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Effects of BGA Rework Cycles on PCB Assembly Reliability

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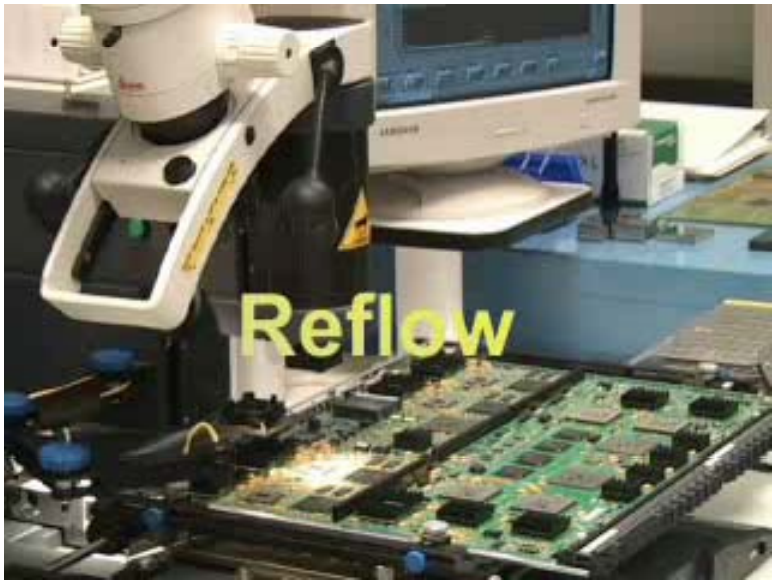
BGA Rework Issues

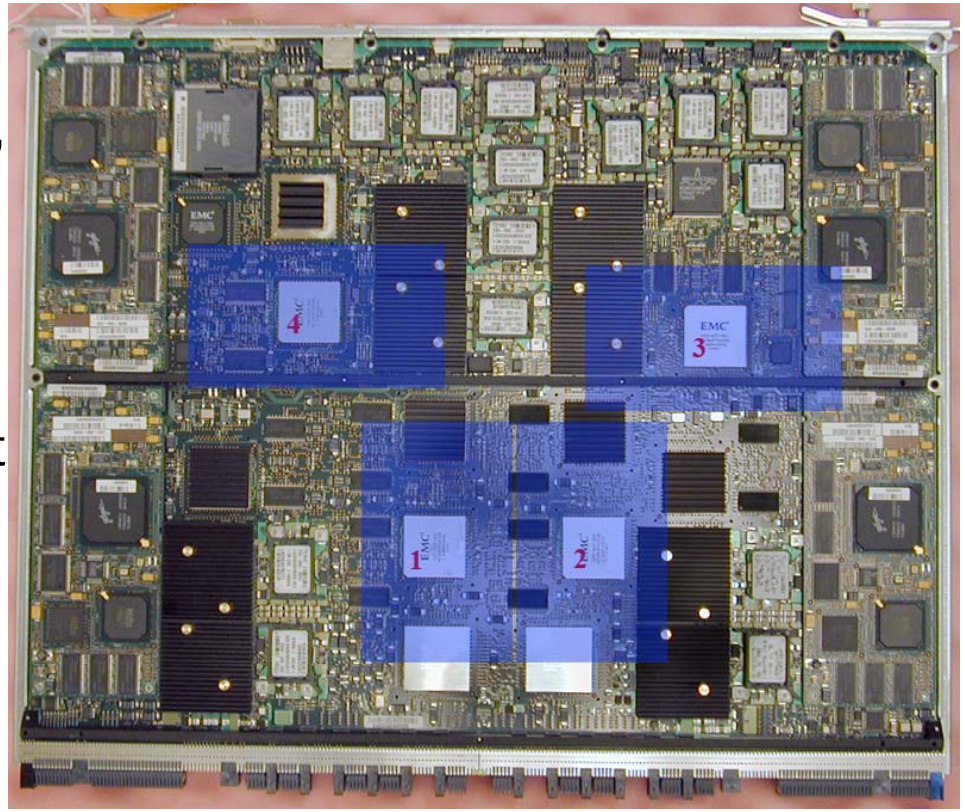
- BGA removal and replacement are required during product development, and for manufacturing and field returns.
- BGA multiple revisions during a product development may force development boards to go through multiple removal and replacement cycles on the same BGA locations.



Rework Risks:
Relationship among rework processes, intermetallic thickness, and mechanical strength of BGA balls, maximum permitted limits to BGA rework.

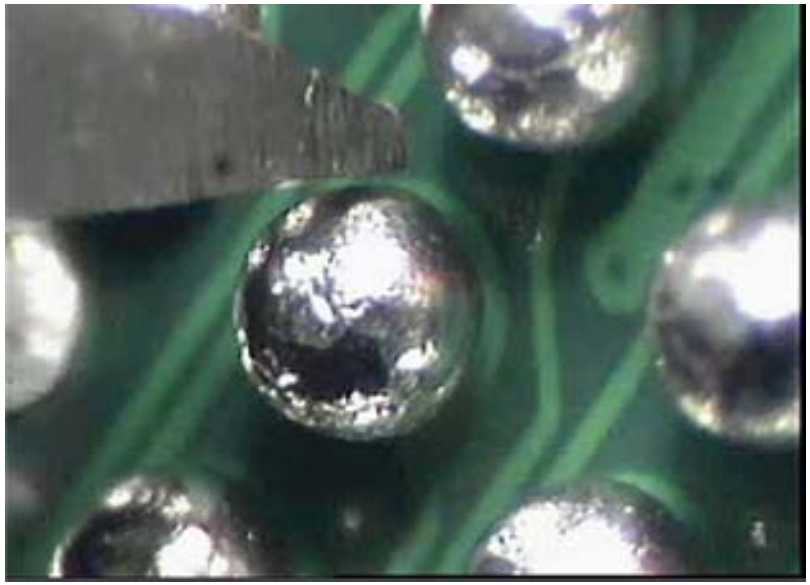
Test Sample Preparation

- Samples are produced under the following conditions: virgin, 1, 2, 3, 5 reworks.
- Each ball shear test sample had 10 attached balls after the last replacement stage, except sample which has virgin conditions



High density/high reliability board

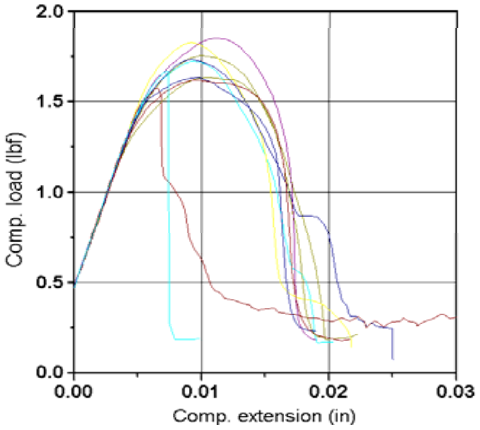
Experimental Setup



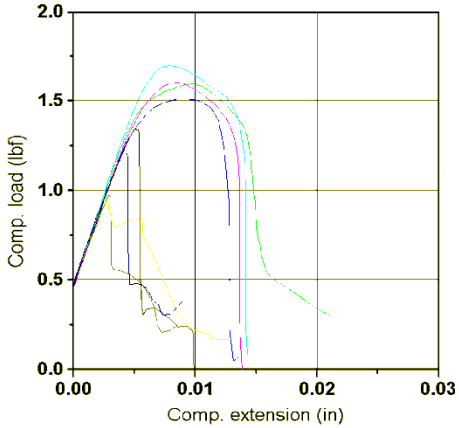
BGA Ball Shearing Test

Four point bending test fixture and setup

BGA Shear Test Results and Analyses



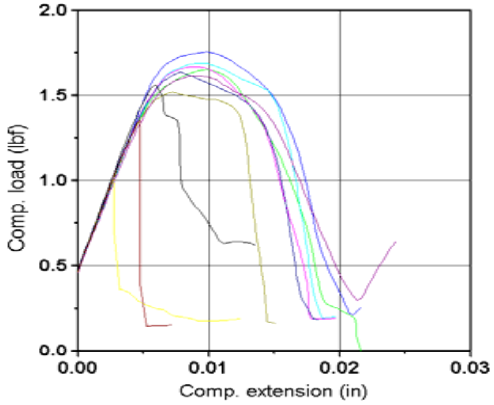
a)



b)

Ball shearing test results for BGA balls with:

a) zero rework
b) one rework
c) two rework
d) three rework
e) 5 rework



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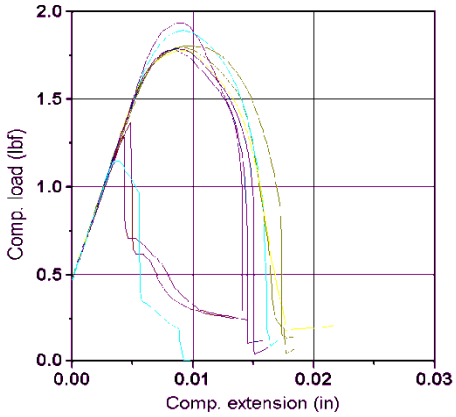

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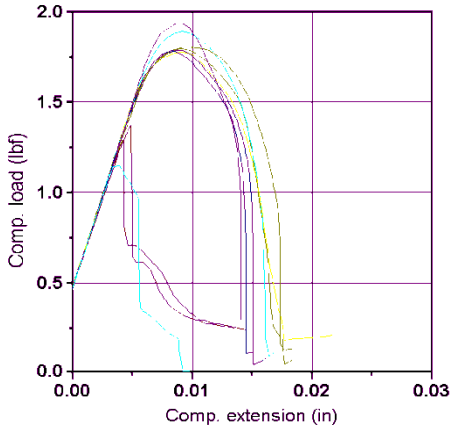

e)

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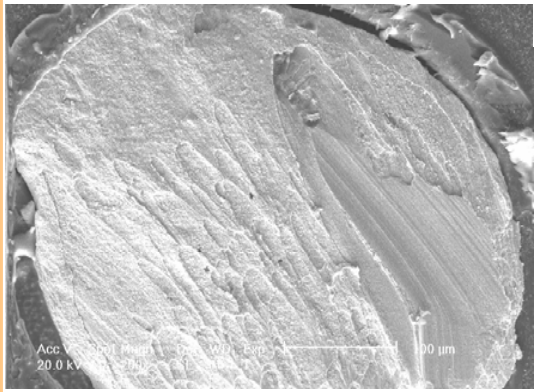
SEM pictures of pad's surfaces after ball shear tests



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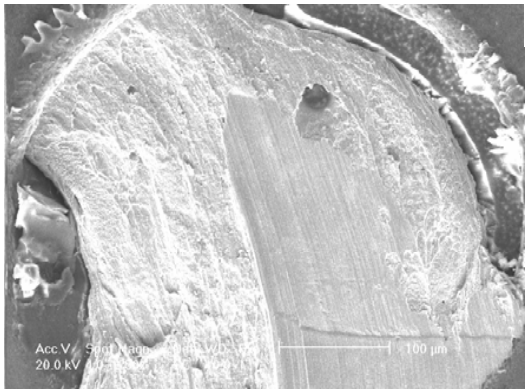

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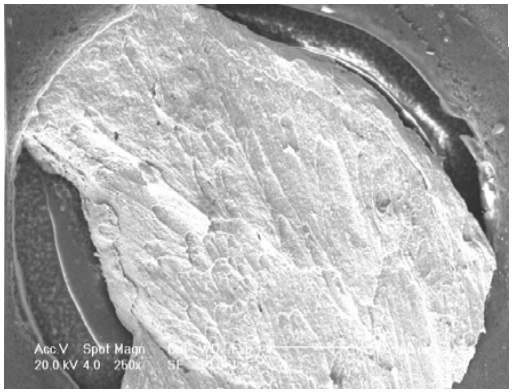

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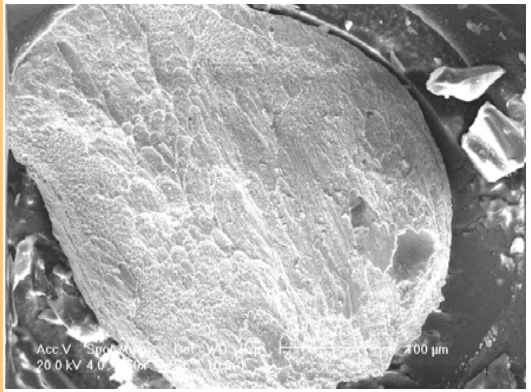

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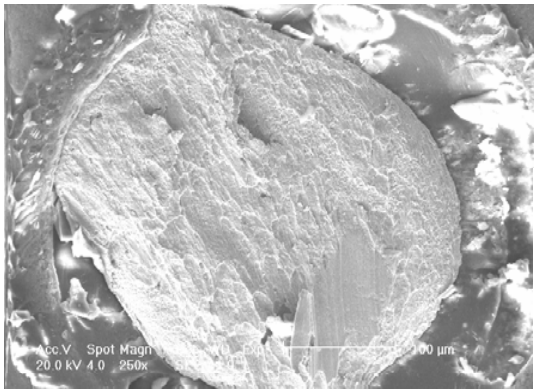
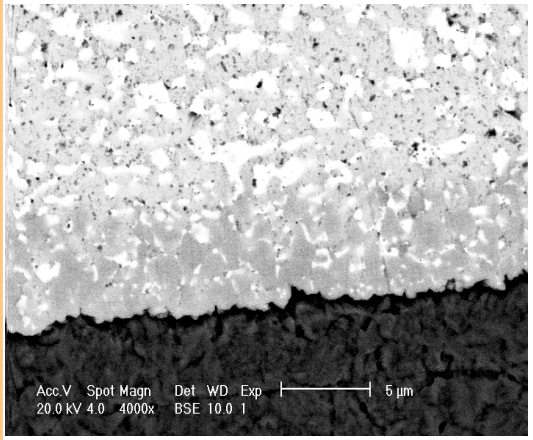


e)

Ball shearing test results for BGA balls with:

a) zero rework
b) one rework
c) two rework
d) three rework
e) 5 rework

Intermetallic Thickness vs. Rework Cycle



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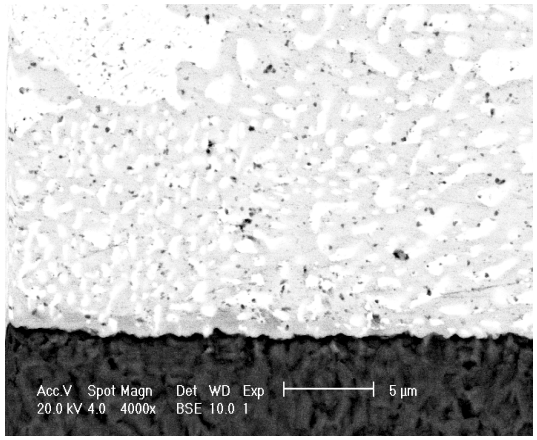

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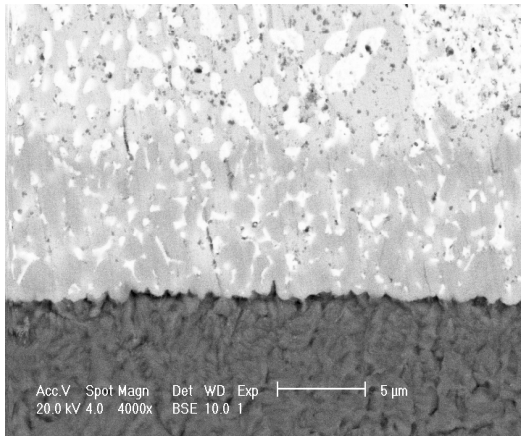

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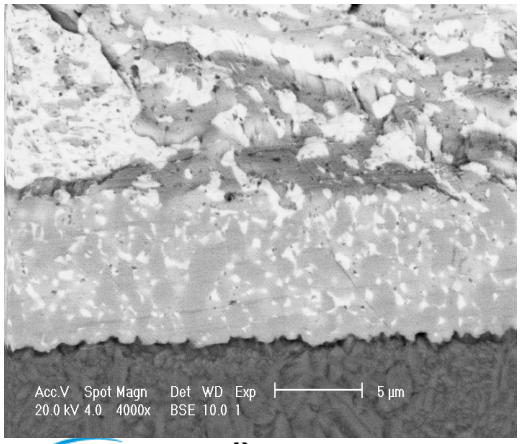

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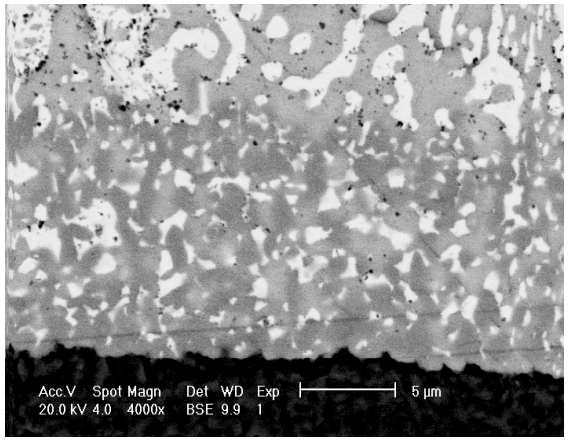


e)

Ball shearing test results for BGA balls with:

a) zero rework
b) one rework
c) two rework
d) three rework
e) 5 rework

Intermetallic Thickness vs. Rework Cycles

Director PCB SMT Pad Cu/Sn Intermetallic Thickness Measurements (Values are in Microinches)

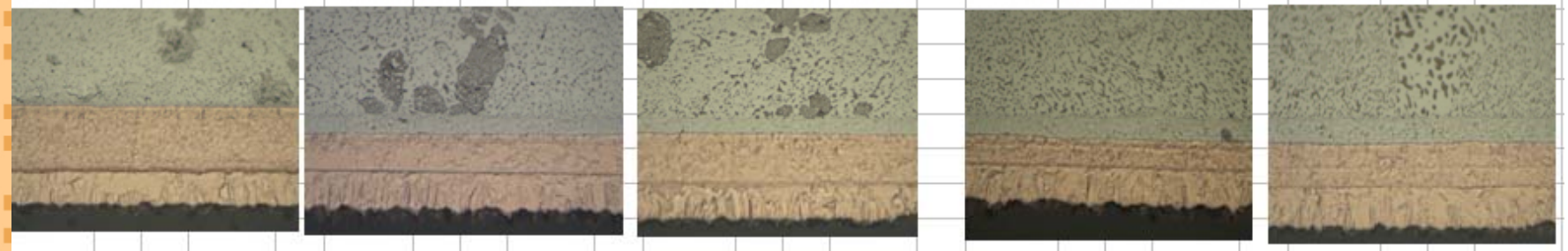
Test Condition	SMT Pad	Area	Measured Value
Virgin	1	A	104
		B	75
		C	83
	2	A	60
		B	65
		C	74
	3	A	68
		B	75
		C	38
Mean:			71
Std. Dev.			18

Test Condition	SMT Pad	Area	Measured Value
Reflow 1x	1	A	279
		B	279
		C	324
	2	A	264
		B	249
		C	317
	3	A	241
		B	271
		C	287
Mean:			279
Std. Dev.			28

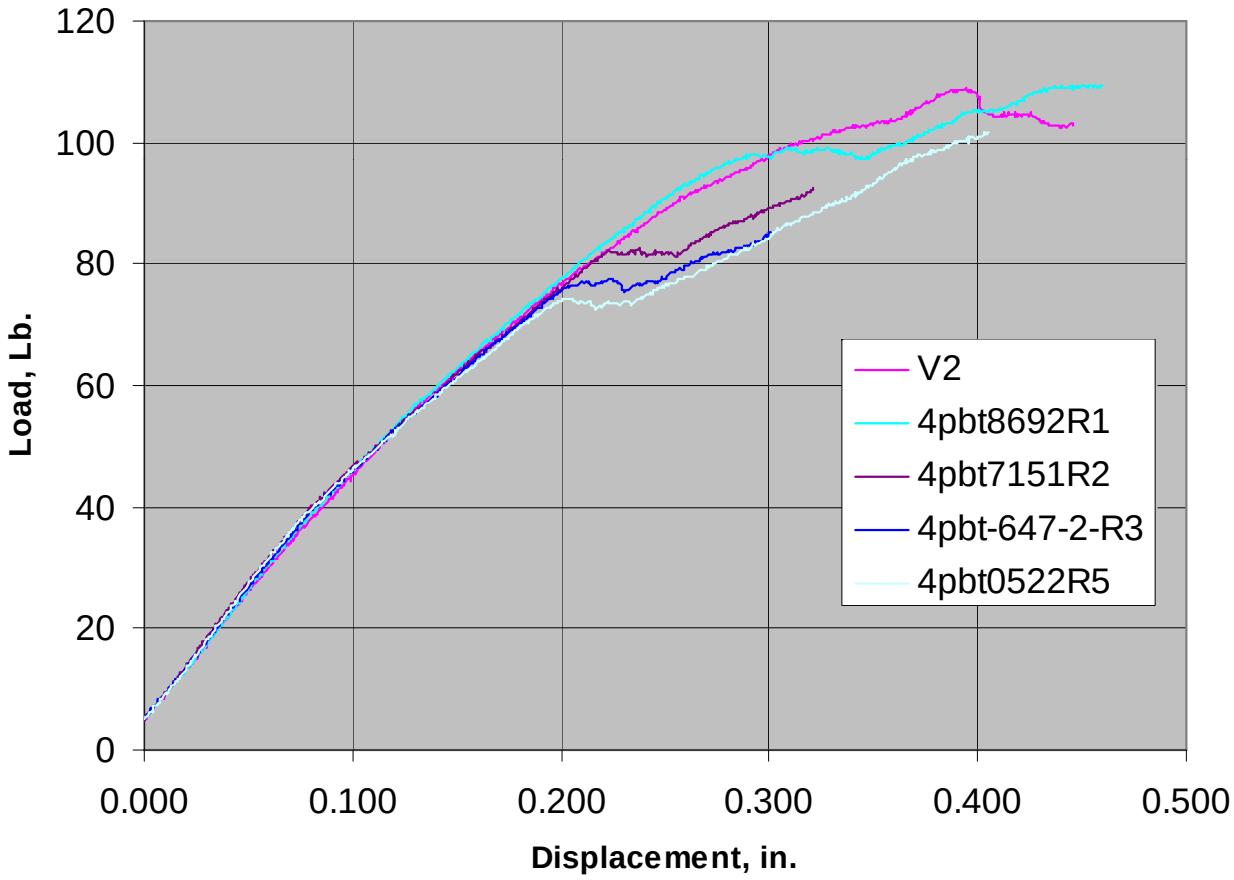
Test Condition	SMT Pad	Area	Measured Value
Reflow 2x	1	A	287
		B	219
		C	234
	2	A	264
		B	271
		C	279
	3	A	362
		B	257
		C	293
Mean:			274
Std. Dev.			41

Test Condition	SMT Pad	Area	Measured Value
Reflow 3x	1	A	354
		B	317
		C	324
	2	A	324
		B	347
		C	339
	3	A	332
		B	317
		C	324
Mean:			331
Std. Dev.			13

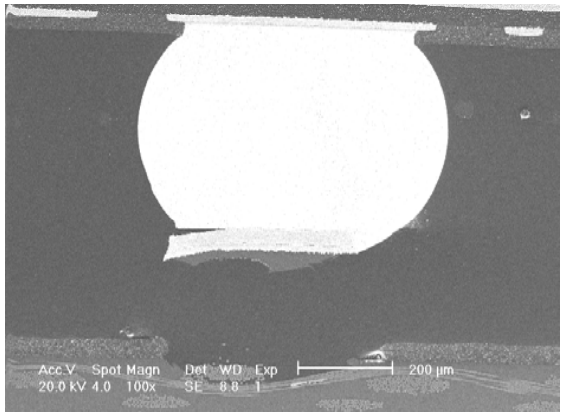
Test Condition	SMT Pad	Area	Measured Value
Reflow 5x	1	A	483
		B	422
		C	445
	2	A	490
		B	400
		C	385
	3	A	452
		B	407
		C	422
Mean:			434
Std. Dev.			36

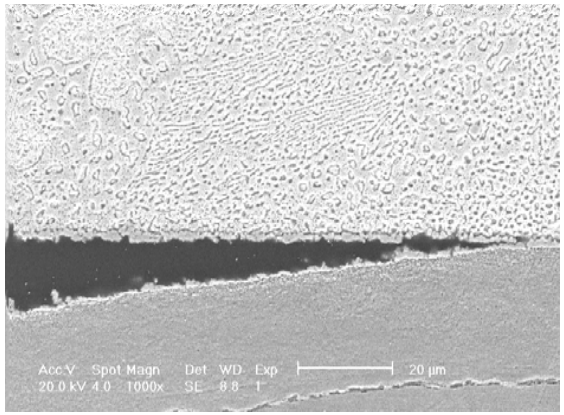


Four point bending test results for reworked BGA/PC boards

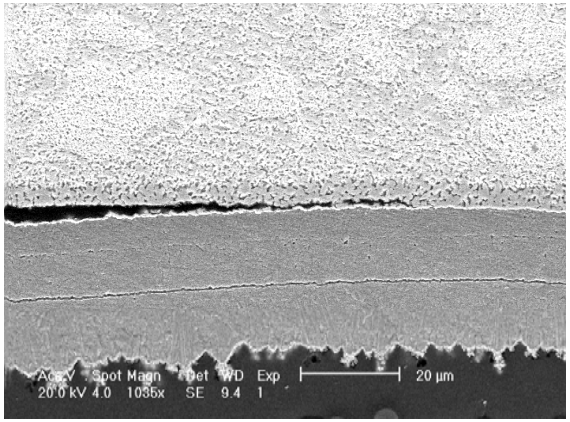


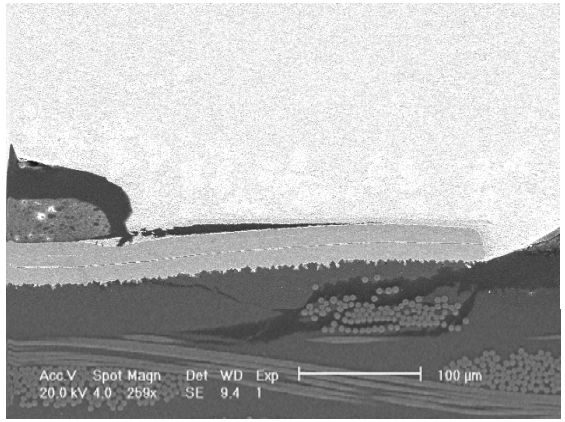
Failure Modes





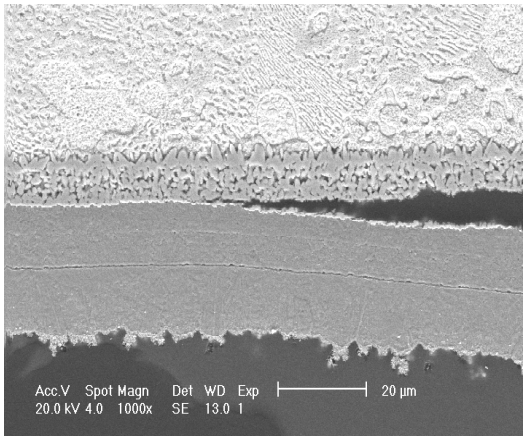
Ball , Copper and laminate separation (zero rework).

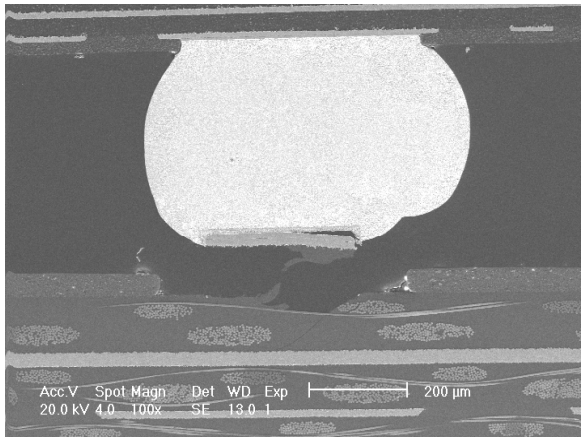




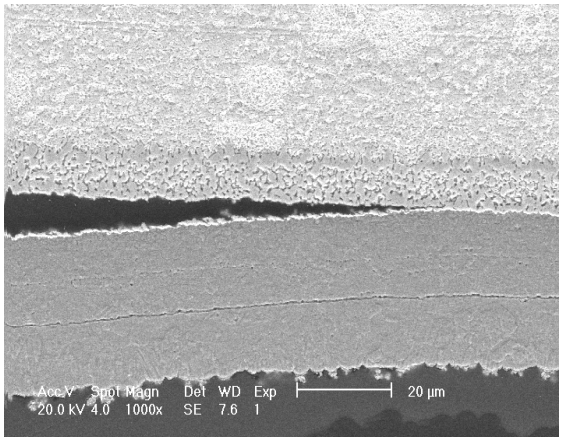
Failure modes of balls from first row of component after 1 rework cycle.

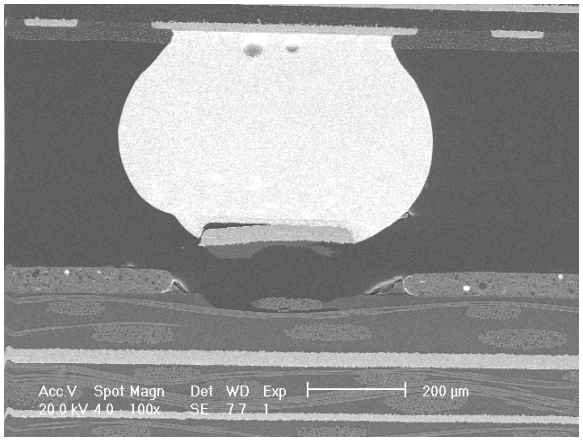
Failure Modes





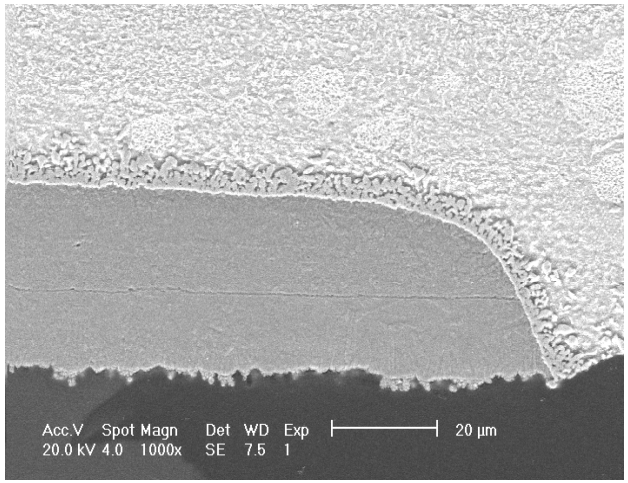
Ball partial cracking and laminate separation after 3 rework cycles.

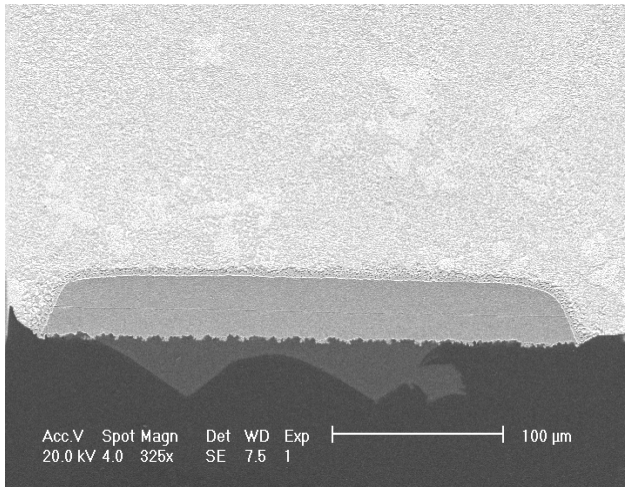




Ball 8-partial cracking and laminate separation 5 rework. cycles

Ball 3-no cracking from first row of component after 5 rework cycles.





The fracture mode categories were defined as follows:

0 - No cracking of within the solder, at the IMC interface, or within the PCB laminate.
1 – Ductile fracture within the bulk solder.
2 – Partial cracking at the IMC interface.
3 – Complete cracking through the IMC interface.
4 – Partial cracking of the PCB laminate.
5 – Complete separation of the Copper pad from the PCB laminate
6 – Mixed mode: Both partial cracking at the IMC and within the PCB laminate.

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Failure modes at each solder ball locations after 4 point bending testing

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
As-Received																																
Row AM	X	1	5	5	5	5	5	5	5	5	5	5	5	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	X
Row AL	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
R1																																
Row A	X	5	3	5	3	5	5	5	3	5	5	5	5	5	5	5	6	6	6	6	0	0	0	0	0	0	0	0	0	6	6	X
Row B	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	0	0	0	0	0	0	0	0	4	6	6	6
R2																																
Row AM	X	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	0	0	0	0	0	0	0	0	6	6	6	6	X
Row AL	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0	0	4	4	4	4	5
R3																																
Row AM	X	6	6	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	5	6	5	5	5	5	5	5	5	5	X
Row AL	6	6	6	6	6	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5
R5																																
Row AM	X	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	0	0	0	0	0	0	4	4	6	6	6	X
Row AL	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	0	0	0	0	0	0	0	0	6	6	6	6

0 no cracking
1 solder crack
2 partial IM crack, no laminate separation or cracking
3 complete IM fracture
4 no cracking in IM, partial cracking of laminate
5 complete laminate fracture
6 partial IM crack, partial laminate cracking

"X" indicates no ball is present due to Bga component construction

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Conclusions

- BGA solder ball strength was not reduced significantly after repair / rework operation from one up to five cycles.
- There is no indication from mechanical tests and cross-section optical / SEM analyses that this thick intermetallic layer would reduce the strength of BGA solder balls
- The bonding strength of the copper pads to the laminates is reduced with rework/repair operation.

This study indicates that further rework (up to 5) causes little further degradation, therefore there is room to increase the total rework cycle limit beyond recommended two for plastic BGA components.