Electronics Design & Manufacturing Activities

Geert Willems
imec
Center Electronics Design & Manufacturing

Electronics Design & Manufacturing

Imec's Center EDM team
>70 years industry
>20 years research
experience in electronics

We bridge the gap between research and industry

Better electronics
at
reduced cost
through
science based
design & production
methods

Content

1. Research and Development

2. Guidelines

3. Industry support

1. R&D activities

EDM wants to provide science based answers to long standing questions in PCB/PBA design and manufacturing.

General question:

Take PCB/PBA design option N

N: component type, PCB material, component placement, test access,...

The buy-in cost of option N is clear but what about:

- PCB Manufacturability and PCB cost?
- PBA Manufacturability and assembly cost?
- Quality and non-quality cost?
- Reliability, field-repair cost and lost reputation?

The answer requires the quantification of less tangible properties like manufacturability, quality and reliability.

EDM imec

1. R&D activities

Quantified Quality:

- The **Quantified Quality *Q*** of a part/product is the probability of having **no defect**.
- A **defect** is any property that does not meet expectations.

Properties:

→ Q=Yield (first pass – after test)

→ Zero Hour Defect Rate= 1-Q (Q: as delivered quality)

→ Q decreases with increasing number of Defect Opportunities (complexity) and manufacturing processes.

→ Q improves by introducing test and repair.

Note: *In real life there is no such thing as "Zero Defect Manufacturing"*

1. R&D activities

Quantified Quality:

- Started with IPC-7912 on PBA
- Expanded to complete mechatronic systems in MoVIP: *Modellering van de Voorspelbaarheid van Initiële Productkwaliteit.* (Point One project)

Added value of Quantified Quality concept:

- **Quality** becomes measurable and quantifiable. One can assign **an objective value** to it.
- **Test** - perceived as an overhead cost - transforms into an quality improving therefore **a value adding process**.
- Predictabillity of quality. Base for **Design-for-Quality**.
- Base for **a common quantified quality language** in the supply chain.

1. R&D activities

R&D behind Quantifed Quality

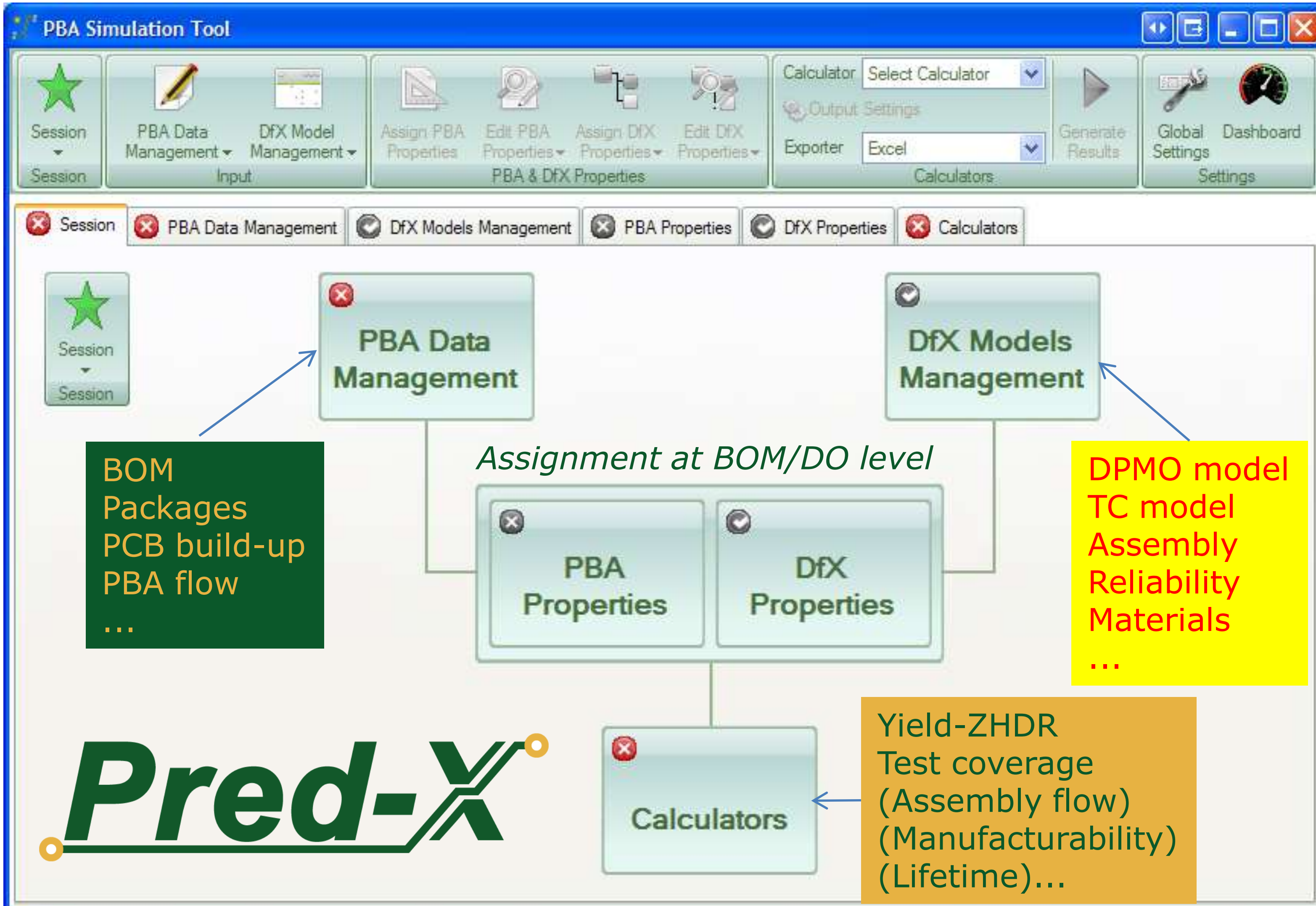
- Development of quantification concept
  - PBA: Based on IPC-7912 defect opportunity *component-placement-interconnection defects*
  - Mechatronic systems: *Parts – Virtual Connector Parts (connections)*
- Manufacturability modeling
- Failure probability models
- Test coverage models
- Tool

1. R&D Activities

Pred-X

- Generic DfX supporting tool
- Can be used very early in design phase (concept phase)
- Quantified prediction of PBA DfX properties
- V1.0: Yield and test coverage prediction (2013)

1. R&D Activities



1. R&D Activities

Manufacturability

- Compatibility of BOM including passives with lead-free solder profiles.
- BOM based estimation of on-board temperature differences during reflow soldering.
- BOM based assembly flow & process time prediction
- PCB manufacturing flow & process time prediction
- Sense or Nonsense of thermal reliefs
- ...

Thermal relief

AC Impedance

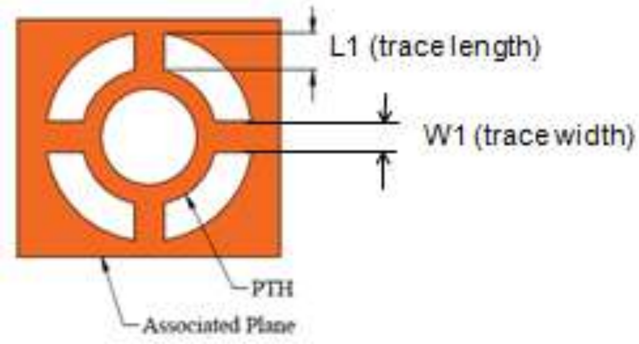
h=0,2mm	h=0,6mm	h=1mm
61pH	76pH	74pH

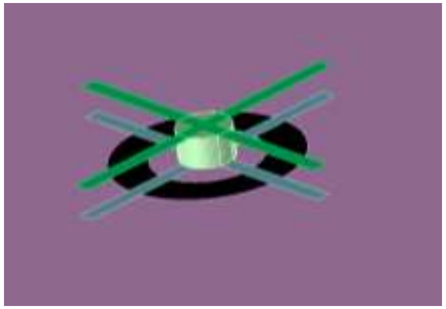
l=0,25mm	l=0,5mm
61pH	101pH

1 leg	2 legs	3 legs	4 legs
439pH	185pH	104pH	61pH

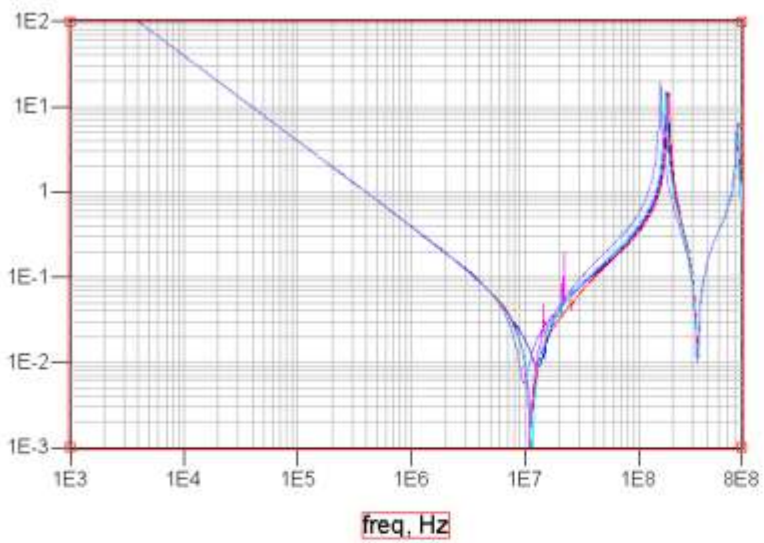
w=100µm	w=200µm	w=300µm
61pH	41pH	26pH

D=0,35mm	D=0,5mm	D=0,65mm
61pH	72pH	77pH





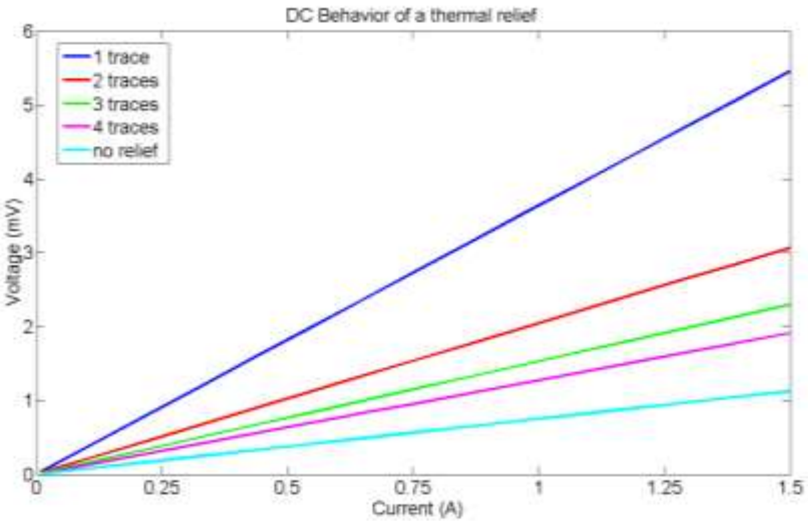
Thermal relief with decoupling caps



At low frequencies, the behavior is **mainly inductive.**
Influence of thermal reliefs at the frequency range of interest is very small to negligible when at least 2 legs are present.

Thermal relief

DC resistance



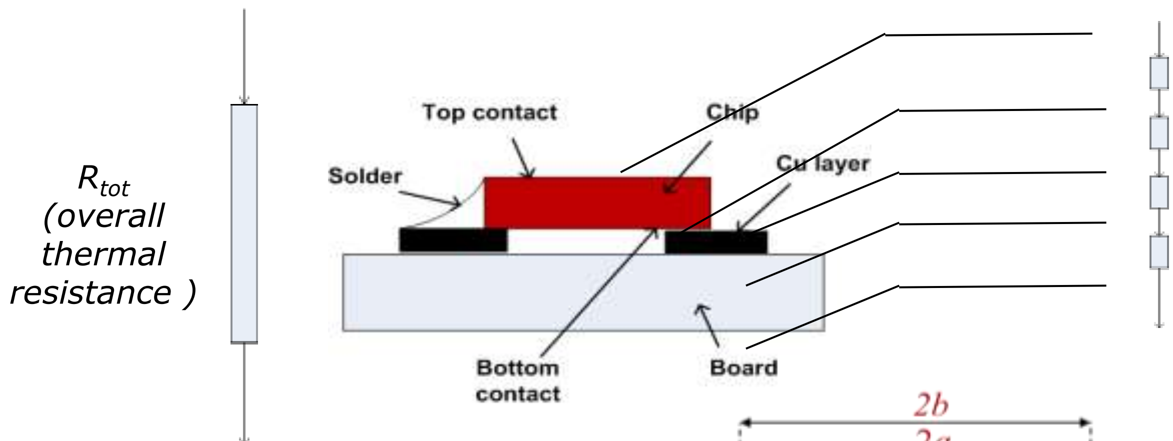
Description	R (mOhm)
No relief	0,752
4 traces	1,28
3 traces	1,53
2 traces	2,04
1 trace	3,64

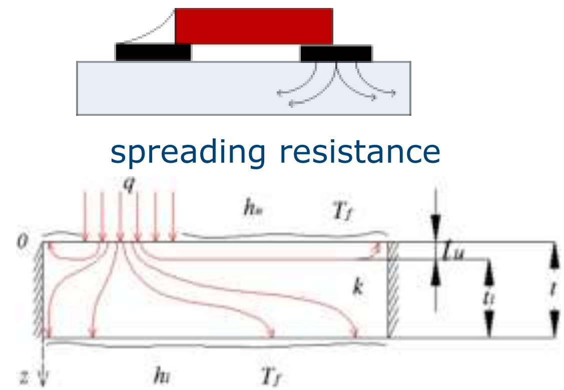
The excess resistance introduced by the presence of a thermal relief lies in the range of **a milliohm to a few milliohms** (25µm Cu)

WIP: Self-heating, Effectiveness in wave solder hole filling sirris

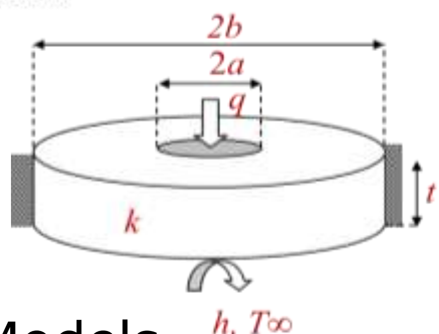
Thermal design

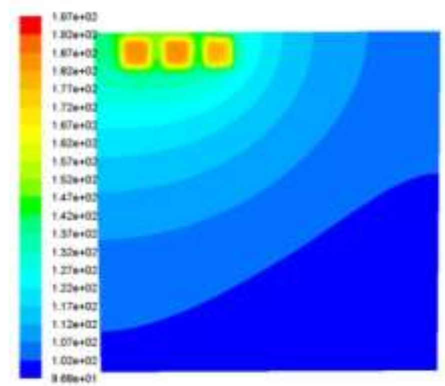
Development of an analytical thermal resistance model at second level interconnect (similar to package level)





- Analytical model
- Fit to Finite Element Models



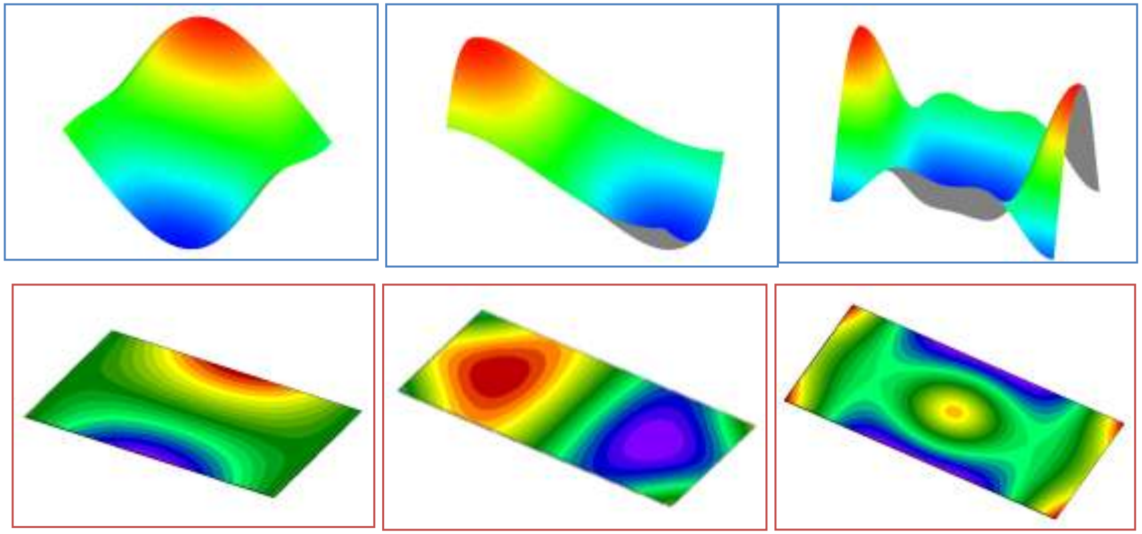


EDM imec

Mechanical Design

Where do we put fixations points in the PCB? (Prior to prototyping!)

Analytical modeling of PBA vibration response.



❖ Tool results

❖ Calculix results

Mode 1 Mode 2 Mode3

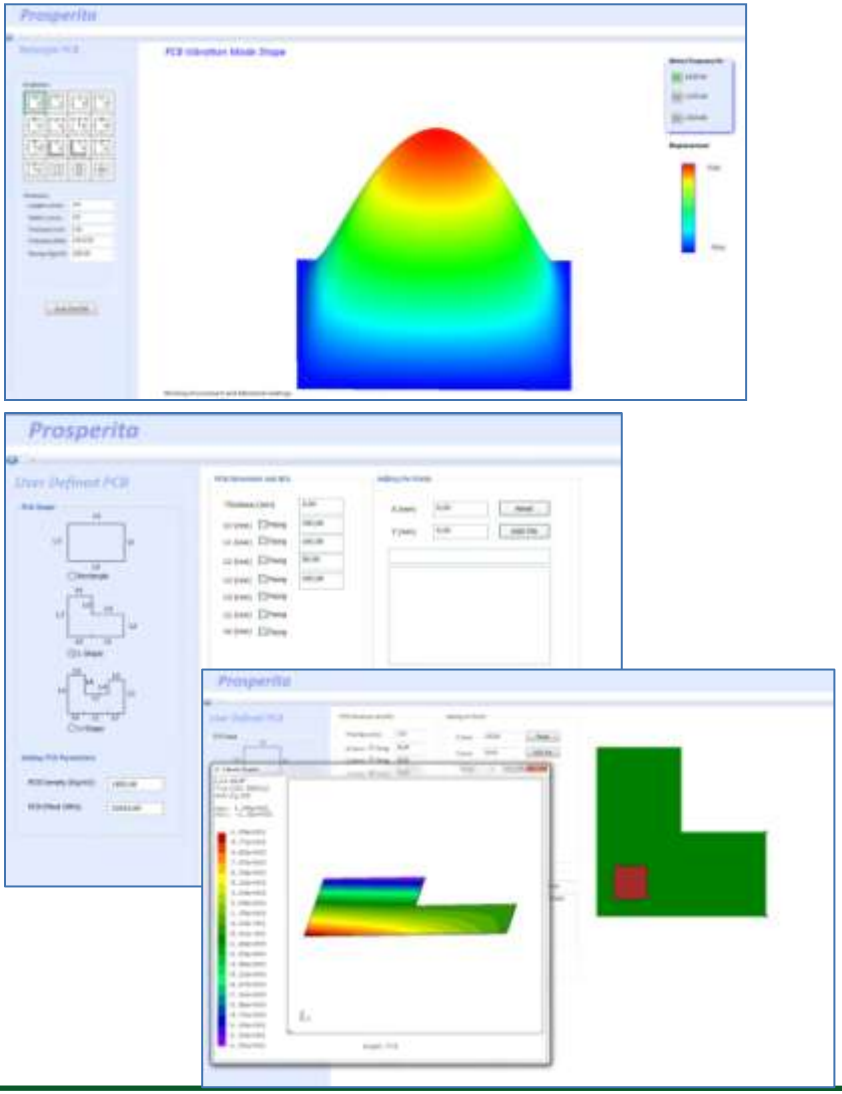
EDM-I-001 Mechanical Integration guideline

1. R&D Activities

sirris

Vibration calculation tool

1. Tool for review at partners
2. Fast calculation of the eigenfrenquency and the mode shape for rectangle PCB
3. Fast evaluation of the effects of heavy electrical components and fixing points for three PCB shapes.
4. Embedded preprocessor to generate mesh, set boundary conditions and run the open source FE software Calculix



EDM imec

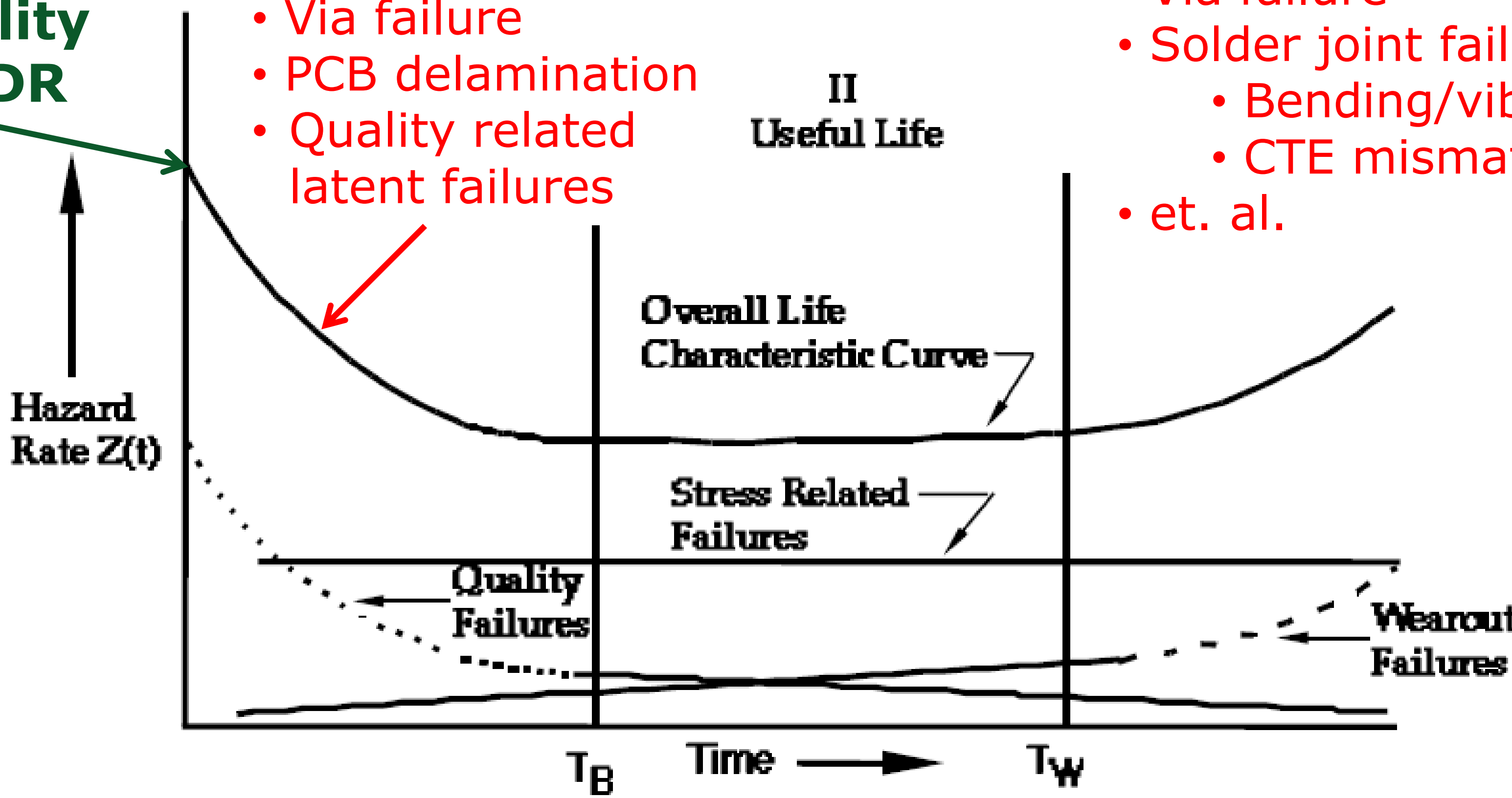
1. R&D Activities

Reliability

Quantified Quality ZHDR

Early failure
- Via failure
- PCB delamination
- Quality related latent failures

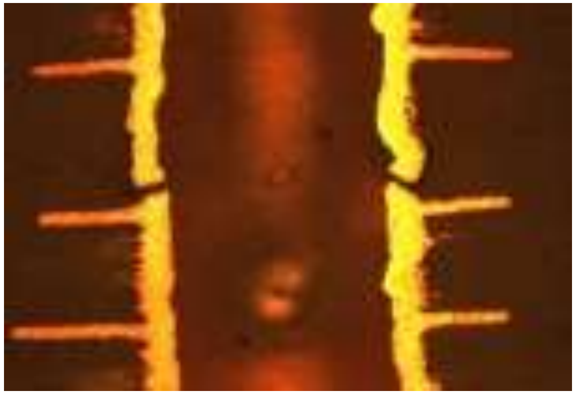
Reliability
- Via failure
- Solder joint failure
  - Bending/vibration
  - CTE mismatch
- et. al.



1. R&D Activities

Via fatigue failure: basics

- Driving force: Difference in CTE between laminate and Cu-plating of via
- Via cracking observed for PTVs
- **Reliability prediction required**

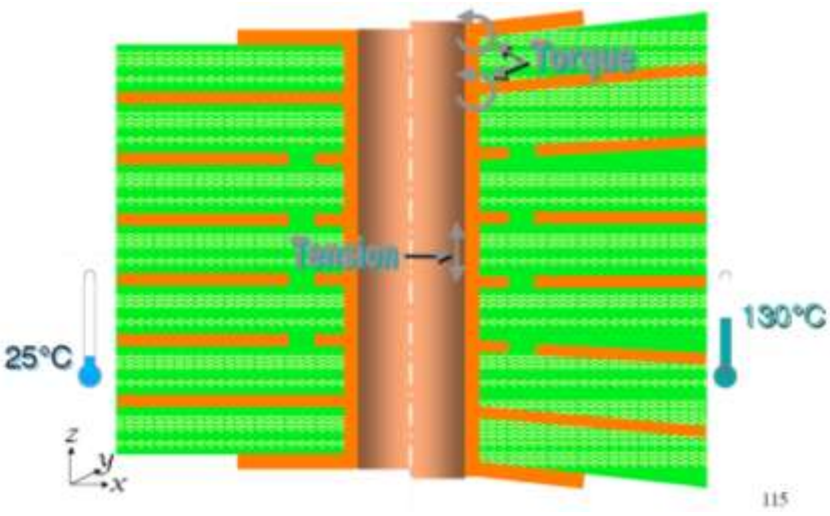


IPC-D-279 (1996)
Design Guidelines for Reliable SMT PBA

1-D analytical model (Engelmaier)

$$\Delta\varepsilon_2 = \frac{FE_E(\Delta T) - FE_{Cu}(\Delta T)}{1 + \frac{A_{Cu}}{A_E}\frac{E_{Cu}}{E_E}}$$

Validity of expression for epoxy loading area A_E?



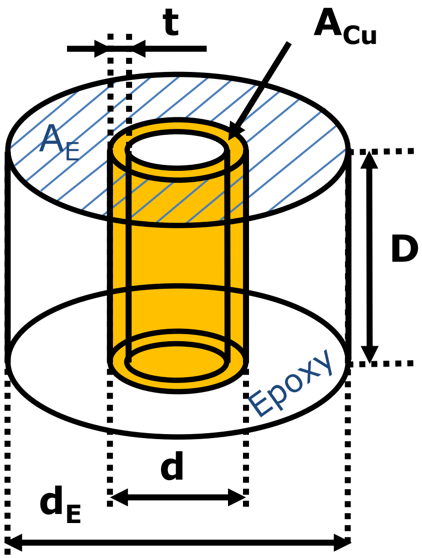
Via strain model improvements by FEM

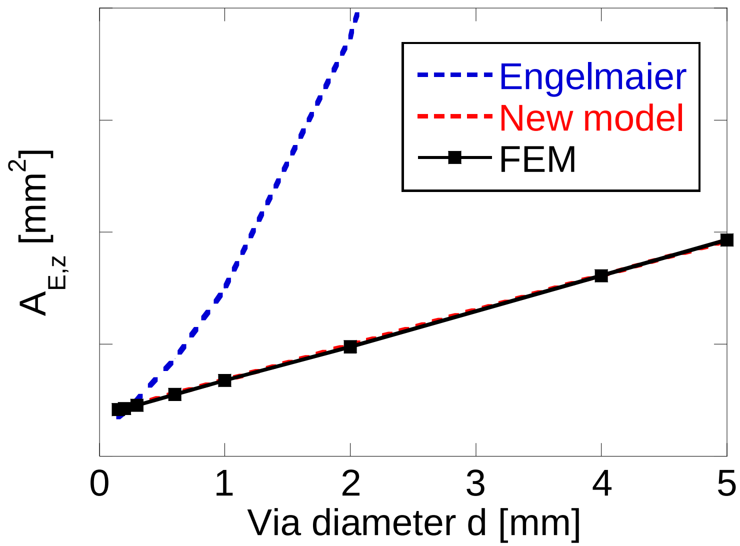
- Empirical relationship Engelmaier overestimates strain for large via diameter

$$A_E = \frac{\pi}{4}\left[\frac{D^2}{4} + 4Dd + 3d^2\right]$$

- ***New $A_{E,z}$ model*** developed depending on epoxy material parameters

$$A_{E,z} = b_1 D^2 + (a_1 E_{rt} + a_2) Dd$$





Via strain model improvements by FEM (2)

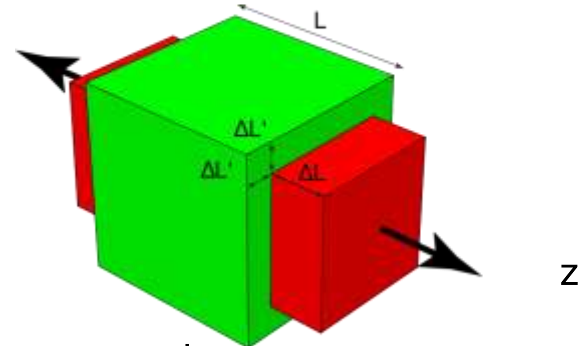
- ***Poisson effect copper*** ν_{Cu} causes reduction axial stress (z) due to in-plane (r,t) stresses
- 1D Engelmaier model extended to ***axisymmetric model*** taking into account ***in-plane epoxy material parameters***
- ***Epoxy influence zone*** $A_{E,t}$

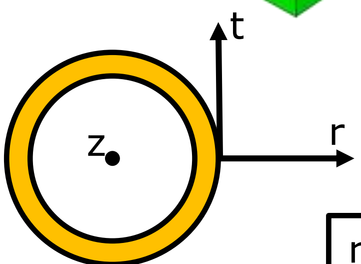
$$\varepsilon_{Cu,z} = \frac{\Delta F E_z \left[L + LM\left(1-\nu_{Cu}^2\right)\right] - \Delta F E_{rt} \nu_{Cu} M}{1 + M + L + LM\left(1-\nu_{Cu}^2\right)}$$

$$L = \frac{E_z}{E_{Cu}} \frac{A_{E,z}}{A_{Cu,z}}, M = \frac{E_{rt}}{E_{Cu}} \frac{A_{E,t}}{A_{Cu,t}}$$

$$A_{E,t} = \left(\mathrm{d} + a_1 \mathrm{D}\right)^2$$

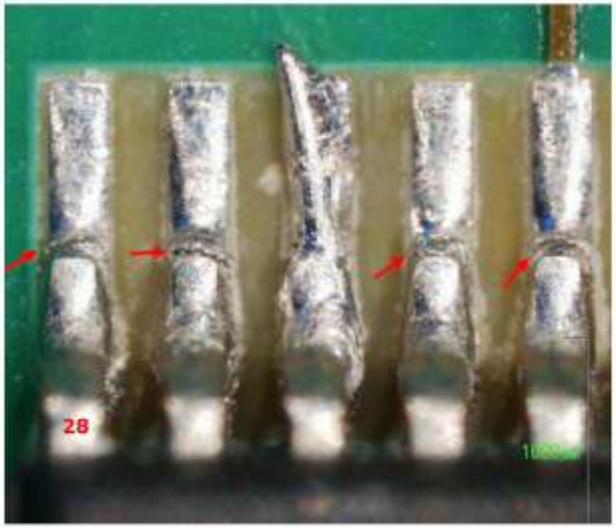
(ν_{Cu}=0: 1-D Engelmaier)





r=radial
t=circumferential
z=axial

1. R&D Activities



Solder joint reliability

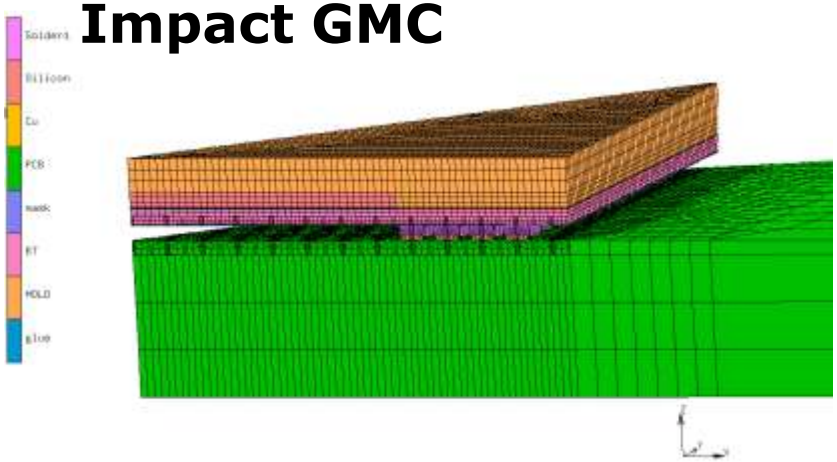
Need for analytical model to address:

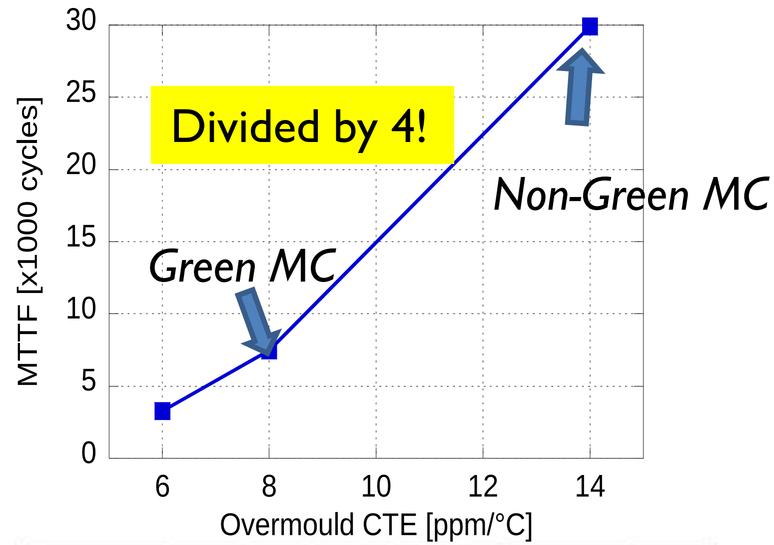
- Low CTE "Green Mould Compound" packages
- Bending/vibration mechanical load

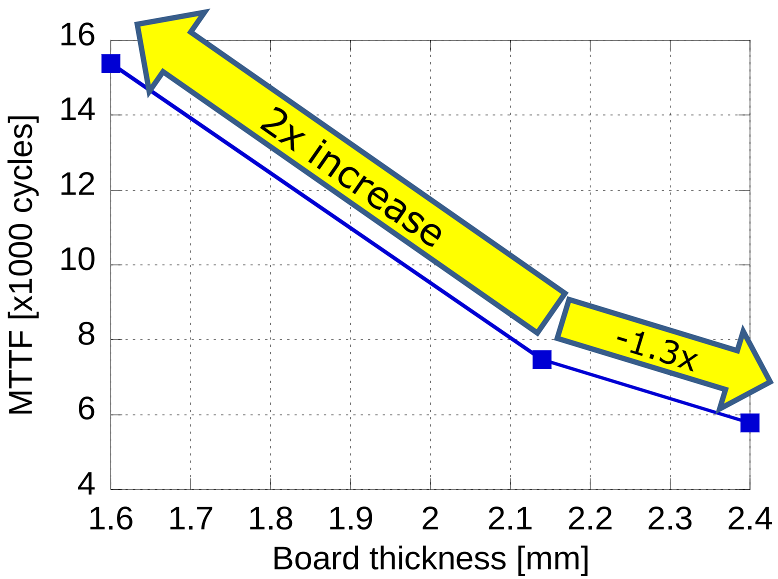
- IPC-D-279 model by Engelmaier
  - Leadless: Only shear loading of solder joints, no bending.
  - Leaded: only valid for elastically deformed solder joints
- New analytical model needs to address PCB and component bending correctly.
- Model concept defined. To be developed 2013.

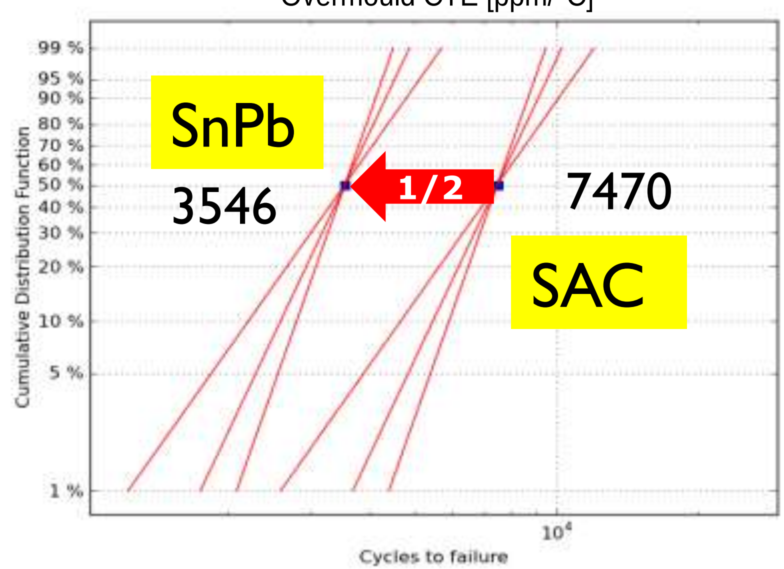
1. R&D Activities

Impact GMC









1. R&D Activities

Research project participation

ENIAC-Greenelec

- Design-for-Recycling Guidelines
- Recyclability rating & tool
- Product data end-of-life availability

IWT-O&O: ISEE

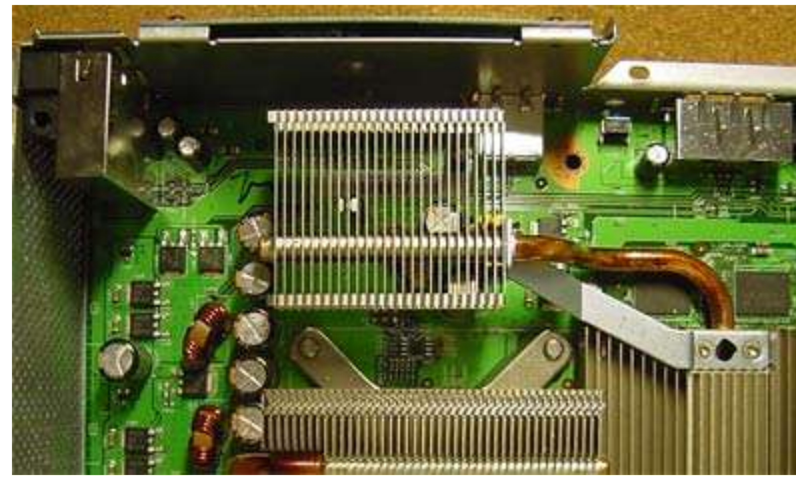
- High reliability interconnection
- Solder and conductive adhesive
- Innovative accelerated testing
- Green Mould Compound testing
- Soldering to Cu vs. Ni (NiAu)
- Via reliability testing
- Accelerated vs. field testing

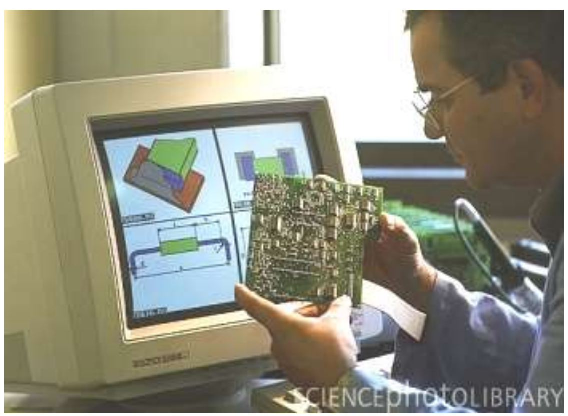
2. Guidelines

VIS-traject PROSPERITA
2011-2014

PBA realization: DfM-DfR-DfT

Extra: D0: Good Design Practice
D1: PCB Specification V2
D2: Component Specification
D3: Assembly material
D4: Design-for-Assembly
D5: PCB density classes
D6: PCB Layout
D7: Design-for-Test






EDM
PBA Design-for-Manufacturing Guideline
Section I: PCB specification
V1.0
January 2010

PBA integration

I1: Mechanical interaction
I2: Thermal interaction
I3: EMC interaction
I4: integration

2. Guidelines
EDM-D-000: Good Design Practice

Status: first draft available (addition to plan)

- Goal:
  General Good DfX Practice – intro DfM guidelines
  1. Applicable Documents
  2. Applicability of the PBA DfM Guideline EDM-D-000
  3. To acknowledge when designing PBA
  4. Do’s and don’t’s of good DfX practice
  5. Basic Design-for-Assembly rules
  6. Basic PCB Design-for-Manufacturing rules
  7. Basic Design-for-Test rules
  8. Basic Design-for-Reliability rules

2. Guidelines:
EDM-D-001: PCB specification

Status: V2.0 – finalization

Major improvements

- Less descriptive, more directive, simplier to use
- Simplification of laminate selection w.r.t. via failure during soldering.
- Fundamentally renewed/improved analytical via model including:
  - Poisson effects in Cu barrel
  - FEM verified and modeled zone of influence in epoxy
  - Accurate full PCB/via dimension range analytical modeling
- Selection of via failure criteria options.
- Inclusion of IPC-1601 PCB moisture handling
- New approach/model for operational via lifetime determination.

2. Guidelines: EDM-D-003: Assembly materials

Status: Review

Goal: Provide Assembly Material specification guidelines

Content:

1. Applicable Documents
2. Applicability of the PBA DfM Guideline EDM-D-003
3. Solder alloy specification
4. Flux specification
5. Soldering paste specification
6. Cleaning of flux residues
7. Non-conductive Adhesives (SMD)
8. Coating, encapsulation, staking and repair polymers
9. Underfill
10. Conductive Adhesives and Films

2. Guidelines: EDM-D-004: Design-for-Assembly

Status: *started*

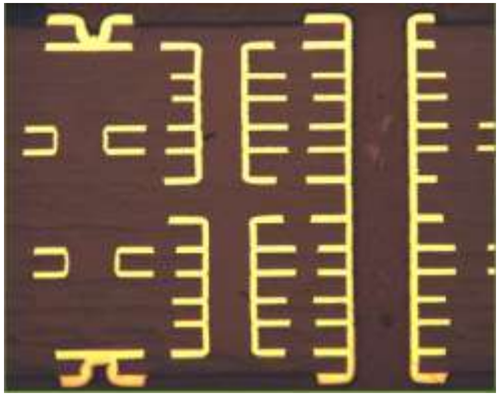
Goal: Provide DfA guideline: component placement

3. PBA performance requirements: general
4. PBA machine handling requirements
5. Selection of PBA type
6. Bill-of-Material (BoM) design
7. Placement: general
8. Placement and soldering: SMT reflow
9. Placement and soldering: THT wave
10. Placement and soldering: SMT wave
11. Placement and soldering: THT reflow
12. Placement and soldering: THT selective
13. Depanelization
14. PBA repair

2. Guidelines:
EDM-D-005: PCB Build-up/Density class

Status: Released

Goal: PCB build-up and interconnection density selection



1. Applicable Documents
2. Applicability of the PBA DfM Guideline EDM-D-005
3. PCB Build-up
4. PCB Density Classification
5. PCB Build-Up nomenclature
6. Guideline to PCB Density Classification application

Appendix A: PCB Density Class vs. BGA break-out

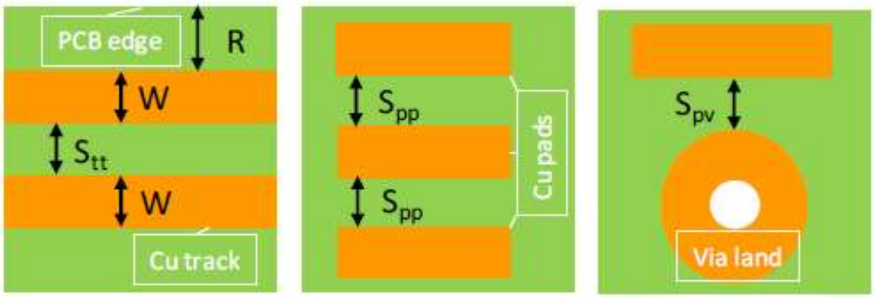
Appendix B: PCB capability inquiry

15th EDM Workshop, 23/11/2012, Barco, Kuurne.

Will be distributed to participants.

2. Guidelines:
EDM-D-005: PCB Build-up/Density class

Track class

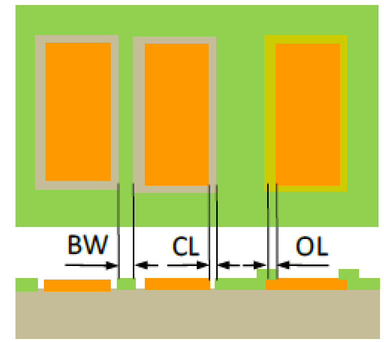


W: Cu track width
S_{tt}: Cu track spacing
R: Routing distance

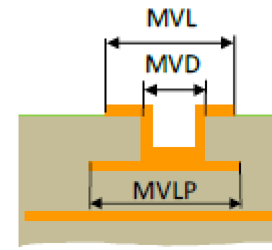
S_{pp}: Pad-to-Pad spacing

S_{pv}: Pad-to-Via spacing

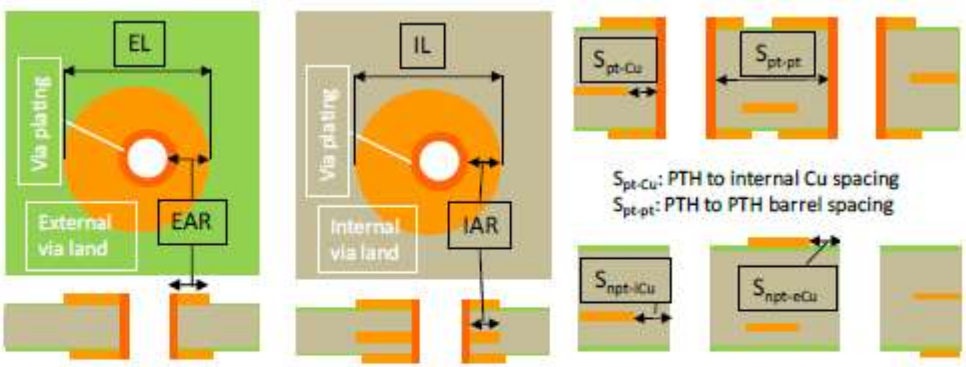
Solder Mask class



BW: Solder mask Barrier Width
CL: Solder mask to Cu clearance
OL: Solder mask to Cu overlap



Via class



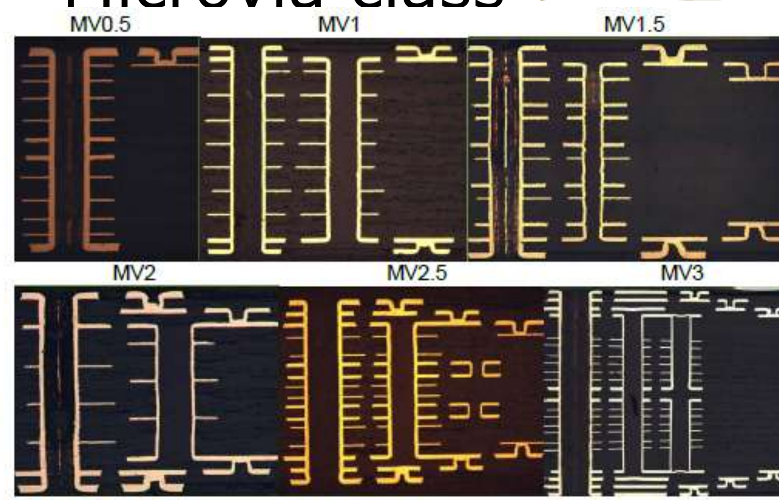
EAR: Minimal External Annular Ring
EL: External Land size

IAR: Minimal Internal Annular Ring
IL: Internal Land size

S_{pt-Cu}: PTH to internal Cu spacing
S_{pt-pt}: PTH to PTH barrel spacing

$S_{npt-eCu}$: NPTH drill to external Cu spacing
$S_{npt-iCu}$: NPTH drill to internal cu spacing

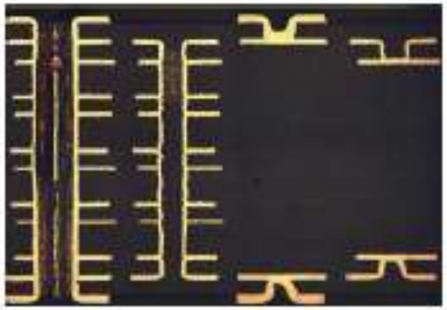
Microvia class



2. Guidelines:
EDM-D-005: PCB Build-up/Density class

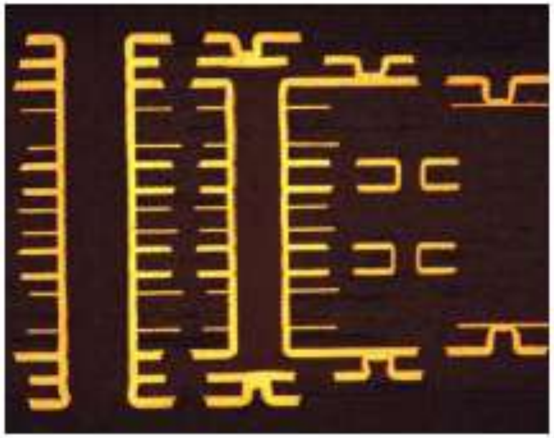
Build-up nomenclature

2-12-T125-V150 -{1.9-10-T100-V125-/121}-/121-MV1.5-SM60-b4



A 2mm thick 12-layer PCB of track class T125 and via class V150 with /121 type laminate with 2 levels of micro-via of which one back-drilled in a 1.9mm thick 10-layer buried via core using T100/V125 density classes and /121 laminates. The PCB has SM60 solder mask and a NiAu finish.

2.4-16-T100+-V125+-{2-12-T125-V125-{2x0.2-2-T125-V125-/101}-/101}-/101-MV2.5-SM50-b1



A 2.4mm thick 16-layer PCB with track class T100 used on the external and the microvia build-up layers. It uses via class V125+ for the Z-direction interconnection of the top level PCB stack made of /101 type laminates. The PCB has one buried via 12 layer stack of 2mm thickness using T125/V125 track and via density classes. This core contains itself two 0.2 thick two layer buried via cores. All laminates are of type /101. The top level structure has two build-up levels of microvia and one level of back drilled microvia totaling three microvia levels. The PCB has a SM50 type solder mask and an immersion Ag finish.

2. Guidelines: EDM-I-001: Mechanical Integration

Status: first working draft

Goal: Determine fixation locations – Mechanical damage mitigation

1. Applicable Documents
2. Applicability of the PBA DfM Guideline
3. EDM-I-001 objective
4. Estimating the mechanical loading on the PBA
5. Mechanical failure mitigation: SMD
   - 5.1. Basic approach to SMD failure mitigation
   - 5.2. Extended approach to SMD failure mitigation
6. Mechanical failure mitigation: Through-hole
7. Mechanical failure mitigation: High profile SMD

2. Guidelines:
EDM-I-001: Mechanical Integration

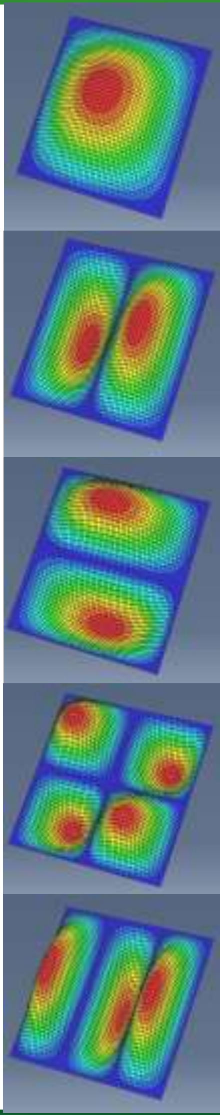
Mechanical integration

Basic approach

- Determine eigenmodes and eigenfrequencies (tool)
- Place fixation points at antinodes of eigenmodes with eigenfrequencies within the loading spectrum.
- Verify.

Advanced approach

- Dermine eigen modes, eigenfrequencies and amplitude.
- Eliminate eigenmodes with amplitudes exceeding limiting bending radius minimum.
- Verify.



3. Industry support

Focus:

Transfering and implementing science based knowledge and methods to local industry.

- Production and operation failure root cause analysis and mitigation: How to avoid?
- Introduction of new technologies (for the company):
  - PCB technology
  - Component technology: packages
  - Assembly technologies
- Design-for-Reliability
- New Product Introduction and industrialisation

3. Industry support

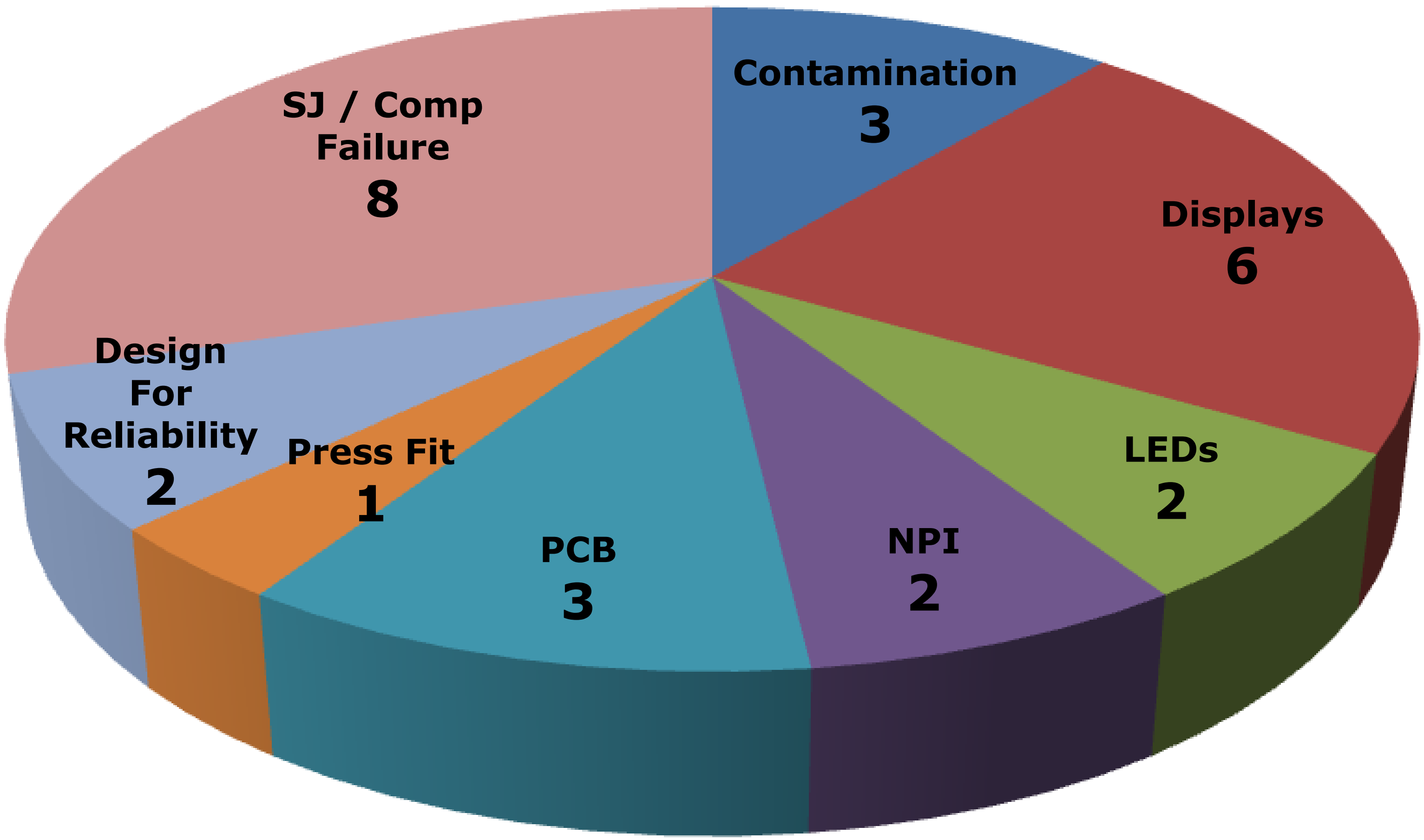
Root cause analysis & how to avoid			
Solder joint failures	Contamination	PCB failures	Displays
Component failures	Assembly quality	LED failures	…

Product- & Process Innovation			
NPI Methodology	PCB/PBA Specification	New assembly processes	Lead free
Component aspects	Design rules	Product / Process / Supplier qualification	…

Training		
Basic PBA Training	Advanced PBA Training	PCB/PBA Technology seminars

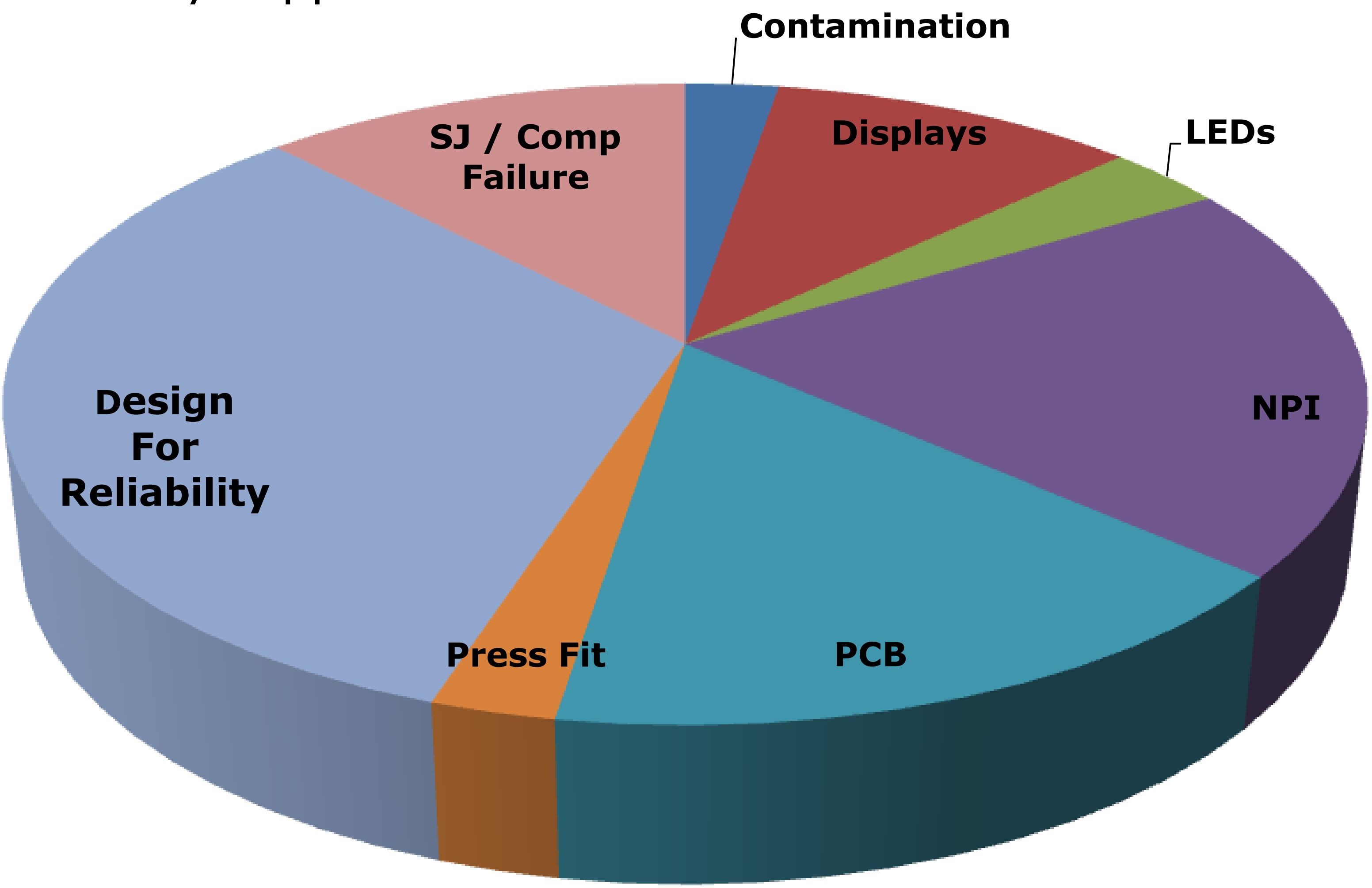
3. Industry support

Most requested consultancy subjects 2012 (27 projects)



3. Industry support

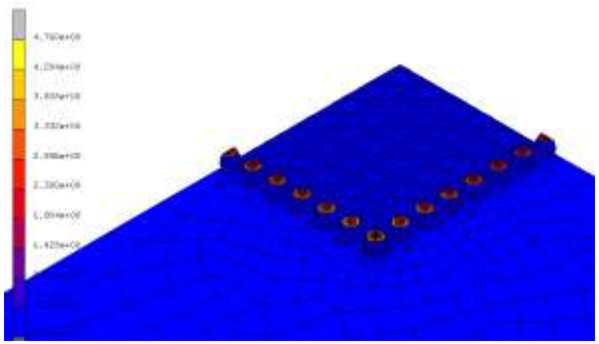
Industry support 2012: effort

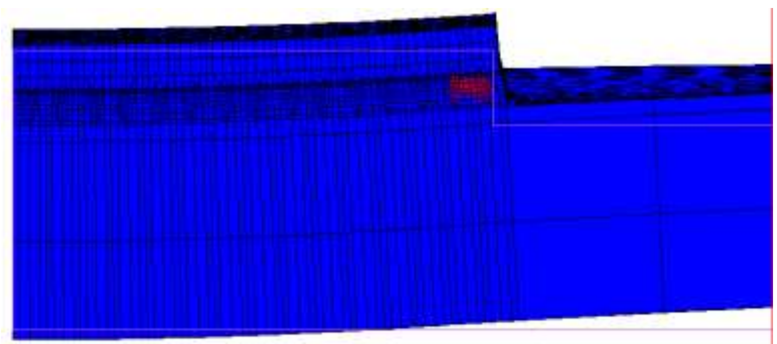


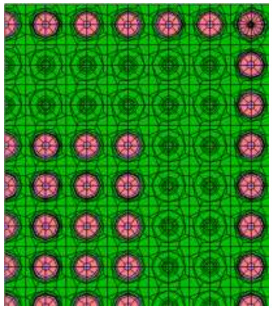
3. Industry support: main topics 2012

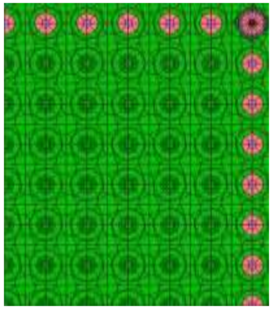
Design-for-Reliability

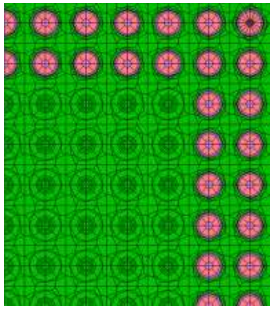
- Goal: Design optimisation for lifetime and cost
- Simulate impact of design parameters (package)
- Predict lifetime

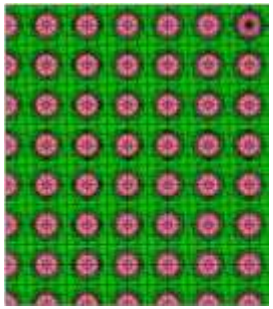








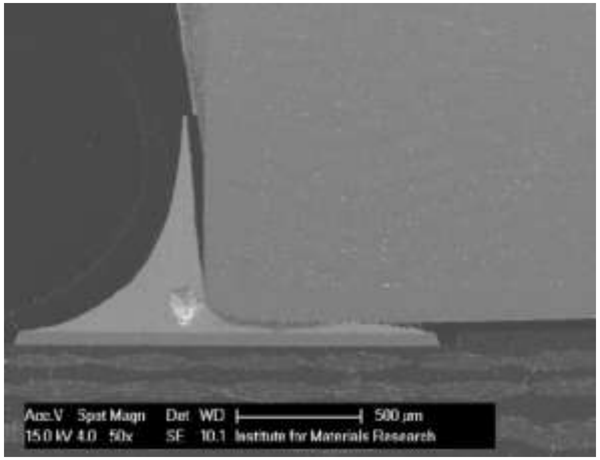


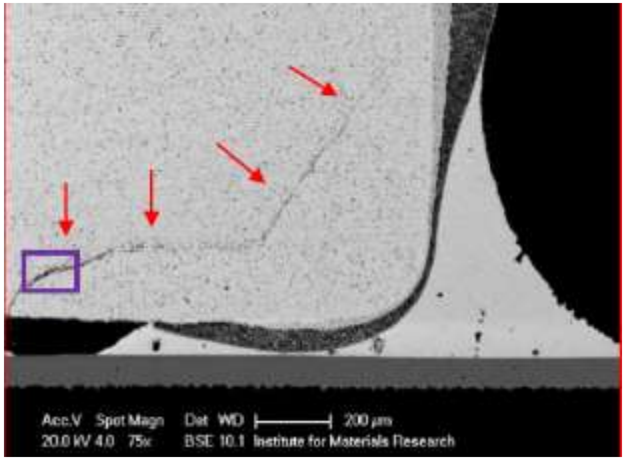


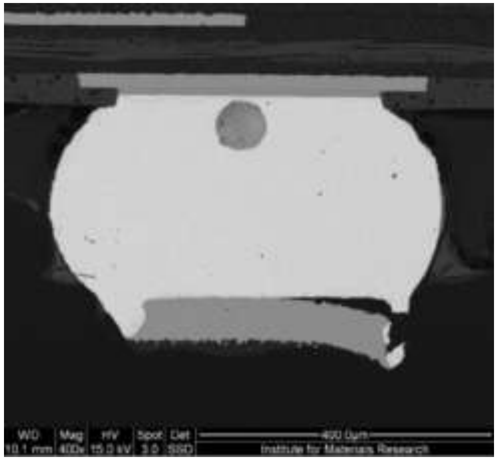
Service projects: main topics 2012

Solderjoint failure / Component failure

- Identify failures: solder joint, lead, PCB, component,...
- Solder joint quality
- Component quality
- Determine root cause and how to prevent
- Impact of design and component specification



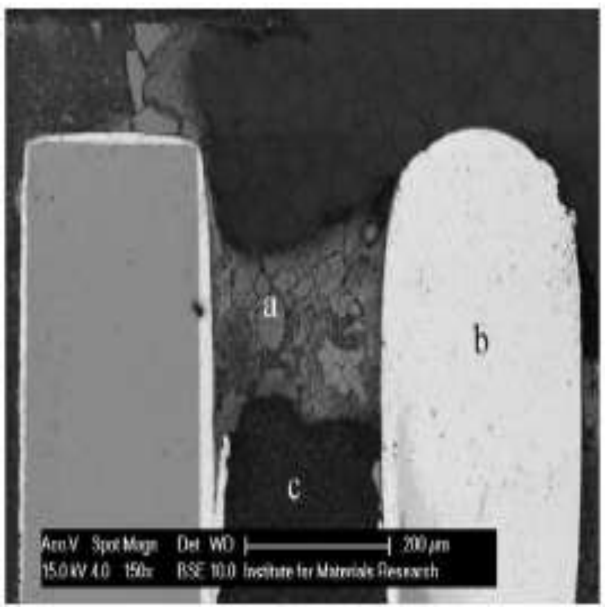


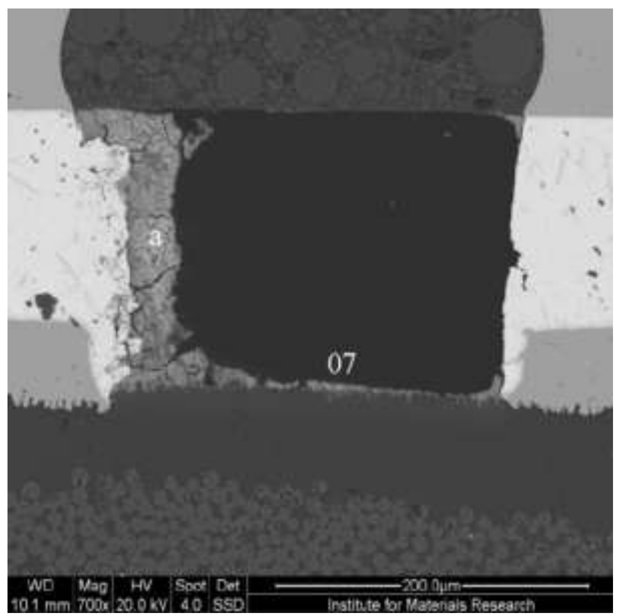


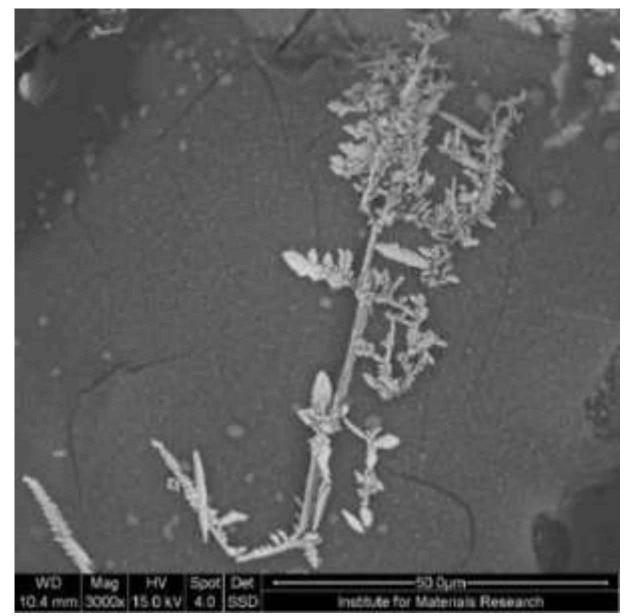
3. Industry support: main topics 2012

Contamination and SIR

- Analysis of PCB or PBA contamination
  - PCB: poor cleaning (HASL flux, finsh chemistry)
  - Assembly materials: poor cleaning (eg. flux)
  - Environment
- Determine root cause and how to prevent



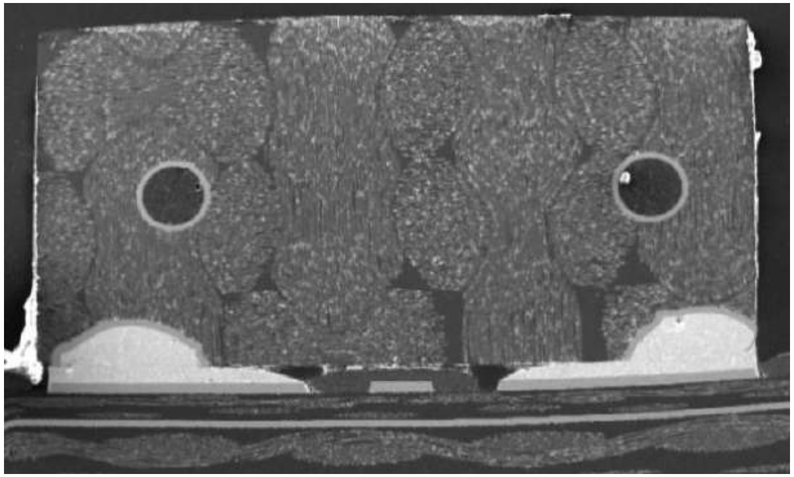


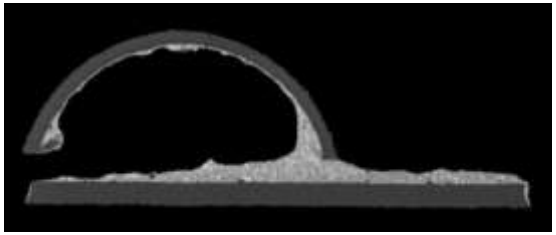


3. Industry support: main topics 2012

LEDs

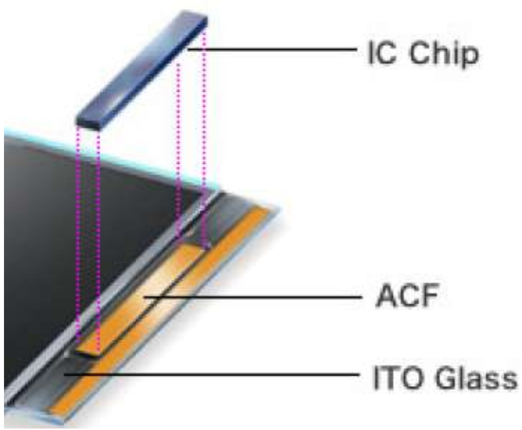
- Solderjoint analysis of odd-shaped leds
- Assembly improvements for led assembly

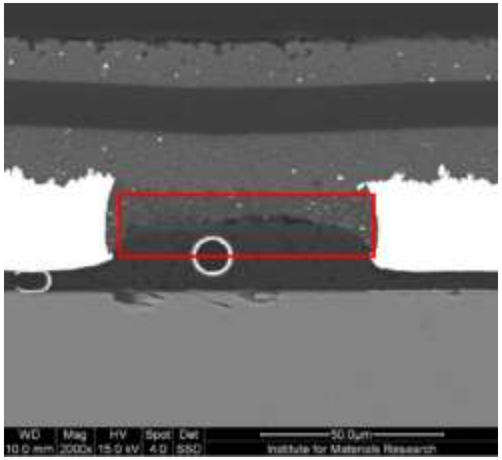


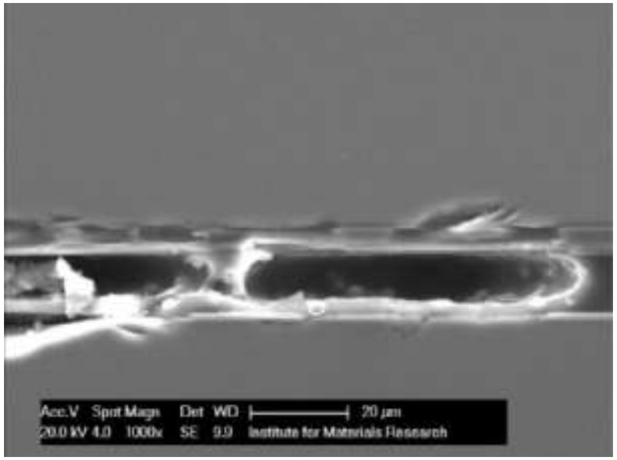


Displays

- Chip On Glass (COG)/Foil On Glass (FOG) technology
- How to test?
- Delamination and voiding
- Design, material and process improvement



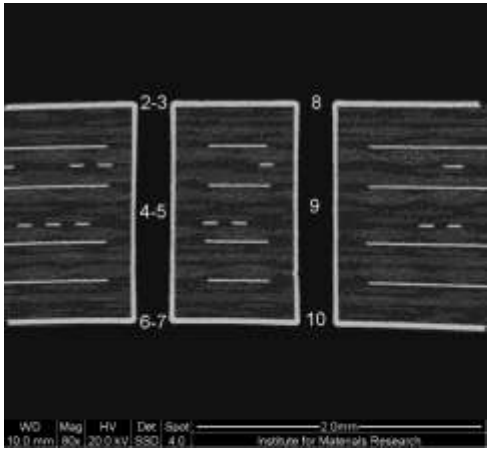


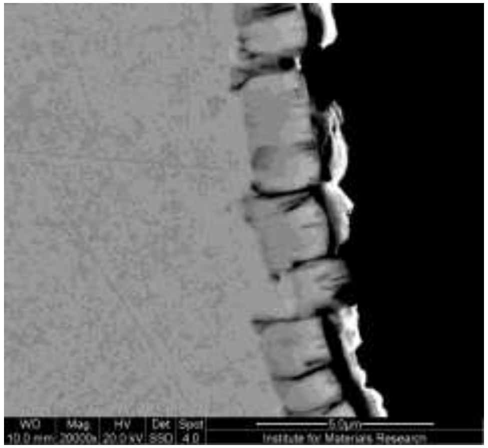


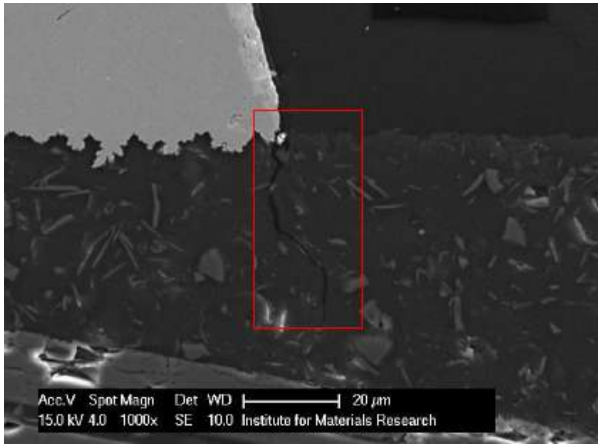
3. Industry support: main topics 2012

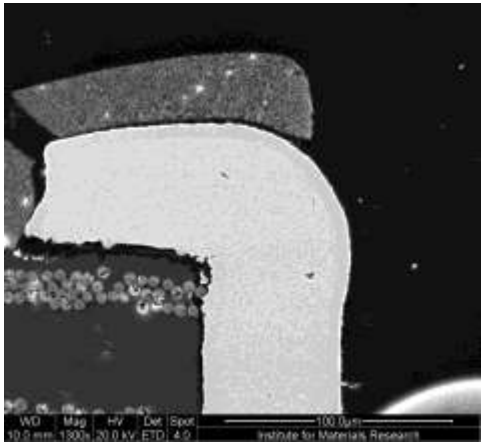
PCB

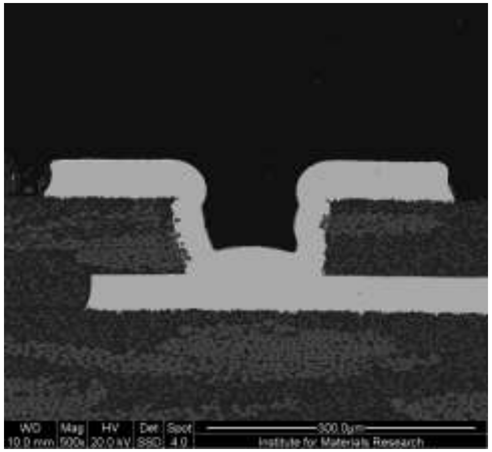
- Analysis of PCB failure
  - Via cracking
  - Delamination
  - Pad cratering
  - SIR
- How to qualify PCB?





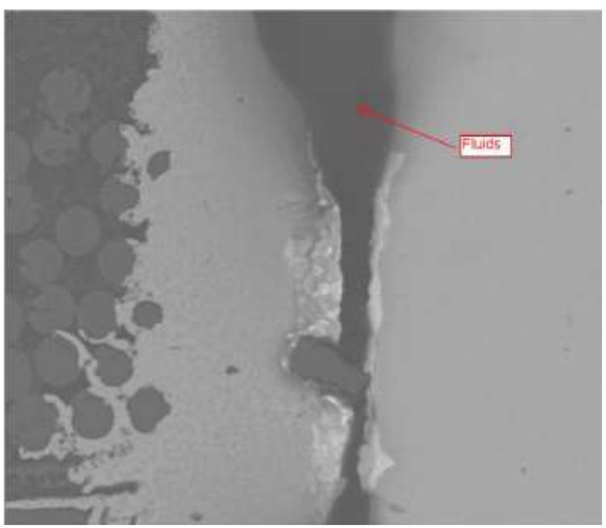


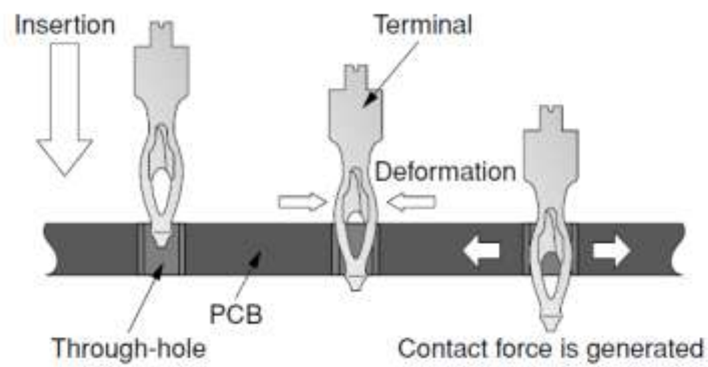




Press Fit

- Detect contact problems and find root cause
  - Design related
  - Fretting corrosion
  - Component quality
  - ...

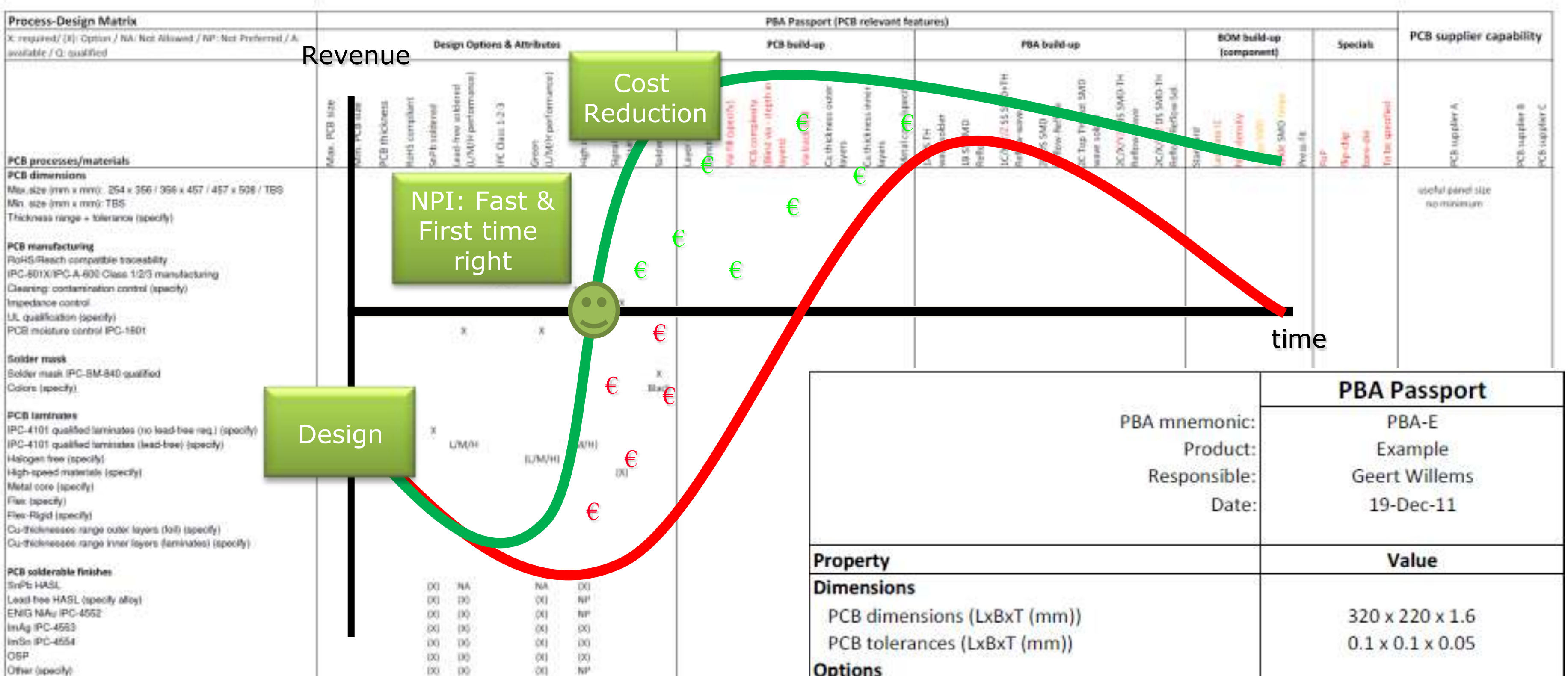




3. Industry support: main topics 2012

New Product Introduction

- NPI Methodology setup, benchmark or advice
- Mapping design versus PCB & PBA supplier capability



Thank you

Geert.Willems@imec.be
++32-498-919464
www.edmp.be