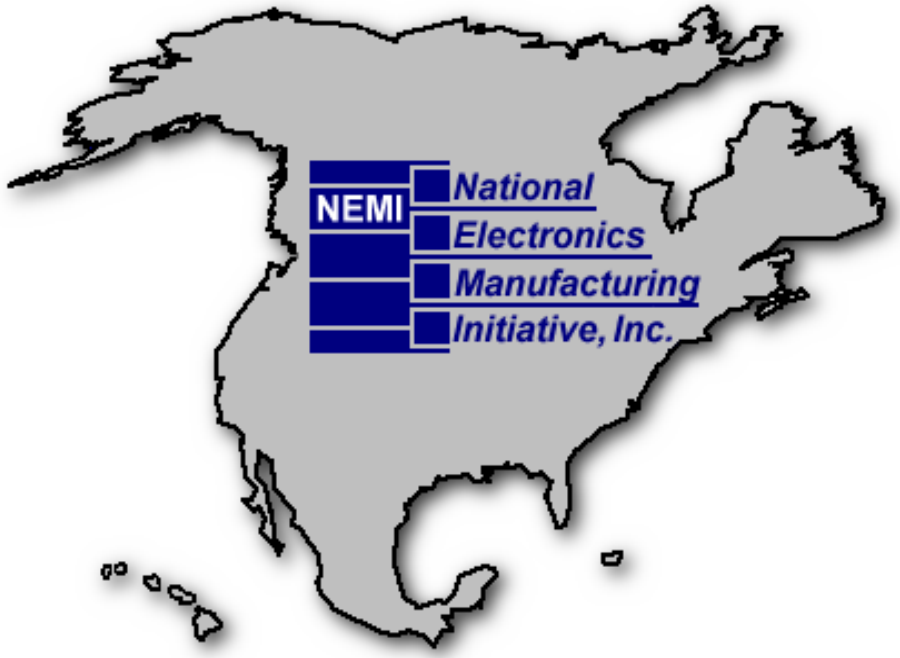


Sn Whisker Fundamentals Modeling Group Survey

Maureen Williams, NIST

1-24-02

Background

- The Fundamentals Group started in May 2001 as an offshoot of the Test Group
- Both groups worked in parallel
- The Fundamentals Group worked to develop a basic understanding of Sn whisker growth

Members

AMD

ChipPAC

Engelhard-Clal

FCI

Hewlett-Packard

IBM

Intersil

Lucent (May to Dec 2001)

Motorola

NASA

NEMI

NIST

Shipley

Soldering Tech

Texas Instruments

Individuals - Dr. Chen Xu and Dr.Yun Zhang

Survey Introduction

- This survey represents the ideas of the group after five months of discussion
- Yun Zhang developed and compiled this survey
- The survey results will be presented in a question/answer format

Factors to Consider Before Electrodeposition

Before Electrodeposition

Deposit Characteristics:

- **Bath chemistry**
- **Carbon content & hydrogen content**
- **impurities**

Deposit

Substrate:

- **Material**
- **Substrate stress/ substrate annealing**
- **External mechanical stress**
  - **Bending**
  - **Scratching**
  - **Thermal cycling (heating & cooling)**

Substrate

Factors to Consider After Electrodeposition

After Electrodeposition

Deposit characteristics:

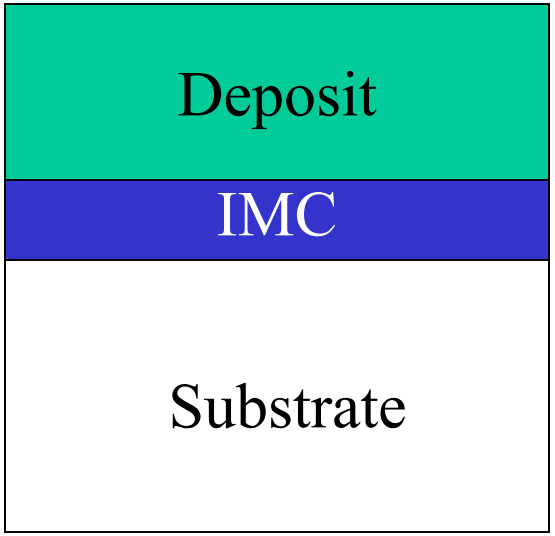
- Grain size/shape/orientation
- Porosity (defects) in tin layer
- Tin layer thickness

Intermetallic Compound (IMC):

- Irregular shape/ thickness/ rate of formation

Substrate:

- External mechanical stress
  - bending/scratching
  - thermal cycling (heating & cooling)
- Dissimilar metal - Coefficient of Thermal Expansion(CTE)
- Diffusion of substrate material into tin deposit
- Localized corrosion/ roughening and pitting of leadframe substrate
- Storage condition (temp., humidity)



Survey Questions
NEMI Whisker Modeling Group

1) Driving force for whisker formation.

2) Factors or sources contributing to the build up of the compressive stress in the tin layer.

3) What factors or sources you have studied or worked with?

4) What are top three most significant stress contributing factors or sources?

5) Is there a threshold of the compressive stress at which whisker begins to grow?

6) Suggested methods to determine the threshold if it exists.

7) Does tensile stress in the tin layer retards/eliminates whisker formation?

Driving force for whisker formation

- Compressive stress in the tin layer
- Tensile stress in the tin layer
- Combination of tensile and compressive (stress gradients)
- Stress from CTE mismatch

- Micro-defects in substrate
- Crystallographic defects in lattice structure
- Bath Impurities
- Copper impurities and trapped hydrogen

- Coating morphology
- Crystal orientation and grain growth
- Diffusion and IMC
- Differences in density IMC volume change , concentration gradient

Survey Responses Ranked for Section 1:
Driving force for whisker formation

Response from 12 members determined ranking

- **1) Compressive stress in the tin layer**
- Tensile stress in the tin layer
- Combination of tensile and compressive (stress gradients)
- Stress from CTE mismatch

- Micro-defects in substrate
- **2) Crystallographic defects in lattice structure**
- **3) Bath Impurities**
- Copper impurities and trapped hydrogen

- Coating morphology
- Crystal orientation and grain growth
- Diffusion and IMC
- Differences in density IMC volume change , concentration gradient

Factors or sources affecting the compressive stress in the tin layer

Deposit characteristics:

- Grain size/shape/orientation
- Bath chemistry
- Carbon content & hydrogen content, impurities
- Porosity (defects) in tin layer
- Tin layer thickness
-

Substrate

- Material
- Substrate stress
- Dissimilar metal CTE
- Diffusion of substrate material into tin deposit
- Deposit or substrate annealing

Survey Responses Ranked for Survey Section 2:
Factors or sources affecting the compressive stress in the tin layer

Response from 12 members determined ranking

Deposit characteristics:

- **1) Grain size/shape/orientation**
- Bath chemistry
- **2) Carbon content & hydrogen content, impurities**
- Porosity (defects) in tin layer
- Tin layer thickness
-

Substrate

- **3) Material**
- **5) Substrate stress**
- Dissimilar metal CTE
- Diffusion of substrate material into tin deposit
- Deposit or substrate annealing

Factors or sources affecting the compressive stress in the tin layer

2. Factors or sources affecting the compressive stress in the tin layer

Intermetallic Compound (IMC)

- Irregular, thick, and fast IMC formation

External mechanical stress

- Bending
- Scratching
- Thermal cycling (heating & cooling)

Others

- Significant roughening and pitting of leadframe substrate
- Localized corrosion
- Post mold cure bake (prior to and after plating)
- Storage condition (temp., humidity)

Survey Responses Ranked for Survey Section 2:
Factors or sources affecting the compressive stress in the tin layer

2. Factors or sources affecting the compressive stress in the tin layer

6) Intermetallic Compound (IMC)

- **Irregular, thick, and fast IMC formation**

4) External mechanical stress

- **Bending**
- **Scratching**
- **Thermal cycling (heating & cooling)**

Other

- Significant roughening and pitting of leadframe substrate
- Localized corrosion
- Post mold cure bake (prior to and after plating)
- Storage condition (temp., humidity)

Survey Responses Ranked for Survey Section 2

Factors or sources affecting the compressive stress in the tin layer

Response from 12 members determined ranking

- 1) Grain size, shape, orientation
- 2) Carbon, Hydrogen, Impurities
- 3) Substrate material
- 4) External mechanical stress: bending, scratching, thermal cycling
- 5) Substrate stress
- 6) Irregular, thick, and fast IMC formation

Survey Section 3 What factors or sources you have studied or worked with?

Survey Responses Grouped by Rank

Response from 12 members determined ranking

- **1)** Deposit characteristics: grain size/shape/orientation
- Carbon content & hydrogen content, impurities
- External mechanical stress:
  - Bending
  - Scratching
  - Thermal cycling (heating & cooling)

- **2)** Substrate material
- Irregular, thick, and fast IMC formation
- Storage condition (temperature, humidity)

- **3)** Bath chemistry
- Tin layer thickness
- Substrate stress

- **4)** Deposit or substrate annealing
- Significant roughening and pitting of leadframe substrate
- Diffusion of substrate material into tin deposit
- Surface oxide or protective layer
- Post mold cure bake (prior to and after plating)

Survey Section 4 Responses

What are top three most significant stress contributing factors or sources?

- Bath Chemistry
- Process
- Crystal mismatch
- Substrate material
- Aging
- Improper bake times
- Substrate diffusion and subsequent IMC formation
- Mechanical effects such as cutting, bending, etc

Survey Responses Ranked for Survey Section 4:
What are top three most significant stress contributing factors or sources?

Response from 12 members determined ranking

- **1) Bath Chemistry**
- **2) Process**
- Crystal mismatch
- Substrate material
- Aging
- Improper bake times
- **3) Substrate diffusion and subsequent IMC formation**
- Mechanical effects such as cutting, bending, etc

Survey Sections 5, 6 and 7 Responses

- **5. Is there a threshold of the compressive stress at which whisker begins to grow?**
- Possibly yes
- No
- Do not know (?)
- **6. Suggested methods to determine the threshold if it exist**
- Methods XRD, cantilever beam, wafer curvature
- Suggested whisker "sensitivity" experiments
- Additional questions raised
- **7. Tensile stress in the tin layer retards/eliminate whisker formation**
- Yes
- Possibly yes
- Do not know (?)
- Additional questions raised
- Additional data needed

Survey Sections 5, 6 and 7
Answers in Bold

- **5. Is there a threshold of the compressive stress at which whisker begins to grow?**
- **Possibly yes**
- No
- Do not know (?)
- **6. Suggested methods to determine the threshold if it exists**
- Methods - **XRD, cantilever beam, wafer curvature**
- Suggested whisker "sensitivity" experiments
- **7. Tensile stress in the tin layer retards/eliminate whisker formation**
- **Yes** **Lack of consensus**
- **Possibly yes**
- **Do not know (?)**
- Additional questions raised
- Additional data needed

Group Consensus -

Compressive stress is the first step in understanding whisker formation

Methods for Measuring Stress

- XRD
- Strain Gauge
- Wafer Curvature
- Vibrating Membrane
- Cantilever
- Moiré Interferometer

Concerns trying to measure stress in Sn

Sn coating properties

Note: 1 ksi = 6.895 MPa

- Low bulk modulus compared to Ni
  (Sn ~58 GPa and Ni ~ 180 GPa)
- Very low stress ~ 10 MPa (Ni ~100 MPa)
- Anisotropic - different properties in different directions
- Textured Structure - crystalline distribution not random
- Thin coatings < 10 um to 15 um may still be influenced by substrate structure (epitaxy)
- Mechanical damage to thin coating during testing

Summary of Survey Factors

Section 1 Driving Force of Whisker Formation

1) Compressive stress in the tin layer
2) Crystallographic defects in lattice structure
3) Bath Impurities

Section 2 Factors effecting the compressive stress in the Sn layer

1) Grain size, shape, orientation
2) Process
3) Substrate material
4) External mechanical stress: bending, scratching, thermal cycling
5) Substrate stress
6) Irregular, thick, and fast IMC formation

Section 4 Top three factors contributing to stress

1) Bath Chemistry
2) Process
3) Substrate diffusion and subsequent IMC formation

The Next Step - DOE

Develop a series of experiments to investigate the important factors revealed in the survey