IPC Electronics Midwest 2010

Drop Testing of a Pb-Free Board after Assembly and SnPb-Rework

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<u>Biography:</u>
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Eva graduated from the University of Toronto with a Bachelor of Engineering (Metallurgy and Material Sciences). She has over 10 years of experience at Celestica and is presently working in Performance Innovation Materials Lab. Previous roles at Celestica include Commodity Management, Supplier Quality Engineer and Project Manager of the Green Services™ team.

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Electronics Midwest

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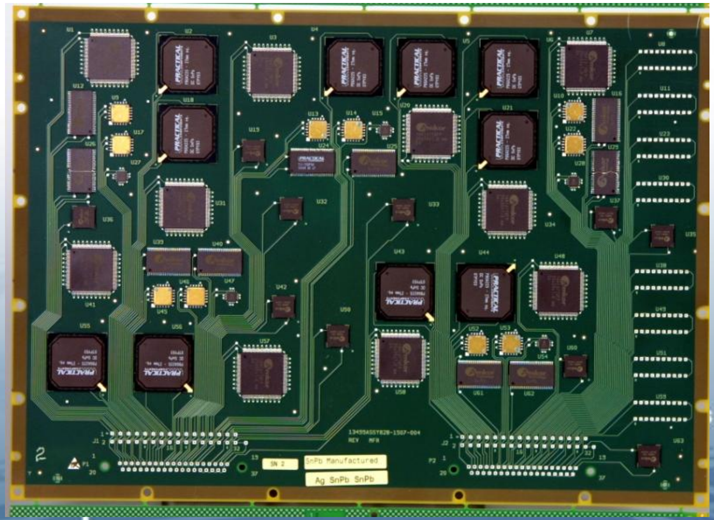
Introduction

- Pb-free: reality for military applications due to part constraints
- Harsh environments have high mechanical reliability requirements
- Mechanical reliability concerns due to:
  - Greater functionality = higher I/O = smaller pitch size
  - Pb-free COTS interconnects prone to brittle fracture
  - Little known about the affect of rework
  - Even less known about rework of Pb-free joints with SnPb
- Robustness of electronics in harsh environments includes drop testing
  - Evaluate high strain and strain rate conditions

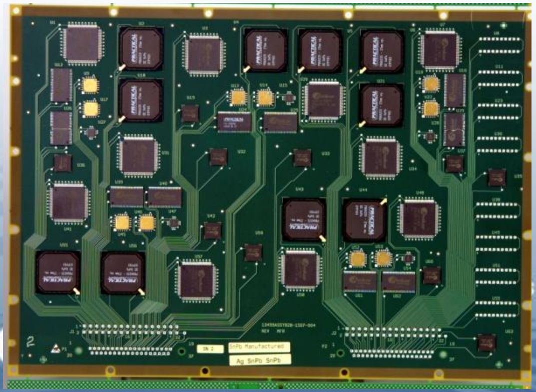
Intent and Objectives

- Investigate specific need of the military
  - Mechanical shock robustness of non-BGA, Pb-free components reworked with SnPb solder
- Military prefers one rework solution in the field
- Simpler than controlling both SnPb and a Pb-free rework processes



Project Overview

- Board-level drop shock test was performed on 9 assemblies
  - 63 parts / board
  - Parts representative of military package styles
- Assembled on Pb-free compatible laminate with SAC 305 solder
- Selection of the non-BGA parts reworked with SnPb solder
- Metallurgical characterization
- Assemblies fixtured to drop table and subjected to 500Gs for a total of 20 drops
- In-situ shock response, net resistance and strain recorded
- Physical FA performed to characterize mechanical damage



Test Vehicle Details

- Test vehicle designed by:
  - Joint Group on Pollution Prevention (JG-PP)
  - National Aerospace Agency (NASA)
  - Department of Defense (DoD)
- Designed to meet IPC-6012, Class 3 requirements
  - 6 layer board with 0.5-ounce copper
  - Pb-free FR4 laminate as per IPC-4101/26
  - Minimum Tg of 170° C
  - Immersion Ag finish
- 9 assemblies selected for this rework study

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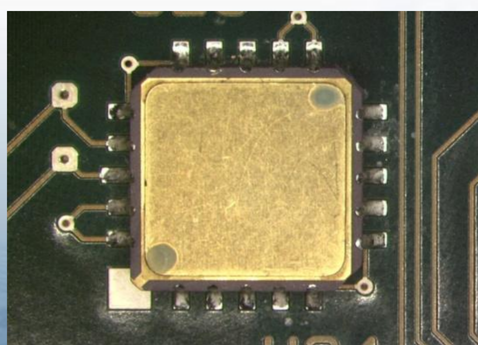
Experimental -Test Vehicle

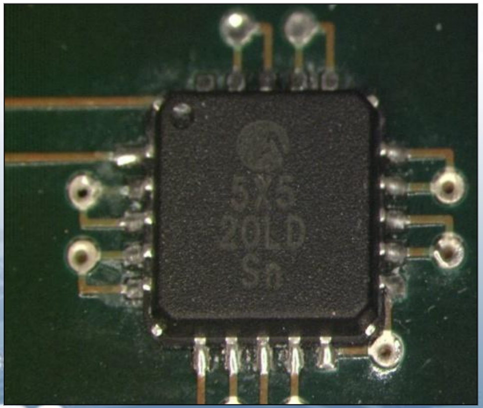
Package	Ball or Finish	Dimensions (mm x mm)	Pitch (mm)	TV-Drop
PBGA225	SAC405	27 x 27	1.5	U02, U04, U04, U06, U18, U21, U43, U44, U55, U56
CSP100	SAC 105	10 x 10	0.8	U19, U32, U33, U35, U36, U37, U42, U50, U60, U63
TQFP-144	Matte Sn	20 x 20	0.5	U01, U03, U07, U20, U31, U34, U41, U48, U57, U58
TSOP-50	Sn	10.16 x 20.95	0.8	U12, U25, U29, U39, U61
	SnBi	10.16 x 20.95	0.8	U16, U24, U26, U40, U62
PDIP-20	NiPdAu	7.5 x 26.16	2.54	U8, U23, U49
	Sn	7.5 x 26.16	2.54	U11, U30, U38, U51, U59
CLCC-20	SAC305	9 x 9	0.8	U09, U10, U13, U14, U17, U22, U45, U46, U52, U53
QFN	Matte Sn	5 x 5	0.65	U15, U27, U28, U47, U54


CLCC-20

TSOP-50

Rework Procedure

- Conductive, solder iron based rework on:
  1. TSOP
  2. TQFP
  3. CLCC (tack wrap procedure)
- Conductive processes as per IPC-7711:
  - Solder wicking & vacuum extraction
  - Heat, lift part, pad cleaning
  - Part placement & fluxing
  - Drag solder replacement & cleaning
- Con**v**ective, hot air rework for QFN devices



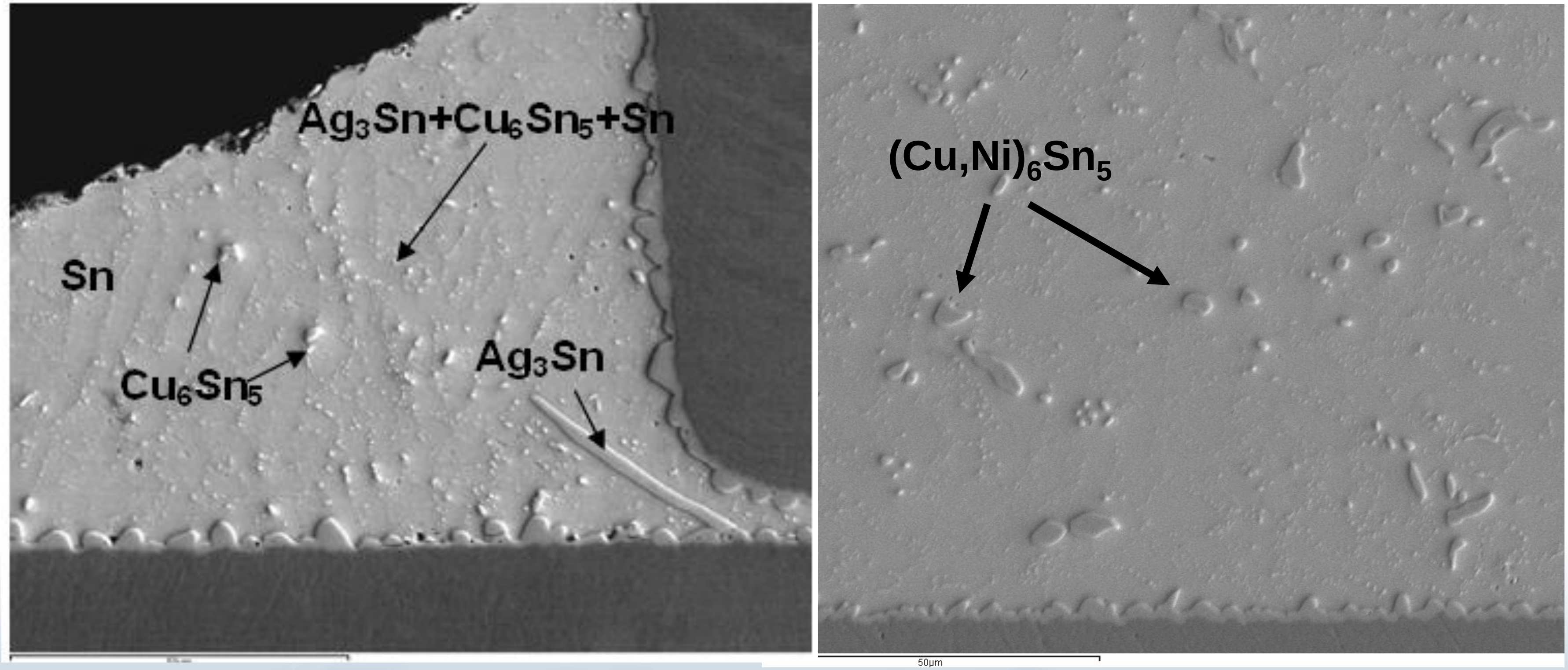
QFN

Microstructure Characterization

- Investigated metallurgy of 3 parts:
    1. TQFP (Cu lead frame)
    2. TSOP (alloy 42 lead frame)
    3. QFN (Cu lead frame)
- Investigated under 3 conditions:
    1. As-assembled SAC 305
    2. 1x rework with SnPb solder
    3. 2x rework with SnPb solder
- SEM / EDX was used to characterize intermetallics

TQFP-144

Microstructure Characterization

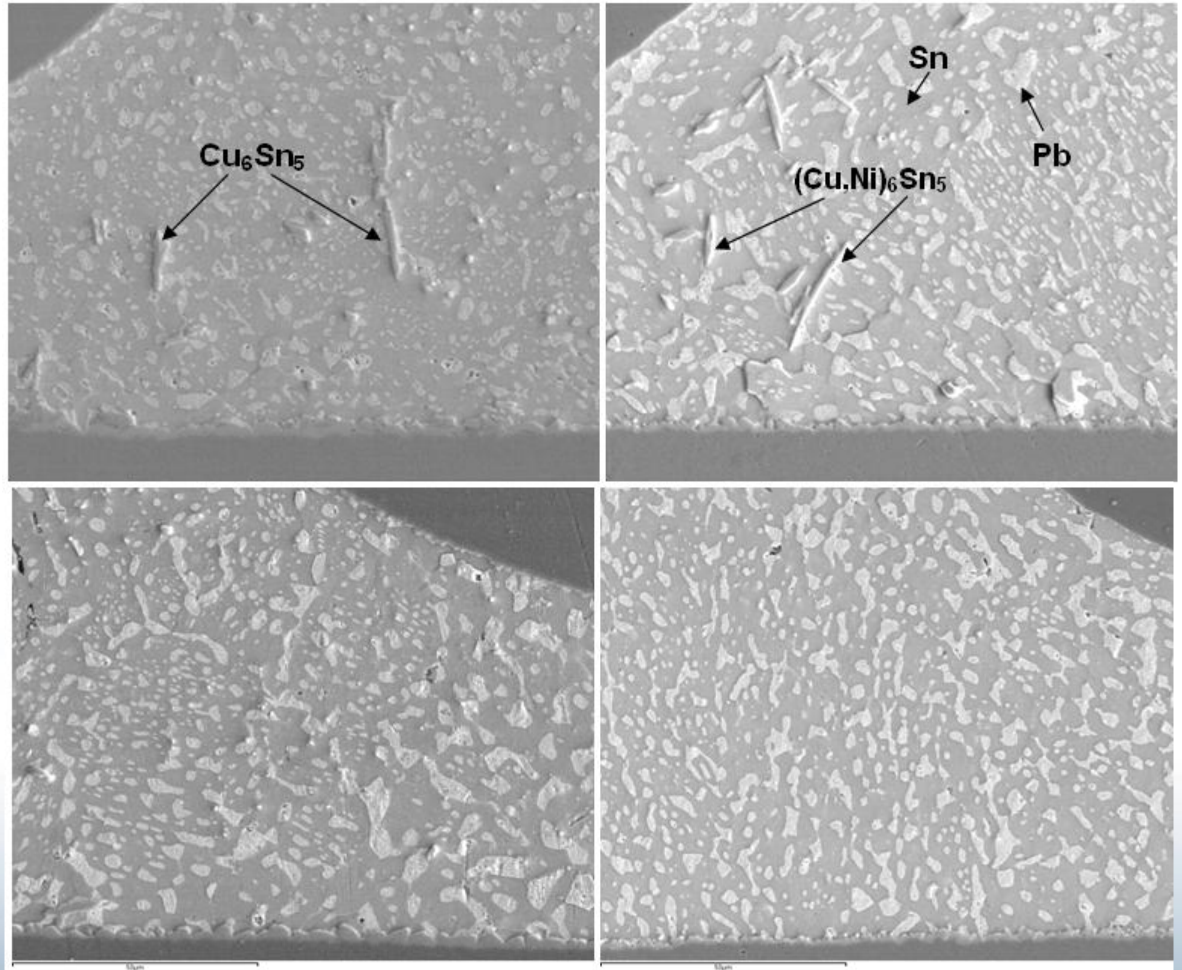


Microstructure of SAC305 solder joints before rework (SEM 1000x)
LHS = TQFP (Cu), RHS = TSOP (alloy 42)

Microstructure after Rework

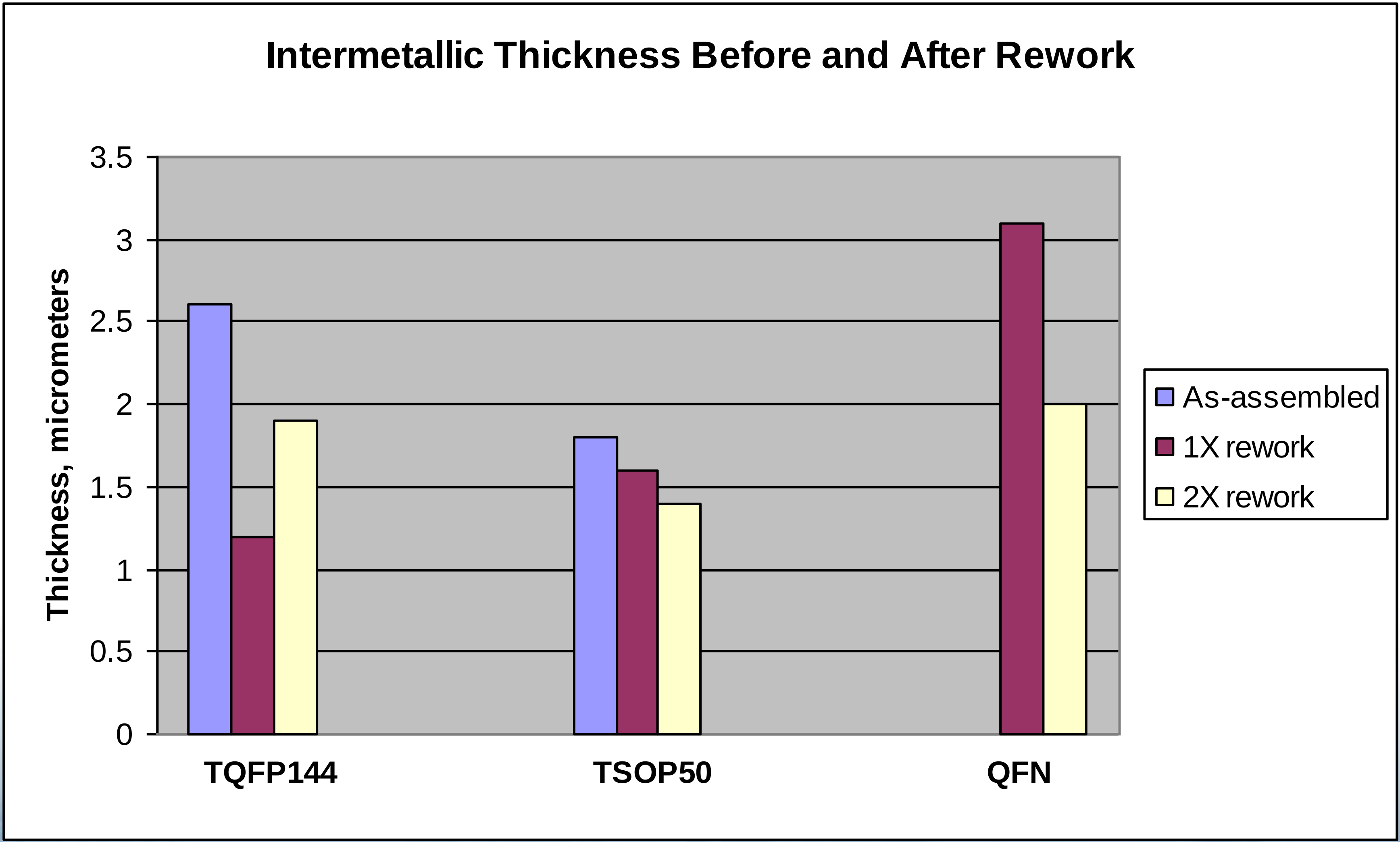
1x

2x

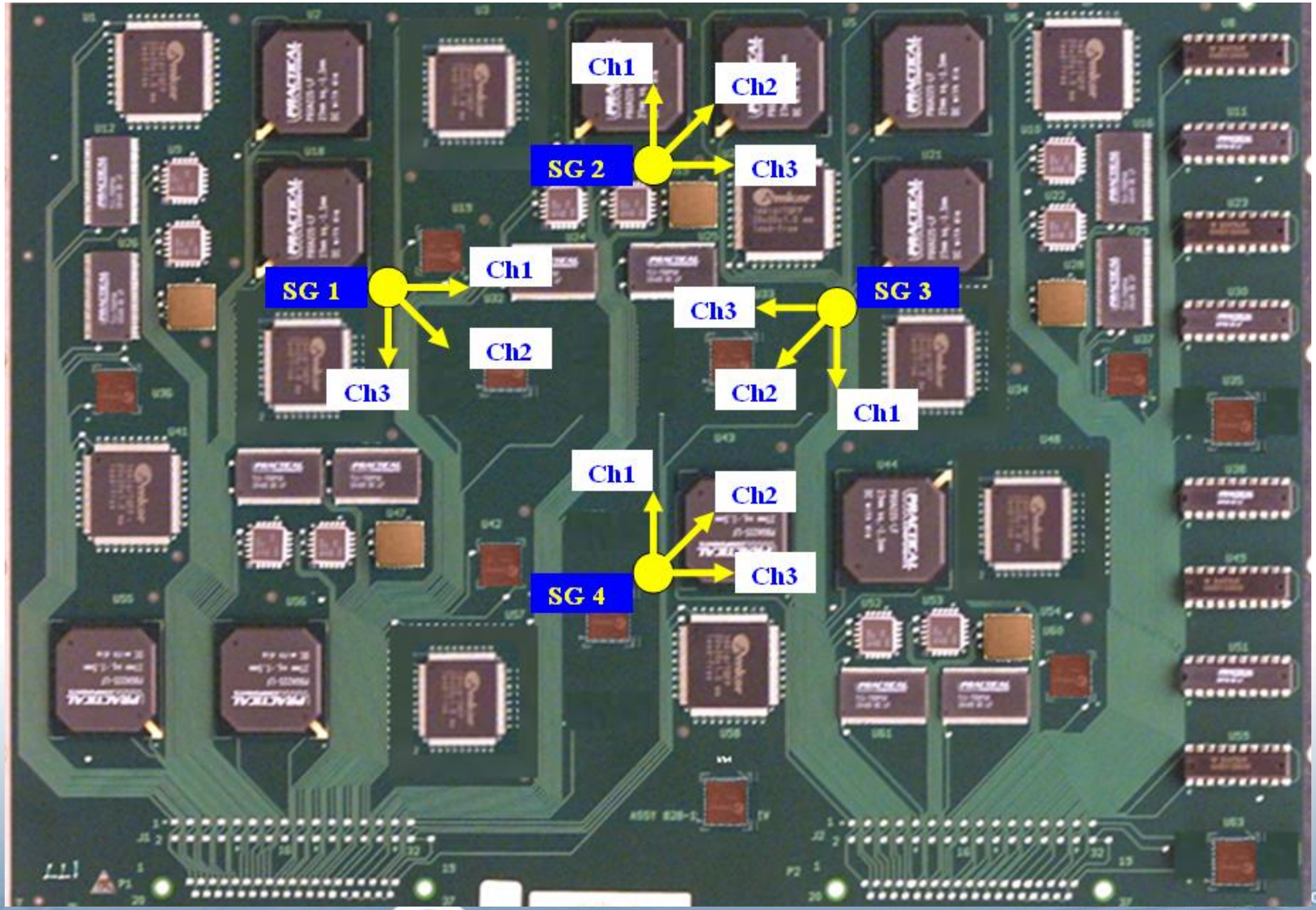


Microstructure of SAC 305 reworked using SnPb solder (SEM, 1000x)
LHS = TQFP (Cu), RHS = TSOP (alloy 42)

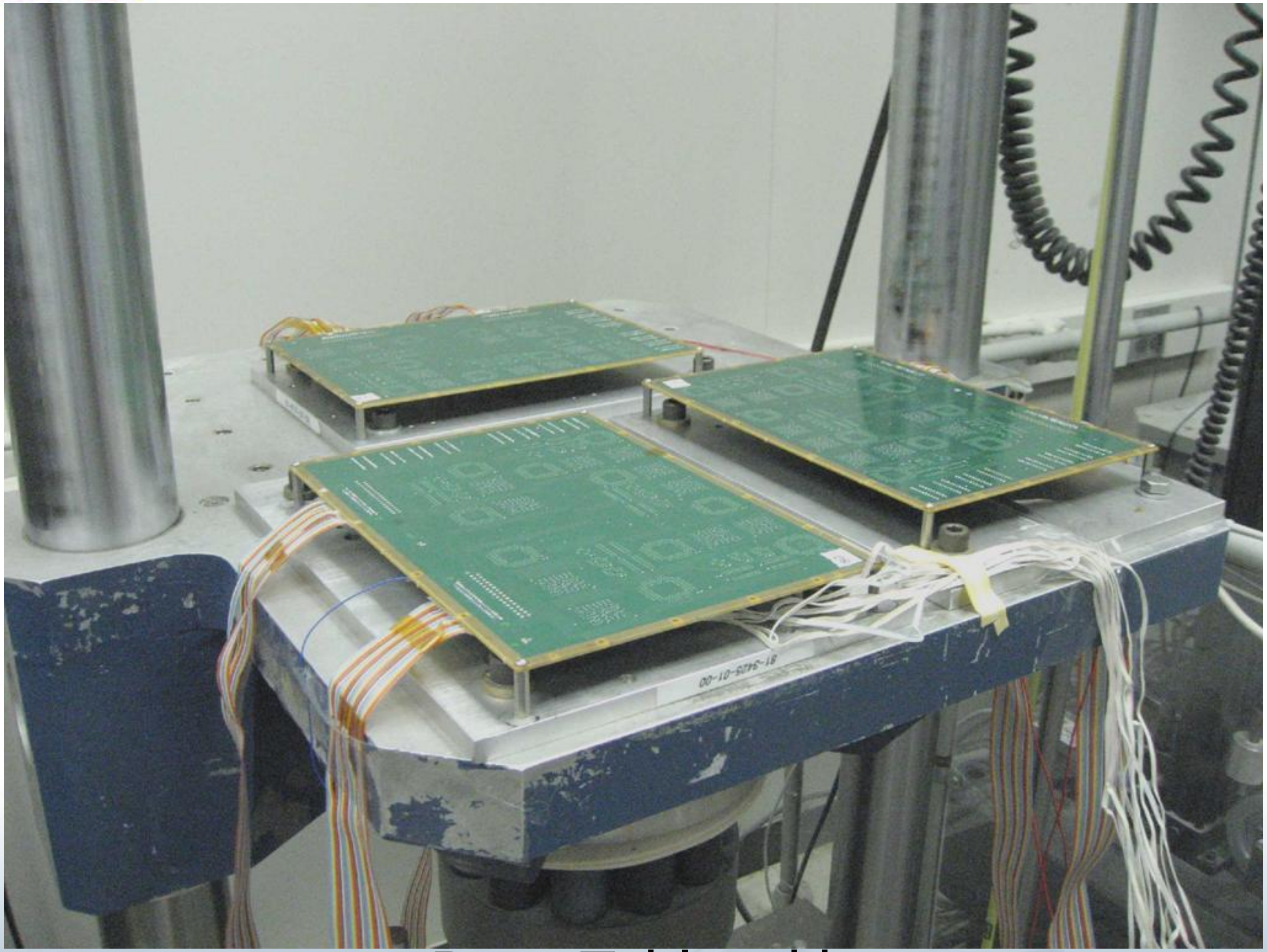
Microstructure Characterization



Experimental – Drop Test



Experimental –Drop Test



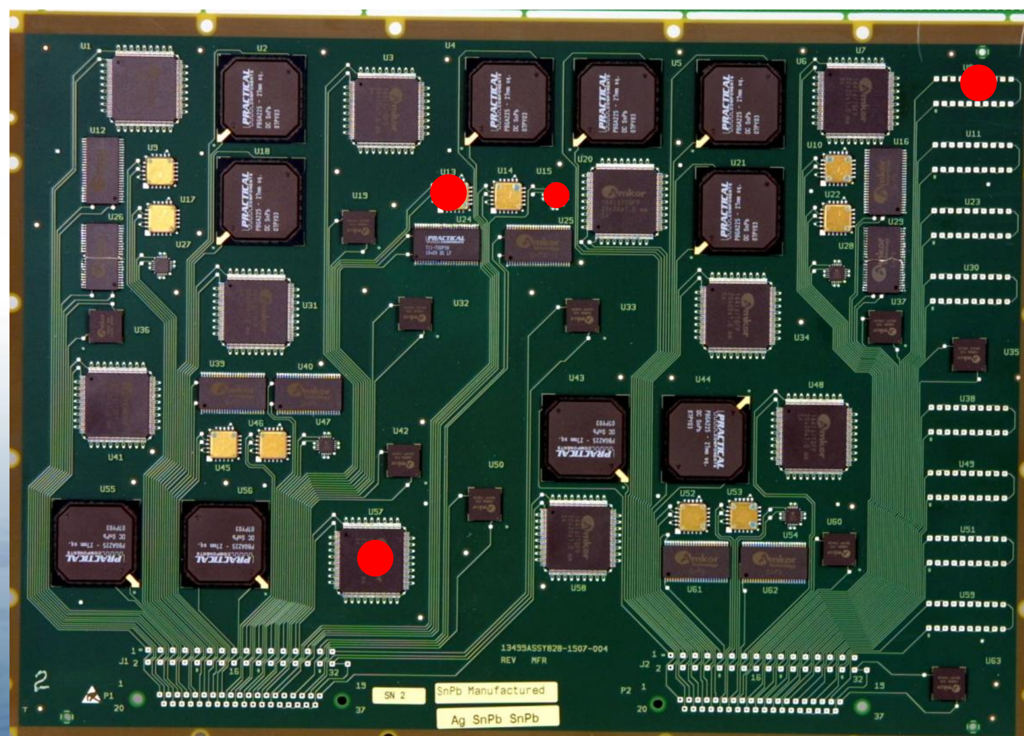
Drop Table with
Fixtured Test Vehicles

Drop Test Results

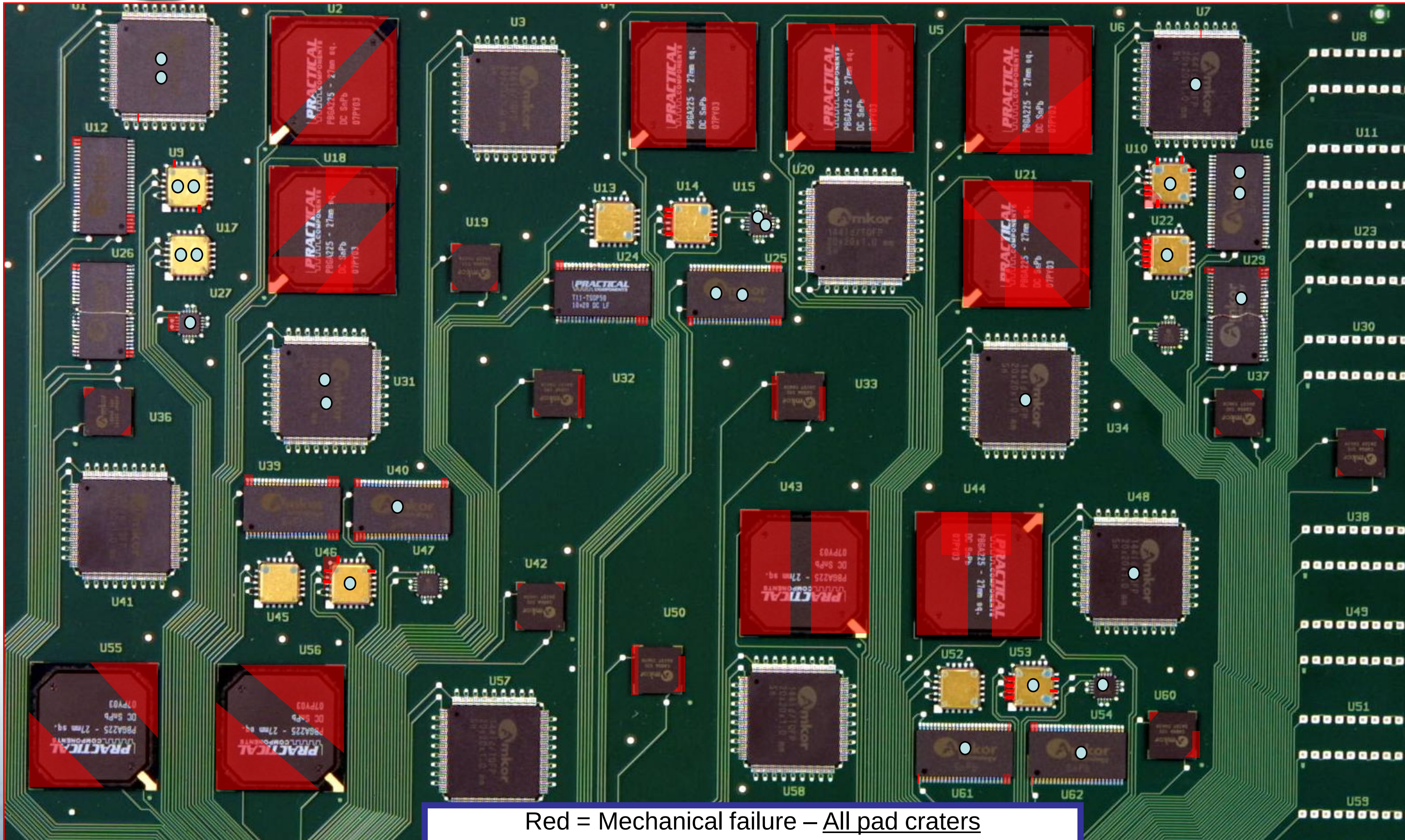
- Vast majority of electrical failures on PBGAs
  - Wide range in # of drops until failure
  - In-situ electrical **38%** (34/90) failed $\leq$ 5 drops
  - Suggests mechanical failure very few drops
  - **99%** (89/90) failed electrically after 20 drops
  - PBGA physical FA will be part of future work
- All 90 CSPs electrically passed drop testing
- 477 non-BGA components were tested
  - only **4 electrically** failed after 20 drops

Rework History of Electrical Fails

- Only **4** non-BGA electrical fails (< 1%)
  - Board SN 84, CLCC-20, U14 was **<u>not</u>** reworked
  - Board SN 85, TQFP 144, U57 **was** reworked **once** with SnPb
  - Board SN 85, PDIP-20, U8 **was** reworked **once** with SnPb
  - Board SN 86, QFN-20, U15 **was** reworked **twice** with SnPb



Mechanical Failures



Red = Mechanical failure – <u>All pad craters</u>

All BGAs are Electrically Failed

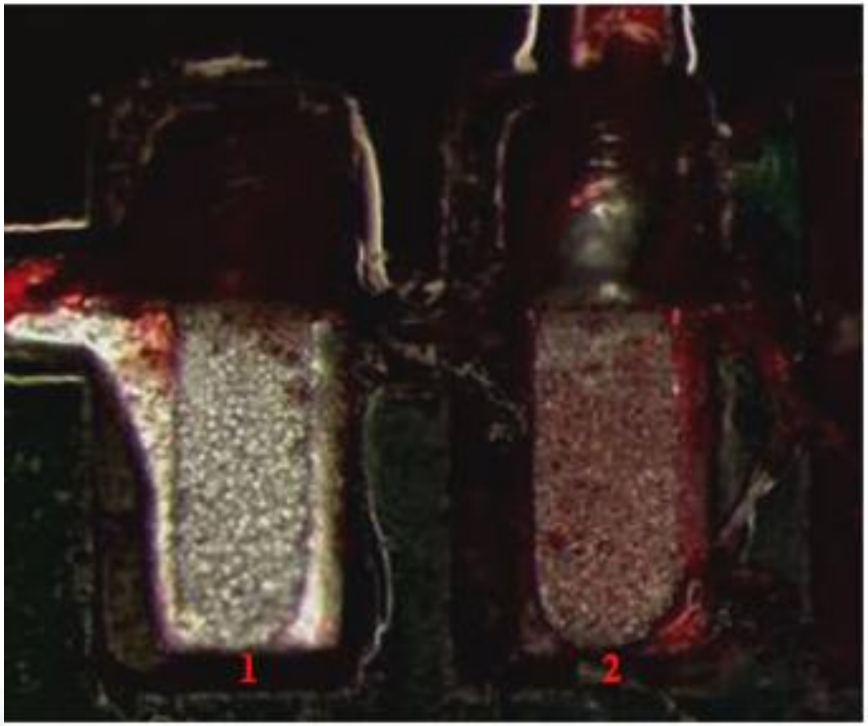
No leaded parts on this exact board electrically failed

Blue Dots on Some Parts = # of SnPb Hand Reworks

Experimental – Physical FA

- Remaining 8 cards:
  - 23 parts dye & pried
  - 15 parts cross-sectioned
- Dye & pry and cross-sectioning was used to determine the:
  - Failure location
  - Failure mode, and
  - Failure mechanism
- Only non-BGA components were examined in this exercise

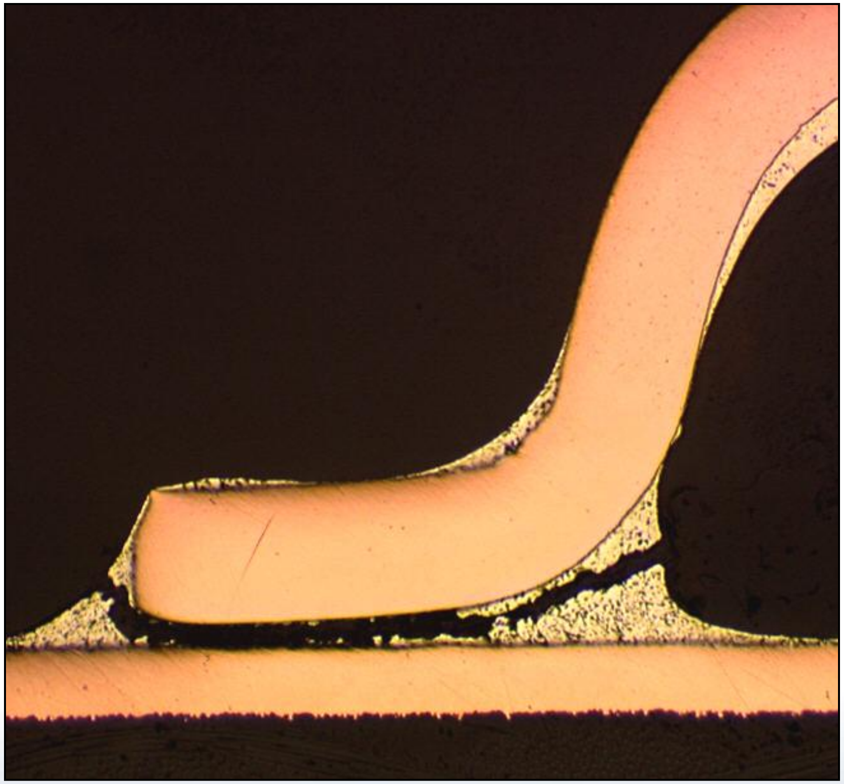
Summary of FA Results



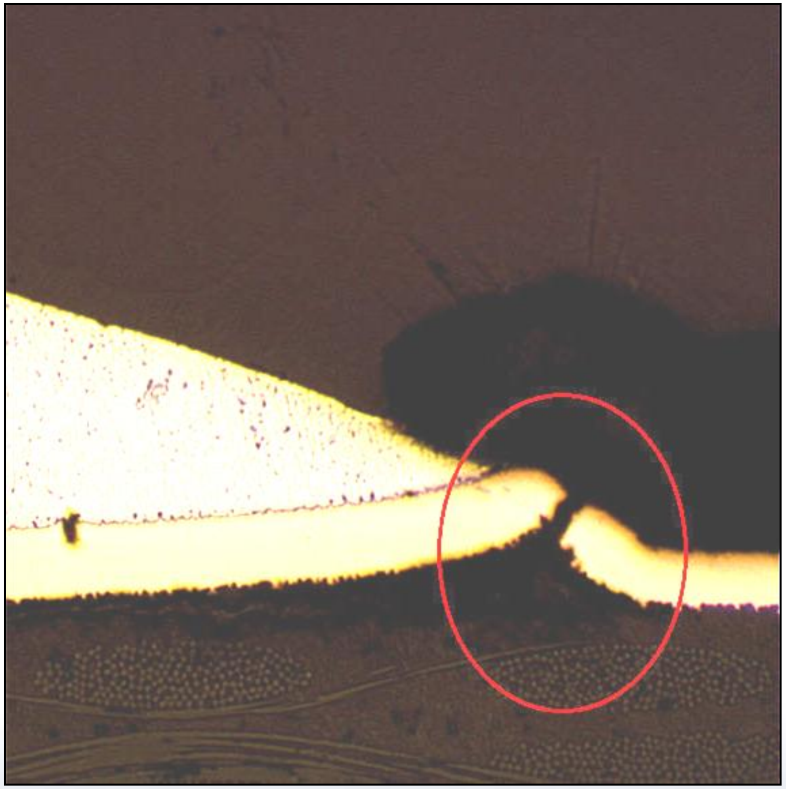
Solder Fracture,
Full Dye Penetration
(QFN, lead 2)

Pad Crater,
Partial Dye Penetration
(CLCC)

Summary of FA Results

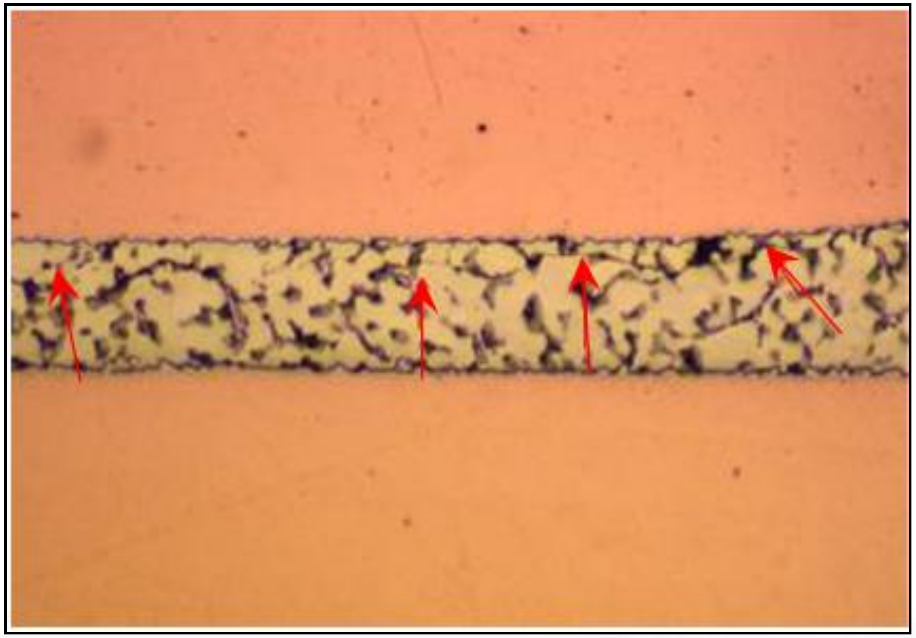


Solder Fracture
(TQFP-144, 1x rework)

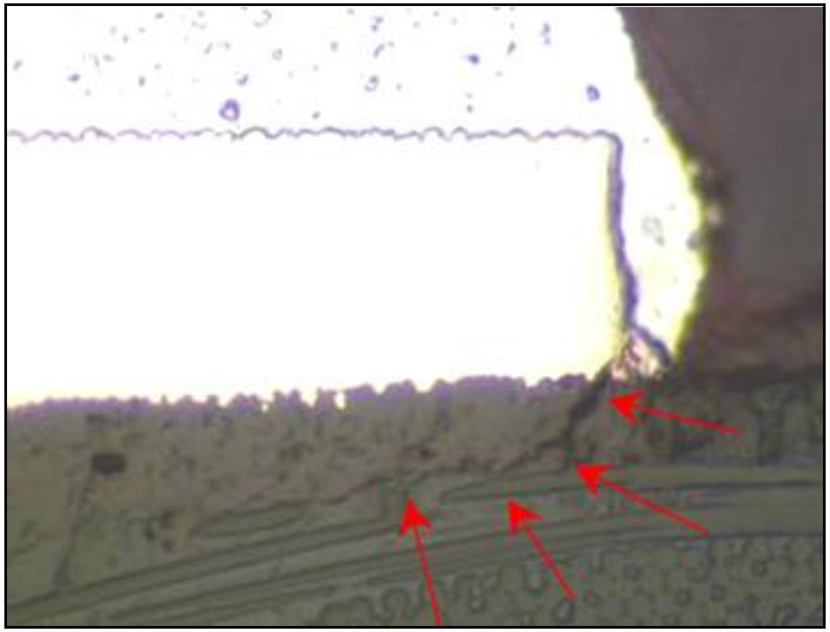


Pad Crater with Trace Break
(CLCC)

Summary of FA Results



Partial Solder Fracture
(QFN-20, 2x rework)



Partial Pad Crater
(QFN-20, 1x rework)

Conclusions

- Majority of non-BGA components survived drop testing
  - In-field rework of Pb-free parts with SnPb solder did not affect mechanical robustness
  - components reworked with SnPb solder are no less reliable than their Pb-free as-manufactured counterparts
- Both electrical and mechanical damage was at a minimum for non-BGA parts
  - Predominant failure mechanism was pwb-side pad cratering
- Electrical inspection not sufficient to assess mechanical robustness
  - ~1/3 of parts that passed electrical test had mechanical damage
- Drop testing showed early in-situ BGA electrical failures
  - mechanical damage may occur after only a few drops on BGAs

Future Work

- Follow-on NASA DoD Pb-free projects:
  - Failure analysis of the BGAs
  - Drop testing on reworked BGAs
  - Results of ATC & vibration testing
  - Future drop testing of non-BGAs will employ a larger number of drops per board

Acknowledgements

The authors would like to thank the following individuals for assistance with the failure analysis:

- Jie Qian and Zohreh Bagheri (Celestica)

Thank You