

Mechanical and Thermomechanical Properties of Solder ball and Solder Columns in BGA and CGA Components. How they affect System Reliability.

TopLine®

By Martin Hart

לשכת המהנדסים
האזרחיים והאקדמיים
במקצועות הפכנולוגיים
בישראל

AEAI



IEEE Israel



**IEEE
ELECTRONICS
PACKAGING
SOCIETY**

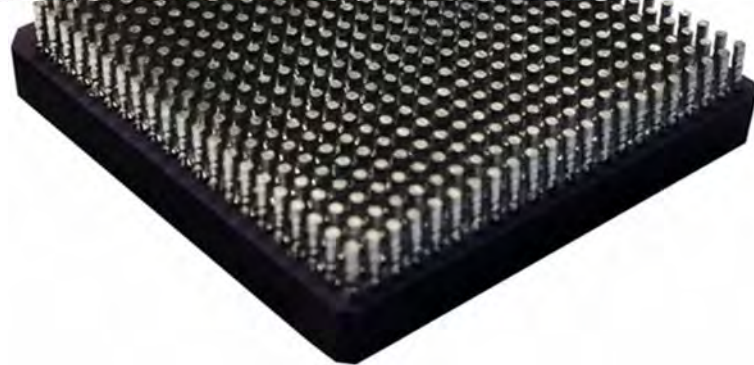
Soldering Technologies Seminar

27 October 2025 - א

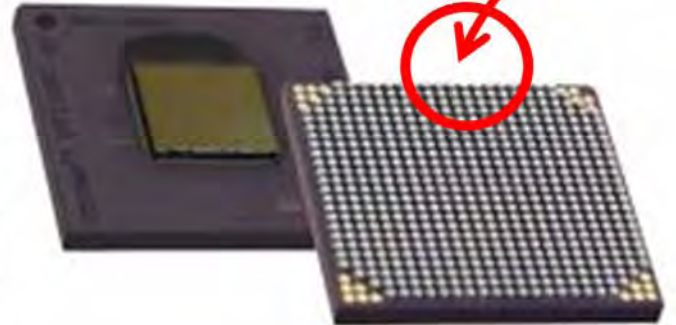
Do you see the difference?

Solder Balls on BGA packages and Solder Columns on CGA packages.

Column



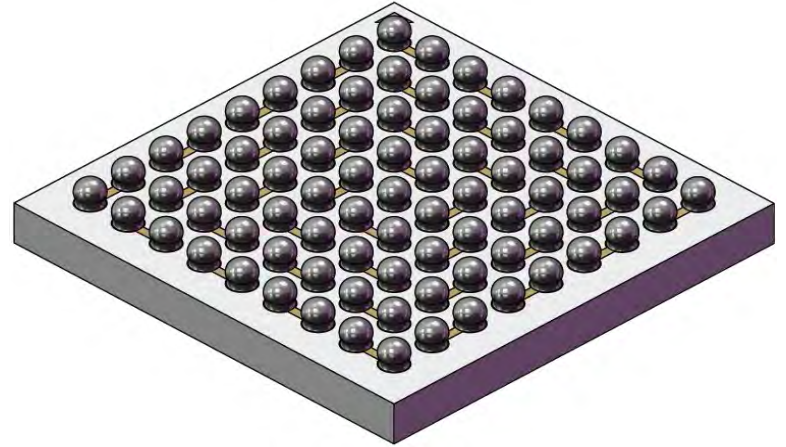
Ball



אתם רואים את ההבדל ?

Advantages

- Low cost.
- Easy to reflow.

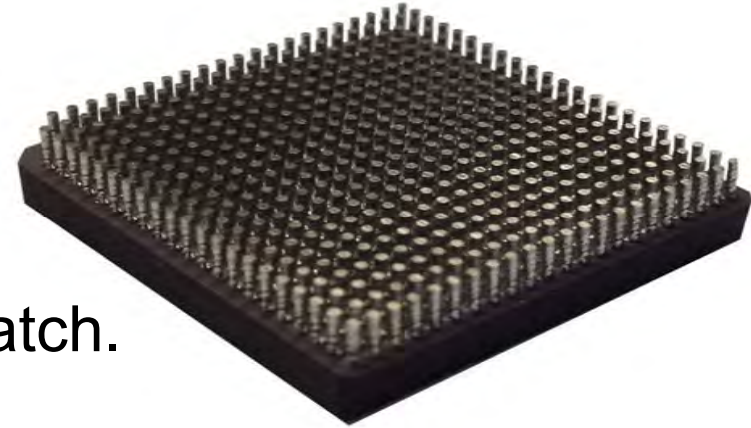


Disadvantages

- Vulnerable to fracture-strain, especially because of large CTE mismatch between the BGA and PCB.
- BGA are less reliable than CGA

Advantages

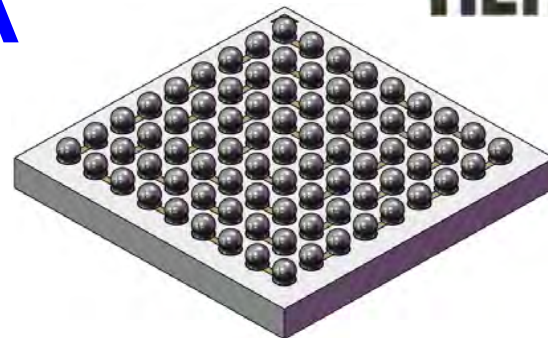
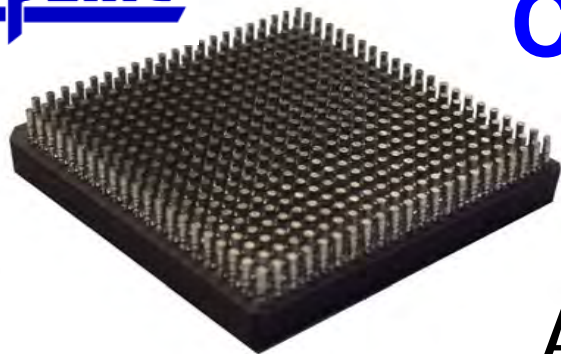
- Solder columns absorb CTE mismatch.



Disadvantages

- Solder Columns are difficult to attach.
- Solder Columns cost more than Balls.

CGA Vs. BGA



As they say:

Solder columns are heroes fighting to protect against CTE mismatch.

But, solder balls have already won the economic war.

כְּמוֹ שְׂאוֹמְרִים

עֲמוּדֵי רֶתֶךְ הֵם הַגְּבוּרִים הַנִּלְחָמִים נֶגְדַּ אֵי-תְּאִימוֹת בְּהִתְפָּרְקוֹת תְּרֻמִּית (CTE).

אָבֵל כְּדוּרֵי רֶתֶךְ כְּבָר נִצְחוּ בַּמִּלְחָמָה הַכִּלְכָּלִית

Re-balling BGA Service

- The Re-balling Service can remove SAC305 Lead Free Balls and replace them with SnPb Tin-Lead Balls for Military and Space.
- It is not so simple as you might think.

• שירות להחלפת כדורי בדיל במארזי BGA

• ההחלפה של כדורי בדיל יכולה להיות קצת מאתגרת.

Let's learn why



Reasons for poor results during BGA re-balling.



Depends on:

- **Package Pitch**
- **Diameter of the Ball**
- **Solder Mask Opening (SRO)**
- **Tacky Flux Paste or Solder (Metal) Paste**

What is better for Ball Attach on the BGA Package?

Tacky Flux Paste or Solder Paste?

✓ **The answer:** Use Tacky Flux Paste for package ball attach.

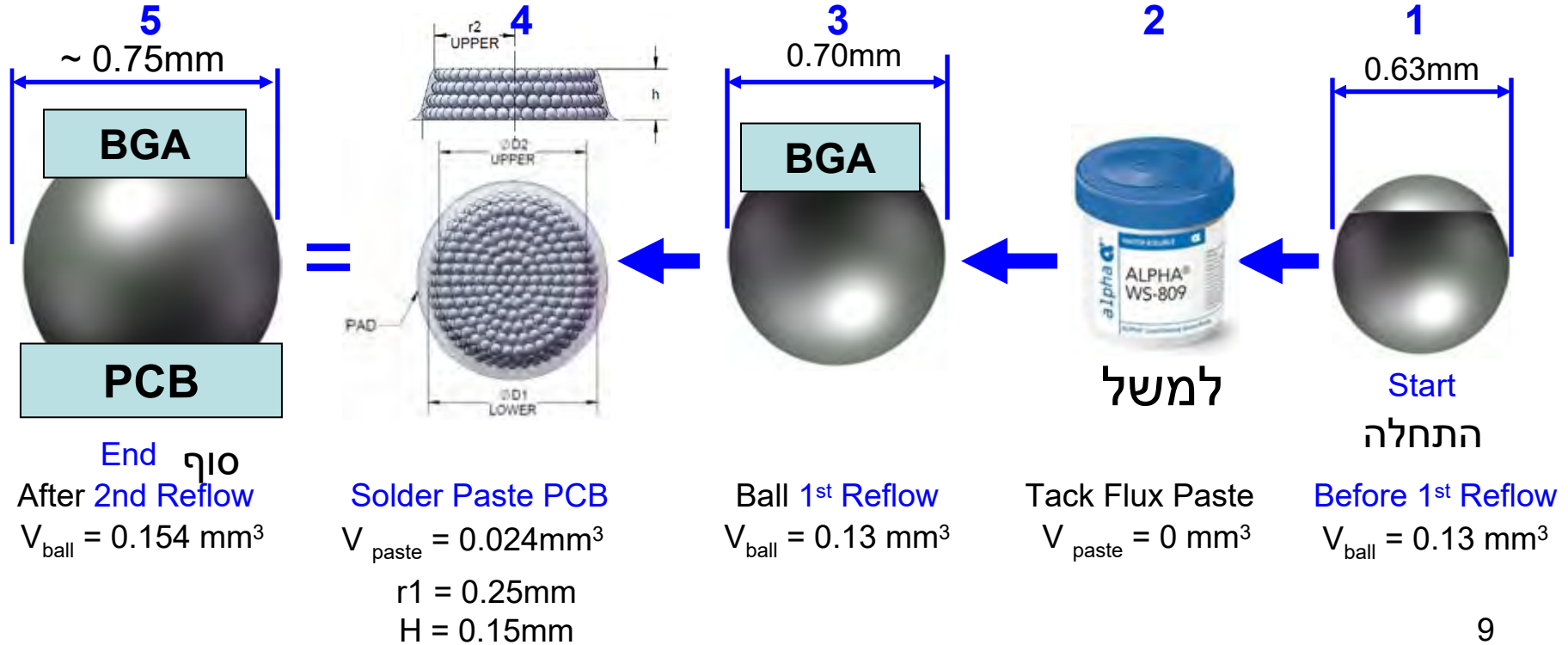
- Tacky Flux paste does not contain solder (no metal).
- This process relies on the metal inside the solder ball itself.
- Tacky Flux does not increase the size of the solder ball.
- The metal in the solder paste combines with the solder ball.



**Caution: The volume of the solder ball will grow
if you use Solder paste during ball attachment to the BGA.**

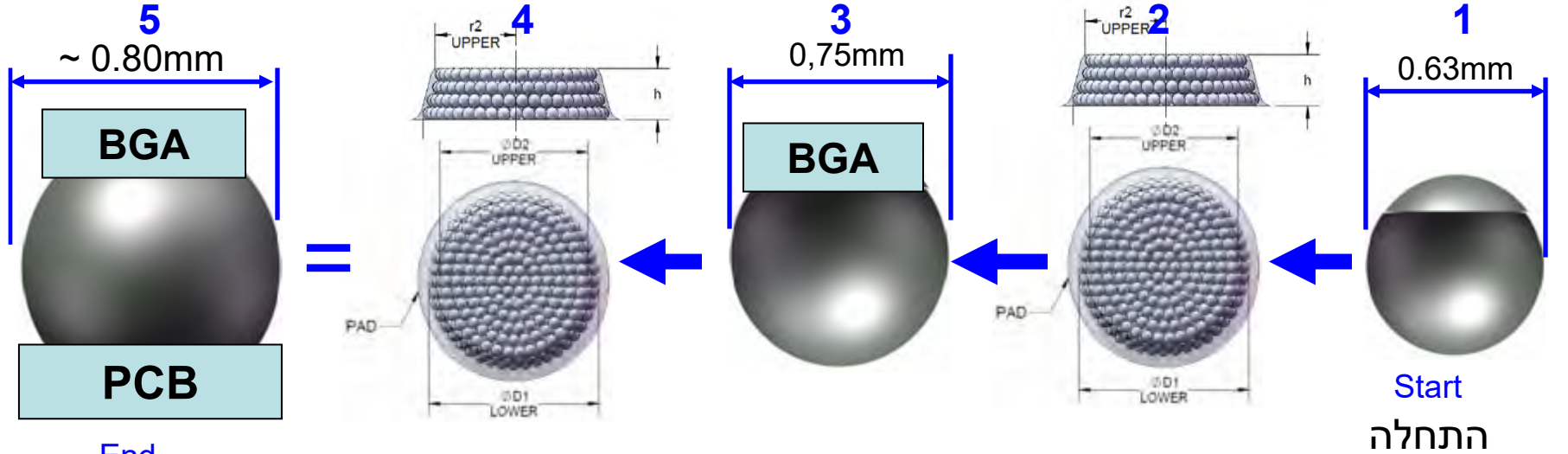
Using Tacky Flux + solder paste limits Ball Volume growth to 18%. 😊

שימוש בפלקס דביק + משחת הלחמה מגביל את גידול נפח הכדור ל - 18%



Using Solder Paste twice Causes the Ball Volume to grow 37%. 🙄

כשמתמשים במשחת הלחמה פעמיים, נפח הכדור גדל בכ-37%



End סוף
After 2nd Reflow
 $V_{ball} = 0.178 \text{ mm}^3$

Solder Paste PCB
 $V_{paste} = 0.024 \text{ mm}^3$
 $r1 = 0,25 \text{ mm}$
 $H = 0,15 \text{ mm}$

Ball 1st Reflow
 $V_{ball} = 0.154 \text{ mm}^3$

Solder Paste BGA
 $V_{paste} = 0.024 \text{ mm}^3$
 $r1 = 0.25 \text{ mm}$
 $H = 0.15 \text{ mm}$

Before 1st Reflow
 $V_{ball} = 0.13 \text{ mm}^3$

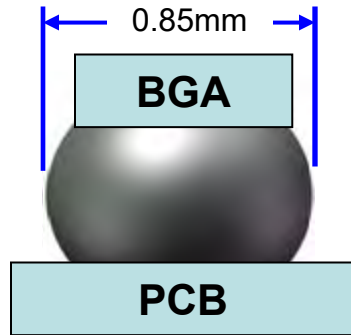
Comparison BGA Solder Ball growth Method 1 compared to Method 2 Reflow

בוא נשווה את גודל כדורי ההלחמה של BGA אחרי ה - Reflow השני:

2

השיטה השנייה

- 1st Reflow to BGA with **Solder Paste**
- 2nd Reflow to PCB with **Solder Paste**



$$V_{\text{ball}} = 0.178 \text{ mm}^3$$

גדול בנפח הכדור ↑

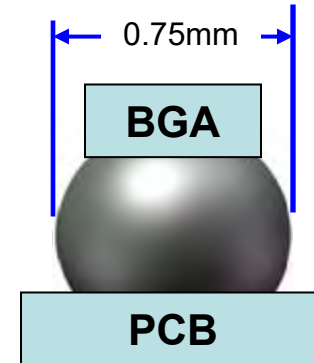
למה זה חשוב ?



1

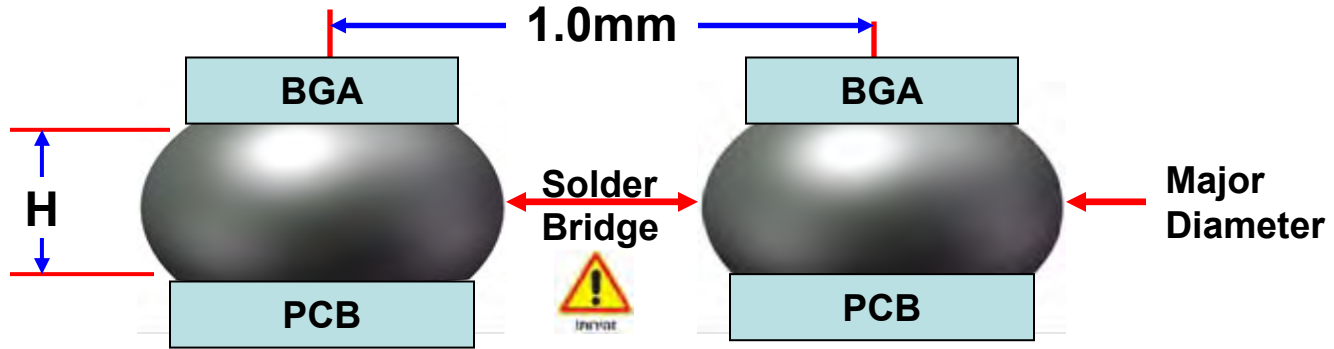
השיטה הראשונה

- 1st Reflow to BGA with **Tacky Flux**
- 2nd Reflow to PCB with **Solder Paste**

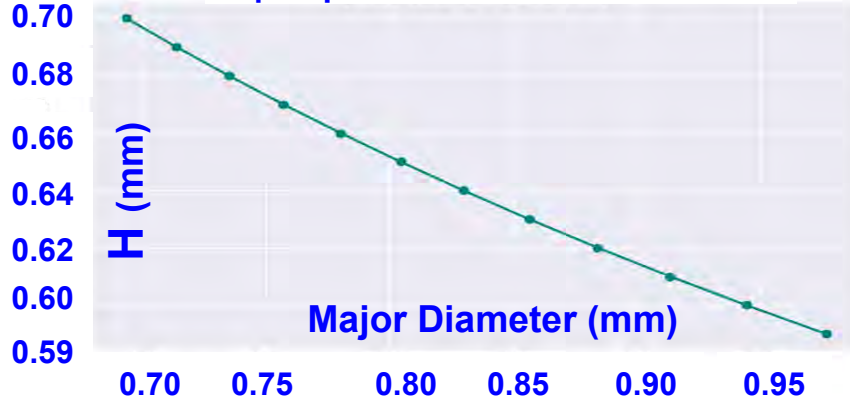


$$V_{\text{ball}} = 0.154 \text{ mm}^3$$

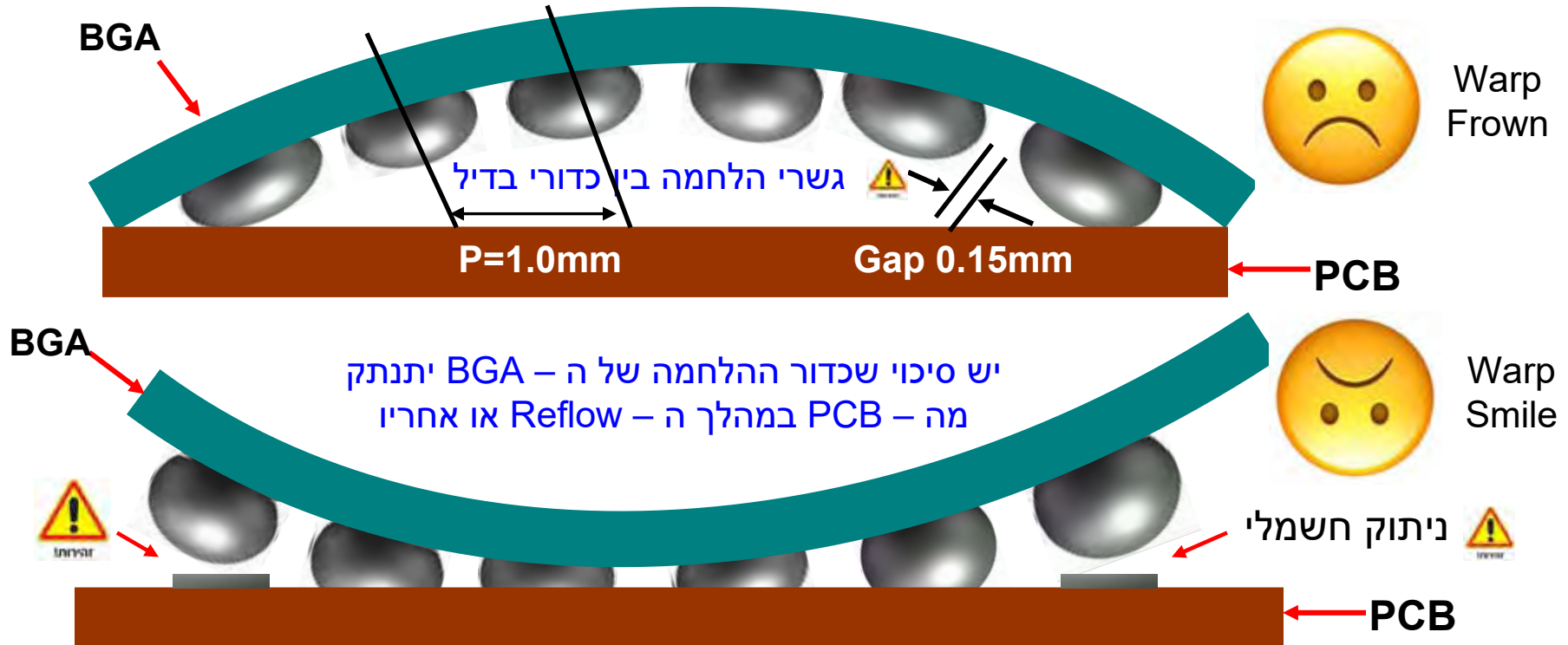
Chance of Solder Bridging Between Major Diameters



יש סיכוי להיווצרות גשר הלחמה בין הקטרים הגדולים



There is a chance of bridging or disconnection during Reflow of BGA to PCB



Which is better for BGA Package? SMD vs NSMD ?

2 Engineers = 3 Opinions

- SMD = Solder Mask Defined Pad

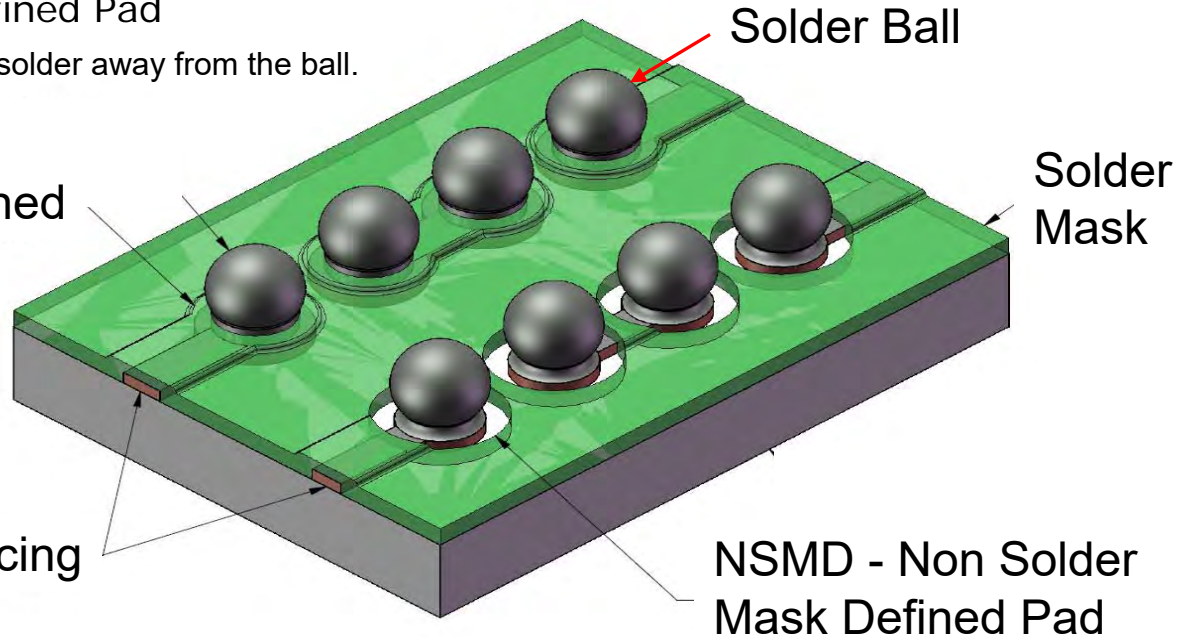
Benefits: Better +/- solder mask registration. Ball shape is more spherical

- NSMD = Non-Solder Mask Defined Pad

Disadvantage: Exposed tracings pull the solder away from the ball.
Causing the ball to be non-spherical.

SMD - Solder Mask Defined

BGA or PCB Tracing



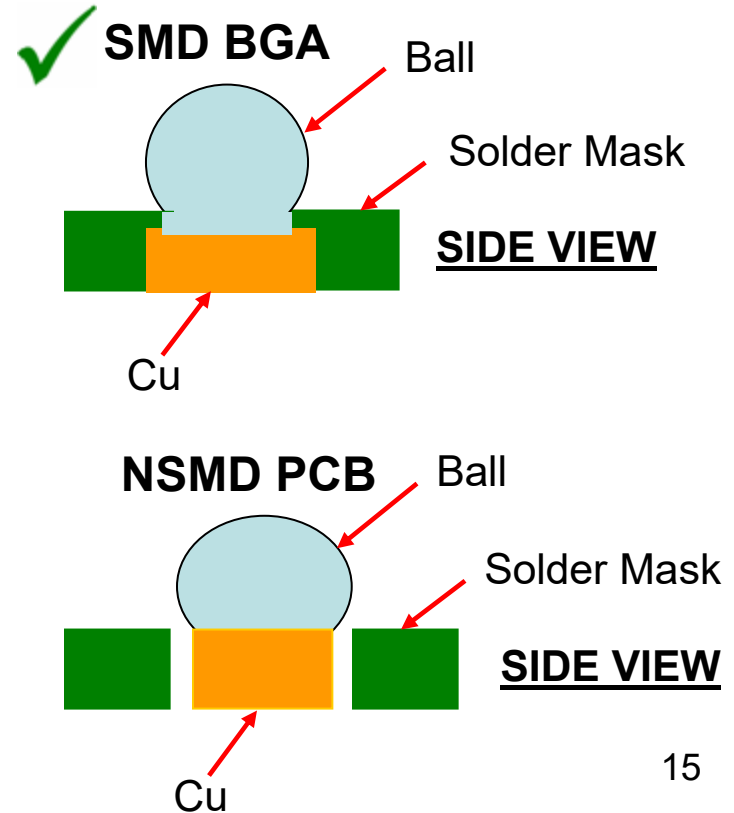
NSMD - Non Solder
Mask Defined Pad

Example of SMD BGA and NSMD PCB (Pitch 0.8mm)

Best Practice Rule:

PCB Pad Diameter should be same as BGA Pad

	Copper Pad Dia	SRO Opening	Mask Type	Ball Size (Before Reflow)
BGA →	0.40mm	0.33mm	SMD	0.40mm
	0.50mm	0.35mm		0.45mm
	0.56mm	0.40mm		0.50mm
PCB →	0.35mm	0.50mm	NSMD	0.40mm
	0.40mm	0.53mm		0.45mm
	0.45mm	0,58mm		0.50mm



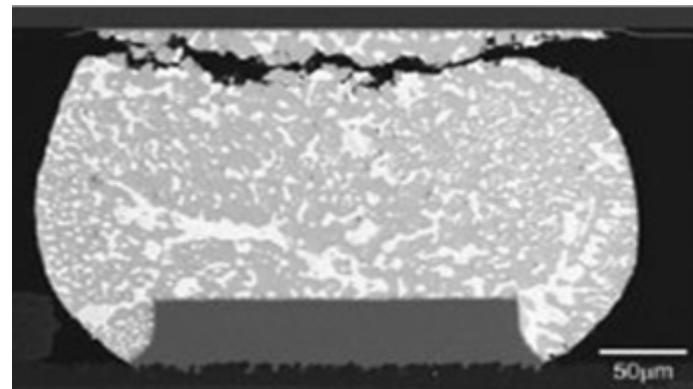
It is not always possible to exactly follow the design rules !

CTE Mismatch can rip balls off your packages.

חוסר תאימה בין מקדמי התפשטות תרמית יכול לשבור כדורי הלחמה של המאָרז

Strain - Movement over Temperature Change		
Package Size	Temp Range $\Delta 300^{\circ}\text{C}$	
	-55°C	+245°C
27x27mm DNP 19mm	57 um 2.2 mil	
45x45mm DNP 32mm	96 um 3.8 mil	
70x70mm DNP 50mm	150 um 6.0 mil	

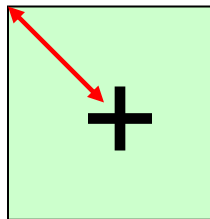
CTE mismatch >10ppm/°C between Package and PCB



Example Solder Ball Fracture

דוגמה לשבר בכדור הלחמה

DNP



BGA

DNP = מרחק מנקודת המרכז
Distance from Neutral Point
from the center of the package

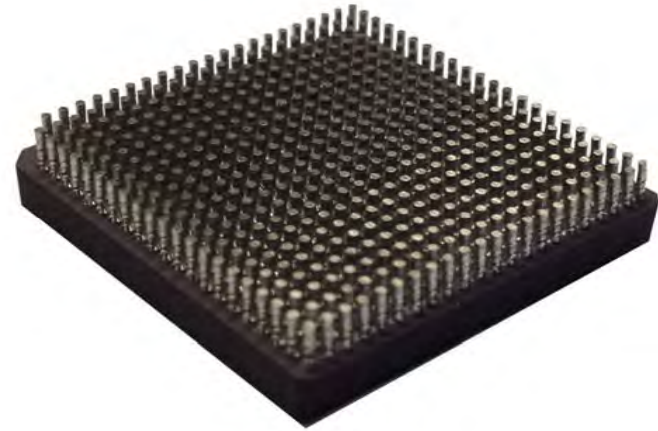
- BGA packages are generally low cost
- Attaching solder balls to BGA packages is relatively easy
- There is a chance of Solder Bridging during reflow.
- CTE mismatch between the BGA & PCB causes mechanical stress during temperature changes.
- BGA might not the best solution for Mission Critical applications.

- מארזי BGA בדרך כלל זולים
- קל יחסית לחבר פדורי הלחמה למארזי BGA
- יש סיכוי לגשרי הלחמה אם הפדור גדול מדי
- יש תאמה בין מקדמי התפשטות תרמית ובין לחץ מכני בין ה - BGA ל - PCB
- לא תמיד מתאים ליישומים קריטיים כמו צבא וחלל

Discovering CGA (Column Grid Array)

Let's apply what we learned about BGA technology and discover if another type of package known as the CGA is more reliable for applications requiring the highest reliability for Military and Space systems.

בואו ניישם את מה שלמדנו על טכנולוגיית BGA ונגלה אם סוג
אחר של מארז, הידוע כ- CGA , אמין יותר ליישומים הדורשים
את האמינות הגבוהה ביותר למערכות צבאיות וחלליות



***CGA Solder Columns replace balls
to reduce stress & breaking solder joints.***

Columns absorb CTE mismatch.



- עמודי הלחמה מחליפים את הכדורים כדי להפחית שבירת חיבורי ההלחמה.
- העמודים סופגים את אי ההתאמה במקדם ההתפשטות התרמית על ידי ספיגת המאמצים הנוצרים

New type of CGA Braided Solder Column.



**Solder Column
relative size**

Solder Core:

- **Pb80/Sn20**
- **Pb90/Sn10**
- **Sn92/Sb8**
- **In50/Pb50**

**16x BeCu wire braid.
Non-collapsible**

**Shown before
Solder Coating**



**Shown After
Solder Coating**

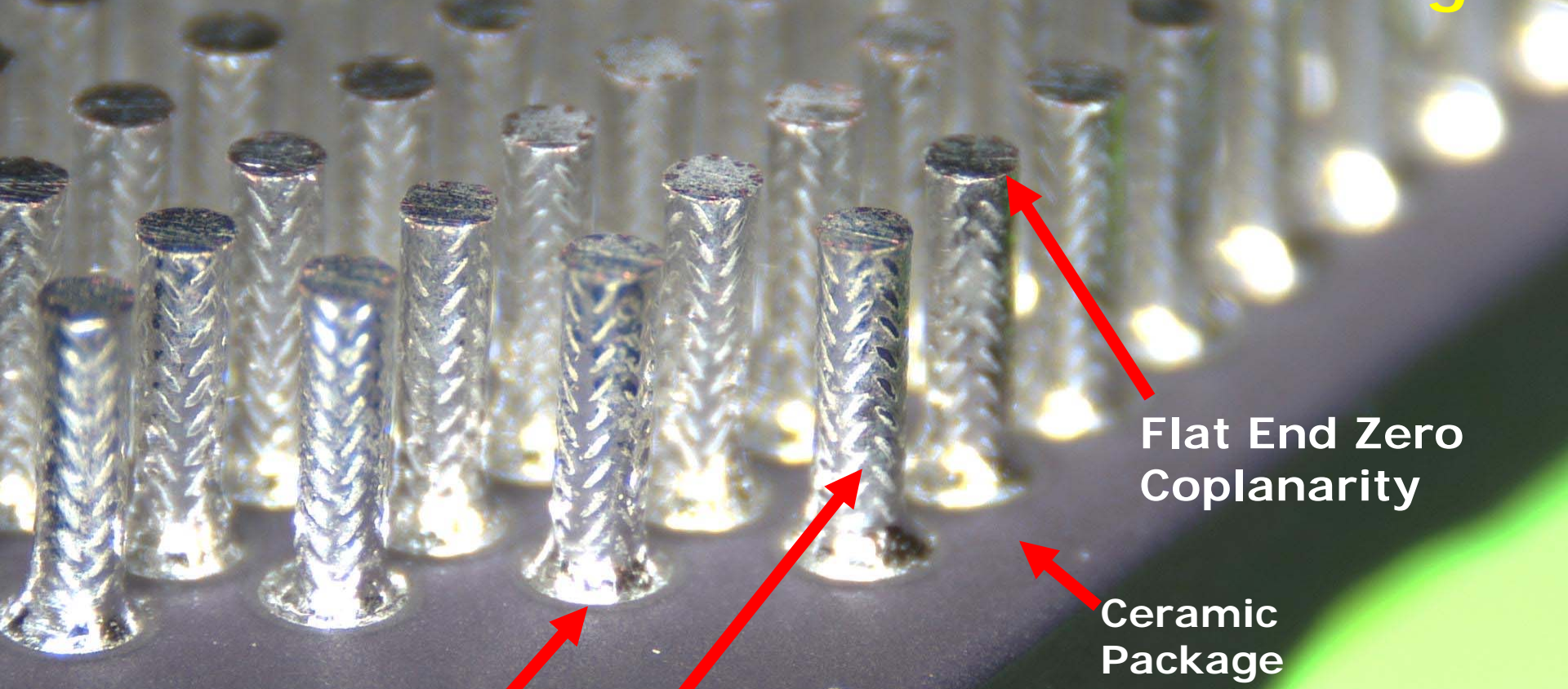


**Length
1.0mm
~2.2mm**

Pitch: 0.65mm ~ 1.27mm

Fillet

Braided Solder Columns - Ceramic Package



Flat End Zero
Coplanarity

Ceramic
Package



Solder Fillet
Sn63/Pb37

High Temp Solder Column
Pb80/Sn20 or Pb90/Sn10



Finite Element Analysis Comparison Bend Strain Ball vs Column

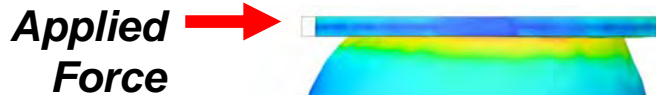
Max Strain



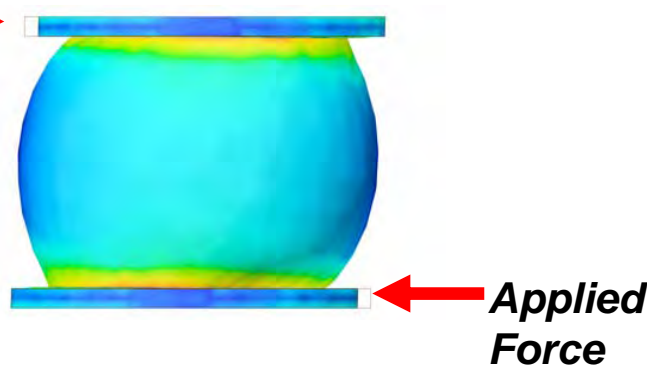
Min Strain

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

עמודי הלחמה קלועים סופגים מתחים ומפזרים את העומס בצורה שווה יותר מאשר הכדורים



Applied Force



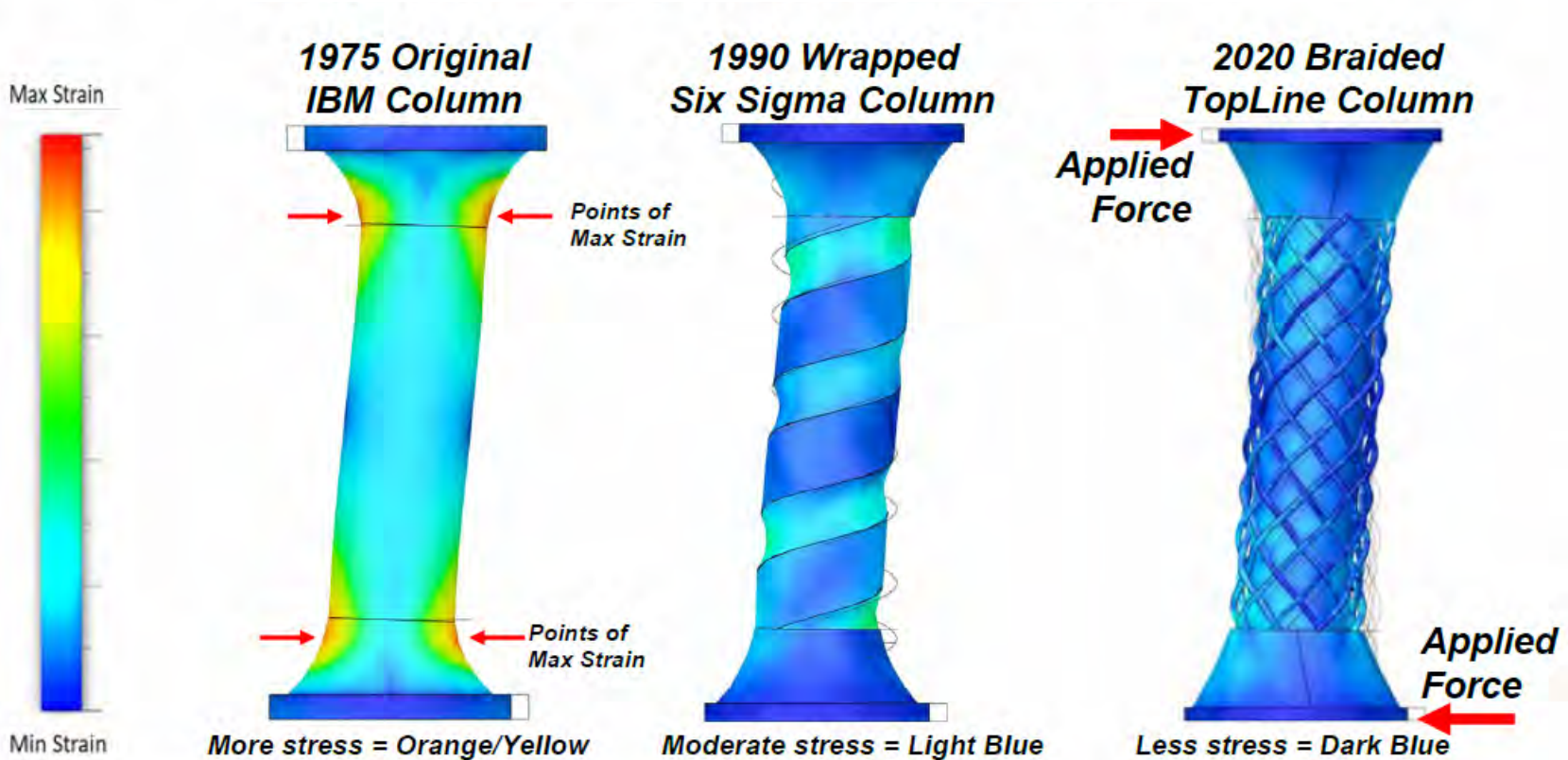
Applied Force



Darker Blue is Better

פחול פקה יותר טוב

Comparative Stress found in Different Column Types



Solder Column Materials

חומרים הנמצאים בעמודי הלחמה



Braided
Solder
Column

Construction	Data Centers -55°C to +125°C	Military -55°C to +125°C
Solder Core	Sn91.5 / Sb8.5	Pb80 / Sn20 <i>Also Pb90/Sn10</i>
Coating	Sn90/Ag3.5/Bi.5/In6	Sn63 / Pb37
Braid Be-Cu	C172	C172
PKG Fillet	Sn90/Ag3.5/Bi.5/In6	Sn63 / Pb37

Design Rules: Column Length

כללי עיצוב אורך עמודות



Pitch	"D" mm	Aspect Ratio (D x L)		
		3:1	4:1	5:1
0.65mm	0.20mm	0.6mm	0.8mm	1.0mm
0.8mm	0.25mm	0.8mm	1.0mm	1.25mm
	0.30mm	0.9mm	1.2mm	1.5mm
0.92mm	0.35mm	1.0mm	1.4mm	1.7mm
1.0mm	0.40mm	1.3mm	1.6mm	2.2mm
	0.50mm	1.5mm	2.2mm	2.5mm

Longer Columns absorb more CTE mismatch

Design Rules: Column Diameter

כללי עיצוב קוטר עמודות



"D" Column Diameter	Pad Diameter Min	Pad Diameter Max
300um	0.40mm	0.50mm
350um	0.45mm	0.60mm
400um	0.60mm	0.80mm
450um	0.70um	0.80mm
500um	0.75um	0.86mm

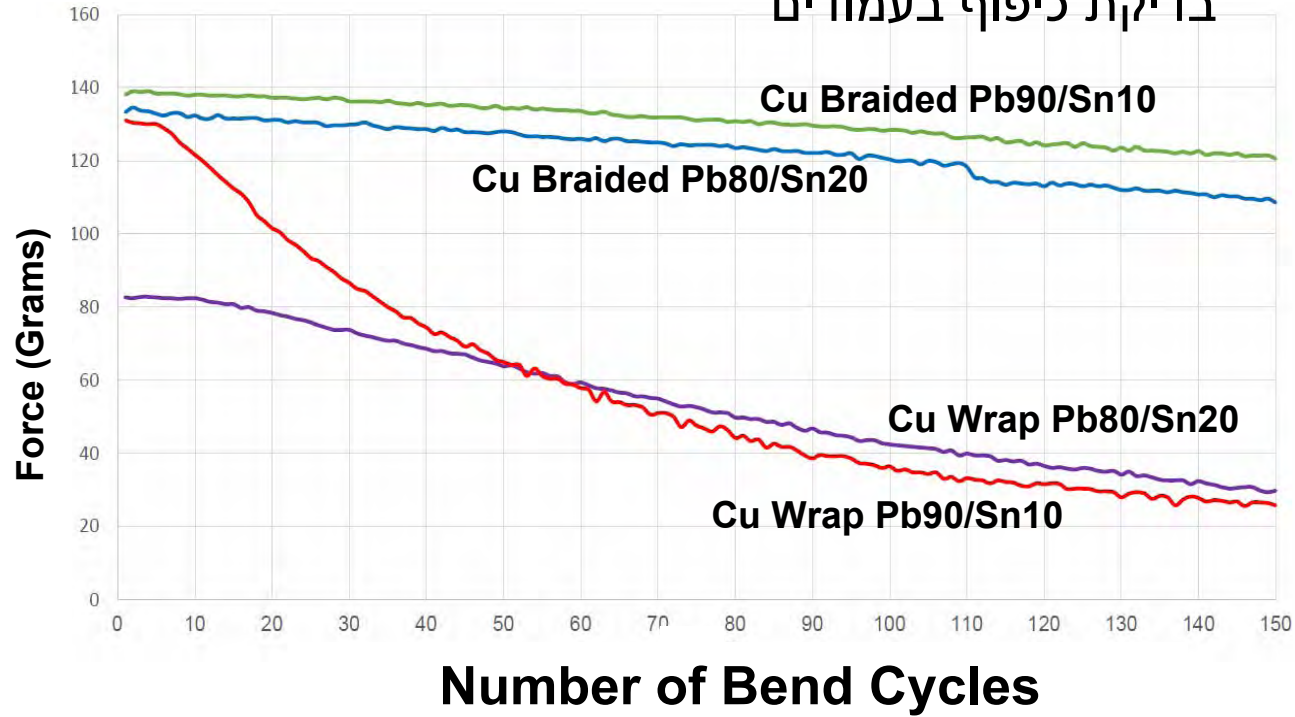
Column diameter "D" should be 66% to 75% of the package pad diameter.

Column Bend Test

בדיקת כיפוף בעמודים

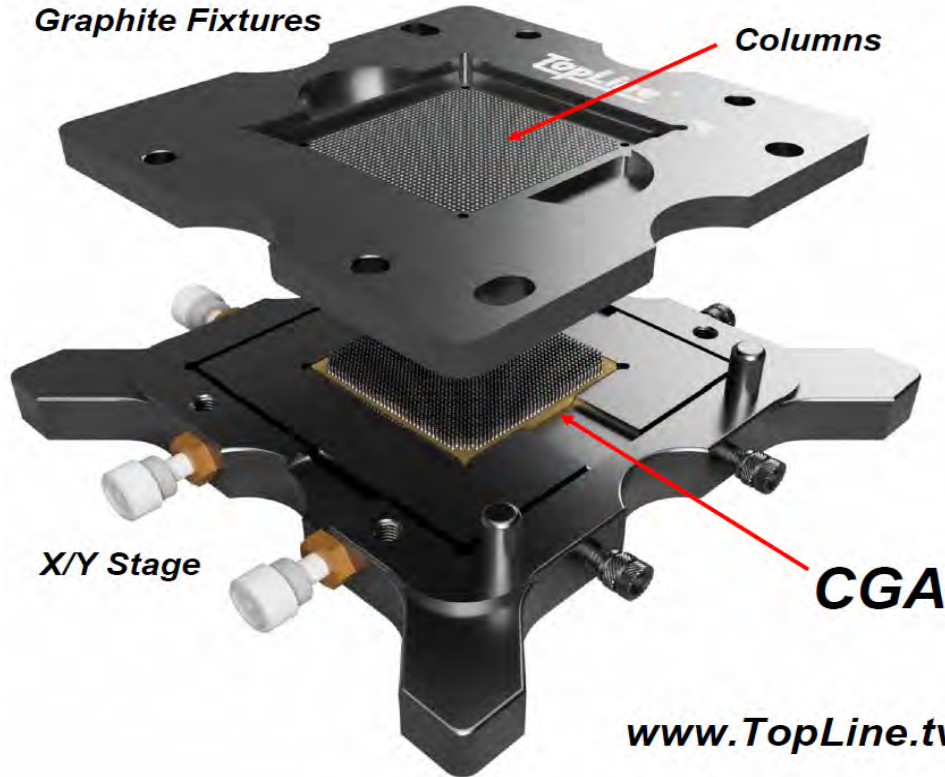


Bend Test Fixture



Thermal cycle testing scheduled at JPL.

Column Attachment Tooling System Holds Columns 90° Vertical During Reflow



Batch Assembly

*Precision tooling system
deposits columns and
holds columns vertically
during reflow.*

US Patents

9,629,259

9,108,262

D908,648

D874,413

D808,350

www.TopLine.tv/CCGA_Tool.html

CGA Summary

- Solder columns reduce CTE mismatch (Coefficient of Thermal Expansion) by absorbing stresses.
- Solder columns increase the operating life of components used in mission critical applications for Military and Space.
- Columns can be used on ceramic and organic packages.
- Columns (>70mm PKG) are available for AI data centers.

BRAIDED SOLDER COLUMNS

**GREAT
FOR SPACE**

US PATENT 10,477,698

**CONNECTS
CHIPS
TO PCB**

**BETTER THAN
BALLS**

TopLine®

Let's Explore

Contact: Sassi Graffi

sassi@gsuit.co.il

Tel: +972-54-329-9300

GSUIT

Contact: Martin Hart

hart@TopLine.tv

TopLine®

www.TopLine.tv/CCGA.html