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# How is the commercial world responding to RoHS?

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Dr. Craig Hillman, DfR Solutions  
301-474-0607, [chillman@dfrsolutions.com](mailto:chillman@dfrsolutions.com)

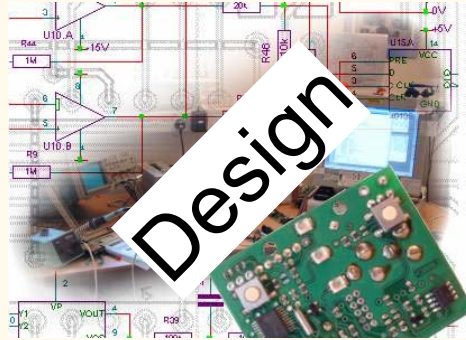
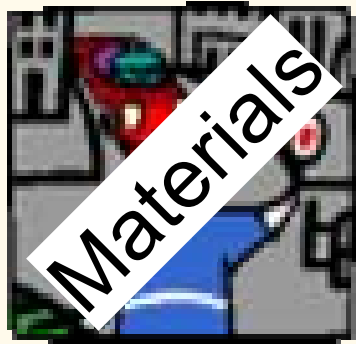
# What is RoHS?

**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<sup>6+</sup>, 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

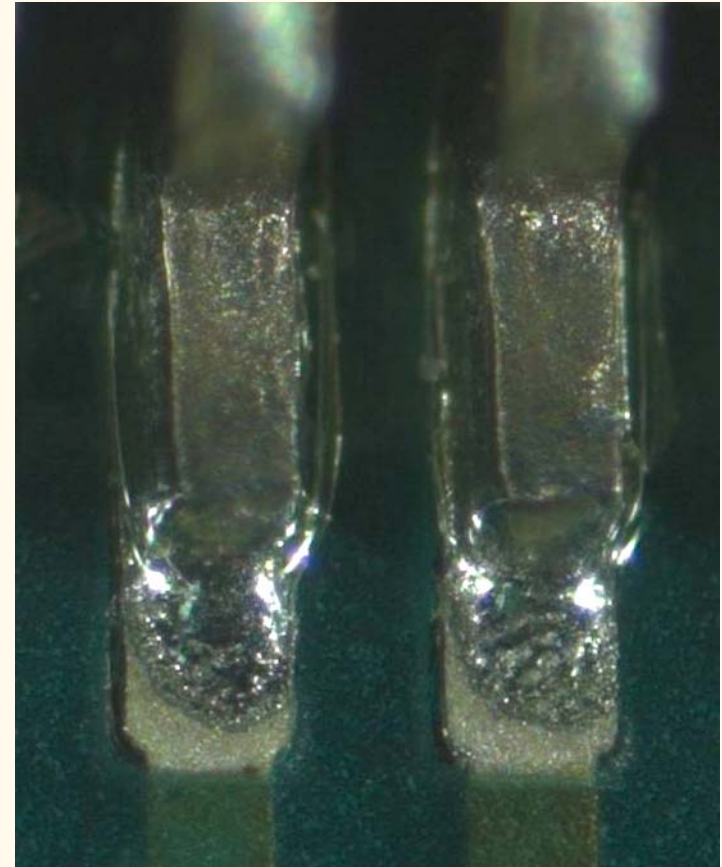


**Everything they've  
always worried about?**



# Design

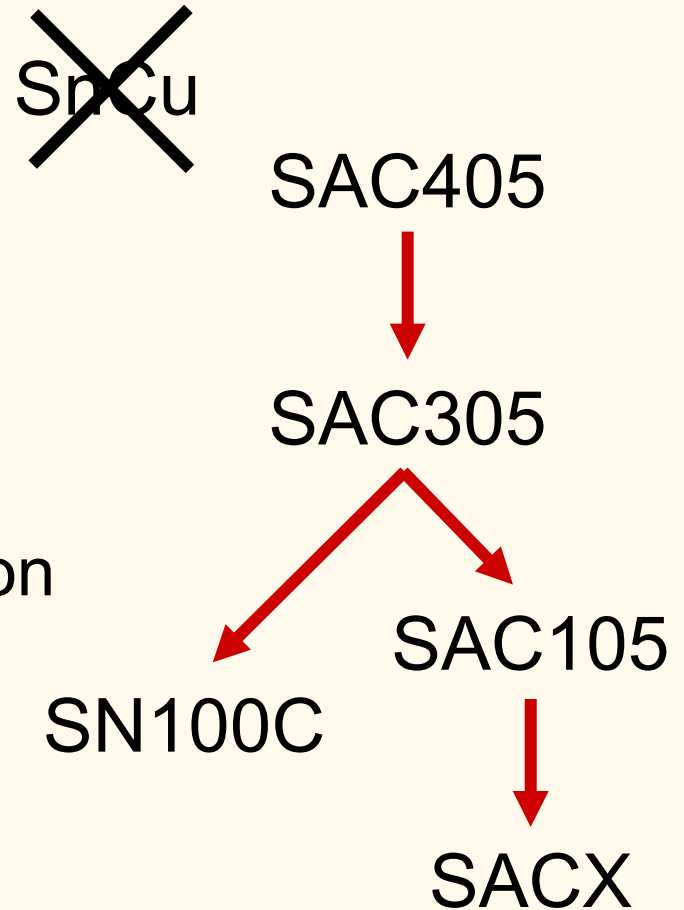
- No major design changes
  - Some reduction in bond pad dimensions
  - Smaller ceramic capacitors for wave soldering



## Good News!

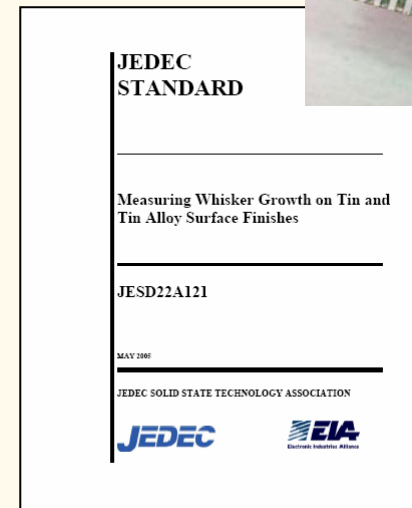
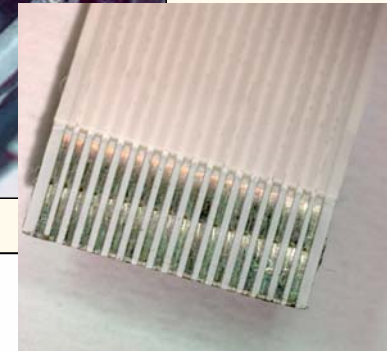
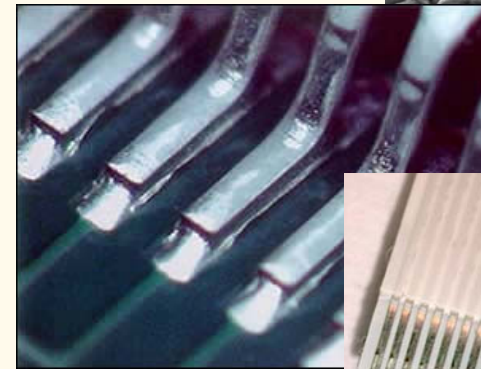
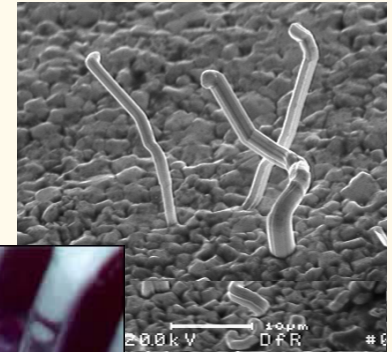
# Suppliers (Parts)

- 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

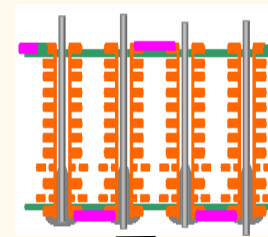
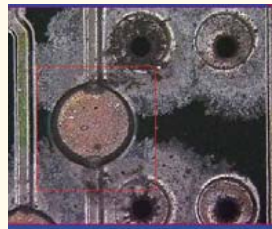
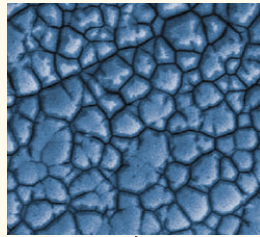


# Supply Chain (Tin Whiskering)

- 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  $\mu\text{m}$ )
  - ❑ Plating thickness > 10  $\mu\text{m}$
- 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

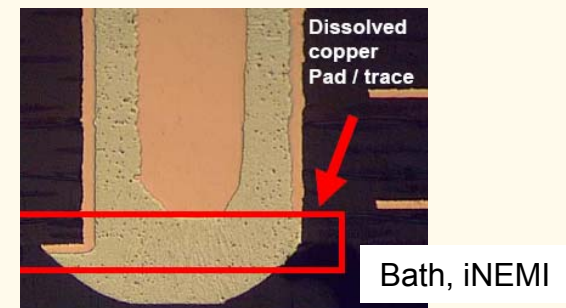
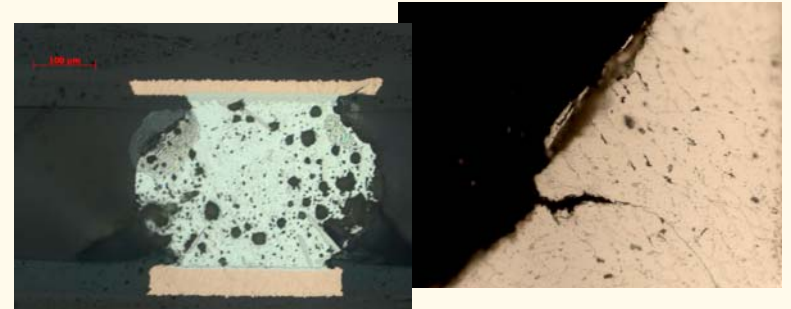
## ■ Damage during reflow

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

| Board thickness | IR-240~250   | IR-260□  |
|-----------------|--|--|
| ≤60mil          | Tg140 Dicy<br>All HF materials OK                              | Tg150 Dicy<br>HF- middle and high Tg materials OK              |
| 60~73mil        | Tg150 Dicy<br>NP150, TU622-5<br>All HF materials OK            | Tg170 Dicy<br>HF –middle and high TG materials OK              |
| 73~93mil        | Tg170 Dicy, NP150G-HF<br>HF –middle and high TG materials OK   | Tg150 Phenolic + Filler<br>HF –middle and high TG materials OK |
| 93~120mil       | Tg150 Phenolic + Filler<br>HF –middle and high TG materials OK | Phenolic Tg170<br>HF –middle and high TG materials OK          |
| 121~160mil      | Phenolic Tg170<br>HF –high TG materials OK                     | Phenolic Tg170 + Filler<br>HF –high TG materials OK            |
| 161mil          | PhenolicTg170 + Filler<br>HF material - TBD                    | TBD  |

# Manufacturing (Printed Circuit Board Assembly)

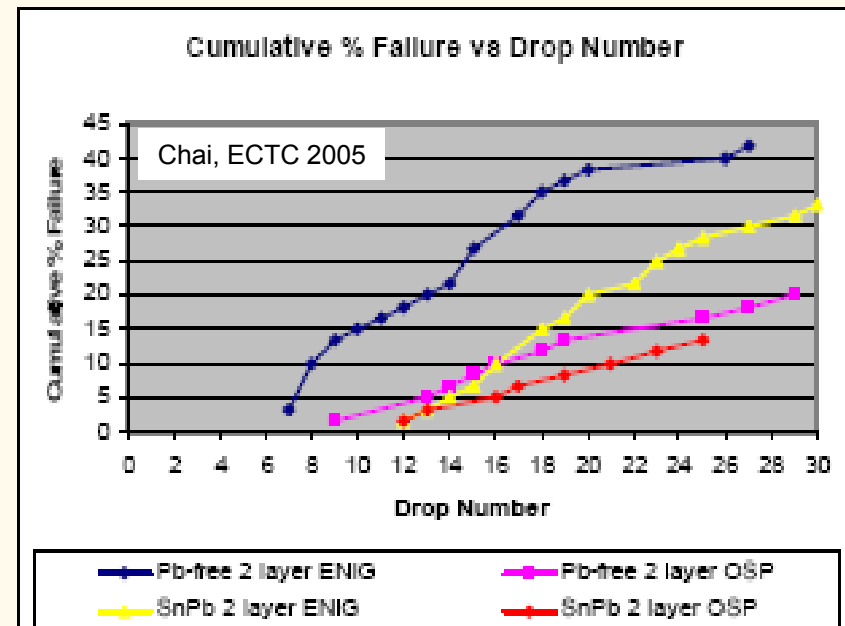
- Narrower process window
  - Solvable (takes more time then you might think)
  
- Hole Fill
  - Higher pot temperatures, avoidance of OSP
- Shrinkage cracks / Hot tearing
  - Solvable
  
- Optical inspection
  - Pb-free now shiny
  
- Copper dissolution
  - Primarily a rework/repair issue
  - Isn't rework/repair always an issue?





# Reliability

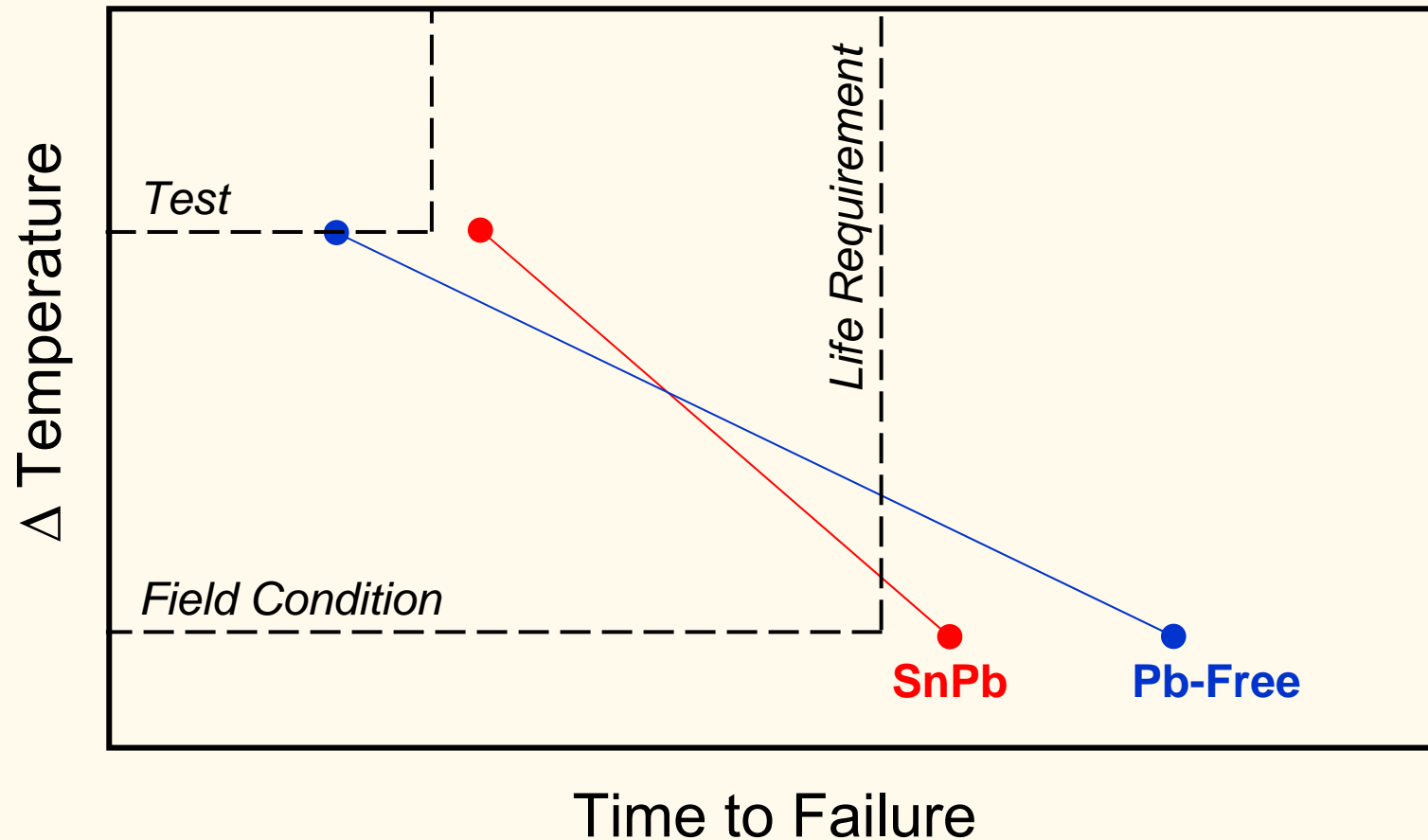
- Number one concern?  
Mechanical shock
  - High stress, high strain rate event
  - Drop, crash, direct-hit
- General findings
  - SAC less robust than SnPb
  - Plating materials are a greater driver
  - Still some uncertainty and contradiction



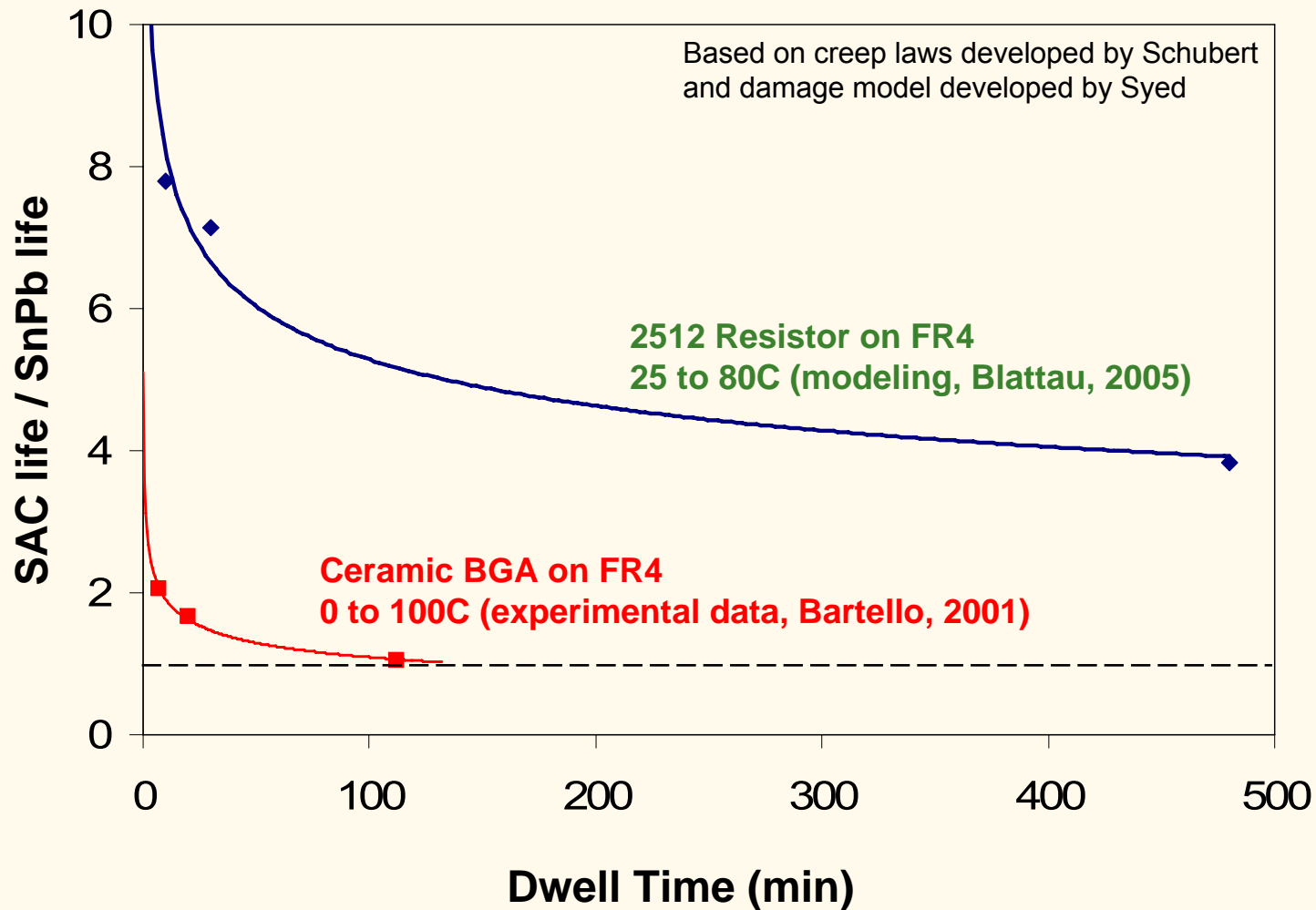
| PQFP (28x28mm, 208 I/O) | Failures |              |
|-------------------------|----------|--------------|
| Pb-Free on ENIG         | 2/6      | 44/50, 45/50 |
| Pb-Free on OSP          | 2/6      | 16/50, 29/50 |
| SnPb on OSP             | 0/6      | --           |

Chong, ECTC 2005

# When is Failure not a Failure?

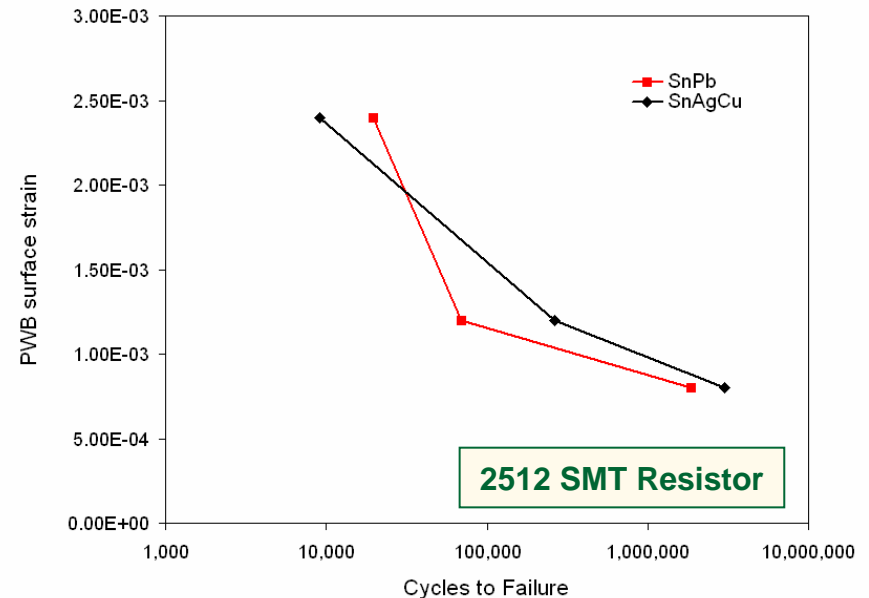
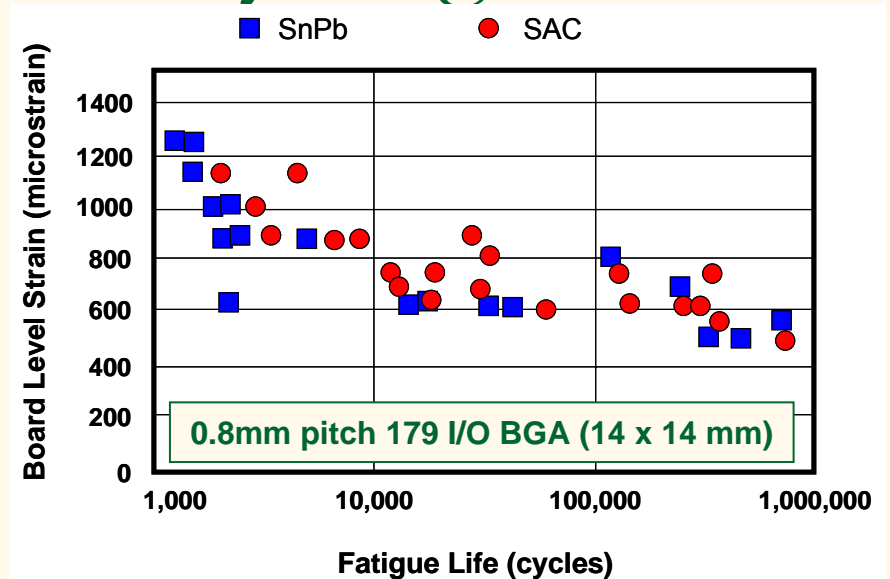


# Long-Term Reliability of Pb-Free



# Vibration / Mechanical Cycling

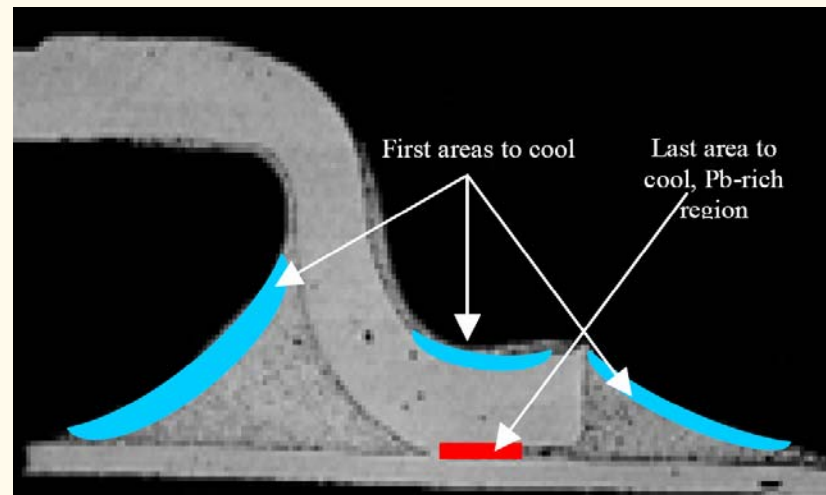
- Findings
  - High strain: SAC worse
  - Low strain: SAC better
- Missing datapoint
  - Leaded devices
  - Failure is in lead, not solder
  - Solder transfers stresses
- What does this mean?
  - Problems with vibration and SnPb → Problems with vibration and SAC
  - No problems now? No problems later



# 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

| Peak Temp (°C) | Example Solder Joints*     |                                |
|----------------|----------------------------|--------------------------------|
| 203            | Reflowed SnPb Solder Paste | SnAgCu (Pb-free) Solder Sphere |
| 210            |                            |                                |
| 217            |                            |                                |
| 225            |                            |                                |



# Material Issues 2

- How to segregate SnPb from Pb-free?



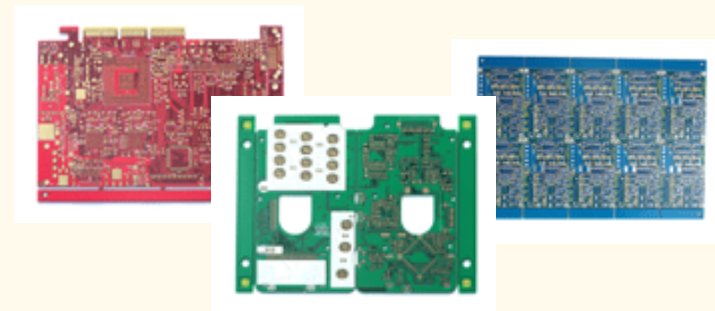
Incoming materials (parts, boards)



Analysis (surprisingly few)



Assembly (different lines, material segregation, change in solder pots)



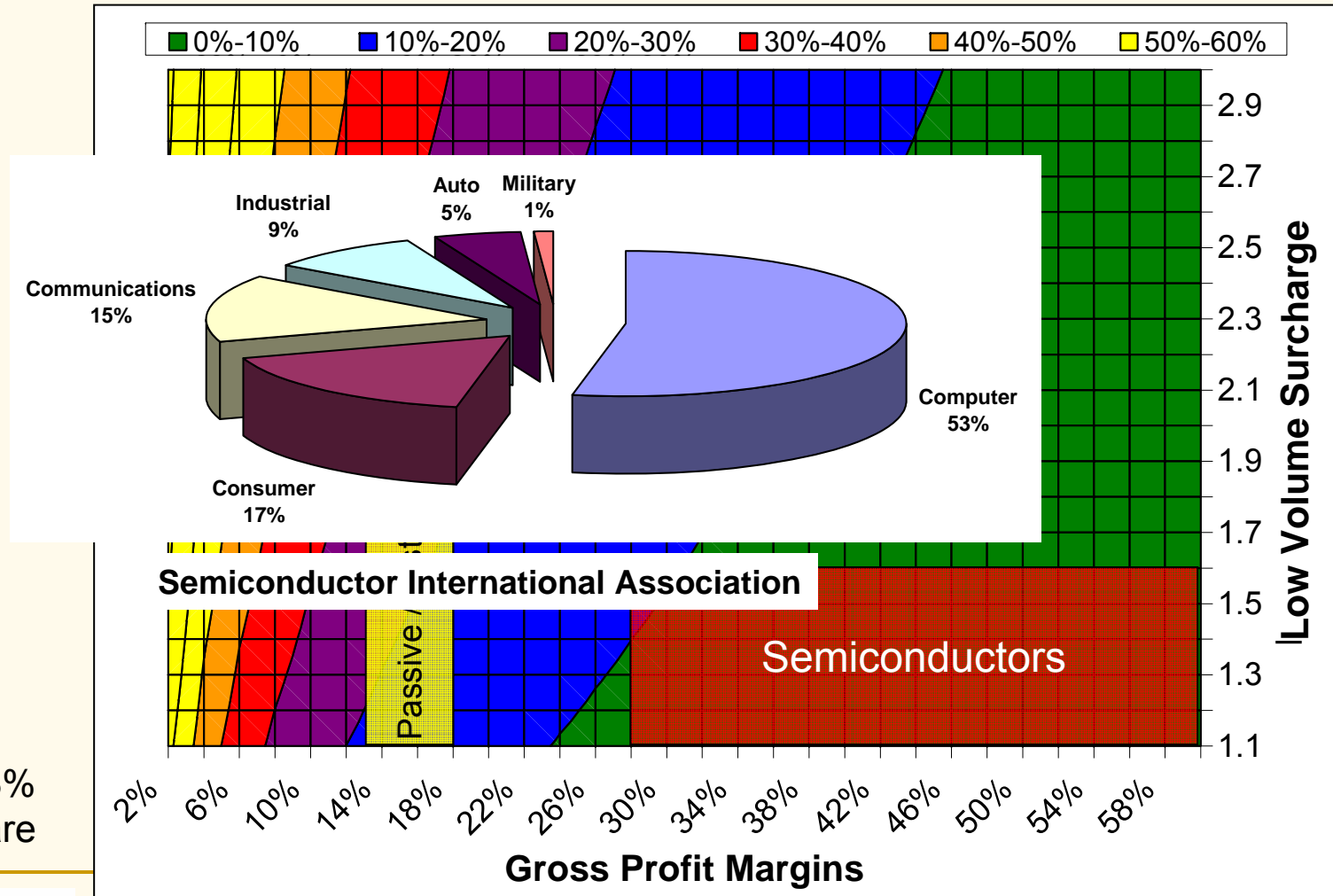
Product markings (part number, label, symbol, solder mask, silkscreen)

# 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