How is the commercial world responding to RoHS?

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What is RoHS?

Restriction On the use of certain Hazardous Substances in Electrical and Electronic equipment (July 1, 2006)

- Created by the European Union
- What is restricted?
  - Lead, mercury, cadmium, Cr$^{6+}$, polybrominated biphenyls (PBB), polybrominated diphenylethers (PBDE)
- Who is covered?
  - Household appliances, IT & telecom, Consumer equipment, Lighting, Tools, Toys and leisure equipment, Automatic dispensers
- Copycats spreading around the world
  - China (2007), Korea (2008), California (2010), South America (?)
- The result?
  - SnPb parts hard to find and getting expensive (40-50% increase)
Concerns of the Commercial Marketplace

Everything they’ve always worried about?
Design

- No major design changes
  - Some reduction in bond pad dimensions
  - Smaller ceramic capacitors for wave soldering

Good News!
Suppliers (Parts)

- Tracking of RoHS5 / RoHS6 compliance
  - Update of part control systems
  - Availability (Obsolescence)
- Market still unsteady; proliferation and evolution of material sets
  - Die Attach
  - Platings
  - Solder ball
- Robustness at elevated reflow temp
  - Pretty much addressed
- Tin whiskering

Diagram:
- SnCu
- SAC405
- SAC305
- SAC105
- SN100C
- SACX
Supply Chain (Tin Whiskering)

- Focus on critical components
  - < 1 mm pitch (0.3 mm spacing)
  - Metal can housing
  - Contact points (flex connector)
  - Welds (electrolytic capacitors)
- Follow industry specifications
  - Perform testing
  - Request test data
- Demand mitigation
  - Anneal for 1 hr at 150C
  - Use nickel underplate (>1.2 μm)
  - Plating thickness > 10 μm
- Request alternatives
  - Not aware of any commercial company considering solder dipping
Manufacturing (Printed Circuit Board)

- HASL – ENIG – ImAg – OSP – HASL (Pb-free)
  - Better wetting, good co-planarity, long storage life

- Damage during reflow

<table>
<thead>
<tr>
<th>Board thickness</th>
<th>IR-240~250</th>
<th>IR-260</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤60mil</td>
<td>Tg140 Dicy</td>
<td>Tg150 Dicy</td>
</tr>
<tr>
<td></td>
<td>All HF materials OK</td>
<td>HF - middle and high Tg materials OK</td>
</tr>
<tr>
<td>60~73mil</td>
<td>Tg150 Dicy</td>
<td>Tg170 Dicy</td>
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<tr>
<td></td>
<td>NP150, TU622-5</td>
<td>HF -middle and high TG materials OK</td>
</tr>
<tr>
<td></td>
<td>All HF materials OK</td>
<td></td>
</tr>
<tr>
<td>73~93mil</td>
<td>Tg170 Dicy</td>
<td>Tg150 Phenolic + Filler</td>
</tr>
<tr>
<td></td>
<td>NP150G-HF</td>
<td>HF -middle and high TG materials OK</td>
</tr>
<tr>
<td></td>
<td>HF -middle and high TG materials OK</td>
<td></td>
</tr>
<tr>
<td>93~120mil</td>
<td>Tg150 Phenolic + Filler</td>
<td>Phenolic Tg170</td>
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<tr>
<td></td>
<td>HF -middle and high TG materials OK</td>
<td>HF -middle and high TG materials OK</td>
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<tr>
<td>121~160mil</td>
<td>Phenolic Tg170</td>
<td>Phenolic Tg170 + Filler</td>
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<tr>
<td></td>
<td>HF -high TG materials OK</td>
<td>HF -high TG materials OK</td>
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<tr>
<td>161mil</td>
<td>Phenolic Tg170 + Filler</td>
<td>TBD</td>
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<tr>
<td></td>
<td>HF material - TBD</td>
<td></td>
</tr>
</tbody>
</table>

HASL – Hot air solder level
ENIG – Electroless nickel/immersion gold
ImAg – Immersion silver
OSP – Organic solderability preservative

IR-260

Phenolic Tg170
HF - high TG materials OK

≤60mil

IR-240~250

Phenolic Tg170
HF material - TBD
Manufacturing (Printed Circuit Board Assembly)

- Narrower process window
  - Solvable (takes more time then you might think)

- Hole Fill
  - Higher pot temperatures, avoidance of OSP
  - Solvable

- Shrinkage cracks / Hot tearing
  - Solvable

- Optical inspection
  - Pb-free now shiny

- Copper dissolution
  - Primarily a rework/repair issue
  - Isn’t rework/repair always an issue?
Reliability

- Number one concern? Mechanical shock
  - High stress, high strain rate event
  - Drop, crash, direct-hit

- General findings
  - SAC less robust than SnPb
  - Plating materials are a greater driver
  - Still some uncertainty and contradiction

<table>
<thead>
<tr>
<th>PQFP (28x28mm, 208 I/O)</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb-Free on ENIG</td>
<td>2/6</td>
</tr>
<tr>
<td>Pb-Free on OSP</td>
<td>2/6</td>
</tr>
<tr>
<td>SnPb on OSP</td>
<td>0/6</td>
</tr>
</tbody>
</table>

Chai, ECTC 2005
Chong, ECTC 2005
When is Failure not a Failure?

\[ \Delta \text{Temperature} \]

Time to Failure

Field Condition

Test

Life Requirement

SnPb

Pb-Free

DfR Solutions

reliability designed, reliability delivered

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Long-Term Reliability of Pb-Free

Based on creep laws developed by Schubert and damage model developed by Syed

2512 Resistor on FR4
25 to 80C (modeling, Blattau, 2005)

Ceramic BGA on FR4
0 to 100C (experimental data, Bartello, 2001)

Visual concept courtesy of J.P. Clech
Vibration / Mechanical Cycling

- Findings
  - High strain: SAC worse
  - Low strain: SAC better

- Missing datapoint
  - Lead devices
  - Failure is in lead, not solder
  - Solder transfers stresses

- What does this mean?
  - Problems with vibration and SnPb → Problems with vibration and SAC
  - No problems now? No problems later

Diagram: Board Level Strain (microstrain) vs. Fatigue Life (cycles) for SnPb and SAC. 0.8mm pitch 179 I/O BGA (14 x 14 mm) and 2512 SMT Resistor.
Material Issues 1

- How to combine SnPb and Pb-free?
- Case Study 1: Pb-Free BGA with SnPb solder
  - >225°C to 245°C peak
  - Vibe, Mechanical Shock performance lacking
- Case Study 2: SnPb Lead with Pb-free solder
  - Potential risk

<table>
<thead>
<tr>
<th>Peak Temp (°C)</th>
<th>Example Solder Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>203</td>
<td>Reflow SnPb Solder Paste</td>
</tr>
<tr>
<td>210</td>
<td></td>
</tr>
<tr>
<td>217</td>
<td></td>
</tr>
<tr>
<td>225</td>
<td>SnAgCu (Pb-free) Solder Sphere</td>
</tr>
</tbody>
</table>
Material Issues 2

- How to segregate SnPb from Pb-free?

  - Incoming materials (parts, boards)
  - Analysis (surprisingly few)
  - Assembly (different lines, material segregation, change in solder pots)
  - Product markings (part number, label, symbol, solder mask, silkscreen)
Recommendations for Program Managers

- No. 1: Be educated, be aware
  - Most commercial suppliers and OEMS, even if exempt from RoHS, are going Pb-free (General Motors / Ford, Maytag / Whirlpool, even Wal-Mart)
    - Diminishing availability and skill set with SnPb
  - Plethora of good research and experience with Pb-free (find it!)
    - Google.com and Scholar.google.com
  - Whether to ban or accept Pb-free product should be based on the capability of the supplier, reliability expectations, use environment, and maintenance requirements
    - Each program’s experiences and concerns will be different
Recommendations (cont.)

- Do not underestimate purchasing power

Assumes 3% market share

Semiconductor International Association