Tin Whisker
Microstructural Analysis
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Whisker Theories

- **Dislocations**
  - Axial Screw Disloc.-M.Peach
  - Prismatic Loops
    - Eshelby(1st), Franks, Lindborg, Lee & Lee
  - Rotating Edge Dislocs.
    - F.C. Frank(1st)
    - W.C. Ellis, et al.

- **Climbing Helices-Amelinckx et al.**

- **Recrystallization**
  - W. C. Ellis (1st)
  - T. Kakeshita, et al.
  - V.K. Glazunova and N.T. Kudryavtsev

- **Cracked Oxide**
  - K.N. Tu (1st)
  - Lee and Lee
  - Chen Xu
Ideas concerning the mechanism of the process include representations of the structure of the deposits, but in most cases these are not confirmed by experiment. To obtain grounds for the proposed schemes of the process mechanism, it would be useful to have data on the fine structure of the tin lattice. This would give a clearer representation of the mechanism of action of the forces leading to "repulsion" of the monomer crystal from the bulk of the coating. At present (1985) the role of dislocations in this mechanism has not been generally recognized".

Koonce-Arnold: 1953

- Whiskers grow from the addition of material to the bottom of the whisker and not from the addition of material to the growing tip.

Fisher, Darken, and Carroll: 1954

- Whiskers form and grow under the influence of compressive stress gradients

W.C. Ellis, et al.: 1958

- Not all whisker growth directions are low-index glide planes...dislocation theories are not relevant to (at least) these non-glide plane growth directions.
Sn whiskers grown on inside of drilled and polished Sn-Al cast alloy


courtesy: M. Boettinger-NIST
H.P. Kehrer and H.G. Kadereit: 1970

Whisker material comes from the plating / substrate interface

U. Lindborg: 1976

Bulk Diffusion cannot sustain the observed whisker growth rates.


micro-diffraction X-Ray shows compressive stress gradients around whisker

W. Stevens-Brookhaven: 2002

synchrotron X-Ray analysis showed vertical compressive stress gradients in tin films ~ 40 MPas
Fig. 19. Sketch of glide of expanded prismatic dislocation loop.

1. whiskers/nodules do not grow from as-plated structures.

2. A localized recrystallization event precedes whisker/nodule formation.

3. The recrystallized region is a region of lower average stress re the surrounding region.

4. If the surrounding region is more compressively stressed-a whisker/nodule may form.

5. A whisker/nodule may erupt thru the surface layer if the oxide is not too thick.

6. A whisker, or filament, is a special case of nodule growth.

7. The whisker/nodule material comes mainly from the surrounding regions thru the grain boundaries-principally from the plating/substrate interface.
bright-tin surface mound (Sn over Cu)

- note crack in upper left quadrant of mound
bright-tin surface eruption (Sn over Cu)
Bright Tin: SEM micrograph (Sn over Cu)

Field service whisker-approx. 250u long
SECONDARY ELECTRON IMAGES

MONTAGE

~50 μm LENGTH BETWEEN ARROWS ON 12-11-02

~4.9 μm LENGTH BETWEEN ARROWS ON THE 11-27-02

courtesy Dr. Thomas A. Woodrow-Boeing Corp.
courtesy of M. Williams, C.E. Johnson, K. Moon, G.R. Stafford, C. Handwerker, W. Boettinger: NIST

Optical micrograph of bright tin plating (unetched)
courtesy: Baudry and Kerros, ST Microelectronics

The first published FIB micrograph of Sn plating showing a cross-section of whisker/plating/IMC/substrate.

Plating type not identified (matte/bright)

Note IMC nodule at root of whisker
courtesy: Chen Xu, Cookson Electronics

Note IMC particle at root of whisker
417-01

Bright Tin: Whisker eruption with "sleeving"

"sleeving" identified as CuSnx (Cu₆Sn₅?)
417-02
Bright tin: FIB cross-section / SEM micrograph

Cross-section outside of whisker-nodule region
Note "voids" at Sn/Cu interface
417-08
Bright Tin: FIB cross-section / SEM micrograph
cross-section in whisker-nodule region
Bright Tin: FIB cross-section / SEM micrograph

cross-section moving thru whisker-nodule
Note: "flap" of CuSnx under nodule
Bright Tin Growth Bump or Mound -45 deg. FIB
FIBs cross-section: bright tin "mound"

- inclusions in plated structure are CuSnx
- Tin plating is over copper substrate
- Cu$_6$Sn$_5$ intermetallic particle at Sn/Cu interface
Bright tin nodule-20020417FIBC......
#0-16
Bright tin nodule: FIB cross-section/FIB micrograph

Note: not the same nodule in previous foil
Triple Trench-bright tin nodule
Plan View HS5-011
Plan View  HS5-017
Plan View HS5-019
Plan View HS5-21
Plan View HS5-022
Plan View HS5-023
courtesy Peter Bush/Irina Boguslavsky

First examples of "remote grain subsidence"
courtesy Peter Bush/Irina Boguslavsky
Scratch-WK10
Bright Tin: FIB cross-section / FIB Micrograph
Whiskers only on scratch
Field Return-3+yrs. of service
Scratch-WK08
Bright Tin: FIB cross-section / FIB micrograph
Scratch-WK06
Bright Tin: FIB cross-section / FIB micrograph
Scratch WK03
Bright Tin: FIB cross-section / FIB micrograph
Scratch WK-01
Bright Tin: FIB cross-section / FIB micrograph
courtesy: N. Vo, Motorola Corp.
Matte Tin (10u) over Ni (.5-1u)
Tin Whisker

-----SnCux (?)

CuSn

Nickel Barrier

NiSn

Copper Leadframe

courtesy N. Vo-Motorola Corp.
CuNiSn01
Bright Tin over Ni over Cu
Field Service-no whiskers observed
CuNiSn12
Fig. 367. Cu-Zn
Fig. 2. Whisker growth model. (a, b) An extra plane of atoms expands by climb of the surrounding edge dislocation loop marked 1. (c) Loop no. 1 has reached full size and started to glide upwards. A second loop has started to expand. (d) Loop no. 1 has reached the surface and pushed out the whisker one atomic spacing. The subsequent loop is in the gliding stages and a third loop is expanding by climb.