Converting Ball Grid Array Components to Column Grid Array

Russell T. Winslow - President

SIX SIGMA

Milpitas, CA 95035

Email: russ@solderquik.com URL: www.sixsigmaservices.com

Introduction

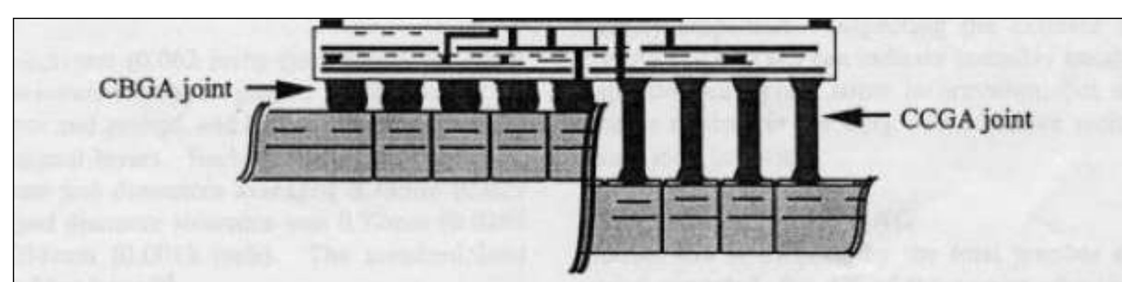
- The availability of Military-grade electronics is declining
- Ball Grid Array (BGA) is rapidly becoming the package style of choice in commercial electronics
- For Military and Space environments, BGA packaging is a reliability compromise (BGAs lack compliant leads)
- Modifications and ruggedization of packaging is essential for ensuring reliability of military electronics[4]

The Problem

Typical temp-cycle failure in high-lead ball [1]

- Solder balls are less compliant than leads
- Stress is induced by:
  - Coefficient of Thermal Expansion (CTE) mismatch (temperature cycle)
  - Thermal mismatch (power cycle)
  - Mechanical (warp, vibration, etc)
- Stress increases with:
  - Distance from neutral point (larger packages)
  - Lower standoff height

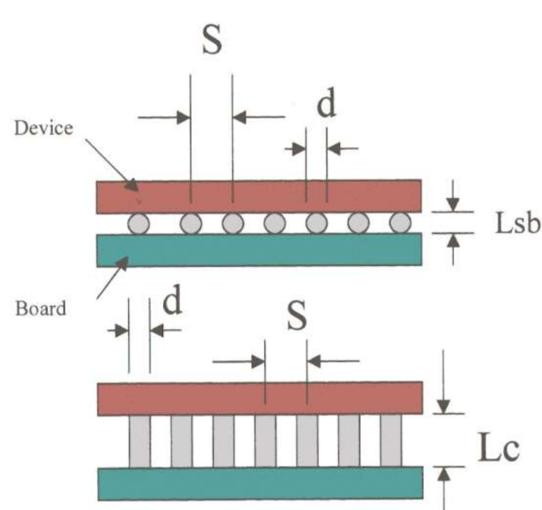
BGA vs. CGA



Ball Grid Array vs. Column Grid Array[1]

- Column Grid Array (CGA) is a flexible interconnect replacement for rigid solder balls
- Higher standoff and compliance in the column alleviates CTE and thermal mismatch between the board and the component

The CGA Solution



- ΔT_1 = Temperature Change of Board
- ΔT_2 = Temperature Change of Component
- α_1 = CTE of the Board
- α_2 = CTE of the Component
- S = Distance from Neutral Point (DNP)
- E = Modulus of Elasticity of Ball or Column
- d = Diameter of Ball or Column
- L = Standoff Height of Ball or Column
- σ_{max} = Maximum Stress

$$\sigma_{max} \approx \frac{1.5 \cdot (\alpha_1 \cdot \Delta T_1 - \alpha_2 \cdot \Delta T_2)(S \cdot E \cdot d)}{L^2}$$

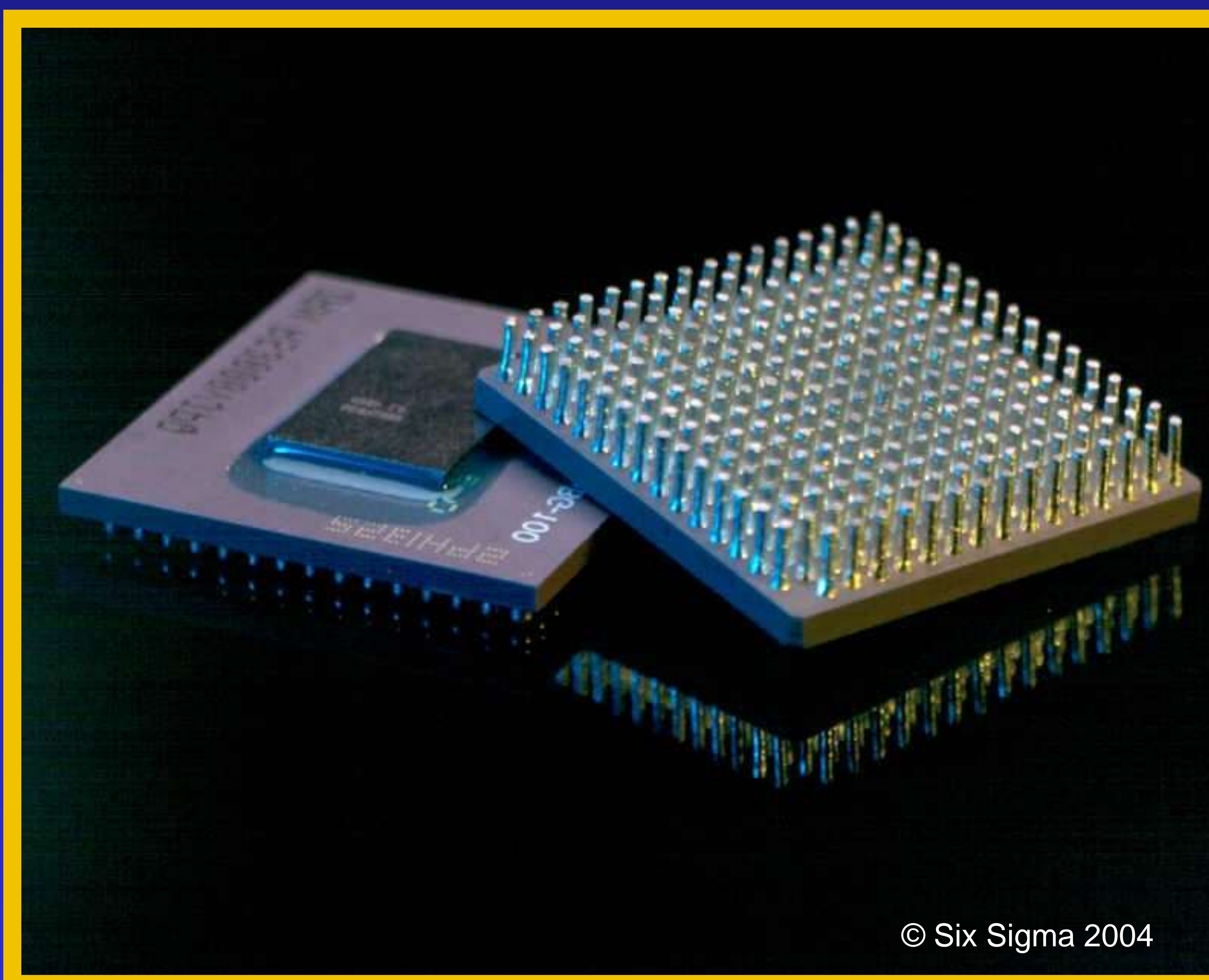
Types of Columns

Wire Column

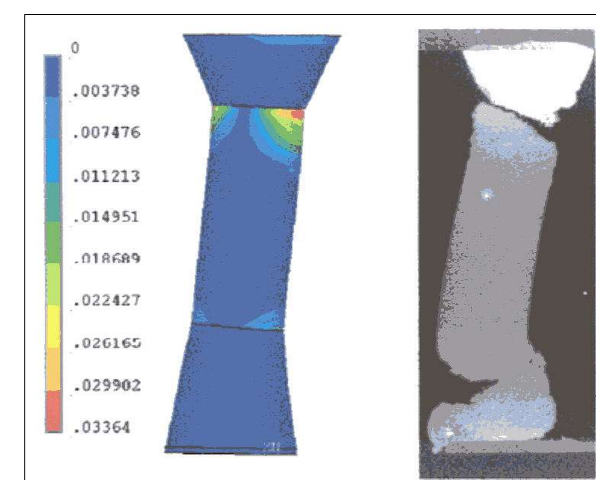
High-Lead wire attached with Sn63-Pb37 fillets

Reinforced Solder Column

High-Lead wire core with spiral wrapped copper ribbon attached with Sn63-Pb37 fillets



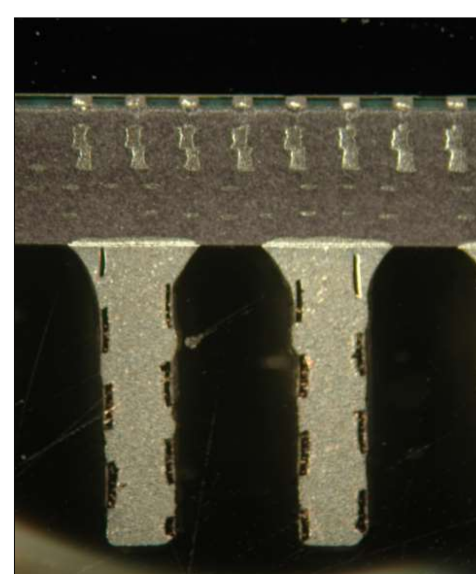
Benefits of the Reinforced Column



Georgia Institute of Technology & IBM [2]

Straight Wire Column

- Finite element model showing location of maximum strain (Left)
- Typical failure of non-reinforced column (Right)



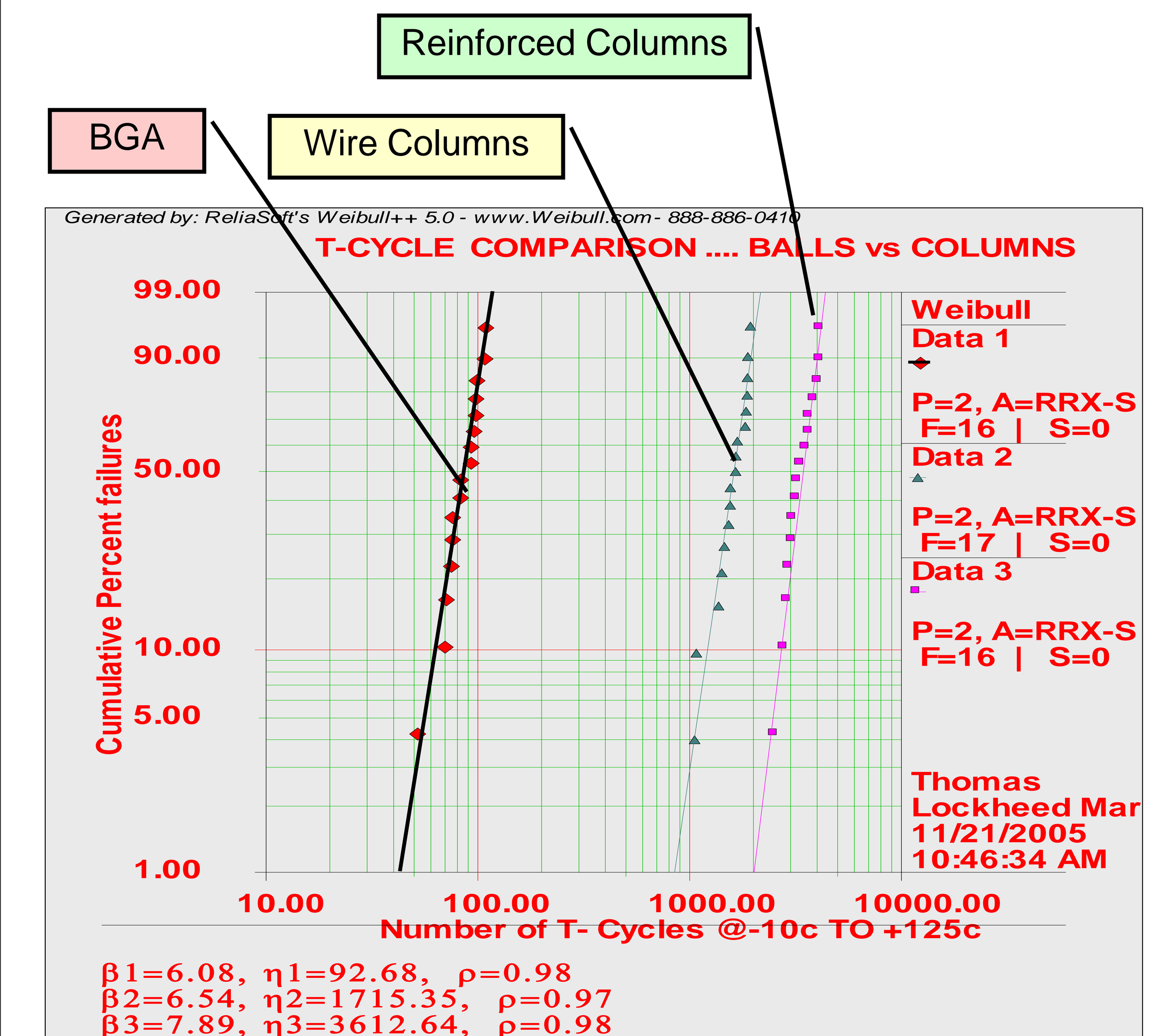
Copper Reinforced Column

- Crack propagation abated
- Redundancy without stiffness
- Continues to function electrically even if core is cracked

Test Results

Temperature Cycles –10 to +125 C
All parts ceramic with 1.27mm pitch
625 pin package 32mm square

CBGA625	BGA with high-Pb spheres
CCGA625	CGA with straight wire columns
CCGA625R	CGA with reinforced columns



Temperature Cycle Test Results – Lockheed Martin[3]

Conclusion

- Many commercial components are not capable of meeting the environmental requirements of military and space applications
- CGA modifications to commercial devices result in
  - Reliability Improvements
  - Robust Designs
- Reinforced solder columns show a significant performance advantage in comparison to other solder columns

Future Work

- Military funding of this technology will allow significant improvements such as:
  - Optimize column design through finite element modeling and analysis of the reinforced column
  - Reliability testing and qualification of enhancements in design and materials
  - Development of a lead-free version

Acknowledgments

The author would like to thank Tom Clifford - Lockheed Martin and William Davis - Applied Material Technologies for their valuable analysis, discussions, and helpful input.

Bibliography

[1] D. Banks, D. Gerke, "Assembly and Reliability of Ceramic Column Grid Array

[2] A. Perkins, S. Sitaraman, "Thermo-mechanical Failure Comparison and Evaluation of CCGA and CBGA Packages

[3] T. Clifford, "Final Report – Phase 1 T-Cycle Test" Lockheed Martin Internal Document

[4] R. Winslow, "Converting Ball Grid Array Components to Column Grid Array" MASH 2005