iNEMI
International Electronics Manufacturing Initiative

iNEMI Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products

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Joe Smetana

and iNEMI Tin Whisker User Group

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The iNEMI Tin Whisker User Group

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Overview

- Pure Tin (and High Tin Content Alloy Pb-Free) Finishes are a reliability risk for electronic products due to potential for tin whisker growth
  - Concerns are more than just short circuits!
- Most Hi-Rel OEM's have acceptance criteria that include a combination of
  - Mitigation Practices
    - Specific plating and/or treatments used with the express purpose of reducing or eliminating Tin Whisker growth
      - Addressed in detail in this presentation
  - Tin whisker Testing Requirements (iNEMI/JEDEC) (JESD-201)
    - Cannot currently be related to field life
      - Very Preliminary acceleration factor data suggests that the testing represents (at best) 5-10 years of field life (field condition dependent) – in many cases – NOT very "accelerating"
    - Primary purpose of testing is to ensure proper application of mitigation and plating practices.
      - Increases confidence that finishes are not whisker prone.
      - Does NOT in any way ensure that finishes are whisker free.
    - Not discussed in detail in this presentation
  - Supplier Process Controls
    - Difficult to define – but very important to ultimate success
    - Not discussed in detail in this presentation
- All 3 of these are necessary for a valid whisker risk reduction strategy!

None of this guarantees whisker free performance in the field!

Caveat to the Viewer/Reader

- **The whisker mitigation practices presented here and the rationale for why they work, or why they might not work is still controversial in many cases.**
- **This is primarily true because the fundamental theory behind tin whisker growth is still controversial. Some key facts:**
  - **The driving force for tin whiskers is compressive stress in the tin films.**
    - **There are a small number of those that still believe the driving force is grain boundary energy. However, Carol Handwerker (formerly of NIST) provided convincing Gibbs free energy calculations clearly showing this is not thermodynamically favorable. This work is currently unpublished.**
  - **Theories of tin whisker growth as a dislocation mechanism (most popular theories) have been largely disproved**
    - **Those who have disproved these theories have pointed to recrystallization**
  - **Only non-disproved theory of tin whisker growth is recrystallization based.**
    - **See “Theory of Tin Whisker Growth, The End Game”, Joe Smetana, presented at iNEMI Tin Whisker Workshop at ECTC, May 31, 2005. Submitted to IEEE for publication in special edition on tin whiskers slated for IEEE CPMT Transactions April 2006.**
- **Presented is the current iNEMI recommendations on what the prevailing thoughts are on these mitigation practices and finish recommendations.**

Sources of Compressive Stress in Sn Films

These statements are simplifications for the sake of time

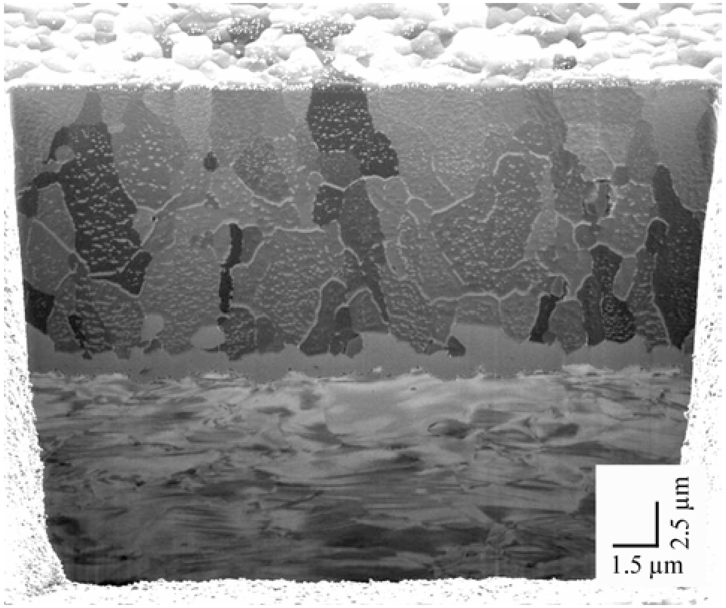
- Intermetallic Formation
  - When the molar volume of the intermetallic is greater than the Sn it "replaces" – it creates compressive stress in the Sn film
    - Example: SnCu intermetallic Cu_6Sn_5 formation
  - When the molar volume of the intermetallic is less than the Sn it "replaces" – it can create tensile stress in the Sn film
    - Example: Ni_3Sn intermetallics
- Oxide Growth
  - Molar Volume of SnO and SnO_2 is greater than the Sn it replaces resulting in compressive stress
    - Severe oxidization (corrosion) can result in high stresses
- Thermal
  - CTE mismatches between Sn and substrate materials create stresses in the Sn films as temperature changes
    - More significant for low CTE base materials such as A42
- Mechanical

*Mitigation Practices **MUST** Address Compressive Stress <u>Sources</u> or <u>relieve the stresses</u> in some manner other than whisker growth*

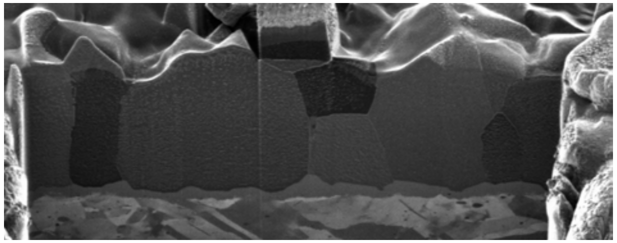
“Mitigation Practice”: Non-Tin Plating

- Non-Tin Plating
  - In “normal” environments (such as what most products encounter), finishes such as NiPd, NiPdAu, and NiAu do not grow whiskers.
    - These are preferred finishes when available
    - Compatible with SnPb or SAC assembly
    - Mold compound adherence may not be as good as Cu and A42 (when pre-plated lead-frames are used) – thus MSL ratings may be more difficult to achieve – process dependent
    - NiPdAu more readily endorsed by IC suppliers than by the IC subcontract packaging world (such as Amkor, ASAT, Stats-Chip Pac)
      - Much of subcontractor value add is in the plating operations
  - Ag based finishes, Ag (over Ni), Ag (over Cu), and AgPd (typically over Ni) only grow whiskers in high sulphur environments <u>but are unwanted finishes</u> for other reasons.
    - Primarily Solderability and Shelf Life Concerns
    - Silver whiskers or Dendrite Growth in presence of H_2S (found in some cases where the environmental air pollution contains SO_2)

Mitigation Practice: Alloys with Sn



SEM Image SnPb - NIST



SEM Image Sn2Bi – Note some horizontal grain boundaries

SnPb

SnPb grain structure does not support significant tin whisker growth (based on "Theory of Tin Whiskers, The End Game")

Lots of horizontal grain boundaries

Almost an equiaxial grain structure. Not a columnar grain structure

(SnPb has also been theorized to work in prevention of whiskers by substitutional diffusion of a large atom or addition of a soft phase that can cushion the Sn grains from high compressive stress)

SnAg and SnBi

Theory is that these work similarly to SnPb
Data – particularly on SnAg - is very limited

Obviously, with the advent of the EU RoHS requirements, alloying with Pb has significant restrictions and in many cases is no longer a viable whisker reduction strategy

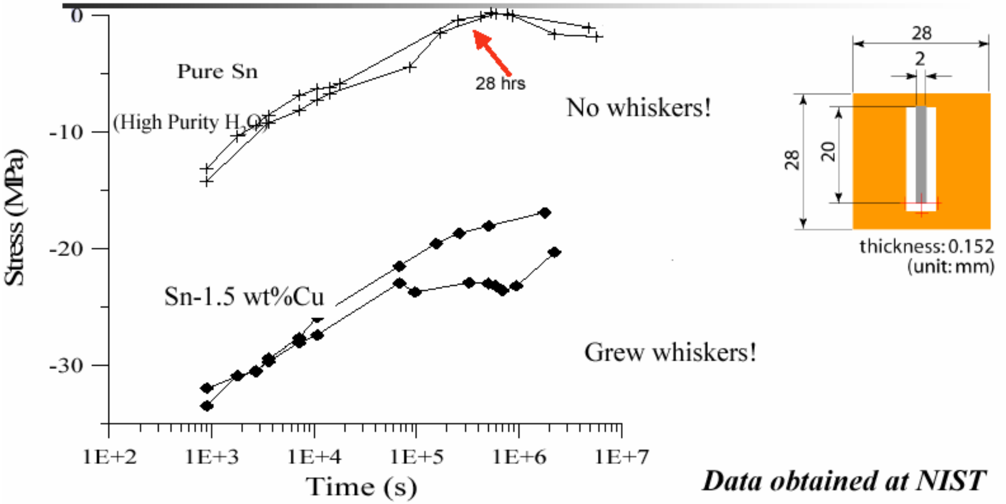
Alloys with Sn - Continued

- **Why alloys with Sn don’t always work to mitigate Tin Whiskers**
  - **Non-uniform concentration of alloying elements**
    - **Particularly true for small concentrations of elements**
      - **iNEMI DOE3 showed whiskers on SnPb in areas where no Pb was detected (nominal Pb concentration ~10%)**
    - **Bi typically plated less than 4% Bi with Sn**
      - **Prevent cracking of finish**
        - **» Too much Bi makes the finish more brittle**
      - **Prevent solderability problems**
      - **Minimize and/or eliminate potential issues with ternary SnPbBi eutectic (m.p. = 96ºC) or peritectic (135ºC)**
    - **Ag as a alloy in Sn limited to ~4% max**
      - **Greater concentrations can result in silver dendrites**
      - **Difficult plating process to control, very limited availability**
  - **Effectiveness of small percentages in changing the grain structure sufficiently is questionable (this is even true for SnPb)**

Alloys with Sn - SnCu

- **SnCu plated alloys are not satisfactory finishes because copper enhances whisker formation and growth when included as an alloying element in tin plating**
  - **Cu increases the compressive stress in the finish**
  - **SnCu on Cu based substrate is probably one of the worst (highest potential for tin whiskers) finishes**

Stress vs. time curves for 16.5 µm thick Sn & Sn-CuBright deposits on Phosphor Bronze



Data obtained at NIST
Courtesy of M. Williams

Bright tin, "as plated", has compressive stress which is spontaneously released as a result of recovery process

Mitigation Practice: Underlayers

- Underlayer plating (primarily Nickel or occasionally Silver)
  - Mitigate whisker formation by eliminating the compressive stress buildup of Cu_6Sn_5 intermetallic associated with Sn over Cu based substrate
    - Two factors for stress with Sn over Cu
      - Predominant growth of intermetallic in Sn Grain Boundaries (G.B. diffusion of Cu at room temperature is much faster than bulk diffusion)
      - Molar volume of resulting intermetallics greater than Sn it replaces
      - See additional details on the following pages
  - Underlayer plating does little or nothing to address stress sources from other than intermetallic growth*
    - Stress from CTE mismatch, oxidation, or mechanical can still result in whisker formation

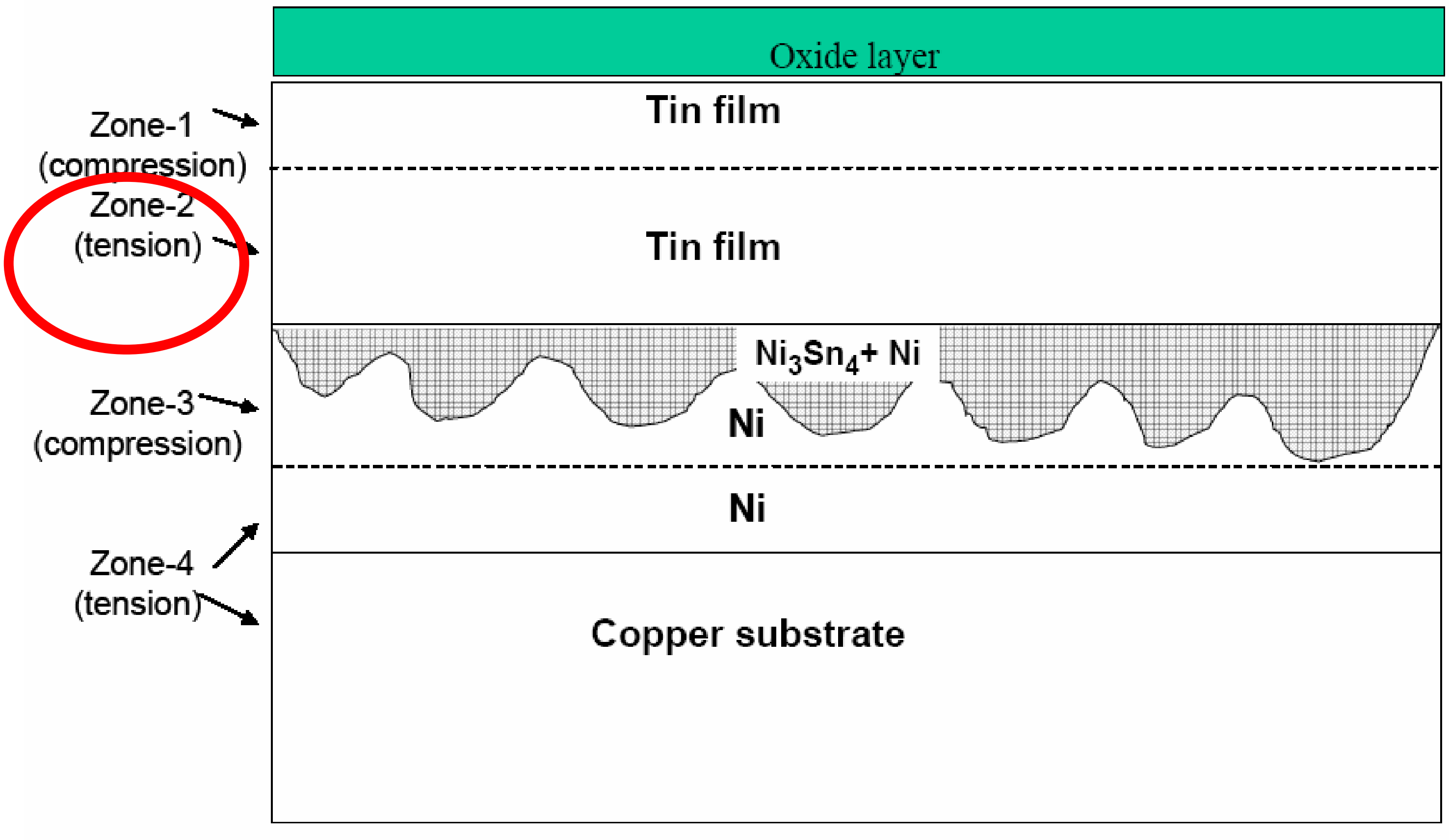
** Potential exception for Nickel Underlayers*

Nickel Under Layer Plating

- **Used heavily in connectors and passives, limited elsewhere**
- **Sn – Ni interdiffusion rates are slower than Sn – Cu**
- **Sn diffuses into Nickel faster than Nickel into Sn**
- **3Ni -> Ni_3Sn_4**
  - **Molar Volume of Ni = 6.6 cc/gm-mole**
  - **Molar Volume of Ni3Sn4 = 75.25 cc/gm-mole**
  - **The molar volume for 3Ni < molar volume for Ni3Sn4**
  - **19.8ccs < 34ccs (an expansionary action)**
- **For Sn/Ni/Cu**
  - **The vacancy rich region is in the tin**
  - **The expansion action is in the nickel**

Portions of slides 10 and 11 are from work by Dr. George Galyon of IBM

Zonal Structure for Tin with Nickel Underlayer

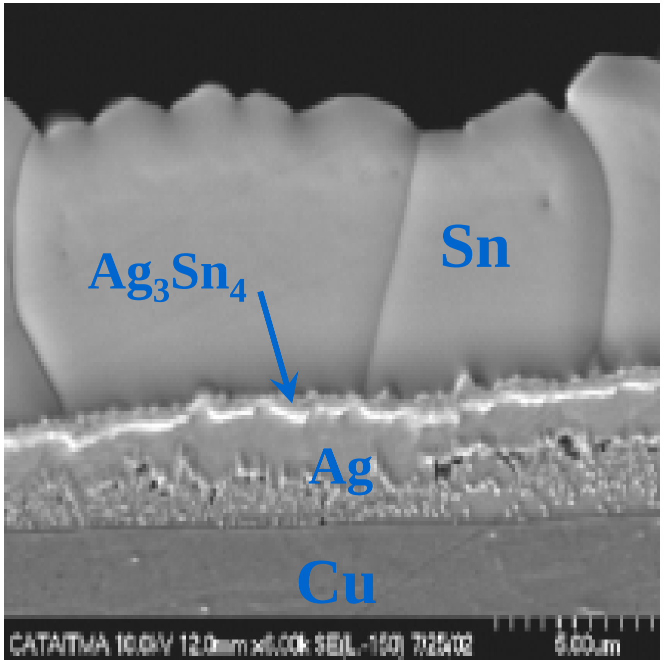


The 4-zone structure for Sn/Ni/Cu after intermetallic formation

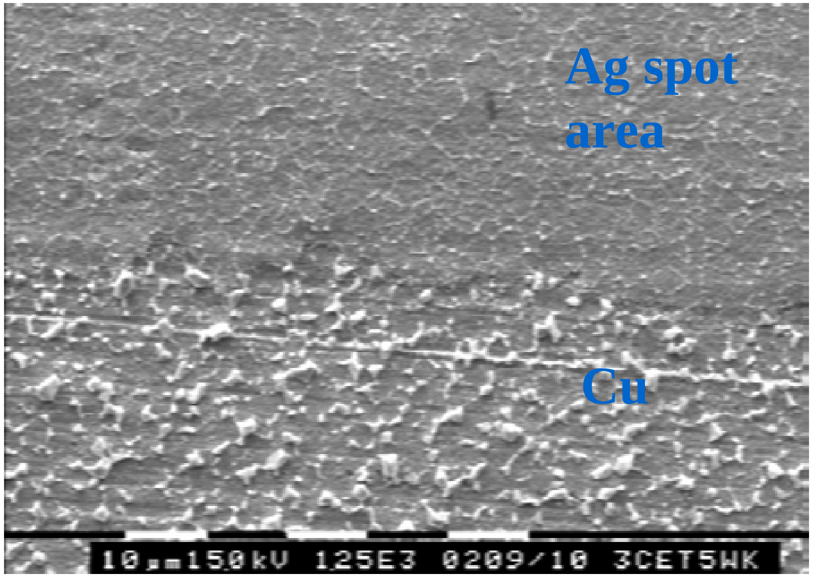
Note that if the Tin film is thin enough (typically ~2µm or less), the tensile stress in the Sn films associated with the SnNi intermetallics may be sufficient to overcome other sources of compressive stress. But must keep sufficient Sn thickness for solderability.

Silver Under Layer Plating

- **Very limited use in industry**
- **Intermetallic growth rate slower than Sn – Cu intermetallics**
- **Very little data on this mitigation practice**
- **Theory/details (i.e. molar volumes, Kirkendahl effects etc.) have not been worked out or studied in detail**



9 months at ambient
Very little intermetallic growth

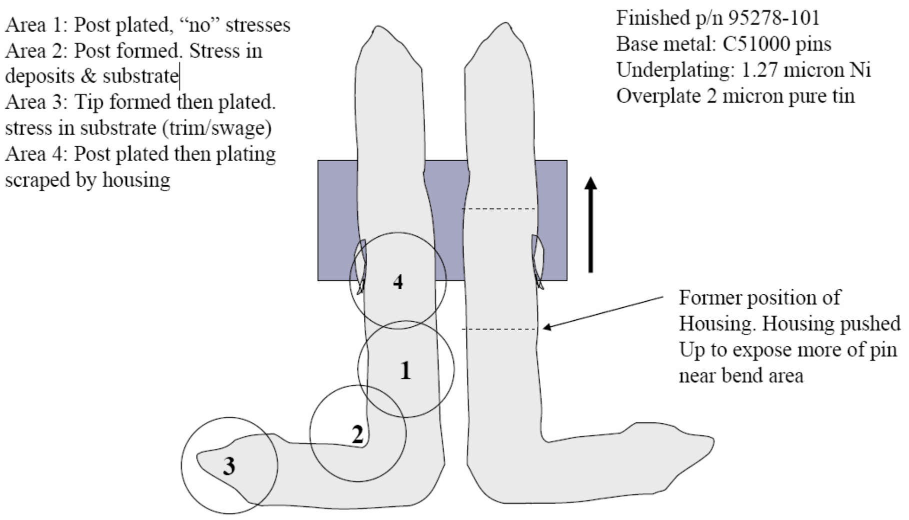


Intermetallic growth after Sn etched away
5 weeks at ambient

(Source: E3)

Why Under Layer Plating Might Not Work

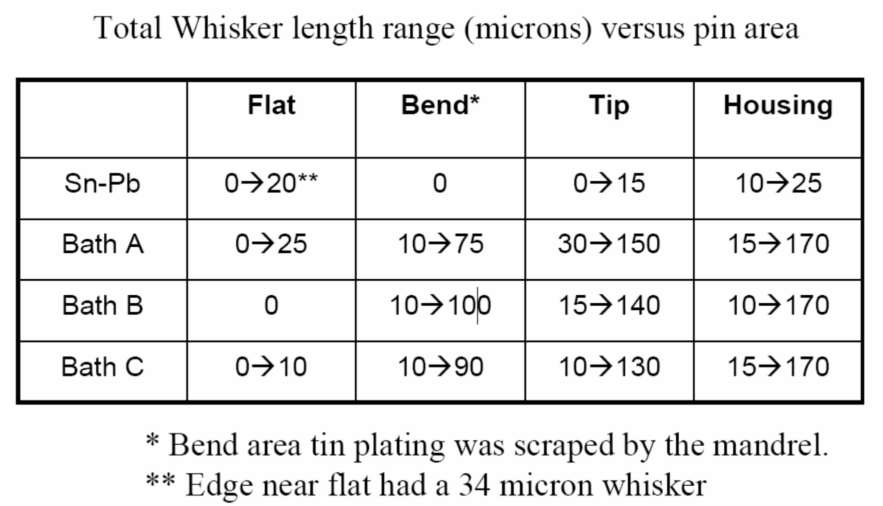
- **Typically ONLY addresses single source of stress**
  - **Intermetallic growth related stresses**
  - **Nickel under layer can help reduce compressive stress from other sources – but may not be able to overcome it all**
  - **Other sources of compressive stress include oxidization (very significant if high amount of corrosion occurs), CTE induced stresses from thermal cycling, or mechanical stresses**
- **If the underlayer is cracked or damaged – significant whisker growth can occur**



Area 1: Post plated, "no" stresses
Area 2: Post formed. Stress in deposits & substrate
Area 3: Tip formed then plated. stress in substrate (trim/swage)
Area 4: Post plated then plating scraped by housing

Finished p/n 95278-101
Base metal: C51000 pins
Underplating: 1.27 micron Ni
Overplate 2 micron pure tin

Former position of Housing. Housing pushed Up to expose more of pin near bend area



Total Whisker length range (microns) versus pin area

	Flat	Bend*	Tip	Housing
Sn-Pb	0→20**	0	0→15	10→25
Bath A	0→25	10→75	30→150	15→170
Bath B	0	10→100	15→140	10→170
Bath C	0→10	10→90	10→130	15→170

* Bend area tin plating was scraped by the mandrel.
** Edge near flat had a 34 micron whisker

Source: Dr. Sudarshan Lal, FCI

Mitigation: Fusing

- Fusing (typically in a hot oil bath) of a plated Sn finish shortly after plating (typically <1 week) has typically been considered an excellent mitigation practice
  - Long field history with good results
    - Very limited used on electronic components however
    - Not used historically with fine pitch components
  - Results in elimination of any remaining inherent plating stresses and grain growth to very large sizes (if distinguishable at all)
    - Grain sizes as much as 10X that of typical matte tin have been identified
  - Builds a intermetallic layer of Cu_6Sn_5 over Cu_3Sn during the process, which will slow growth rate of further intermetallic compounds (and the associated stress buildup)

Mitigation: Fusing (continued)

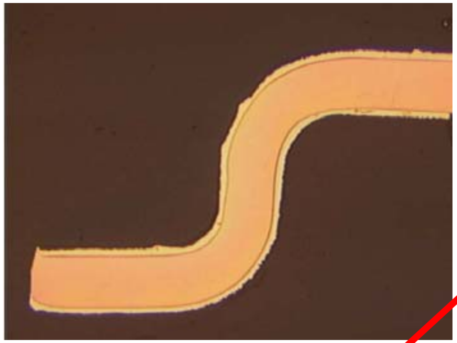
- **Fusing (reflow) of Component finishes as part of assembly process has not demonstrated the same effectiveness**
  - **Geometry effects result in pooling and thin areas (this may also happen in the initial fusing operation)**
  - **Intermetallic layers are dissolved into Sn finish and may result in high stress area – particularly as the Cu precipitates into the tin after it cools. This may also break up the grains into smaller grains that are whisker prone**
  - **A significant number of tests have now shown that assembly and/or assembly reflow cycles (without assembly) has an effect on whisker performance (next two pages)**

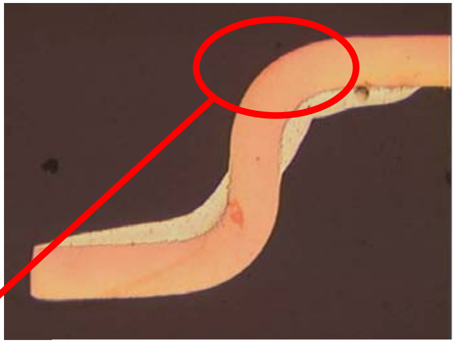
Examples of Assembly Effects

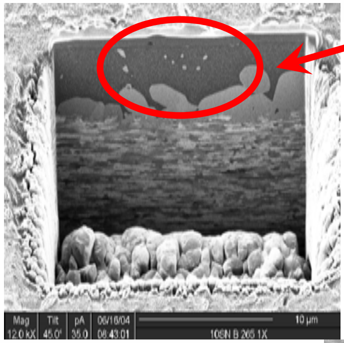
TDK Data

Sometimes it makes it worse

Item (Terminal)	# Components (leads) Lot(Total)	Precondition	Test Condition								
			Storage – No Bias			Aging – No Bias			Thermal Cycle–No Bias		
			High Temperature Strage (85°C)			Temperature & Humidity (60°C, 93%RH)			Thermal Cycling (-40°C to + 85°C)		
			1000h	3000h	4000h	1000h	3000h	4000h	1000cyc	3000cyc	4000cyc
NLV25T-000J-PF (SnCu)	3(90)	4 weeks RT	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	Whiskers (35)	Whiskers (90)	Whiskers (90)	Whiskers (90)
NLV25T-000J-PF (SnCu)	3(90)	4 weeks RT, then Assembly Sim @ 215°C	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	No Whiskers (0)	Whiskers (54)	Whiskers (90)	Whiskers (90)	Whiskers (90)
NLV25T-000J-PF (SnCu)	3(90)	4 weeks RT, then Reflow @ 255°C	No Whiskers (0)	No Whiskers (0)	Whiskers (45)	No Whiskers (0)	No Whiskers (0)	Whiskers (90)	Whiskers (90)	Whiskers (90)	Whiskers (90)



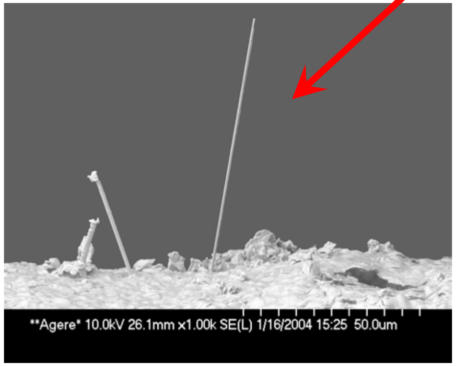




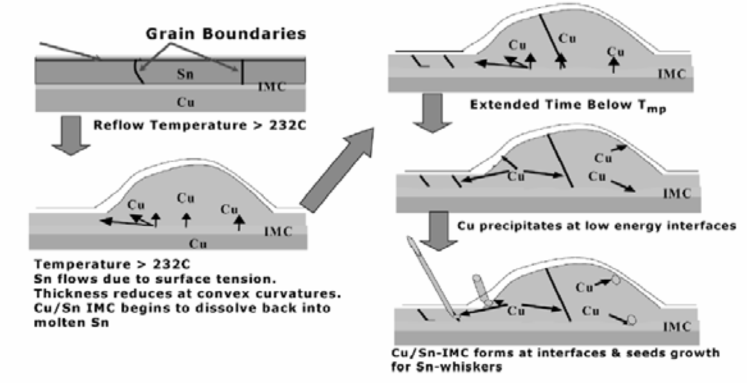
SnCu Precipitates

Agere study with 260°C reflow

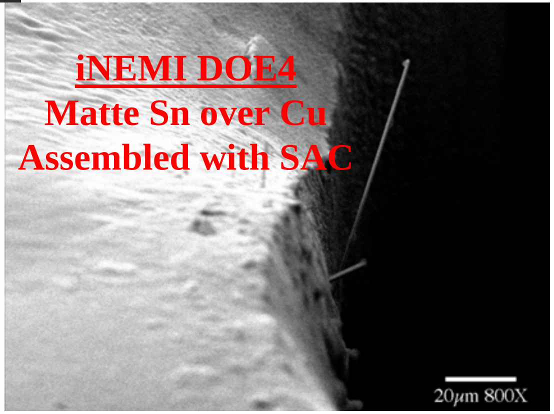
(to the left)



64µm whisker



Schematic showing the model for whisker formation post reflow.



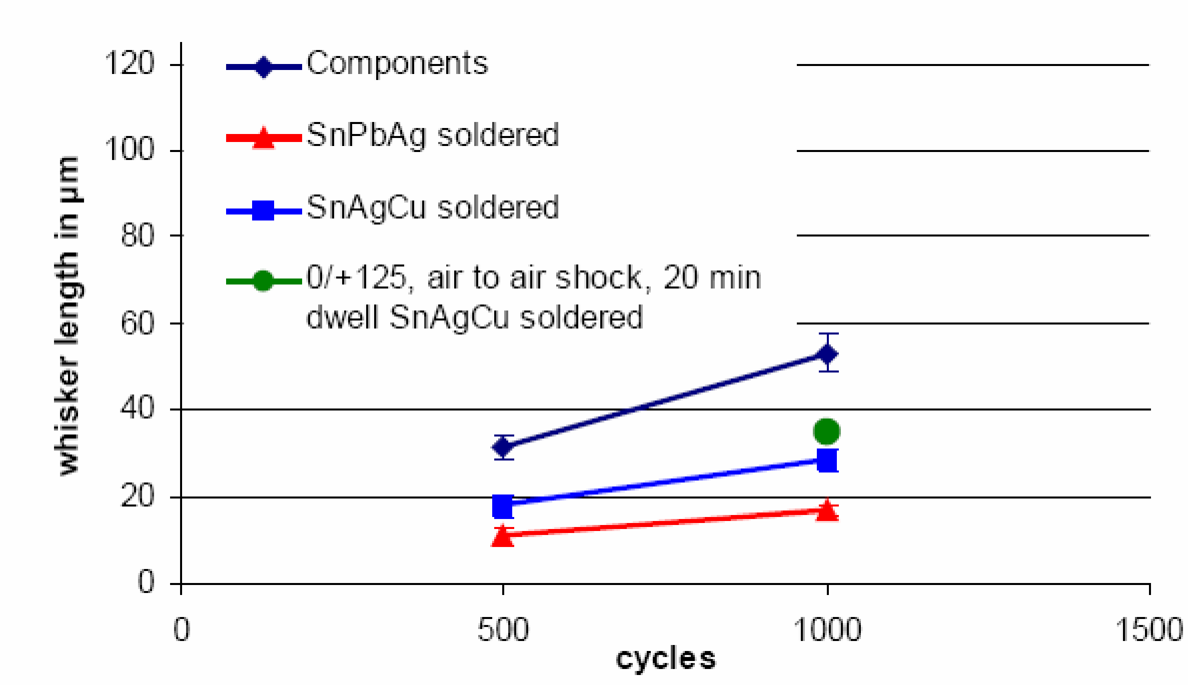
iNEMI DOE4

Matte Sn over Cu

Assembled with SAC

Examples of Assembly Effects

But it might make it better!



Also – some component suppliers have claimed no measurable effect of reflow on whisker growth

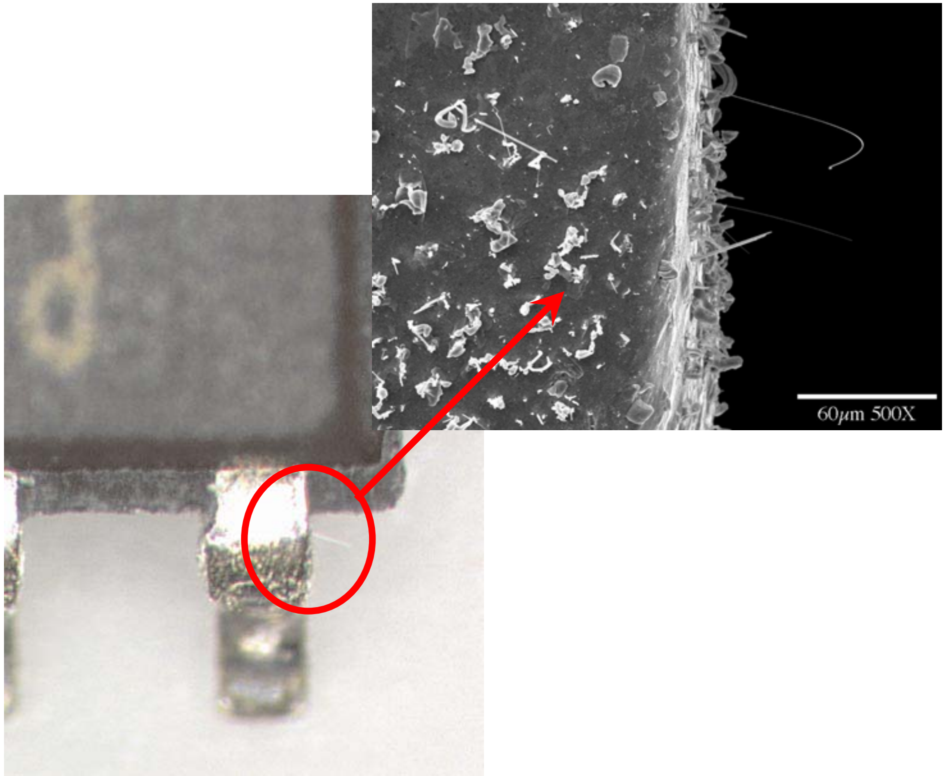
Whisker growth after –40 °C / +85 °C, 5ºK/min, 30 min dwell on unsoldered components and modules SnAgCu,- or SnPbAg soldered Alloy 42 lead-frame components

Mitigation: Hot Dipping

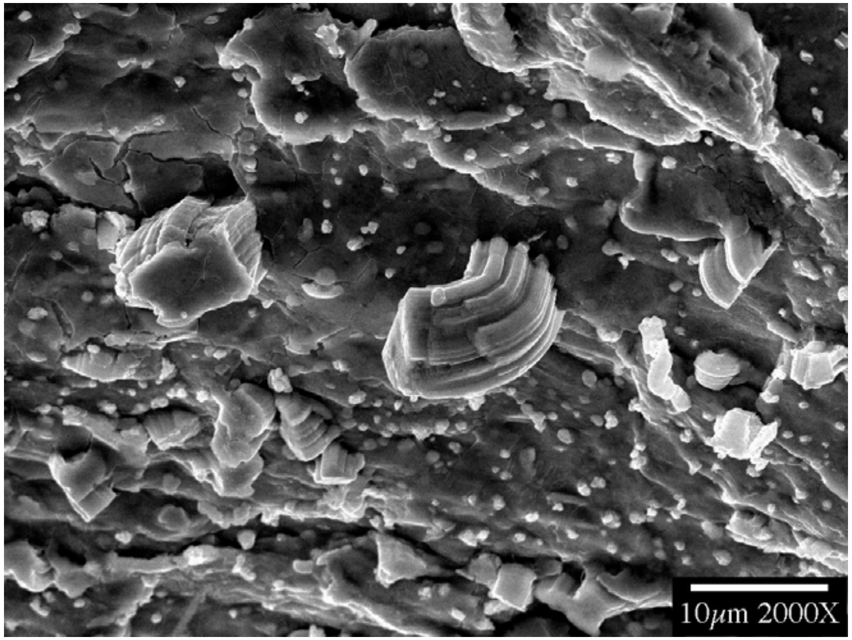
- Hot Dipping with Pure Sn, SnAgCu, SnAg or even SnCu can be a viable mitigation practice
  - Good field history – but limited use on electronic components. Has been used for structural steel parts, connectors and devices such as relays
  - Has similar positive effects as fusing of plated finishes (grain growth and low stress finish, builds intermetallic layer)
  - Alloys such as SnAgCu and SnAg have the added benefit of the alloy mitigation in addition to the reflow. Additionally the alloy is well controlled – better than plating.
  - SnCu the biggest question due to the added Cu
  - However, there are many other variables in the dipping process that may affect whisker performance
    - lead/component geometry (similar to fusing)
    - base materials
    - forming practices after dipping
    - post -dipping cooling practices
    - solder bath maintenance and impurity levels
    - flux types

Mitigation: Hot Dipping (continued)

It doesn’t ALWAYS work!



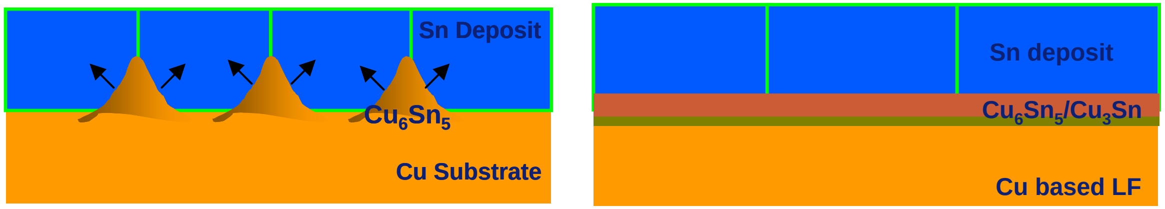
iNEMI DOE3, Hot Dipped Sn
3000 Hrs @60ºC, 93%RH



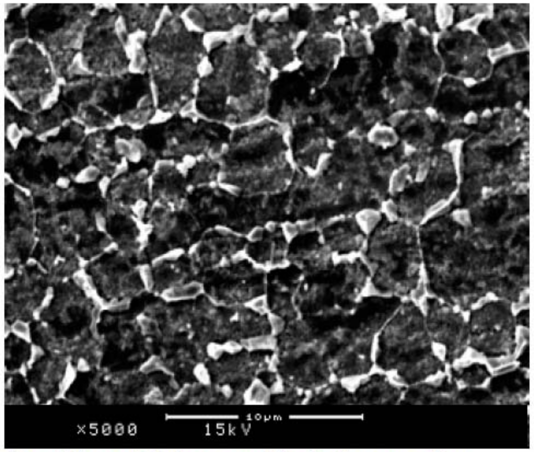
SUNY Buffalo, Hot Dipped SnAgCu
500 Hrs@85ºC/85%RH followed by 500 Thermal Cycles -55 to +125ºC
(Note – these are not good test conditions for growing whiskers!)

Mitigation: Annealing

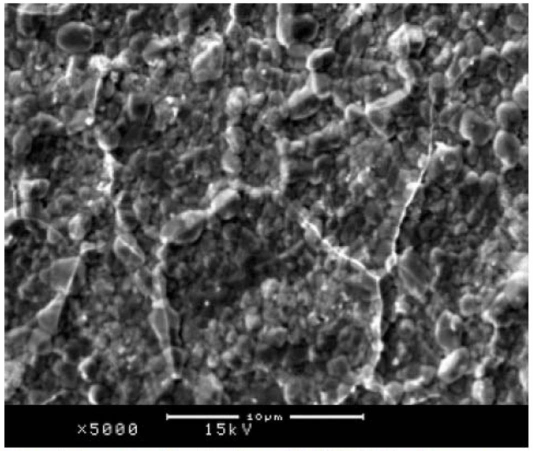
- **Annealing/Heat Treating of Sn finishes (on Cu based substrate) using a 150ºC 1hr. Post plating bake. Bake required within 24 hours of plating to be effective**
  - **Heavily adopted by IC industry (lead by E4)**
  - **Relieves plating stresses, causes grain growth/increased grain sizes and forms a uniform intermetallic layer of Cu_6Sn_5 over Cu_3Sn which slows further intermetallic growth**



Schematic representation of effect of Annealing Process



Sn stripped 6 days ambient storage after plating (white grains Cu_6Sn_5, dark copper)

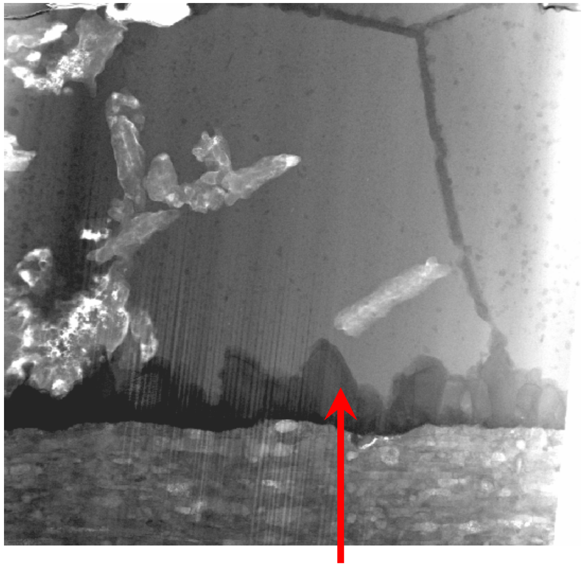


Sn stripped after baking 150 °C / 1h (copper completely covered with Cu_6Sn_5, significant Sn grain growth)

Source: "E3" (Infineon, Philips, ST Microelectronics)

Mitigation: Annealing (continued)

Material	Bake	T_{reflow}	RT Storage time = 56days	-55C/+85C T/C 2000 cycles	60C/93%RH Storage time =68days	60C/93%RH Bias (3.3 & 5 V) time =68days
Cu/Sn/1.5	no	no	whiskers	whiskers	whiskers	--------------
Cu/Sn/1.5	yes	no	whiskers	whiskers	whiskers	--------------
Cu/Sn/15	no	no	No whiskers	No whiskers	No whiskers	No whiskers
Cu/Sn/15	yes	no	No whiskers	No whiskers	No whiskers	No whiskers
Cu/Sn/15	yes	215C	No whiskers	whiskers	No whiskers	No whiskers
Cu/Sn/15	yes	260C	No whiskers	No whiskers	whiskers	whiskers



Note – uneven intermetallic after 2500 hours at 60ºC – even though sample annealed for 1hour at 150ºC within 2 hours of plating

Note reflow affect – similar to fusing

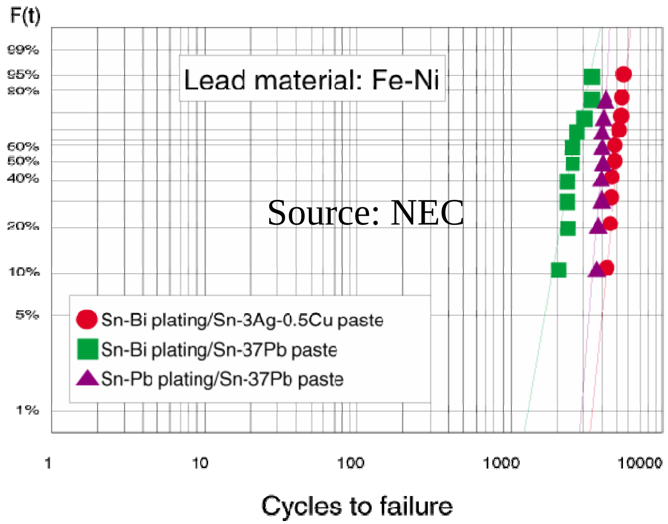
It doesn't always work!

Very dependent on Sn Plating process and possibly other factors
May only delay whisker growth

Source: Dr. John Osenbach, Agere

Alloy 42

- Alloy 42 (Fe42Ni)
  - Intermetallic considerations are largely irrelevant. The driving force for whiskers on A42 is CTE mismatch. As such, underlayer plating or annealing are ineffective.
  - Samsung offers pre-plated NiPdAu Alloy 42 lead-frames – but few takers
    - Still concerns with corrosion – but Samsung has data showing their process has resolved this
  - SnBi alloy has shown some effectiveness in mitigating whisker growth on A42. However, there are concerns with reduced solder joint fatigue life when soldered with SnPb. (Not an issue with SnAgCu assembly)
  - In thermal cycling – long whisker growth is often seen on Alloy 42 lead-frames
    - Less of an issue for Office conditions – but significant in outdoor, or similar conditions
    - Infineon claims, and has submitted some limited data, that after actual assembly, the whisker performance improves and is equivalent to that of SnPb



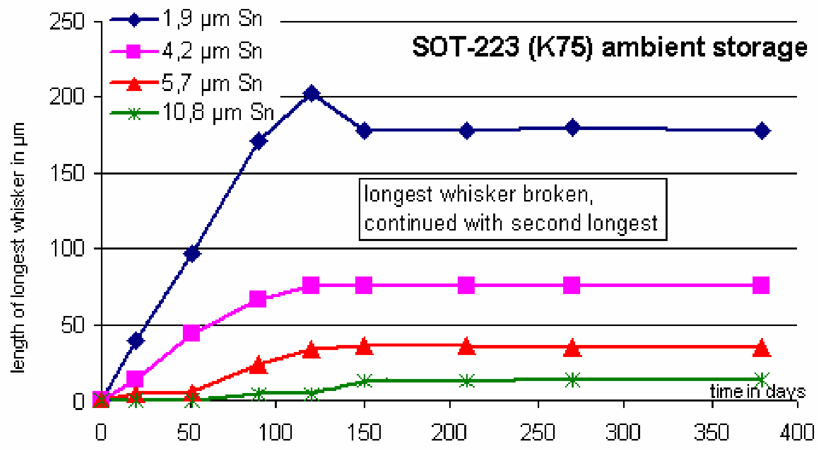
Source: NEC

Other Considerations

- **Matte vs. Bright Tin Finishes**
  - **Matte finishes “typically” have lower propensity for whisker growth. They are “typically” lower stress finishes and have larger grain sizes. Claims of these finishes being “whisker free” are highly questionable and should be regarded with much skepticism.**

Parameter	Matte Sn	Bright Sn
Carbon Content	.005%-0.050%	0.2%-1.0%
Grain Size	1µm-5µm	0.5µm-0.8µm

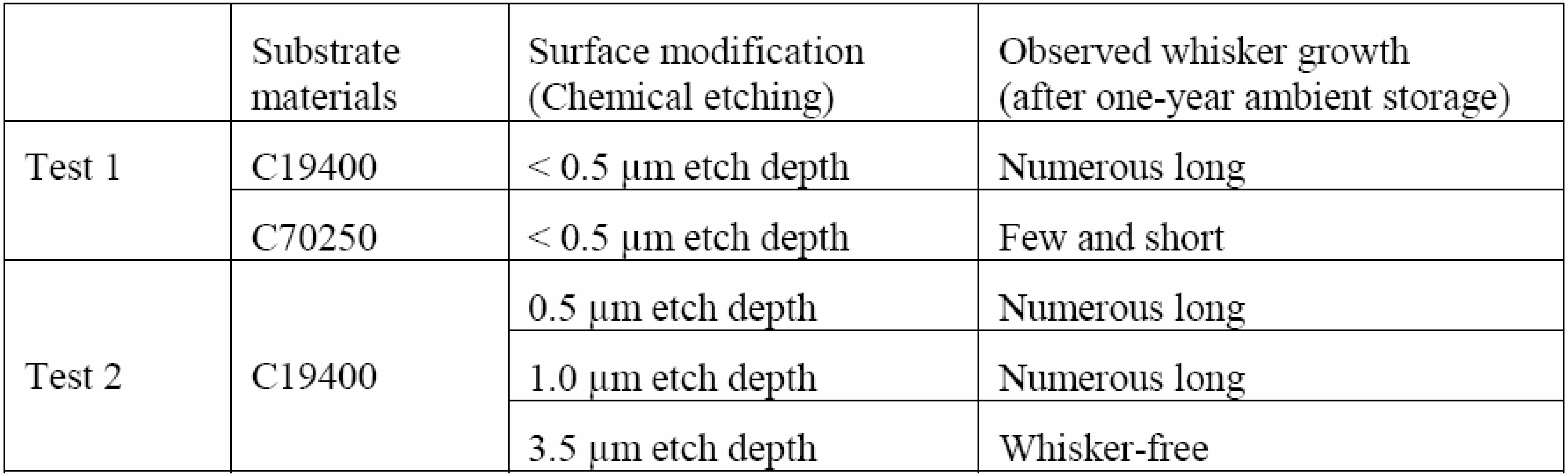
- **Thick vs. Thin Sn Finishes**
  - **Thicker finishes typically delay the onset of whisker growth (longer incubation time) compared to comparable thinner finishes**



Source: E3

Other Considerations

- **Surface chemical etching**
  - **In very limited testing has shown promise in reducing tin whisker growth when the etching depth is in the range of 3 to 4µm. The only theory as to why this may be true relates to changes in the 4-zone model – such that "hills and valleys" in the intermetallic formation may result in a "vertical effect" rather than compressive stress in the finish.**

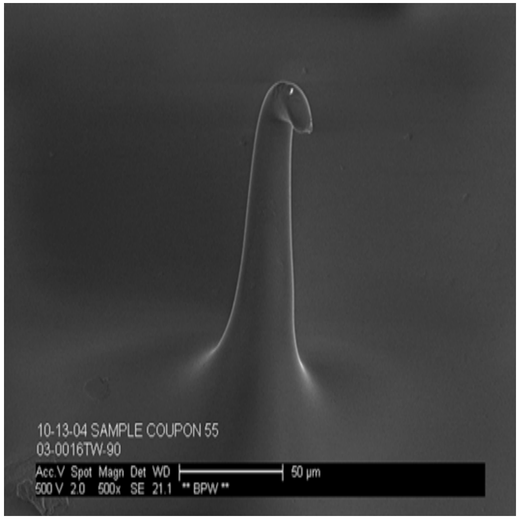


	Substrate materials	Surface modification (Chemical etching)	Observed whisker growth (after one-year ambient storage)
Test 1	C19400	< 0.5 µm etch depth	Numerous long
	C70250	< 0.5 µm etch depth	Few and short
Test 2	C19400	0.5 µm etch depth	Numerous long
		1.0 µm etch depth	Numerous long
		3.5 µm etch depth	Whisker-free

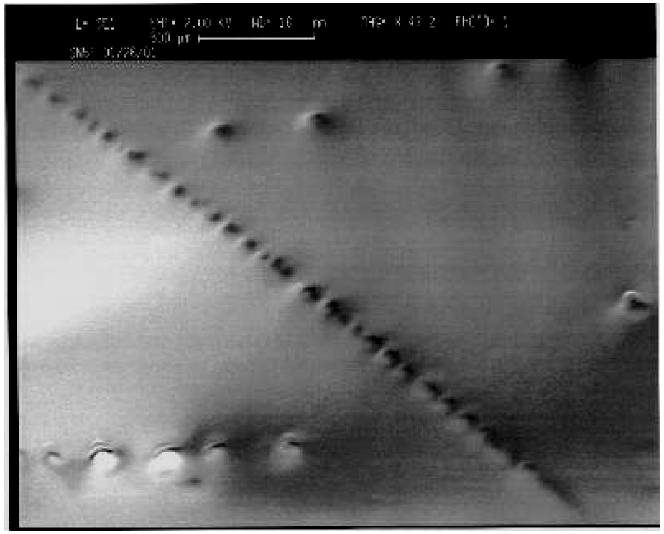
Source: Wan Zhang, Rohm and Hass

Other Considerations

- **Conformal Coating**
  - **Coating after assembly has shown some promise in reducing the rate of whisker growth**
  - **Appears to be specific to the material types used and the environment**
  - **Data does not support conformal coating to be a cure for whisker growth**
  - **Adds an insulation barrier that may prevent shorting should long whisker growth occur**



Whisker "pushing up" thick conformal coating. Other instances show break through.
(Source: Dr. Thomas Woodrow, Boeing)



Whiskers growing "underneath" 2-mils of Polyurethane conformal coat. (Source: Mike Sampson, NASA)

Component Solderable Finish Matrix

Solderable Finish	Base Material								
	Cu (7025, 194, etc)			Low Expansion Alloy (Alloy 42, Kovar)			Ceramic (such as resistors and capacitors) – no lead-frame		
	Cat 1 %	Cat 2 %	Cat 3 %	Cat 1 %	Cat 2 %	Cat 3 %	Cat 1 %	Cat 2 %	Cat 3 %
NiPdAu	100			100			100		
NiPd	100			100			100		
NiAu	100			100			100		
Matte Sn w/ Nickel underplate	9	91		NA			100% are 1 or 2 (1)		
Reflowed Sn	18	82		9	82	9	10	90	
Hot Dipped SnAgCu	55	45		50	50		56	44	
Matte Sn w/Silver underplate		100			100			100	
Hot Dipped SnAg	9	73	18	22	78		25	75	
Hot Dipped Sn	18	82		9	91		10	90	
Hot Dipped SnCu	9	73	18		82	18	10	70	20
SnAg (1.5-4%Ag)	10	90			100			100	
Matte Sn – 150C anneal	10	90		10	70	20		50	50
Matte SnCu – 150C anneal		73	27		46	64		50	50
SnBi (2-4% Bi)(2)	9	64	27		73	27		70	30
Matte Sn		36	64(4)		60	40(4)		44	66(4)
Semi-Matte Sn		36	64(4)		55	45(4)		45	55(4)
SnCu		27	73(4)		18	82(4)		20	80(4)
Bright Tin w/Nickel underplate	9	36	55	9	36	55	9	36	55
Bright Tin		9	91(4)		9	91(4)		9	91(4)
Ag (over Ni)(3)	100			100			100		
AgPd (over Ni)(3)	100			100			100		
Ag (3)	100			NA			100		

iNEMI Tin Whisker User Group Recommendations

Category 1: No tin whisker testing required
Category 2: Finish must pass tin whisker testing
Category 3: Do not accept this finish in any case

<u>Simplified</u>

Non-Tin Finishes:

- No testing required

Finishes with preferred and acceptable mitigation practices:

- Pass iNEMI(or future JEDEC JESD-201) acceptance testing

Some finishes not acceptable - period

(Some users will accept some of these finishes without testing.)

🟩 Preferred finishes
🟦 Finishes with preferred tin whisker mitigation practices
🟨 Finishes with tin mitigation practices that are less desirable than preferred practices
🟧 Finishes without tin whisker mitigation that are often not acceptable to users
🟥 Finishes to avoid

iNEMI Finish Recommendations for Separable Connectors

Finish	Termination finish use only as a solderable finish	Terminal finish use as a separable interface for fine spacing applications	Terminal finish use as a separable interface for large spacing applications
NiAu	1	1	1
NiPd	1	1	1
NiPdAu	1	1	1
Ag (over Ni)*	1	1	1
Hot Dipped SnAgCu	1	1	1
Reflowed Sn	1	2	2
Hot Dipped Sn	1	2	2
Hot Dipped SnCu	1	2	2
Matte Sn w/ Nickel underplate	2	2	2
Matte Sn w/Silver underplate	2	2	2
Matte Sn – 150C anneal	2	2	2
Matte SnBi (2-4% Bi) w/Nickel underplate	2	2	2
Matte SnAg (1.5-4%Ag) w/Nickel underplate	2	2	2
SnCu w/Nickel underplate	2	2	2
Bright Tin w/Nickel underplate	2	2	2
Matte SnBi (2-4% Bi)	2	2	2
Matte SnAg (1.5-4%Ag)	2	2	2
Matte Sn (no underplate)	3	3	2
Bright Tin	3	3	3
SnCu	3	3	3

More agreement among users

<u>Simplified Summary</u>:

- Non-Sn and a few preferred finishes don’t require whisker testing.
- Most other tin finish options are acceptable provided that they pass tin whisker testing
- As with components, there are some finishes that are just not acceptable – period.

iNEMI Recommendations for Bus Bars

Finishes	Solderable (Yes/No)	Base Materials	
		Copper Alloys	Aluminum
None (unfinished)	No	OK	OK
Nickel	No	OK	Over Copper Strike Plating OK
Chromium(3)	No	OK	Over Copper Strike Plating OK
SnAgCu Solder Dip	Yes	OK	Over Copper Strike Plating OK
Silver(1) **(Immersion or Electroplate)**	Yes	OK	Over Copper Strike Plating OK
Matte Sn(2)	Yes	Not Recommended(2)	Over Copper Strike Plating, Not Recommended (2)

(1) Silver (Ag) plating, while frequently used for bus bars, is susceptible to corrosion in sulfurous environments or dendritic growth in the presence of moisture.

(2)When utilized on bus bars as a finish, tin whiskers are a concern for this finish, particularly when bus bar connections result in mechanical stresses on the finish. As such, the iNEMI Tin Whisker User Group recommends that this finish not be used for bus bars. If Sn finishes are used, a tin whisker mitigation practice is recommended. This finish has been used on bus bars in many products for years, so the application may still be acceptable even with tin whiskers. It is up to the user to make the final decision as to acceptance of this finish.

iNEMI Recommendations for Heat Sinks

Surface Finish	**Solderable Surfaces (Yes/No)**	**Heat Sink Base Material**		
		Aluminum	**Copper**	**Graphite**
None (or anodized for Aluminum)	No	OK	OK	OK
Nickel	No	NA	OK	NA
SnAgCu	Yes	OK (Over Cu Strike)	OK	NA
Matte Sn over Nickel	Yes	(Over Cu Strike) Tin Whisker Testing Required (1)	Tin Whisker Testing Required (1)	NA
Matte Sn	Yes	(Over Cu Strike) Not Recommended(1)(2)	Not Recommended (1)(2)	NA

(1) Tin whisker testing required

(2) This finish is generally not recommended due to tin whisker concerns. However, it may be acceptable if one of the preferred mitigation practices is used (see Table 1). Also, if the matte Sn surface is fully wetted by solder during assembly, the finish is generally acceptable.

iNEMI Tin Whisker Considerations for Pb-Free PCB Finishes

PCB Finish	Tin Whisker Test Requirements?
SnCu HASL	Yes
Immersion Sn	Limited
Electroless NI/Immersion Au	None
Electroplated NI/Electroplated Au	None
Immersion Ag	None
OSP (e.g. Entek)	None

In general, tin whiskers are not the primary concern in selecting a PCB Finish

iNEMI Hi-Reliability RoHS Task Force Statement – Tin Finishes/Whiskers

- **Adopt one of the iNEMI-recognized whisker mitigation practices as an integral part of Sn and/or high Sn content (>95%) Pb-free plating processes.**
- **Perform testing and adhere to the qualification criteria of either of these protocols:**
  - **iNEMI Tin Whisker Acceptance Test Requirements (latest version is July 28, 2004 – references test methods of JESD22-A121)**
  - **Final agreement of the JEDEC tin-whisker acceptance ballot (JESD-201) qualification criteria in conjunction with the JESD22-A-121 test method.**
    - **JESD-201 has passed JEDEC Committee Ballot and is expected to formally release in February 2006**
- **Continue to provide an alternative non-whiskering finish, such as SnPb or NiPdAu, until the requirements of the iNEMI/JEDEC acceptance tests have been met.**

Summary

- Mitigation Practices are only one of three key requirements to have a valid tin whisker risk reduction strategy
  - Testing and Process Controls are also important
- This three-fold strategy reduces the risk of tin whiskers but it does not eliminate it!
- Other mitigation strategies might be feasible – but they should have both
  - A theory associated with why they work
  - Valid Test Data (per iNEMI/JEDEC test conditions)
- iNEMI has provided finish recommendations relative to Tin Whiskers that include Testing when applicable

For More Information

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