TEXAS INSTRUMENTS

SLVA333
Application Report
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BGA Package Component Reliability After Long-Term Storage

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ABSTRACT

The white paper *Component Reliability After Long Term Storage* (Texas Instruments application report SLVA304, http://focus.ti.com/lit/wp/slva304/slva304.pdf) detailed a risk analysis with supporting data to extend the storage life of packaged devices in a warehouse environment. The paper focused on leaded devices with a NiPdAu lead finish and specifically excluded BGA-type packages with solder bumped electrical connections. This exclusion was established because bumped devices were not included in the test and evaluation sample. Since the report was released, testing of BGA packages was completed successfully and the results of those evaluations are published in this paper which will serve to extend the storage life criteria for this BGA package category. Besides visual inspection and solderability tests, physical deprocessing on BGA and Die Size Ball Grid Array (DSBGA) packages was completed.

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INTRODUCTION

This paper provides additional data in support of shelf life extension for BGA and Die Size BGA (DSBGA) Packages.

BACKGROUND

In 2008, the white paper *Component Reliability After Long Term Storage* was published in support of shelf life extension for leaded packages beyond a self-imposed two-year limit. The success and acceptance of the Shelf Life Extension Program led to a request for additional data to support extended storage for devices with solder ball interconnects.

PROCEDURE

This study evaluated 11 devices that were packed using tape and reel packing methods. These devices had been stored in a warehouse environment (<40°C and <90% RH) for periods of time ranging from two to ten years.

Packing materials were exhaustively studied in the original white paper, and no evaluations of the tape and reel or storage containers were included in this study because the same packing material described earlier was used for the leaded packages.

The devices were carefully examined for signs of deterioration. Visual examination was done at both low and high magnification with an optical microscope and three devices were examined with scanning electron microscopy.

Surface analysis was completed on three of the samples to verify the absence of anomalous material or contaminants on the surface of the solder balls. The solder balls were cross-sectioned and examined optically with the Scanning Electron Microscope (SEM) for evidence of appropriate intermetallics and surface features of the various materials and interfaces.

The samples were exposed to humidity and temperature (steam-aged) and then soldered to ceramic plates and printed-circuit boards (PCB) to assess solder wetting.

DEVICE SAMPLES INCLUDED IN THE EVALUATION

Device	Package	P-Type	Leadfree	Quantity	Datecode (M/Y)	Label DC	Test Board #	Alernative Footprint
TPSDC6235	YZG	DSBGA		336	06/2005	06/03/05	45	YEG
TPS62302	YZD	DSBGA		250	04/2007	07/24-04	45	Uso YEG
SN74LVC2G32	YEA	DSBGA		>1K	02/2003	0307	41	YEA
SN74LVC2G14	YZA	DSBGA		>1K	12/2002	0251	41	YEA
CDCUA877	ZQL	BGA		600	05/2006	0619	56	
SN74SSTV32852	GKF	BGA		980	06/2001	0127	56	ZKF
Mechanical Sample	GGU	u*BGA			09/1999	40/99	40/34	
Mechanical Sample	GGU	u*BGA			09/1999	36/99	40/34	
TNETC4320	AGDS	BGA			2004			
XD751793	GVU	BGA			2004			
DLKPC192S		BGA			2002			

SOLDERABILITY TEST CONDITIONS AND DETAILS

Used Reflow Profiles for the evaluation:

The following profiles show the temperature during the soldering process on a test board. Temperature measured on the package.

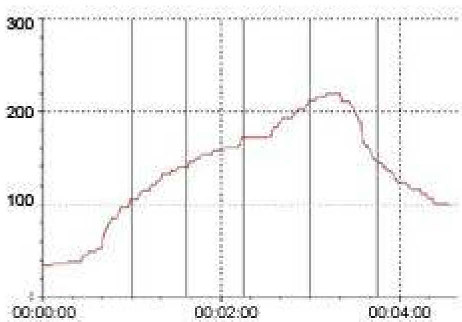


Figure 1. Reflow Profile for SnPb Solder Paste

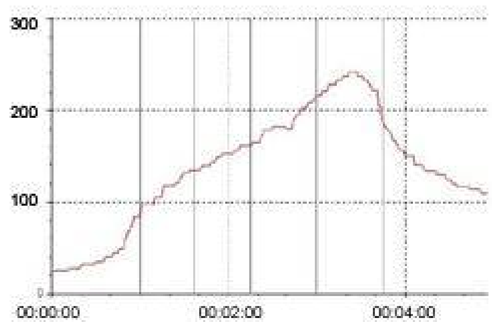


Figure 2. Reflow Profile for SnAgCu Solder Paste

- The following solder pastes have been used for the evaluation:
  - Lead-free (SAC) Heraeus F645 SA30C5-89M30 (Alloy Sn/Ag/Cu – 96.5/3/0.5)
  - Lead (SnPb) Heraeus F816 SN63-90 B30 (AT) (Alloy Sn/Pb – 63/37)
- TI internally designed Test Board #B40, #B41, #B45, #B56 with board material FR4 and NiAu finish. The board design is single-sided, 1.5mm thickness, 100 x 160mm size (approximately 4 x 6 inches).
- Ceramic Plate: 100 x 100mm (4 x 4 inches); approximately 0.8mm thick without test pads on the surface. The ceramic plate was used to remove the devices after the soldering test to inspect the ball bottom side. This test is also known as a Surface Mount Test.
- Reflow Oven: Rehm SMS-V5-N2 2100/400; reflow atmosphere in the peak zone was nitrogen with approximately 500ppm remaining oxygen.
- Two groups of units were used for this evaluation:
  - — Virgin devices out of the packing material
  - — Devices with artificial aging (8-hour water steam-aging prior to the soldering test).

PACKAGE SPECIFIC TESTING

VISUAL INSPECTION TPSDC6235YZG

Bottom view – Units not soldered

Figure 3. Virgin Unit

Figure 4. Unit After Steam Aging

Units placed on Test Board #45. SnAgCu solder paste for lead-free balls, peak temperature 240°C

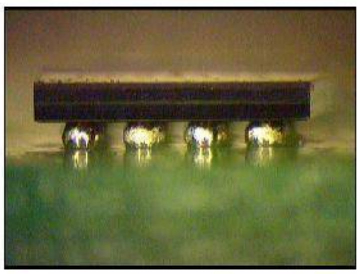


Figure 5. Virgin Unit

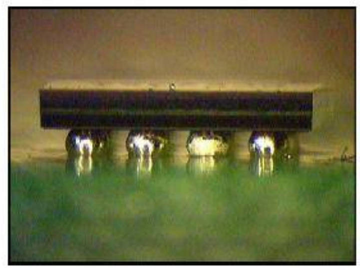


Figure 6. Steam Aging

Units placed on ceramic plate. SnAgCu solder paste for lead-free balls, peak temperature 240°C

Figure 7. Virgin Units

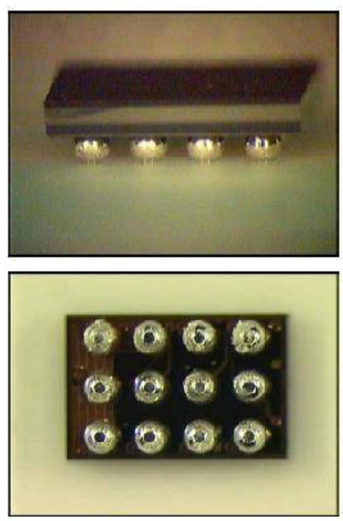


Figure 8. Steam Aging

VISUAL INSPECTION TPS62302YZD

Bottom view – Units not soldered

Figure 9. Virgin Unit

Figure 10. Unit After Steam Aging

Units placed on Test Board #45. SnAgCu solder paste for lead-free balls, peak temperature 240°C

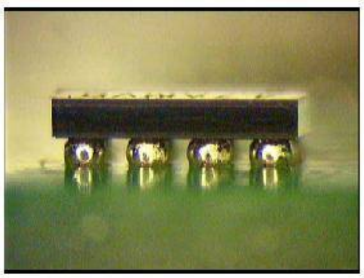


Figure 11. Virgin Unit

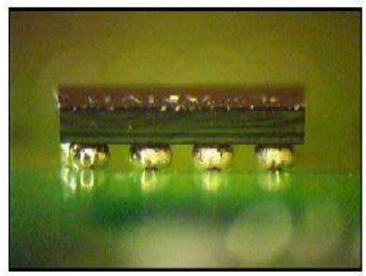


Figure 12. Steam Aging

Units placed on ceramic plate. SnAgCu solder paste for lead-free balls, peak temperature 240°C

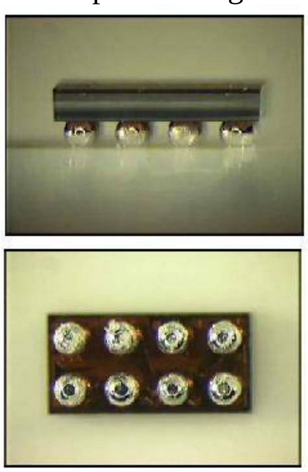


Figure 13. Virgin Units

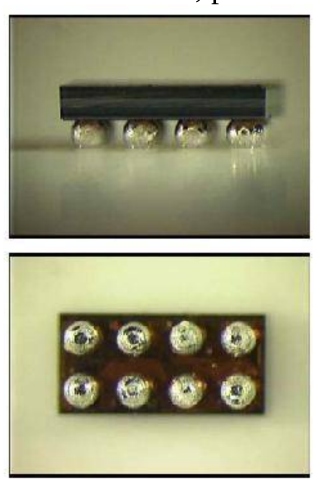


Figure 14. Steam-Aging

VISUAL INSPECTION SN74LVC2G32YEA

Bottom view – Units not soldered

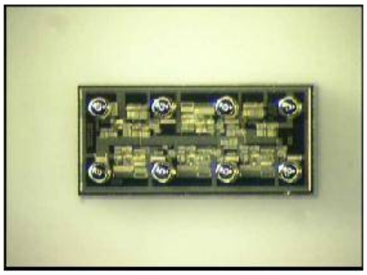


Figure 15. Virgin Unit

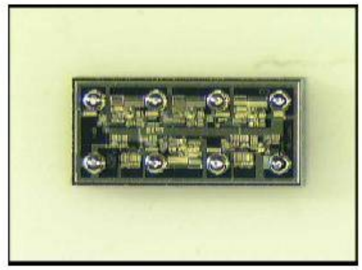


Figure 16. Unit After Steam-Aging

Units placed on Test Board #41. SnAgCu solder paste for lead-free balls, peak temperature 240°C

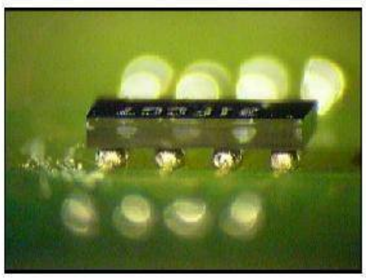


Figure 17. Virgin Unit

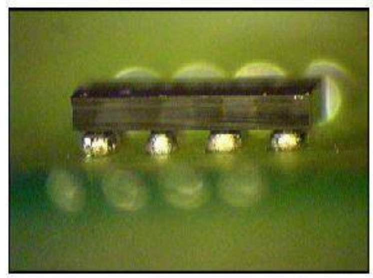


Figure 18. Steam-Aging

Units placed on ceramic plate. SnAgCu solder paste for lead free balls, peak temperature 240°C

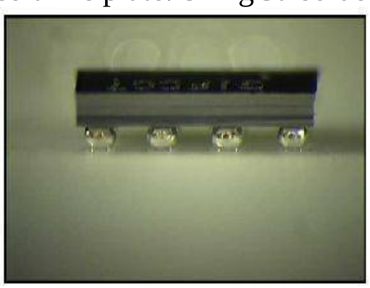


Figure 19. Virgin Unit

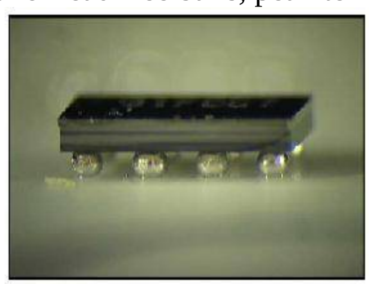


Figure 20. Steam-Aging

VISUAL INSPECTION SN74LVC2G14YZA

Bottom view – Units not soldered

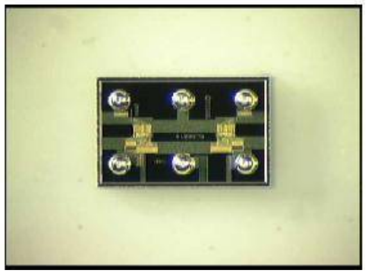


Figure 21. Virgin Unit

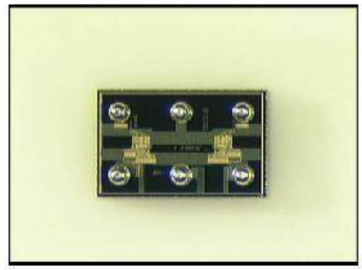


Figure 22. Unit After Steam-Aging

Units placed on Test Board #41. SnPb solder paste for non lead-free balls, peak temperature 220°C

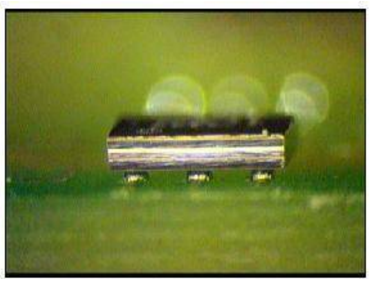


Figure 23. Virgin Unit

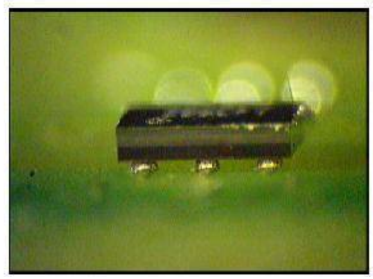


Figure 24. Steam-Aging

Units placed on ceramic plate. SnPb solder paste for non lead-free balls, peak temperature 220°C

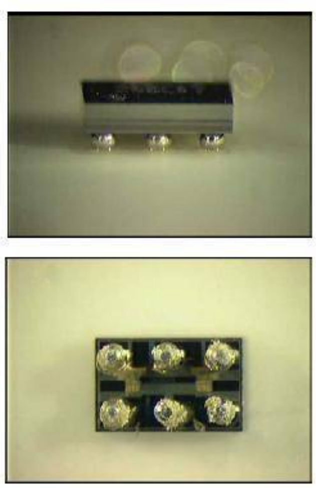


Figure 25. Virgin Units

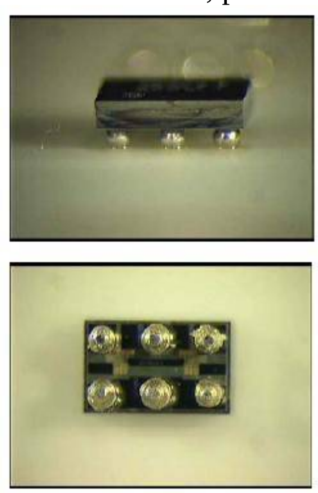


Figure 26. Steam-Aging

VISUAL INSPECTION CDCUA877ZQL

Bottom view – Units not soldered (Originally, some balls were not populated on the package.)

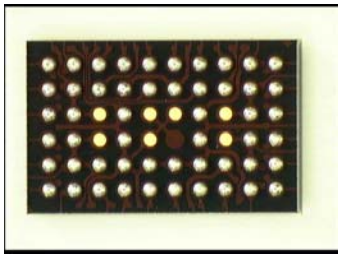


Figure 27. Virgin Unit

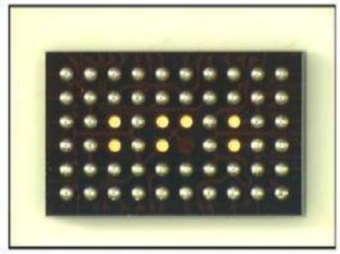


Figure 28. Unit After Steam-Aging

Units placed on Test Board #56. SnAgCu solder paste for lead-free balls, peak temperature 240°C

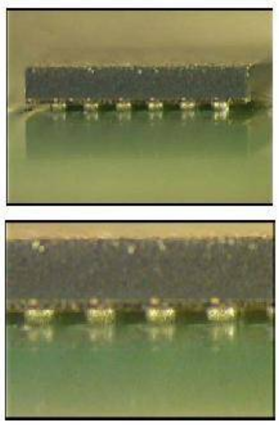


Figure 29. Virgin Units

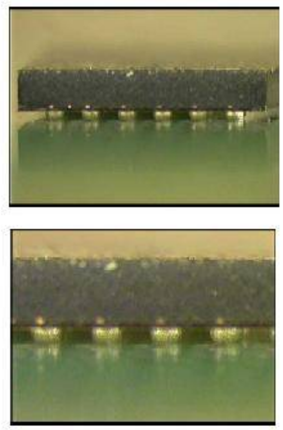


Figure 30. Steam-Aging

Units placed on ceramic plate. SnAgCu solder paste for lead-free balls, peak temperature 240°C (Originally, some balls were not populated on the package.)

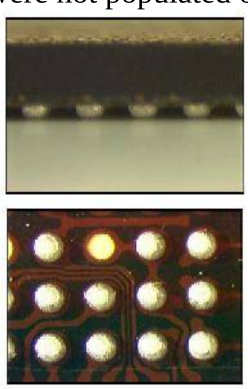


Figure 31. Virgin Units

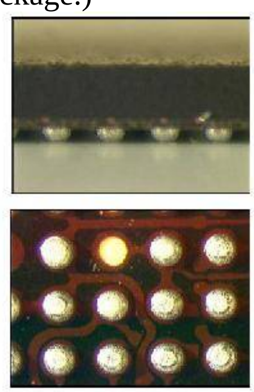


Figure 32. Steam-Aging

VISUAL INSPECTION SN74SSTV32852GKF

Bottom view – Units not soldered

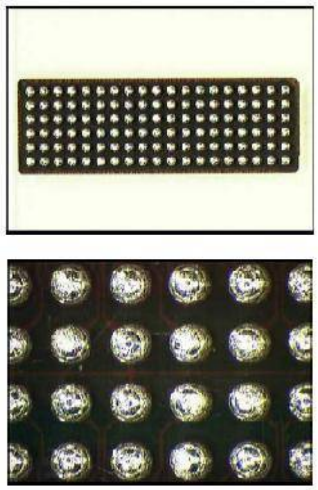


Figure 33. Virgin Units

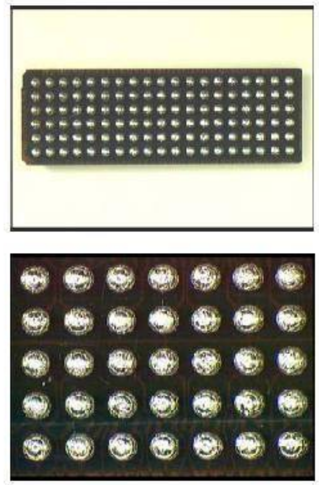


Figure 34. Units After Steam-Aging

Units placed on Test Board #56. SnPb solder paste for non lead-free balls, peak temperature 220°C

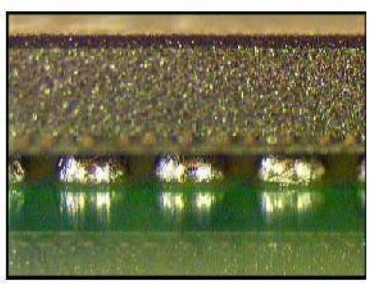


Figure 35. Virgin Unit

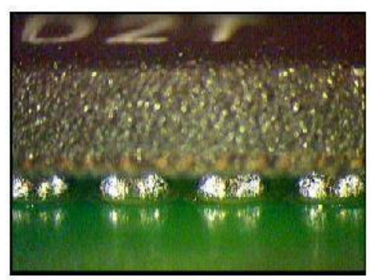


Figure 36. Steam-Aging

Units placed on ceramic plate. SnPb solder paste for non lead-free balls, peak temperature 220°C

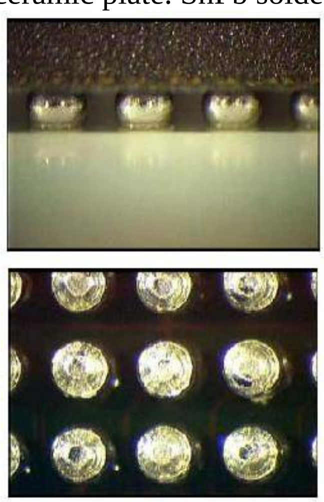


Figure 37. Virgin Units

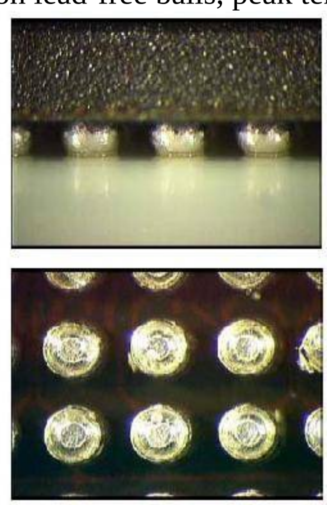


Figure 38. Steam-Aging

VISUAL INSPECTION MECHANICAL SAMPLE FROM OCTOBER 1999

Bottom view – Units not soldered

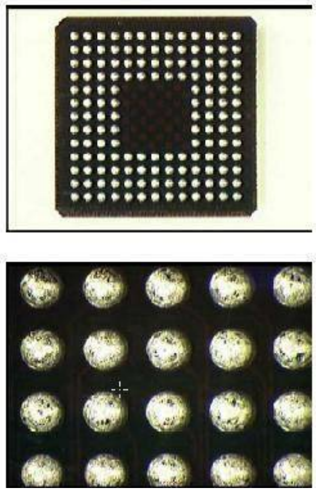


Figure 39. Virgin Units

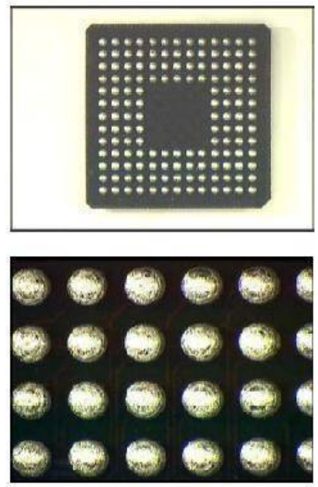


Figure 40. Units After Steam-Aging

Units placed on Test Board #40. SnAgCu solder paste for lead-free balls, peak temperature 240°C

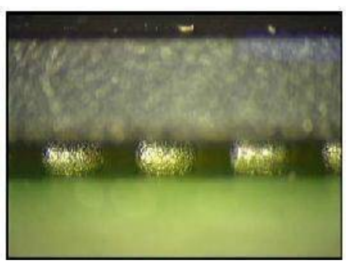


Figure 41. Virgin Unit

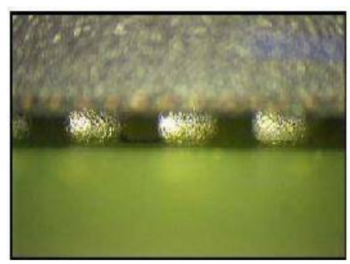


Figure 42. Steam-Aging

Units placed on ceramic plate. SnAgCu solder paste for lead-free balls, peak temperature 240°C

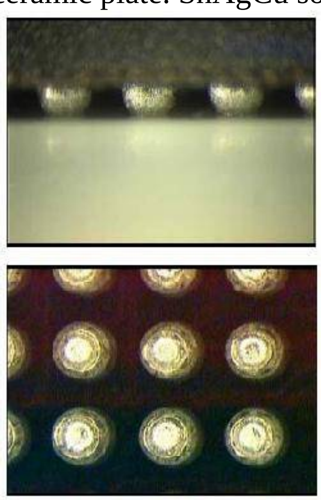


Figure 43. Virgin Units

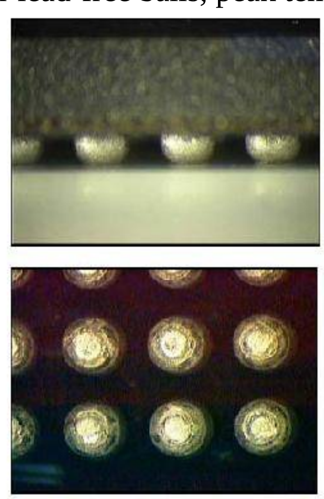


Figure 44. Steam-Aging

VISUAL INSPECTION MECHANICAL SAMPLE FROM SEPTEMBER 1999

Bottom view – Units not soldered

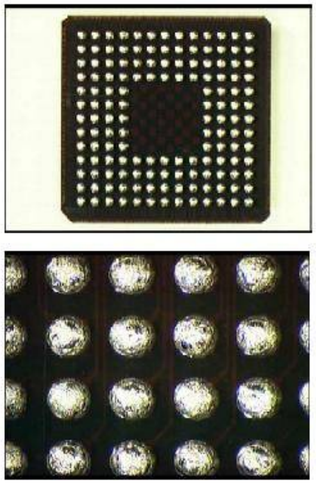


Figure 45. Virgin Units

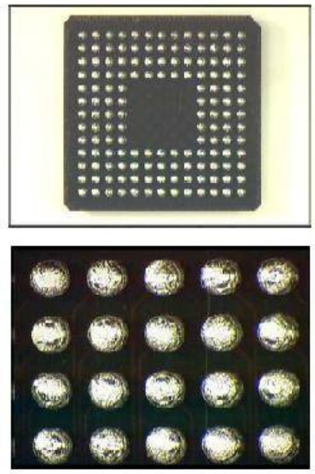


Figure 46. Units After Steam-Aging

Units placed on Test Board #40. SnPb solder paste for non lead-free balls, peak temperature 220°C

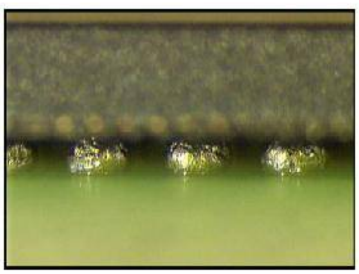


Figure 47. Virgin Unit

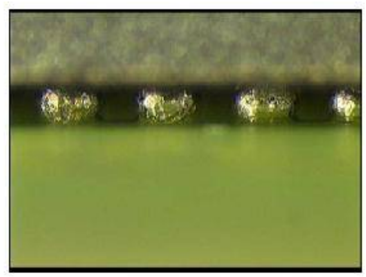


Figure 48. Steam-Aging

Units placed on ceramic plate. SnPb solder paste for non lead-free balls, peak temperature 220°C

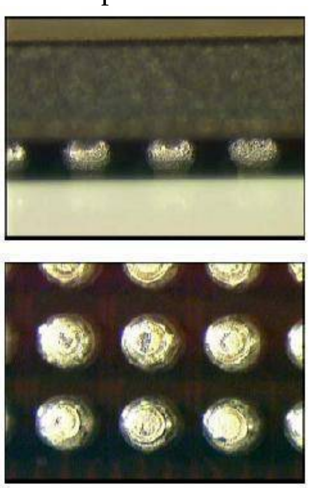


Figure 49. Virgin Units

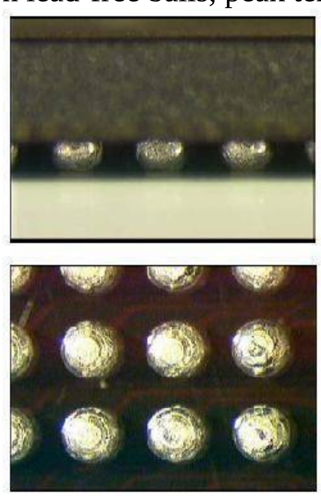


Figure 50. Steam-Aging

DESTRUCTIVE PHYSICAL ANALYSIS (DPA)

Some of the package samples collected for this study have been further investigated for any signs of aging or other environmental influence during the extended storage time. Besides in-depth optical inspection under the microscope, electron microscopy and cross-sectioning through the package were performed at a solder ball attach location.

DESTRUCTIVE PHYSICAL ANALYSIS - TNETC4320AGDS

Microscopic image of large BGA package not soldered. Manufactured: 2004
DPA performed at TI Tucson

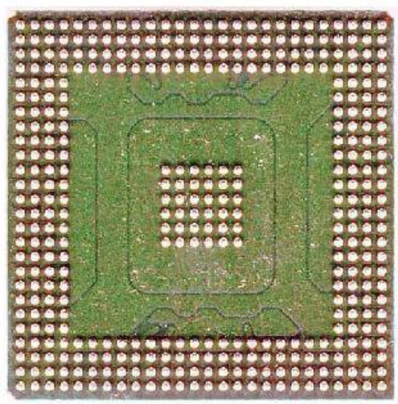
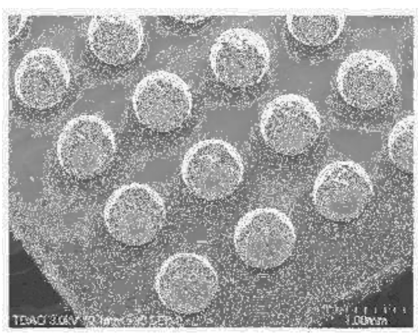


Figure 51. Virgin Unit **Figure 52. Virgin Unit, Bottom View**

Field Emission Scanning Electron Microscopy (FESEM) Micrograph of representative TNETC4320AGDS device solder balls.



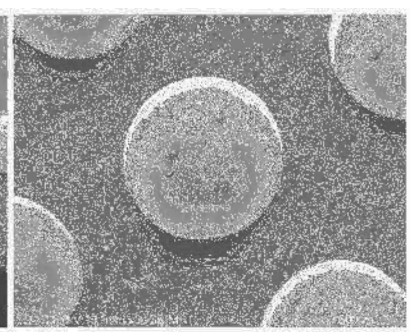


Figure 53. Image of Solder Balls **Figure 54. Detailed View**

FESEM Micrograph and Energy-Dispersive Spectroscopy (EDS) spectrum of representative TNETC4320AGDS device solder ball.

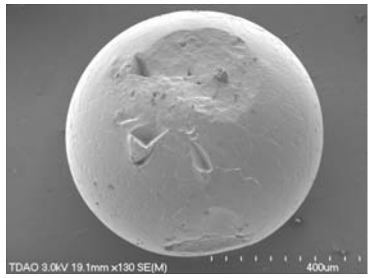


Figure 55. Detailed Image of Solder Ball

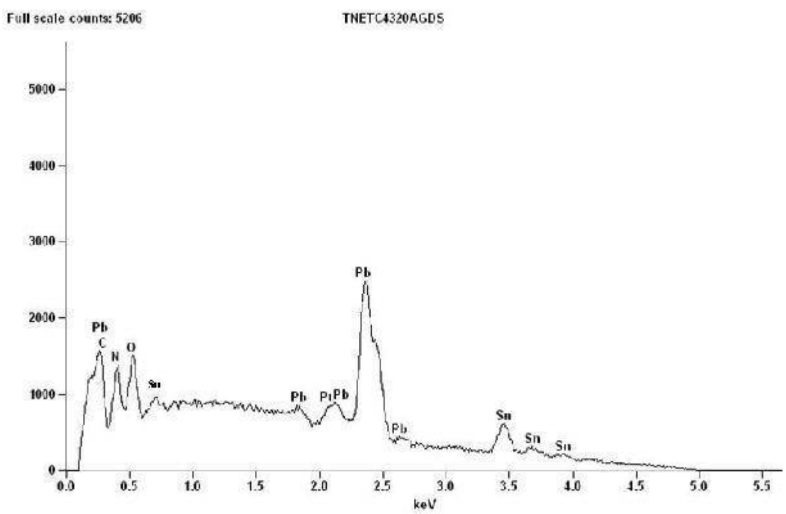
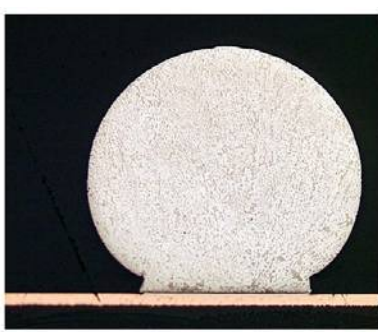


Figure 56. Element Analysis of the Solder Ball

Optical and FESEM micrograph of a representative TNETC4320AGDS device solder ball cross-section. No abnormalities were observed.



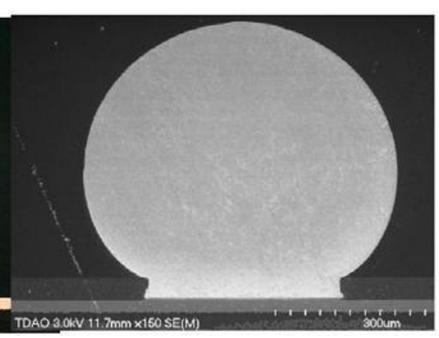


Figure 57 Microscopic View **Figure 58. FESEM Image of Solder Ball Cross-section**

DESTRUCTIVE PHYSICAL ANALYSIS - DLKPC192S

Microscopic image on large BGA package not soldered. Manufactured: 2002

Figure 59. Virgin Unit

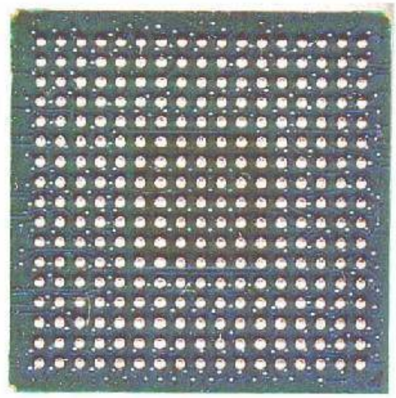


Figure 60. Virgin Unit - Bottom View

FESEM micrograph of representative DLKPC192S device solder balls.

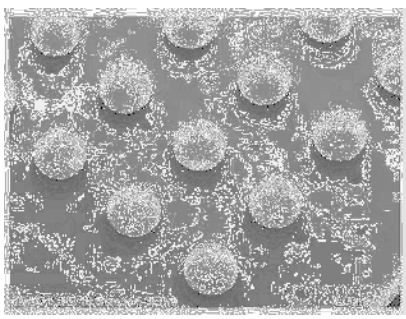


Figure 61. Solder Ball View

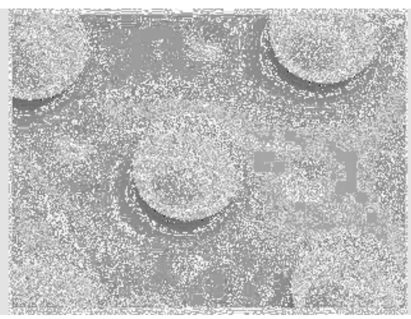


Figure 62. Detailed View

FESEM micrograph and EDS spectrum of a representative DLKPC192S device solder ball.

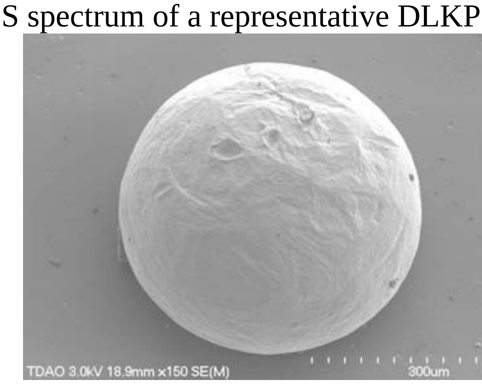


Figure 63. Solder Ball Detailed View

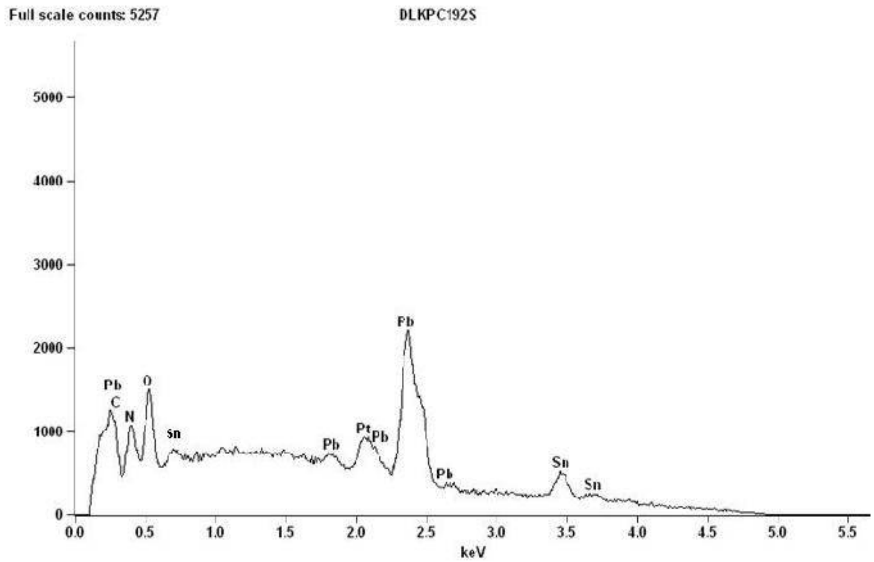
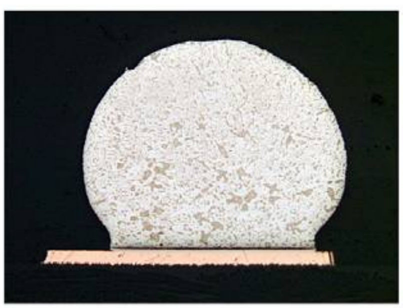


Figure 64. Element Analysis of the Solder Ball

Optical micrograph and FESEM micrograph of a representative DLKPC192S device solder balls.



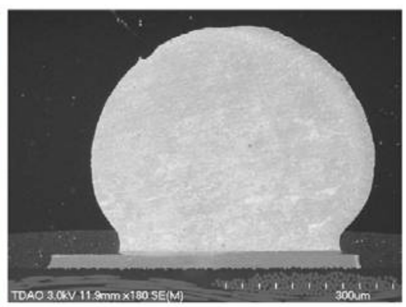


Figure 65. Microscopic View

Figure 66. FESEM Image of Solder Ball Cross-section

DESTRUCTIVE PHYSICAL ANALYSIS - XD751793GVU

Microscopic image of large BGA package not soldered. Manufactured: 2004

Figure 67. Virgin Unit

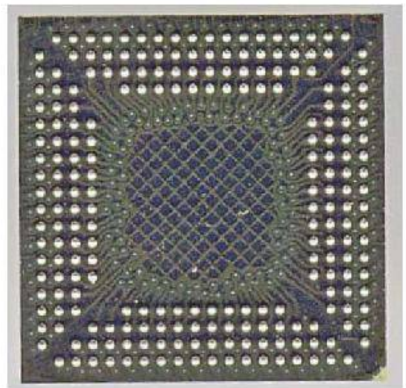


Figure 68. Virgin Unit - Bottom View

FESEM micrograph of representative XD751793GVU device solder balls.

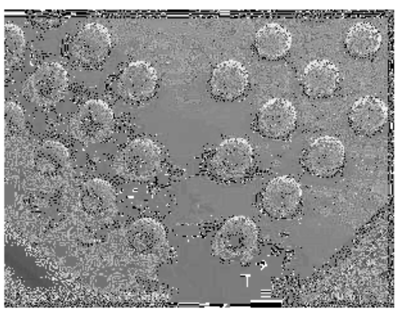


Figure 69. Image of Solder Balls

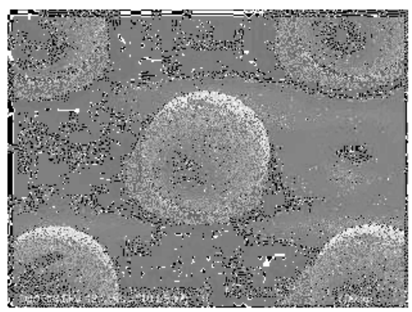


Figure 70. Detailed View

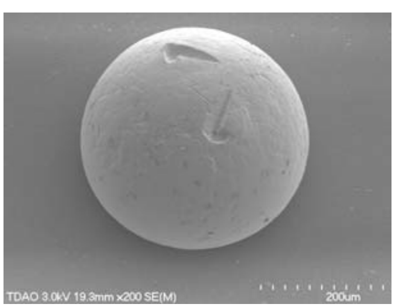


Figure 71. Detailed View - The visible scratches on the ball surface are from the electrical test socket contractor.

EDS spectrum of a representative XD751793GVU device solder ball.

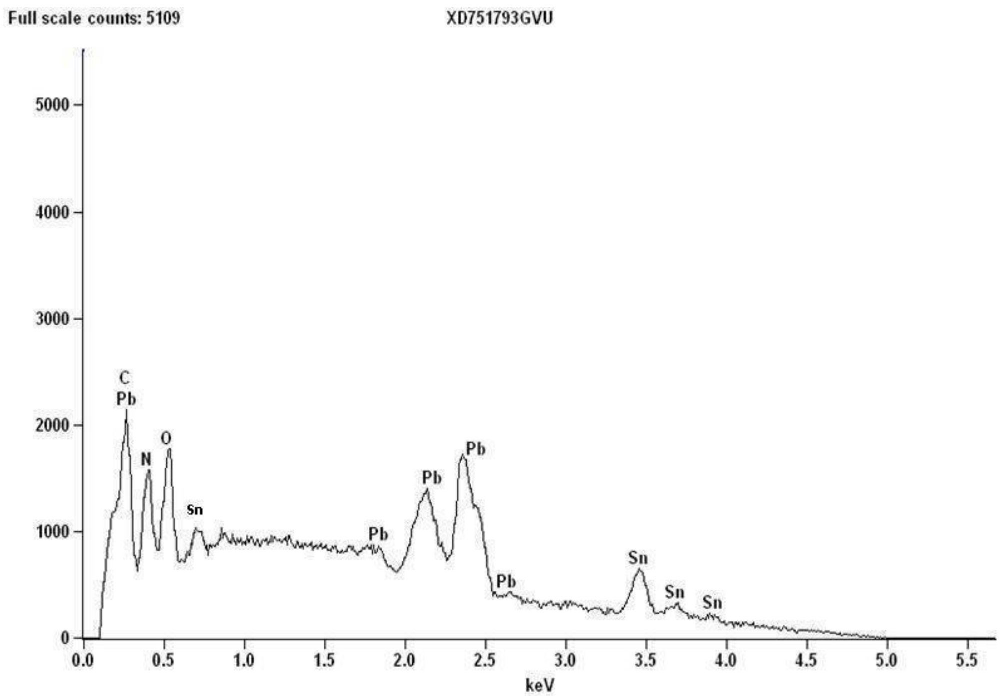
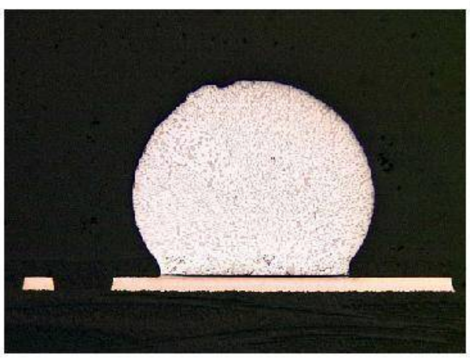


Figure 72. Element Analysis of the Solder Ball

Optical and FESEM micrograph of a representative XD751793GVU device solder ball cross-section.



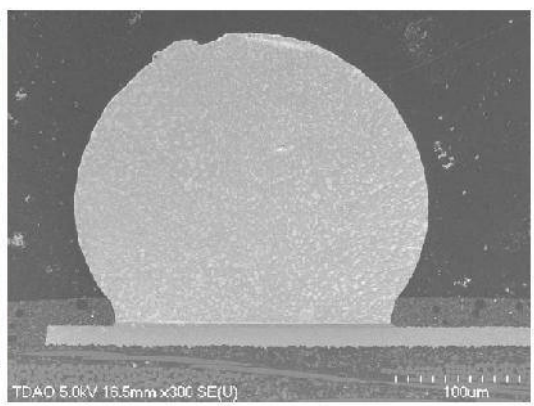


Figure 73. Microscopic View

Figure 74. FESEM Image View

DESTRUCTIVE PHYSICAL ANALYSIS - TPSDC6235YZG

Microscopic image of the investigated DSBGA package – Lead-free solder ball composition.
Manufactured: June 2005

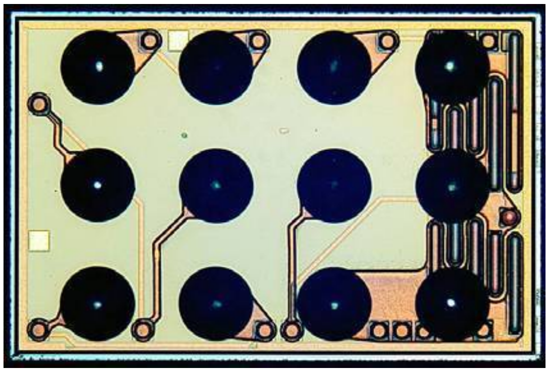


Figure 75. Microscopic View

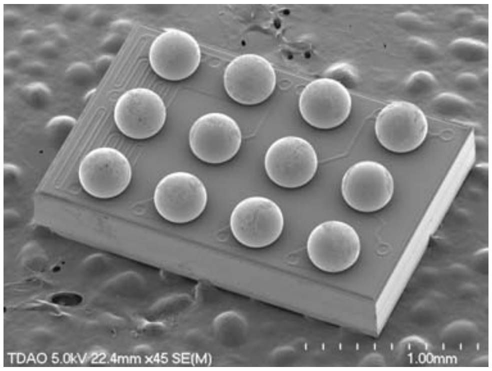


Figure 76. FESEM Image View

FESEM micrograph of representative TPSDC6235YZG device solder ball

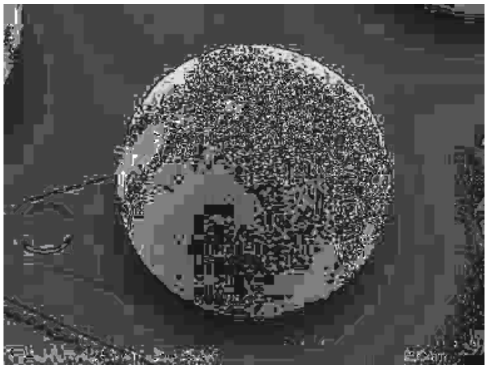


Figure 77. Detailed View of Solder Ball

Microscopic view of TPSDC6235YZG cross-section

Figure 78. Solder Ball Cross-section View

DESTRUCTIVE PHYSICAL ANALYSIS - TPS62302YZD

Microscopic image of the investigated DSBGA package – Lead-free solder ball composition. Manufactured: April 2007

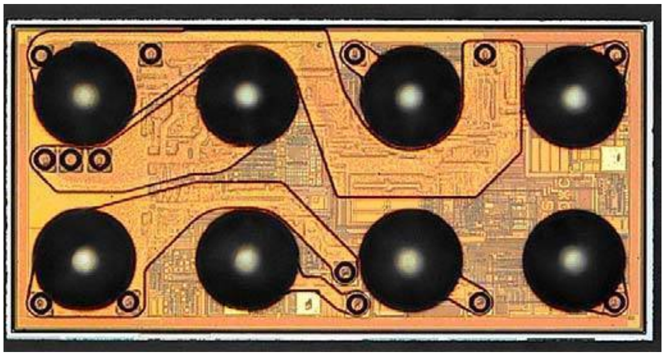


Figure 79. Microscopic View

FESEM micrograph of representative TPS62302YZD device solder balls

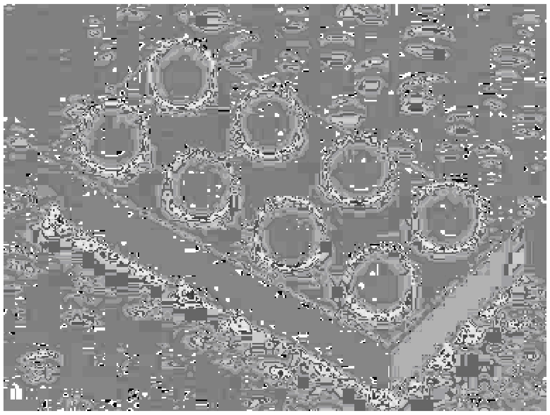


Figure 80. FESEM Image View

FESEM view of TPS62302 and Optical microscope cross-section

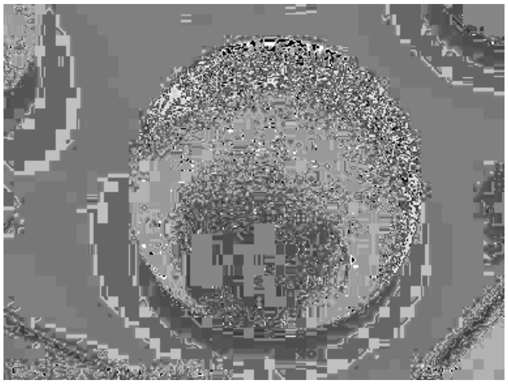


Figure 81. FESEM Image View

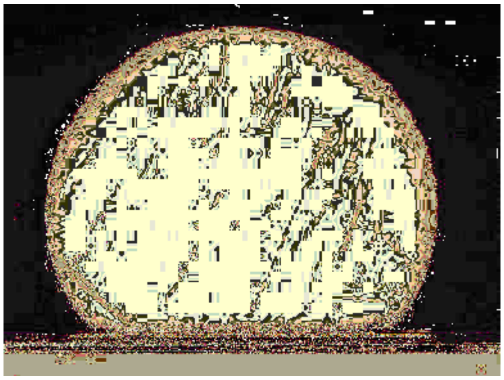


Figure 82. Solder Ball Cross-section View

SUMMARY OF RESULTS

- No failure mechanisms have been identified that compromise the reliability of solder bumped BGA packages stored for extended periods of time in a warehouse environment.
- Surface analysis of solder balls revealed expected elements. SEM and optical microscopy revealed nothing abnormal. No degradation of the solder balls was observed.
- Solderability of all devices met expectations and was indistinguishable from current devices.
- All materials and internal interfaces of the solder ball structure revealed no anomalies.

CONCLUSION

The shelf life of extended storage life devices as determined by solderability, SEM visual, SEM spectral analysis, cross-sectional analysis, and optical microscopy is greater than 10 years.

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- The TI Reliability Laboratory in Freising, Germany for the solderability test evaluations performed on the samples published in this report.
- Julie Terlisner compiled all photographs and text into this report format.