BGA Reballing for Mission-Critical Applications

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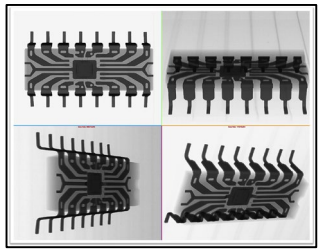
COMPANY OVERVIEW

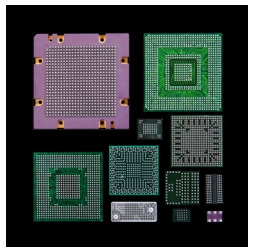
- Winslow Automation, Inc.: Parent Company
  - 1986 – Incorporated **(Celebrating 40 Years in 2026)**
    - Built fixtures for hot solder dip and automated equipment for semiconductor assembly
  - 1989 – FlexLine® Robotic Solder Dip System
    - Developed for major semiconductor manufacturers (ATT, TI, LSI Logic, etc.) for military product lines

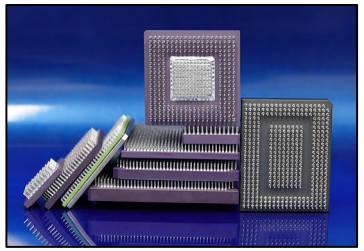
- Six Sigma: Subcontract Services Division
  - Founded in 1990
    - Provide solutions for high-reliability integrated circuits (ICs) primarily used in military and space applications

SIX SIGMA MICROELECTRONICS

- Areas of Expertise (All Performed In-House)
  - Robotic Hot Solder Dip: 22M+ hot solder dipped devices since 1990
  - Ball Attach & Reballing: 3M+ reballed BGAs since 1997
  - Solder Column Mfg: 200M+"Genuine" Six Sigma Solder Columns since 1996
  - Column Attach: 250K+ column attached CGAs since 1998
  - Analytical Services: SEM-EDS, 2D X-Ray w/ CT, Acoustic Microscopy, Solderability, Hermeticity, PDT, XRF, Column Pull, etc.





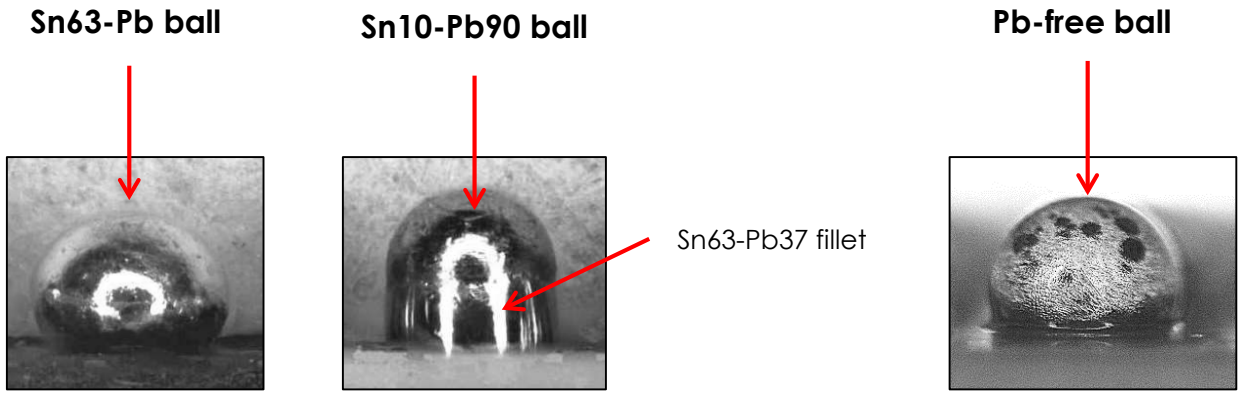


QUALIFICATIONS

- **QML-V/Y/Q** Certified for Column Attach and Hot Solder Dip
- **DLA Laboratory Suitability** Approved for Military Product (Environmental Testing)
- **AS9100** (Aerospace) Certified
- **ISO 9001** Certified
- **ITAR** Registered
- **DMEA Trusted** (Secret-Level Facility Clearance)

WHAT IS BGA REBALLING?

- Removal of existing solder ball and replacement with another solder ball
- Different configurations:
  - Pb-free to Sn63-Pb37
  - Pb-free to Pb-free
  - Sn63-Pb37 to Pb-free
  - Sn63-Pb37 to Sn63-Pb37
  - Sn63-Pb37 to Sn10-Pb90



WHY BGA REBALLING?

- Diminished availability of Sn-Pb BGAs due to RoHS Directives
  - Commercial market has moved to Pb-free (but the military is still using Sn-Pb)
    - RoHS Restricted Substances (6 + 4)
      - Cadmium (Cd): < 100 ppm (used in batteries, metal coatings, pigments)
      - **Lead (Pb): < 1000 ppm** (used in solder, batteries, CRT glass)
      - Mercury (Hg): < 1000 ppm (used in fluorescent lamps, switches, thermostats)
      - Hexavalent Chromium (Cr VI): < 1000 ppm (used in metal finishing)
      - Polybrominated Biphenyls (PBB): < 1000 ppm (flame retardants in computer monitors and plastics)
      - Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm (flame retardants in plastic enclosures)
      - ***Bis(2-Ethylhexyl) phthalate (DEHP):*** < 1000 ppm (plasticizer for PVC and vinyl insulation on electrical wires)
      - ***Benzyl butyl phthalate (BBP):*** < 1000 ppm (plasticizer for PVC and vinyl insulation on electrical wires)
      - ***Dibutyl phthalate (DBP):*** < 1000 ppm (plasticizer for PVC and vinyl insulation on electrical wires)
      - ***Diisobutyl phthalate (DIBP):*** < 1000 ppm (plasticizer for PVC and vinyl insulation on electrical wires)

WHY BGA REBALLING? – cont'd

- Primary Reasons for BGA Reballing
  - Reliability concerns with mixed assemblies
    - Sn-Pb boards with Pb-free BGAs
  - Replacement of damaged solder balls
  - **Sn-Pb is more ductile (less brittle), and therefore, makes a more reliable solder joint**
  - **Restore solderability**

Sn-Pb ALLOYS

- Advantages
  - Lots of data available
  - Lower melting point
  - Good wetting
  - Good mechanical properties
  - Pb does not form IMCs with other constituents in the system
  - Better solder joint reliability
- Disadvantage
  - Toxic

Pb-Free ALLOYS

- Sn-based alloys > 90% wt Sn
- Most commonly used: Sn-3.0Ag-0.5Cu (SAC 305)
- Advantages
  - Good wetting
  - Good mechanical and electrical properties
  - Non-toxic
- Disadvantage
  - High soldering temperatures
  - IMCs, dissolution of base metal, spalling, and voiding
  - Brittle

INDUSTRY REBALLING STANDARDS

- J-STD-001
  - Requirements for Soldered Electrical and Electronic Assemblies
- GEIA-STD-0006
  - Requirements for Using Solder Dip to Replace the Finish on Electronic Piece Parts
- IEC TS 62647-4: International Electrotechnical Commission
  - Process management for avionics – Aerospace and defence electronic systems containing lead-free solder
    Part 4: Ball grid array (BGA) re-balling
    - Not for Column Grid Array (CGA) or Chip-Scale components
    - Addresses 2 types of configurations:
      - Configuration 1: A BGA package that will be deballed & then reballed with Sn-Pb balls compatible with a Sn-Pb soldering assembly process
      - Configuration 2: A BGA package that will be deballed & then reballed with Pb-free balls compatible with a Pb-free soldering assembly process
    - Intended to be used by deballing/reballing providers and customers, typically avionics OEMs (but can also be used by other industry sectors at their discretion).

SIMPLIFIED REBALLING PROCESS

- Incoming Inspection
  - Inspect devices for incoming issues
- Ball Removal (Deball)
  - Remove existing solder balls
- Reballing
  - Attach new solder balls
- Inspection & Testing
  - Inspect devices after reballing & test (solderability, ball shear, ionic cleanliness, etc.)
- Marking
  - Designate that BGA has been reballed from one alloy composition to another

IEC TS-62647-4 MAIN REQUIREMENTS

- Deball
  - Temperature Excursions: Thermal profile for the specific BGA; should not introduce add'l thermal stresses.
  - Flux: Shall be in accordance with J-STD-004 or equivalent (preferably ROL0, REL0, or ORL0); applied before preheat.
  - Preheat: Supplier determines if preheat is needed; if needed, ramp up rates & T_p shall not exceed OCM specification.
  - Solder Ball Removal (Deball): The previous alloy shall be removed and pads left protected w/ replacement solder alloy; the process shall not scratch the pads or damage the solder mask.
  - Cool Down: Minimize thermal shock before cleaning; cooling rates shall not exceed OCM specification.
  - Post-clean: BGA component and pads thoroughly cleaned to remove all flux residues and contaminants.

IEC TS-62647-4 MAIN REQUIREMENTS – cont'd

- Reballing
  - Solder Paste: Shall be in accordance with J-STD-005 or equivalent.
  - Ball Placement: Ensure tooling is properly selected to maintain BGA alignment and coplanarity.
  - Preheat: Supplier determines if preheat is needed; if needed, ramp up rates & T_p shall not exceed OCM specification.
  - Reflow Temperature Profile: The supplier shall have an appropriate atmosphere, temperature profile, and solder alloy; ensure control over temperature excursions per IPC J-STD-001.
  - Cool Down: Minimize thermal shock before cleaning; cooling rates shall not exceed OCM specification.
  - Post-Clean: BGA shall be thoroughly cleaned to remove all flux residues and contaminants; cleaning shall be performed within time limit per OCM specification.

ELECTRONIC COMPONENT CLASSES

CLASS	DESCRIPTION	CLASS DEFINITION
1[a]	General electronic products	Products suitable for applications where the major requirement is function of the complete assembly.
2[a]	Dedicated service electronic products	Products where continued performance and extended life are required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.
3[a]	High performance / harsh environment electronic products	Products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment can be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.
Space[b]	High performance / extremely severe environment electronic products	Products where performance is required for surviving the vibration and thermal cyclic environments getting to and operating in space.

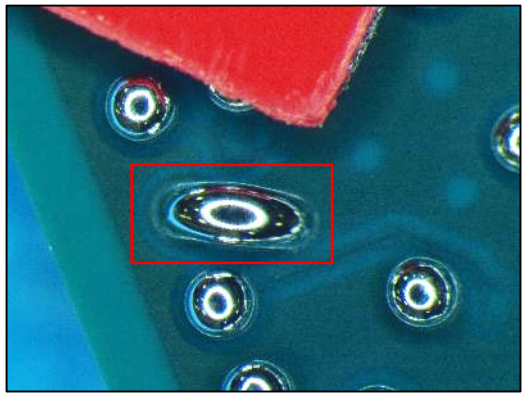
[a] See IPC J-STD-001
[b] See IPC J-STD-001xS (Space Addendum)
**Table per IEC TS 62647-4*

TYPICAL PRODUCTION LOT TEST METHODS

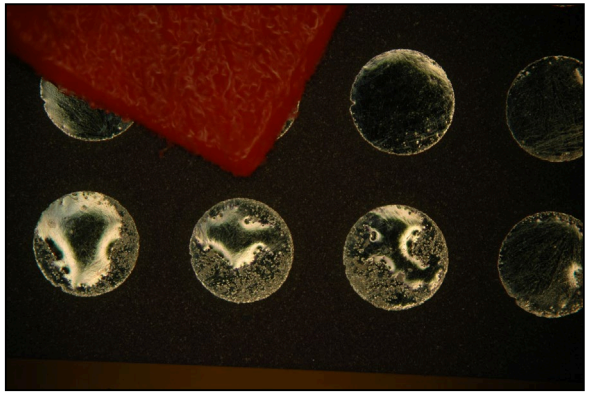
TEST METHOD (TM)		Sample Size
Post-Reballing	TM 100 (Visual Inspection)	100%
	TM 300 (Acoustic Microscopy – PEMs Only)	10
	TM 500 (Ionic Cleanliness)	3
	TM 600 (Solderability)	3
	TM 1000 (DPA)	3
	TM 1100 (X-Ray Inspection)	3
	TM 1200 (XRF)	3
	TM 1300 (Ball Shear)	3

**Table per IEC TS 62647-4*

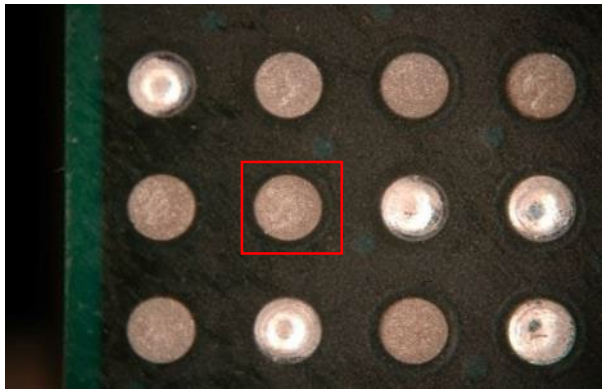
EXAMPLES OF REBALLING ISSUES



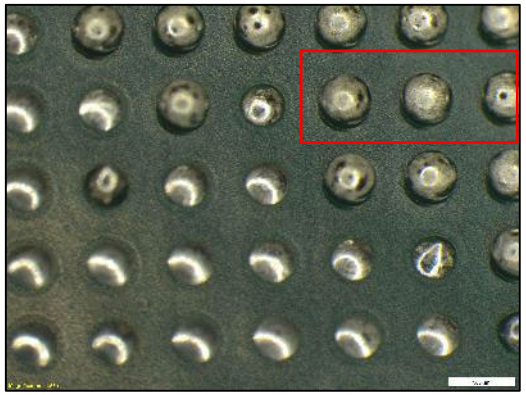
Bridging



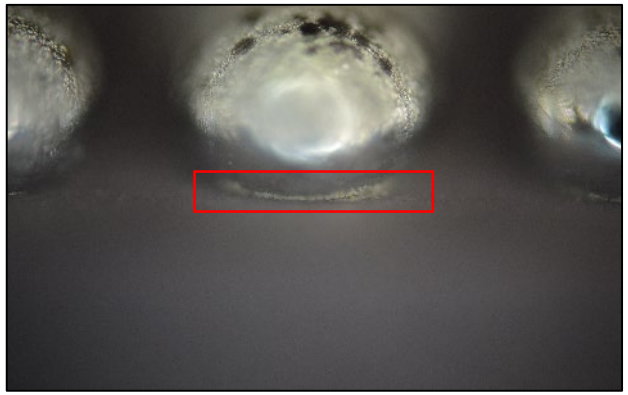
Pad dewetting



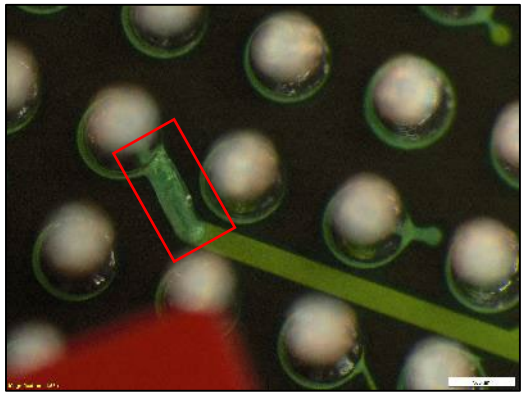
Oxidized pads



Incomplete deball

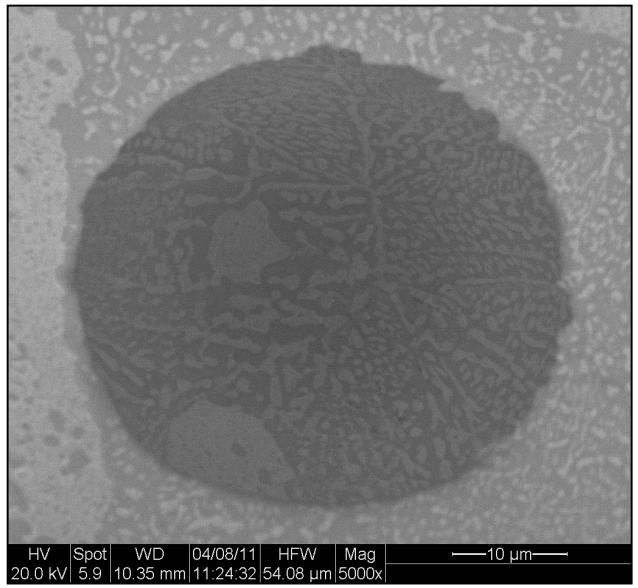


Residue around the solder ball

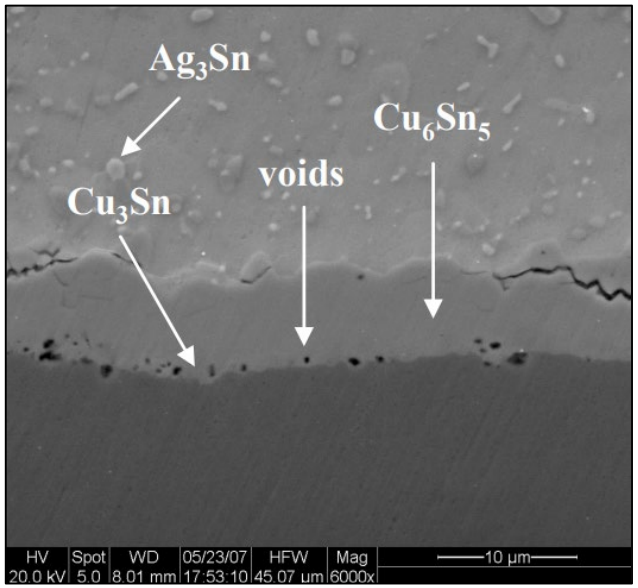


Solder wicking

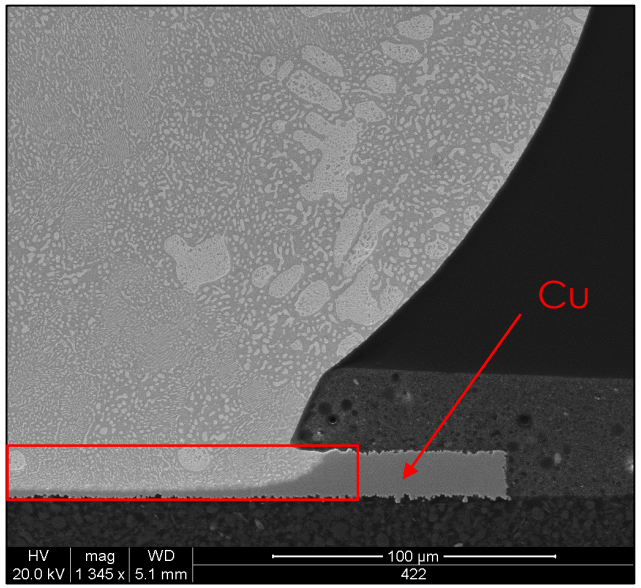
EXAMPLES OF REBALLING ISSUES – cont'd



Void



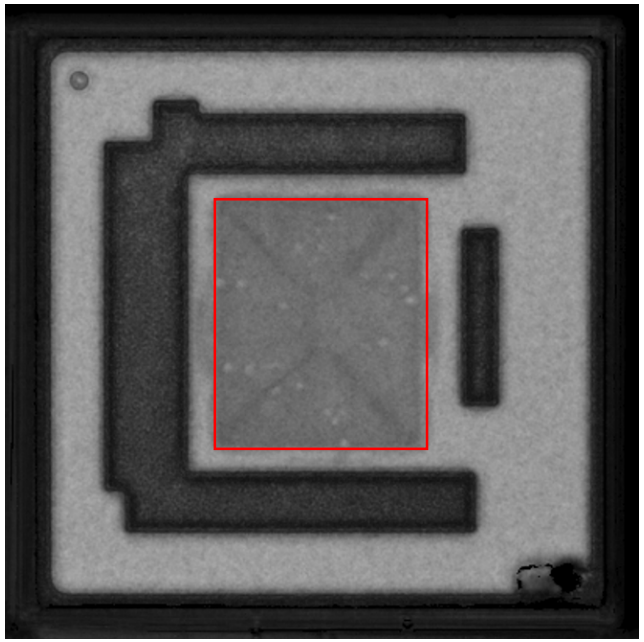
IMCs



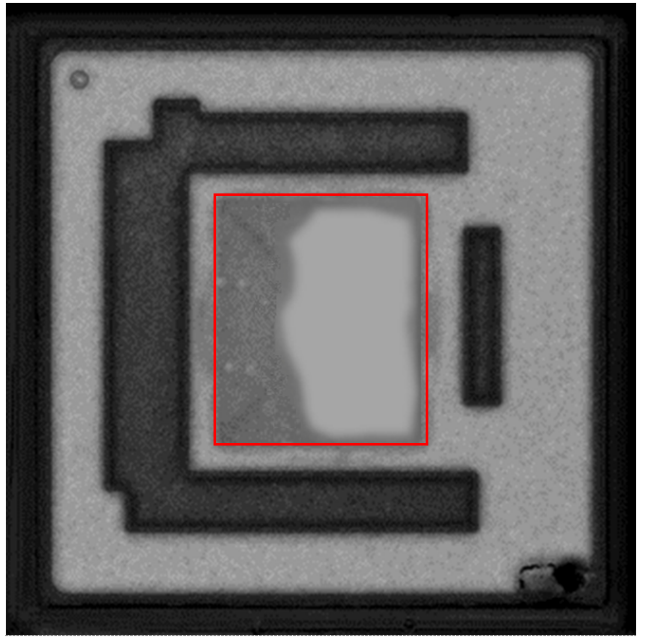
Cu Dissolution

SEM

EXAMPLES OF REBALLING ISSUES – cont'd



TIM (as-received)



TIM (after processing)

Acoustic Microscopy

TO REBALL, or NOT TO REBALL: THAT IS THE QUESTION

- When to Reball
  - To change from one solder alloy to another
  - To restore solderability after testing (e.g., burn-in)
  - To restore solderability of an obsolete device
  - To improve board-level reliability by increasing stand-off (high-Pb BGA or CGA)

- When Not to Reball
  - To salvage a replaceable device
  - When the desired alloy is readily available
  - When reballing could jeopardize the reliability of the device

SUMMARY

- Sn-Pb and Pb-free solder alloys have their advantages and disadvantages, and users need to carefully assess what their "acceptable risks" are.
- Users need to decide when it is beneficial to reball and when they should look for alternative solutions.
- Reballed BGAs can be used for mission-critical applications as long as qualified and approved reballing suppliers are utilized.
  - As a minimum, the reballing supplier must be compliant with the applicable industry standards.

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Thank You!

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