

TI Tin Whisker and Pb-free Finish Evaluations

Don Abbott
Texas Instruments, Attleboro, MA
Doug Romm
Texas Instruments, Sherman, TX

*MASS. Toxics Use Reduction Institute
Lead Free Electronics Workshop
June 19, 2003 - Marlborough, MA*

Tin Whiskers - Agenda

- What is the Problem?
- What are Sn whiskers?
 - Definition
 - Examples
 - Proposed test conditions
- NEMI working groups and other resources
- What is TI's Answer to Sn whiskers?
- Conclusions

What is the Problem?

- Pb-free is a requirement of electronics in the 21st century.
- Matte Sn is one alternative Pb-free finish for terminations/leads.
 - It is convenient and drop in.
- Matte Sn can develop Sn whiskers that will:
 - Short adjacent leads
 - Break off and short remote leads or disable MEM's
- Sn whisker growth and prevention are not understood .
- No iron-clad accelerated test exists for Sn whiskers.
- Sn whiskers can take YEARS to develop.

NEMI Definition of Sn Whiskers

A spontaneous columnar or cylindrical filament, which rarely branches, of mono-crystalline tin emanating from the surface of a plating finish.

Tin whiskers typically have the following characteristics:

- An aspect ratio (length/width) >2
- Can be kinked, bent, twisted
- Generally have consistent cross-section
- Rarely branch
- May have striations/rings

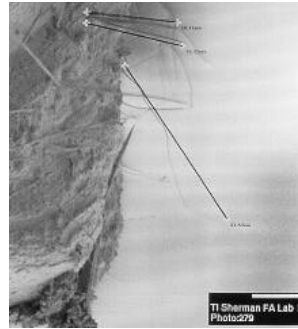
Note: Do not confuse Sn-whiskers with dendrites: fern-like growths formed by electro-migration of an ionic species.

Example of Sn Whiskers



Subcontractor 'A' SOIC unit at 1400X, 3000 hours exposure, no precondition, bias + 51C/85RH. Whiskers with length = 8.0-17.7µ .

Example of Sn Whiskers



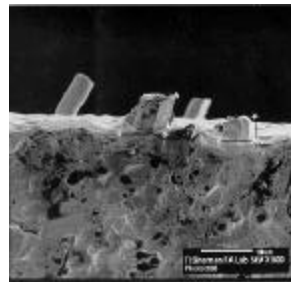
Subcontractor 'A' SOIC unit at 1500X, 3000 hours exposure, no precondition, bias + 51C/85RH. Scratched surface. Whiskers noted with length = 15-34 µ.

Example of Sn Whisker



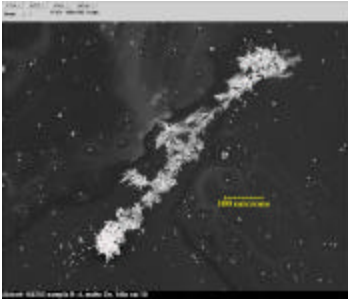
Subcontractor 'C' TO-220 unit at 7500X, 3634 hours exposure, precondition + 51C/85RH, unbiased. Whisker length = 9.3µ.

Example of Sn Whiskers



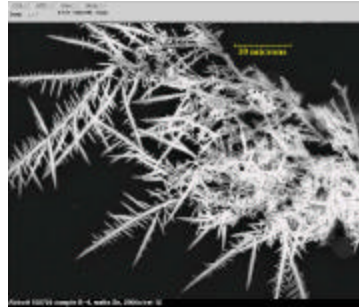
Subcontractor 'C' TO-220 unit at 1600X, 3634 hours exposure to 51C/85RH, no precondition, unbiased. Multiple whiskers noted with length = 4.6-6.2 microns.

Example of Dendrite



SEM @ 140X

Example of Dendrite



SEM@2000X

NEMI Proposed Test Conditions

Temperature Cycling:

-55 +0/10°C to 85 +10/-0°C air to air temperature cycle per JEDEC Temperature Cycling Standard No. 22-A104, Test condition A, soak mode 3 (10 minutes), typically 3 cycles/hour.

• Temperature/Humidity Storage:

60 ± 5 °C, 93 +2/-3 % RH

• Ambient storage:

20 - 25 °C, ~30-80% RH

All three tests are required

Each test condition is to be performed independently

NEMI Test Recommendations

- NEMI has recommended: test specimen handling, preparation and inspection procedures (300X SEM minimum) and defined the areas on a part to be inspected.
- NEMI has a proposed inspection intervals and a “Tin Whisker Tests Standard Report Format”
- This will tend to codify the Sn whisker data base going forward.

TI Sn-Whisker Test Conditions

Run	Pre-Condition (-40C/+55C, 24 hrs)	Bias + Relative Humidity (RH)	Board Mount	Bake Temp
1	Yes	No Bias, 51C Bake only	No	51C
2	Yes	Bias + 51C/85RH	Yes	51C
3	No	No Bias, 51C Bake only	No	51C
4	No	Bias + 51C/85RH	Yes	51C

Inspected out to 3000+ hours.

NEMI Working Groups

Tin Whisker Test Standards Committee (Test Group) 42 companies including two governmental organizations

Tin Whisker Modeling Group

13 companies including one governmental organization.

Tin Whisker Users Group

10 companies - started in late 2002

www.nemi.org

Other Sn Whisker Resources

NASA - <http://nepp.nasa.gov/whisker>

CALCE www.calce.umd.edu/lead-free/

SOLDERTEC - www.lead-free.org/

Communications Group of JEITA - www.jeita.or.jp

<ftp://nemi.org/webdownload/newsroom/TinWhiskerBibliography.pdf> (An excellent annotated bibliography of Sn - Whisker literature.)

<http://focus.ti.com/docs/apps/catalog/resources/appnote/abstract.ihtml?abstractName=szza037a> (TI applications note.)

TI's Solution to Sn Whiskers

Gold (30 – 150 angstroms)

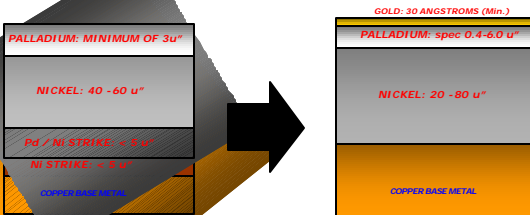
Palladium (0.01 μ min.)

Nickel (.5 μ min.)

Copper Base Metal/Leadframe Surface

TI's Solution to Sn Whiskers

Use of Pb-Free Pre-plated Finishes



NiPd finish: Past

NiPdAu finish: Present

- NiPdAu structure shown has been in use since early 1990s.
- Enhanced wetting performance with NiPdAu finish seen in solderability tests.

Pre-Plated v. Post-Mold Finish

NiPdAu is a pre-plated finish (PPF).

The solderable finish is applied at the leadframe maker,
not in a post-mold finishing operation.

This eliminates wet processing at the integrated
circuit assembly/test site.

Wire Bonding and Soldering

Wire bonding is done to the Ni surface, the Au wire goes right through the thin Pd and Au.

Solder joints to NiPdAu finished leads look different than solder joints to solder finished leads.

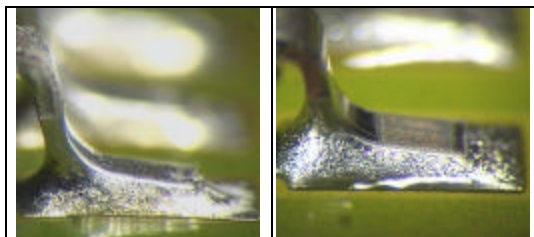
The only solder brought to the joint is in the paste.

Board assembly house controls solder volume.

Early there were issues of machine vision not recognizing good solder joints - this is fixed.

Studies with SnAgCu and SnBi show compatibility.

Solder Joint Appearance



Typical wetting of NiPdAu finished SOP components with Sn/Pb/Ag Solder, NiAu PWB finish.

Typical wetting of NiPdAu finished SOP components with Sn/Ag/Cu Solder, NiAu PWB finish.

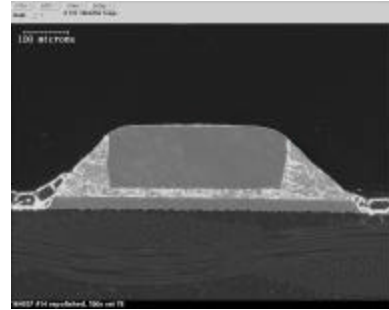
Solder Joint Cross-Sections



Typical wetting of NiPdAu finished SOP components with Sn/Pb/Ag Solder, NiAu PWB finish.

Typical wetting of NiPdAu finished SOP components with Sn/Ag/Cu Solder, NiAu PWB finish.

Solder Joint Cross-Section



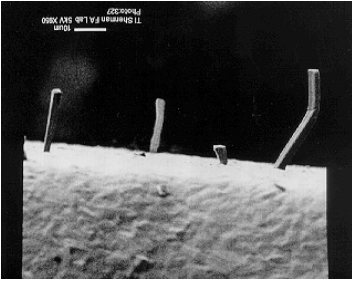
Summary of NiPdAu Finish

- NiPd based lead finishes have been commercialized for >12 years. This is not a “new” technology.
- Given a close to 100% conversion at the A/T site, the economics work well for total cost of ownership.
- There are concerns about the supply/demand of Pd.
- NiPdAu has no whisker or solderability issues.
- Pd finishes are compatible with Pb-free solders (SnAgCu, SnBi).

Conclusions

- There is a need for Pb-free lead finishes in electronics, driven by legislation and marketing concerns.
- Matte Sn is an “obvious” replacement: cheap, compatible with existing manufacturing equipment, i.e. Sn/Pb post mold plating lines. It’s “comfortable.”
- Matte Sn can develop Sn whiskers – the mechanism of which is not well understood.
- There is no iron-clad Sn whisker test method.
- Sn whiskers can take YEARS to develop.
- Using matte Sn carries the risk of catastrophic failures.

Sn Whiskers



Subcontractor 'C' TO-220
950X
3634 hours exposure.
Precondition + 51C/85RH,
unbiased.
Multiple whiskers
Length ranging from 6.1 to
32 microns.

Conclusions - Continued

- Long term risk is a factor...can you say Firestone?
- Much interesting work is being done on Sn whiskers.
- There is a viable, proven, cost competitive alternative to matte Sn now – [NiPdAu](#) based lead finishes.
- Interest is growing...