



International Electronics Manufacturing Initiative

**A Statistical Study of Sn Whisker
Population and Growth
during Elevated Temperature and
Humidity Storage Tests**

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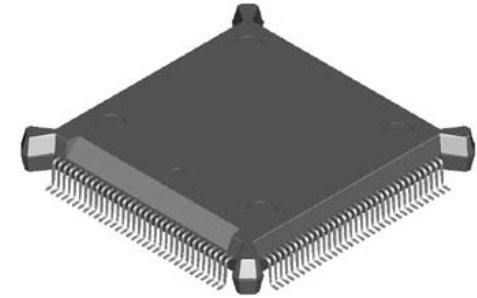
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(Part of an E4 joint study, with Infineon, Phillips, and STMicroelectronics)

- Package types and manufacturing process
- Test matrix
- Location of whiskers
- Comparison of humidity levels and in-group variations
- Growth of whiskers with time
- Board-mounted components
- Summary

- **Components**

- All components were 132 PQFPs, 25.4mm x 25.4mm in size, with a lead pitch of 0.635mm
- Components were also mounted on PWBs with either SnPb or SnAgCu solder pastes (each with 2 flux types, aqua-clean and no-clean)
- At each read point, every lead on the 4 or 5 components used for that read point was inspected and all whiskers above 10 μ m were recorded.



- **Matte Sn finish**

- All components were plated at the same supplier, with the same plating chemistry and process
- Target thickness of Sn is 10 μ m
- Components were baked at 150C for 1 hour within 24 hours of plating, prior to forming
- SnPb components were used as reference

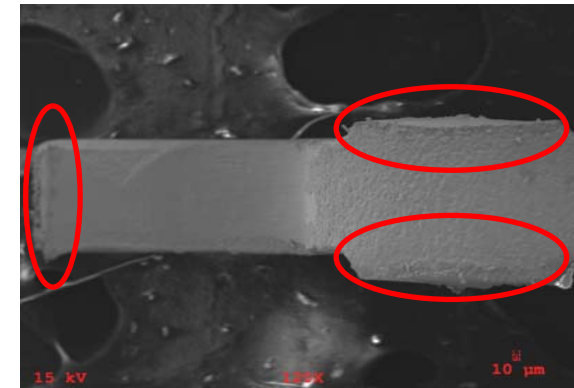
- **Test Conditions**

- Three conditions were tested: 60C/93%RH, 60C/90%RH, and 60/85%RH
- Most comparison in this presentation is done with the 85% and 93%RH data
- Whisker growth at the 60C/90%RH condition, in terms of length and density, fell between those of the 69/85%RH and 60C/93%RH conditions.
- The chamber capabilities of the 60C/93%RH were: humidity +/- 2.5%RH, temperature +/- 0.3°C. The 60C/85%RH chamber was a qualification tool and maintains a minimal 85%RH.

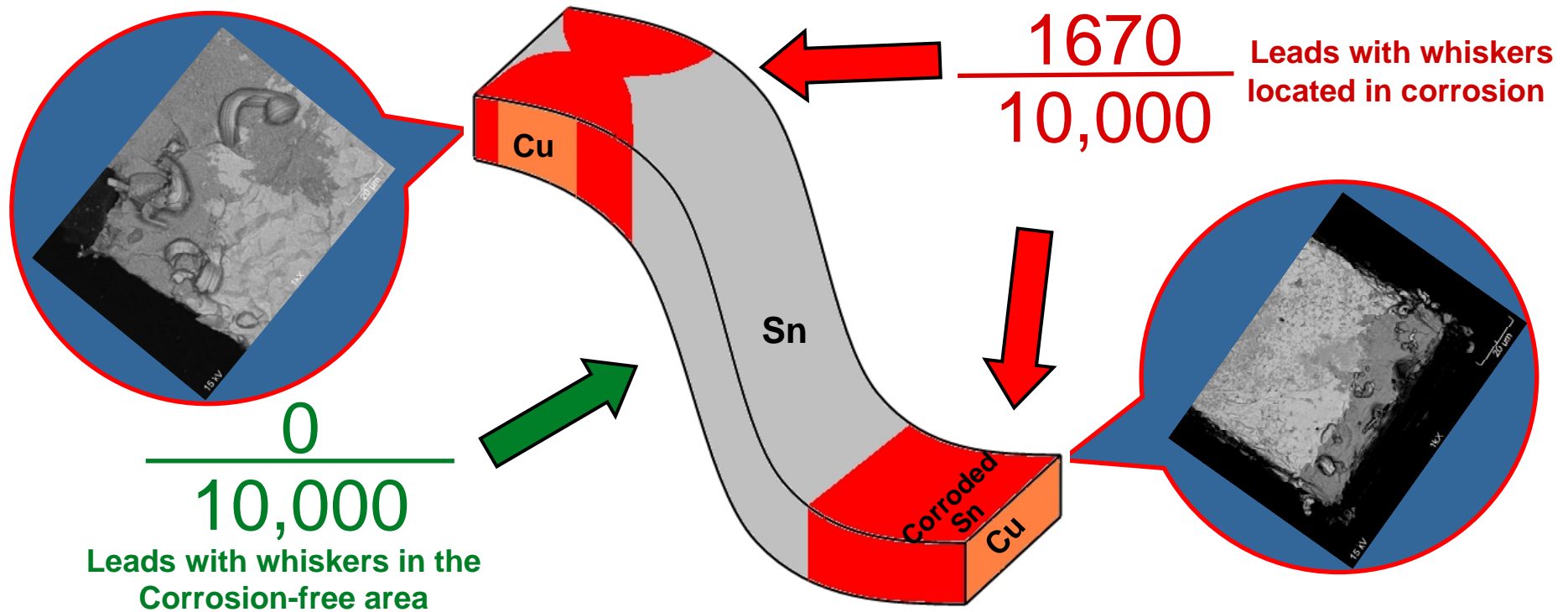
- The matrix below is for loose components, not board-mounted components. All board-mounted components did not have the deflash process (data on page 8).
- Variables for the loose components include finish type, deflash (to remove flakes of mold compound due to incomplete mold closure in die casting), pre-bake (1 hour at 60C before putting in test chamber), and reflow (260C peak temperature)
- The matrix below applies to all three humidity levels

Cell	Type	1000 hours		2000 hours		3000 hours		4000 hours		5000 hours	
		leads	Max (µm)	leads	Max (µm)	leads	Max (µm)	leads	Max (µm)	leads	Max (µm)
1	SnPb	No corrosion, no whiskers									
2	SnPb Reflowed										
3	Sn No Deflash	No Whiskers		No Data (inspection skipped)		Completing Inspection				Test in Progress	
4	Sn No Deflash Pre-baked										
5	Sn No Deflash Reflowed										
6	Sn Deflash	No Whiskers		No Data (inspection skipped)		Completing Inspection					
7	Sn Deflash Reflowed										

- During the high-humidity tests, galvanic potential difference between the Cu (CDA194) leadframe and Sn caused corrosion of Sn near the exposed Cu areas on the leads
- Entire population of whiskers, at all humidity levels and durations, are located within the corroded areas on leads, as confirmed by backscatter imaging
- When area of corrosion grew, locations of whiskers moved further away from the exposed Cu while the whiskers continue to grow only in the corroded areas
- On the ~10,000 leads on 75 components inspected so far (3000 and 4000 hours read points), no whiskers have been observed in the mid-section of the leads, where no corrosion is present

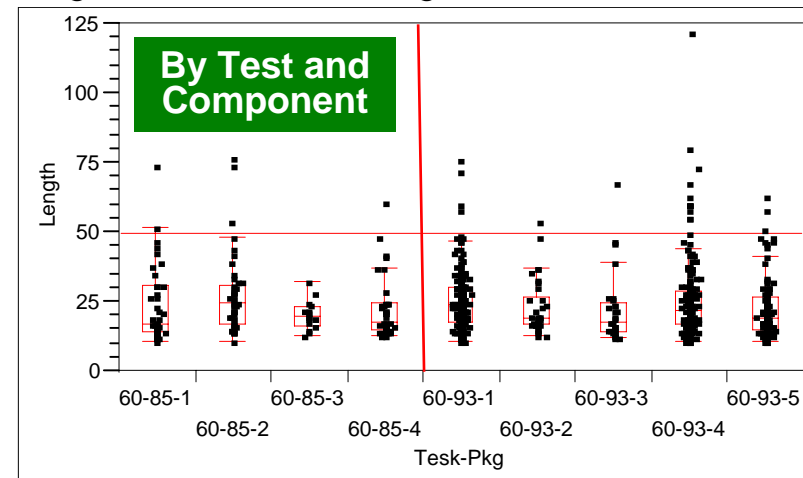
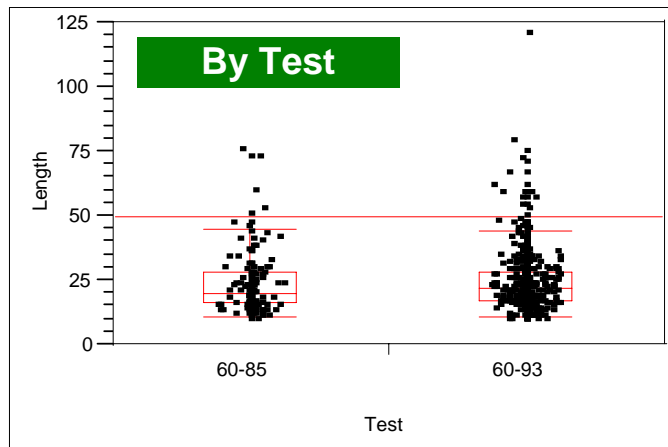


Summary of leads with whiskers at the 3000 and 4000 hours read points, from all humidity levels



Comparison of Humidity Levels and In-group Variations

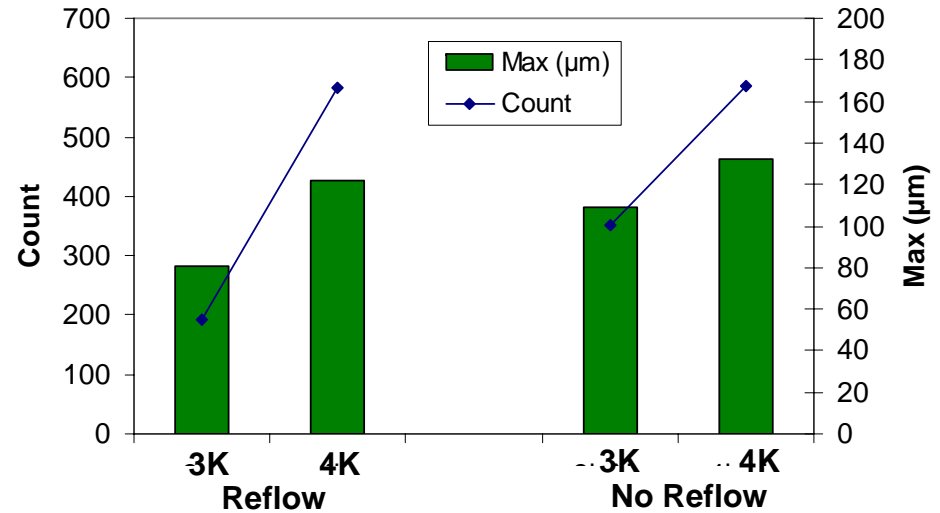
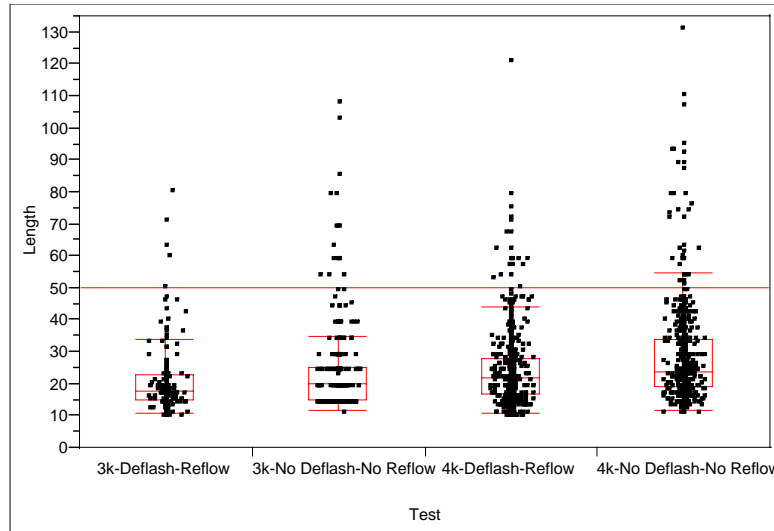
- Whisker population data below are taken at the 4000-hour read point, from the 60C/85%RH and 60C/93%RH tests
- Components in the 60C/93%RH group have more severe level of corrosion. The mean and max whisker length, as well as portion of leads with whiskers are all higher than the 60C/85%RH condition.
- The components within the same test have large variation in whisker population, while maintaining similar mean and standard deviation of whisker length.
- Components with higher level of corrosion also have higher level of whisker growth.



Test	Count of Whiskers	Leads with Whiskers	Max (µm)	Mean (µm)	Std Dev (µm)
60-85	147 (36.8 / part)	13.8%	77	23.9	12.4
60-93	582 (116 / part)	14.2%	122	24.6	11.9

Component	Count of Whiskers	Leads with Whiskers	Max (µm)	Mean (µm)	Std Dev (µm)
60-85-1	42	14.4%	74	23.4	13.6
60-85-2	46	18.2%	77	27.5	14.0
60-85-3	16	6.8%	32	20.5	5.1
60-85-4	43	15.9%	61	22.0	10.4
60-93-1	202	14.4%	76	25.2	10.4
60-93-2	34	11.4%	54	23.2	9.9
60-93-3	29	10.6%	68	22.6	12.7
60-93-4	213	25.0%	122	25.6	13.7
60-93-5	104	9.8%	63	22.4	10.9

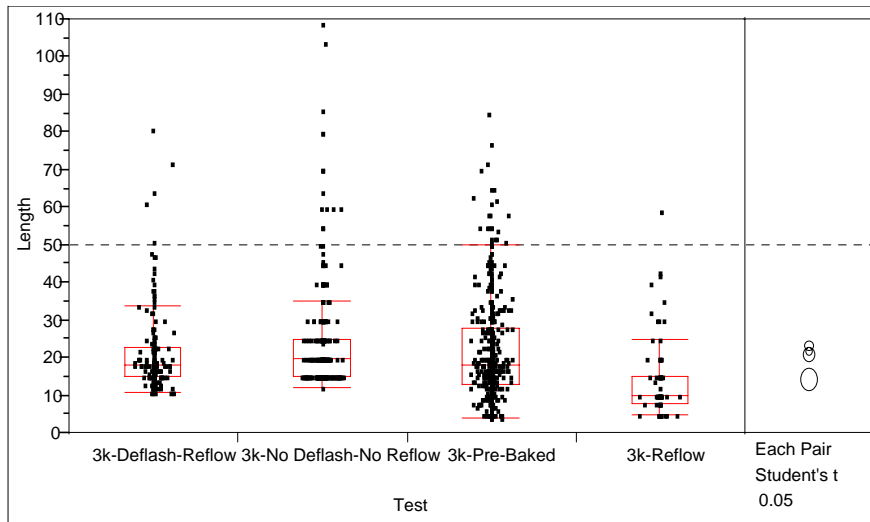
- The growth of whisker in density and length is strongly correlated to the growth in areas of corrosion.
- The longest whiskers are always observed near the Sn-Cu boundaries, where the corrosion of Sn is the most severe.
- The mean of the whisker population grew less than 5um from 3000 to 4000 hours, while the increase of the maximum whisker length is much larger, and varied greatly from component to component.



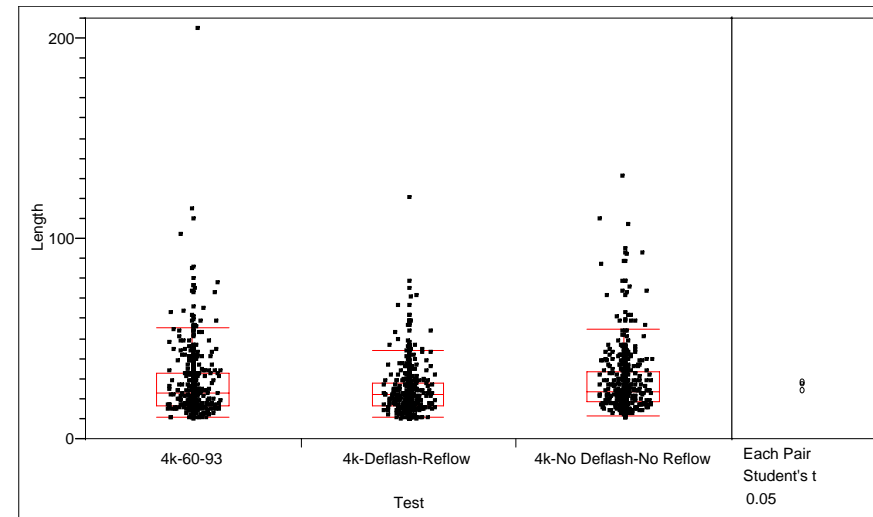
Test	Mean (µ m)	Std Dev (µ m)
3k-Reflow	20.9792	10.5632
3k-No Reflow	23.2663	13.4463
4k-Reflow	24.6065	11.9046
4k-No Reflow	28.6410	15.3801

Test	Count of Whiskers	Max Length (µ m)
3k-Reflow	192	81
3k-No Reflow	353	109
4k-Reflow	582	122
4k-No Reflow	585	132

- Process variations are compared in the following charts.
- At 3000 hours, reflowed components had the smallest mean whisker length, and the lowest whisker count
- At 4000 hours, reflowed components continued to showed a statistically different (lower) mean whisker length, while the density of whiskers is nearly comparable to other cells



Test	Count	Max	Mean	Std Dev
3k-Deflash-Reflow	192	81	20.9792	10.5632
3k-No Deflash-No Reflow	353	109	23.2663	13.4463
3k-Pre-Baked (60C)	519	85	21.8863	13.1246
3k-Reflow	72	59	14.4167	10.6093

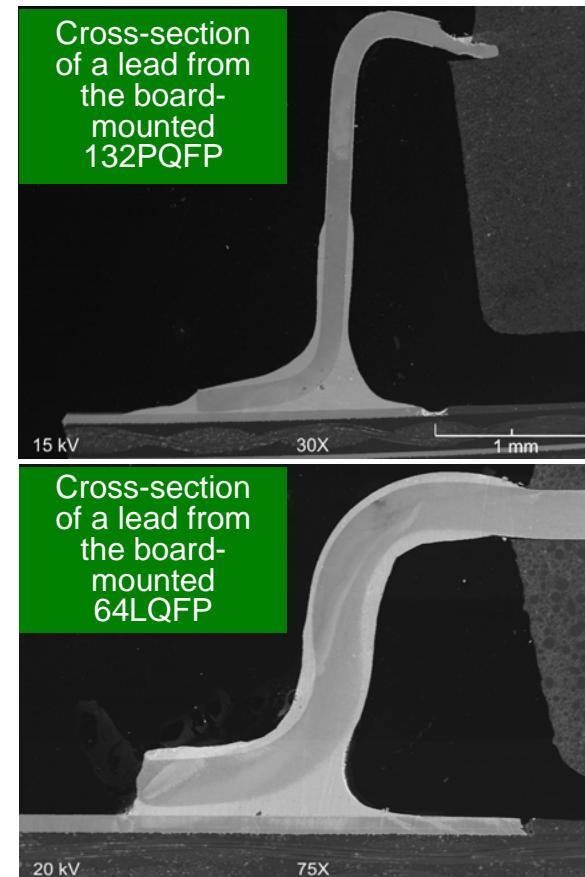
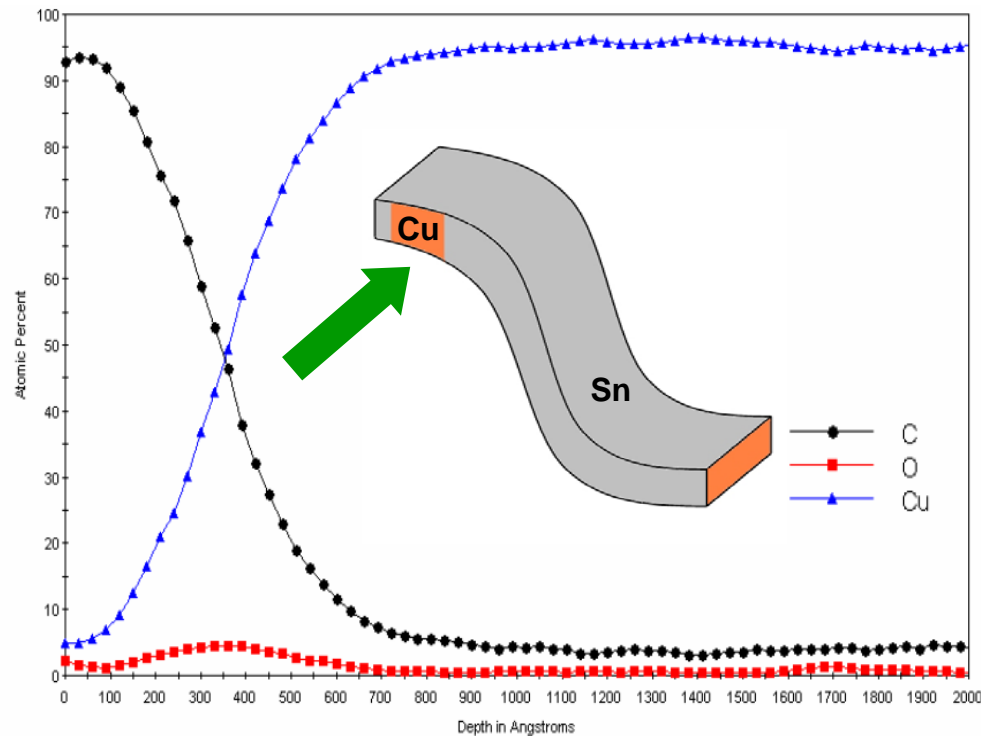


Test	Count	Max	Mean	Std Dev
4k-60-93	524	206	27.5611	16.9320
4k-Deflash-Reflow	582	122	24.6065	11.9046
4k-No Deflash-No Reflow	585	132	28.6410	15.3801

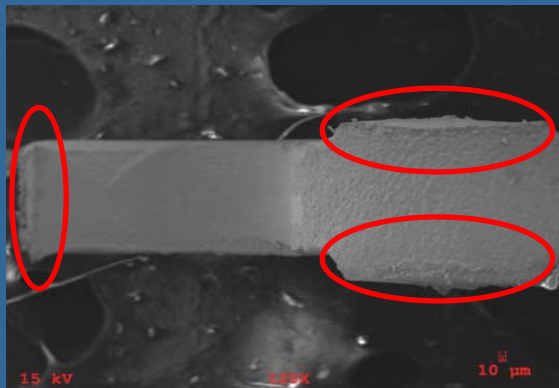
- At 4000 hours, zero whiskers were observed on any of the board-mounted components, at both of the 60/85 and 60/92 conditions.
- There is little corrosion observed on the leads
- No leads were entirely covered with solder paste due to the high profile of the package (image next page)

Package and Test	Process		1000 Hours	2000 Hours	3000 Hours	4000 Hours	5000 Hours
132PQFP 60°C/93%RH	SnPb Paste	No-clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	Test In Progress
		Clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
	SnAgCu Paste	No-clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
		Clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
132PQFP 60°C/87%RH	SnPb Paste	No-clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
		Clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
	SnAgCu Paste	No-clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	
		Clean Flux	0/528lds	0/528lds	0/528lds	0/528lds	

- Leads were cut off from board mounted components that had been tested for 3000 hours at 60C/93%RH
- The exposed Cu near the package is analyzed with Auger on 4 leads
- Trace amount of N was also observed.
- The thick carbon layer is likely coming from flux residue. It covers the Cu and Cu oxide and greatly reduced the rate of the Sn-Cu galvanic reaction
- Note this package type has a very high profile. Leads on smaller package types are often entirely covered with solder paste and the possibility of Sn corrosion is nearly non-existent (i.e. zero whiskers).



- During the elevated temperature / humidity tests, galvanic reaction between Sn and Cu is the driving force for the corrosion of Sn finish and Sn whisker growth
- Statistically the components within each of the tests have similar mean and standard deviation for the Sn whisker population. The localized difference in the level of corrosion among components causes the much greater difference in whisker density and maximum length of whisker.
- Corrosion always starts at the Sn-exposed Cu boundaries, and at extended durations the corrosion grows further into the Sn finish. The longest whiskers are always observed at the Sn-exposed Cu boundaries, where the corrosion remains to be the most severe throughout the tests.



- When corrosion of Sn is not present, such as for the mid-section of the leads on the loose components and the board mounted components, matte Sn does not grow any whiskers during these tests up to at least 4000 hours.
- Board-mounted 132PQFPs showed little corrosion and zero whisker up to 4000 hours, on component mounted with multiple varieties of solder paste and fluxes. Flux residue likely provided a layer of insulation and greatly reduced rate of corrosion.
- On smaller packages, when board-mounted, the leads are covered completely with solder paste and the possibility for the corrosion of Sn and whisker growth is nearly non-existent.
- At normal application temperature and humidity levels, corrosion of the Sn should not occur. Additionally, the current manufacturing processes of Sn plating and board assembly have already provided good protection against Sn corrosion.
- Further process improvements are being developed to increase this protection and further reduce the risk of whisker growth.