International Electronics Manufacturing Initiative

Current investigation focuses of iNEMI's Sn whisker committee

Peng Su, Ph.D.

2nd International Symposium on Tin Whiskers

Tokyo, Japan

April 24, 2008

Advancing manufacturing technology

Outline

- Committee Introduction
- Past achievements
- Current investigations
  - Global stress level measurements
  - Impact of microstructures on whisker growth
- Future plans
  - Role of stress
  - Fundamental growth mechanisms
  - Impact of assembly processes
  - Test method improvement

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Committee Members

Tyco Electronics

Alcatel·Lucent

Allegro MicroSystems, Inc.

hp

in

ON Semiconductor ON

IBM

Olin

Launched by Motorola freescale semiconductor

Amkor Technology

Infineon technologies

intel

sti

PHILIPS

ROHM AND HAAS

BOSCH

Microsemi

intersil

IPC

SOLECTRON

ST

KEMET

ChipPAC INCORPORATED

ITRI innovation

molex

DfR Solutions reliability designed, reliability delivered

DELPHI

cisco

MICROCHIP

UB University at Buffalo

TECHNIC INC

Cookson Enthone

MOTOROLA

TEXAS INSTRUMENTS

FCI

LSI

Sun microsystems

NIST

AMD

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Committee Organization

- Participants
  - Companies
    - Plating suppliers
    - Component manufacturers
    - Users
  - Universities
  - Government research institutions

- Organization
  - Richard Parker (current Chair) – Delphi Electronics
  - Heidi L. Reynolds (former Chair) – Sun Microsystems
  - Jack McCullen (Co-Chair) – Intel
  - Mark Kwoka (Co-Chair) – Intersil
  - John Osenbach (Co-Chair) – LSI

- Weekly teleconferences
  - Date: Thursdays, bi-weekly
  - Time: 8am PST

- Contacts
  - Richard Parker at richard.d.parker@delphi.com

Outline

- Committee Introduction
- **Past achievements**
- Current investigations
  - Stress level measurements
  - Impact of microstructures
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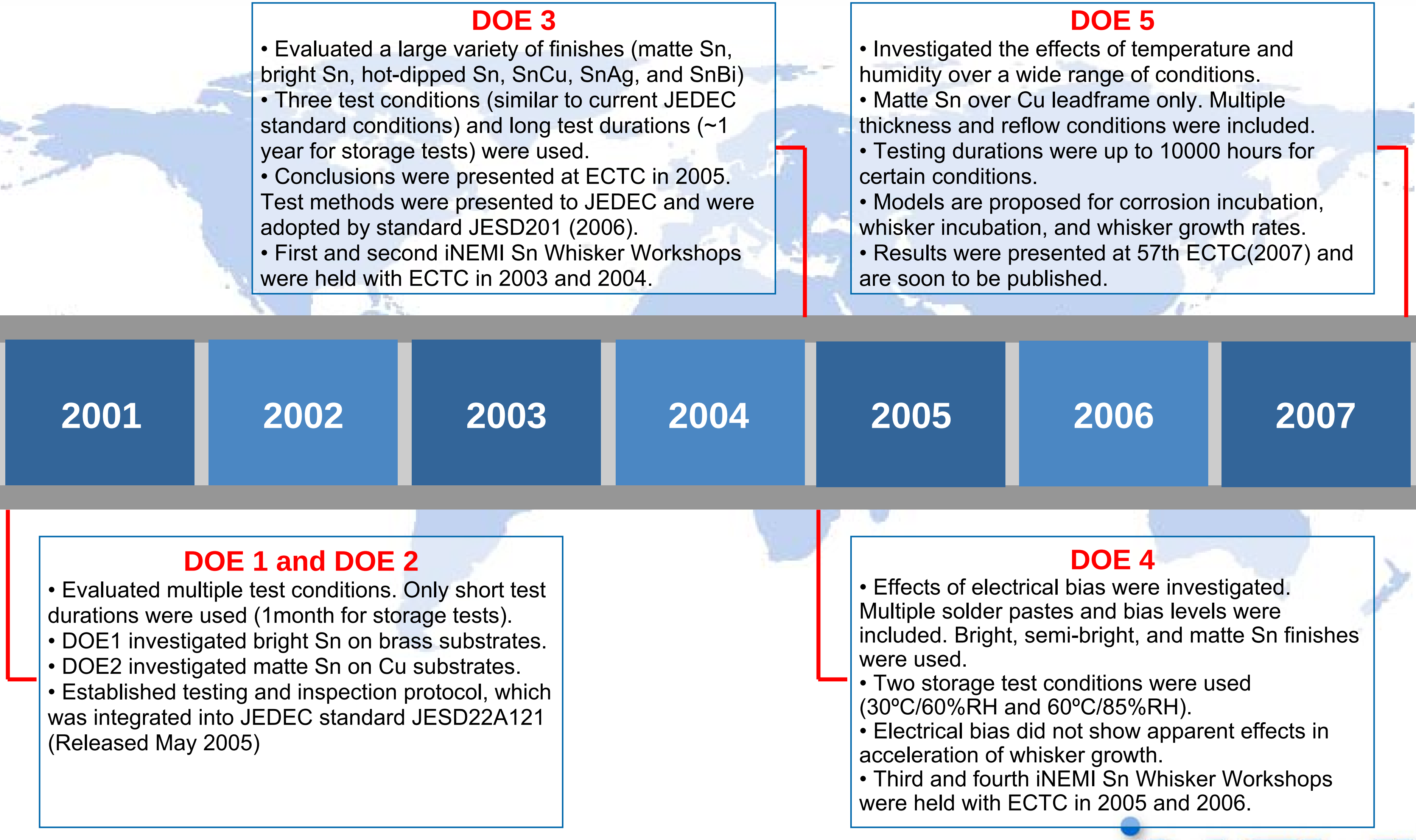
Past Achievements



DOE 3
- Evaluated a large variety of finishes (matte Sn, bright Sn, hot-dipped Sn, SnCu, SnAg, and SnBi)
- Three test conditions (similar to current JEDEC standard conditions) and long test durations (~1 year for storage tests) were used.
- Conclusions were presented at ECTC in 2005. Test methods were presented to JEDEC and were adopted by standard JESD201 (2006).
- First and second iNEMI Sn Whisker Workshops were held with ECTC in 2003 and 2004.

DOE 5
- Investigated the effects of temperature and humidity over a wide range of conditions.
- Matte Sn over Cu leadframe only. Multiple thickness and reflow conditions were included.
- Testing durations were up to 10000 hours for certain conditions.
- Models are proposed for corrosion incubation, whisker incubation, and whisker growth rates.
- Results were presented at 57th ECTC(2007) and are soon to be published.

2001 2002 2003 2004 2005 2006 2007

DOE 1 and DOE 2
- Evaluated multiple test conditions. Only short test durations were used (1month for storage tests).
- DOE1 investigated bright Sn on brass substrates.
- DOE2 investigated matte Sn on Cu substrates.
- Established testing and inspection protocol, which was integrated into JEDEC standard JESD22A121 (Released May 2005)

DOE 4
- Effects of electrical bias were investigated. Multiple solder pastes and bias levels were included. Bright, semi-bright, and matte Sn finishes were used.
- Two storage test conditions were used (30ºC/60%RH and 60ºC/85%RH).
- Electrical bias did not show apparent effects in acceleration of whisker growth.
- Third and fourth iNEMI Sn Whisker Workshops were held with ECTC in 2005 and 2006.

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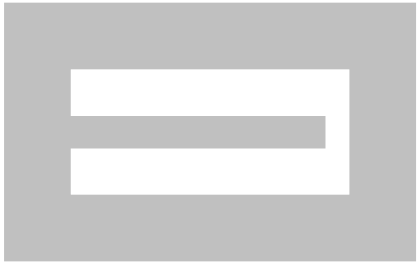
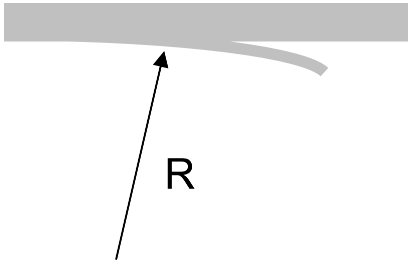
Stress Measurement of Sn Finish

- Objectives
  - This project was established based on the hypothesis that a increased level of global stress would accelerate the overall whisker growth rate of the Sn finish.
  - The first step is to evaluate the feasibility of using a flex beam test structure to quantitatively measure the residue stress in plated Sn finish.
  - Rate of stress relaxation in Sn finish after plating is yet be understood.
  - The ultimate goal is to conclude whether measured stress levels can be correlated to whisker growth rates.
- Test structure proposal (Matte and bright Sn plated over only 1 side of a substrate, e.g. Cu)





- Basic stress calculation (Stoney's formula)

$$\sigma_f = \frac{E_s}{6R(1-\gamma_s)} \cdot \frac{d_s^2}{d_f}$$

σf: Residual stress in the finish
Es: Modulus of the substrate
R: Measured curvature of the beam
γs: Poisson's ratio of the substrate
ds, df: Thickness of the substrate and the finish

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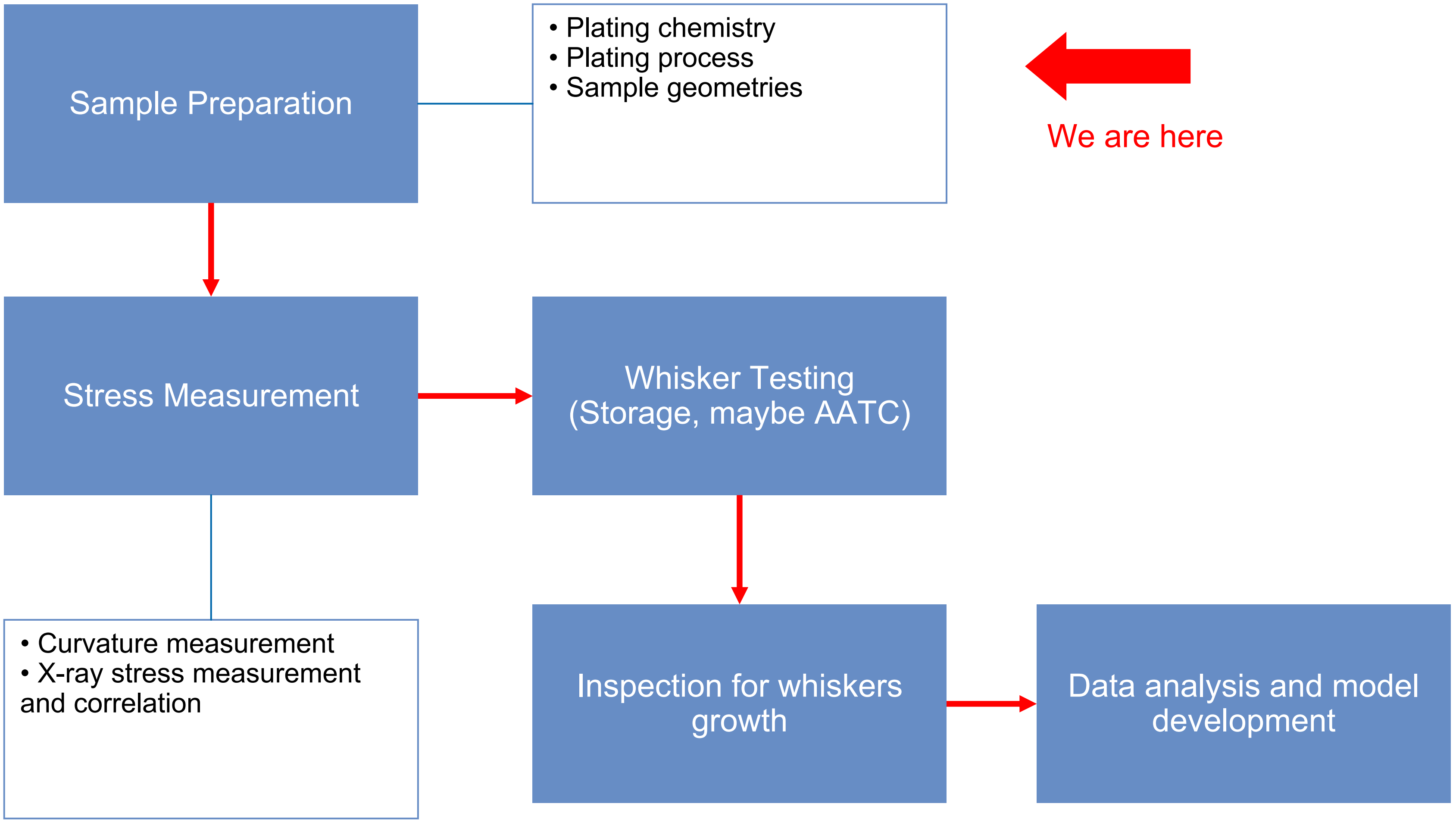
Stress Measurement of Sn Finish



Sample Preparation

- Plating chemistry
- Plating process
- Sample geometries

We are here

Stress Measurement

- Curvature measurement
- X-ray stress measurement and correlation

Whisker Testing (Storage, maybe AATC)

Inspection for whiskers growth

Data analysis and model development

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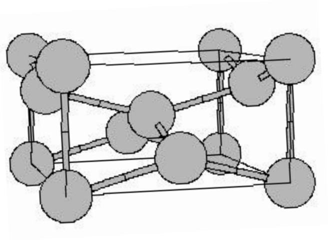
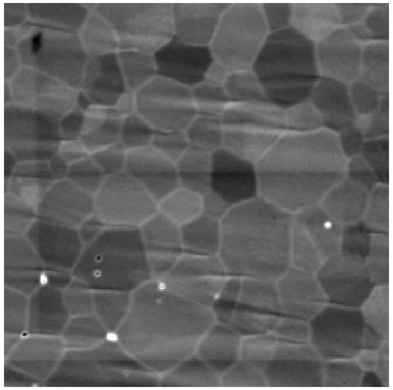
Impact of Microstructures

- Objectives
  - The hypothesis for this project is that the crystallographic orientations of the Sn grains have an impact on the local stress levels, which could accelerate whisker growth at certain locations of the finish.
  - The first step is to better define the effects of plating chemistry and process on the microstructure of as-plated Sn finish (matte and bright Sn).
  - Grain orientation will be analyzed with a series of techniques, including EBSD and X-ray diffraction.
  - Attempt will be made to correlate the locations of whiskers after growth tests to the orientation information of surrounding grains prior to tests.
  - The ultimate goal is to define what texture a ‘good’ plating finish would have.

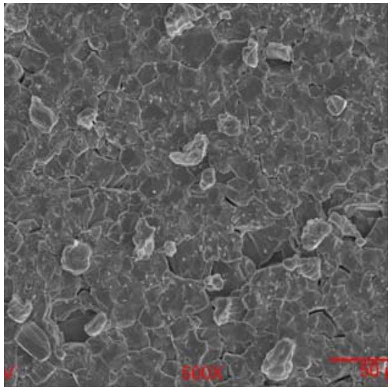
- Whisker growth tests
  - AATC (standard at -40-85ºC)
  - Storage test (30ºC/60%RH)



Sn unit cell (body centered tetragonal)



Matte Sn after FIB



Whisker after AATC

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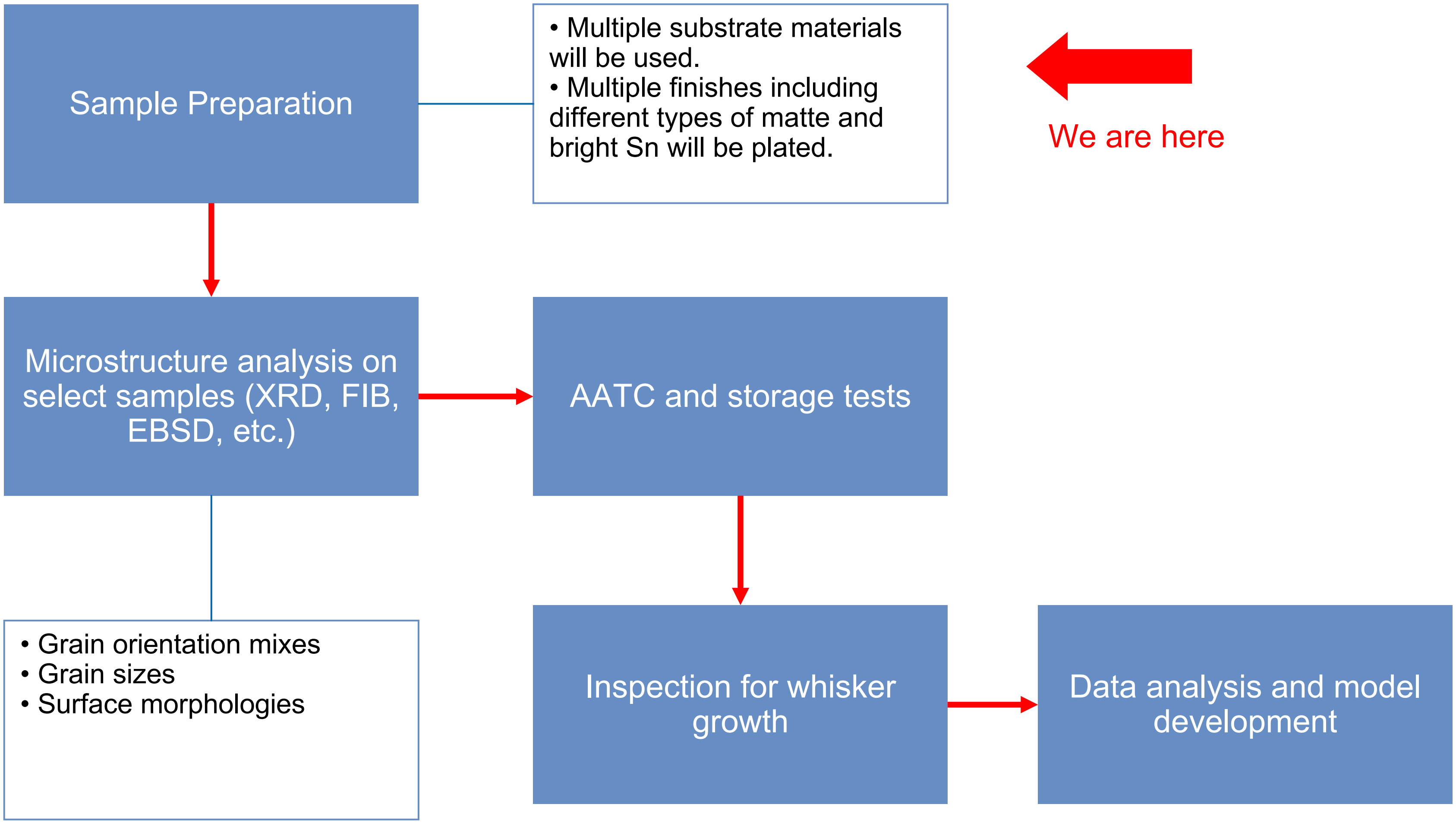
Impact of Microstructures



Sample Preparation

- Multiple substrate materials will be used.
- Multiple finishes including different types of matte and bright Sn will be plated.

We are here

Microstructure analysis on select samples (XRD, FIB, EBSD, etc.)

- Grain orientation mixes
- Grain sizes
- Surface morphologies

AATC and storage tests

Inspection for whisker growth

Data analysis and model development

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  - Impact of microstructures
- **Future Investigations**
  - **Role of stress**
  - **Fundamental growth mechanisms**
  - **Impact of assembly processes**
  - **Test method improvement**

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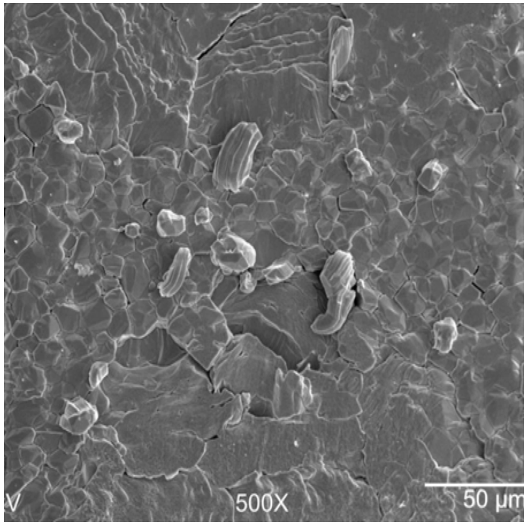
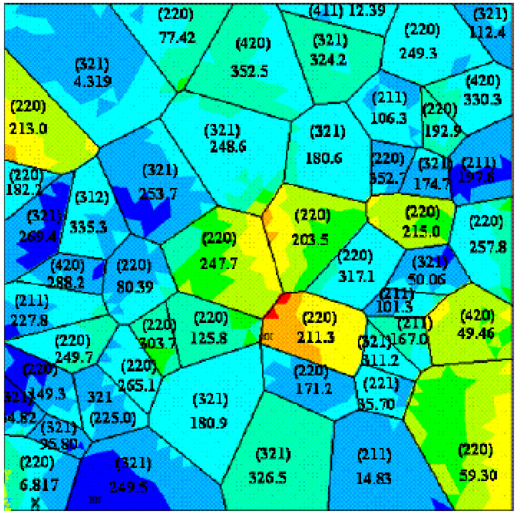
Role of Stress

- Global vs. local stresses
  - Which is more important, global or local stress?
  - Why do whiskers only grow at certain locations of the finish?
  - Can we quantify the relationship between stress levels and whisker growth rates?

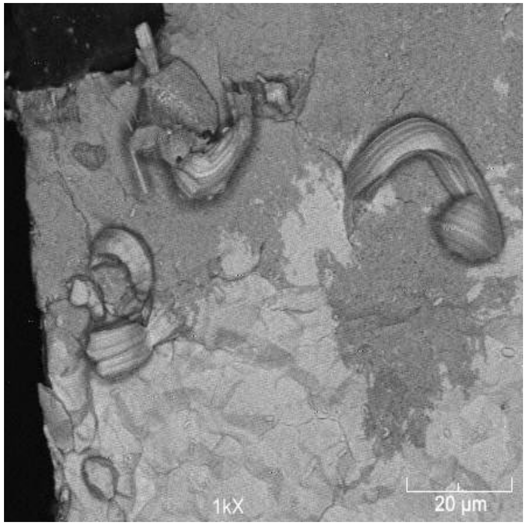
➔ Challenge: Accurate measurement of global and local stress levels.



Whisker growth (AATC)



Simulated stress distribution (AATC)



Whisker growth after 60ºC/93%RH

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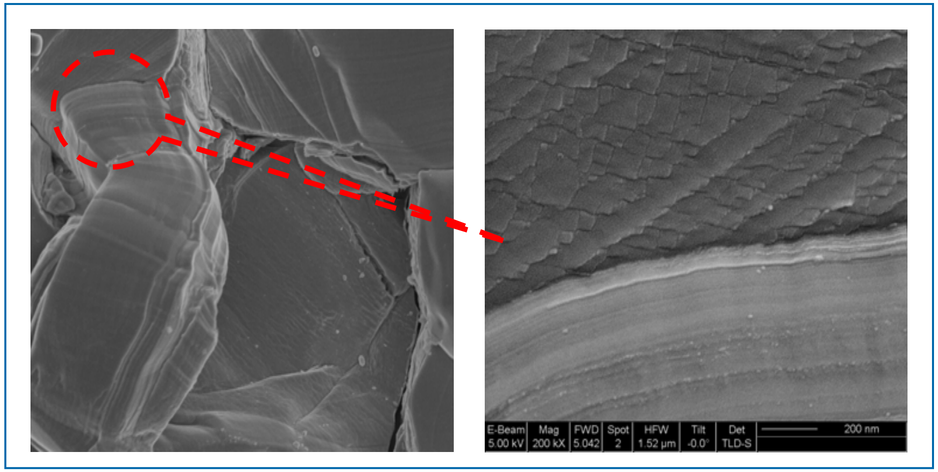
Fundamental Growth Mechanisms

- Stresses: Necessary or sufficient condition for whisker growth?
  - Is stress the sole driver for whisker nucleation and growth?
  - What other processes are involved?
  - Re-crystallization and growth: What are the details of these processes?

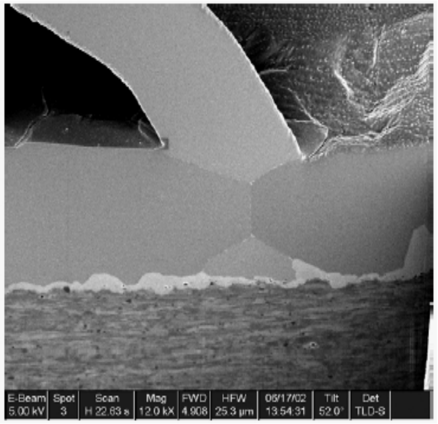
- Impact of non-Sn components
  - Second phase elements (Pb, Cu, Ag, etc.): Is there another ‘magic’ additive other than Pb that can reduce whisker nucleation and growth?
  - Organic contents (C, N, etc.): What are the exact impact of these elements?

➔ Challenge: Collection of microstructure data (crystallographic, chemical, geometrical, etc)

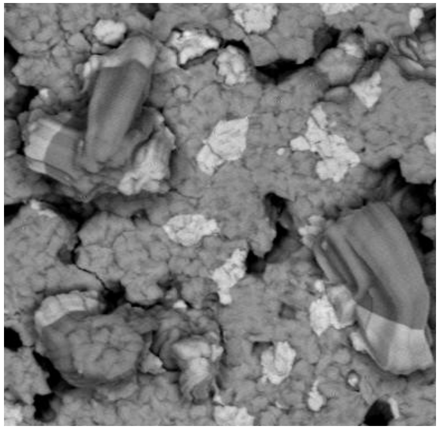


Whisker growth after AATC

Details near root of the whisker



Cross-sectional of a whisker



Whisker on SnPb after AATC

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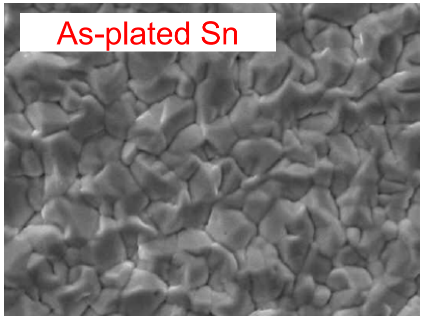
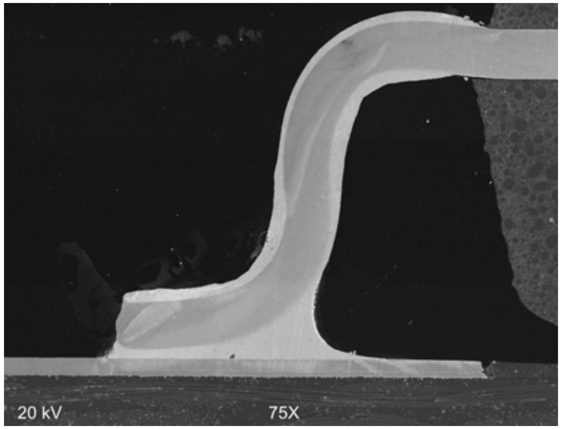
Impact of Assembly Processes

- Impact of paste coverage and alloying
  - What are the impact of assembly process variations on solder paste coverage and alloying (paste type, volume, reflow profiles, etc.)?
  - How will these variations impact the whisker growth rate?

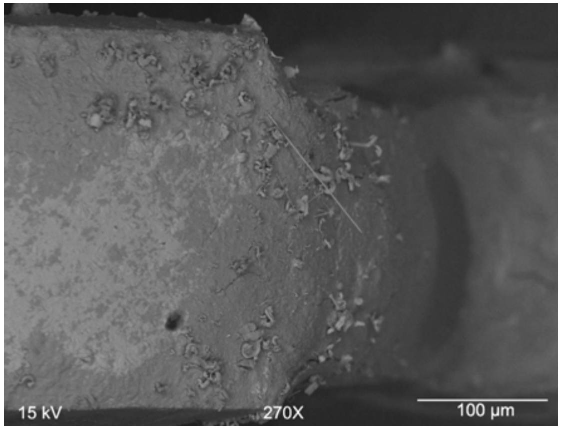
➔ Challenge: Microstructure data collection

➔ Challenge: Precise control of assembly processes

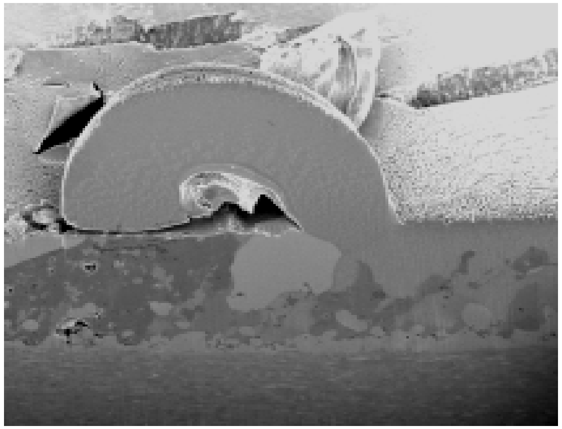




Cross-section view of a lead



Whisker growth (high T/H)



Cross-section of a whisker

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Test Method Improvement

➔ Ultimate goal:

Timely and reliably distinguish a ‘good’ plating from a ‘bad’ plating.

- Improve current test methods
  - JEDEC standard JESD201 is being revised to remove ‘non-practical’ pre-conditioning requirements
  - Recent results of iNEMI DOE5 have shed light on the effects of humidity levels.
  - AATC testing conditions may need to be re-visited. Impact of temperature ranges and/or ramping rates need to be further investigated to better reflect field thermal and power cycle levels.

- Improve requirements on plating properties and plating processes
  - Current definitions of ‘matte’, ‘bright’, etc. do not correlate well with test or field whisker growth propensity.
  - Organic content levels and grain sizes are apparently not sole determining factors of whisker growth rates.
  - Current typical process control parameters (thickness, organic and metal contamination levels, etc) do not guarantee repeated performance.

➔ We still have a long way to go, and we must work together!

www.inemi.org

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