RoHS: Challenges for the OEM and its supply chain

Geert Willems
Imec

23 April 2012
Agoria – RoHS2 seminar

sirris
driving industry by technology

imec

EDM
Electronic Design & Manufacturing

Electronic Design & Manufacturing program MISSION

To support industry *in the development of high quality, reliable and cost-effective electronic modules (PBA) by means of* ***knowledge*** *creation and sharing,* ***scientifically sound methodologies*** *and* ***collaboration*** *throughout the electronic supply chain.*

Collective

- Awareness creation
- Design Guidelines
- PBA development tools
- Seminars - training

Bilateral

- Consultancy
- Knowledge transfer
- Implementation
- Training

Better electronics at reduced cost through science based design & production methodologies.

Content

1. RoHS & Printed Board Assembly
   1. What has changed since 2006?
   2. What brings RoHS2 additionally?
2. The electronic supply chain: who's doing what?
3. What can (and regularly does) go wrong?
4. What to do?

1.1. What has changed since 2006? Soldering processes

SnPb Era

Solder: Tm 179-183°C

$Sn_{63}Pb_{37}$, $Sn_{62}Pb_{36}Ag_2$

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

- **More alloys**
- **Higher temperatures**
- **Smaller process window**

1.1. What has changed since 2006? Components

SnPb Era

Plastic packages

J-STD-20A 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}

RoHS Era

Plastic packages: new materials

–J-STD-20D.1 qualification

–Tmax: 245°C-250°C-260°C

–Special repair requirement

–Moisture sensitivity:
MSL increase 0 to 2 levels

Supersedes:
IPC/JEDEC J-STD-020D - August 2007
IPC/JEDEC J-STD-020C - July 2004
IPC/JEDEC J-STD-020B - July 2002
IPC/JEDEC J-STD-020A - April 1999
J-STD-020 - October 1996

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 23 for fine-pitch components: SnPb – RoHS2: only for spare parts of equipment placed on market before 24/9/2010.

BGA balls

–$SnAg_3Cu_{.5}$, $SnAg_4Cu_{.7}$, $SnAg_{3.8}Cu_{.7}$, $SnAg_1Cu_{.5}$,…

(M… w Ag content balls)

…-free solution available

Process sensitivity (MSL, PSL) and terminal metallurgy have become critical design parameters.

1.1. What has changed since 2006? Printed Circuit Board

SnPb Era

Laminate (standard)

FR4 Tg=130°C-140°C

High Tg FR4: Tg up to 180°C

Finish

SnPb HASL

ENIG NiAu

OSP

RoHS Era

Laminate (Lead-free solder compatible)

- –Issues: delamination, via cracking, CAF, degradation
- –High Tg FR4 160°C-180°C (poor solution)
- –New FR4-like non-dicy cured filled laminates
  Reduced CTEz, increased Td and T260/T288
  NEW FAILURE MODE: brittle fracture of laminate!
- –Large variety of materials. FR4 is insufficient as material identifier. New set of specifications & tests.

Finish

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

PCB failure rate has strongly increased. Laminate selection and solderable finish are critical design parameters.

1.1. What has changed since 2006? Assembly and supply chain

SnPb Era

Component ID

- Functional
- Package

Traceability

Only for specific applications

Assembly operation

One solder alloy for all soldering operations

One

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

Assembly operation

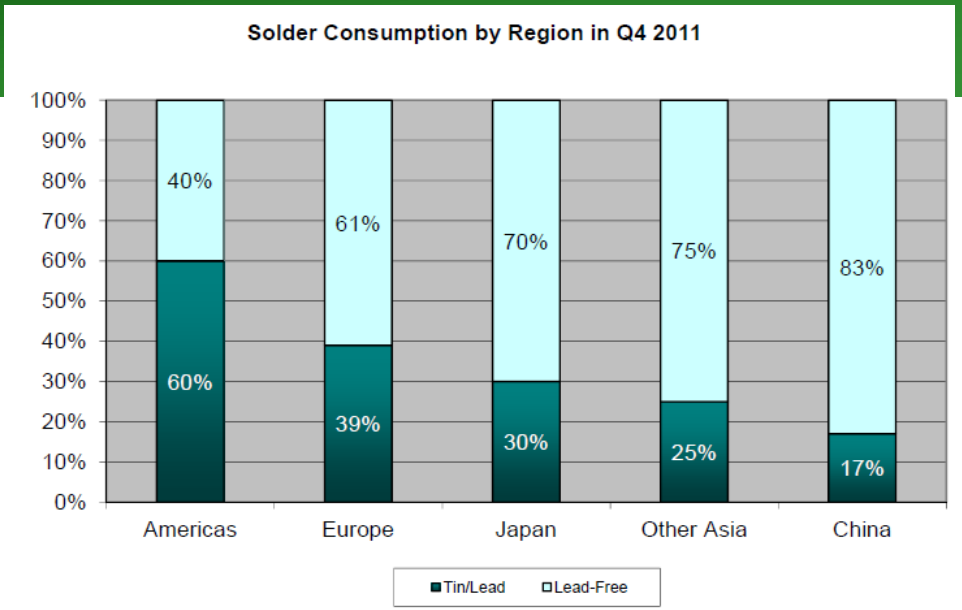
- SnPb solder plus one or more lead-free alloys
- SnPb and lead-free soldering processes/equipment
- **Product groups**

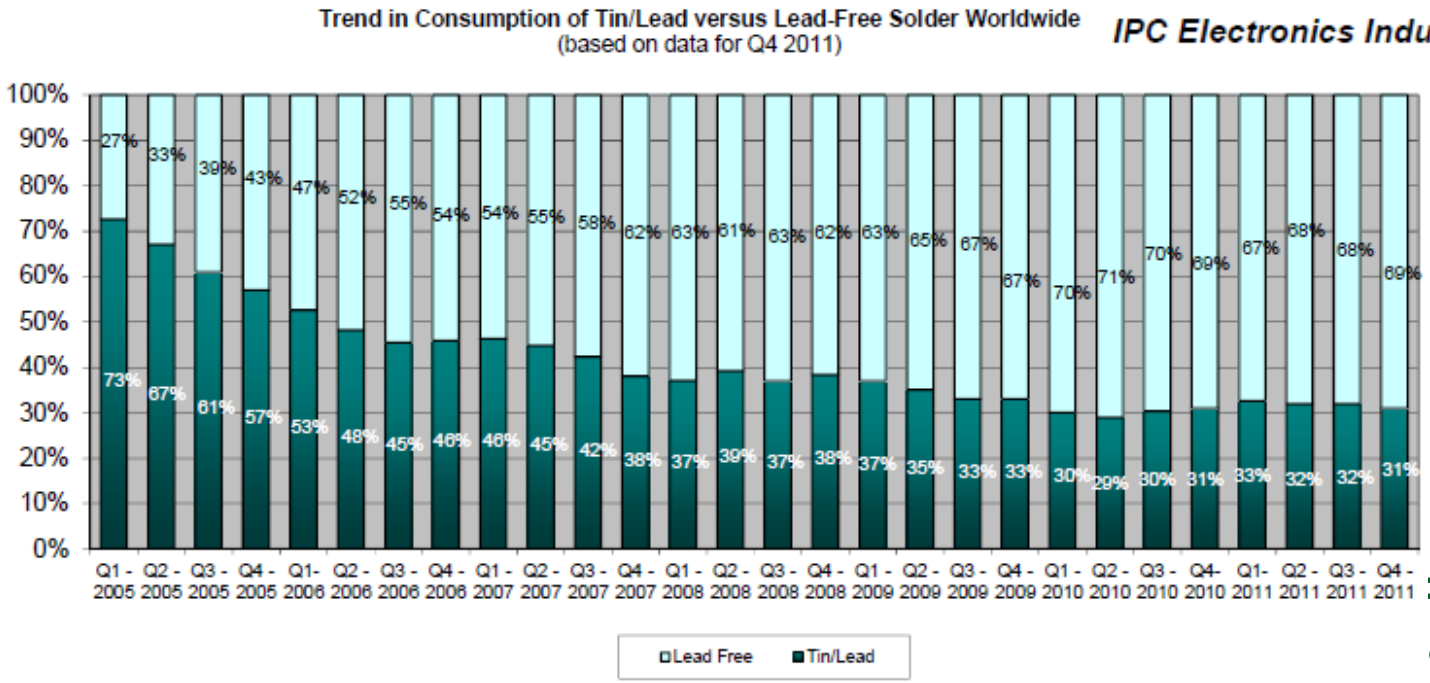
RoHS ≠ lead free ≠ lead-free solderable!

- **Traceability required but…**
- **RoHS2 traceability is MANDATORY (CE)!**
- **Many more parameters per component: complexity of identification and logistics**

1.1. What has changed since 2006? Solder use

- SnPb soldering remains important for the foreseeable future.
- Mixed SnPb/lead-free supply chain remains a reality.





IPC Electronics Industries Market Data Update Winter 2012

Q4-2011 World

Lead-free 69%

SnPb 31%

1.1. What has changed since 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, pad cratering…)
  - Shifting of failure location: from solder joint to solder joint environment.
  - New materials jeopardizing product reliability.
  - Identification and tracking errors, human error and lack of robust supply chain control systems.
  - Counterfeiting of components (5-10%)
  - We are still in the learning curve!
- … and several unknowns

1.2. What brings RoHS2?

1. RoHS part of CE certification: A major logistical challenge!
   → Full traceability is mandatory
   → Readiness of ERP systems?

2. Even more complexity for OEM and EMS:
   1. Separate exemptions for medical/monitoring/control devices.
   2. ELV and RoHS exemptions are different! Automotive producers be aware!
   3. Various exemption expiration dates for various exemptions.
   4. Different products come in scope at 22 July 2014,16,17. "all EEE" by 2019.
   5. There are still PBA to be designed/produced for out-of-scope products.

3. No additional ban of substances with major impact.

4. More clarification and specifications but...

1.2. What brings RoHS2?

5. Large stationary industrial tools unresolved

(3) 'large-scale stationary industrial tools' means a large-scale assembly of machines, equipment, and/or components, functioning together for a specific application, permanently installed and de-installed by professionals at a given place, and used and maintained by professionals in an industrial manufacturing facility or research and development facility;

RoHS?

- *Large-scale: How large?*
- *Assembly of... for a specific application:*
  Valid for all industrial tools, machines, equipment.
- *Permanently installed:*
  Nothing is permanent. How long is permanent?
- *Installed, de-installed, maintained by professionals:*
  Valid for all industrial tools, machines, equipment.

→ All industrial equipment out of scope?

Same issue with "fixed installation".

1.2. What brings RoHS2?

6. Conflict between RoHS principles and analysis methods

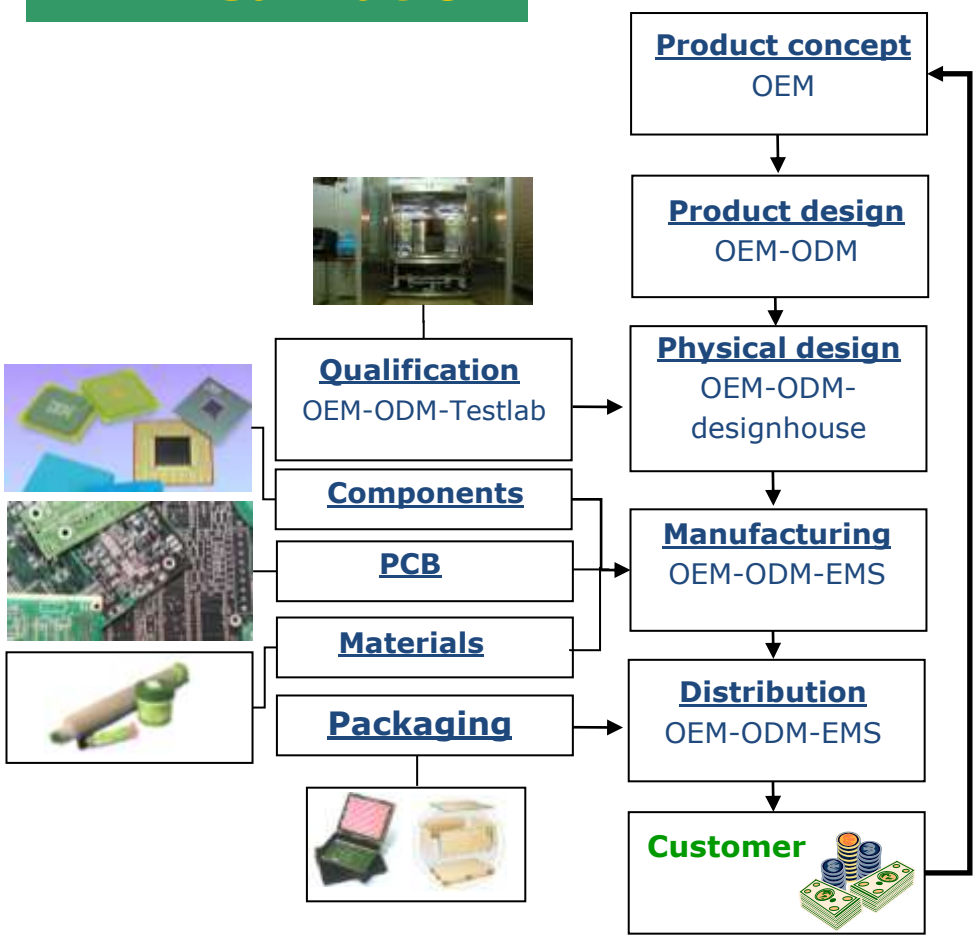
- RoHS is based on homogeneous materials and application specific exemptions of the use of banned substances. Thus: *Technological knowledge is MANDATORY to verify RoHS compliancy.*
- RoHS enforcement authorities look for *"Technology-Dummy-Black Box"*-analysis methods to determine RoHS conformity. *Black-Box analysis is IN PRINCIPLE IMPOSSIBLE.*

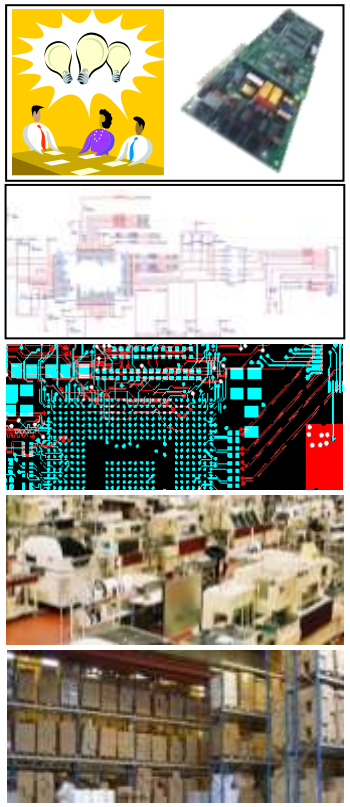
Be aware:

- That RoHS compliancy CANNOT be proven by analysis, only disproved!
- Technology know-how is mandatory when RoHS compliancy is challenged!
- There is a lot of legal lead in RoHS compliant electronics. Don't call your electronics "Lead-Free" when it is only RoHS!

2. Electronic supply chain: who is doing what?

PBA realization



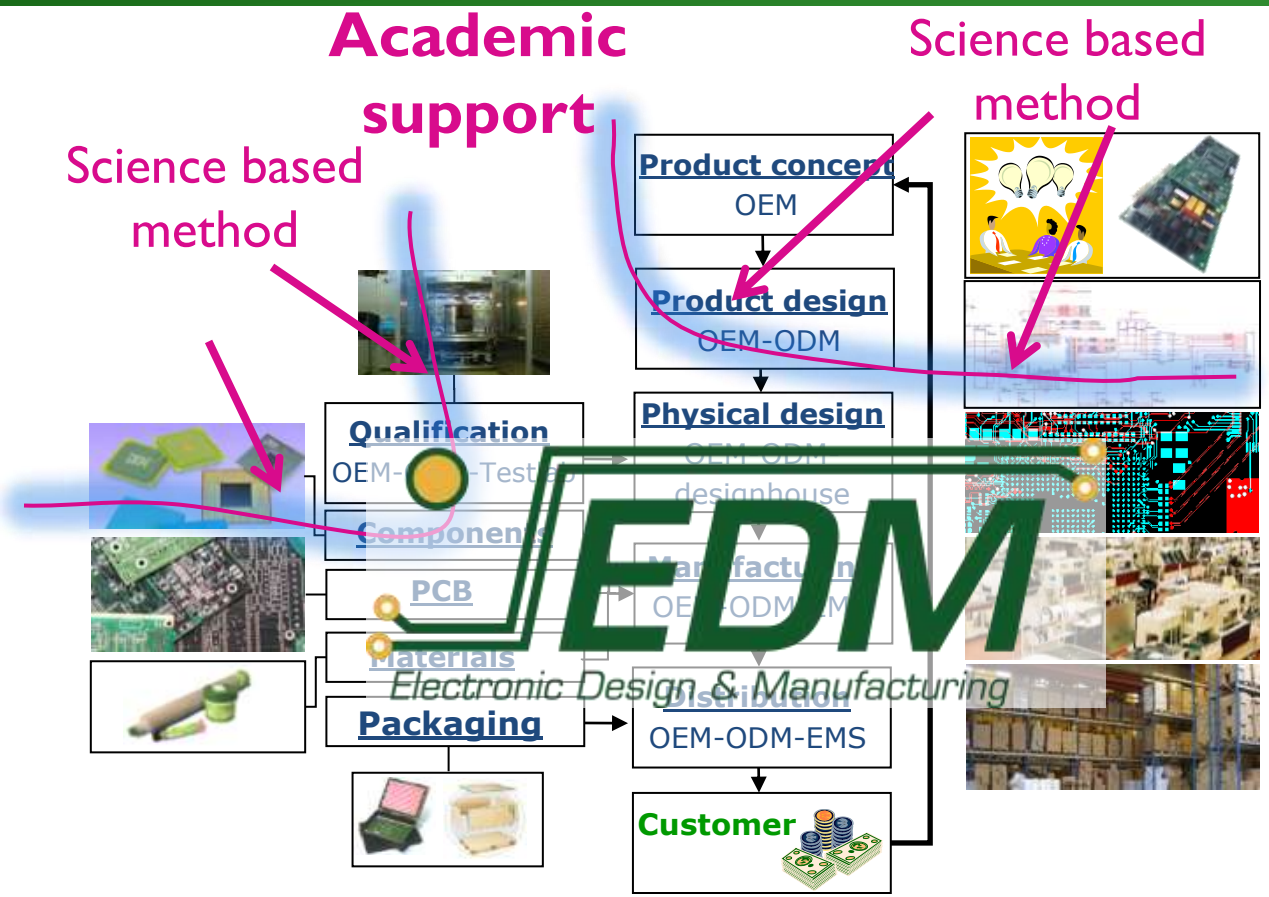


- Many players.
- International.
- Very complex.
- Fragmented responsibility.
- Insufficient academic support.
- No PBA education at master level (engineers).

Consequence

- Poor PCB/PBA product specificat.
- Poor control of the supply chain.
- Development of design guidelines has stopped?

2. Electronic supply chain: who is doing what?



Electronic product realization
Experience-based industrial approach

Scientific basis and level of education too weak:

- PCB manufacturing
- PB assembly
- Test coverage
- PCB/PBA technology
- Failure-mechanisms
- Design-for-X
- Reliability tests
- etc.

to handle todays and future complexity and Reliability challenges.

2. Electronic supply chain: who is doing what? In practice

- 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 a European *StuffIt* PBA plant.
- ODM *CreateIt* is responsible for Engineering Change Orders.

2. Electronic supply chain: who is doing what? In practice

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*)?
- Are there clear agreements made?
- Is there sufficient know-how present?
- How to control that specifications are met?
- What about communication between links?
- What about traceability?

2. Electronic supply chain: who is doing what? In practice

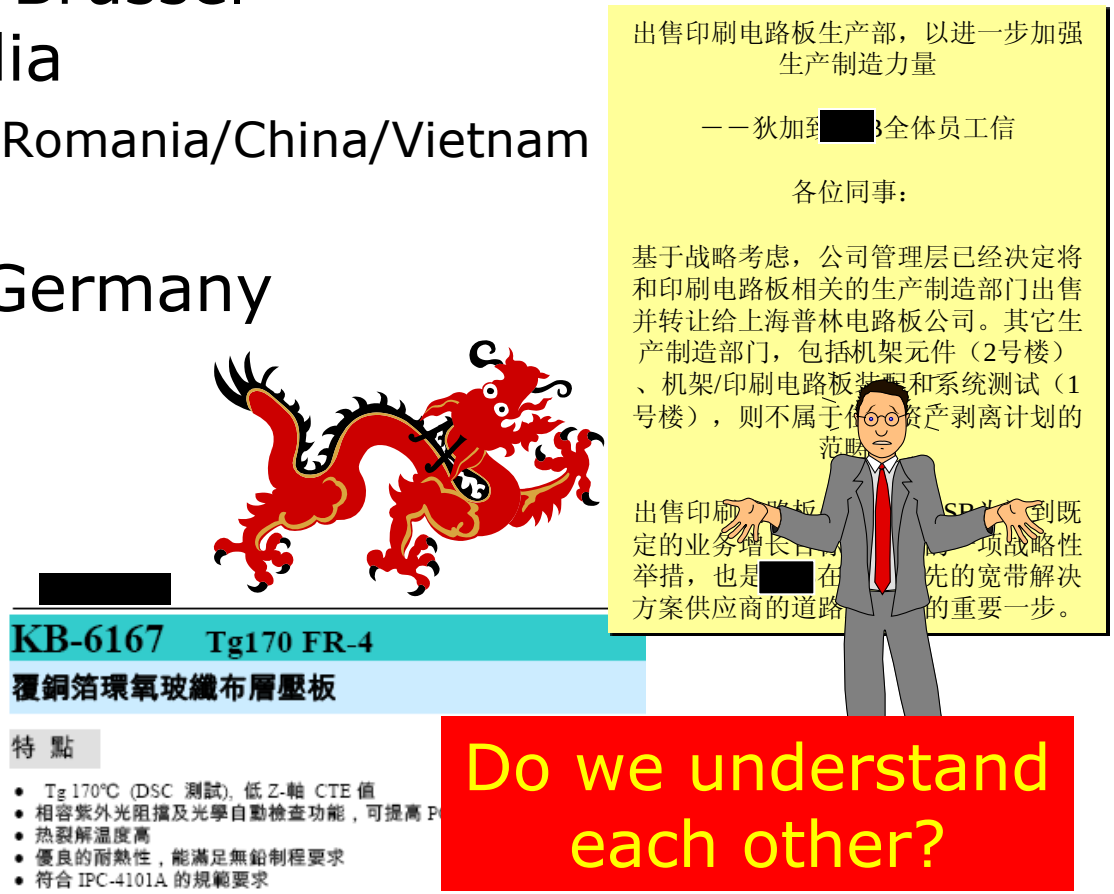
What if:

- OEM *BestProduct*: Brussel
- ODM *CreateIt*: India
- EMS *Stuffit*: France/Romania/China/Vietnam
- PCB *Print*: China
- Brooker *GetItAll*: Germany
- Second sourcing?

Language, culture, legislation, ...

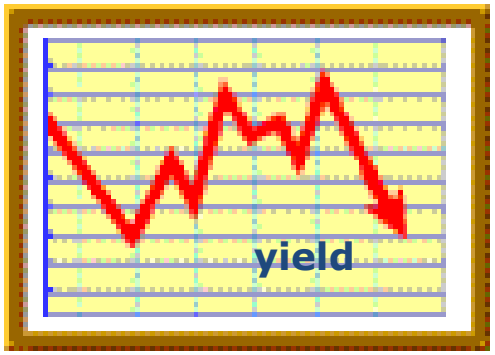
Standardisation:

- IPC standards in Asia?

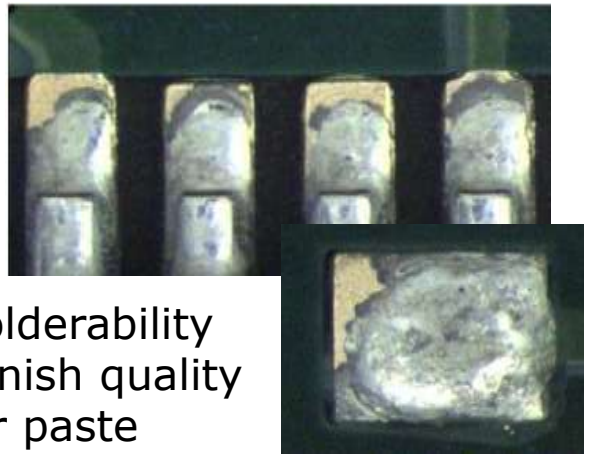


3. What can go wrong?

In assembly: Yield and quality

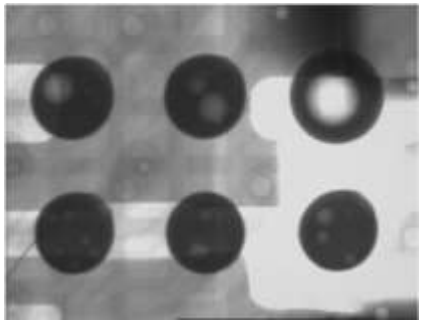


Poor quality
- Components
- PCB
- Assembly process
- Design



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

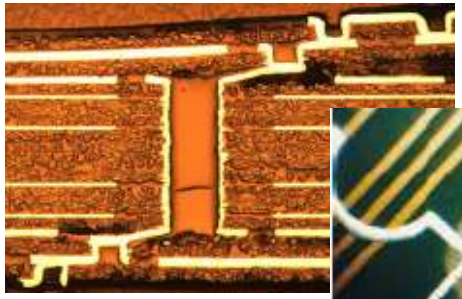
Through-hole filling
- Solder process
- Solderability of component or PCB



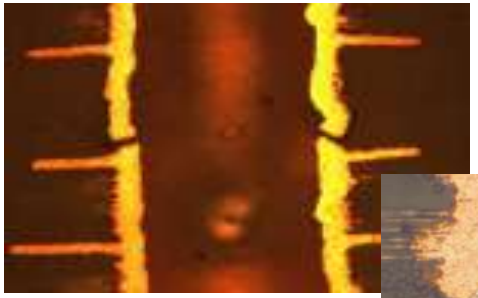
BGA voiding
- Reflow process
- Solder paste
- PCB design

3. What can go wrong?

In assembly: damaged PBA

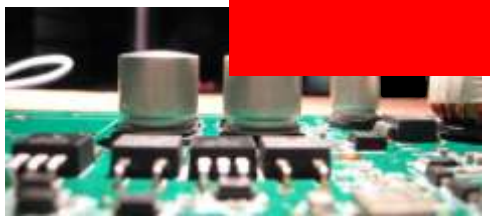


PCB



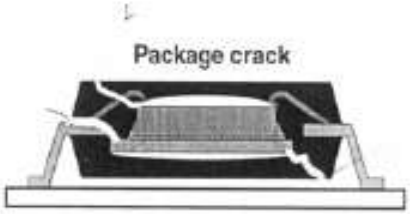
Dela
•PCB
•Pro

Major cause of failing electronics!
Estimated damage for Belgian products:
Tens of million Euros



Component

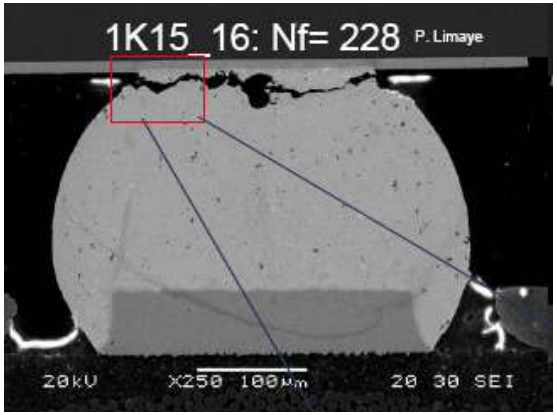
•Overheating
•Incompatibility of component with lead-free soldering



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

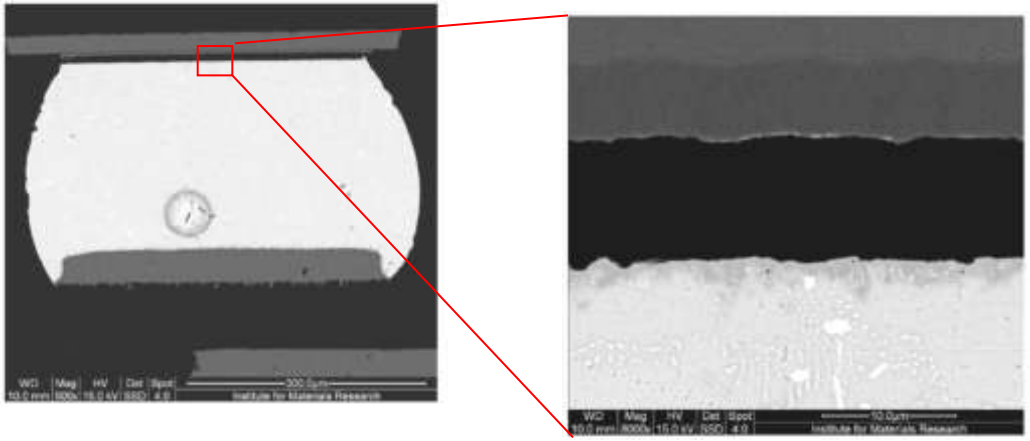
3. What can go wrong?

During operation: solder joint failure … on the rise!



Solder joint fatigue

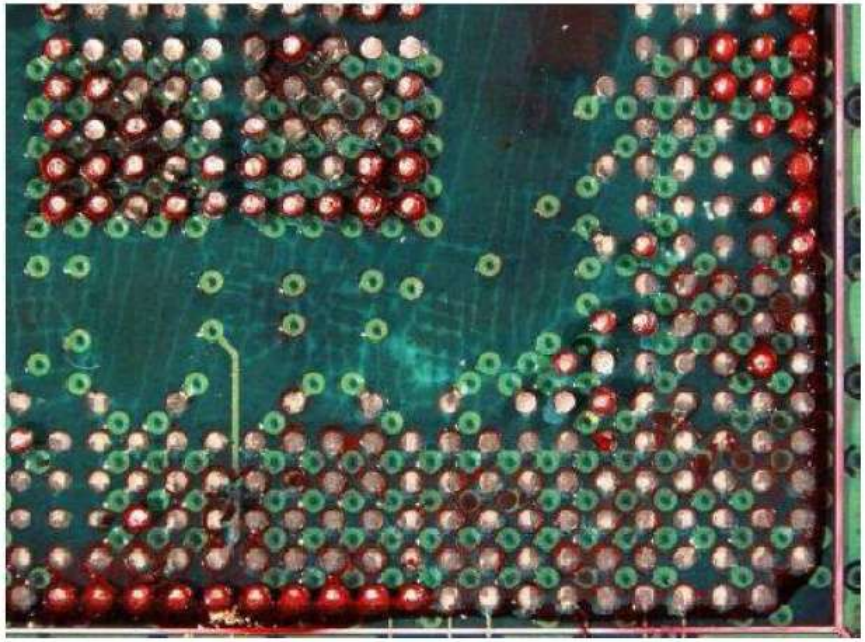
- Design: CTE mismatch
- Design vs. operational conditions
- Lead-free solder alloy

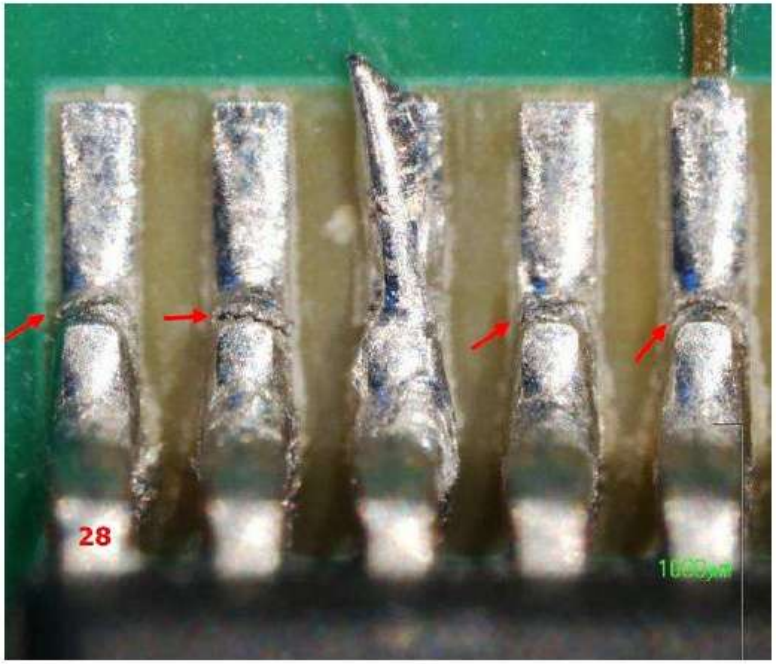


Interface failure

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

3. What can go wrong?
"Green" mold compound

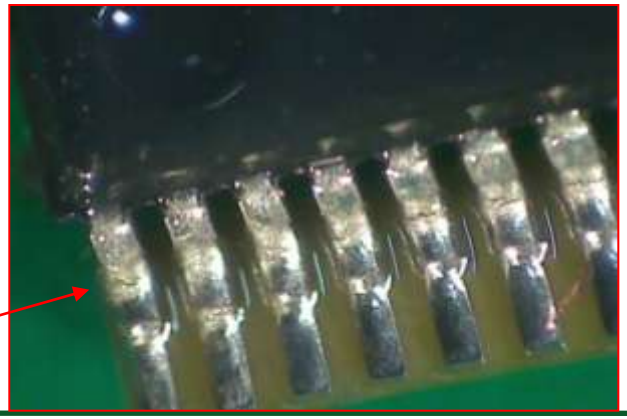




Unexpected early failure

Solder joint failure: BGA and TSOP II

Lead failure: TSOP I – Cu leadframe



3. What can go wrong?
"Green" mold compound

Driven by:

- Need for reduced moisture sensitivity (RoHS-lead-free)
- "Going Green" trend: Halogen-free plastics
- Die stress: new IC-dielectrics
- Cost

→ Electronic component manufacturers introduced highly SiO_2 filled (85%) "Green mold compounds"

February 10, 2010 CN-021010

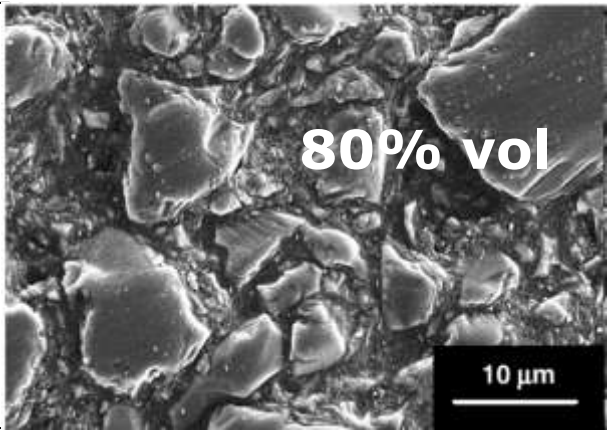
Customer Notification
Mold Compound Change

Dear Valued Customer:

This notification is for the purpose of informing you of that our Assembly supplier is converting all mold compounds to green material sets.

Purpose

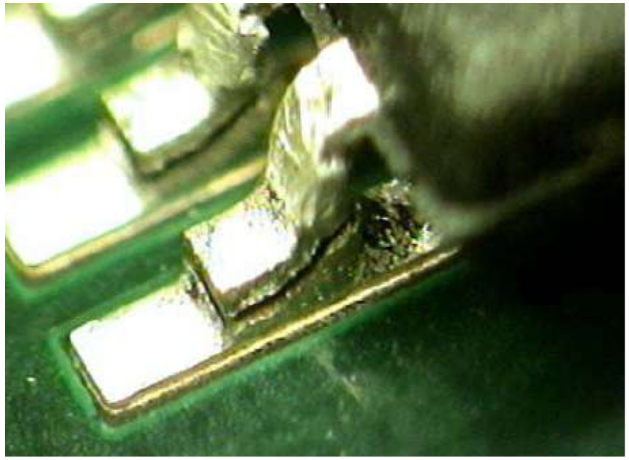
Due to their worldwide GREEN policy, ASE will transfer all devices which use non-green molding compounds to green molding compounds.



3. What can go wrong?
"Green" mold compound

- High SiO_2 filling creates molding compound with very low thermal expansion: 6-10 ppm.
  (For reference: CTE Al_2O_3 = 6.7ppm (ex. CBGA))
- In the past it matched the PCB CTE of 14-18 ppm
- This creates a nearly **tenfold** increase in thermal mismatch between component and PCB.
- Depending on component and PCB details:
  A major increase of thermo-mechanical strain of solder joints and component leads (TSOP).

A major threat to solder joint and interconnect reliability



3. What can go wrong? "Green" mold compound

But component supplier customer notification claims

Customer Notification
Mold Compound Change

Customer Impact

No customer impact is anticipated with this change; there is no change to form, fit, or function.

In general (there are exceptions):

- SJ reliability knowledge is i
- SJ reliability is not tested b
- Customers are misinformed

Today's electronics has a significantly shorter lifetime but you may not be aware of it (yet)!

Consequences:

- The change towards low-CTE mold compounds has passed below the radar of the OEM and EMS suppliers.
- A major threat to the reliability of non-consumer electronics. Considerable reduction in lifetime expected: a factor of 1 to 4

Vandevelde, B.; Lofrano, M. and Willems, G.
Green mold compounds: impact on second level interconnect reliability.
Electronics Packaging Technology Conference - EPTC. ieee, 2011. (7-9 December 2011; Singapore)

3. What can go wrong?

During operation: failing insulation

PCB surface

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

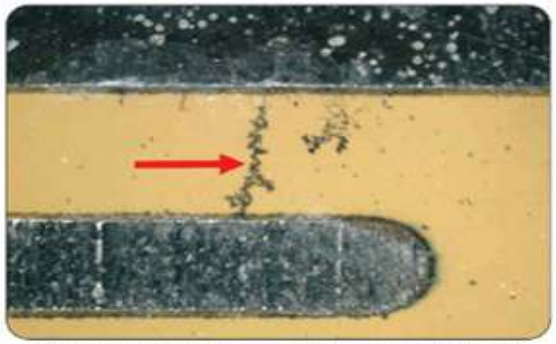
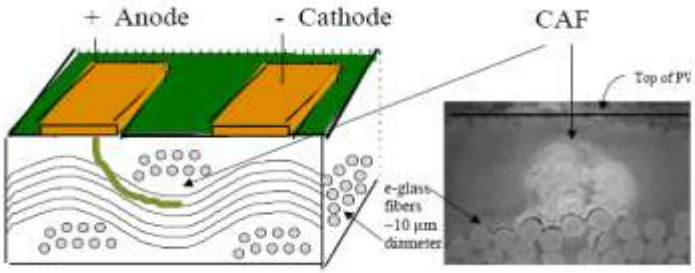
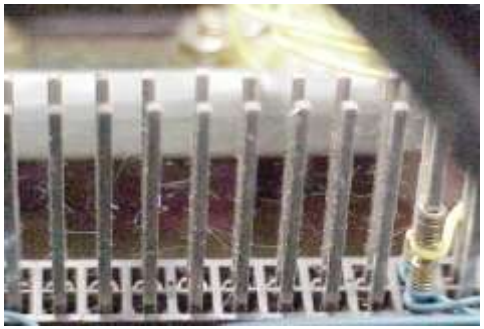


Figure 3-1: Dendrite growth between positively and negatively biased conductors (top and bottom).



Conductive Anodic Filament
- Design
- PCB laminate selection
- PCB quality
- PBA quality

PCB internal



Component terminals

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

3. What can go wrong?
In the newspapers

More than an academic discussion

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

WIKIPEDIA
The Free Encyclopedia

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

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 w 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 reportir

Cost: >US$ 1.000.000.000

Toyota Recalls 1.1 Million Corolla, Matrix Cars For Stalling

By John Voelcker
Senior Editor
August 26th, 2010

318 Views
comment now!

Toyota

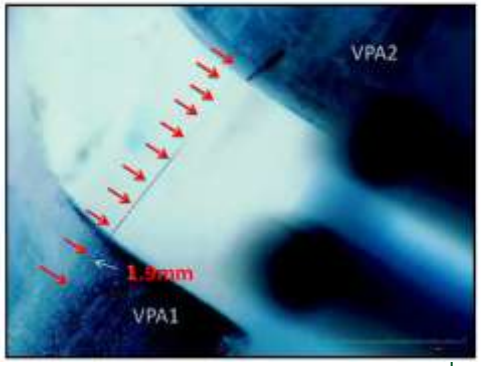
Toyota today announced that it would recall roughly 1.1 million Corolla s and Matri

The recall is a response to concerns over stalling issues reported in those models. The

Adm tion (NHTSA) has b late last year.

Under certain circumstances, Toyota says, solder connections may develop a crack that creates unpredictable behavior in the circuit. A crack may also develop where a component called a varistor (which protects against excessive voltage) is attached to the circuit board.

Whiskers in Faulty 2003 Toyota Camry APP Sensor



4. What to do?

KNOWLEDGE, SPECIFATION AND CONTROL

- We can no longer afford to design and produce our electronics with 20th century methodologies.
- The realisation of an electronic product is much more than designing electrical circuitry and throwing it over the wall towards the (outsourced) supply and production chain.
- A legal, reliable product with predictable cost and delivery performance requires specification and realisation of the components, PCB and assembly with **technological, manufacturing and operational KNOWLEDGE** throughout the complete supply chain.
- The required knowledge (preferably quantitative):
  - Technological: components, PCB, PB Assembly
  - Manufacturing: quality risks, logistical and cost elements
  - Reliability: failure mechanisms, accelerated testing, lifetime,..

Translated into Design-for-X guidelines.

4. What to do?

The OEM perspective: *The driver seat*

1. **Define** the product requirements related to RoHS, cost, quality and reliability for the operational conditions of the product.
2. **Define** the design rules and selection criteria for PCB, components, PBA materials and processes.
3. **Specify** explicitely EACH part and EACH relevant aspect of the product.
4. **Qualify** parts (components, PCB) and the suppliers.
5. **Verify** that requirements and associated specifications are maintained through-out the complete product lifetime.
6. **Establish** full traceability with appropriate methodologies and tools throughout your complete supply chain to fulfill RoHS and Reach obligations.

4. What to do?
Need to know

- Components
  - RoHS compliancy: documents, analysis, traceability, control,...
    Be aware of counterfeit!!
  - (Lead-free) soldering compatibility
  - Terminal metallurgy & "body" materials: Green Mold Compound!
  - Logistical aspects: availability, storage

Counterfeit components find new markets

By Rob Spiegel – 4/9/2009
EDN

Although it's impossible to know for sure, industry experts estimate counterfeiting cost at $100 billion to $200 billion annually, or nearly 10% of all electronic equipment sold worldwide. Most industry experts claim that the problem is escalating and note that, although the federal government and several industry associations have taken measures to limit counterfeiting, it continues to plague the components industry.

Counterfeiters are even targeting low-cost, passive components. "Everything is getting counterfeited," says Robin Gray (photo), executive vice president of NEDA (**National Electronic Distributors Association**). "It's not just the high-value items, [such as] semiconductors. It can be connectors, resistors, anything that can turn a good profit, anything that's on allocation, anything that's in high demand."

- PCB
  - RoHS compliancy: lead-free solderable finish
  - PCB technology: possibilities and limitations
  - (Lead-free) soldering compatibility!
    - Use of lead-free soldering compatible laminates!
    - Understand impact of solderable finish
  - Logistical aspects: storage (shelf life, moisture)

4. What to do?
Need to know

- Assembly
  - RoHS compliancy: traceability on the production floor
  - PBA technology and assembly: possibilities and limitations
  - **Design-for-Assembly** principles
  - Properties of assembly materials
  - Yield, defect rates: determining factors

- PBA failure mechanisms
  - Understand failure mechanisms:
    components, PCB, interconnect, insulation.
  - Impact of desigbn: component selection, PCB properties, dimensions, materials,… → **Design-for-Reliability**
  - Impact of operational conditions

Conclusion

RoHS has introduced a major paradigm shift.

Many more things can go wrong with PBAs…

… but do not have to go wrong!

- Good DfX design, specification and verification are essential. Acknowledge technicality!
- The OEM bears full legal, quality and reliability responsibility. Acknowledge this.
- Know what you need to know. Do not underestimate! 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!

Thank you!

EDM
Electronic Design & Manufacturing

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

Met steun van het IWT