

# HEALTH, SAFETY, AND ELECTRONICS MANUFACTURING

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# Overview

- Technical Background
- Safety Training
- Health and Safety in Electronics Manufacturing
- Metal Whiskers
- Unintended Consequences

# Technical Background

- **ACI Technologies, Inc., Philadelphia, PA**
  - Research Associate: Performed analytical services, failure analysis, technical instruction, and project management of electronics manufacturing programs.
- **NanoSelect, Inc., Newark, DE**
  - Staff Scientist: Developed functional coatings on carbon nanotube (CNT) films for water quality sensors.
- **Naval Air Warfare Center Weapons Division, China Lake, CA**
  - Postdoctoral Researcher: Developed functional coatings for charge storage (supercapacitor) devices.
- **University of Southern California, Los Angeles, CA**
- **Texas A&M University, College Station, TX**
  - Graduate Research Assistant: Developed lanthanide-doped organic light-emitting materials for display and telecommunications applications.
- **Mayo Clinic Jacksonville, Jacksonville, FL**
  - Research Technologist: Developed small molecules and oligomeric materials for diagnostic tools and therapeutic candidates.

# Safety Training

- Safety Training at Many Research Institutions Typically Include:
  - **Proper Protective Equipment (PPE)**
    - Eyewear, Gloves, Filter Masks, SCBA, Dosimeters, etc.
  - **Safe Handling, Storage, and Disposal of Hazardous Materials**
    - Acids, Caustics, Chlorinated Solvents, Combustibles, Toxins, etc.
    - Electrostatic- and Shock-Sensitive Materials, e.g. Explosives
    - Waste Minimization Policies
    - Nanomaterials – Need for Standard Practices
  - **Classes of Fires, Types of Fire Extinguishers**
    - Oxygen- and Water-Sensitive Materials, Metal Fires, Radioactive Materials, etc.
    - Water, Carbon Dioxide, Powder Extinguishers, and Sand
    - Nanomaterials have a much higher surface area, creating a fire or explosion hazard, such as with aerosolized metals, like aluminum.

# Health and Safety in Electronics Manufacturing

- Reduction of Hazardous Substances (**RoHS**) Directive from EU
  - Restricts the use of:
    1. Lead (Pb)
    2. Mercury (Hg)
    3. Cadmium (Cd)
    4. Hexavalent chromium (Cr<sup>6+</sup>)
    5. Polybrominated biphenyls (PBB)
    6. Polybrominated diphenyl ether (PBDE)

# Health and Safety in Electronics Manufacturing

- Waste Electronic & Electrical Equipment (**WEEE**) Directive from EU
  - The producer of EEE must make sure that it is disposed of in an environmentally sound way, including the treatment, reuse, recovery and recycling of the components where appropriate.
  - The regulations aim to:
    - reduce waste from electrical and electronic equipment
    - encourage the separate collection of WEEE
    - encourage treatment, reuse, recovery, recycling and sound environmental disposal of WEEE
    - make producers of EEE responsible for the environmental impact of their products
    - improve the environmental performance of all those involved during the lifecycle of EEE.

# Materials – Metals that Whisker

- **Zinc Whiskers**

- Electroplated (galvanized) with zinc for corrosion protection.
- Found on zinc-electroplated steel underside of raised floor tiles
- Root Cause: compressive stresses

- **Silver Whiskers**

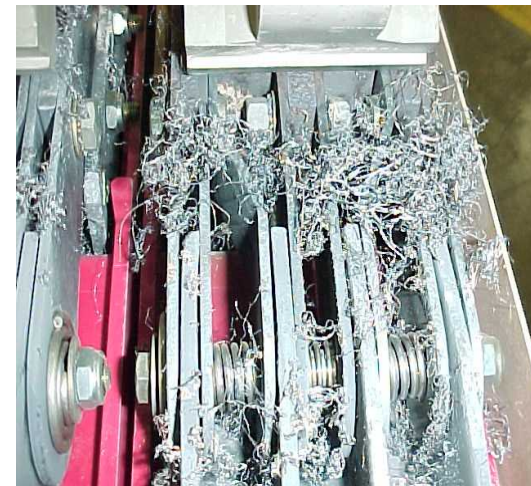
- Current carrying components
- Major environmental factor
  - Relatively low concentration of hydrogen sulfide ( $H_2S$ )

- **Cadmium**

- Considered a toxic substance
- Banned from specific applications
- Known to sublime at temperatures above  $75\text{ }^{\circ}\text{C}$



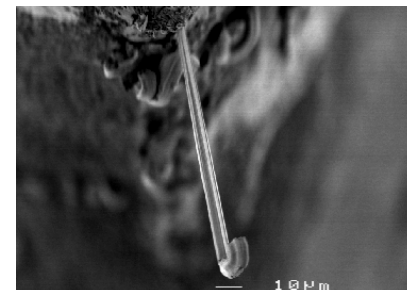
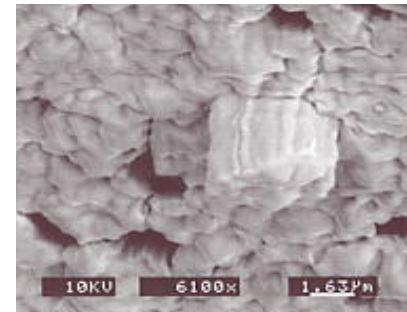
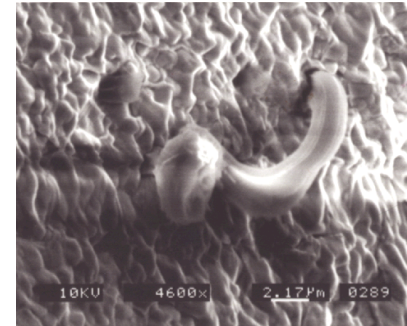
Courtesy of NASA



Courtesy of Dr. B. Chudnovsky,  
Schneider Electric/Square D

# Materials – Metals that Whisker

- **Tin Lead (SnPb)**
  - Requires more stress to generate whisker
  - Rarely is found, due to the amount of energy and compressive stress required is high
- **Tin Bismuth (SnBi) Plating**
  - Used on component finishes
  - Not found on SnBi solder joints
- **Tin Copper (SnCu) Plating**
  - Used on component finishes
  - Not found on SnCu solder joints



Courtesy of NASA  
and Motorola



# Unintended Consequences

- No drop in replacement for tin-lead solder.
  - Wide variety of lead free solders available and in use.
  - Has different mechanical, thermal, reliability, and whiskering properties, that do not follow the tin-lead models and tin-lead's over 40 years of historical data.
  - New solder materials have unknown reliability, which is of great concern for aerospace, military, and medical device industries.

# Unintended Consequences

- A partial list of costly electronic equipment losses and availability losses is highlighted here to underscore the serious risk associated with this whiskering phenomenon.<sup>1</sup>
  - Nuclear Utilities Unplanned Shutdown – availability loss
  - Space Shuttle Fleet Main Engine Gimbal Avionics – availability loss
  - Seven Satellites: complete microprocessor failures – hardware loss
  - Patriot Missiles – availability loss
  - Six Other Missile Programs: complete failure – hardware loss
  - Heart Pacemakers: complete failure – hardware loss
  - Heart Defibrillators: complete failure – hardware loss
  - F-15 Radar – availability loss
  - Several Other Military Planes – availability loss
  - Telecom Equipment – availability loss

1. *The Lead Free Electronics Manhattan Project: Phase I*. Philadelphia, PA: ACI Technologies, 2009.