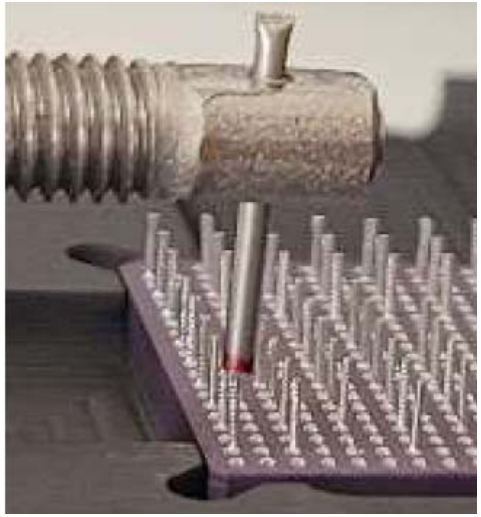
Cu Wrap Column

Bottom Line Up Front

- **CGA Packages with Two Column Types were compared at JPL**
  Heritage Copper-Wrap columns (Supplier: Six Sigma Supplier)
  Newly developed Braided columns (Supplier: TopLine)

- **Assembly of Daisy Chain CGA with 1657 Columns**
  10x CGA Braided Columns and 1x CGA Copper Wrap Column.
  5-Zone Daisy-chain DC Resistance Monitoring

- **Thermal Cycle Testing: Total 400 Cycles**
  Step#1 = 200 cycles -55^{o}C to 125^{o}C
  Step#2 = 200 cycles -100^{o}C to 125^{o}C



Measuring Reliability

Test #1 - CGA Component Level

Compares the mechanical characteristics by using bending fatigue strengths.

Test #2 - PCB Assembly Level

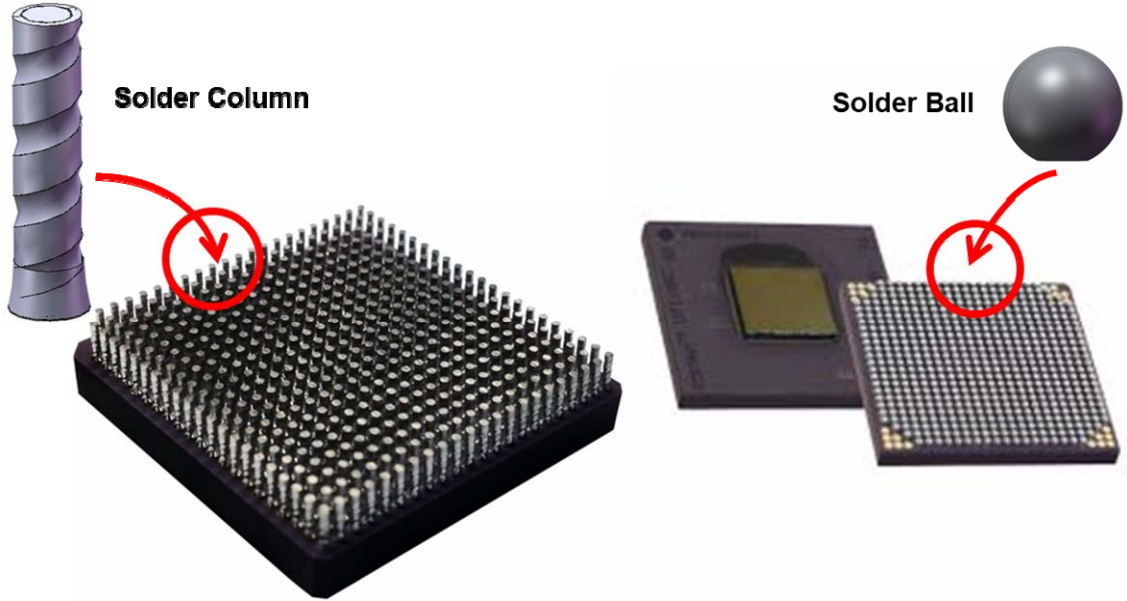
Solder joint reliability “Cycles-to-Failure” between hot and cold end-points.

Harsh Conditions: -55°C to +125°C

Extreme Cold: -100°C to +125°C

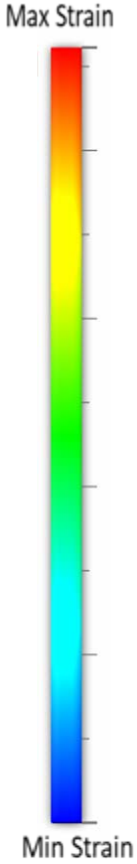
Solder Columns replace balls to reduce fracture-strain in solder interconnections

Columns absorb CTE mismatch between the package and boards.

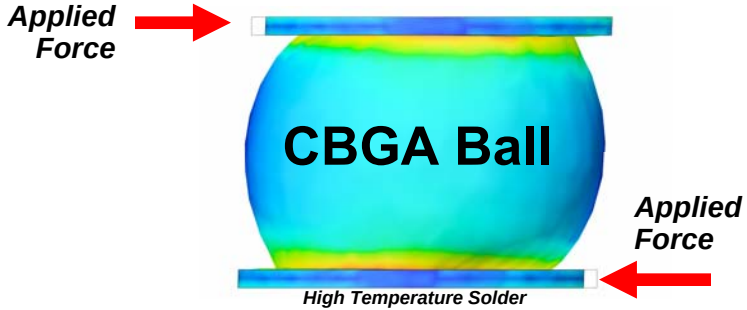


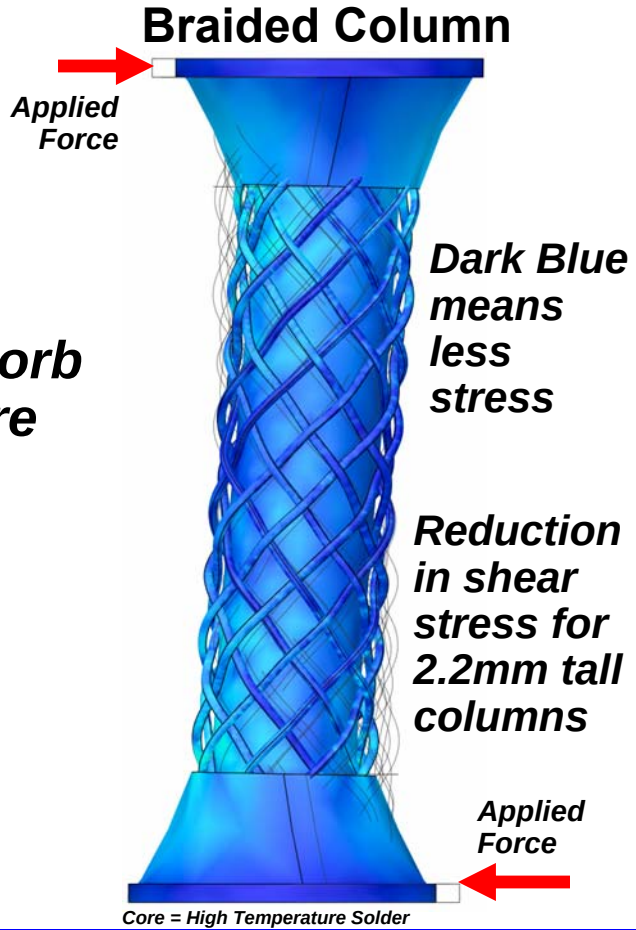
Finite Element Analysis

Comparison shear strain Ball vs Column



Observation: ***Braided Columns absorb stress and distribute the load more evenly than balls.***





50 Year History: Three Column Types

1980

Original Column: IBM 1970s

Heritage Cu Wrap Column

New Braided Column

2020

Solder Column relative size

16x BeCu wire braid Non-collapsible

Braided Solder Column

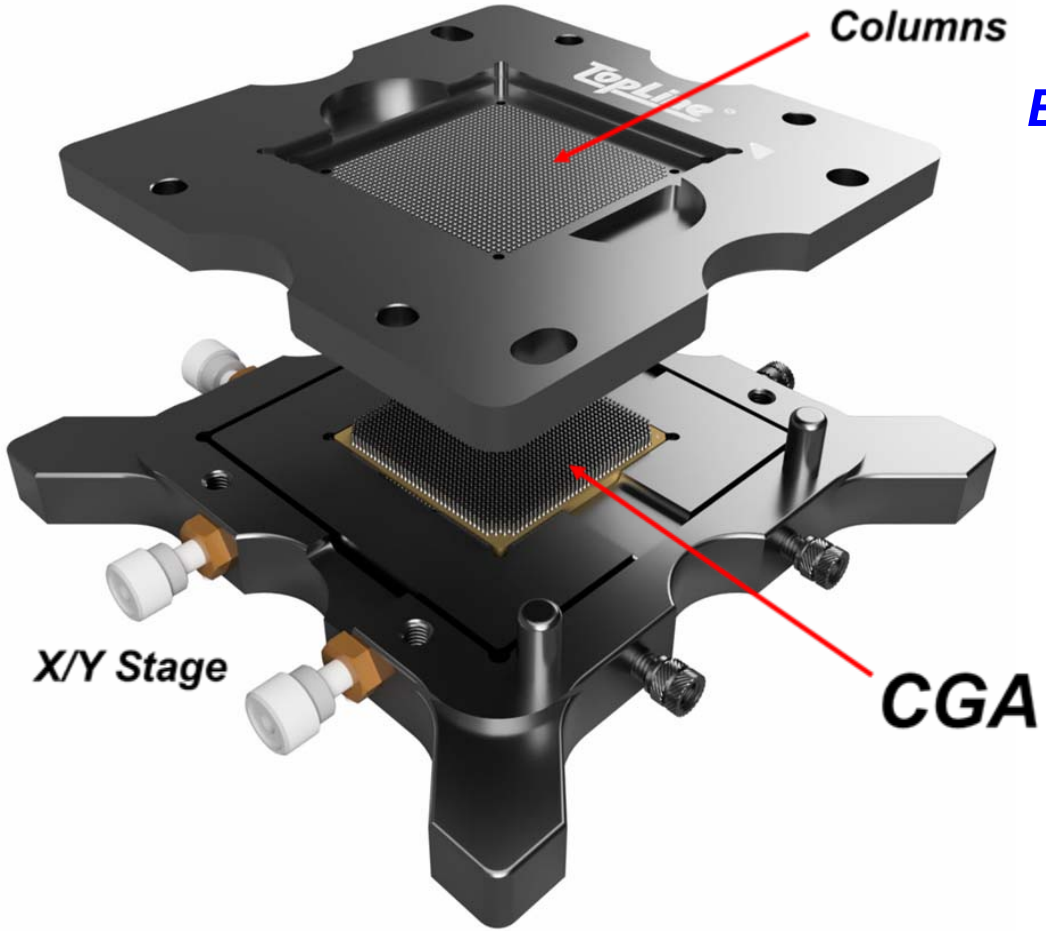
Shown before Solder Coating

Shown After Solder Coating

Length 1.0 ~ 2.2mm

Fillet

Pitch: 0.65mm ~ 1.27mm

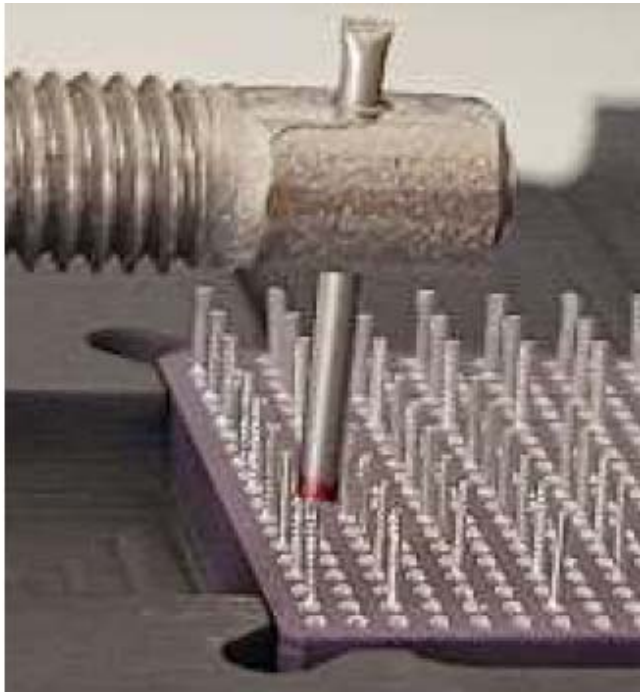


Example Graphite Fixture for Batch Package Assembly

Tooling system deposits columns onto ceramic or plastic package and holds columns vertically during reflow cycle in oven.

Same tool is used for Braided and Copper-Wrap or Plain Columns

Highly Accelerated +/-12.5mil Column Bend Test



Bend Test Fixture

Solder core cracks on Braided and Copper-Wrap columns after accumulation of inelastic damage caused by bending +/- 12.5 mils (0.317mm) at 25°C

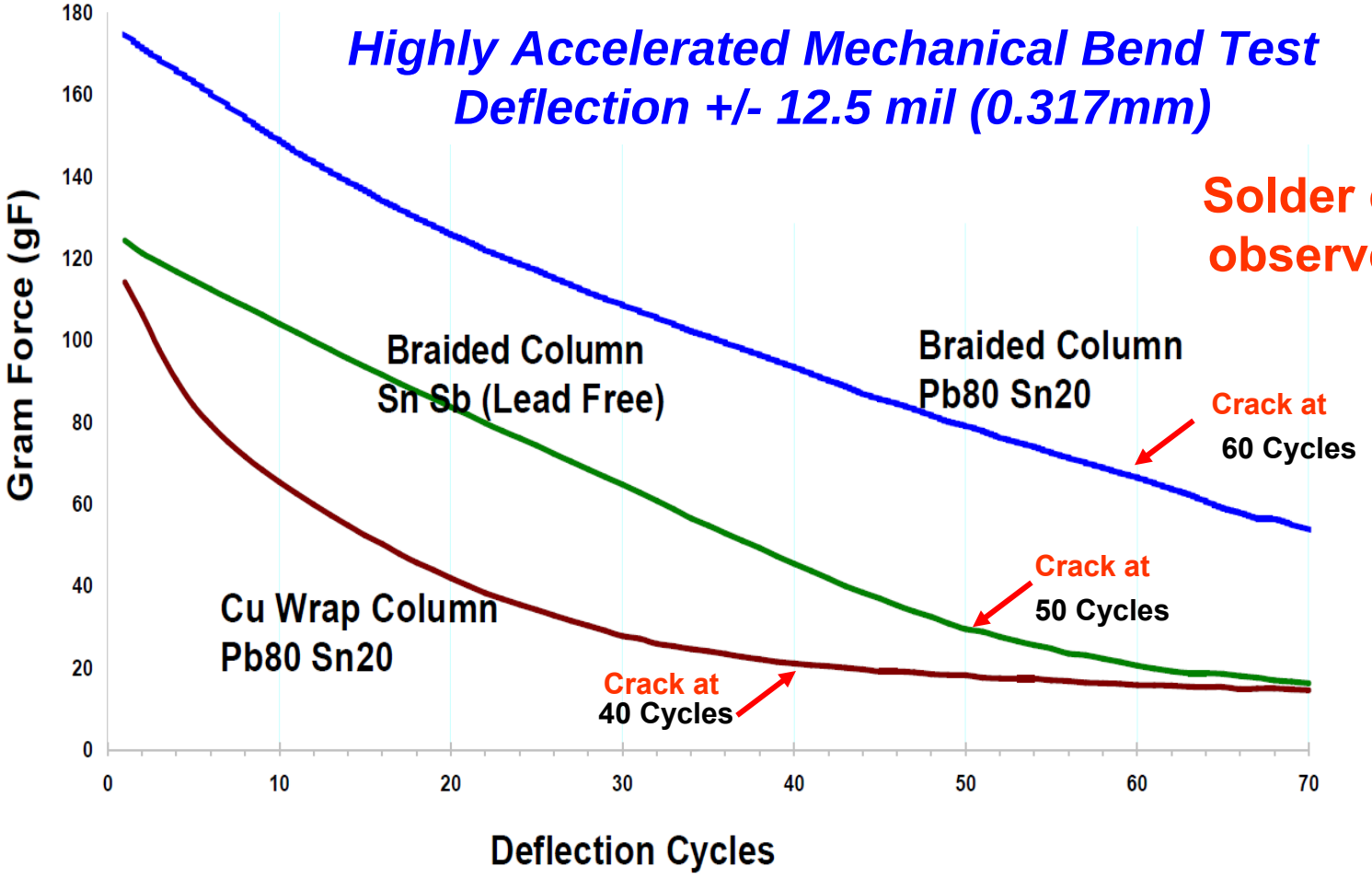
Braided Columns cracked after 60 Bends

Pb80/Sn20

Copper Wrap Columns cracked after 40 Bends

Pb80/Sn20

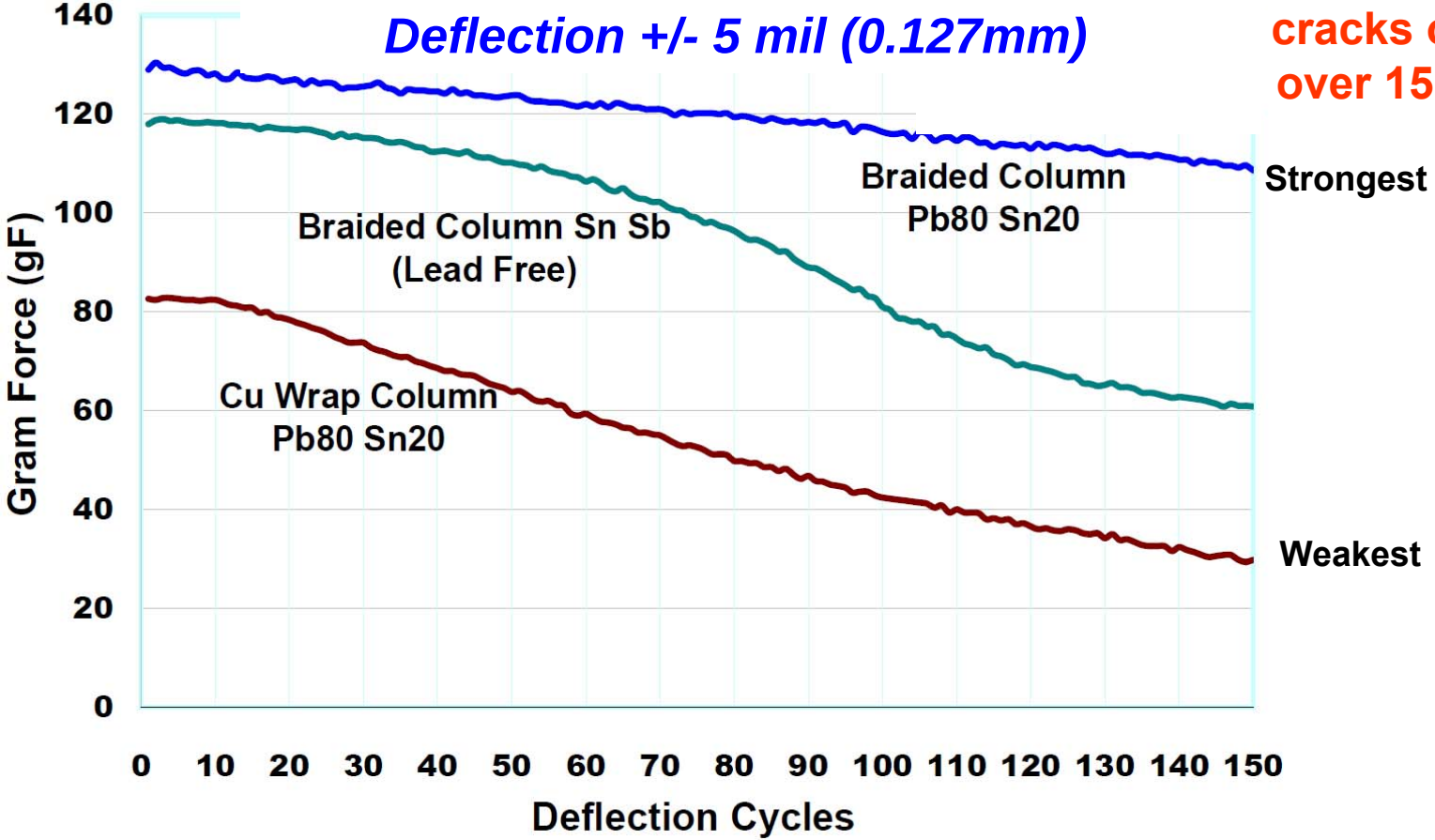
Highly Accelerated Mechanical Bend Test
Deflection +/- 12.5 mil (0.317mm)



Solder core cracks observed all types

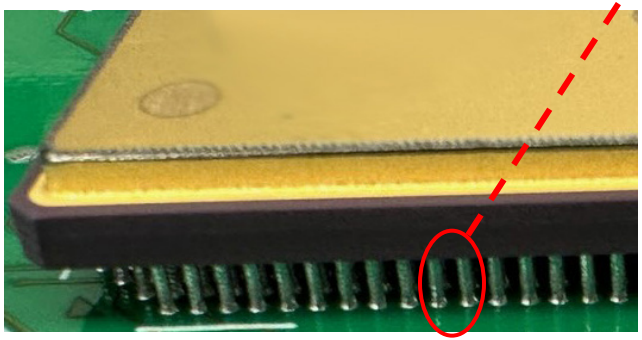
Mechanical Deflection Test
Deflection +/- 5 mil (0.127mm)

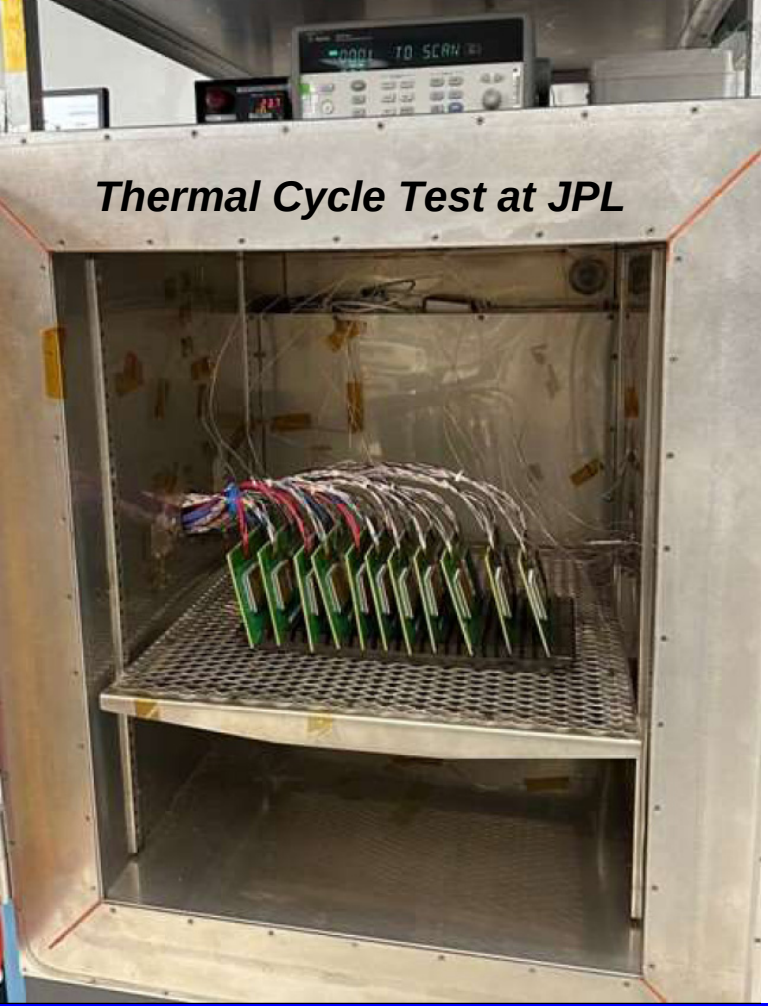
No solder core cracks observed over 150 cycles.



Braided CGA PCBA Assembly Daisy Chain

Braided Column





Thermal Cycle Test at JPL

Accelerated Thermal Cycle Test

Continuous DCR resistance monitoring of 5 Zone Daisy-Chain Loops

Total 400 Thermal Cycles
No Failures Observed on 11 Assemblies

200 Cycles - Harsh conditions:
-55°C to + 125°C

Followed by
200 Cycles - Extreme Cold:
-100°C to + 125°C

15 minutes dwell at temperature extremes
75 minutes per cycle

Summary of Reliability Tests:

• Reliability characteristics for 2 columns types:
Braided and Copper-Wrap at the package level on a PCB.

• ***Mechanical Bend Test @ 25°C:***

Harsh: 150 deflection cycles +/- 5 mil (0.127 mm) – ***No Failures***

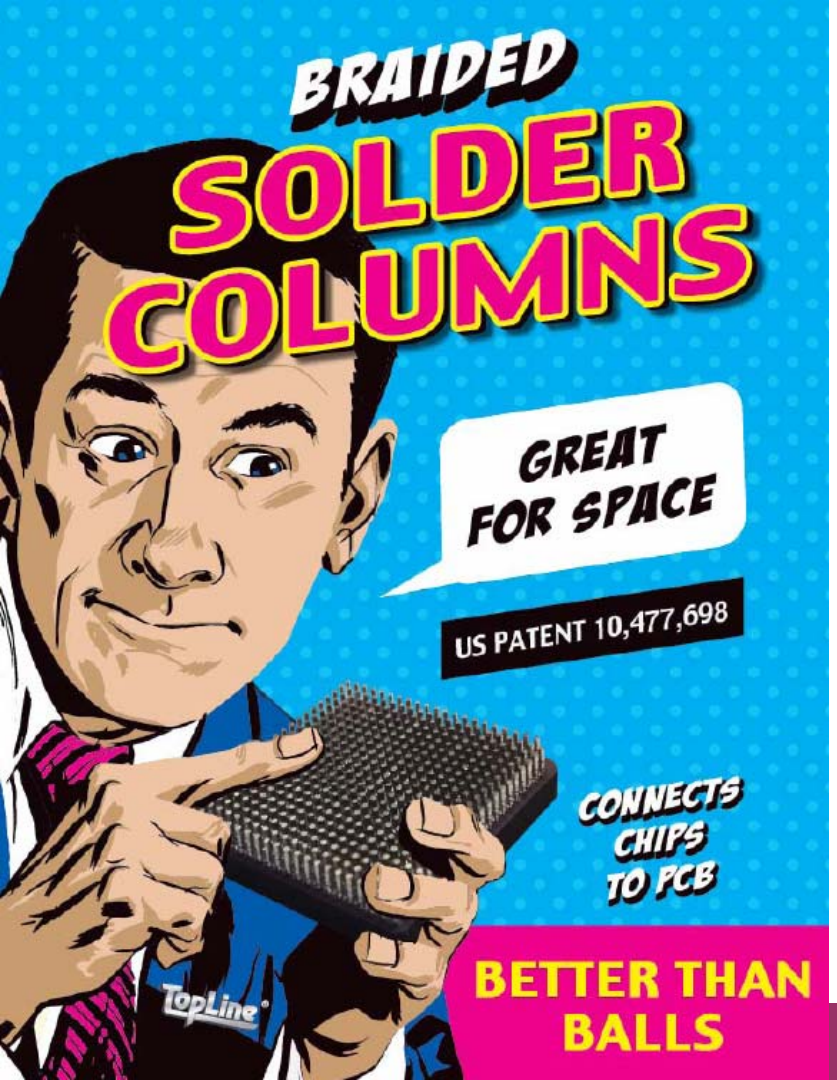
Extreme: 60 deflection cycles +/- 12.5 mil (0.317 mm) – ***Cracking Observed***

• ***Thermal Cycle Testing at two temperature ranges:***

Harsh: 200 cycles -55°C to +125°C – ***No Failures***

Extreme: 200 cycles -100°C to +125°C – ***No Failures***

Next Steps: ***More thermal cycle testing needed to produce failures.***



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Thanks and Appreciation to:

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Backup

Measuring Reliability

Reliability in the solder joints are determined by performing "Cycles-to-Failure" between hot and cold end-points.

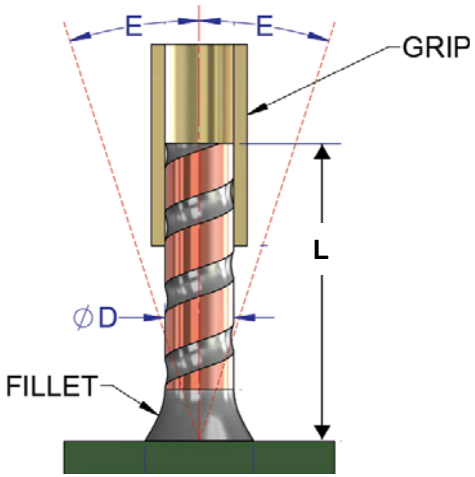
Harsh Conditions: -55^{o}C to +125^{o}C

Extreme Cold: -100^{o}C to +125^{o}C

Method #1: Daisy Chain components with solder columns were mounted on PCB assemblies and the DC resistance of the circuit loops were continuously measured during 400 thermal cycles.

Method #2: Our study also compares the materials and mechanical characteristics by using pull and bending fatigue strengths.

Deflection Test vs Thermal Cycle Test



Bend Testing @25°C :

- Initially columns start the strongest.
- The gram force load rapidly decreases during early cycling due to microstructional changes in the solder material.
- The column experiences alternating tensile and compressive stresses with progressive microstructual damage.
- Ultimately leading to cracking of the solder core.

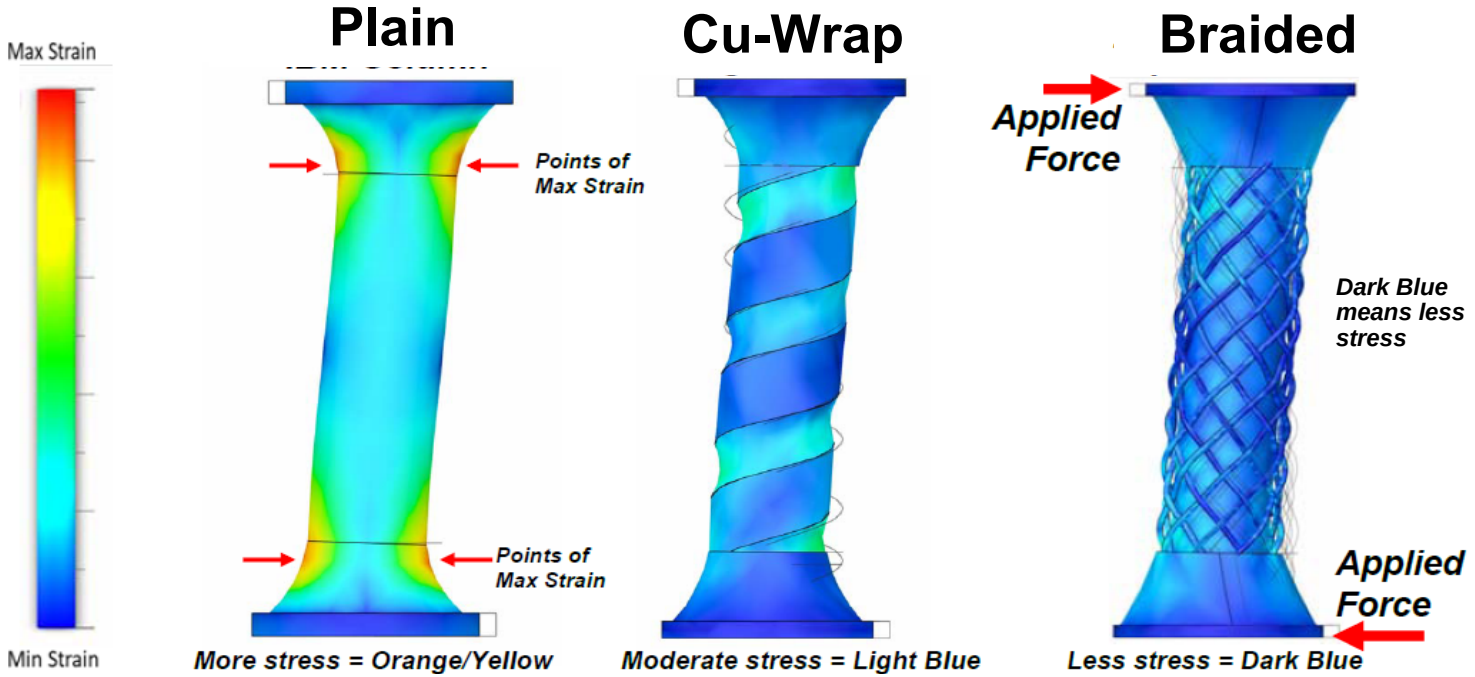
Harsh Conditions:
-55°C to +125°C

Extreme Conditions:
-100°C to +125°C

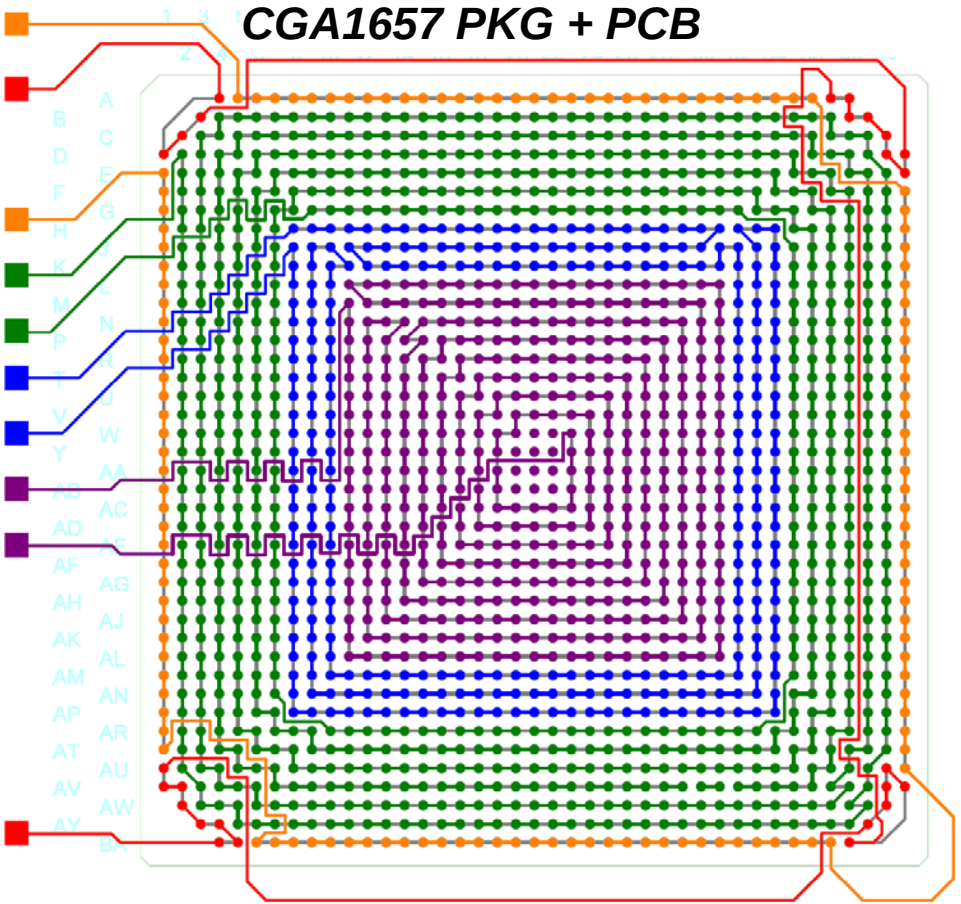
Thermal Cycle Testing:

Damage progressions include re-crystallization and creep that are associated with thermal failure mechanisms.

Comparative Shear Stress in 3 Different Columns

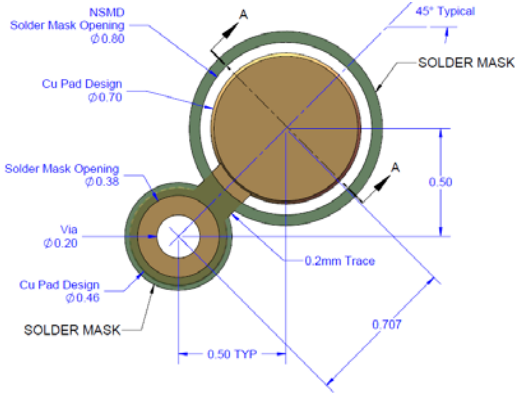


Columns are able to Absorb CTE mismatch better than solder balls.

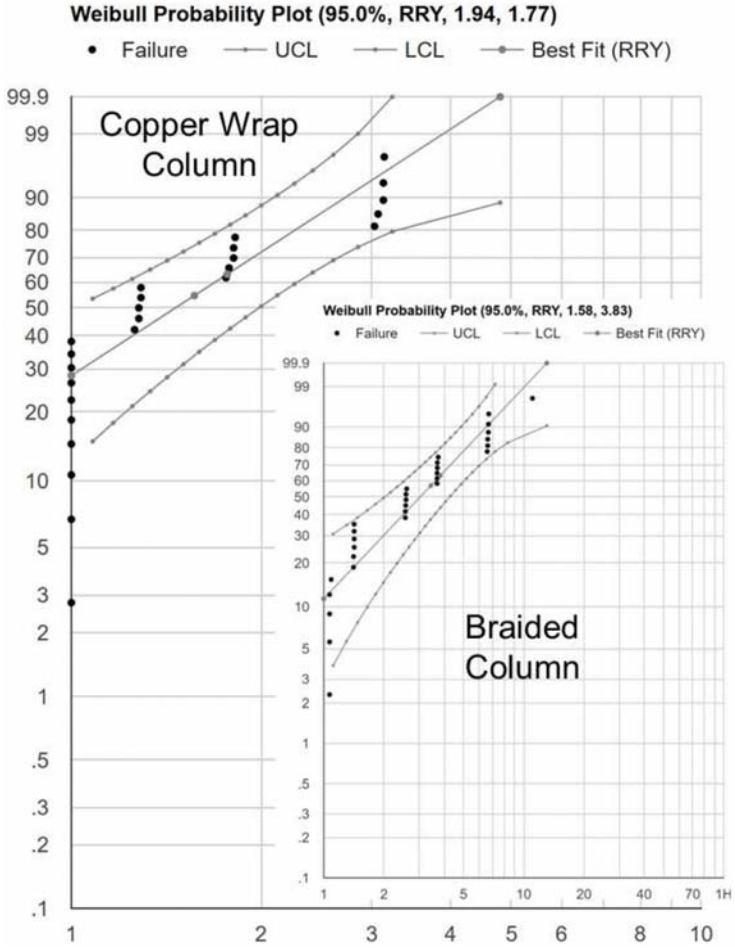


5-Zone Daisy Chain

1. Corners of Package
2. Perimeter of Package
3. Outside the Die Boundary
4. Corners of Die
5. Under Die



Typical PCB Dog-Bone Via.
More reliable than Via-in-Pad.



Comparison Weibull Plots

Daisy Chain resistance monitoring for Copper Wrap and Braided Columns

Column Size:

20x87mils (0.5mm x 2.21mm)

Individual Column Resistance:

Braided Column 2.12 milli-ohms

Cu-Wrap Column 1.65 milli-ohms

SN #	As Is or TC Condition	CGA1657	Assembly Condition	Chain 1 Corner	Chain 2 Perimeter	Chain 3 Die Outside	Chain 4 Die Corner	Chain 5 Die Center
SN01	As Build	Braided Column	Vapor Phase Reflow	1.07	1.41	6.57	2.56	3.69
SN01	200 TC (-55/125C) + 200 TC (-100/125C)			1.05	1.43	6.6	2.54	3.702
SN02	As Build	Braided Column	Vapor Phase Reflow	1.09	1.42	6.66	2.6	3.74
SN02	200 TC (-55/125C) + 200 TC (-100/125C)			1.07	1.42	6.67	2.6	3.73
SN03	As Build	Braided Column	Vapor Phase Reflow	1.07	1.41	6.61	2.57	3.69
SN03	200 TC (-55/125C) + 200 TC (-100/125C)			1.06	1.42	6.62	2.59	3.7
SN04	As Build	Braided Column	Vapor Phase Reflow	1.07	1.42	6.61	2.56	3.69
SN04	200 TC (-55/125C) + 200 TC (-100/125C)			1.07	1.43	6.62	2.58	3.7
SN05	As Build	Braided Column	Vapor Phase Reflow	1.07	1.42	6.67	2.58	3.70
SN05	200 TC (-55/125C) + 200 TC (-100/125C)			1.07	1.43	6.69	2.6	3.72
SN06	As Build	Braided Column	Rework Station	1.06	1.42	6.69	2.58	3.7
SN06	200 TC (-55/125C) + 200 TC (-100/125C)			1.09	1.42	6.7	2.6	3.7
SN07	As Build -Extra Heat	Cu-Wrap Column	Profile Devlop Reflow first	0.74	0.81	3.13	1.28	1.82
SN07	200 TC (-55/125C) + 200 TC (-100/125C)			0.74	0.82	3.13	1.3	1.84
SN08	As Build	Cu-Wrap Column	Vapor Phase Reflow	0.73	0.81	3.07	1.28	1.78
SN08	200 TC (-55/125C) + 200 TC (-100/125C)			0.73	0.83	9.08	1.28	1.78
SN09	As Build	Cu-Wrap Column	Vapor Phase Reflow	0.72	0.79	3.03	1.26	1.76
SN09	200 TC (-55/125C) + 200 TC (-100/125C)			0.73	0.8	3.03	1.28	4.78
SN10	As Build	Cu-Wrap Column	AirVac Rework	0.73	0.81	3.13	1.29	1.81
SN10	200 TC (-55/125C) + 200 TC (-100/125C)			0.74	0.81	3.13	1.31	1.84
SN11	As Build	Cu-Wrap Column	Rework Station	0.72	0.81	3.14	1.29	1.81
SN11	200 TC (-55/125C) + 200 TC (-100/125C)			0.72	0.82	3.15	1.3	1.82

CGA1657 Daisy-chain DCR

Cu-Wrap and Braided Columns

200 Cycles - Harsh conditions:
-55°C to + 125°C

Followed by :

200 Cycles - Extreme Cold:
-100°C to + 125°C

Additional Types of Columns Ready for Testing 2026-2027

Type	Patent	Applications
Copper Core	US 10,937,752	High Current Capability. Potential to conduct heat away from the package. Lunar Extreme Cold -223°C
Indium-Niobium	US 12,526,920	Cryogenic / Quantum Superconducting at low temperatures.