Solder Ball Attachment Assessment of Reballed Plastic Ball Grid Array Packages

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EXECUTIVE SUMMARY

This paper presents lead-free ball grid array (BGA) packages subjected to two ball removal and two ball attachment techniques. Solder attach strength is used as a metric to examine the reballing process. The impact of isothermal aging is also examined. In this study, lead-free (SAC305) 676 IO and 256 IO BGAs were reballed with eutectic tin-lead solder spheres. Two solder ball removal processes and two ball re-attachment processes were examined. For the 676 IO BGAs, the solder wick and low temperature solder wave removal process were examined. Ball re-attachment for this part was conducted with the perform method. For the 256 IO BGA, the low temperature solder wave removal process was applied followed by either perform or ball drop re-attach methods. Ball shear and the cold bump test results do not show a correlation with the reballing process. Further, isothermal aging does not appear to greatly influence the interconnect strength of tin-lead solder. Non-reballed lead-free solder balls were found to have greater strength and a wider strength distribution as compared to the reballed tin-lead solder samples. For the cold bump test, an increase in pull speed correlated to an increase in solder pull strength.

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Background

- In recent years, many countries banned the use of lead in select high volume electronic equipment. However, exemptions from lead-free legislation have been granted for certain products, especially those intended for security and life critical applications. However, manufacturers with exemption are facing dwindling supply of lead based parts for their products [1]-[5].
- In cases where conventional tin-lead ball grid array (BGA) parts are not available, some manufacturers have looked into reballing lead-free area arrays with tin-lead solder balls.

Introduction to Reballing

- As the name implies, reballing is a technology for replacing the solder spheres of a Ball Grid Array (BGA) package. It has been used to reclaim parts from defective or discarded assemblies. It has also been used to change the lead-free parts to tin-lead parts, or vice versa. It removes the original solder balls and places new solder on the pads of package.

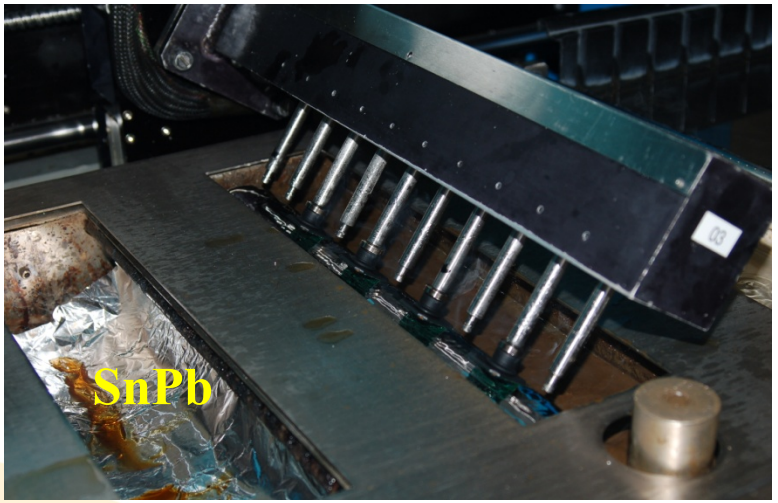
- Reballing process involves two major steps
  - Solder ball removal
  - Solder ball attachment

Scope of Study

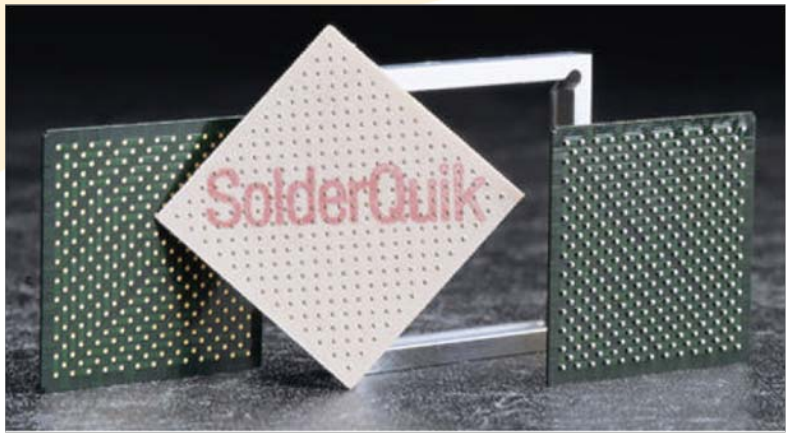
- Two types of plastic ball grid array packages were selected for reballing.
- Two deballing methods were examined.
- Two ball attachment methods were examined.
- 480 PBGA parts were reballed.
- Reballed parts were examined to determine if reballing process results in measurable differences in solder ball attach strength. Strength tests include Ball Shear and Ball Pull Methods.

Reballing Methods

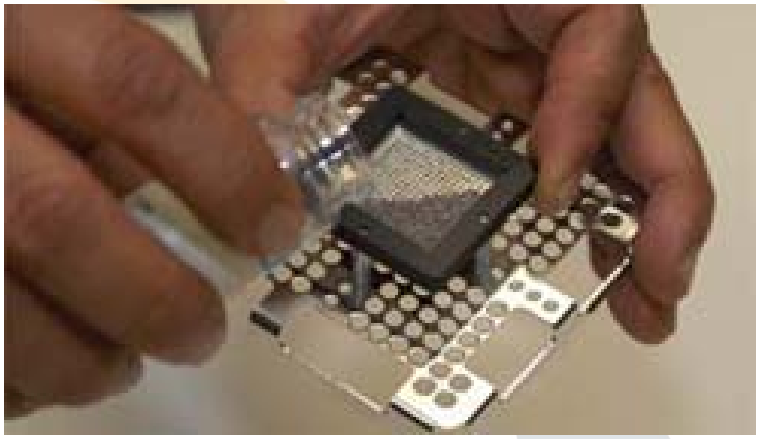
Solder Wick (SW)



Low Temperature Wave Solder (LTWS)



Preform (PF)



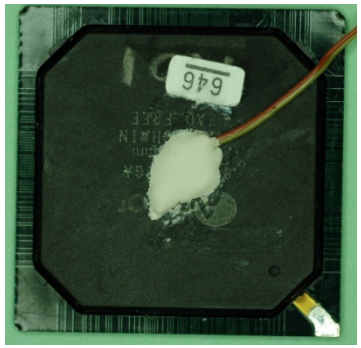
Ball Drop (BD)

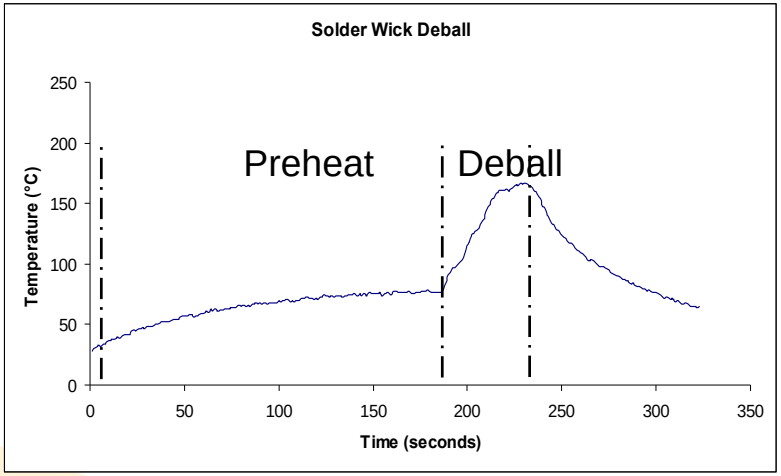
Reballing Process Matrix

Two Plastic Ball Grid Arrays (PBGAs): 676 IO (1.0 mm pitch) and 256 IO (1.27 mm pitch) with Pb-free (Sn3.0Ag0.5Cu) solder were reballed with eutectic SnPb solder balls.

Reballing Process Treatment	Part (Count)	Solder Ball Removal Approach	Solder Ball Attachment Approach
Reballed 1 LTWS+PF	676 IO PBGA (120)	Low temperature wave solder (LTSW)	Preform method (PF)
Reballed 2 SW+PF	676 IO PBGA (120)	Solder wick (SW)	Preform method (PF)
Reballed 3 LTWS+PF	256 IO PBGA (120)	Low temperature wave solder (LTSW)	Preform method (PF)
Reballed 4 LTWS+BD	256 IO PBGA (120)	Low temperature wave solder (LTSW)	Solder ball drop method (BD)

Temperature Characterization





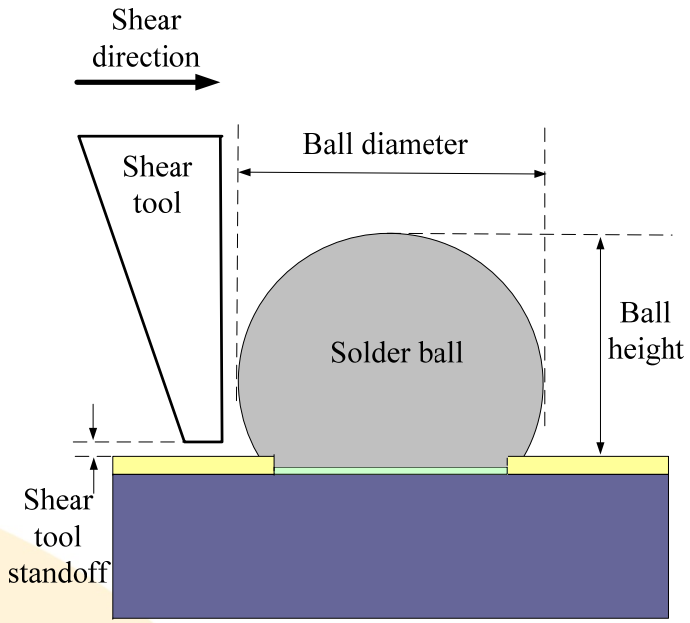
Sample Profile (SW)

To characterize temperature on BGA parts, a hole was drilled into a sample part and a thermocouple was mounted just above the internal die.

Reballing Process Treatment	Part	Solder Ball Removal Peak Process Temperature	Solder Ball Attachment Peak Process Temperature
LTWS+PF	676 IO PBGA	164.5	213
SW+PF	676 IO PBGA	167	213
LTWS+PF	256 IO PBGA	164.5	213
Reballed 4	256 IO PBGA	164.5	211

Ball Shear Test

- Ball shear test is a destructive test conducted to determine the ability of Ball Grid Array (BGA) solder balls to withstand mechanical shear forces.
- Standard: JEDEC JESD22-B117A (October, 2006) [15]
- Test setup
  - Equipment: DAGE 2400, load cell: 2Kg
  - Shear tool standoff: 50 µm
  - Shear speed: 200 µm /s



676 (256*) I/O BGA	Non-Reballed (Virgin) (gF)			Reballed Type 1 (gF)			Reballed Type 2 (gF)		
	Non-aged	100ºC 24hrs	125ºC3 50hrs	Non-aged	100ºC 24hrs	125ºC3 50hrs	Non-aged	100ºC 24hrs	125ºC3 50hrs
Sample Size	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls

** 256 I/O BGAs did not include non-aged samples.*

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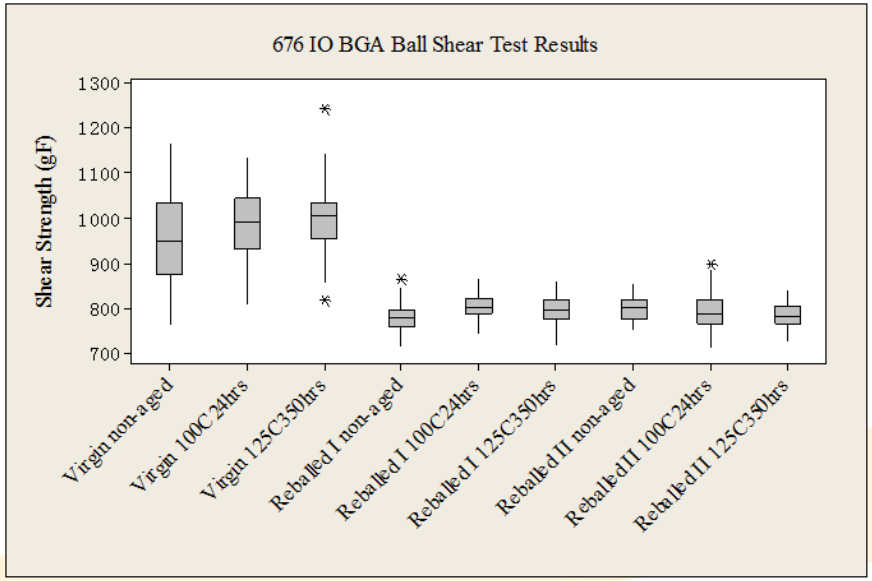
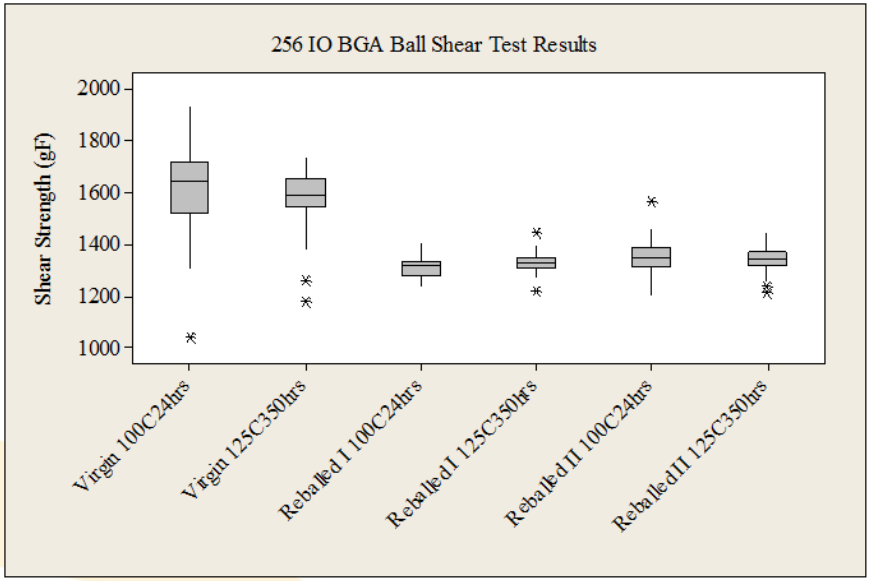
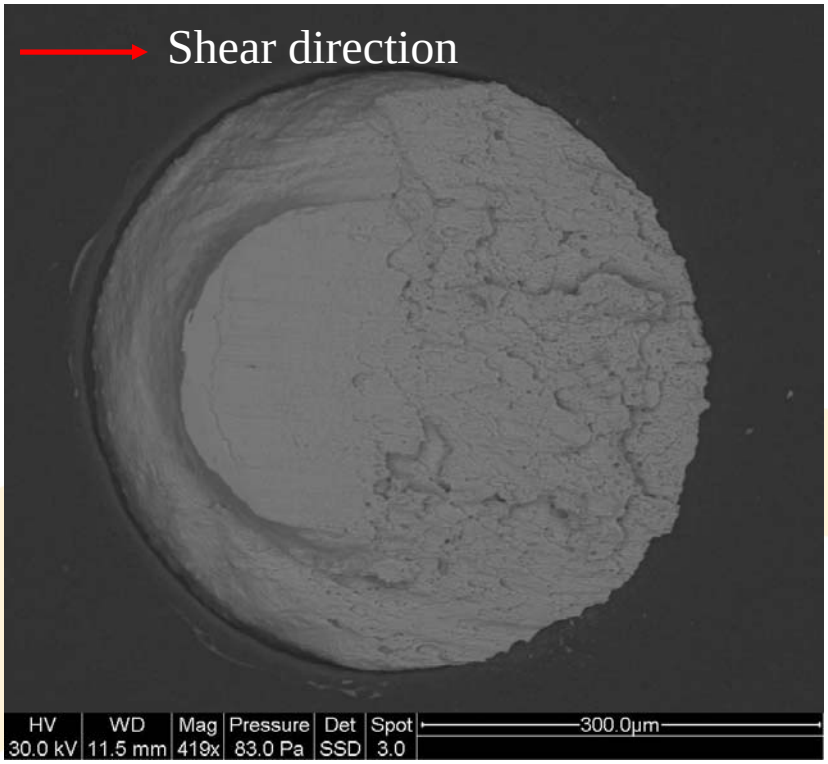
Ball Shear Test Results



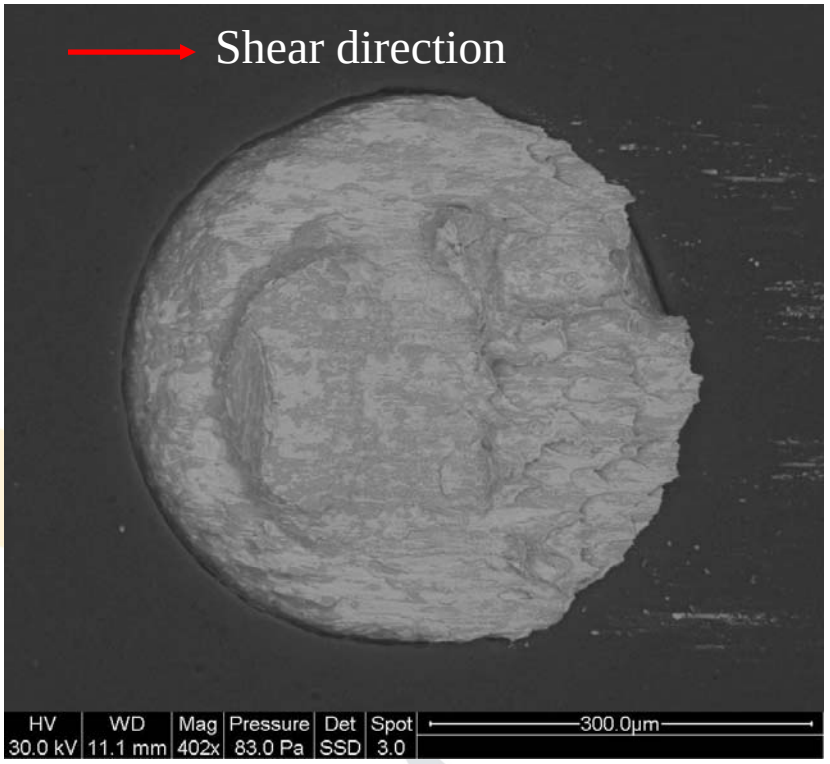


- The non-reballed parts with SAC305 exhibited a higher shear strength than the reballed parts with Sn37Pb solder.
- The distribution of shear strength was larger for the lead-free parts than the reballed tin-lead parts.
- For the reballed BGAs, the shear strength had a smaller distribution and the shear strength level appears to be independent of reballing method.
- All the BGAs failed in the bulk solder.

Failure Mode Analysis of Ball Shear Test



Virgin 676 I/O BGA aged at 125°C for 350 hrs



Reballed Type II 676 I/O BGA aged at 125°C for 350 hrs

Both the virgin and tin-lead samples have the failure mode as ductile.

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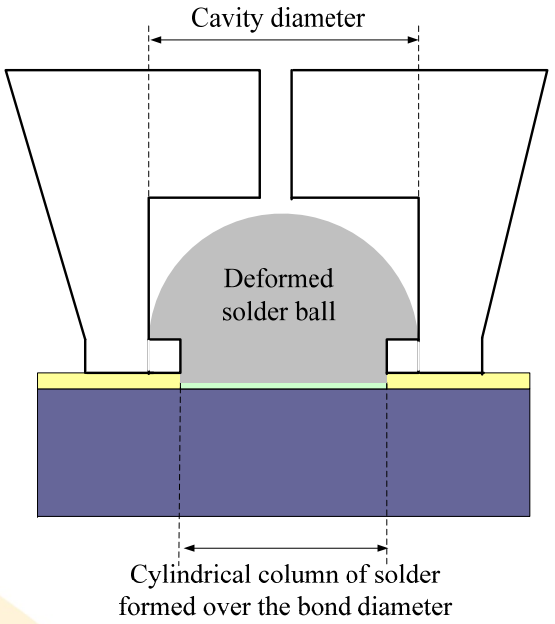
Cold Bump Pull Test

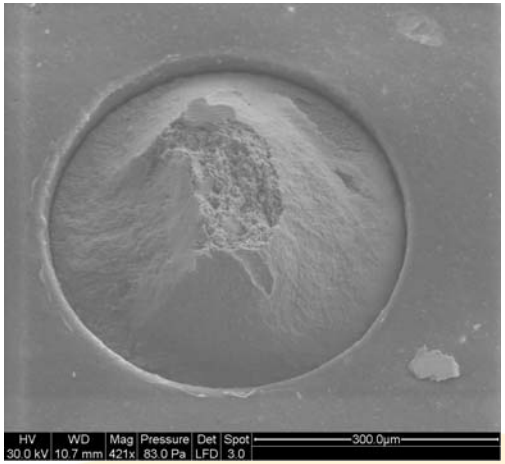
- Cold bump pull (CBP) test is an alternative to the traditional ball shear testing method for characterizing the attachment strength of solder interconnection.
- There is no industrial standard for cold bump pull test.
- Test setup
  - Equipment: DAGE 4000, load cell: CBP/TP 5Kg
  - Pull speed: 500 µm /sec and 5000 µm /sec



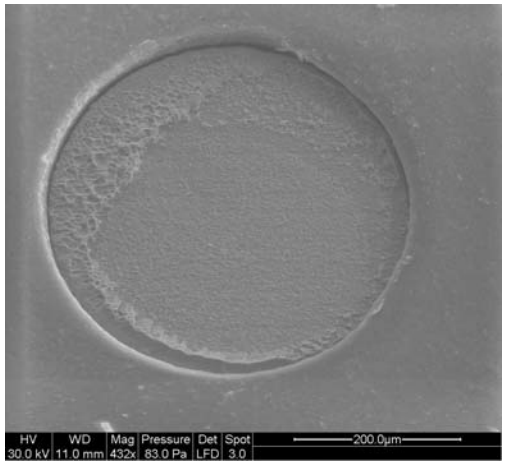
676 (256*) I/O BGA	Nom-Reballed (Virgin) (gF)			Reballed Type 1 (gF)			Reballed Type 2 (gF)		
	Non-aged	100ºC 24 hrs	125ºC 350 hrs	Non-aged	100ºC 24 hrs	125ºC 350 hrs	Non-aged	100ºC 24 hrs	125ºC 350 hrs
Sample Size	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls	50 balls

** 256 I/O BGAs did not include non-aged samples.*

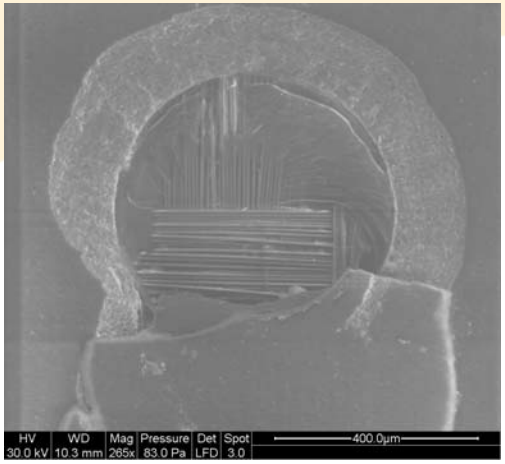
Failure Modes Analysis of CBP Test



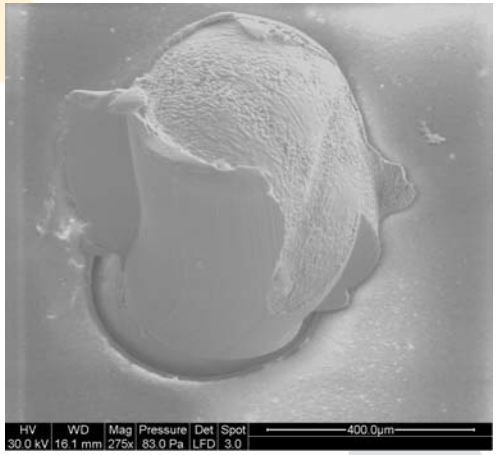
Ball failure of Non-Reballed 676 I/O BGA



Bond failure of Non-Reballed 676 I/O BGA



Pad failure of Non-Reballed 676 I/O BGA



Ball extruded of Non-Reballed 676 I/O BGA

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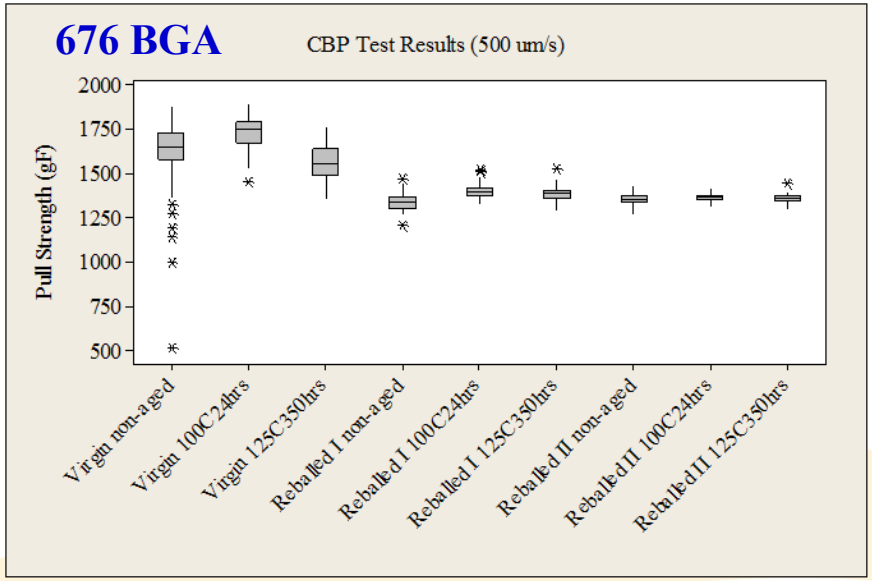
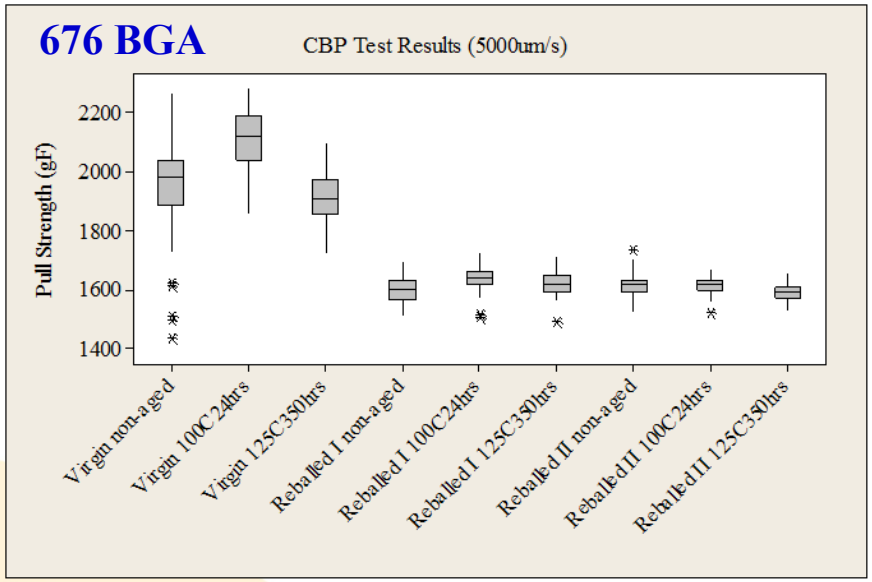
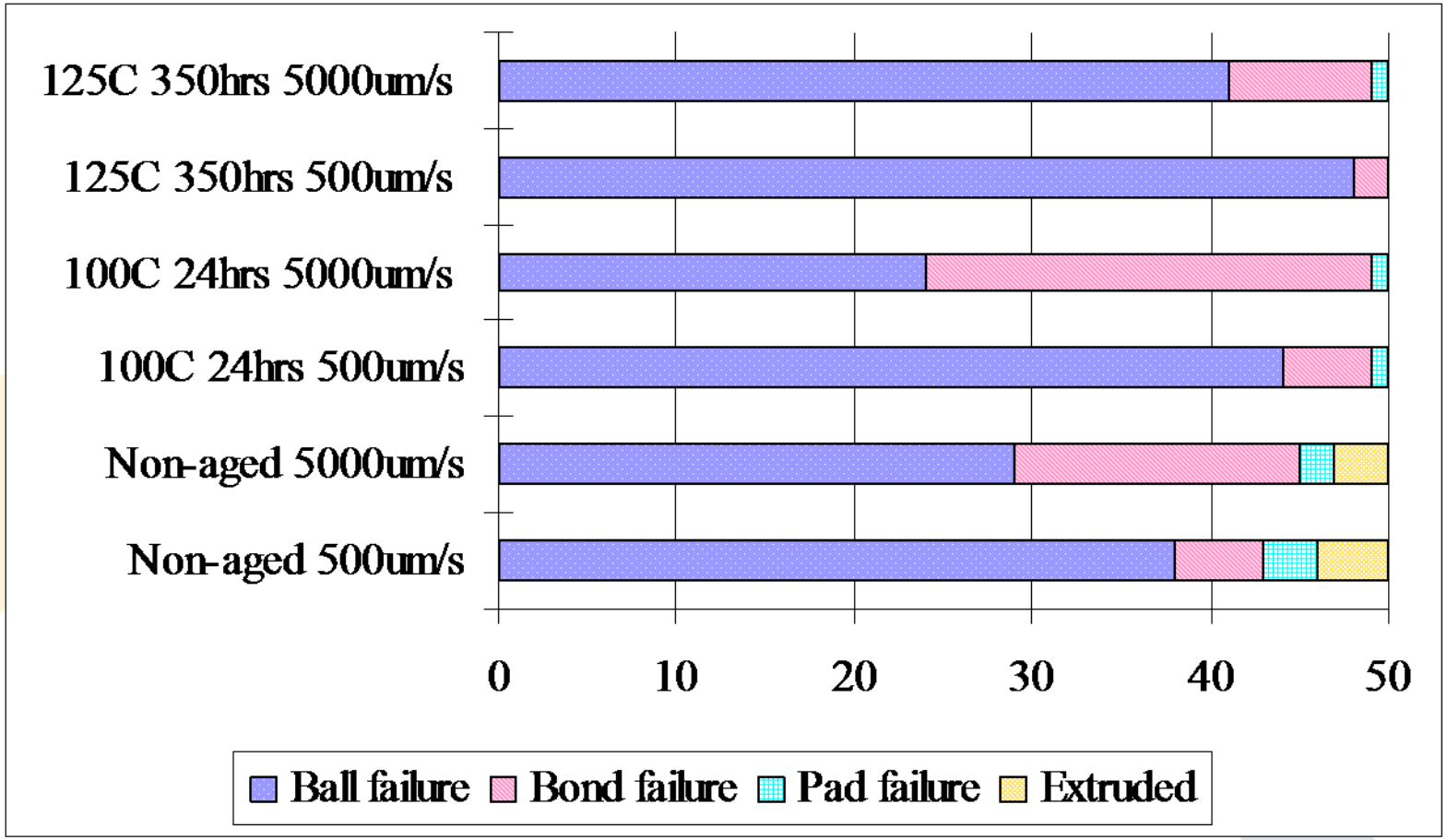
CBP Test Results





- Original SAC solder balls have a higher pull strength than the tin-lead replaced solder balls at the same pull speed.
- A a wider strength distribution was observed for original SAC solder balls.
- As the pull speed increases, the pull strength increases, regardless of solder ball composition.
- The failure mode of the reballed BGAs is ball failure.

CBP Failure Modes of Non-Reballed 676 IO BGAs



The higher pull speed generated a greater number of bond failures.

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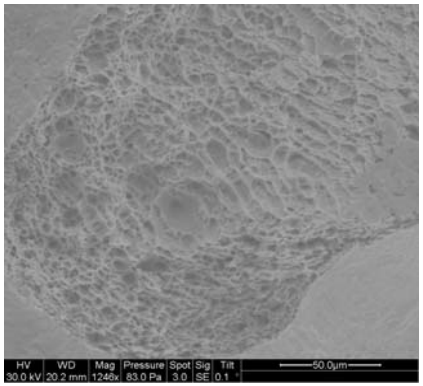
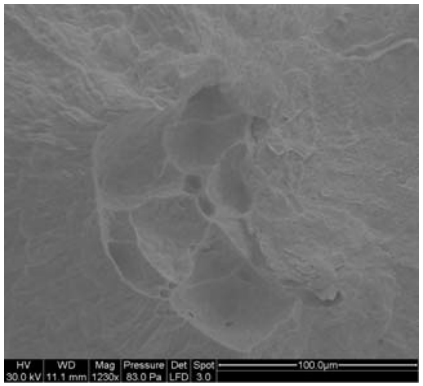
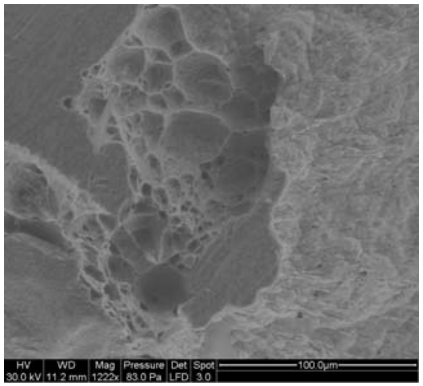
Microstructural Analysis of Ball Failure Mode



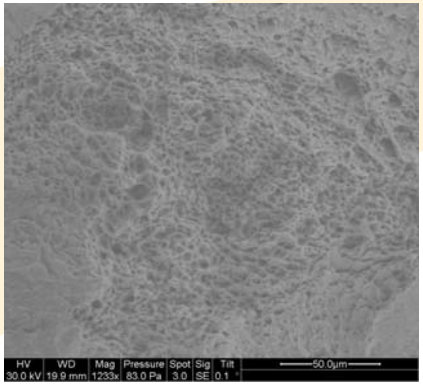
500 µm/sec non-reballed



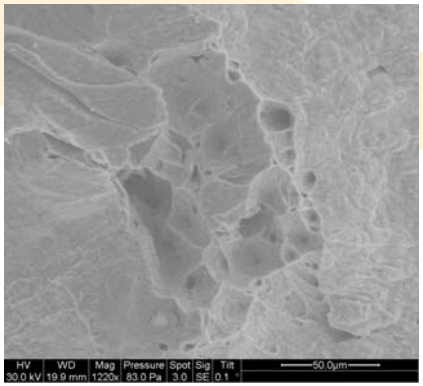
500 µm/sec Reballed I



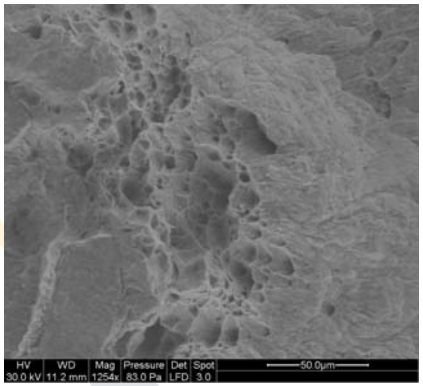
500 µm/sec Reballed II



5000 µm/sec non-reballed



5000 µm/sec Reballed I



5000 µm/sec Reballed II

- high pull speeds block the dimple from coalescing and growing, which lead to smaller dimple size.
- During the pull process, the lamellar SnPb structure fractures show a smoother edge than those of SAC solder.

Conclusions

- Ball shear and the cold bump test results do not show a correlation with the reballing process.
- Non-reballed lead-free solder balls were found to have greater strength (>15% higher than that of reballed tin-lead BGAs) and a wider strength distribution as compared to the reballed tin-lead solder samples.
- Isothermal aging does not appear to greatly influence the interconnect strength of tin-lead solder.