Office of the Secretary of Defense

Defense Microelectronics Activity (DMEA)

Lead-Free Impacts on DoD Microelectronics

Vance Anderson
Defense Microelectronics Activity
Microelectronics Systems Branch
anderson@dmea.osd.mil
(916) 231-1646

DMSMS Workshop
San Antonio, TX
14-15 December 2005

www.dmea.osd.mil

Outline

- Lead-free Background
- Lead-free Impacts on DoD
- Mil/Aero Lead-free Efforts
- Mitigation Strategies
- Summary

Lead-Free Background

There is a global transition to lead-free

- Lead-free brings new and re-emerging failure modes in electronics
- **Reduction of Hazardous Substances (RoHS)**
  - EU Directive banning "placing on market" new electronic equipment containing specific levels of the following after July 1, 2006
    - **Lead**, Cadmium, Mercury, hexavalent chromium, polybrominated biphenyl (PBB), polybrominated diphenyl ether (PBDE) flame retardants
- **Waste Electrical and Electronic Equipment Directive (WEEE)**
  - EU directive aims to minimize the impact of electronic waste
  - Encourages and sets criteria for collection, treatment, recycling
  - Makes the *producer responsible*
- Related legislation underway in China and Japan

Lead-free Impacts on DoD

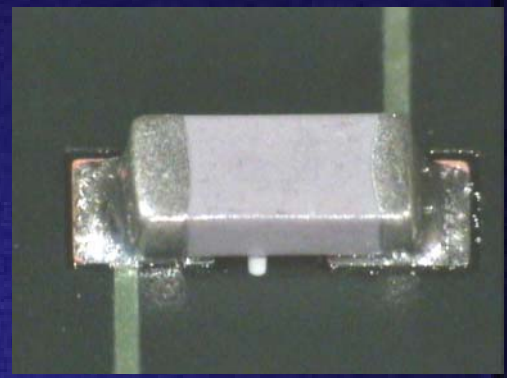
- DoD (and Aerospace) systems have unique requirements
  - High reliability
  - VERY long service life
  - Extended temperature ranges
  - We still *repair* boards!

- Primary lead-free impacts
  - Lead-free solder issues
  - Tin whisker failures
  - Availability of leaded solder and components
  - New processes / configuration control

Commercial solution strategies for lead-free may not apply to Military / Aerospace applications

Lead-free Solder Issues

- **Temperature stress**
  - Prevailing Pb-free solder replacement (SnAgCu) has ***~35°C higher*** reflow temperature
  - Infant mortality
  - Latent failures
  - Requalification?



- **Solder joint reliability (durability)**
  - Intermetallics between solder and lead/pad
  - Cross contamination of different alloys
  - Changed / unacceptable wetting characteristics
  - New qualification parameters

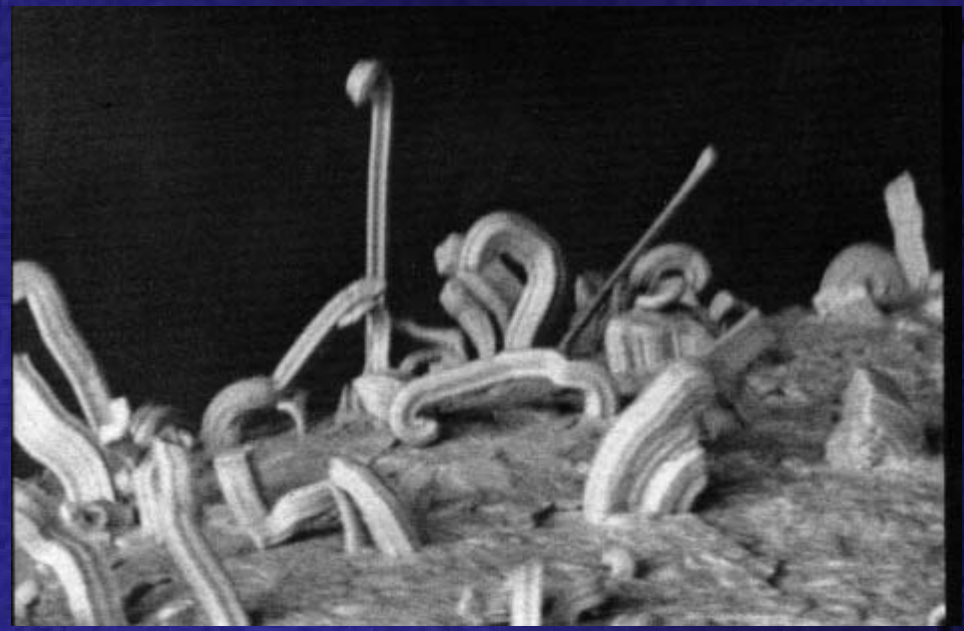
Cracked Solder Joint

- **Configuration control**
  - Must prevent mixing of incompatible alloys
  - Patent infringement

Tin Whisker Impacts

- **Tin whisker effects documented since the 1940's**

- **Tin Whiskers**
  - "grow" from nearly all tin alloys
    - pure Sn
    - SnBi, SnCu, SnAgCu
    - Few microns to over 1mm
  - Electrically conductive
  - Crystalline



(Photo courtesy of NASA Goddard Space Flight Center)

- **Whisker induced failures:**
  - *Short Circuit* – bridges two adjacent pins
  - *Metal vapor arc* – high voltage and specific atmosphere can result in plasma arc capable of catastrophic damage
  - *Contamination* – whisker breaks off and interferes with mechanical, optical, or MEMS component

Process & Availability Impacts

- **DMS due to *finish* and/or *package* (vs. die)**

- **New processes, policies, and mitigation strategies must be developed**
  - Lead-free mitigation programs
  - Revision and re-qualification of manufacturing processes
  - Configuration control
  - Change costs $$$

Mil/Aero Lead-Free Efforts

- The commercial industry has spent millions in development and conversion to lead free
  - *They have not solved all our problems*

- Military and Aerospace specific lead-free efforts
  - Industry and academic lead-free research efforts
  - Government, Industry, and International working groups
  - Development of a lead-free educational curriculum for DoD PMs

Mil / Aero Lead-free Efforts

- University of Maryland - CALCE
  - Computer Aided Life Cycle Engineering (CALCE) Electronic Products and Systems Center (EPSC)
  - Several projects and tools related to lead-free and tin whisker
- NASA – Goddard Space Flight Center
  - Extensive research and documentation on tin whisker effects
  - Check out the pictures!
- JCAA/JG-PP and NASA Kennedy
  - Lead-Free Solder Testing for High-Reliability Applications
- Navy – ONR
  - Office of Naval Research (ONR)
  - Best Manufacturing Practices Center of Excellence (BMPCOE)
  - Ongoing tin whisker research with Raytheon, CALCE, NASA, Boeing, Honeywell, Northrop Grumman

LEAP-WG

Lead-free Electronics in Aerospace Project (LEAP) Working Group

- GEIA, AIA, AMC, Aerospace, Military Contractors, Government
- LEAP is developing "actionable" guidance documents for Military and Aerospace use

•GEIA-STD-0005-1, *Performance Standard for Aerospace and Military Electronic Systems Containing Lead-free Solder*
•GEIA-STD-0005-2, *Mitigating the Effects of Tin on Aerospace and Military Electronic Systems Containing Lead-free Solder*
•GEIA-HB-0005-1, *Program Manager's Handbook for Managing the Transition to Lead-free Electronics in Aerospace and Military Systems*
•GEIA-HB-0005-2, *Technical Guidelines for Aerospace and Military Electronic Systems Containing Lead-free Solder*

IEC TC-107

- International Electrotechnical Commission – IEC
  - International standards body (like ANSI for US)
- IEC/TC-107 – Process Management for Avionics
  - Develops standards for aerospace and avionics
- IEC/TC-107 has initiated efforts to further transition the GEIA / LEAP WG documents as International Standards

DoD ELFIPT

DoD Executive Lead-Free Integrated Process Team (ELFIPT)

- Initial meeting Oct 19, 2005 in DC
- Senior Membership from:
  - DoD
  - DLA
  - Army
  - Navy
  - Air Force
  - Industry
- Identify DoD specific issues
- Coordinate service efforts
- Provide policy guidance
- Identify research efforts

Mitigation Strategies

- Implement a lead-free transition strategy
- Utilize industry best practices and standards in development and maintenance processes
  - Upcoming GEIA Standards
  - Tools
  - Perform a tin-whisker risk assessment
- Documented methods to *reduce* tin whisker effects
  - AVOID the use of PURE TIN (!)
  - Hot solder dip
  - Strip and replate
  - Matte Sn and underplate with Ni
  - Control the plating process
  - Conformal coating

Summary

- ***There is a global shift to lead-free electronics***
  - Lead-free exemptions will only buy a little time
- Develop and implement a lead-free strategy
  - Avoid pure tin finishes
- Inform and Educate DoD PMs
- Coordinate and support lead-free research

Remember: Lead-free processes that work for your cell phone don't necessarily work for your weapon system…

References

- Join the new DMEA Lead-Free Distribution List
  - Lead-free info, news, articles
  - To JOIN: send email with “lead free” in the Subject to Vance Anderson, anderson@dmea.osd.mil

A few lead-free resources

NASA Goddard	nepp.nasa.gov/whisker/
IPC Lead Free	www.leadfree.org
INEMI	www.inemi.org/CMS/
CALCE	www.calce.umd.edu/lead-free/
BMPCOE	www.bmpcoe.org

Questions ?

"Snakes in the Cockpit" with permission of JCAA & Hank Caruso