

# “The Impact of Lead Free Solder on PCB Test & Inspection”

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# TERADYNE

*Assembly Test Division*

# The Impact of Lead Free Solder on PCB Test & Inspection



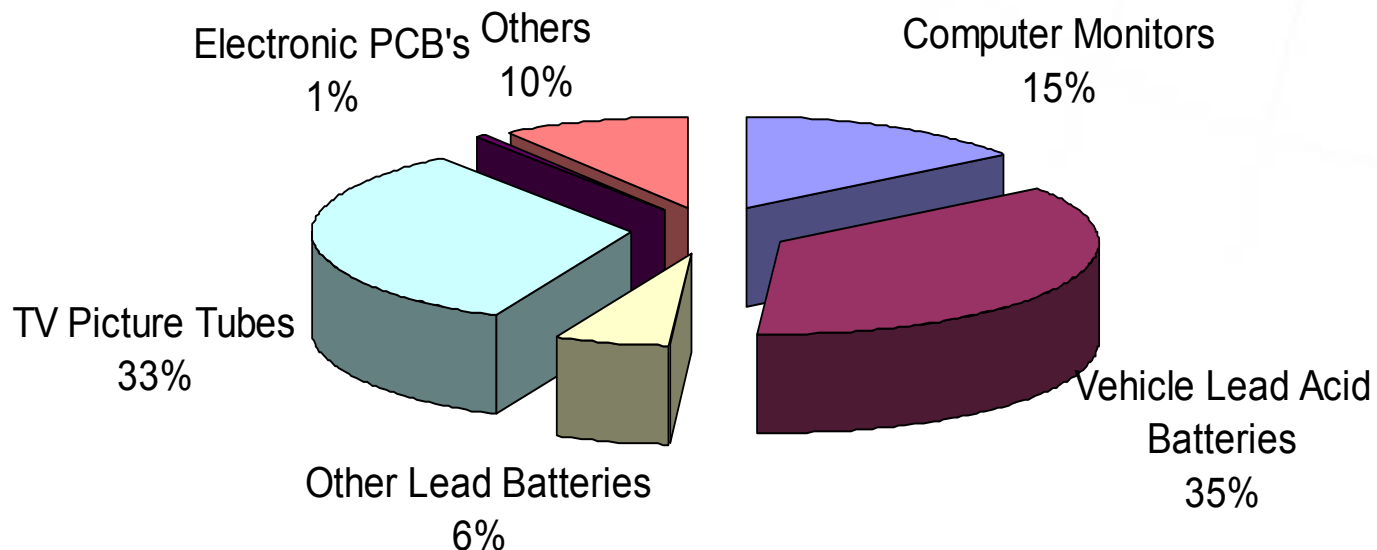
- Agenda
  - Why Lead-Free Solder?
  - Technologies Issues
  - Manufacturing Issues
  - Automatic Optical Inspection
  - Automatic X-Ray Inspection
  - Incircuit Test
  - Functional Test
  - Rework of Lead-Free Solder

# Why Remove Lead Free Solder in Electronic?



- Examples of Discards Lead in the Environment

- Batteries > 41%
- Cathode Ray Tubes > 48%
- Electronics < 1%



# Lead Free Solder

## - Environmental Changes - Europe



- The WEEE (Waste Electrical & Electronic Equipment) and Restrictions of Hazardous Substances (RoSH) Directives
  - was finalised on 18 December 2002, and member states are in the process of transposing it into law.
    - Under the directive, there is a dual focus: the producer pays the cost of recycling schemes (a producer is, for instance, a computer hardware manufacturer), and businesses are obliged to implement appropriate disposal policies or face penalties.
  - From the business customer point of view there are three main impacts:
    - Businesses will pay more for new IT equipment
    - Businesses without IT asset management will face high disposal costs
    - Businesses caught scrapping IT will be penalised

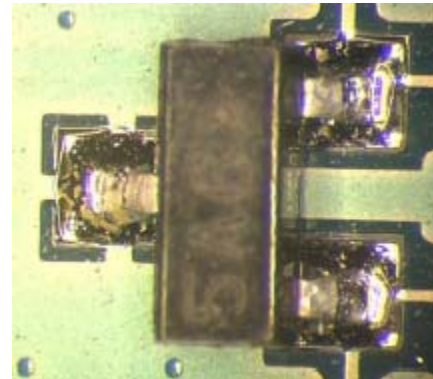
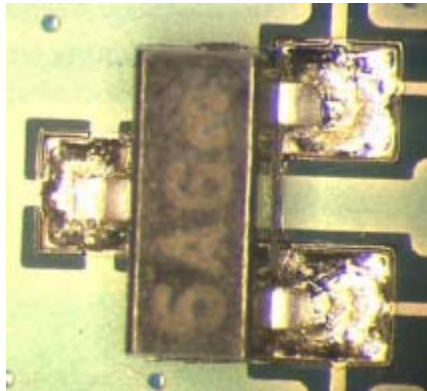


# Lead Free Solder

## - Environmental Changes - Japan



- 1991: The Waste Disposal Law requires disposal within the facility when the detected lead amount is over 0.3mg/L by eluting test of industrial waste.
- 1994: The Water Pollution Prevention Law lowers the lead content of rivers from 0.1mg/L to 0.01mg/L.
- 2001.4: The Consumer Electronics Recycle Law requires manufacturers to recover harmful materials.



# Lead Free Solder

## - Environmental Changes - USA



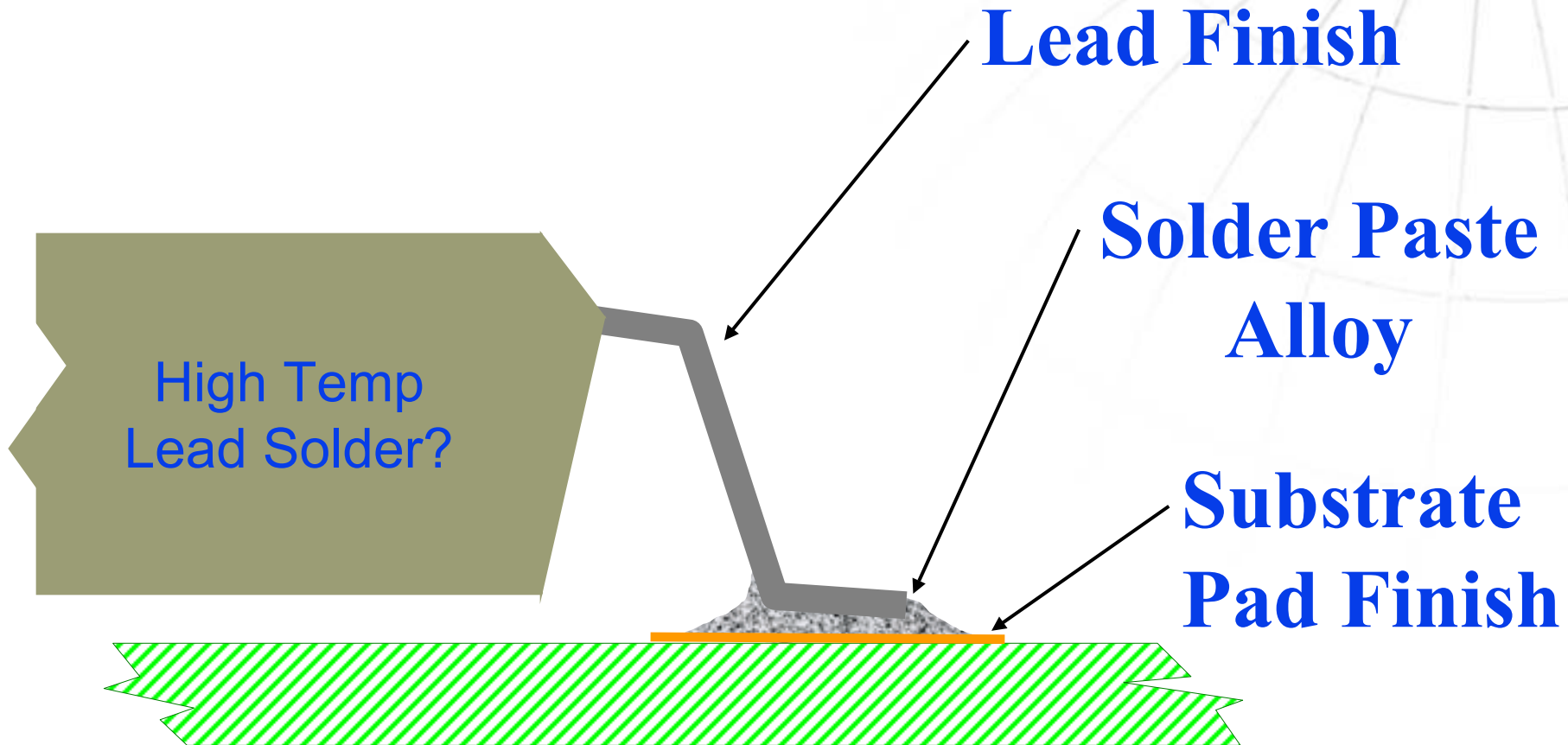
- 1990: Introduced a bill prohibiting use of solder containing over 0.1% lead. (However, this excludes the electronics industry.)-
- 1999: Industrial organization NEMI, formed by the USA electronic parts manufacturing industry, government organizations and universities, started research and development targeting the total abolition of lead products by 2004.
- End Of Life legislation pending in 20 plus states.

# Lead Free Solder - Technology Issues



- Traditional solder chemistry
  - Tin + Lead (Sn + Pb) Typically 60/40 eutectic mix
- New lead-free formulations ( NEMI recommendation)
  - Tin + Silver + Copper (Sn + Ag + Cu)
    - Sn + 3.9% Ag + 0.6% Cu for reflow @ 217°C
    - Sn + 0.7% Cu for wave
  - Tin + Copper (Sn + Cu)
    - Sn + 0.7% Cu for component finishing
- Sony has successfully devised a type of lead-free solder with a low melting point of 196°C, based on a mixture of tin and zinc (Zn).

# Lead Free Solder - But where?



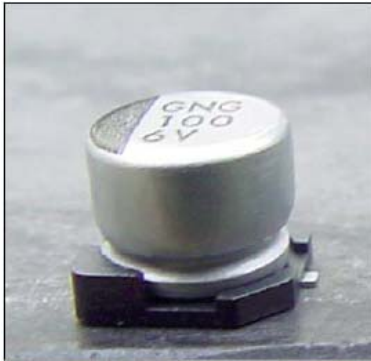
# Lead Free Solder - Manufacturing - Packages



- Components
  - Qualification for higher Temperatures
    - Thicker package walls?
  - High Temperature warpage of BGA's ( Solder ball shorts)
  - Storage/Moisture issues ( “Popcorn Effect” when heated ).

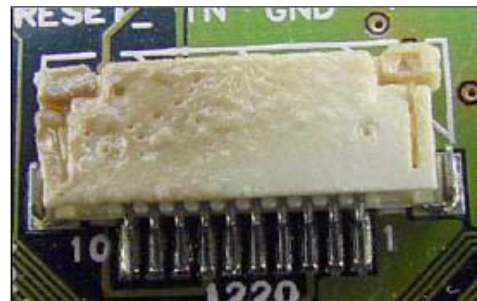
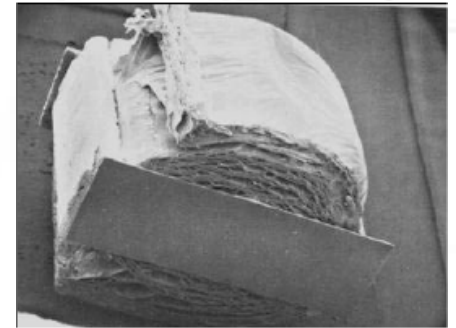
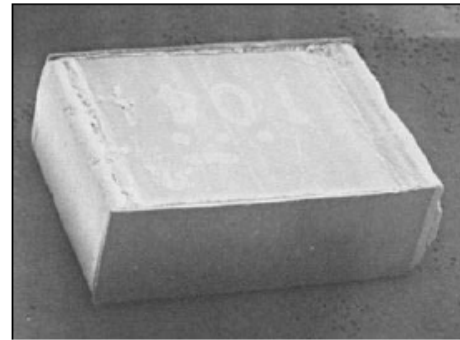
JEDEC Moisture Sensitivity Level		Previous Materials			New Pb-free Process Compatible Materials		
Level	Floor Life	225°C	240°C	260°C	225°C	240°C	260°C
2A	1 Month	Pass	Fail	Fail	Pass	Pass	Pass/Fail
3	1 Week	Pass	Pass	Fail	Pass	Pass	Pass
4	3 Days	Pass	Pass	Pass	Pass	Pass	Pass

# Lead Free Solder - Manufacturing - Packages



225°C->250°C

225°C->255°C

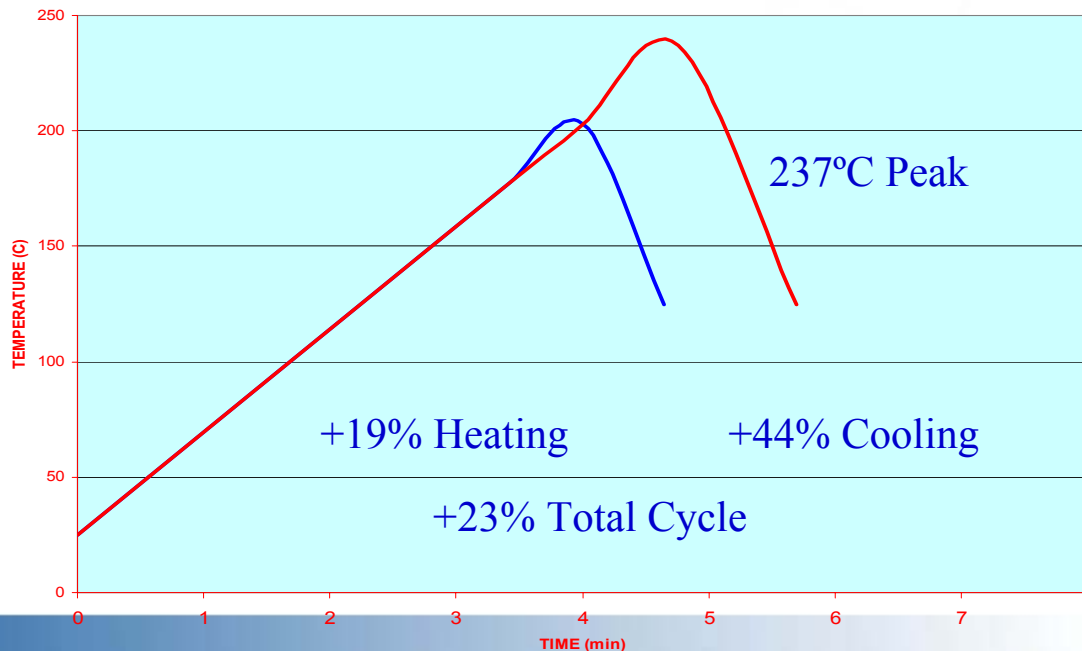


240°C->270°C

# Lead Free Solder - Manufacturing



- Solder reflow profile changes
  - Melt temperatures rises from 183°C to ~ 217°C
  - Reflow profiles as high as ~240°C
    - Temperatures can be reduced by longer pre-heat but risk the formation of more voids.

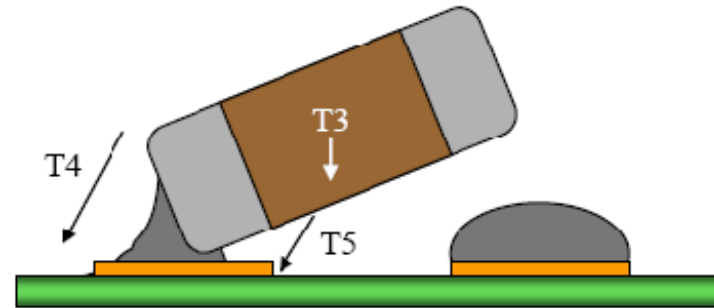
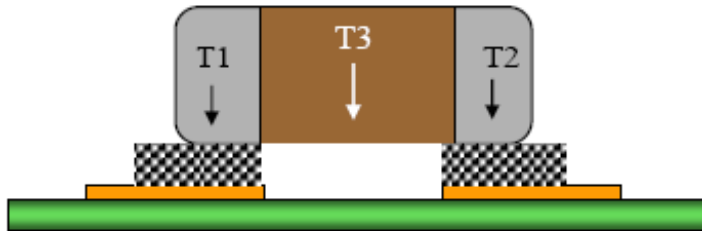


# Lead Free Solder

## - Defects Higher Tombstone Failures



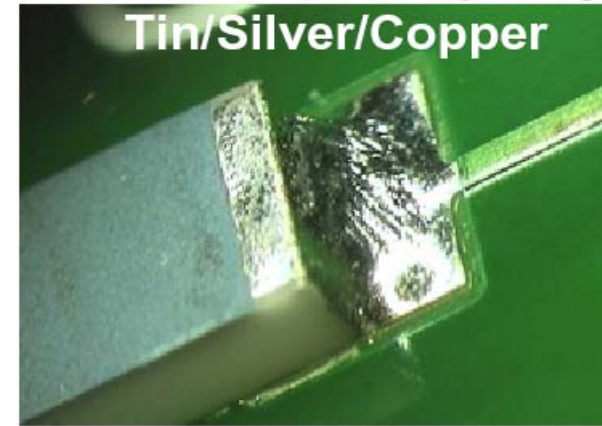
- Lead free solder is more prone to tombstone failures due to higher coalescent ( Surface Tension) forces



- T4 is significantly higher
  - using lead free solder



# Lead Free Solder - Optical Inspection Issues



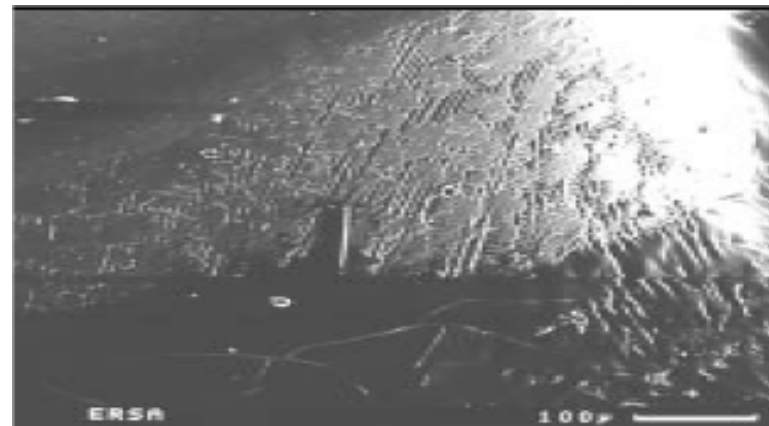
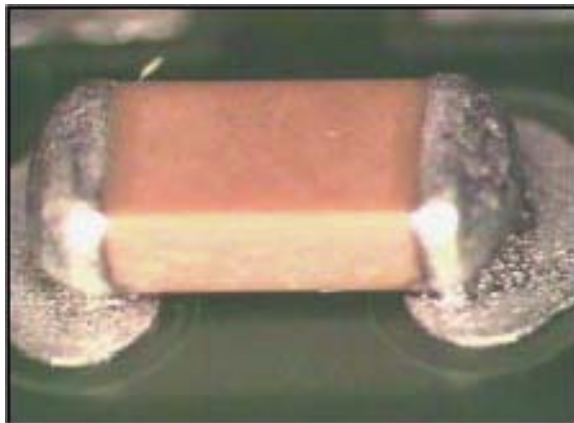
- Lead free solder joints are typically more striated and rough than corresponding leaded joints, due to the phased transition from liquid to solid
- Lead free solder has a higher surface tension and does not flow as readily as leaded solder causing a slightly difference shaped fillet

Source: Boeing Company report, 1st European Union/United States Lead-Free Solder Interface Meeting London, W1A U.K. March 27, 2002

# Lead Free Solder - Optical Inspection Issues



- More examples
  - Orange Peel
  - Freezing lines.



# Lead Free Solder

## – Industry Study On Solder Inspection



- In 2002 Teradyne helped fund the NPL (National Physical Laboratory) to independently evaluate AOI's ability to inspect lead-free solder joints
  - “NPL is the United Kingdom's national standards laboratory, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science.”
- Study Title: “A Comparison Of Automated Optical Inspection Systems For Use With Lead-Free Surface Mount Assemblies” - July 2002
  - “The purpose of this project was to determine if lead-free assemblies presented any problems for automatic optical inspection equipment.”

# Lead Free Solder - NPL Study Summary



- Study Conditions:
  - 15 target boards, some with defects, some defect free
  - Identical algorithms were used for lead-free inspection as are used for the inspection of conventional lead solder assemblies
- AOI Study Results:
  - The results “clearly demonstrate” that most AOI systems can be used in the inspection of lead-free surface mount assemblies
  - “False detect rates were also similar for both sets of results.”

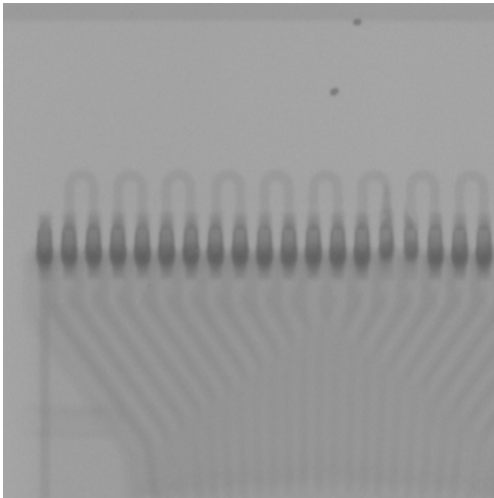


**Figure 1: Study Test Vehicle**

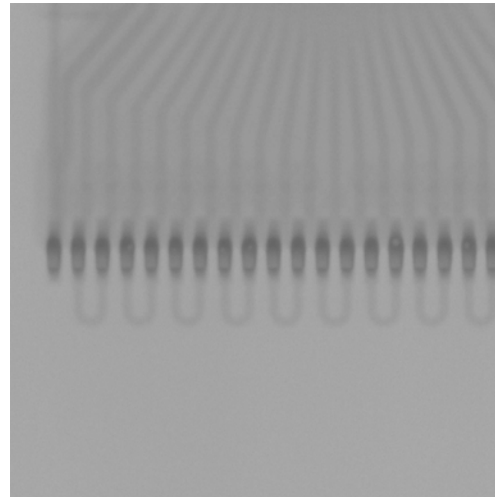
# Lead Free Solder - X-ray Images



Tin/Lead Joint



Tin/Silver/Copper Joint



Tin/Silver/Copper paste

Tin/Lead coated Leads

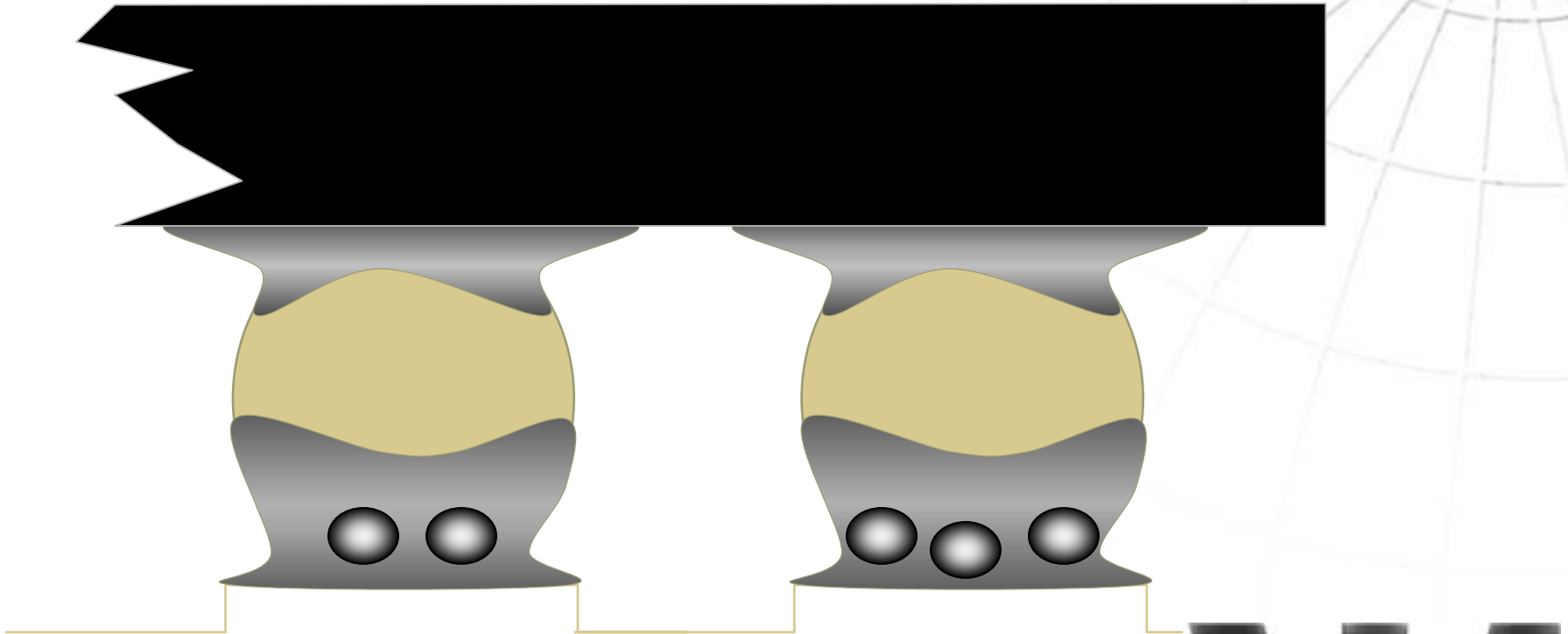


**Implication:**

**AXI has no problem imaging different lead free materials**

Approximately 20% less dense

# Lead Free Solder - X-ray Inspection



- With lead free solder ball joints, an increase in voids is expected due to flux trapping.
- Void detection will become very important



# Lead Free Solder - Incircuit Test



- Concern over increased flux residues
  - Probe tip contact resistance build up
    - New probe styles
    - More aggressive cleaning schedules
    - Shorter probe replacement cycles
- Lead Free brittle solder maybe damaged by:-
  - Excessive board flexing on the fixture
  - Shape probe styles

# Lead Free Solder - Incircuit Test

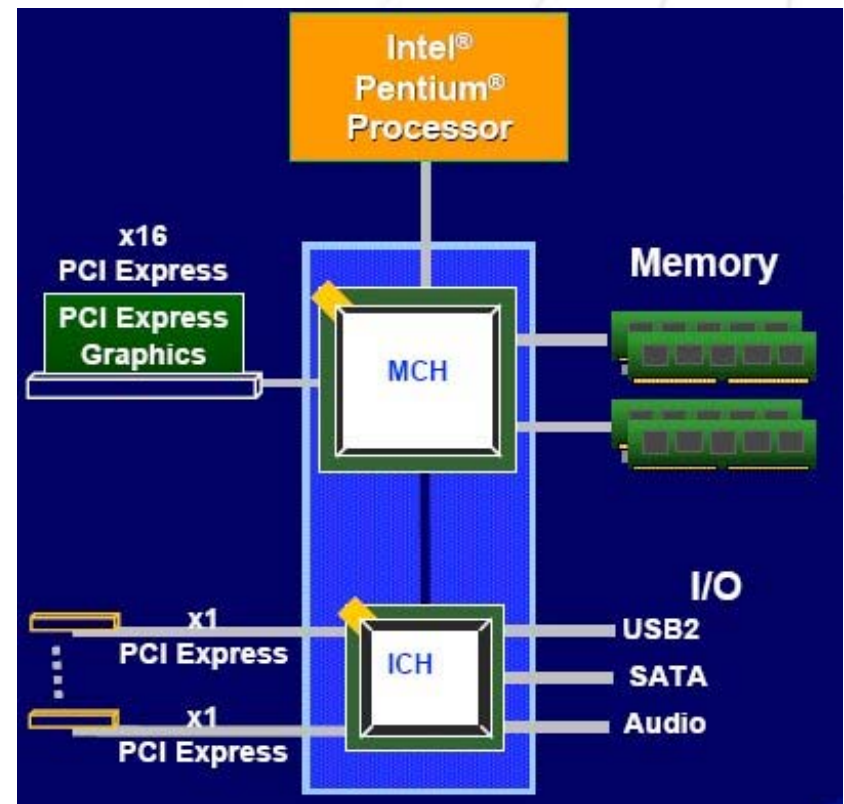


- Tin whiskers
  - Tin alloys grow whiskers between joints due to incomplete reflow and solder placed under compression.
    - Effect being evaluated by NEMI and other organisations.
- Flying Probe systems may also damage brittle lead free solder with repetitive probing of the same point.
  - Probe styles and algorithms may have to change

# Lead Free Solder - Inspection & Test



- Functional Test
  - It seems that many companies already employing a lead-free process are using more aggressive fluxes to help counter potentially higher oxidation rates at these higher operating temperatures
  - Excess flux can effect RF ( Radio Frequency) circuit performance
  - Everything now has RF speeds
    - PCI Express,
    - SATA ( Serial Advanced Technology Attachment)
    - USB2



# Lead Free Solder - Rework



- With the introduction of lead-free solder and the elimination of certain fire-retardants within the bare PCB, the higher temperatures required for rework may :-
  - Reflow Temperatures of ~235°C
  - Packages specifications of 240-250°C
  - Hot Air at > 300°C
  - Damage the component and/or board.
  - Cause reflow opens and shorts on other devices.
- These problems are being investigated by the NEMI “Lead-Free Hybrid Assembly and Rework Project”.

# Lead Free Solder

## - Rework



- Many companies may find that they need to **minimize or eliminate defects** from the PCB assembly line to reduce rework.
  - “zero-defect” line may become a reality.
- Others will want to **minimize rework** and the types of rework with **accurate diagnostics** and **NO false failures**.
  - Open faults rather than device faults
- Reworked boards will have to be **retested on ICT**.
  - AOI and AXI are not designed to image manually reworked boards.

# The Impact of Lead Free Solder on PCB Test & Inspection



- The series will continue on the 31<sup>st</sup> March 2004 with....
  - “Impact of Low-Voltage Devices on PCB Test and Inspection”
- Also Visit.
  - [www.nemi.org](http://www.nemi.org)
  - [www.ipc.org](http://www.ipc.org)
  - [www.npl.co.uk](http://www.npl.co.uk)
    - “A Comparison Of Automated Optical Inspection Systems For Use With Lead-Free Surface Mount Assemblies”
  - [www.teradyne.com/cbti](http://www.teradyne.com/cbti)
- Additional Questions
  - [Michael.J.Smith@Teradyne.com](mailto:Michael.J.Smith@Teradyne.com)



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