Part A
Whisker Formation on Tin Plated Cu based Leadframes
Results and Conclusion
October 2004

Part B
Whisker Formation on Tin Plated FeNi42
Results and Conclusion
August 2004

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Part A
Whisker Formation on Tin Plated Cu based Leadframes

Results and Conclusion

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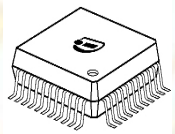
Content

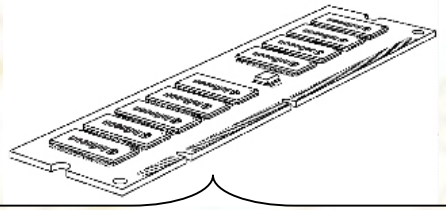
- Introduction
- Experience E4
- Main cause whisker growth on Cu LF
- Countermeasures
- Conclusions

Introduction

Period of potential whisker growth

	storage conditions	service life conditions
FeNi42 L/F	no whisker growth	whisker see FeNi42 presentation
Cu-based L/F	whisker → countermeasure baking see this presentation	no whisker growth





tin plating → board assembly/ soldering → product end of life

≤ 2 years **~ 15 years**

Part A

Experience in Tin plating within E4

Electrolytes

Production line	Lab scale
Shipley ST-200	Shipley ST-150
Shipley ST 300	Shipley ST-200
Schlötter Slototin40	Shipley ST 300
Pyramid Pyra Tin Lux	Schlötter Slototin 40
Technic Technistan EP	Pyramid Pyra Tin Lux
OMG Reel Satin 2544 LF	Technic Technistan EP
Lucent Satin bright Tin	OMG Reel Satin 2544 LF
	Atotech HSM

Leadframe Material

ASTM / material number	Brand name / short notification	Composition
C14415	K 81 / CuSn0,15	0.1 Sn; <0.02 Ni/Zn
C18070	K 75 / CuCrSiTi	0.3 Cr; 0.35 Si; 0.07 Ti
C19210	K80 / CuFeP, KFC	0.1 Fe; 0.03 P
C18090	K62, CuSn1CrNiTi	0.6 Sn; 0.4 Ni; 0.3 Cr; 0.3 Ti
C19400	Olin 194, K 65 / CuFe2P	2.4 Fe; 0.12 Zn; 0,03 P
C50710	MF 202 / CuSn2ZnP	2.0 Sn; 0.2 Ni; 0,15 P; 0,15 Zn
C70250	Olin 7025, K 55 / CuNi3Si1Mg	3.0 Ni; 0.65 Si, 0.15 Mg; <1.0 Zn
C22000	MS10	CuZn10
	Alloy 42	FeNi42

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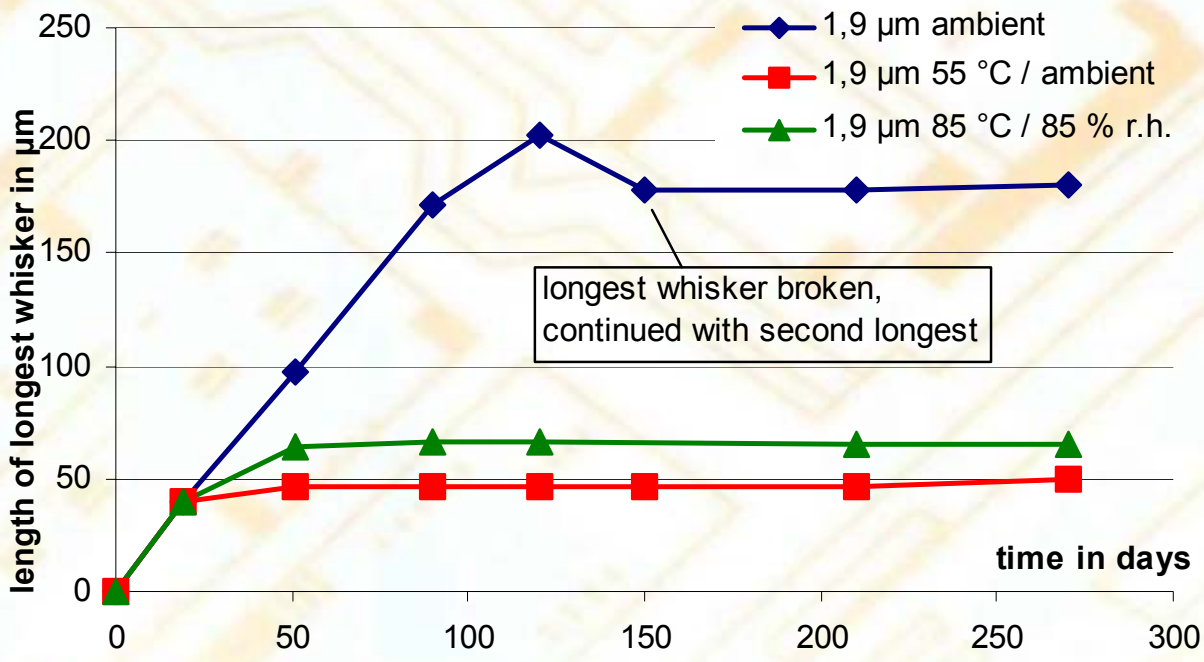
Storage conditions

- Test data showed that whiskers grow longest at room temperature
- Explanation: irregular intermetallic growth



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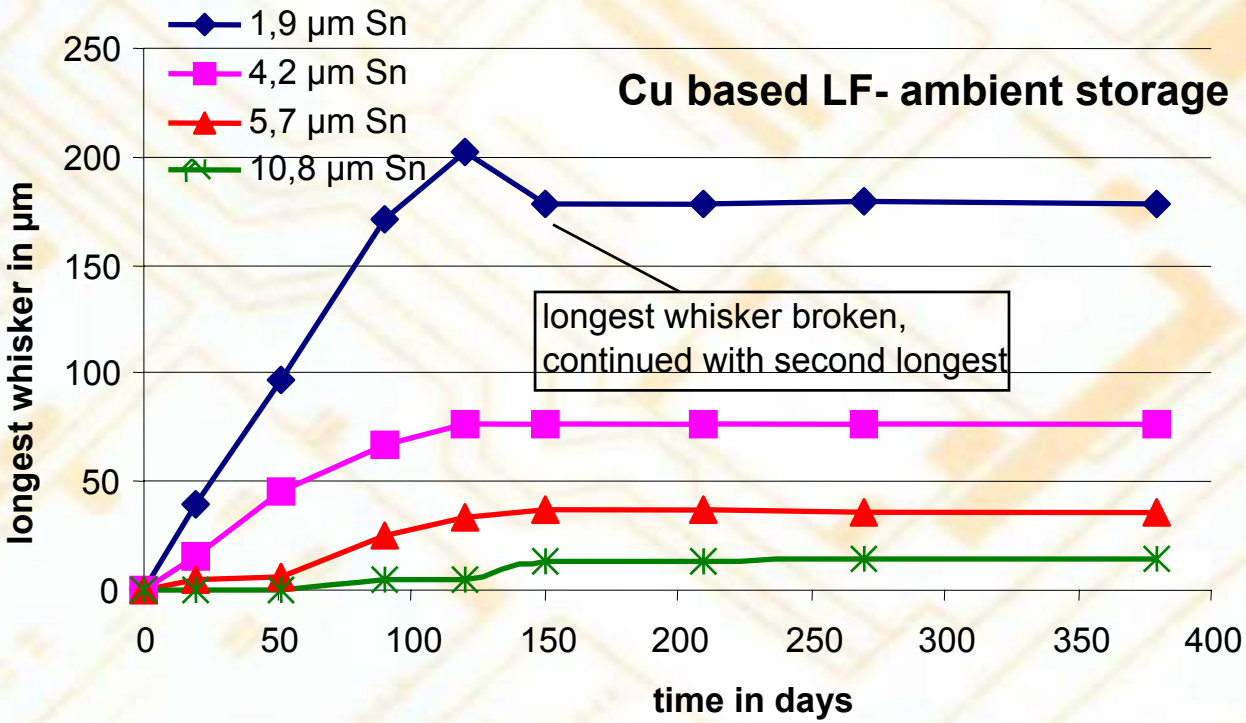
Part A

Influence of Plating Thickness



- Observation of strong dependency on thickness may result in acceleration factor according to thickness
- Similar results available for 4 Cu-materials and 3 electrolytes

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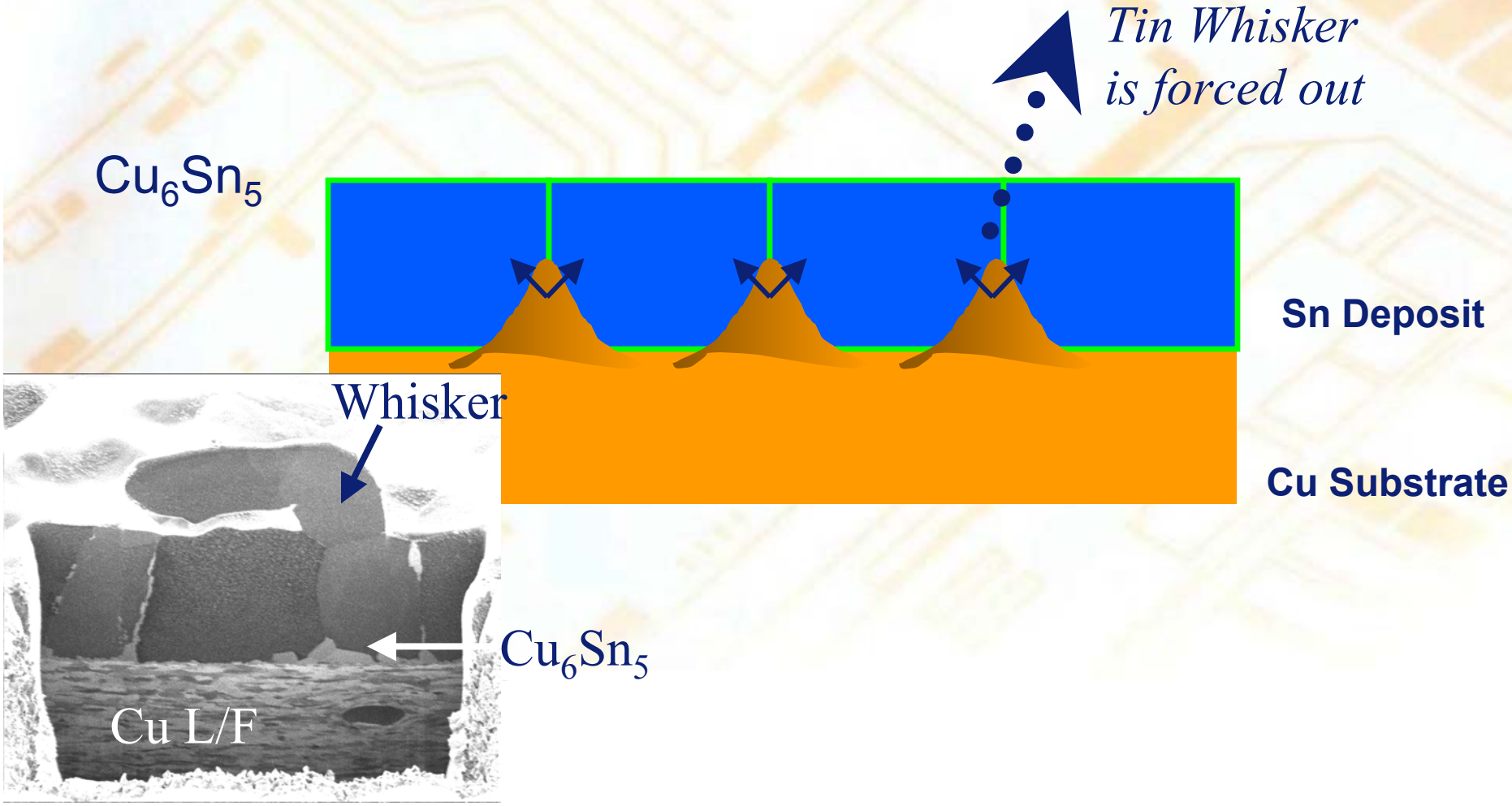
Part A

Whisker Mechanism on Cu based leadframes

Whiskers grow because of compressive stress in the plating which is caused by irregular growth of intermetallics

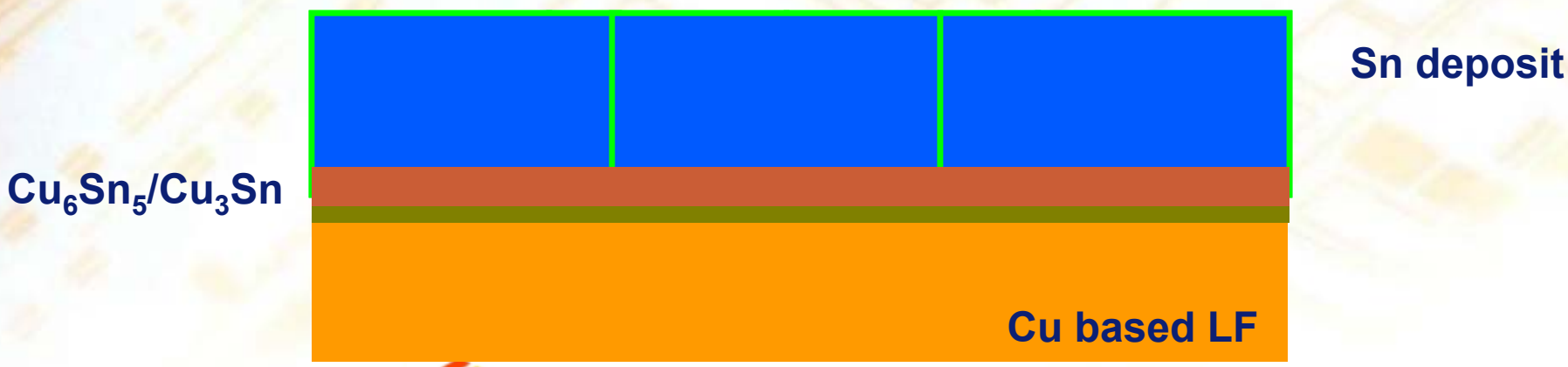


Protection by Postbake (1h, 150 °C)

(Within 24 hours of plating)

- Because of higher temperature diffusion will shift from grain boundary to bulk diffusion and thus regular intermetallics
- Recrystallization of Sn
- Diffusion barrier for further intermetallic growth
- Annealing of stress
- Postbake does NOT change CTE mismatch!

No whisker!



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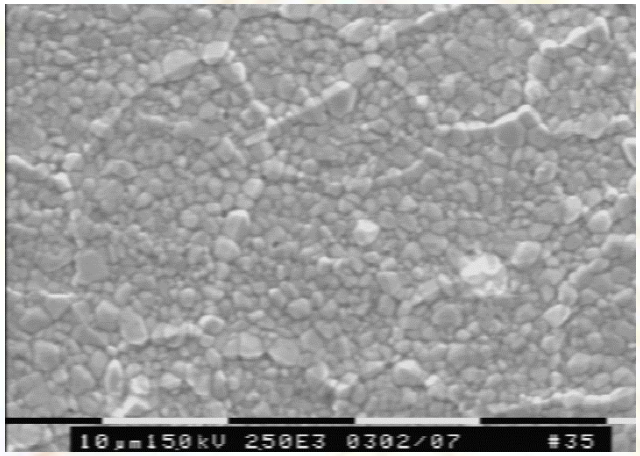
Part A

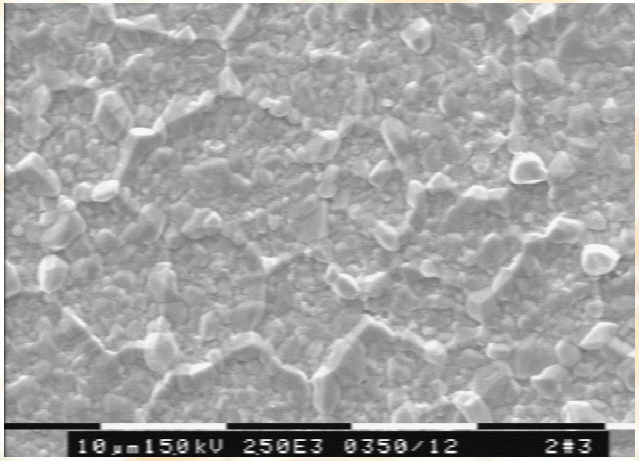
Morphology of the Intermetallics



1 h 150 °C

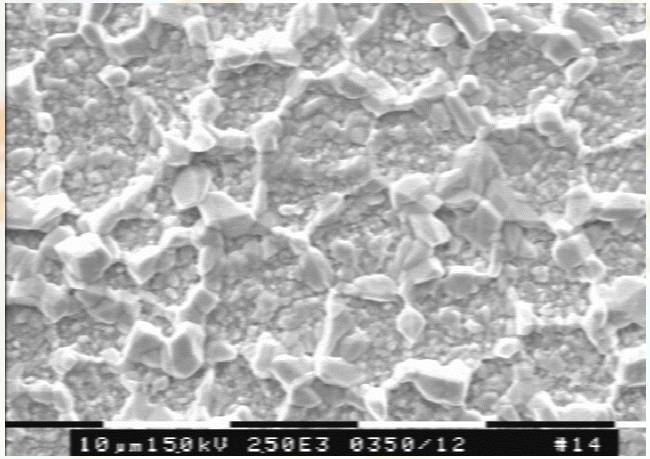
Bulk Diffusion

Recrystallization



4 h 125 °C

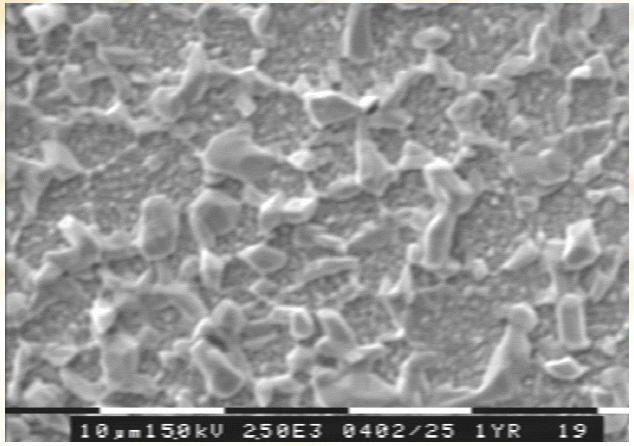
Same amount of intermetallics!



42 days 55 °C

Grain Boundary Diffusion

Less Recrystallization



1 year RT

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Postbake Characteristics

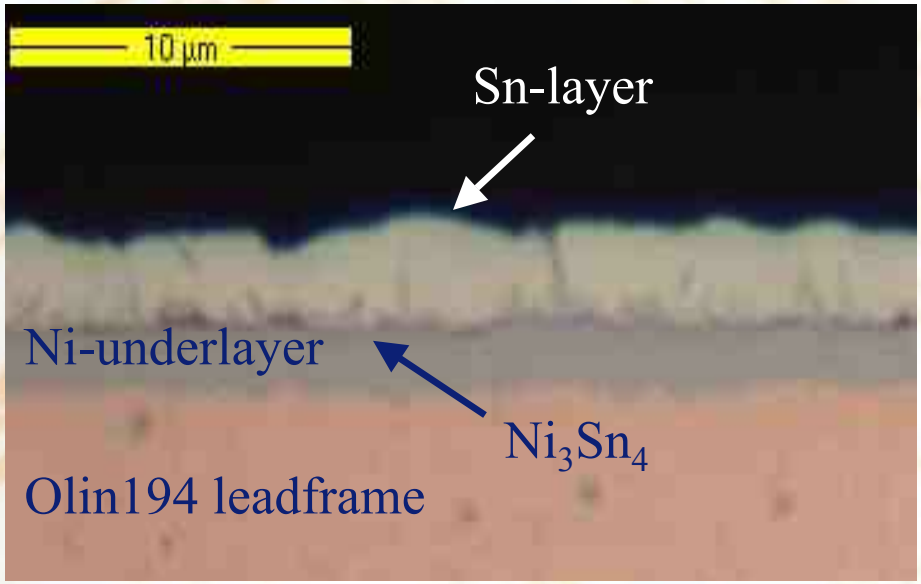
- Postbake results in double layer of Cu_3Sn and Cu_6Sn_5
- The average layer thickness of the resulting intermetallic is 0.7 Tm (+0.2/-0.3)
- Sn grain size 5 to 25 μm
- No additional intermetallic after 12 months storage at ambient

Protection by underlayer

Whisker on Cu

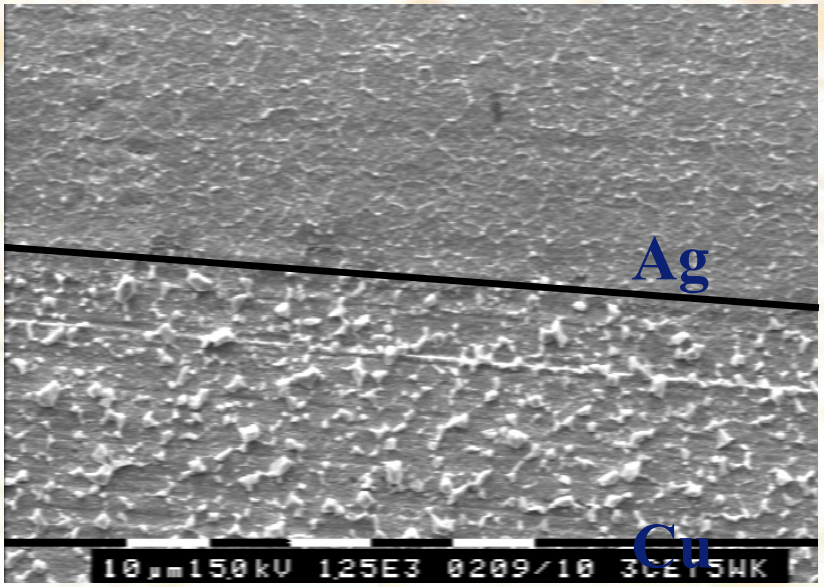
Changing underlayer results in other than Cu_6Sn_5 intermetallics, no stress build-up!

Ni underlayer:



Cross-sectioned view of 5µm Sn on Cu-based leadframe with 2 µm Ni underlayer

Ag underlayer:



Surface after stripping Sn showing intermetallics: upper half Ag underlayer, lower half Cu substrate (5 weeks@R.T)

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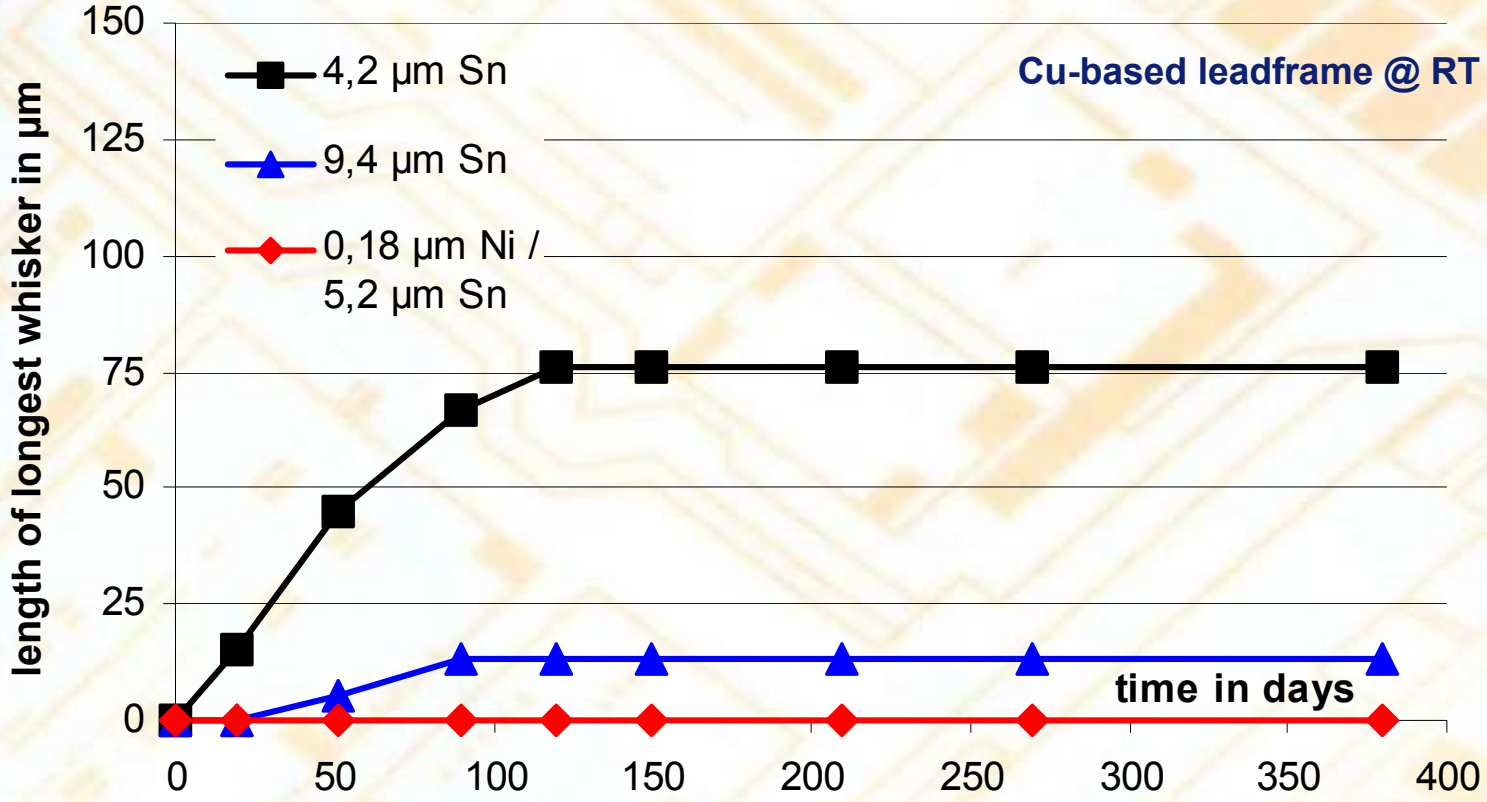
Part A

Protection by underlayer

Whisker on Cu



Sn-plating on Cu-base-material is prone to whiskers.

Ni-underlayer will eliminate whisker risk.

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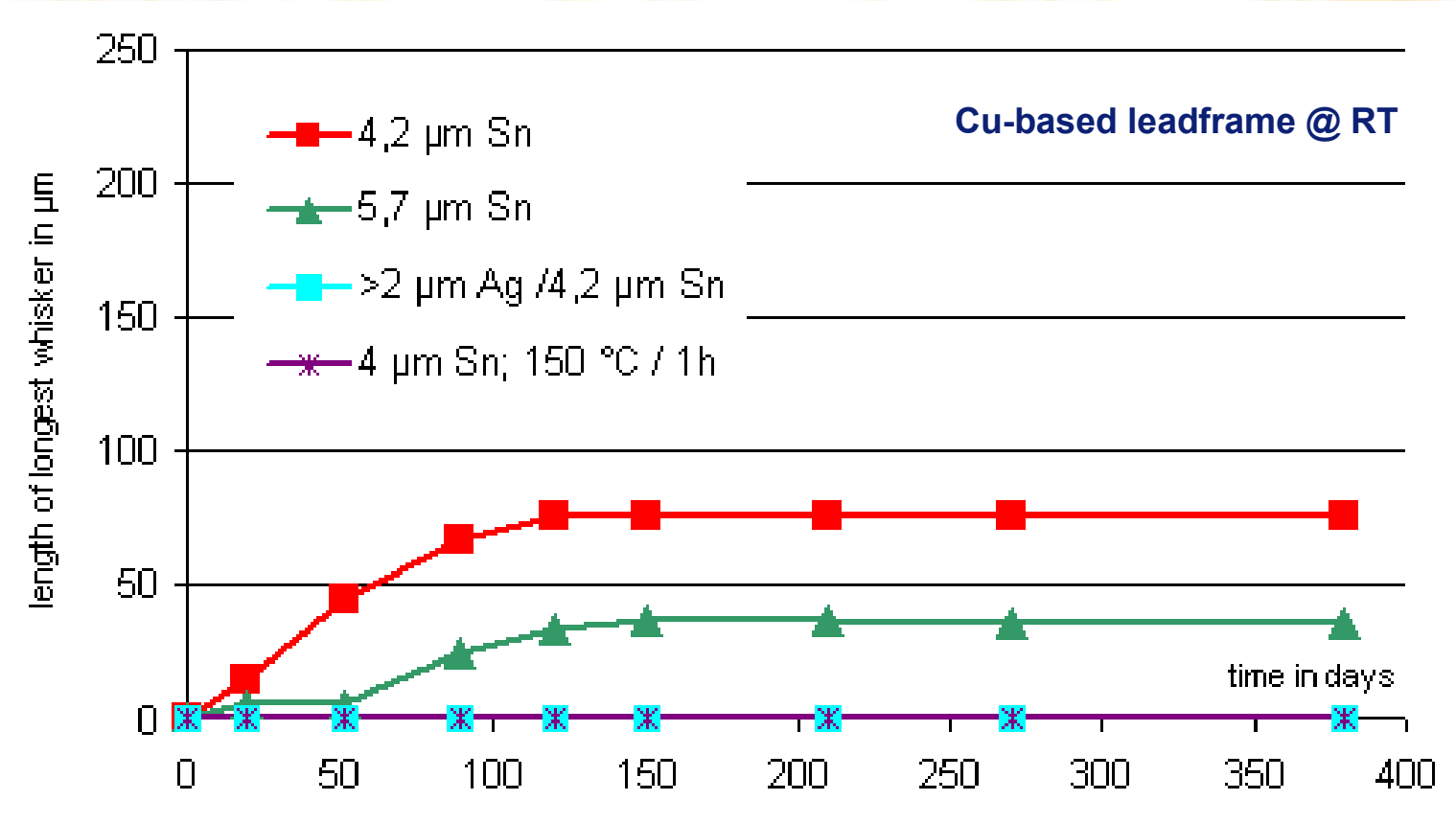
Part A

Protection by underlayer

Whisker on Cu



Sn-plating on Cu-base-material is prone to whiskers.

Ag-underlayer will eliminate whisker risk.

A bake process will eliminate whisker risk.

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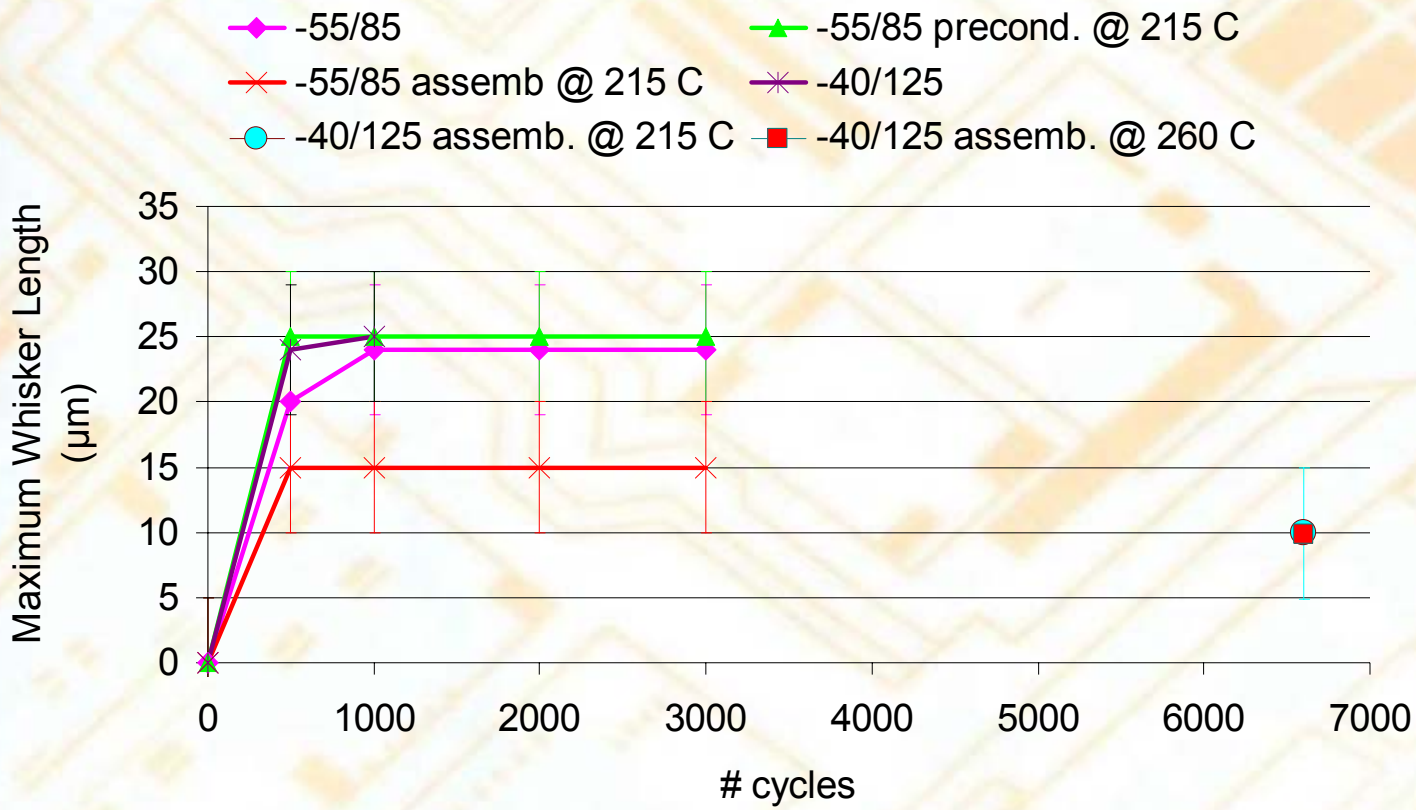
Cu Leadframes and Temperature Cycling



- Small whiskers can occur due to limited mismatch of CTE
- Postbake does NOT change this mismatch

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Test Results

Part A

Test condition	Preconditioning	Non postbaked Cu leadframes		Postbaked Cu leadframe	
		Max. Whisker Length (µm)	Time (h)/ # Cycles	Max. Whisker Length (µm)	Time (h)/ # Cycles
20-25 °C, 30-80 % r.h.	-	~ 90	> 5000	<10	~ 8000
20-25 °C, 30-80 % r.h.	simulated reflow @ 215 °C	0	> 8000	0	~ 6000
20-25 °C, 30-80 % r.h.	simulated reflow @ 260 °C	-	-	0	~ 6000
20-25 °C, 30-80 % r.h.	assembly @ 215 °C	0	> 8000	0	~ 6000
20-25 °C, 30-80 % r.h.	assembly @ 260 °C	0	> 8000	0	~ 3000
20-25 °C, 30-80 % r.h. with 5 V bias applied	assembly @ 215 °C	-	-	0	~ 5000
55 °C/85% r.h	-	~ 60	> 5000	< 10	~ 4500
60 °C/93% r.h	-	-	-	0*	~ 4000
60 °C/93% r.h	simulated reflow @ 215 °C	-	-	0*	~ 6000
60 °C/93% r.h	simulated reflow @ 260 °C	-	-	0*	~ 6000
60 °C/93% r.h	assembly @ 215 °C	-	-	0	~ 5000
60 °C/93% r.h	assembly @ 260 °C	-	-	0	~ 5000
55 °C/85% r.h	assembly @ 260 °C	0	~ 5000	-	-
60 °C/93% r.h with 5 V bias applied	assembly @ 215 °C	~ 30	~ 1000	0	~ 4000
-40 °C/125 °C, TST, >7' dwell	-	~ 30	1000	~ 30	1000
-55 °C/85 °C, TST, 10' dwell	-	~ 30	1000	~ 25	1000
-55 °C/85 °C, TST, 10' dwell	simulated reflow @ 215 °C	-	-	~ 30	3000
-55 °C/85 °C, TST, 10' dwell	simulated reflow @ 260 °C	-	-	~ 30	3000
-55 °C/85 °C, TST, 10' dwell	assembly @ 215 °C	-	-	~ 15	3000
-55 °C/85 °C, TST, 10' dwell	assembly @ 260 °C	-	-	~ 15	3000
-40 °C/125 °C, TST, 20' dwell	assembly @ 215 °C	< 10	~ 6600	-	-
-40 °C/125 °C, TST, 20' dwell	assembly @ 260 °C	< 10	~ 6600	-	-

* whiskers found after severe corrosion and exceeding 3000 h test time.

NEMI DoE3 Test results 60°C/93%RH

60C/93RH STORAGE
6000 HRS INSPECTION

Finishes Ranked by Max. Whisker Length
Isothermal Storage 6000hrs

Substrate	Plating	Max.Whisker Length
CDA194	Matte Sn/2-3Bi	360
CDA194	Matte Sn	270
Cu 7025	Matte Sn	200
CDA194	150C 1hr Matte Sn	160
CDA194	Hot-dipped Sn	150
CDA194	Matte Sn/2-3Cu	150
CDA194	245C reflow Matte Sn	110
CDA194	Matte Sn 3 - 5um	110
CDA194	Sn/2-4Ag	100
CDA194	SnPb	75*

*on areas with no Pb

DOE3 Test Results Update
August 2004
Peter Bush, SUNY at Buffalo

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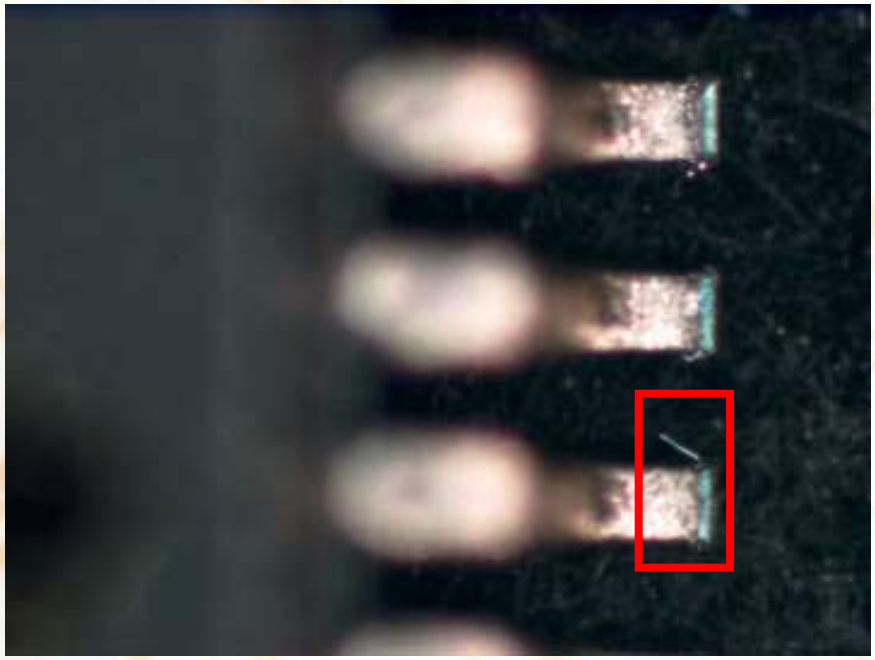
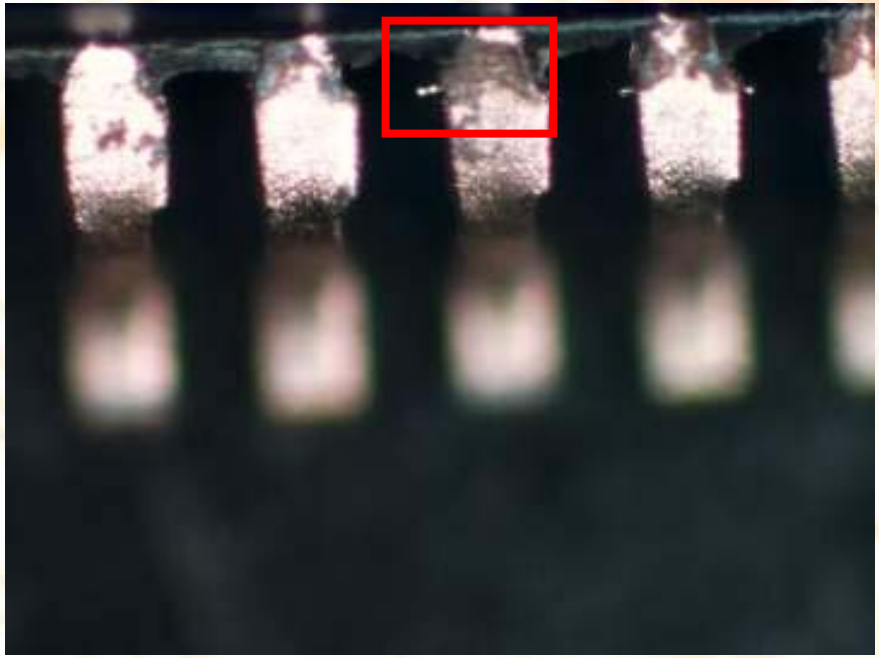
Part A

60 °C/93 %RH Corrosion



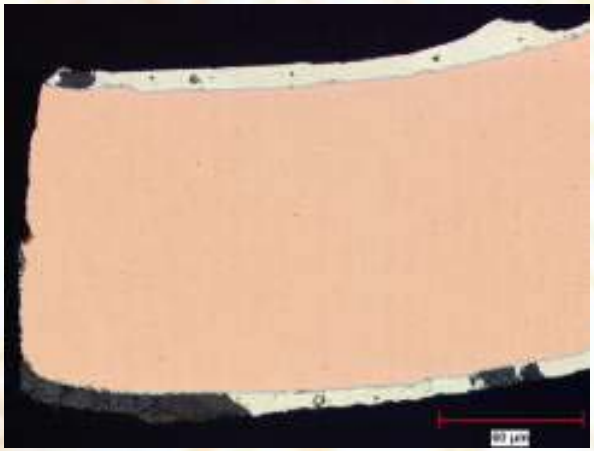
Toe area of QFP after > 3000 h 60 °C/93%RH



Shoulder area of QFP after > 3000 h 60 °C/93%RH

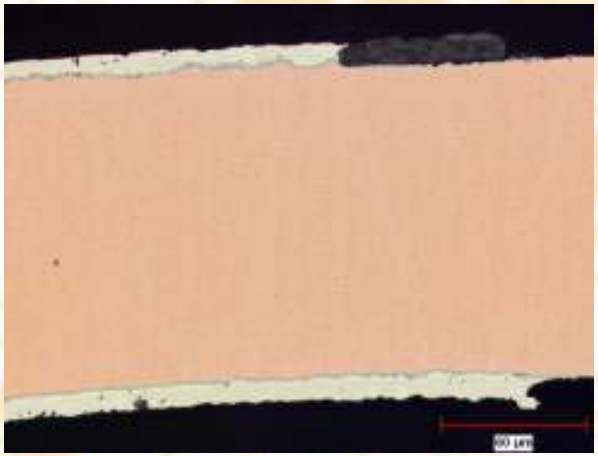
Part A

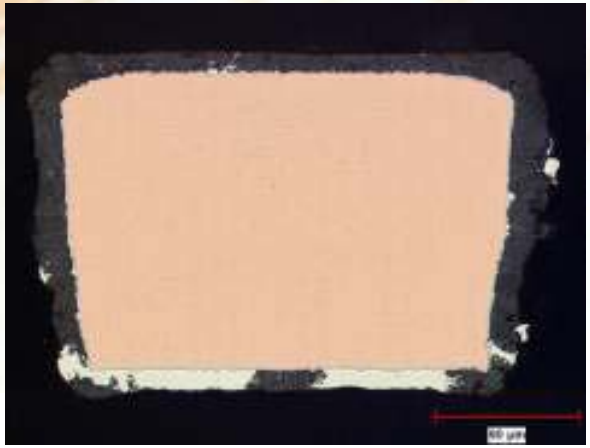
60 °C/93 %RH X-sections



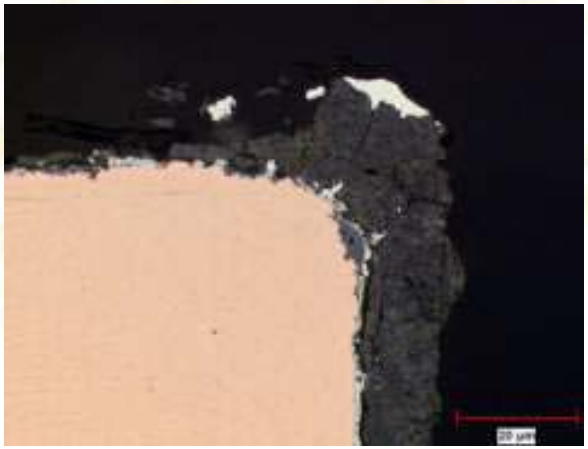
Parallel cross-sections after aging > 3000h

Foot Shoulder





Perpendicular cross-sections on foot area after aging > 3000h



Conclusions

- Compressive stress is the driving force in pure tin layers (without compressive stress no whiskers).
- Whisker growth on Copper leadframes is mainly caused by large, irregular intermetallic Cu_6Sn_5 growth at interface substrate / plating layer.
- Storage in ambient atmosphere produces longest whiskers on copper leadframe (compared to all other tested storage conditions).
- The thicker the Sn-layer the shorter is the whisker.
- Countermeasures are postbake, Ni-, Ag-underlayer.
- Postbake 1h, 150°C is performed after plating.
- Temperature cycling may cause a maximum whisker length of 30 μm on Cu leadframes.
- Maximum specified whisker length is 50 μm for accelerated tests.
- After 2 years storage at ambient and/or soldering on board matt tin plated Cu-L/F, with above mentioned countermeasures, does not show evidence of whiskers.

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Part B
Whisker Formation on Tin Plated FeNi42

Results and Conclusion

August 2004

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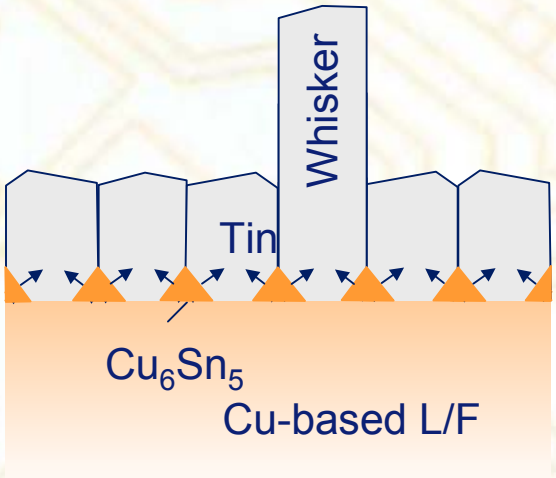
Outline

- Introduction
- Experimental procedure and inspection
- Results
- Summary and Conclusions

Introduction

Major mechanism and conditions for whisker formation

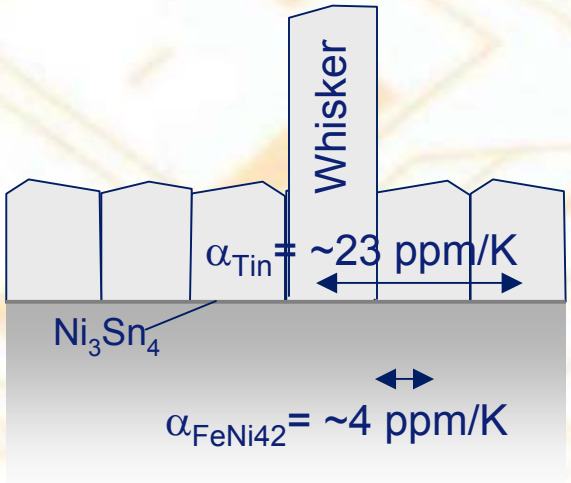
Copper



irregular growth of intermetallics

isothermal storage at moderate temperature

FeNi42



mismatch of cte

thermal cycling

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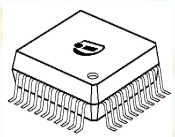
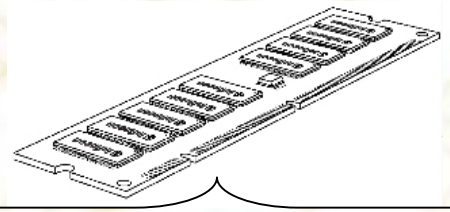
Introduction

Period of potential whisker growth

	storage conditions	service life conditions
FeNi42 L/F	no whisker growth	whisker see this presentation
Cu-based L/F	whisker → countermeasure baking	no whisker growth





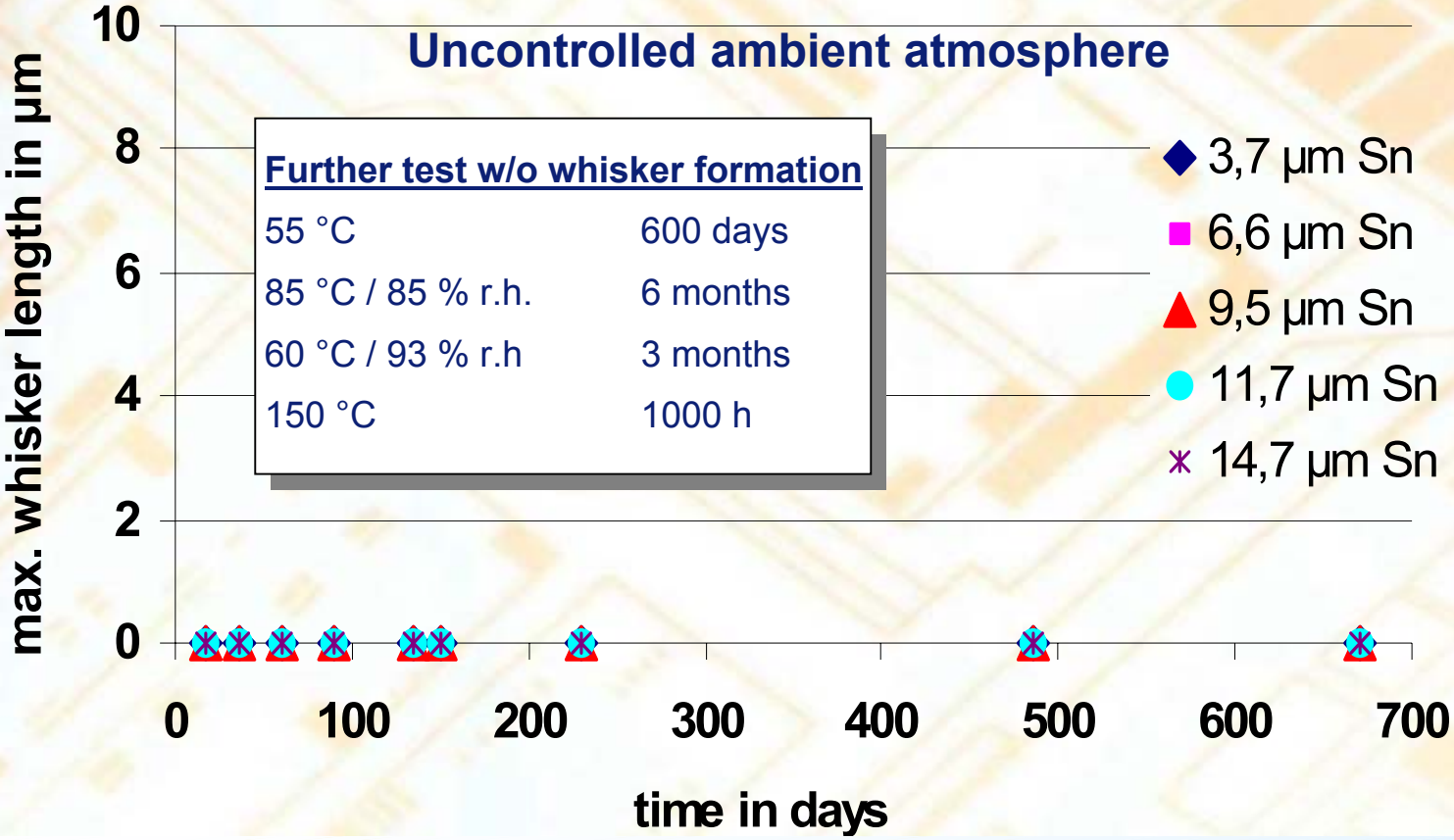
tin plating → board assembly/ soldering → product end of life

≤ 2 years **≤ 15 years**

Part B

Whisker on FeNi42 leadframes

Isothermal storage of tin plated FeNi42



Further test w/o whisker formation

55 °C	600 days
85 °C / 85 % r.h.	6 months
60 °C / 93 % r.h	3 months
150 °C	1000 h

Isothermal storage does not result in whisker formation for matt Sn plated FeNi42 based components

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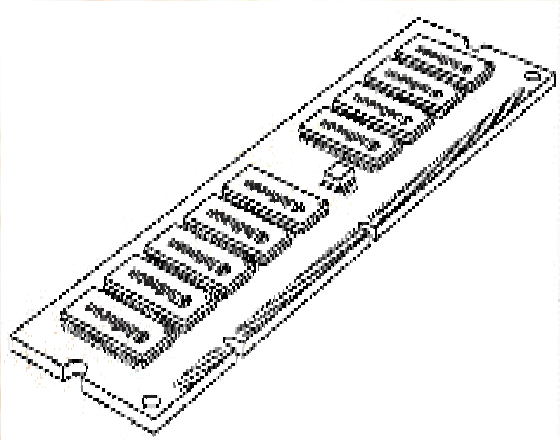
Experimental procedure and inspection

Part B

test package
TSOPII-66
8.5 µm matt tin
on FeNi42
assembled modul

⇨ Thermal cycling ⇨ Optical microscope ⇨ SEM



5 components per test condition and read number of cycles for readout (5 data per 330 leads)

identify longest whisker per component

- overview photo
- photo of longest whisker per package
- length measurement

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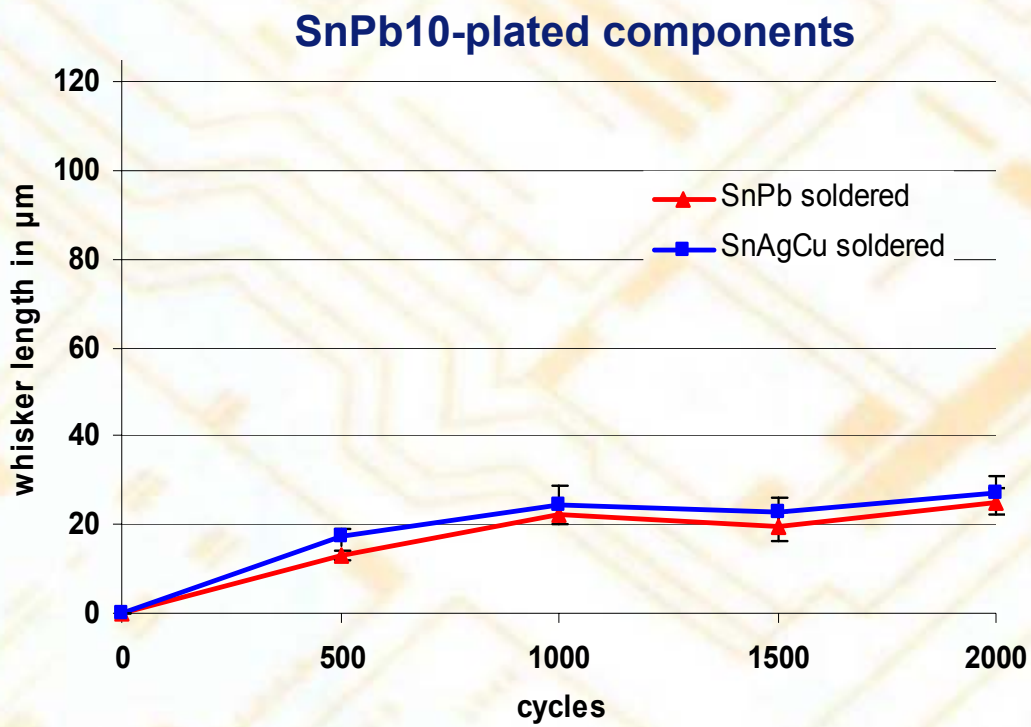
Whisker on FeNi42

Temperature cycling after board assembly



-40 °C / +85 °C,
5 K/min,
30 min dwell

- SnPb plating shows whiskers after TC testing
- No difference between SnAgCu and SnPbAg soldering

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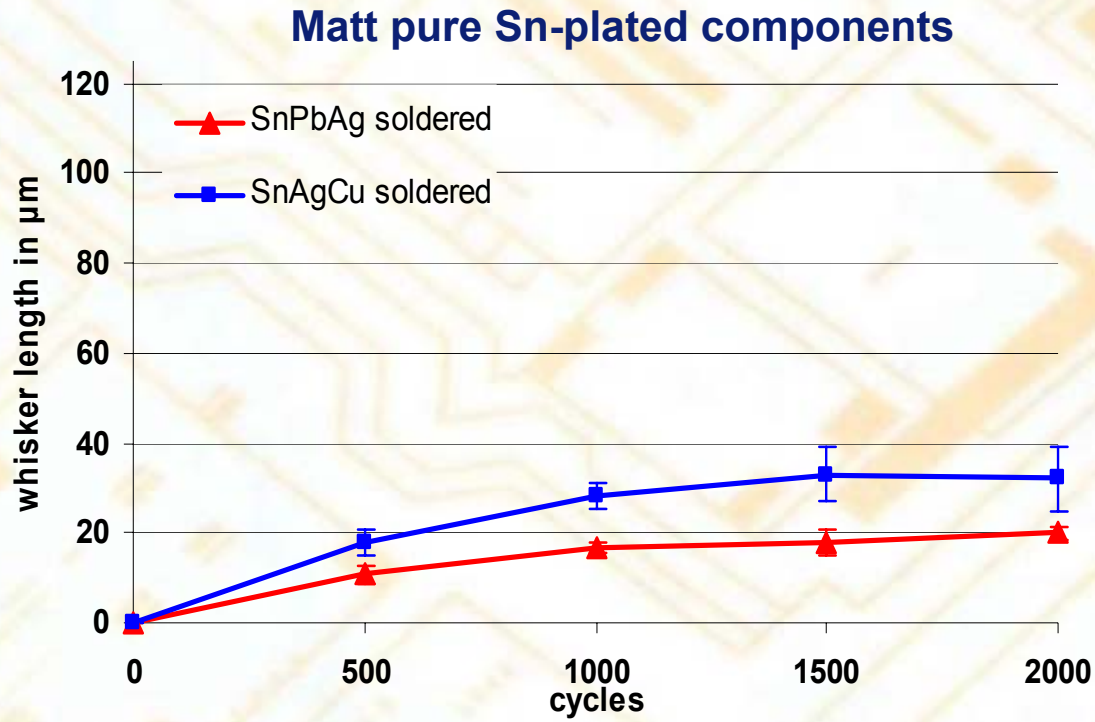
Whisker on FeNi42

Temperature cycling after board assembly



-40 °C / +85 °C,
5 K/min,
30 min dwell

- Sn-plated components show whisker of similar size as SnPb plated components
- Little difference between SnAgCu and SnPbAg soldering

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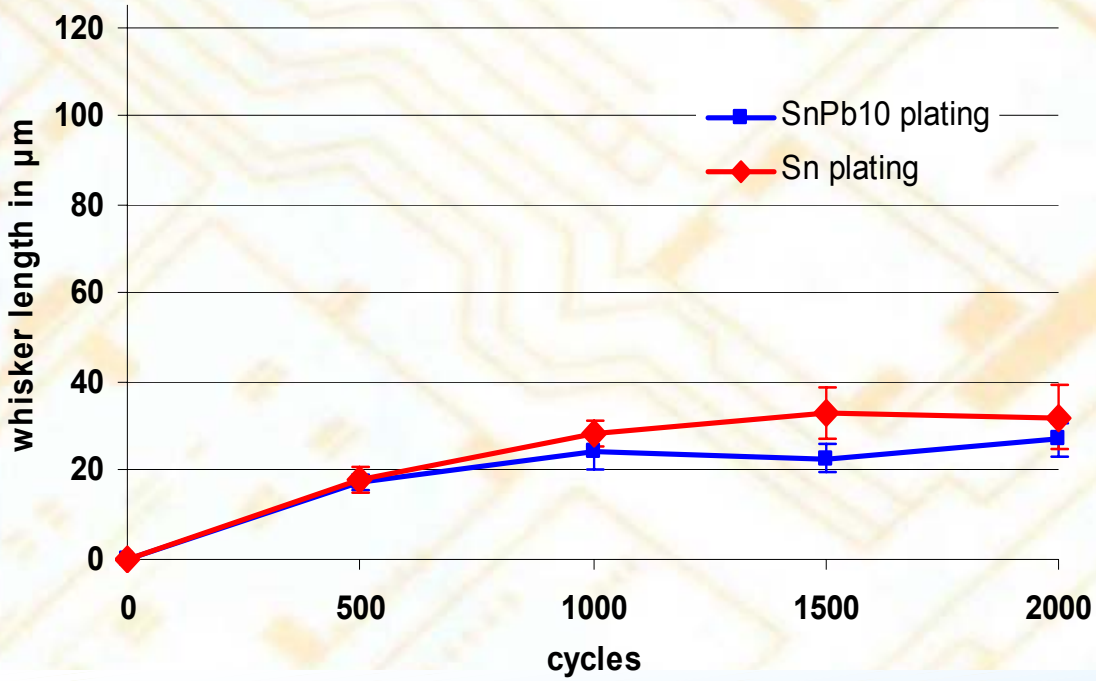
Whisker on FeNi42

Temperature cycling after board assembly

Comparison of Sn- and SnPb10 plated components

Board assembly with SnAgCu paste and process



-40 °C / +85 °C,
5 K/min,
30 min dwell

- SnPb plating shows whiskers of similar size as Sn-plated components

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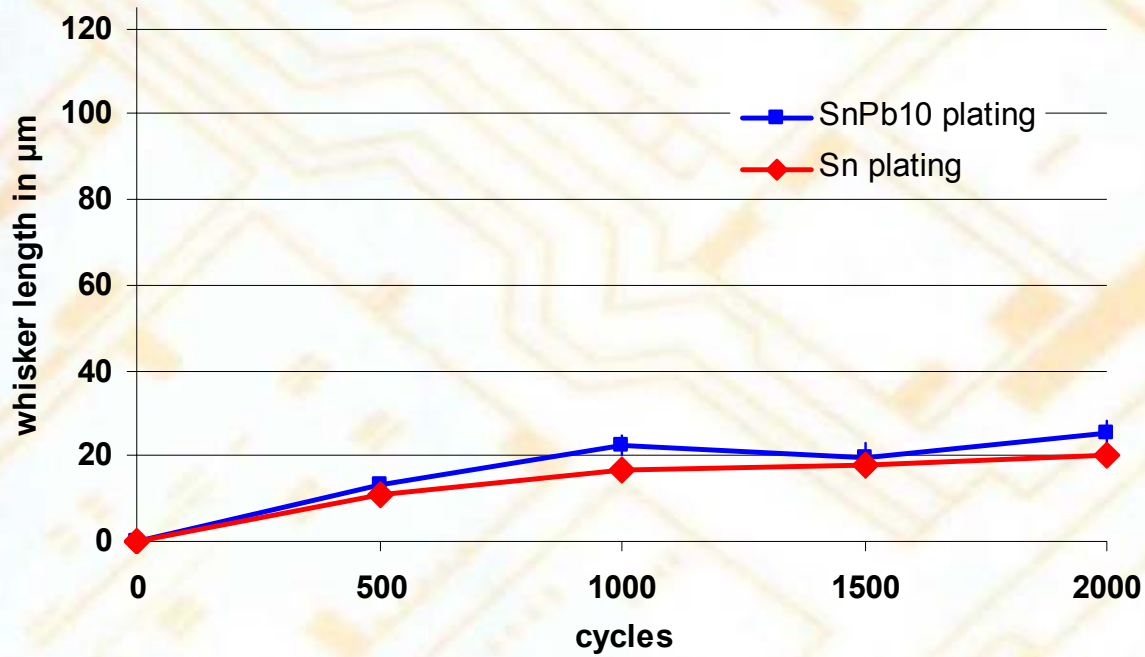
Whisker on FeNi42

Temperature cycling after board assembly

Comparison of Sn- and SnPb10 plated components

Board assembly with SnPbAg paste and process



-40 °C / +85 °C,
5 K/min,
30 min dwell

- SnPb plating shows whiskers of similar size as Sn-plated components

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Summary and conclusions

- Whisker length after board assembly equal for Sn-plated and SnPb10 plated components
- Little influence of solder paste type and respective process for board assembly

➡ Whisker risk for Sn-plated components equal to actual SnPb standard plated components

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