ÓBUDAI EGYETEM
BÁNKI DONÁT GÉPÉSZ ÉS
BIZTONSÁGTECHNIKAI MÉRNÖKI KAR

Assessment of application of PCA rework at large manufacturers

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Definitions

- Rework – the act of reprocessing noncomplying articles, through the use of original or equivalent processing, in a manner that assures full compliance of the article with applicable drawings or specifications.
- Repair – the act of restoring the functional capability of a defective article in a manner that does not assure compliance of the article with applicable drawings or specifications.
- Printed Circuit Assembly (PCA or PCBA) - An assembly that uses a printed circuit board for component mounting and interconnecting purposes.
- Limitation of rework – IPC-7711/21 (Rework, modification and repair of electronic assemblies) standard doesn’t limit the maximum number of rework actions to a PCA.
- User - The individual, organization, company or agency responsible for the procurement of electrical/electronic hardware and having the authority to define the class of equipment and any variation or restrictions.

Source: Ref. 1.

Introduction

- In automotive electronics industry, the rework of solder joints of PCA is generally not permitted.
- The prime cost of scrapped reworkable products can range from a few 1k EUR to as much as a 100k EUR per month!
- Case studies to demonstrate why manual rework is banned in automotive industry.
- Based on reference studies, the lifetime results of reworked solder joints of several component packages (chip, TSOP, BGA) are summarized.
- Reasons whether it is possible/reasonable to rework automotive products without risking the reliability of the product.

A few word about manual rework process

Steps of manual rework process

1. component desoldering,
2. solder lands (pads) preparation,
3. component installation.

Two common defects introduced by manual rework

1. Microbridge formation
2. Dendrite formation

Microbridge formation

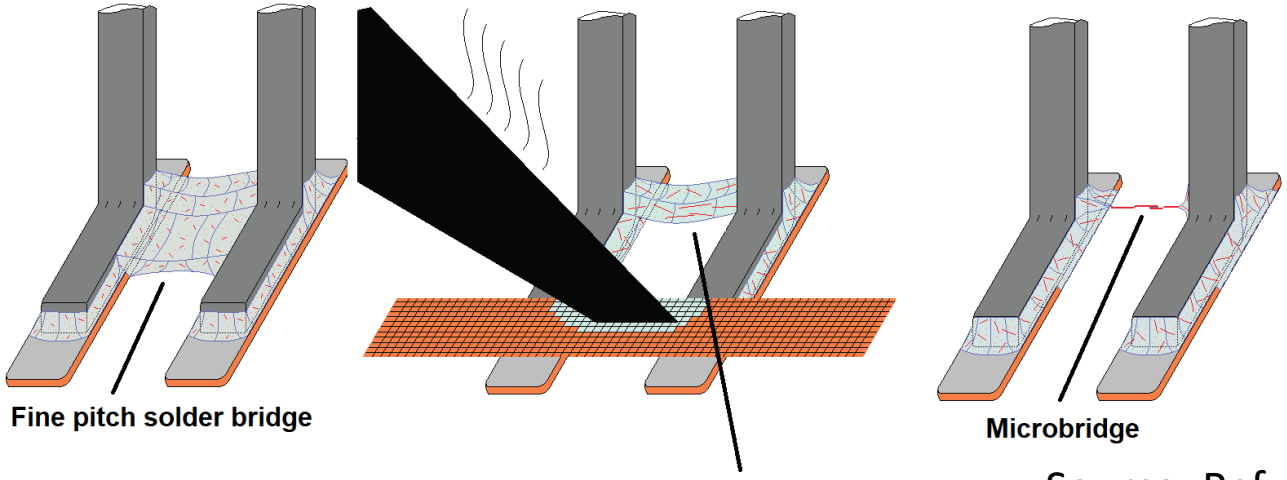
Solder: Sn63Pb37, component: SOIC, pitch:0.64 mm, gap:0.24 mm,

Microbridge caused short circuit between component leads during rework.

Steps of microbridge formation:

- Solder bridge is already saturated with copper.
- During rework the solder bridge return to the liquid state.
- Additional Cu from lands, leads and desoldering braid dissolve to the solder.
- It is form Cu_6Sn_5 crystals. (Melting point of this crystal: 415 °C)

Cause: the partially soaked desoldering braid was applied along the extreme outside edge of the lands! (In this case there was enough time for copper dissolution.)



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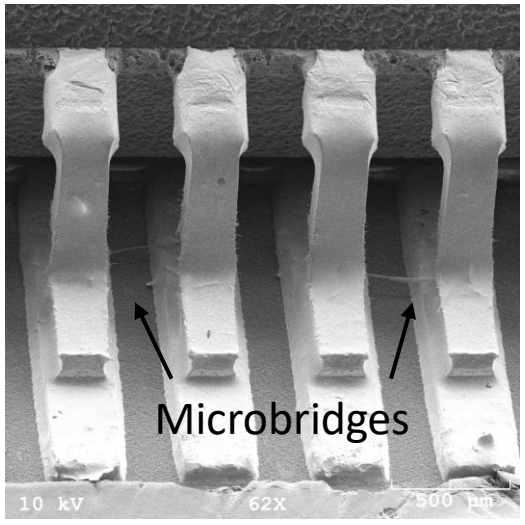
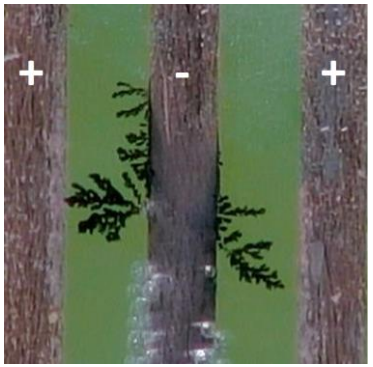


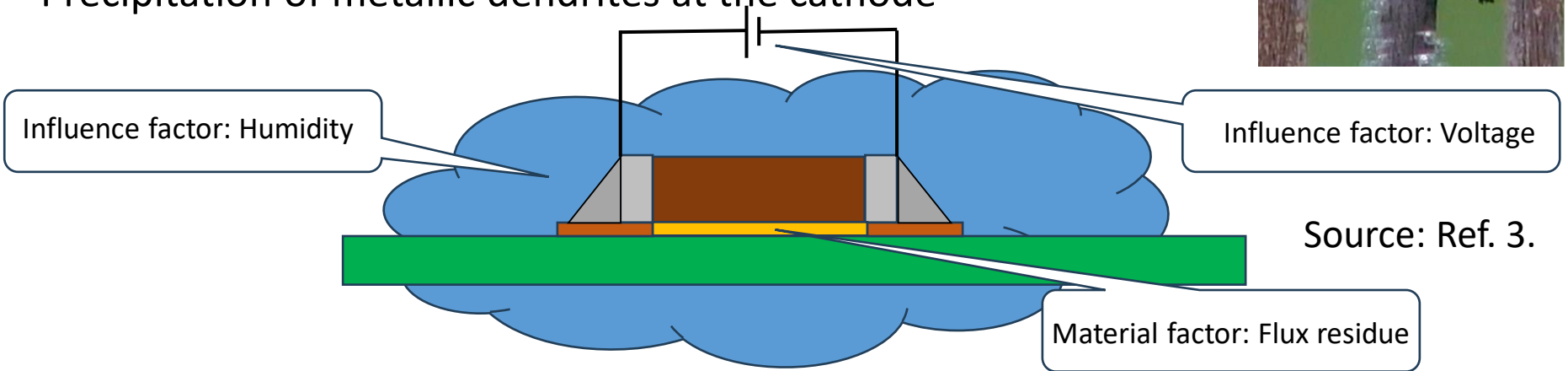
Dendrite formation

Steam/humidity + ionic contaminations (e.g. flux) = Conductive electrolytes + Stress voltage = **Electrochemical migration (ECM)**

Mechanism:

- Water dissociates under voltage (OH^- formation) at the cathode.
- Local increase of pH value (alkalization) on the cathode.
- Alkaline and acidic ranges form in the water film. (Corrosion of metal surfaces get started.)
- Dissolution metal (cations) at the anode.
- Ion migration to the cathode due to potential difference.
- Precipitation of metallic dendrites at the cathode





Source: Ref. 3.

Dendrite formation

Component packages to be discussed

2512 Chip resistor

- 6.4 x 3.2 mm
- Thick film resistive layer covered by glass protecting coting.
- High grade (Al_3O_3) ceramic substrate.
- Typical applications include automotive, telecommunications, and industrial.

50-TSOP – Thin Small Outline Package

- 10.16 x 20.95 mm.
- Gull-wing lead component, package thickness: 1 mm.
- Lead pitch: 0.8 mm.
- They are frequently used for RAM or Flash memory.

FCBGA - Flip Chip Ball Grid Array

- A surface mount package where balls for terminations are formed in a grid on the bottom of a package.
- 1849 I/O with SAC305 solder.
- 1 mm pitch distance, solder ball dia. 0.5 – 0.6 mm
- Application area: processors for high bandwidth system and communication devices.

Passive components

Components: 2412 (6.3 x 3.2 mm) chip resistor. Solder: SAC305; PCB: FR4 with OSP finish

Rework: hot air for desoldering, copper desolder brad for land redressing, standard soldering iron (tip temp: 371 °C) for installation

Temperature cycles: -55 – 125 °C with 15 min dwell time (overall cycle time 72 min.)

Rework times	Position type	Characteristic life
3x	Rework	4474
	Adjacent	21975
1x	Rework	8249
	Adjacent	16050

- The fatigue life of one-time reworked and three-time reworked parts experienced about a 49% to 79% reduction compared to adjacent components.
- The fatigue life of the solder joint increase with the solder thickness. The lower thickness shows bad fatigue resistance.

Source: Ref. 4.

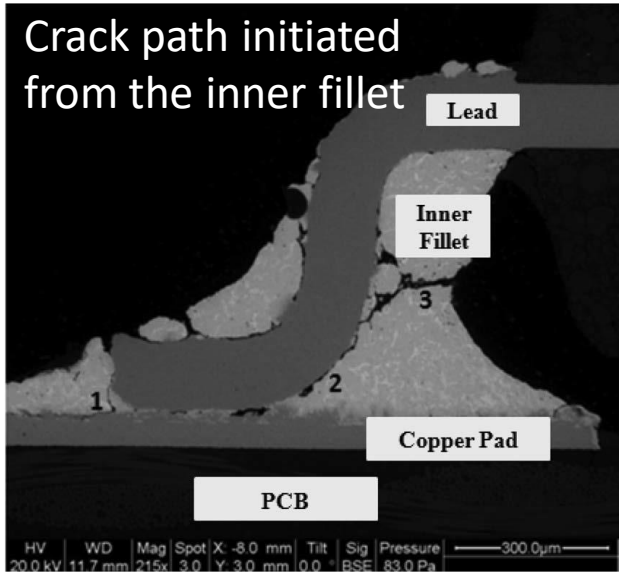
Gull-wing components

Components: 50-TSOP, pitch: 0.8 mm. Solder: SAC305; PCB: FR4 with OSP finish

Rework: hot air for desoldering, copper desolder brad for land redressing, standard soldering iron (tip temp: 371 °C) for installation

Temperature cycles: -55 – 125 °C with 15 min dwell time (overall cycle time 72 min.)

Operation	Cycles to Failure	
	Cycles to 10% Failure	Cycles to 50% Failure
SAC 3x Adjacent	1789	2798
SAC 3x Rework	2316	3020
SAC 1x Adjacent	2021	2731
SAC 1x Rework	2118	2761
SAC (No-Rework)	2180	2761



- There isn't significant difference between the failures of the 1 or 3 times reworked and adjacent and nonreworked components.
- The reduction of copper pad thickness with rework cycles might increase the reliability risk and reduce the viability of rework beyond three cycles.

Source: Ref. 4.

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BGA components

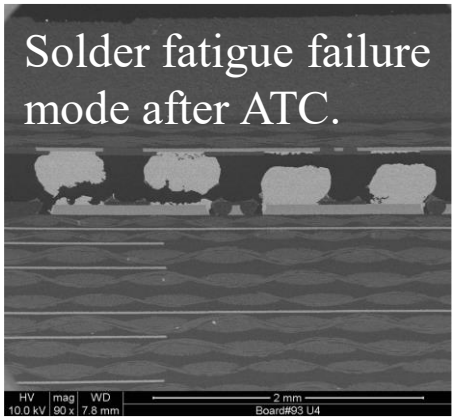
Components: CABGA with 288 I/O, Rework: with hot air station

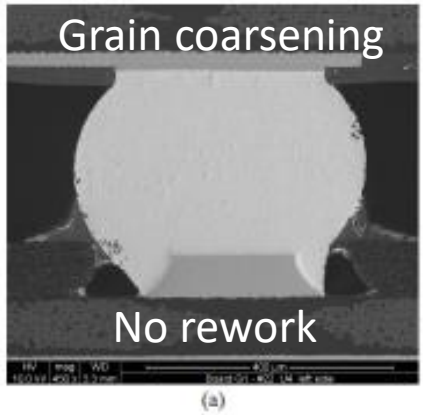
This component wasn't reworked just laid in the other side of the board. (so-called: Clam-shell design)

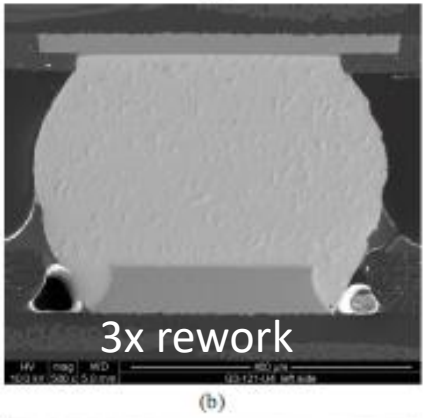
Solder: SAC305; PCB: FR4 with OSP finish

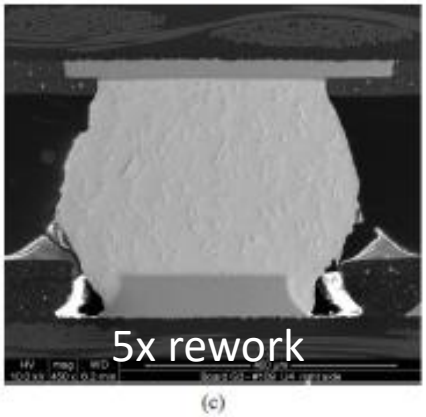
Temperature cycles: 0 – 100 °C with 10 min dwell time (10 °C/min)

Characteristic life	U4
No Rework	1028
3x rework on U1	932
5x rework on U1	698









- Rework on the other side of the board degraded the CABGA solder joints fatigue life significantly by 10% after three times rework, and 32% after five times rework.
- This fatigue life drop due to grain coarsening after multiply rework. In this case there are fewer grain boundaries and intermetallic particles around β-Sn grains to block the dislocation movement, causing a loss of strength of the material.

Source: Ref. 5 and 6.

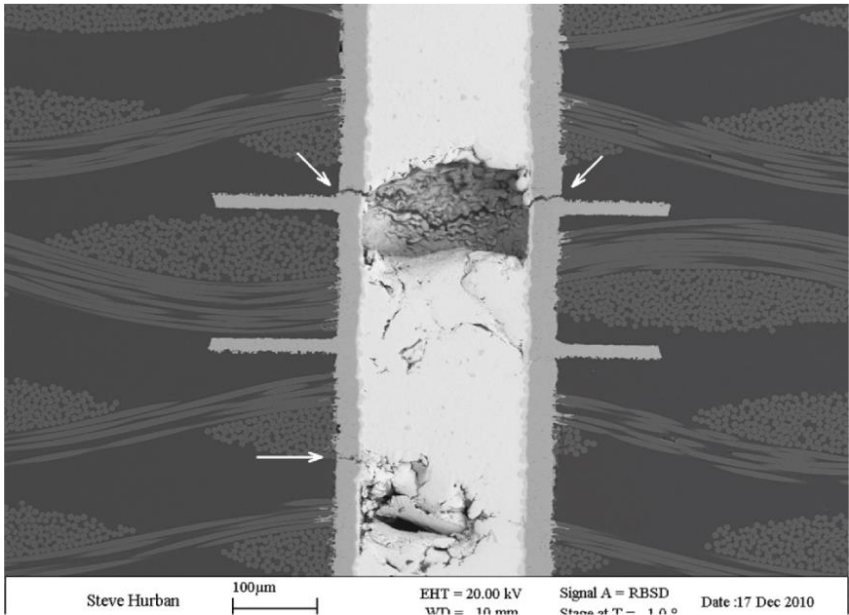
BGA components

Components: FCBGA with 1849 I/O (U1 and U2 parts), Rework: with hot air station
Solder: SAC305; PCB: FR4 with OSP finish; 0 and 3- and 5-times rework cycles
Temperature cycles: 0 – 100 °C with 10 min dwell time (10 °C/min)

Characteristic life	U1	U2
No Rework	>6000	4730
3x rework on U1	5184	1240
5x rework on U1	3362	-

- The fatigue life of three times reworked U1 component is approx. 1.5 times of five times reworked components' life.
- U2 had through hole via barrel crack failures at much lower thermal cycles (4730) than other FCBGA (U1) with microvias.

Source: Ref. 5.



Conclusions

- Manual rework process contains many critical steps that are not allowed for automotive products.
  - Usage of automated rework process necessary (e.g., auto scavenger for solder removal)
- Based on tests, one rework cycle might be allowed by the user without significant solder joint fatigue life decreasing with some limitation:
  - During rework of a part another component doesn't lay on the other side of the board (clamshell design). Otherwise, there might be the risk of grain coarsening.
  - The thickness of the copper lands has been limited the rework cycle because of copper dissolution.
  - In terms of rework the daisy-chain PTHs are particularly unfavourable solution for component electrical connection. (Trace or microvias most favourable for these components.)
  - As the expected lifetime of the solder joints of different components decreases to a different extent. The rework process and components need to be validated as the new product.
- Plans:
  - Sample/coupon preparation for rework and lifetime tests according to previous aspects.

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