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Surface Mount Technology in the Pb-free Era

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Automotive Electronics Council Reliability Workshop 2006

9th – 11th of May 2006

Contents

- Introduction
- Thermal management
- Component Issues
- Reliability of Pb - free
- Concluding remarks

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- **Introduction**
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Introduction

- RoHS forbids the use of Pb in consumer Electronics in Europe from 1st of July 2006
- Therefore, many suppliers are Pb-free
- For automotive ELV till 2010

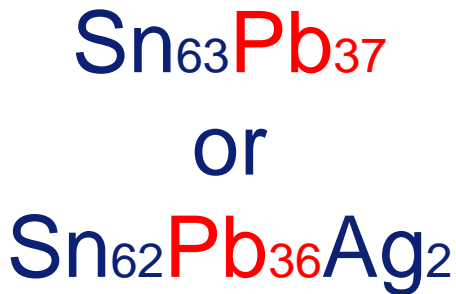
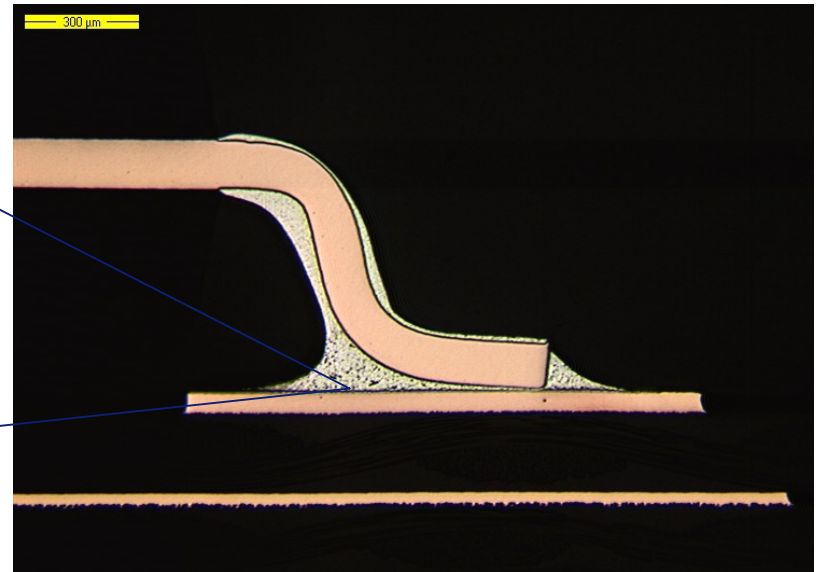
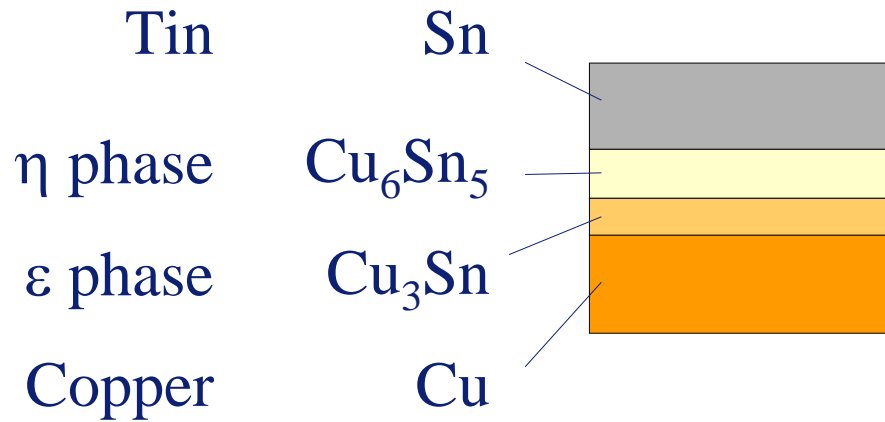
However,

Pb – free is not a drop in replacement for a SnPb process!!!

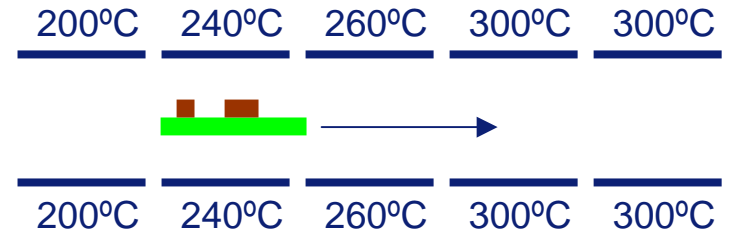
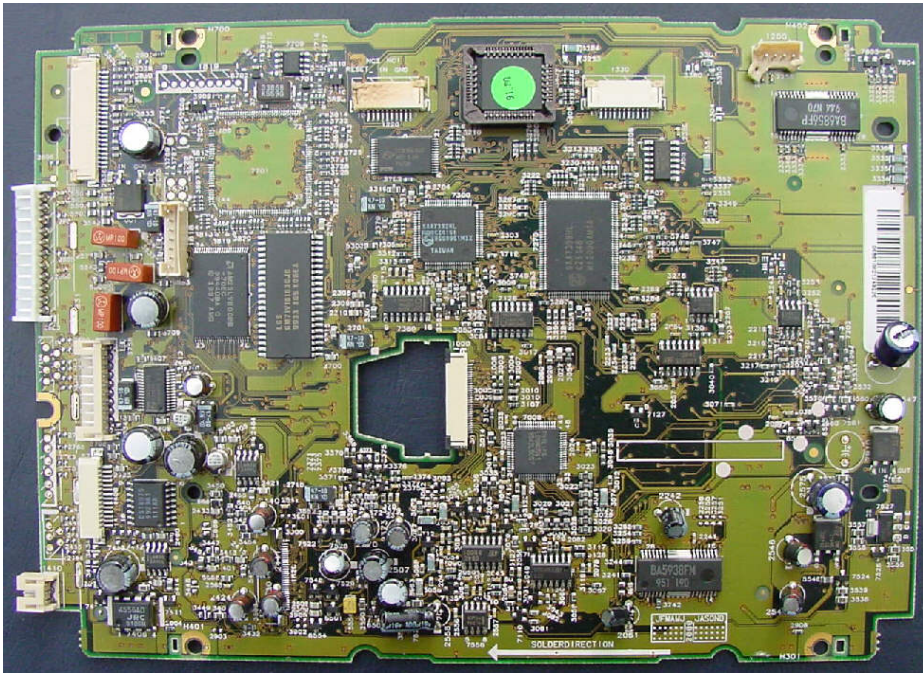
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Solder composition

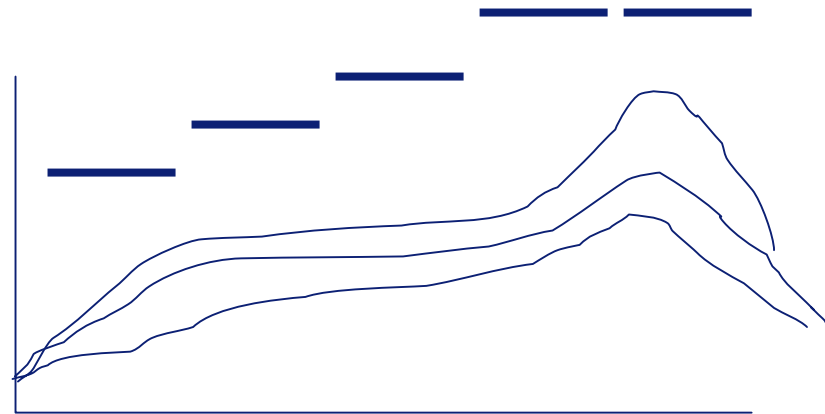


Main problem Temperature differences:



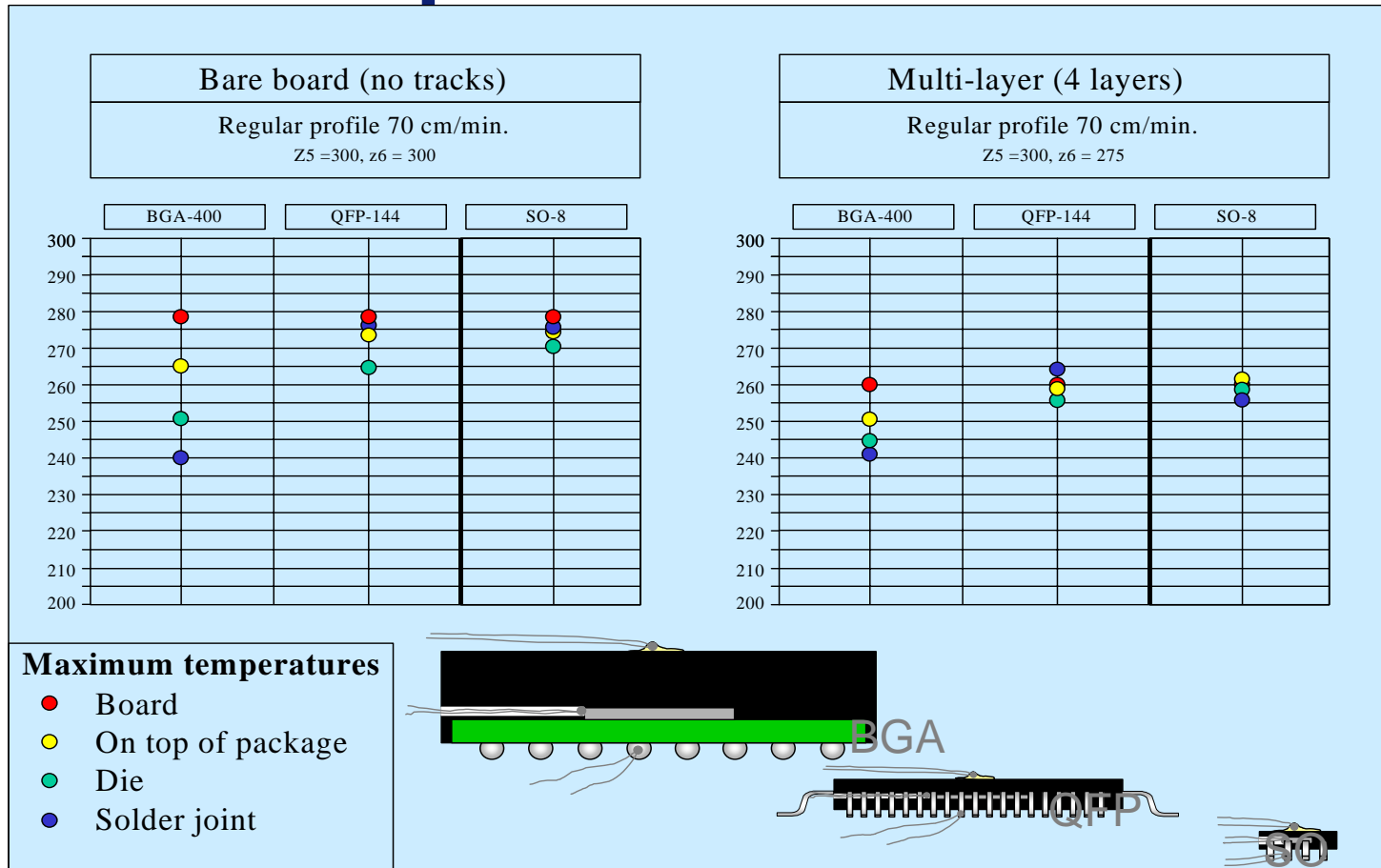
Convection heating =
non-equilibrium process !!

Temp.



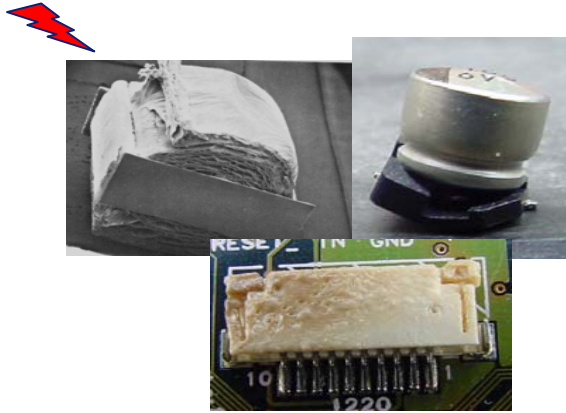
Time

Different Temperatures on products

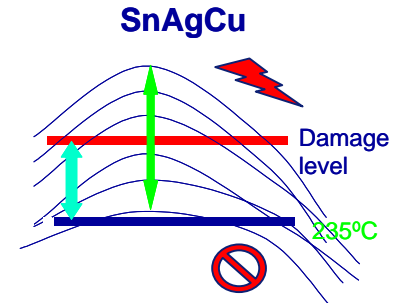
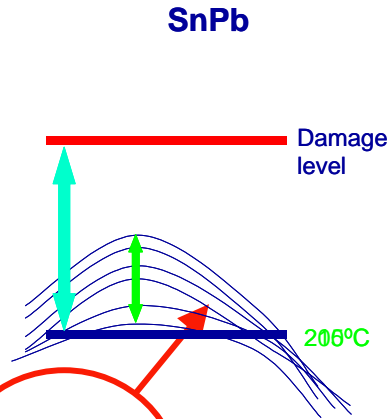
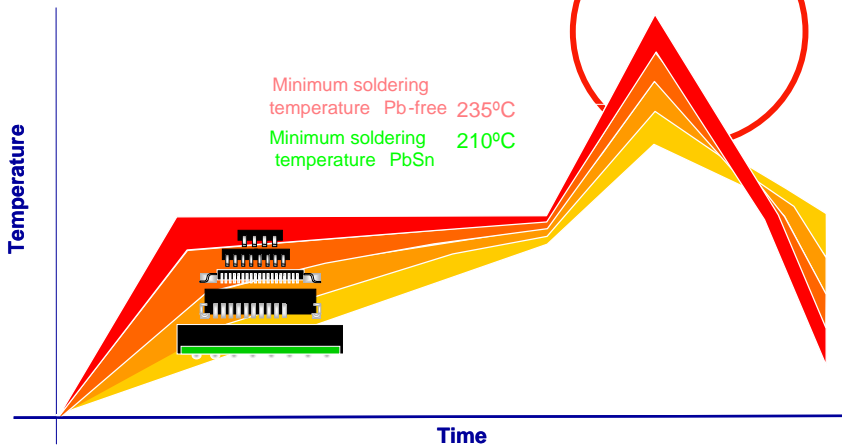


Temperature @ body is not equal to temperature @ solder joint

Pb-free soldering

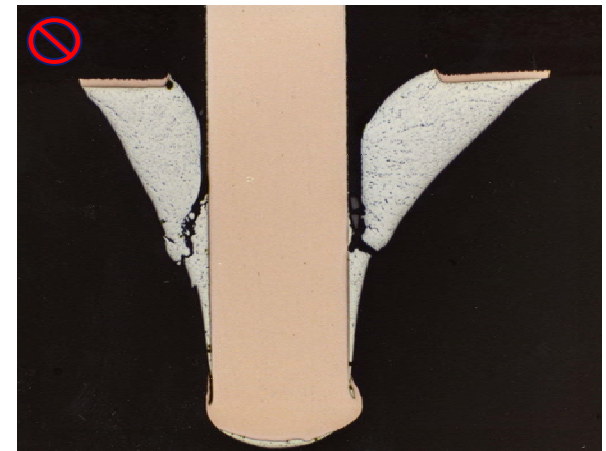


Component level



Lead-free :

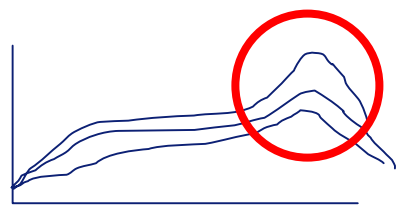
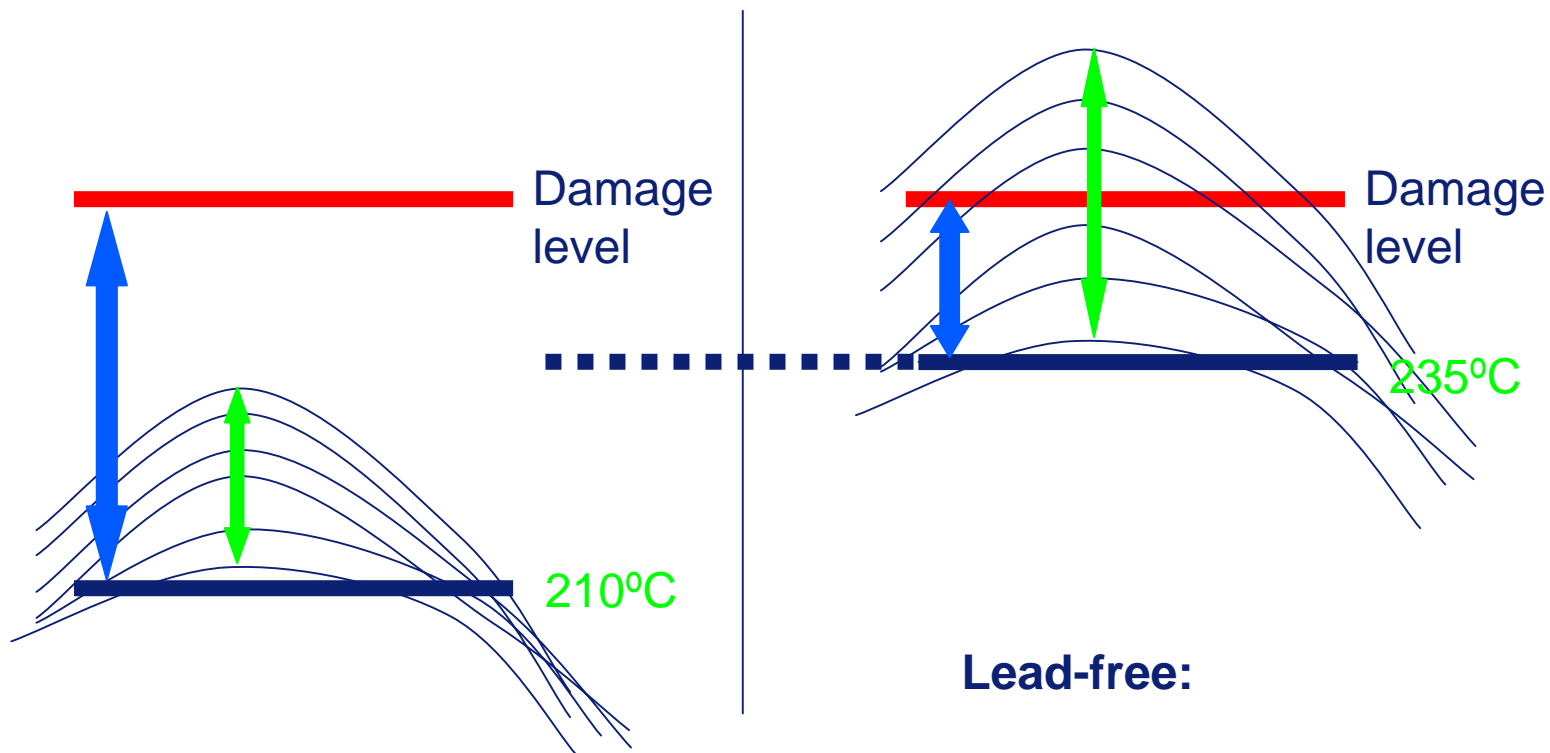
- Process window : smaller
- Temperature differences : larger



Process window

SnPb

SnAgCu



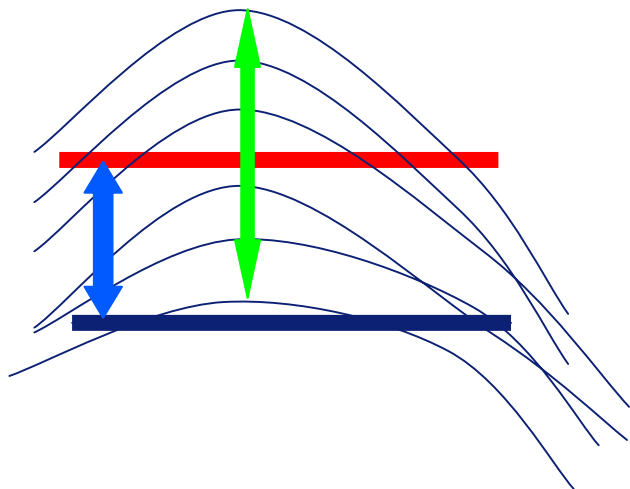
Lead-free:

- Process window: smaller
- Temperature differences: larger

Process adjustment

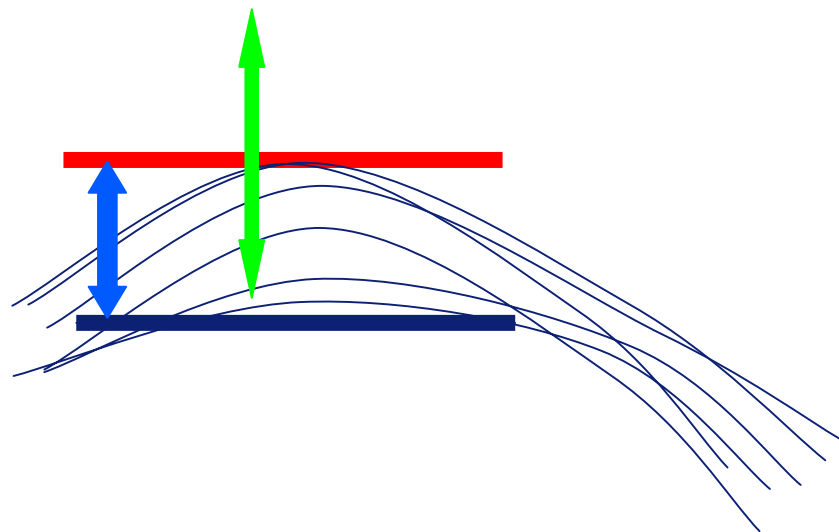
Fast process

SnAgCu



Slow process

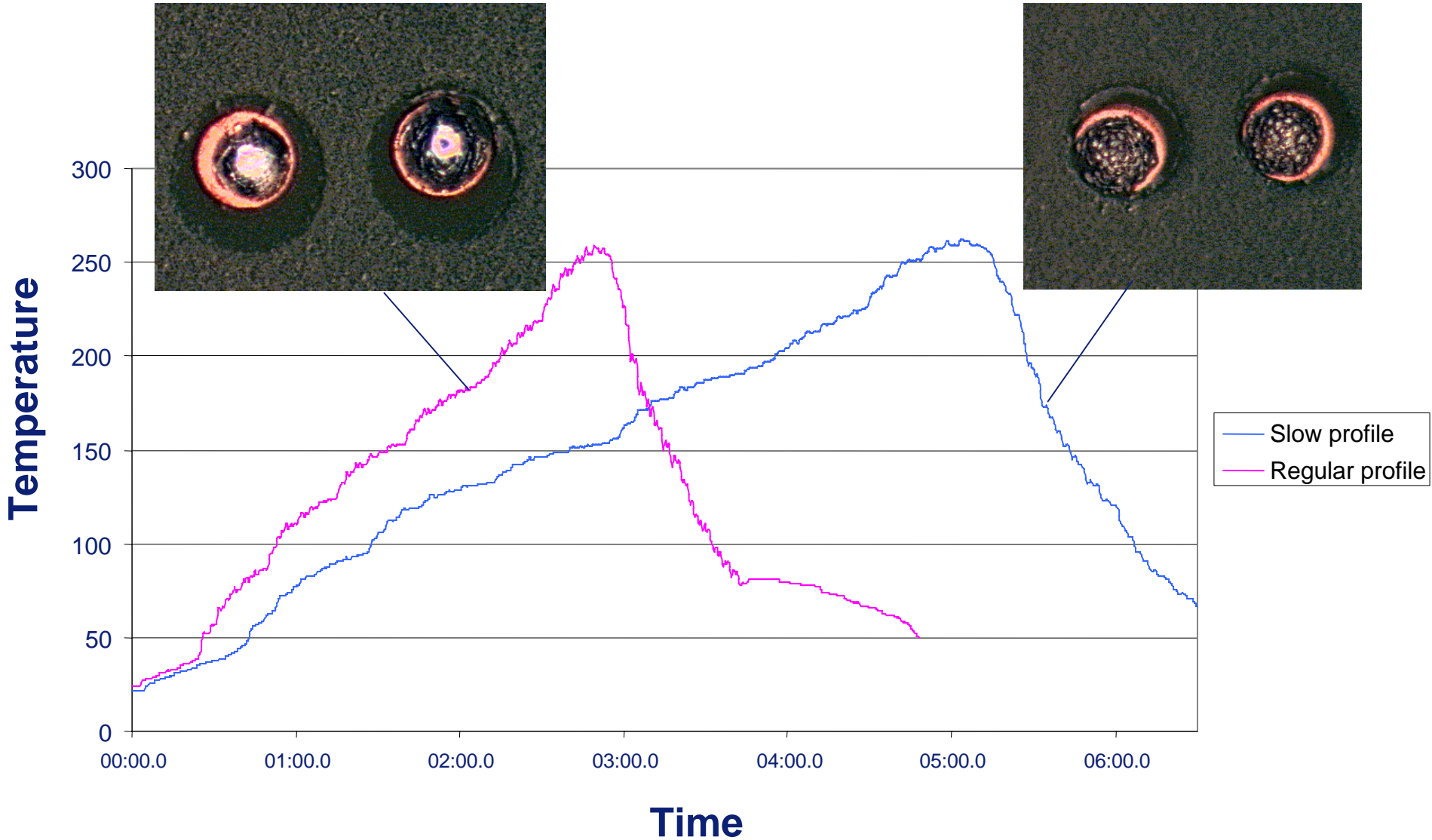
SnAgCu



Damage level

235°C

Solder paste degradation



Assessment of hottest & coldest spots

- Pass a board with solder paste and populated with components through oven at high speed.
- Decrease the speed until the first joint reflows: **↻ hottest spot.**
- Decrease speed further until the last joint has reflowed: **↻ coldest spot.**
- Apply micro-thermocouples to these spots (plus other relevant spots).
- Tune the oven profile so that the required minimum peak temperature is reached at the coldest spot, without over-heating the hottest spot.

- **This procedure is largely ignored in SnPb reflow production, whereas it becomes even more crucial in lead-free reflow.**

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Lead-free soldering
is
no "drop-in" technology!

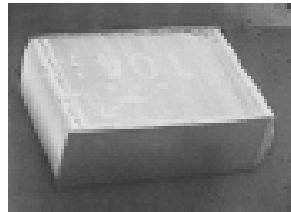
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- **Component Issues**
- Reliability of Pb - free
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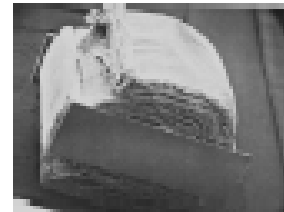
Critical components

Component thermal damage risk

225° C



255° C



240° C



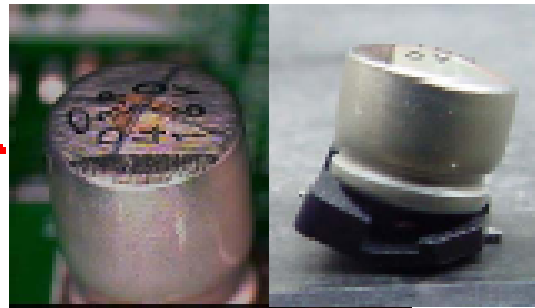
270° C



225° C



250° C



Critical components

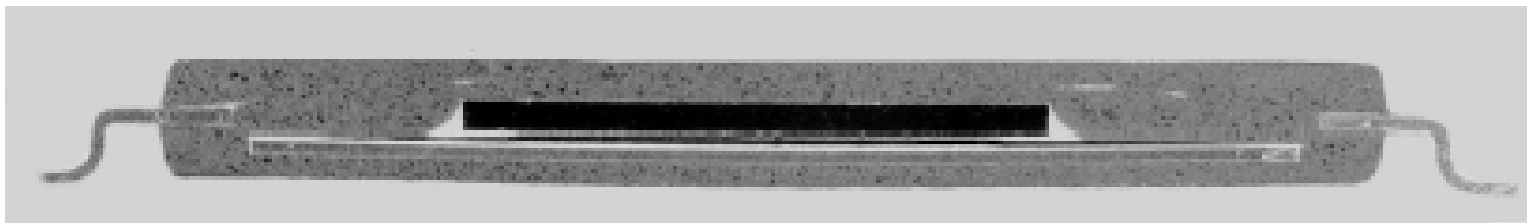
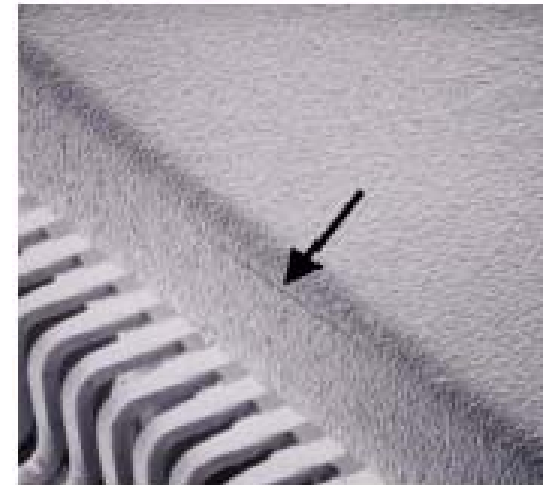
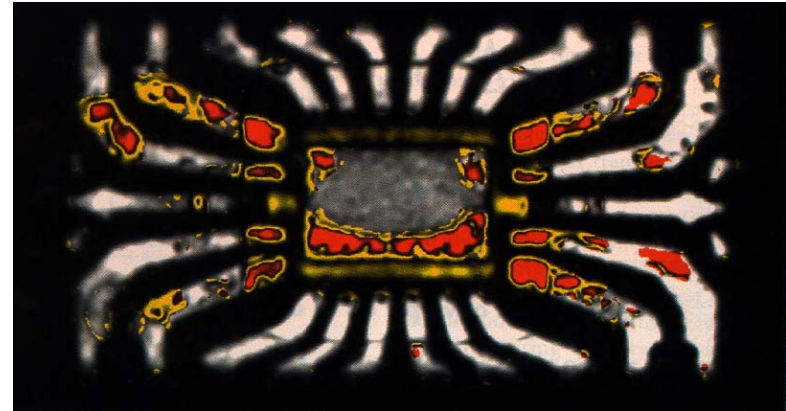
IC damage risk due to:

Popcorn effect

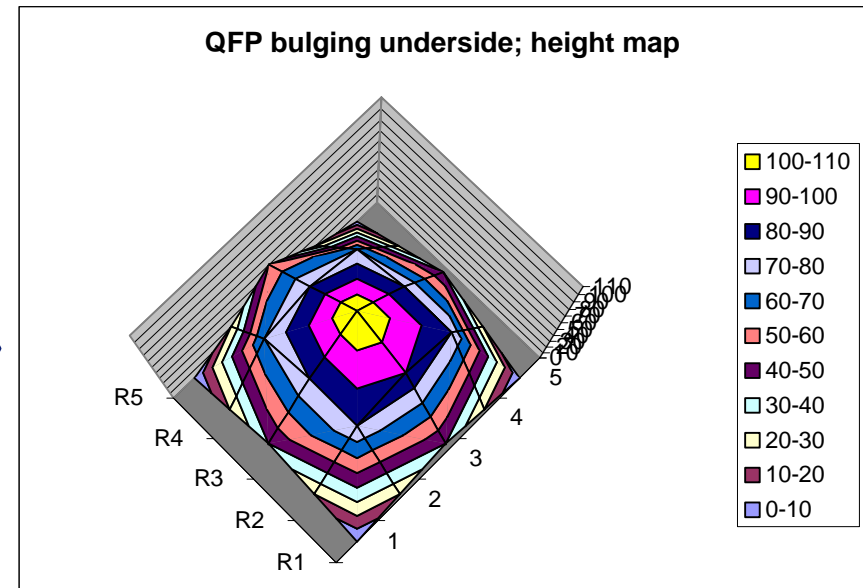
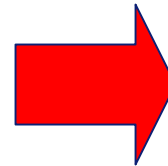
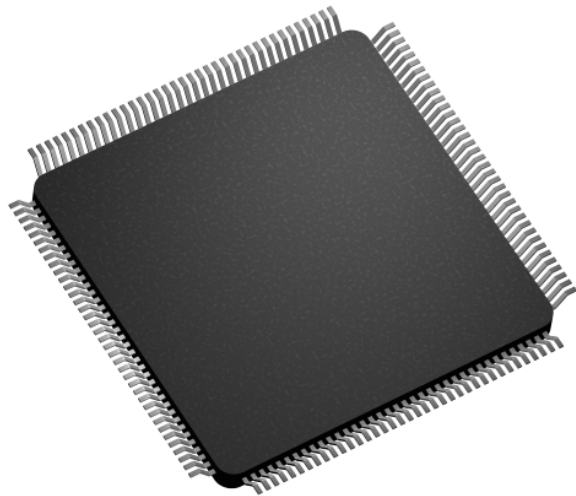
MSL level

Time of component out of packing

Humidity in assembly area

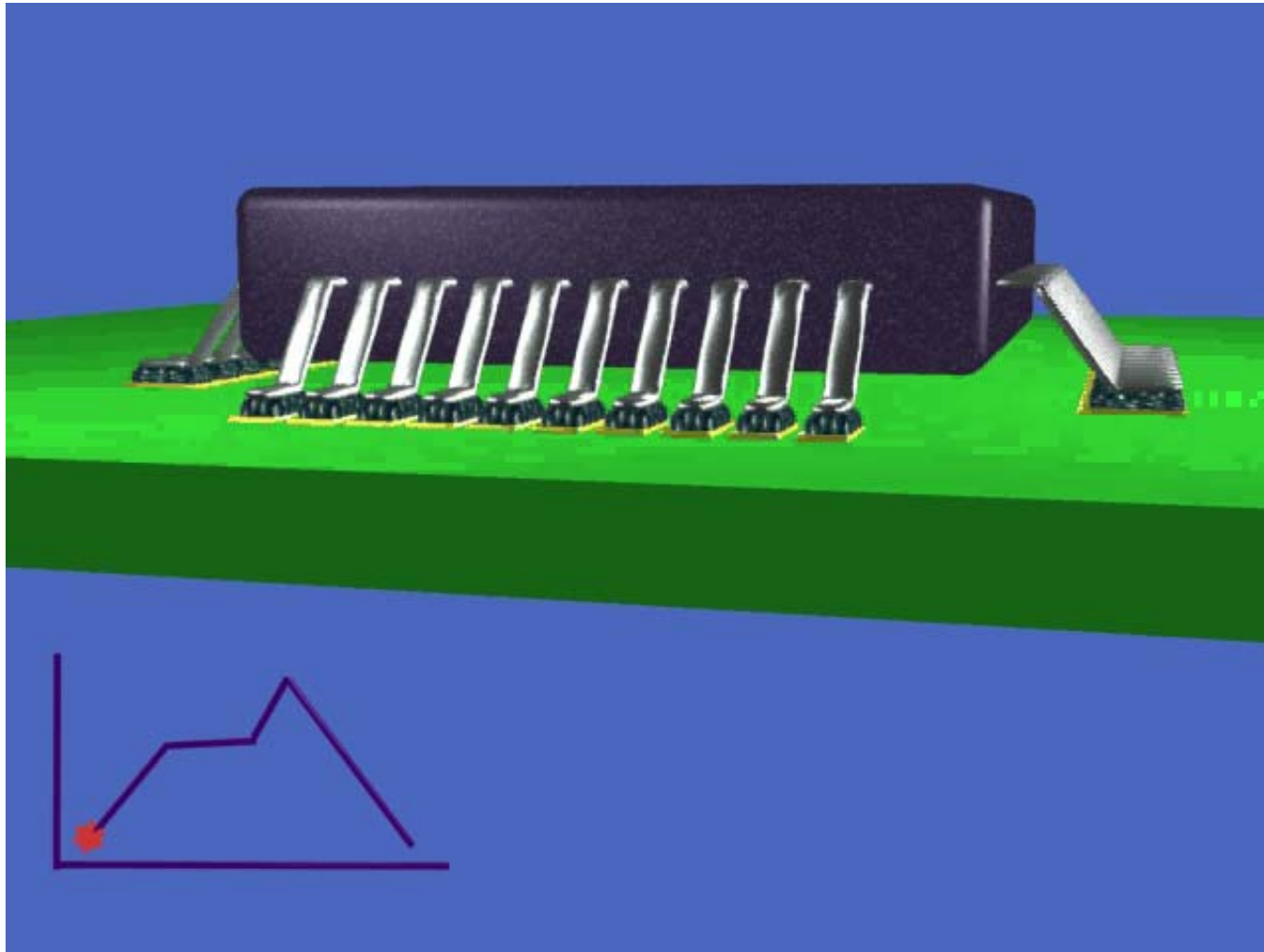


Component deformation after reflow



Height change ~ 0.1 mm

Board warpage



Result of board warpage and component bulging

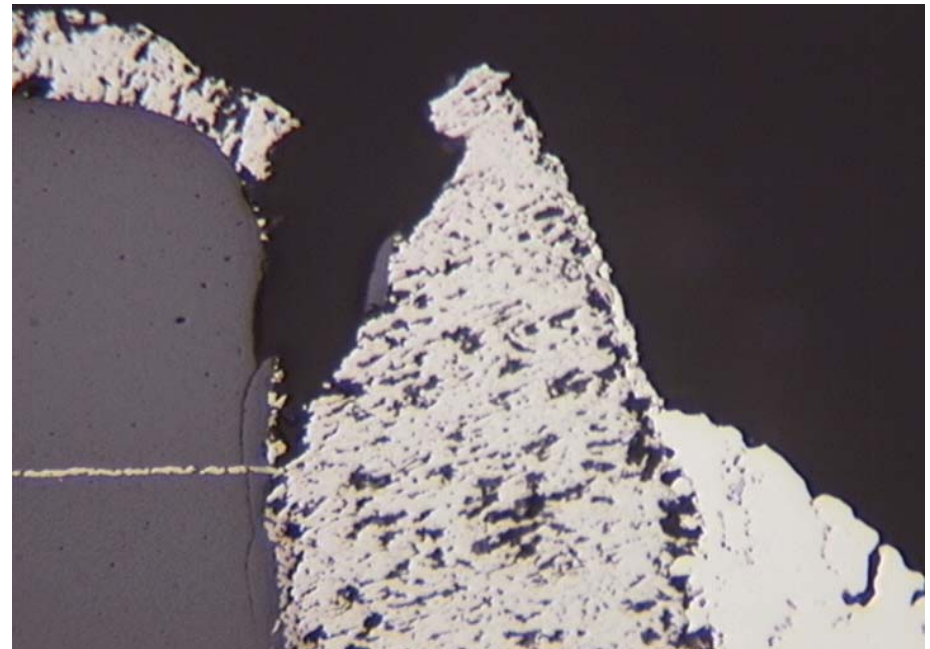
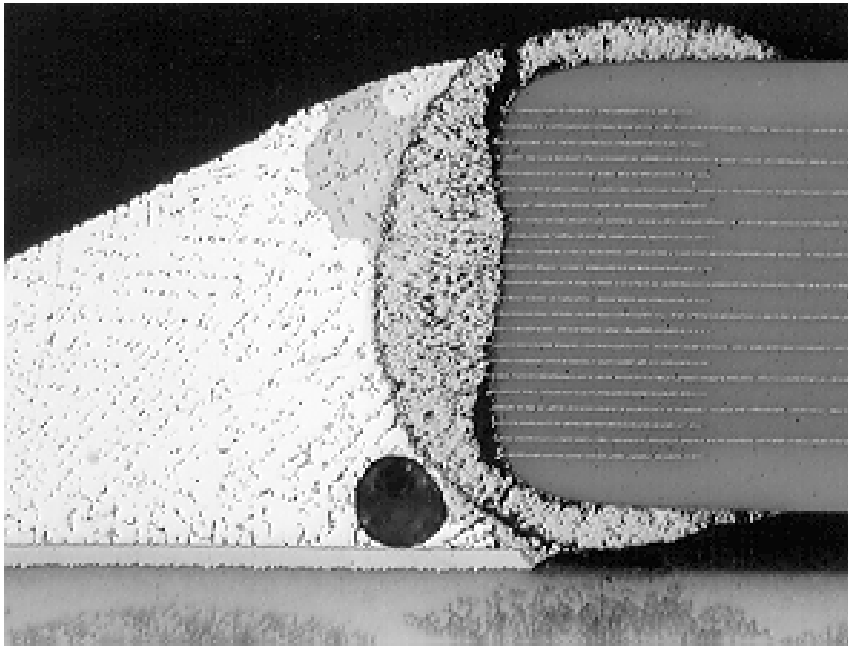


Open joints

Metallurgical effects

Growth of intermetallic layers:

- AgPd fired metallisations are **incompatible** with lead-free solder

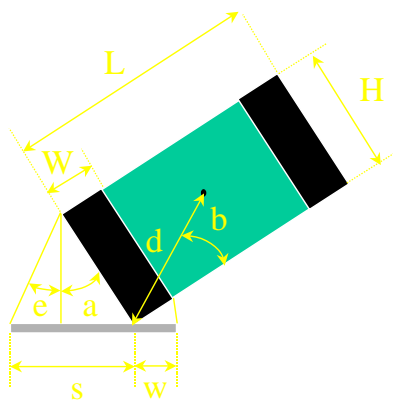


Tombstoning



Tombstoning

Tombstoning model

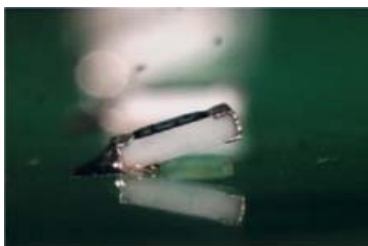


$$M1 = M * g * d * \cos(a+b)$$

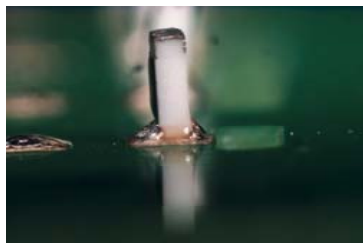
$$M2 = y * W * \cos(a/2)$$

$$M3 = y * H * \sin(a+e)$$

M = component mass
 g = gravitation
 y = surface tension of solder

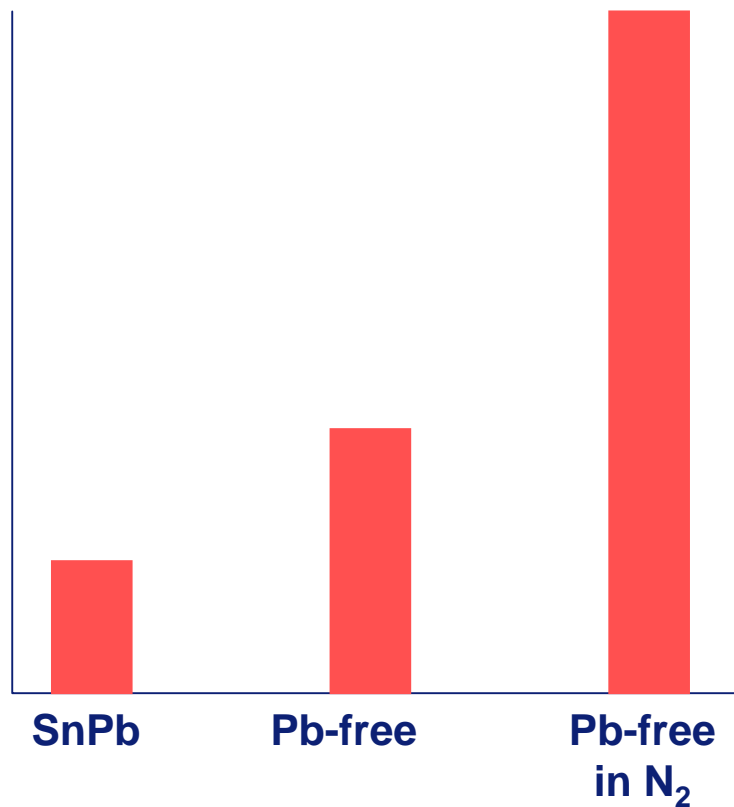


SnPb

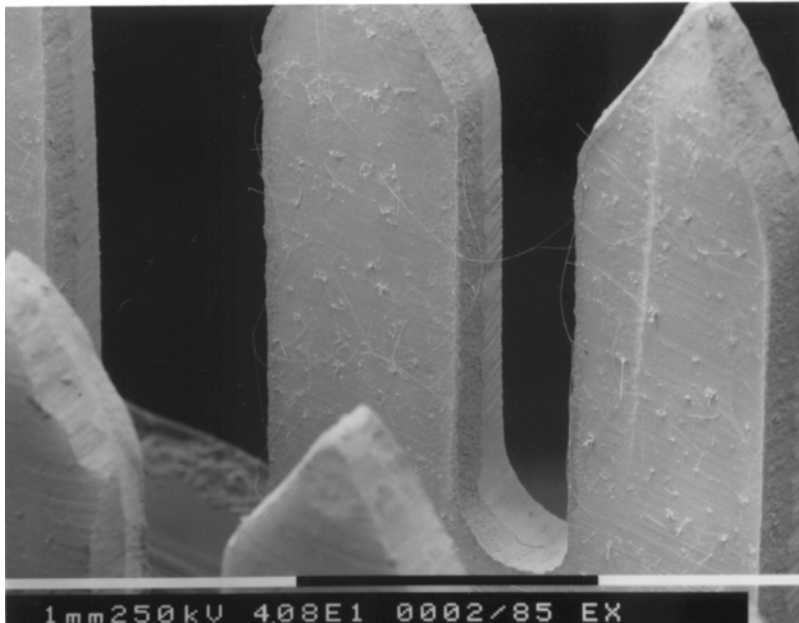


Lead-free

Sensitivity to tombstoning



Whiskers



See presentation of AEC Reliability Workshop
Nashville 2004

Critical components

Connectors (components with plastics parts)

Plastic pot meters

Electrolytic capacitors

Foil capacitors

Optical components (LED, Camera)

Moister sensitive components

Electro mechanical components

Components with non compatible finish

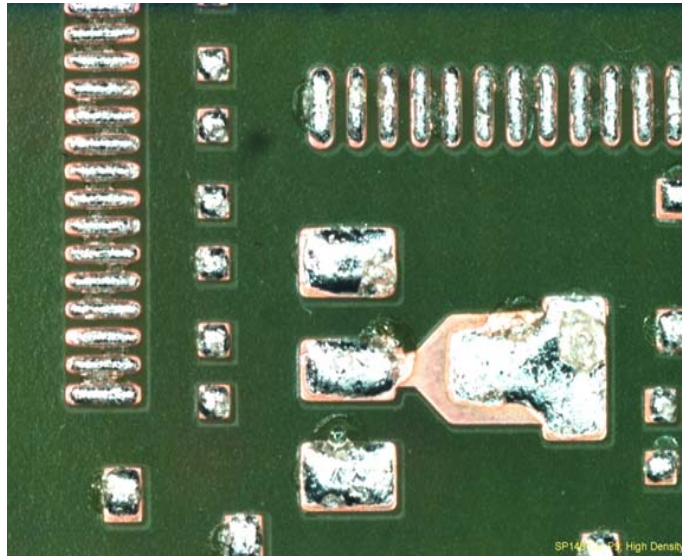
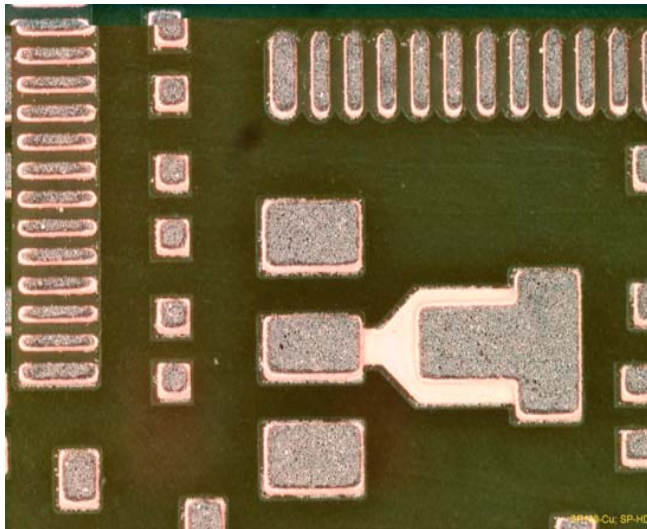
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Process compatibility

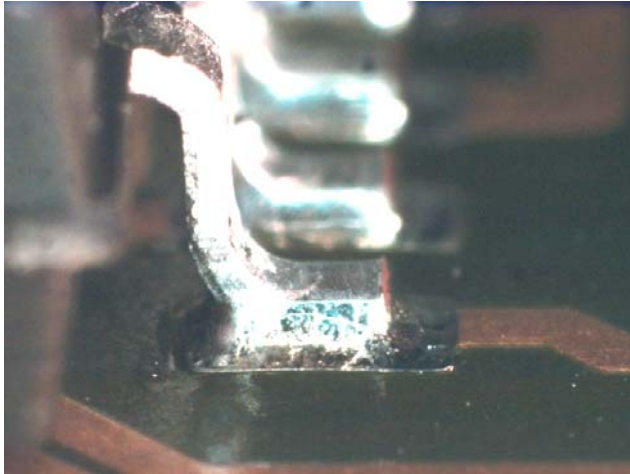
- Larger contact angle due to limited solder flow

Typical Solder Flow of SnAgCu Pastes

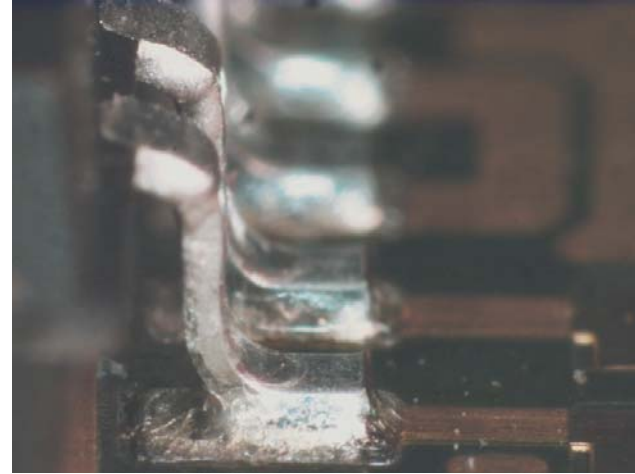


Limited flow; finite contact angle

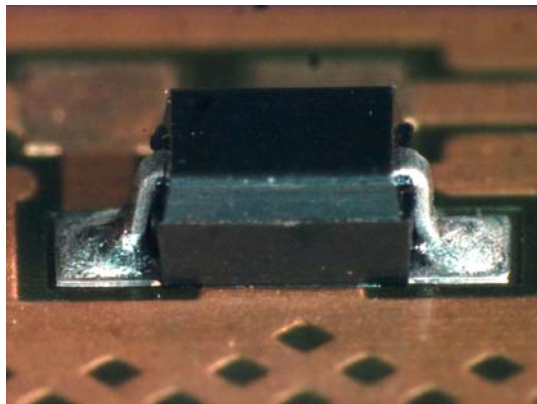
Appearance differences



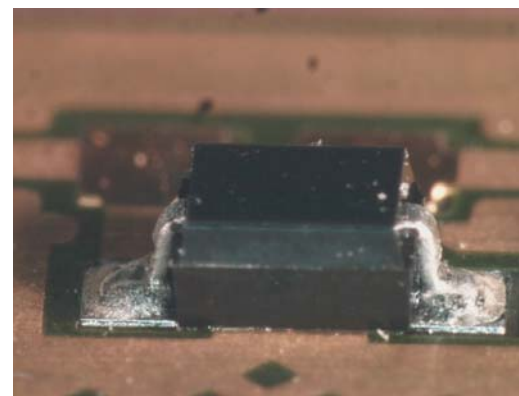
HSOP20 Sn plated, SnPb solder



HSOP20 Sn plated, SAC solder



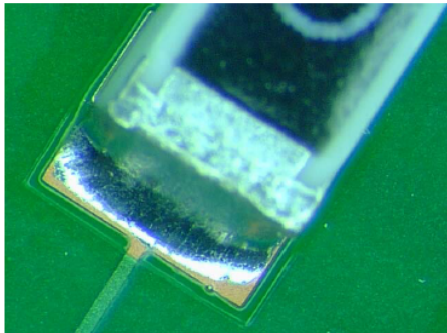
SOD323 Sn plated, SnPb solder



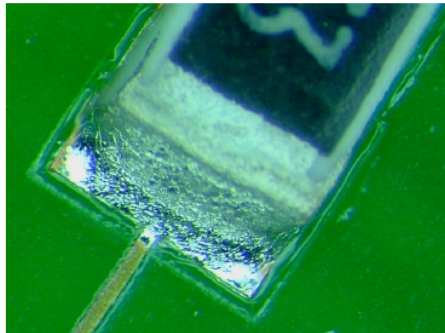
SOD323 Sn plated, SAC solder

Lead-free joints look different

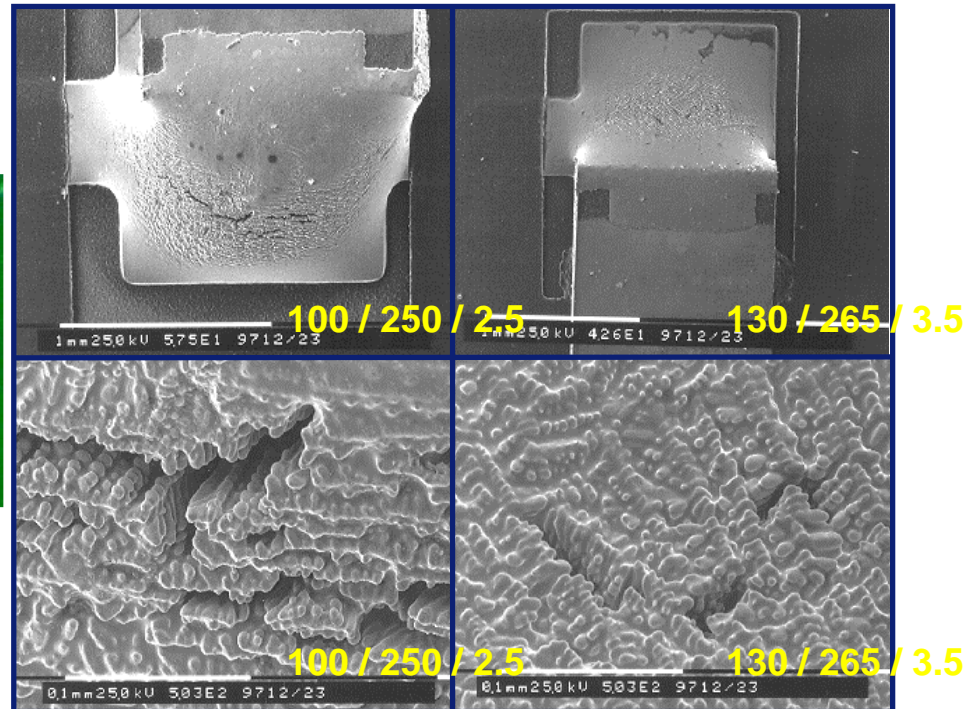
Acceptable Solder Joints



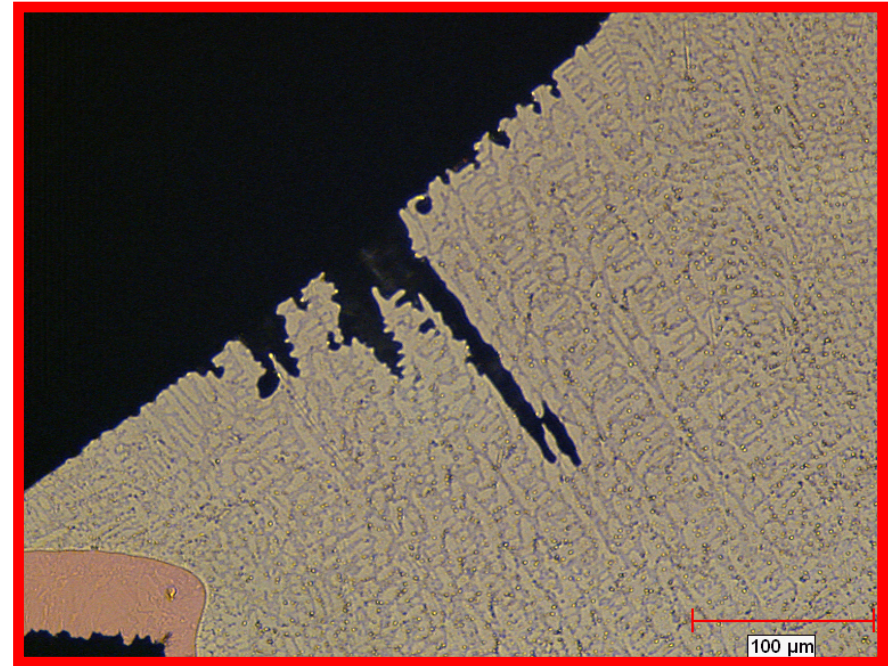
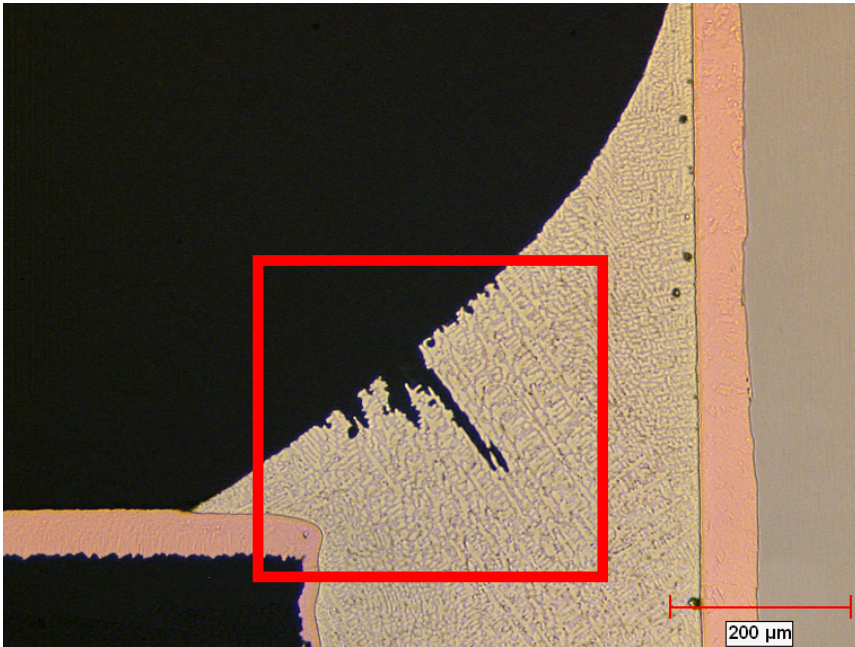
Tin-Lead solder joint
Features: Smooth and shiny



Tin-Silver-Copper solder joint
Features: Grainy and shiny

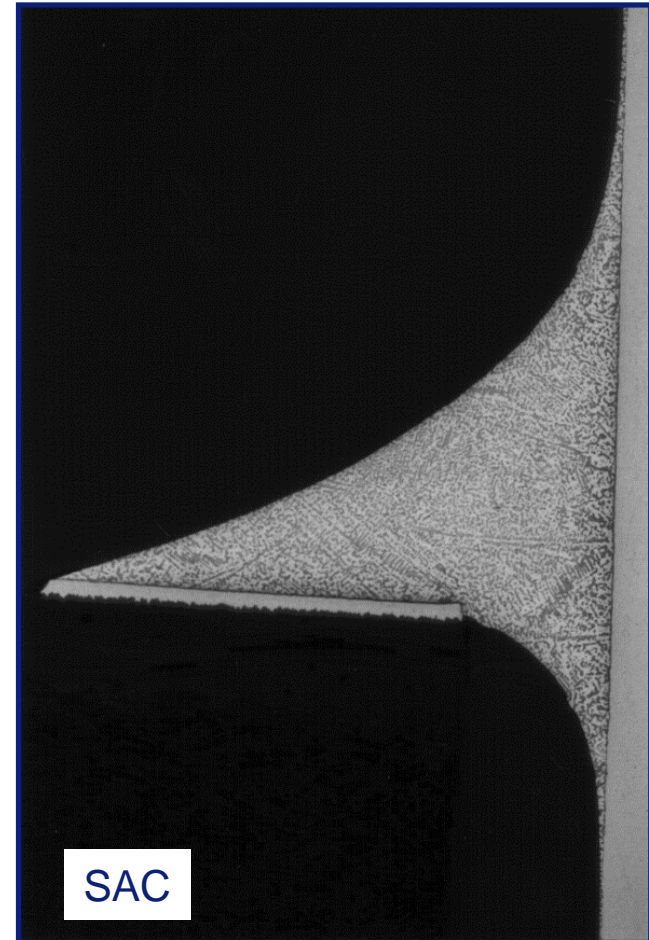
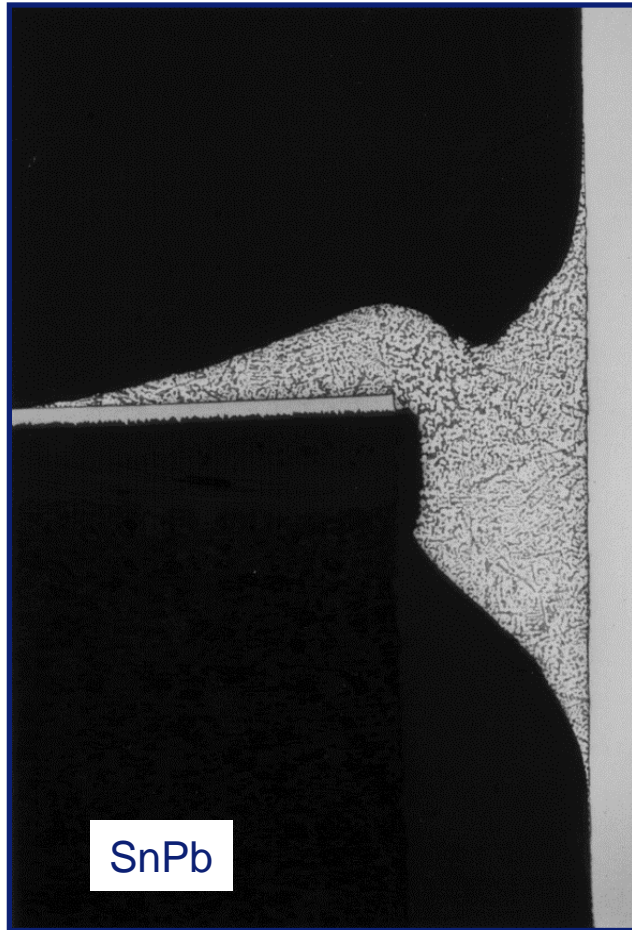


Volume Contraction



Does not impact reliability

Lead free joints behave different



Creep rate of Pb-free is smaller than for SnPb

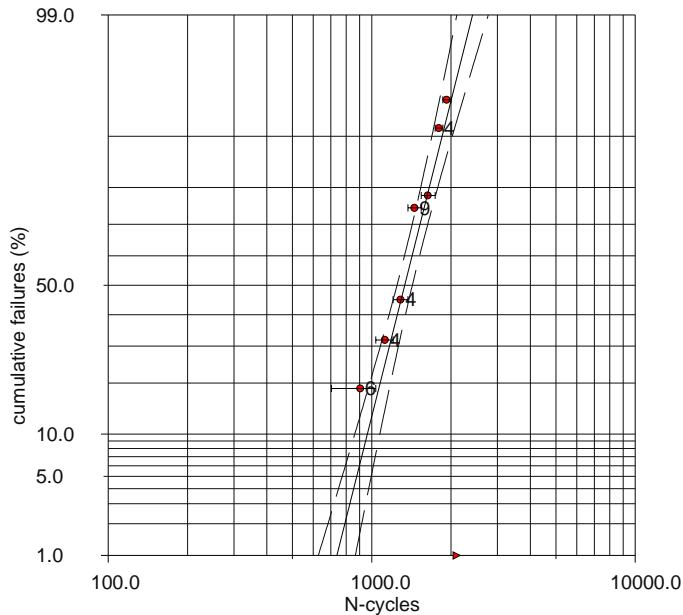
Reliability comparison of Pb-free and SnPb soldering

SAC solder with Tin finished component on Imm Sn and NiAu finished boards

Lead tin solder with Tin finished component on Imm Sn and NiAu finished boards

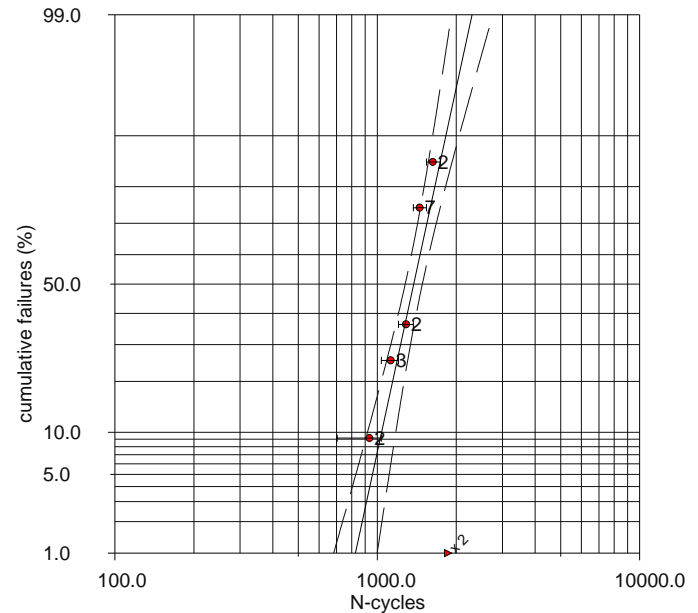
ReliaSoft's Weibull++ 6.0 - www.Weibull.com

Probability - Lognormal



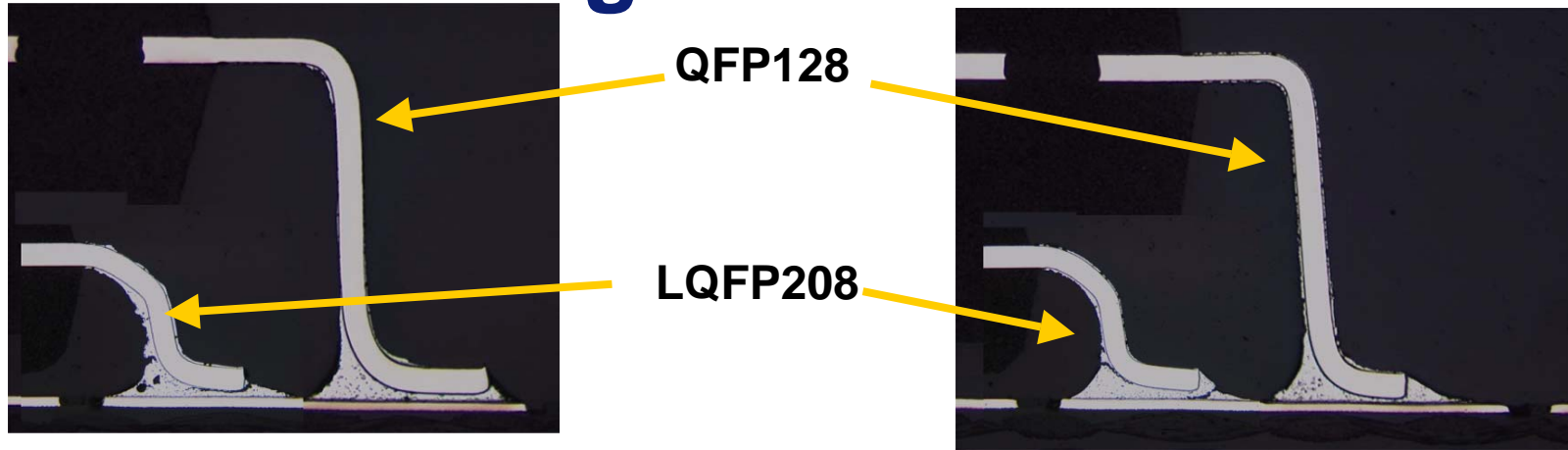
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Probability - Lognormal



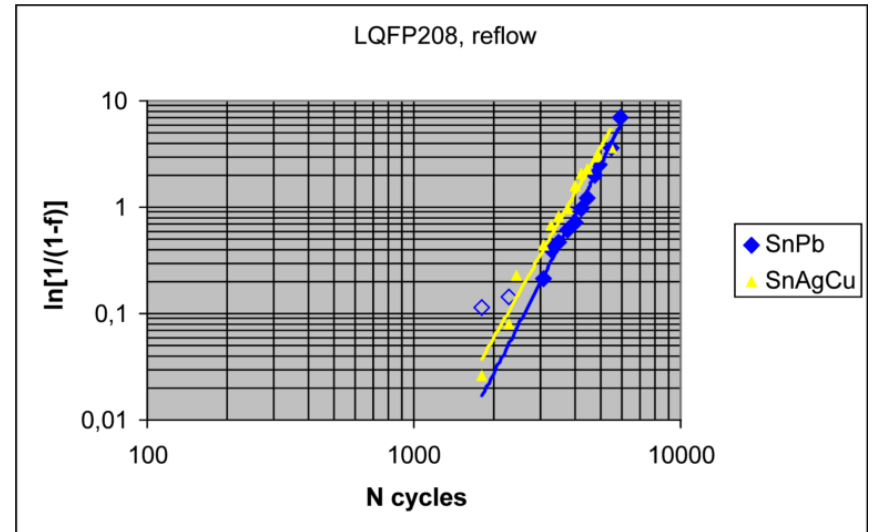
- Lead-free does not affect reliability

Solder joint reliability with SnAgCu and SnPb



**QFP128: 5% failures after 6600cycles: - 40 °C to +125 °C
1st failure: 6600 cycles**

**LQFP208: 97% failures after 6600cycles: - 40 °C to +125 °C
1st failure: 1800cycles**



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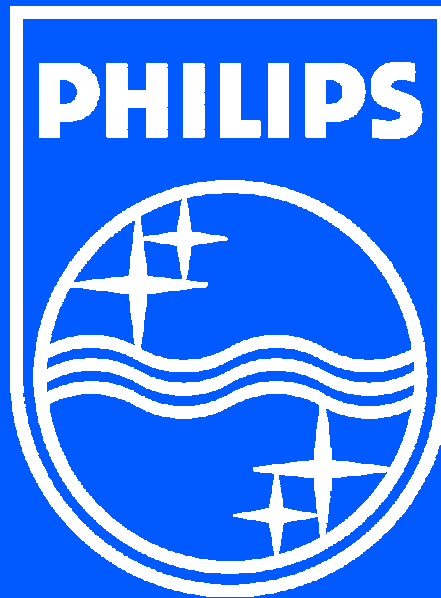
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Possible 'line of marching'

- **Secure the design**
- **Cover all component aspects for lead-free**
- **Choose right board finish**
- **Check metallurgical aspects**
- **Secure the Process**
- **Build lead-free models**
- **Reliability tests on models**
- **Guide production ramp up**

Conclusions

- Legally required transition to lead-free products is **not a mission impossible**.
- **Time to act** for transition to Pb-free: **now**
- It is a challenge for **component suppliers** to **convince** their **customers** on the feasibility of their products for lead-free assembly.
- It is a challenge for the **assembly houses** and OEMs to **find** the **equilibrium** between cost, risk and reliance on suppliers.
- From **technical** point of view there are **no** main **hampers** to make the transition to lead-free products.
- But...Pb-free technology is not a “drop-in” solution



Thank you for your attention