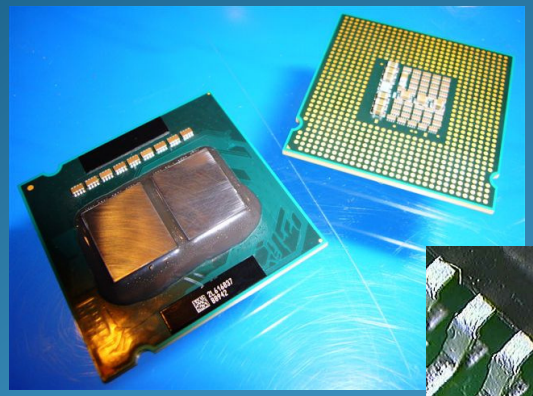
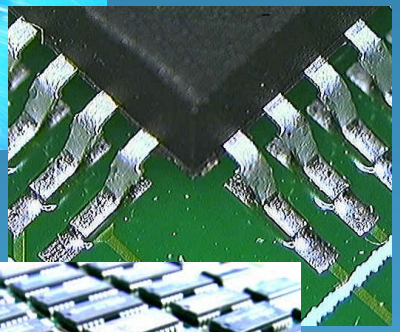
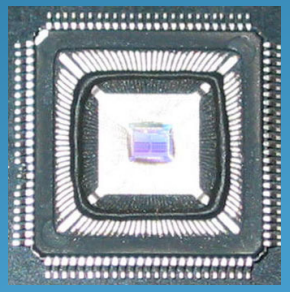
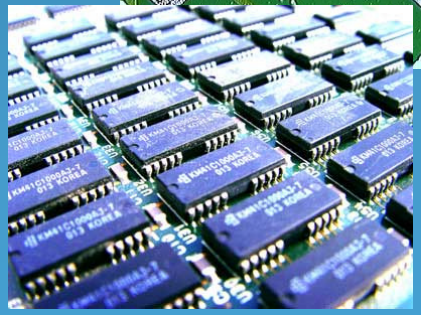
Lead-Free Challenges to Defense Industry

















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Lead-Free Background

- Reduction of Hazardous Substances (RoHS)
  - EU Directive prohibiting the use of lead and other harmful substances in new electrical and electronic equipment put on market after 1 July 2006.
    - Lead, Cadmium, Mercury, Hexavalent Chromium, PBB, PBDE
  - Related legislation currently in China and Japan
- Defense & aerospace industries and batteries exempt
  - 80% of lead in landfills comes from batteries

Lead-Free Background

- Electronics industry reaction
  - Began defaulting to non-lead parts
  - Could not compete in Europe without making the switch
  - Reduced or eliminated tin-lead production lines
  - Pb parts became more expensive to procure









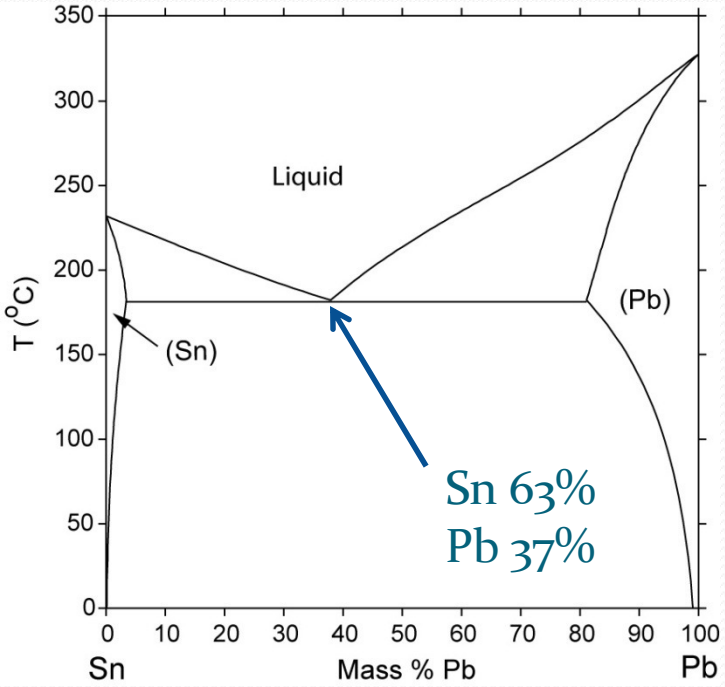


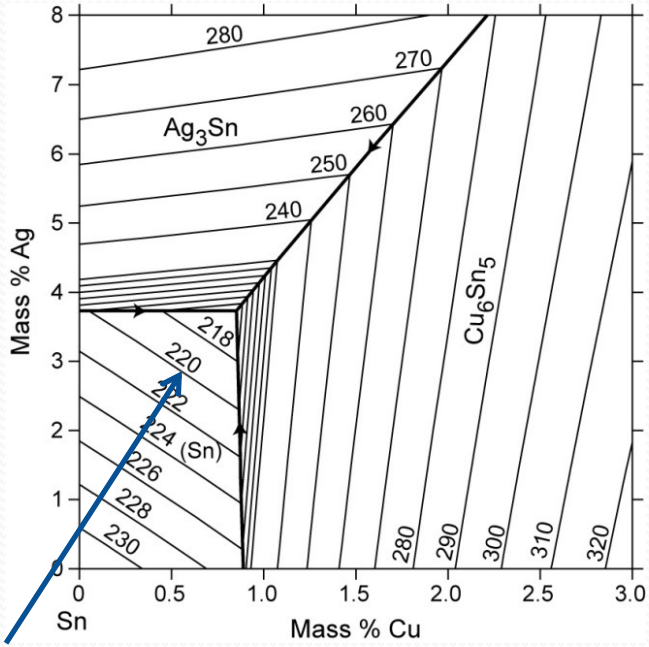
Lead-Free Impact on Defense Industry

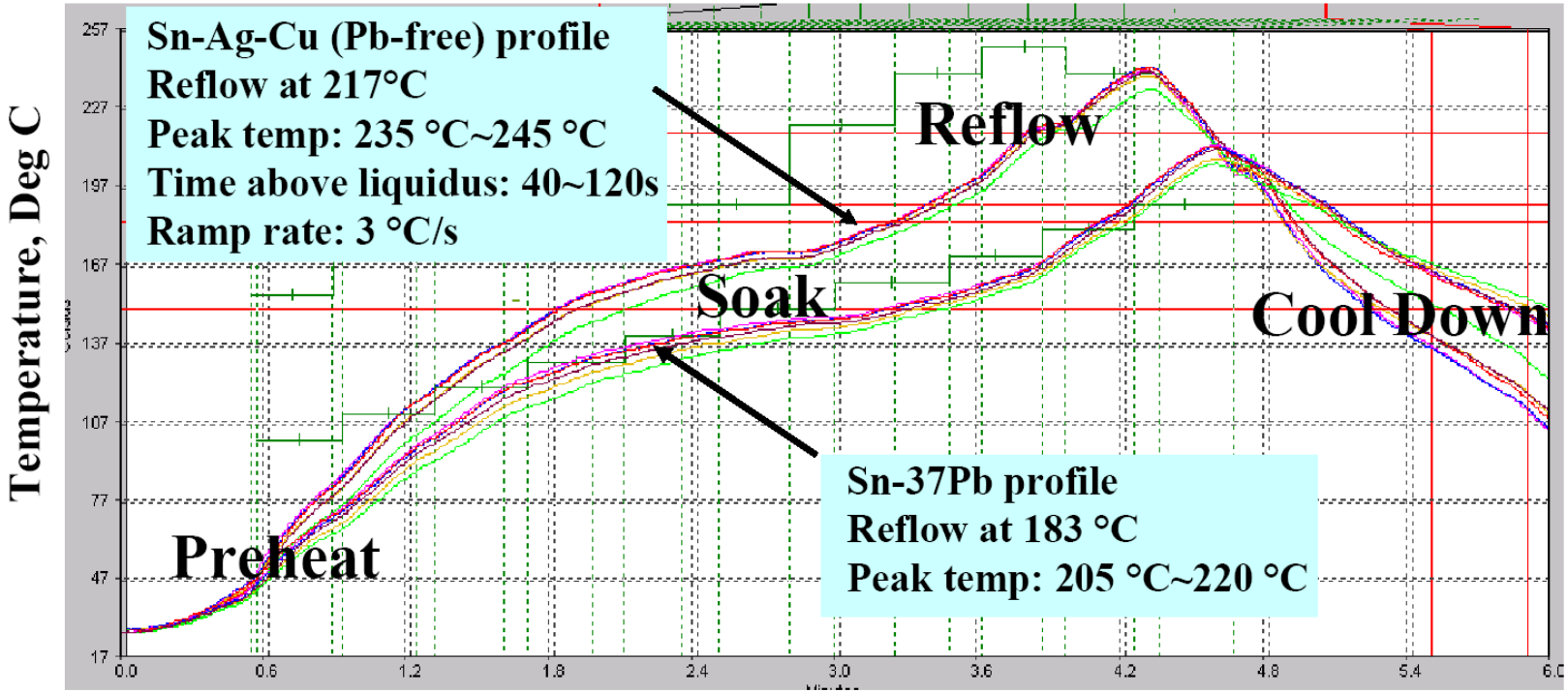
- Defense Industry has unique requirements
  - High reliability
  - Extended service life
  - Extreme temperature ranges
  - Repair and rework
- Lead-Free Impacts
  - Unproven solder joint reliability
  - Higher processing temperatures
  - Tin Whisker formation
  - No drop in replacement for Pb-free alloy
    - Solder selection may vary based on application

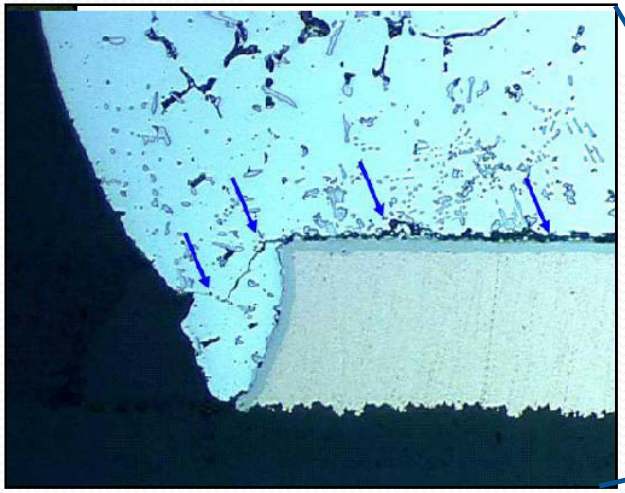
Higher Processing Temperatures

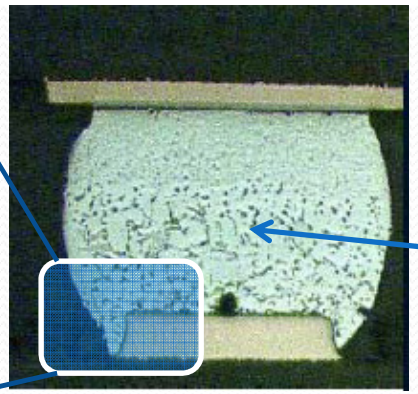
- Most popular replacement (SnAgCu) has ~35°C higher reflow
- Delamination and warping of printer circuit board
- Damage can occur to adjacent tin-lead parts during rework







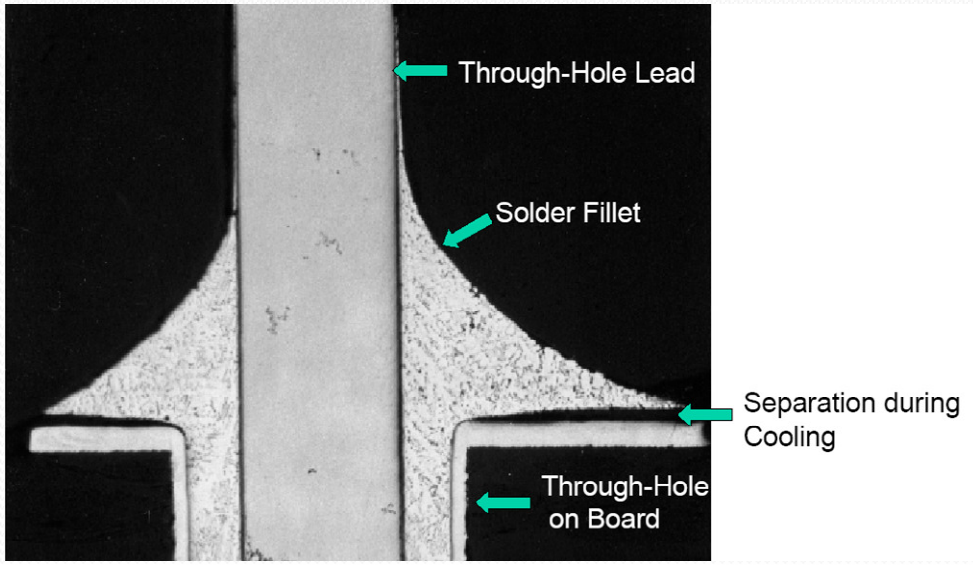




A SAC305 BGA assembled under Sn37Pb solder process

Solder Joint Reliability

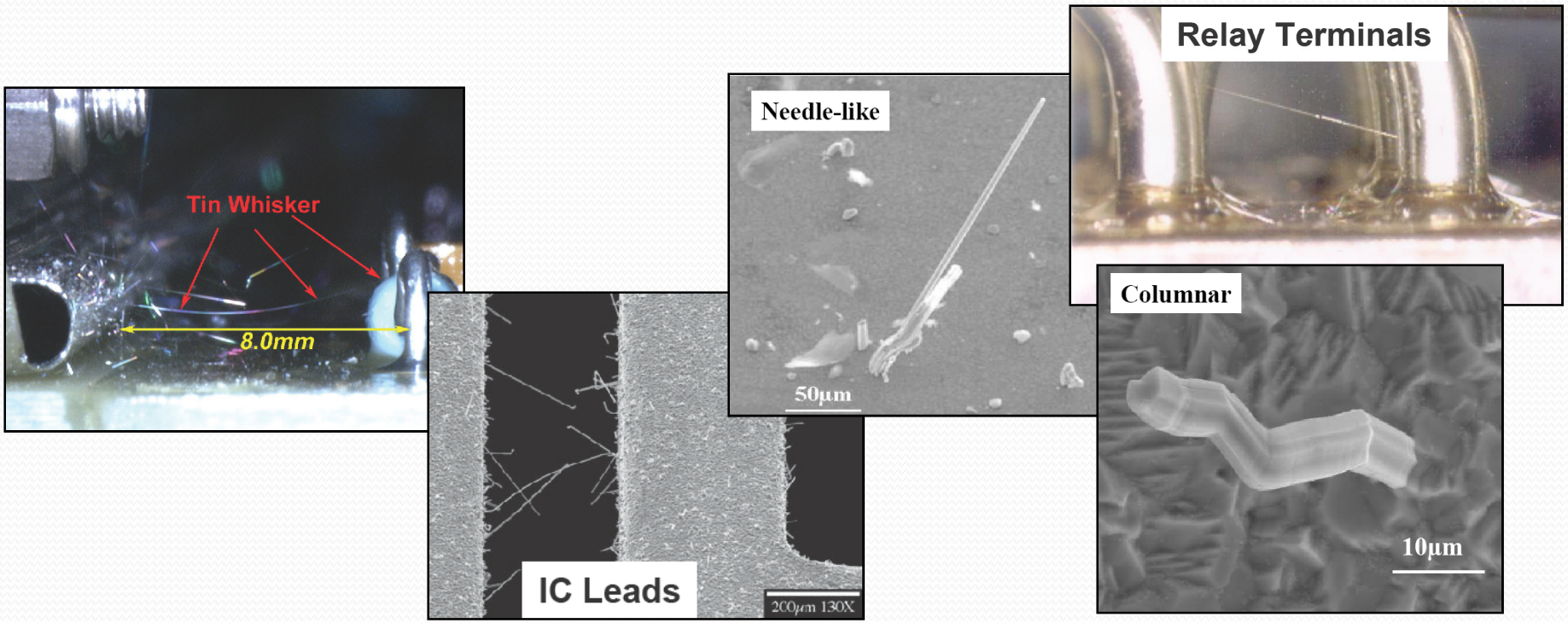
- Pb-free parts with SnPb solder processing
  - Assure higher reflow temp
  - May result in cold joints
- Pb boards with lead-free solder
  - Shown to produce fillet lifting (picture left)
- Pb-free solder joints equally reliable to Pb solder joints when using matching alloys



Avoid cross contamination between different alloys

Tin Whiskers

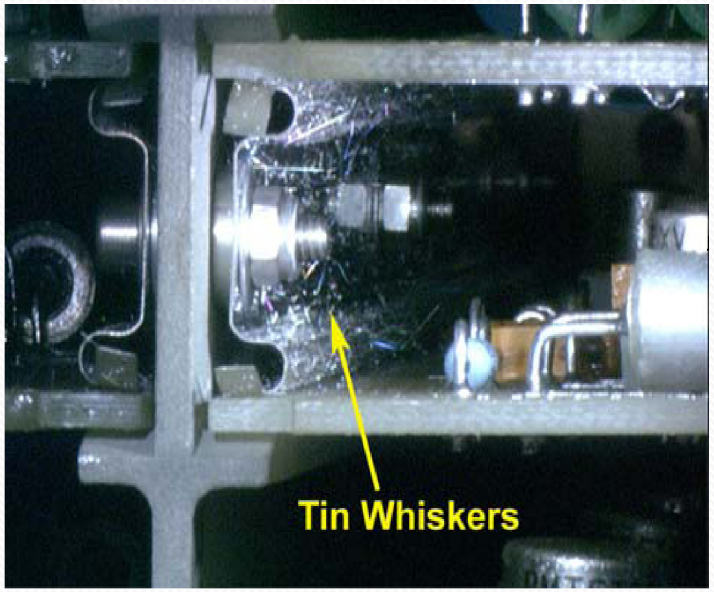
- "Hair-like" growths from tin and high tin alloy finishes
- May take years to develop
- Growths can range from a few microns to 10 millimeters
- Methods can reduce whisker formation but not eliminate or predict it
  - Pb significantly reduces whisker growth

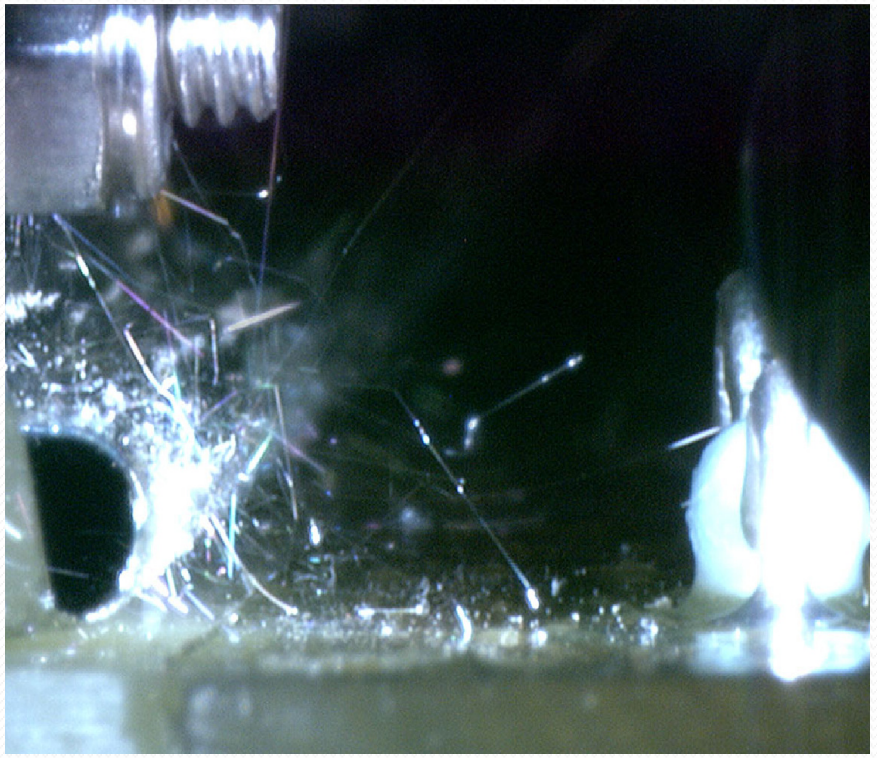


History of Whisker Failures

Year	Program	Cause
1986	F-15 Radar	Hybrid Package
1989	Phoenix Air to Air Missile	Hybrid Package
1990	Duane Arnold Nuclear Power Plant	LPRM Detectors
1998	Galaxy IV Satellite	Relays
1998	Dresden Nuclear Power Plant	LPRM Detectors
1999	South Texas Nuclear Power Plant	Relays
2000	Patriot Missile II	Power Terminal Short
2000	Galaxy VII Satellite	Relays
2000	Solidaridad I Satellite	Relays
2005	Millstone Nuclear Power Plant	Diode Axial Leads
2006	Space Shuttle Flight Control System Avionics Box	Tin Card Guides

Space Shuttle Avionics Failure





Tin Plated Guides Caused Failure
52 Avionics Boxes Required Rework

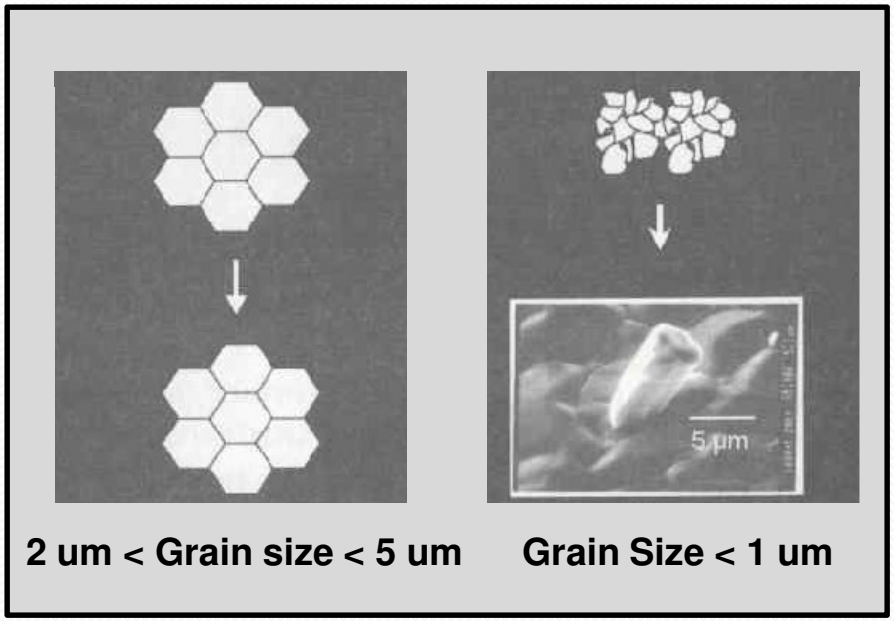
Factors of Tin Whisker Formation

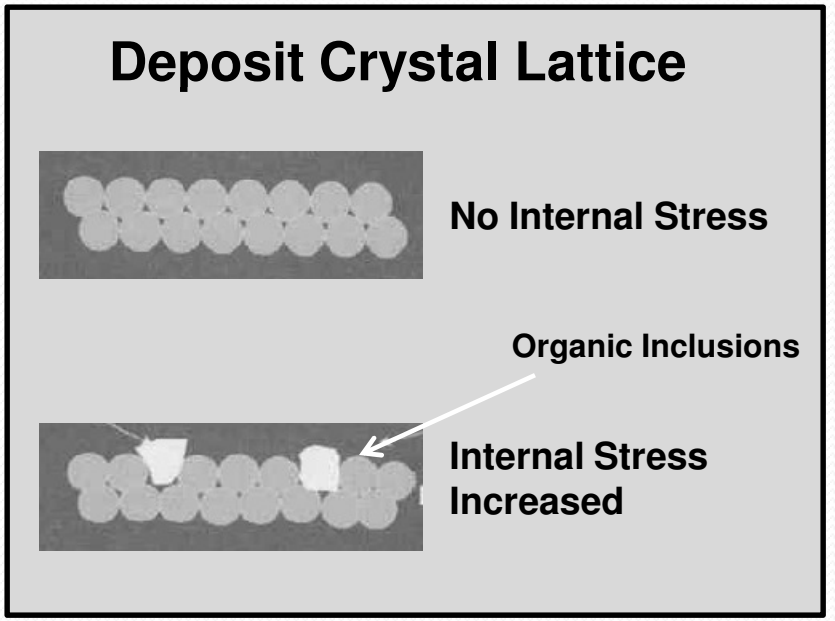
- Generally agreed that compressive stress in the finish causes whisker formation

- Whisker formation factors
  - Bending surface after plating
  - Scratches or nicks in plating by handling
  - Coefficient of thermal expansion mismatch between plating material and substrate
  - Grain orientation
  - Grain size of plating
  - Temperature cycling

Grain Size and Impurities

- Internal stress builds up when grain size falls below 1 um
- Organic Inclusions increase internal stress



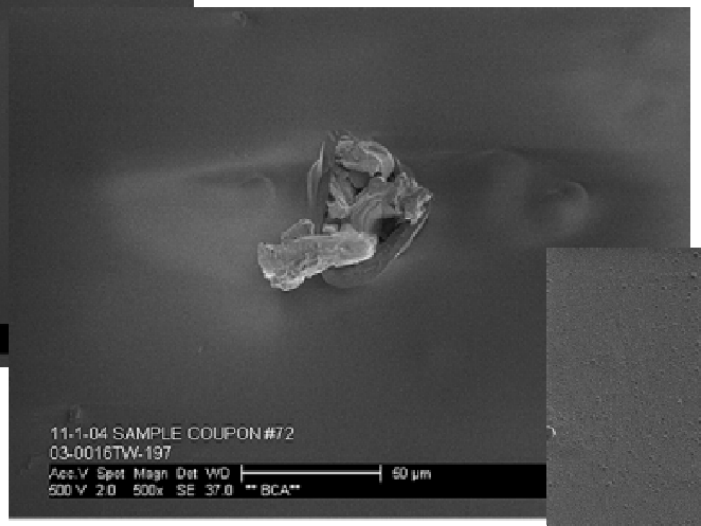


Mitigate Growth with Conformal Coat

- While conformal coating provides protection against shorts, it has not shown to be complete



Urethane
Acrylic 33um



Silicone 33um



Parylene C 20um

Tin Whiskers
Penetrating Coating

Summary

- Currently all Pb-free tin alloys appear susceptible to whisker formation among other reliability risks
- Many steps may delay whisker growth but none have been shown to prevent it
- Defense companies currently avoid Pb-free products
  - Becoming increasingly difficult and expensive to obtain Pb-free parts as suppliers convert
- Strategy going forward
  - Leverage off research performed by consumer industry
  - Support Pb-free research by CALCE, NASA, INEMI, BMPCOE and others
  - Implement Pb-free transition strategy
    - Update best design practices and production facilities to account for Pb-free

Cost of RoHS

- As of April 2008, RoHS has cost the electronics industry **32 billion dollars**
- The average company spent $2.6 million to achieve initial compliance and another $482,000 for annual maintenance
- The average cost increase in component and manufacturing costs because of RoHS was 11.6%
- Exempt industries including defense and aerospace have yet to invest in the switch to Pb-free

http://www.purchasing.com/article/CA6552730.html

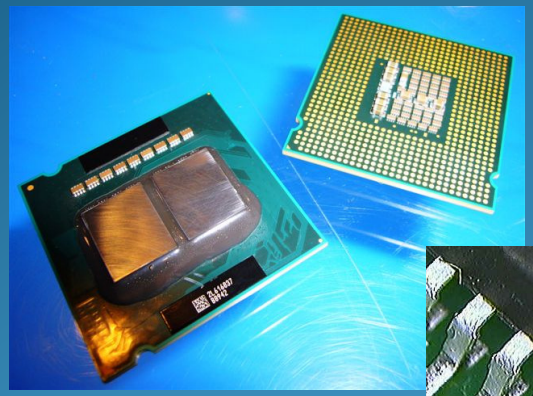
References

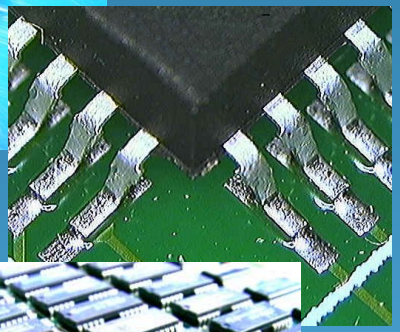
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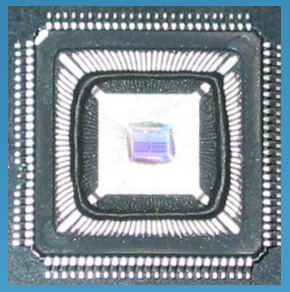
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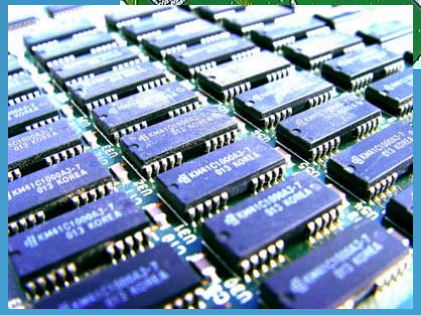
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Lead-Free Challenges to Defense Industry

















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