PBA DfX in the RoHS era: Specify the requirements!

Geert Willems

www.rohsservice.be

IMAPS Autumn Event 2007
8 november 2007
TBP Electronics, Dirksland

0498/919464

RoHS
Service

imec

Met steun van:

Content

1. The RoHS era: what has changed?
2. PBA: What needs to be specified?
3. A typical way of working…
4. … and what may happen.

© imec/restricted 2006

1. The RoHS Era: What has changed?

1 July 2006: RoHS bans lead in majority of electronics

- Lead-free soldering forms the basis of a massive, mandatory change in the electronics industry.
- A change that is NOT limited to the electronic assembly plant!
- A change that affects the complete electronic supply chain.

Why?

- SnPb solder has been used for well over 50 years as the general purpose soldering material.
- There is NO drop-in lead-free solder replacement.
- Major adaptation required of: (temperature/metallurgy)
  - Soldering materials, processes and equipment
  - Components
  - Printed Circuit Boards

© imec/restricted 2006

1. The RoHS Era: What has changed?
The soldering operation

SnPb Era

Solder: Tm 179-183°C

Reflow soldering:

205°C - 235°C
typical: 215°C
process window: 30°C

Wave soldering

245°C-255°C

RoHS Era

Solder: Tm *199-**210-217-227°C

- SAC: $SnAg_3Cu_{.5}$, $SnAg_4Cu_{.7}$, $SnAg_{3.8}Cu_{.7}$
- Low Ag SAC: SACX, $SnAg_1Cu_{.5}$
- SnCu alloys
- *SnZn, SnBiZn
- **SnAgBi

Reflow soldering:

SAC: 232°C - 245°C (260°C)
typical: 240-245°C (+25-30°C)
process window:13°C (28°C)

Wave soldering

260°C-270°C

© imec/restricted 2006

1. The RoHS Era: What has changed? Components

SnPb Era

Plastic packages

J-STD-20 qualification

Tmax: 220°C-235°C

Lead finish periferal

SnPb3-10%, NiPdAu, Passives: NiAu, NiSn Ag, AgPd,…

BGA balls

$Sn_{63}Pb_{37}$, $Sn_{10}Pb_{90}$ (CBGA)

RoHS Era

Plastic packages: new materials

J-STD-20C qualification

Tmax: 245°C-250°C-260°C

Special repair requirement

Moisture sensitivity: MSL increase 0 to 2 levels

Lead finish periferal: lead-free

Pure Sn (whiskers), SnBi (whisker, SnPb compatibility), **NiPdAu** (cost, availability), SnAg, NiSn, SnAgCu, Ag, AgPd,…

Anti-whiskering treatment and testing

Exemption for fine-pitch components: SnPb

BGA balls

$SnAg_3Cu_{.5}$, $SnAg_4Cu_{.7}$, $SnAg_{3.8}Cu_{.7}$, $SnAg_1Cu_{.5}$,…
(Major reliability issue: low Ag content balls)
CBGA: $Sn_{10}Pb_{90}$, no lead-free solution available

© imec/restricted 2006

1. The RoHS Era: What has changed?
Printed Circuit Board

SnPb Era

Laminate (standard)

- FR4 Tg=130ºC-140ºC
- High Tg FR4 Tg up to 180ºC

Finish

- **SnPb HASL**
- ENIG NiAu
- OSP

RoHS Era

Laminate (Lead-free solder compatible)

- Issues: delamination, via cracking, CAF, degradation
- High Tg FR4 160ºC-180ºC (poor solution)
- New FR4-like non-dicy cured filled laminates Reduced CTEz, increased Td and T260/T288
- Large variety of materials. FR4 is insufficient as material identifier.

Finish

- Lead-free HASL: thermal load
- **ENIG NiAu**: Weak interface, black pad, skip plating, NiP issues
- Immersion Sn: solderability if too thin
- Immersion Ag: SO_2 sensitive
- OSP: solderability, multiple process steps

© imec/restricted 2006

1. The RoHS Era: What has changed? Assembly operation and supply chain

SnPb Era

Component ID

Functional

Package

Traceability

Only for specific applications

Assembly operation

One solder alloy for all soldering operations

One group of products

RoHS Era

Component ID

Functional & package

RoHS, RoHS5 (telecom), non-RoHS, non-EU RoHS

SnPb solderable, lead-free SAC solderable
Application specific compatibility depending on lead metallurgy, thermal load resistance, RoHS exemptions, reliability requirements,…

"Green" components, lead-free components,…

Traceability

General requirement for RoHS compliancy demonstration

Assembly operation

SnPb solder plus one or more lead-free alloys

SnPb and lead-free soldering processes/equipment

RoHS/leadfree – RoHS/SnPb – non-RoHS/leadfree – non-RoHS/SnPb product groups

© imec/restricted 2006

Summary

PBA design and manufacturing has become:

- Significantly more complex with many more parameters to control.
- More critical due to higher temperatures and smaller process window.
- With a significant higher chance of failure due to:
  - Enhanced failure mechanism (fatigue, via-cracking, delamination,…)
  - New failure mechanisms (whisker, kirkendall voiding,…)
  - Identification and tracking errors, human error and lack of robust supply chain control systems
  - Counterfeiting of components
  - The steep learning curve
- … and many unknowns

© imec/restricted 2006

2. What needs to be specified?

A lot and much more than before because:

- The number of variables has increased significantly.
- Lead-free soldering processes are significantly less forgiving than SnPb soldering.
- The "damage" may not always be easy to detect but will finally turn-up in the field.
- There is less margin with regards to reliability. Increased number of potential failure mechanisms to take care of.

To be specified

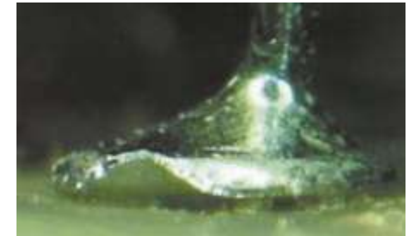
- Printed Circuit Board
- Components
- Assembly materials
- Assembly operation

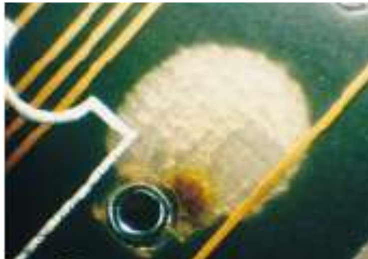
© imec/restricted 2006

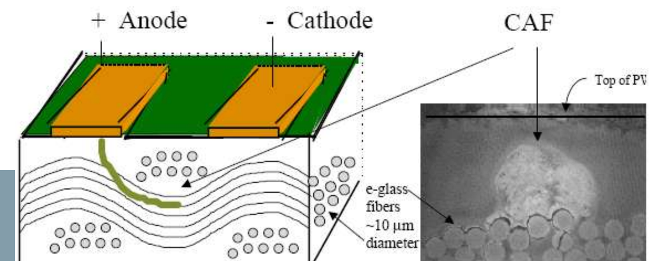
2. What needs to be specified?

Printed Circuit Board

- Lead-free compatible laminate type
  - During soldering: delamination, via cracking, heat damage
  - Product operation: CAF, surface insulation and corrosion, pad lifting
  - Relevant laminate properties:
    - Non-dicy curing
    - Decomposition temperature Td
    - Time to delamination at 260ºC or 288ºC: T260 or T288
    - CTE in z-direction
    - You are not safe with a just a high Tg material! Tg is of secondary importance!
    - Warning!
Real values may deviate significantly from specifications.
    - Conductive Anodic Filament growth resistance







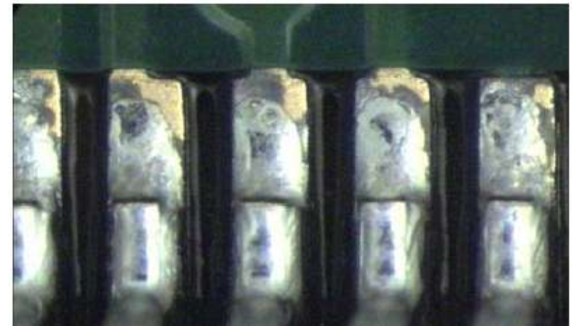
2. What needs to be specified?

Printed Circuit Board

- Solderable finish
  - Soldering process: solderability, multiple soldering, shelf life, process window
  - Product operation: solder joint (interface) reliability, surface insulation and corrosion
  - Options: Leadfree HASL, ENIG NiAu, Im Ag, Im Sn, OSP
    All have pro's and con's.

Most popular lead-free finish: ENIG NiAu

But it is NOT the obvious solution!



- ENIG is complex process with several pitfalls: skip plating, black pad, Ni oxidation
- Soldering to Ni instead of Cu: reduced soldering process window
- Weaker/more brittle solder/Ni interface
  - Intrinsic more brittle SnNi intermetallics
  - Negative contribution of P in Ni – Ni_3P formation at interface
  - (non ENIG NiAu: Gold embrittlement)
- Critical operational conditions: shock, vibration, high tensile load

© imec/restricted 2006

2. What needs to be specified?

Printed Circuit Board

The PCB manufacturer:

- Not all PCB manufacturing operations are created equal! Many more things can go wrong in trying to reduce cost!
- Qualify your PCB supplier for good manufacturing practice and consistent product quality.

What may go wrong when cost pressure is high:

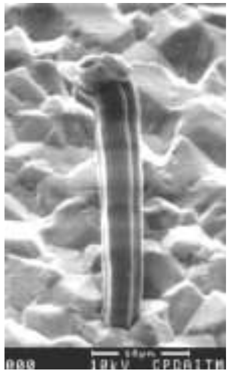
- Multiple lead-free HASL-ing to repair HASL bridges
- Shortened press-cycle leading to undercured PCB laminates
- Lengthening of the time drills are used leading to damaged drill holes. Note: fillers in new FR4 materials reduce drill life by a factor of 2!
- Insufficient through hole plating
- Shortened cure time of solder mask
- Shortened deposition time of ImSn bath
- Insufficient control of NiAu chemistry
- …

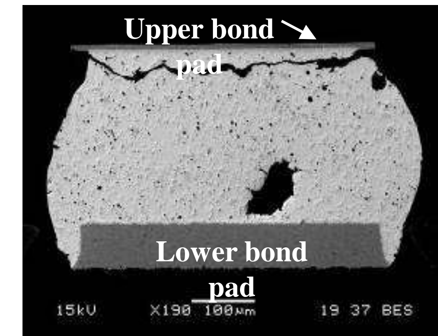
© imec/restricted 2006

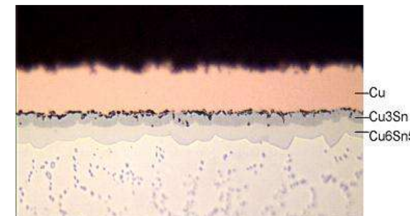
2. What needs to be specified?

Components

- RoHS requirements (legal) <> lead-free!
- <> Lead-free soldering requirements!
- Reliability requirements
  - Solder joint fatigue
    - Thermal mismatch component/board
    - Test requirements
  - Whiskering on Sn-finished leads
    - Acceptable finishes including mitigation techniques
    - Test requirements
  - Kirkendall voiding in BGA
    - Test requirements
- If needed: SnPb soldering requirements.







Components: Lead-free soldering requirements

- Metallurgical requirements:
  - No lead
  - BGA: SAC balls for SAC soldering
- Thermal load requirements
  - Active components:
    J-STD-20C lead-free solder requirements
  - Check moisture sensitivity level:
    MSL>4 take special measures

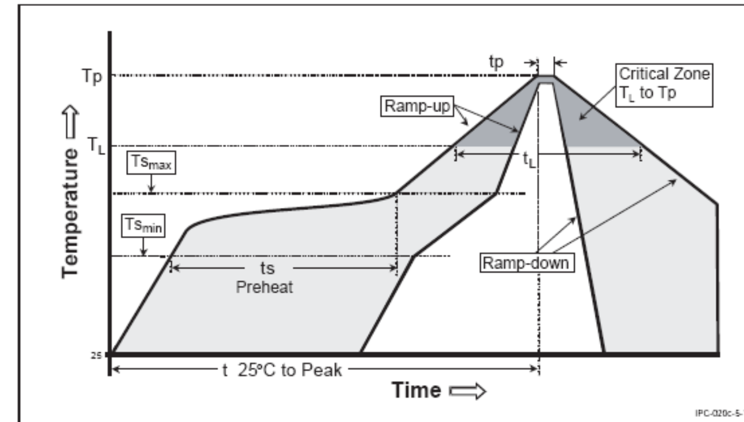


Figure 5-1 Classification Reflow Profile

  - Passive components: standardisation?
    - Should also be capable to withstand J-STD-20C requirements
    - May also be moisture sensitive: no standardisation
  - Large plastic BGA require special attention related to warpage during reflow and especially in repair.

2. What needs to be specified?

Components: SnPb soldering

Not all lead-free/RoHS components are backward compatible!

- Use SnPb balled BGA for SnPb soldering.
- Do not use SnBi finished components for high reliability SnPb soldered products
- Also when soldering with SnPb you may have a whiskering issue on the Sn-finished components

Even when you are exempted RoHS will affect you!

2. What needs to be specified?

Solder materials

Alloy:

- Sn63Pb37, Sn62Pb36Ag2 (Ag finished components)
- SAC305, SAC405, SAC387

Wave soldering different alloy allowed?

- Sn100C (SnCuNi), SACX (0.3% Ag SAC),...

Wire soldering (repair)

- Mixing of SAC and SnCu alloys allowed?

© imec/restricted 2006

Solder materials

Flux: corrosion and Surface Insulation Resistance

- Lead-free soldered PBA are more susceptible to SIR and corrosion issues.
- No-clean flux classification: what is allowed?
  - J-STD-004
  - Low (L), Mild (M), High (H) activated flux
  - (almost) no halogenes (0), halogenes present (1)
  - Flux type: organic acid (OR), rosin (RO), resin (RE)
  - Additional test requirements e.g. Telcordia (Bellcore)
  - Green assembly: VOC-free?
  - Do not forget the specification of the solder wire!
- Cleaning requirements

© imec/restricted 2006

2. What needs to be specified?

Assembly operation

- Documented RoHS compliant operation (legal)
- PBA acceptability criteria:
  IPC-A-610D, J-STD-001, specify product class: 1,2,3?
- Process window
  - Minimal soldering conditions (time/temperature)
  - PBA Bill-Of-Materials compatible with standard maximum soldering conditions (J-STD-20C)?
  - If not: specify maximum soldering conditions (time/temperature)
- Assembly instructions w.r.t. manual assembly
- Process and material qualification practice of plant
- Change notification procedures

Audit the assembly plant

© imec/restricted 2006

3. A typical way of working…

- OEM *BestProduct* defines functionality of new electronic product.
- *BestProduct* makes the electronic design and specifies Processor, memory and ASIC components.
- Layout based on the electronic schematics is subcontracted to ODM *CreateIt*.
- ODM *CreateIt* orders the PCB's at PCB-plant *Print*.
- The PCB assembly is subcontracted by *CreateIt* to PBA plant *StuffIt*.
- The *StuffIt* organisation orders components from different sources including component brooker *GetItAll*.
- Critical components (cost, lead-time,…) are directly ordered by OEM *BestProduct* and shipped to *CreateIt* from which the different *StuffIt* PBA plants get their supply.
- Functional testing is done by OEM *BestProduct* for IP reasons.
- Repair from testing and field returns are shipped to one of the *StuffIt* PBA plants.
- ODM *CreateIt* is responsible for Engineering Change Orders.

© imec/restricted 2006

3. A typical way of working…

Questions raised by a complex supply chain:

Who makes the rules of the game?

- Who specifies what? (complete or partially)
  - PCB (*BestProduct*, *CreateIt*, *Print*, *StuffIt*)?
  - Components (*BestProduct*, *CreateIt*, *StuffIt*, *GetItAll*)?
  - Assembly materials (*BestProduct*, *CreateIt*, *StuffIt*)?
  - Assembly operations (*BestProduct*, *CreateIt*, *StuffIt*)?
  - Reliability requirements related to operational conditions (*BestProduct*, *CreateIt*, *Print*, *StuffIt*)?
- Is there sufficient know-how present?
- How to control that specifications are met?

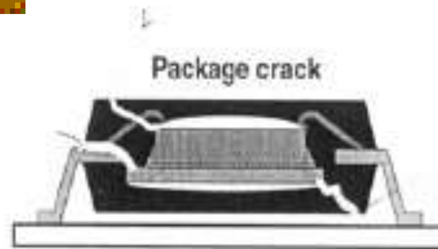
© imec/restricted 2006

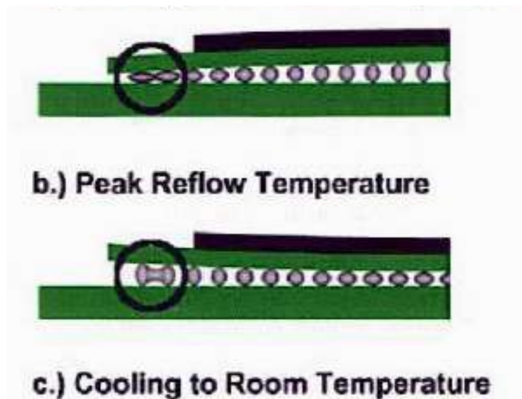
4. …and what may happen!

In assembly (1)

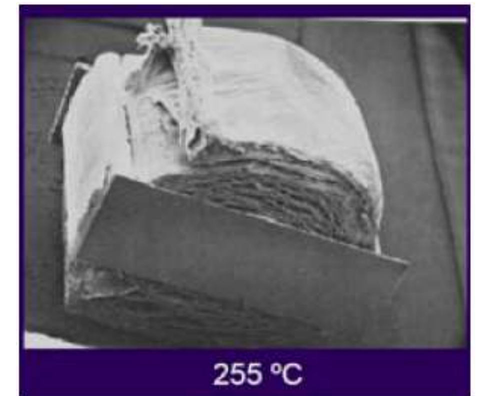
Poor quality
- Components
- PCB
- Assembly process
- Design

- Overheating
- Incompatibility of component with lead-free soldering





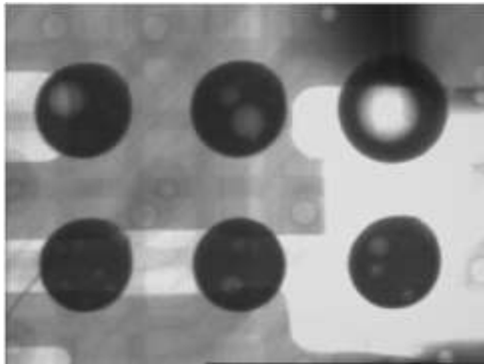
- Moisture level rating
- Component quality
- Logistics of moisture sensitive components



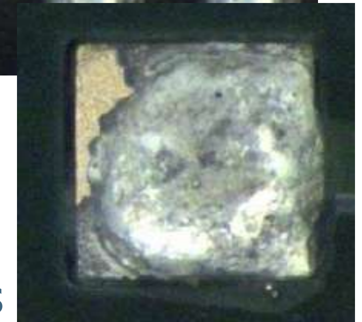
© imec/restricted 2006

4. …and what may happen!

In assembly (2)

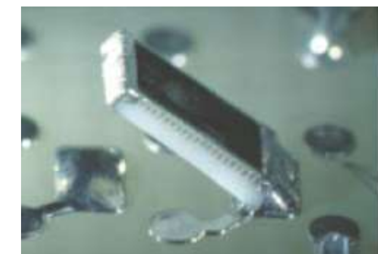


BGA voiding
- Reflow process
- Solder paste
- PCB design



Poor solderability
- PCB finish quality
- Solder paste
- Storage conditions

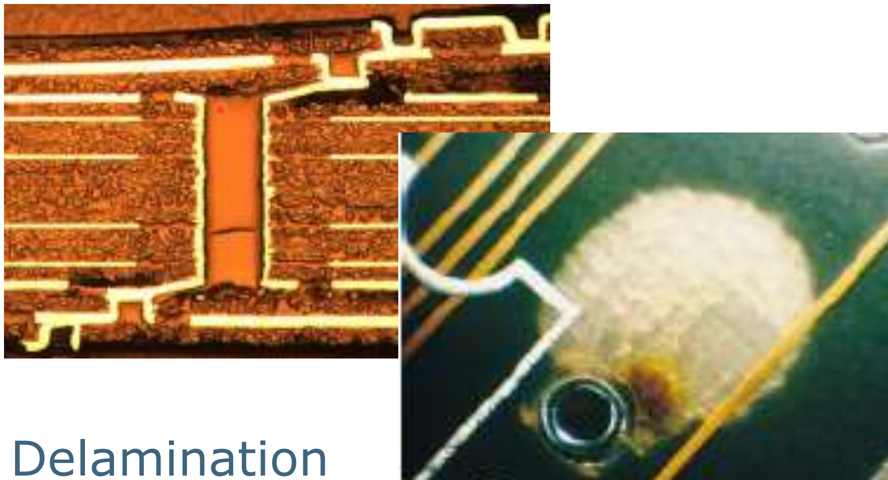
Through-hole filling
- Solder process
- Solderability of component or PCB



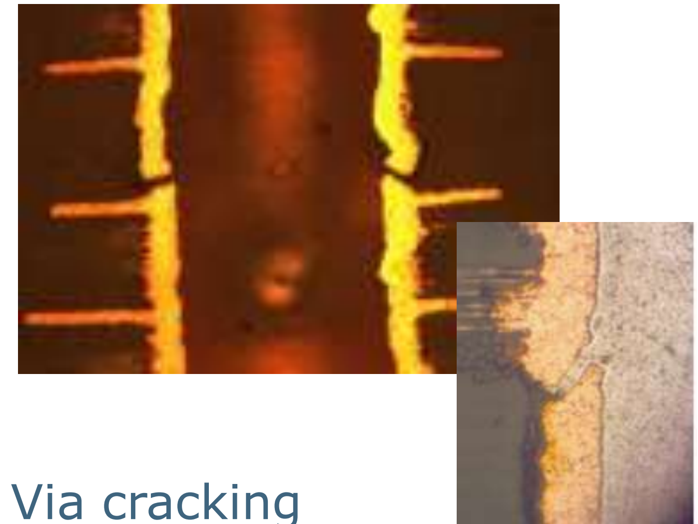
Tombstoning
- Design
- Process

4. …and what may happen!

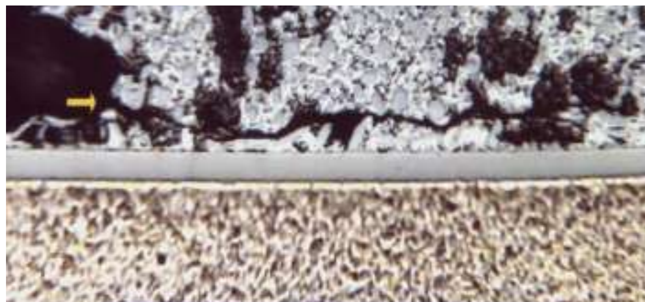
In assembly (3)



Delamination
- PCB lead-free compatibility
- Process: overheating



Via cracking
- PCB lead-free compatibility
- Process: overheating
- Excessive # repair cycles

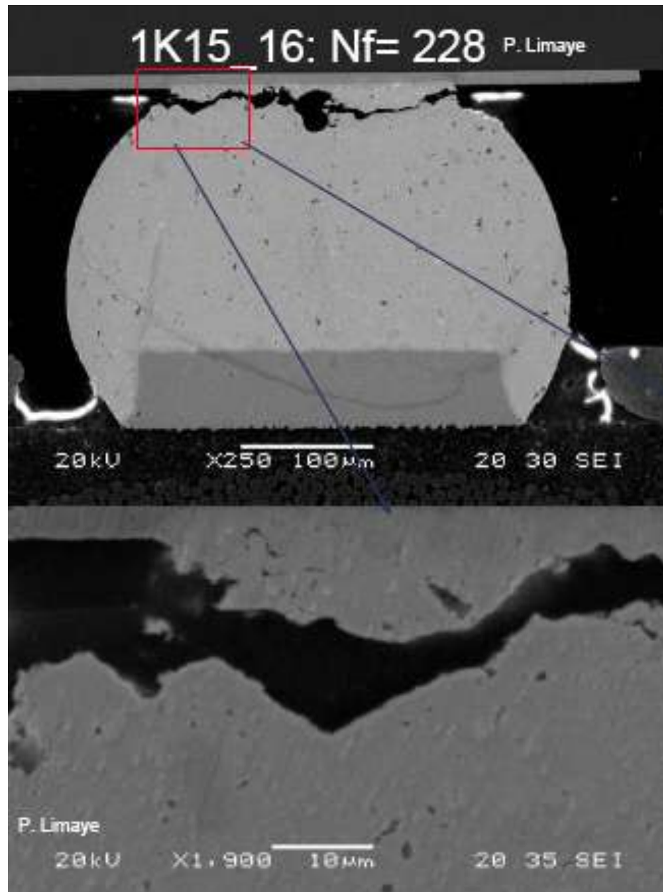


Contamination
- Pb in SAC
  - BOM control
  - Process contamination
- Au
  - BOM control

© imec/restricted 2006

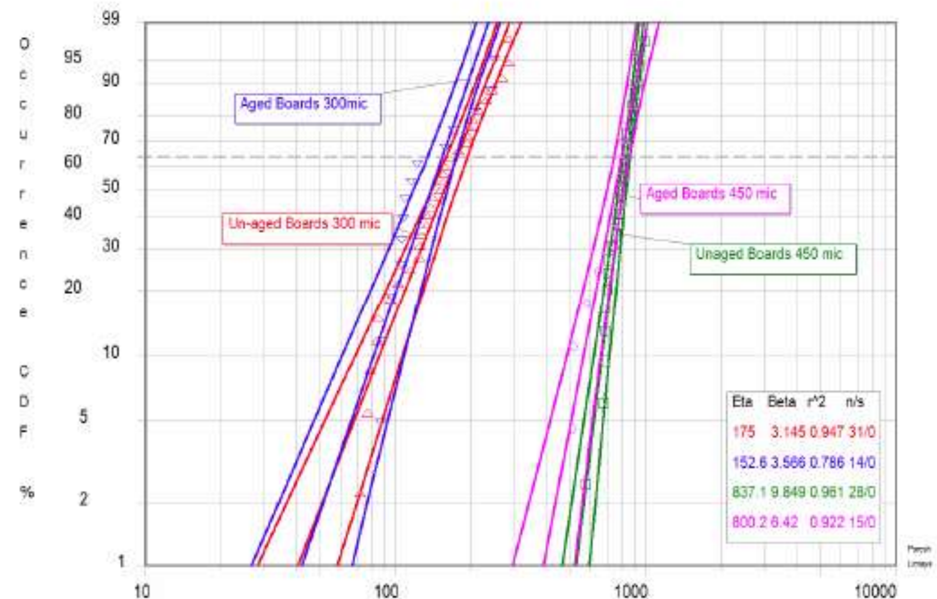
4. …and what may happen!

During operation (1)



Solder joint fatigue

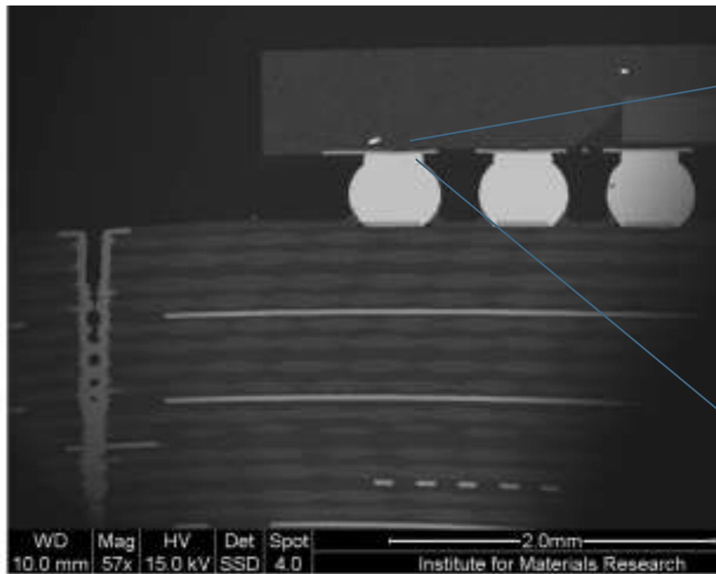
- Design: CTE mismatch
- Design vs. operational conditions
- Lead-free solder alloy

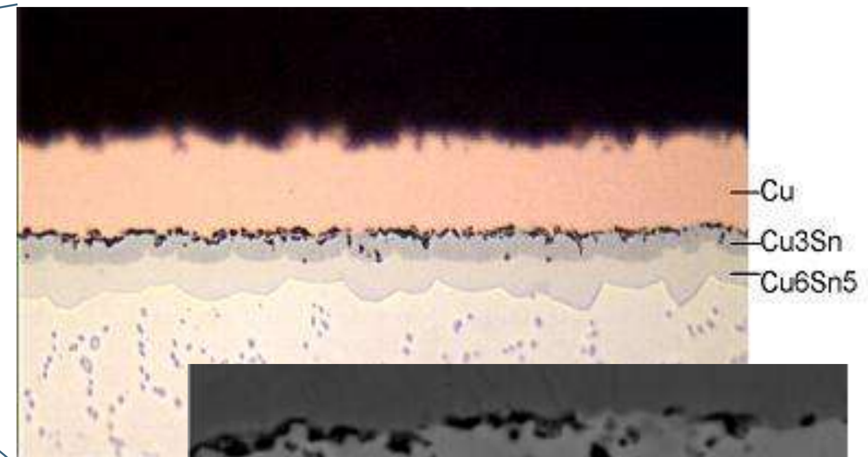


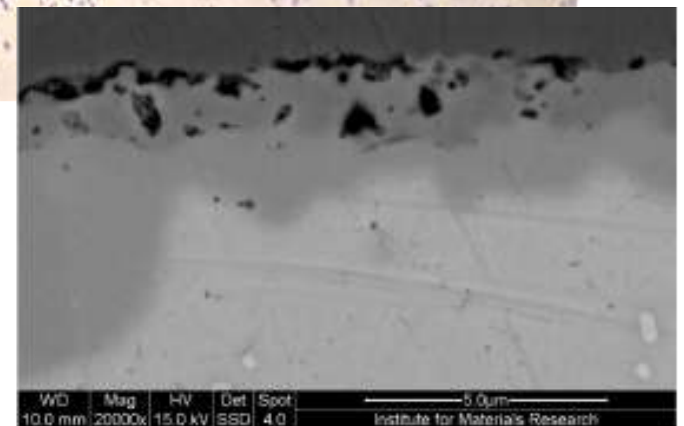
© imec/restricted 2006

4. …and what may happen!

During operation (2)







Kirkendall voiding
- Component testing

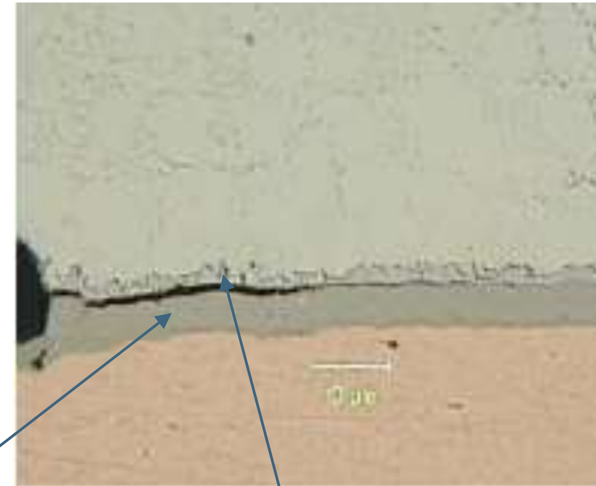
© imec/restricted 2006

4. …and what may happen!

During operation (3)

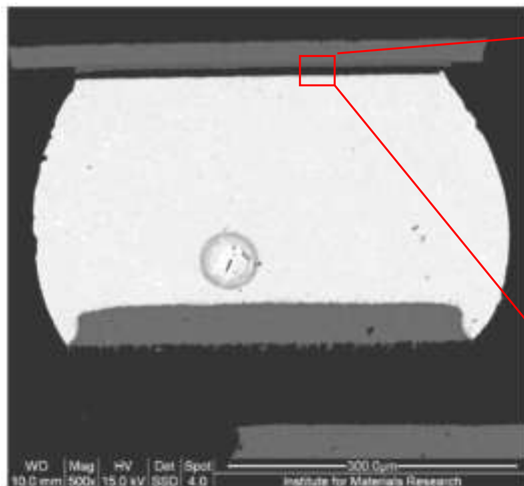
Interface failure

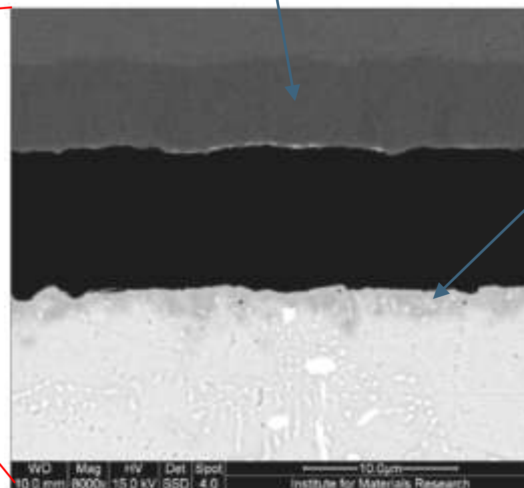
- Use of NiAu:
intrinsic weak Ni-solder interface
- PCB: ENIG quality
- Design vs. mechanical load:
shock, vibration, tensile stress



Ni

SnNi im





4. …and what may happen!

During operation (4)

SIR failure: dendrite growth
- PCB quality: ionic contamination
- PBA assembly quality
- Solder material flux classification
- Environment vs. design

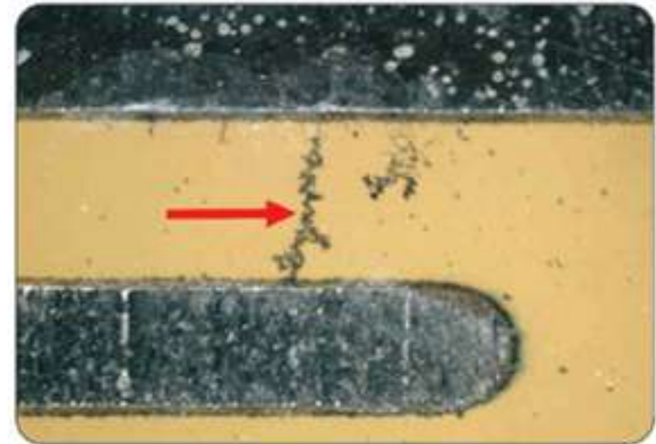
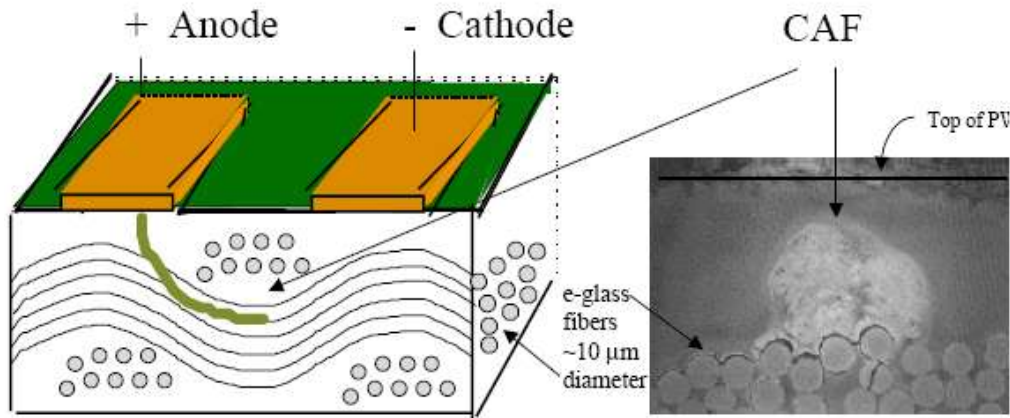


Figure 3-1: Dendrite growth between positively and negatively biased conductors (top and bottom).



Conductive Anodic Filament
- Design
- PCB laminate selection
- PCB quality
- PBA quality
  - Overheating
  - Excessive repair cycles

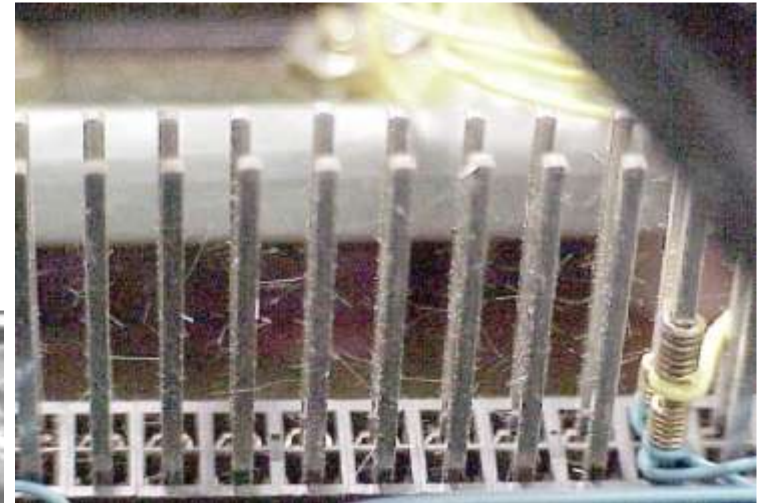
© imec/restricted 2006

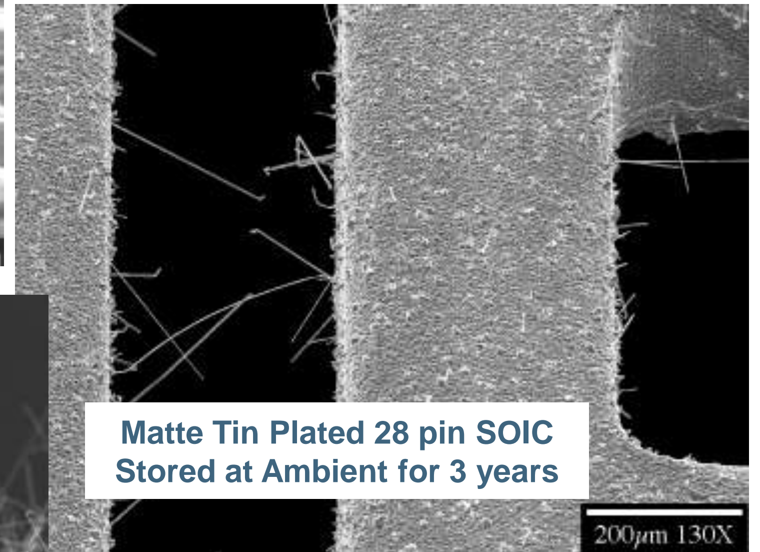
4. …and what may happen!

During operation (5)

Sn whisker

- Use of Sn, SnCu
- Lack of mitigation practice
- Component selection

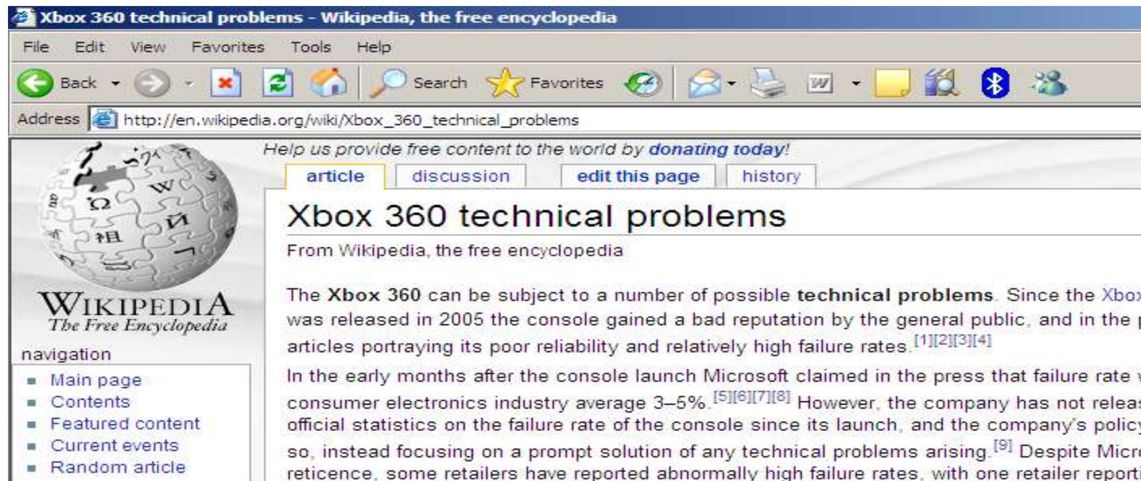




© imec/restricted 2006

4. ...and what may happen!

During operation (6): Microsoft Xbox 360


Xbox 360 technical problems - Wikipedia, the free encyclopedia

File Edit View Favorites Tools Help

Address http://en.wikipedia.org/wiki/Xbox_360_technical_problems

Help us provide free content to the world by ***donating today!***

article | discussion | edit this page | history

Xbox 360 technical problems

From Wikipedia, the free encyclopedia

The **Xbox 360** can be subject to a number of possible **technical problems**. Since the Xbox was released in 2005 the console gained a bad reputation by the general public, and in the p articles portraying its poor reliability and relatively high failure rates.[1][2][3][4]

In the early months after the console launch Microsoft claimed in the press that failure rate v consumer electronics industry average 3–5%.[5][6][7][8] However, the company has not releas official statistics on the failure rate of the console since its launch, and the company's policy so, instead focusing on a prompt solution of any technical problems arising.[9] Despite Micro reticence, some retailers have reported abnormally high failure rates, with one retailer reporti

WIKIPEDIA
The Free Encyclopedia

navigation
- Main page
- Contents
- Featured content
- Current events
- Random article

Estimated failure rate: 25-33%

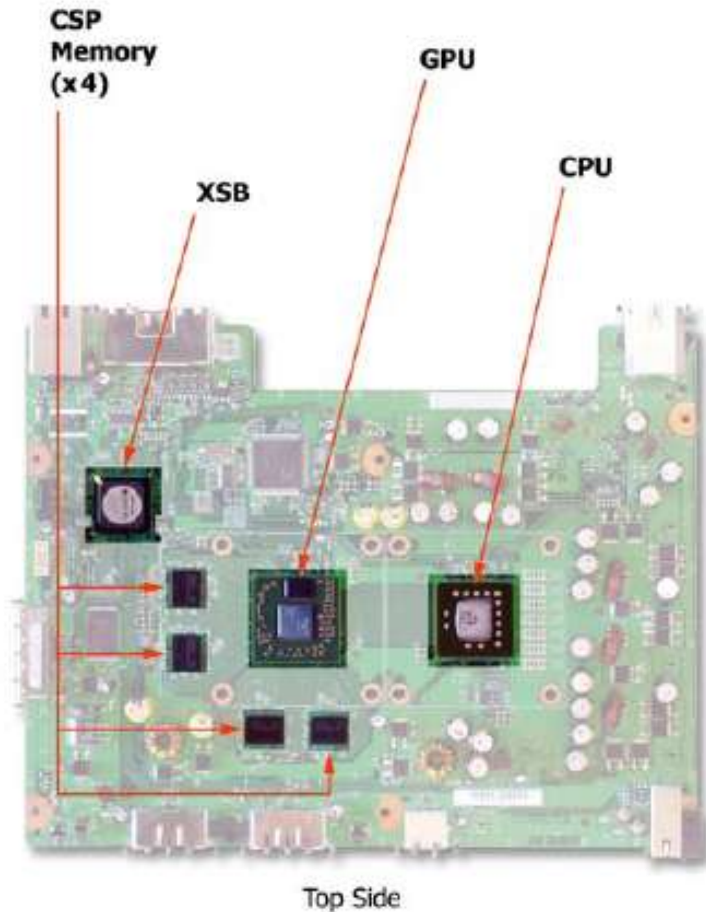
Cost for Microsoft:
>US$ 1.000.000.000

4. …and what may happen!

© imec/restricted 2006

4. …and what may happen!

During operation (6): Microsoft Xbox 360



Issues:
- Thermal design
- Component design?
- Mechanical load on lead-free BGA joints
- Soldering quality?

© imec/restricted 2006

Conclusion

RoHS has introduced a major paradigm shift.

Many more things can go wrong with PBAs…

… but do not have to go wrong!

- The OEM bears full product responsibility. Acknowledge this.
- Know what you need to know. Acknowledge the complexity.
- Explicitely specify every aspect of the PBA directly or indirectly through clear delegation.
- Control the supply chain.

Do not take anything for granted.

© imec/restricted 2006

Thank you for your attention

Geert Willems
RoHS@imec.be
www.rohsservice.be
0498 91 94 64

Een gezamenlijke dienstverlening

Met steun van:

© imec/restricted 2006