Tin Whisker Investigation of SnPb Plated Parts with Marginal Pb Content

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Summary

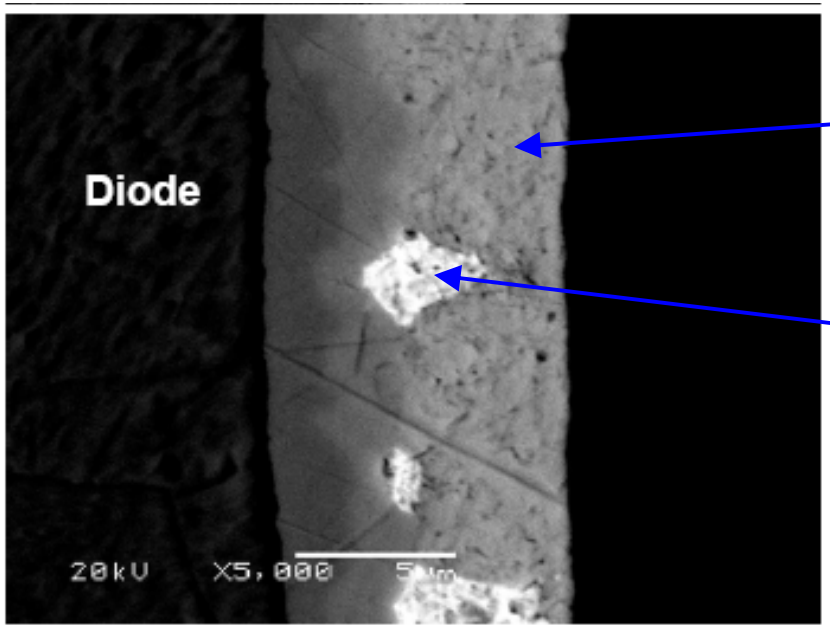
- **Barrel plated finishes have greater variability between surfaces and less homogeneity within a surface than dipped finishes**
- **Lack of homogeneity can lead to XRF results showing finish as acceptable but SEM EDS showing the finish as a failure**
- **Our results show that the lack of homogeneity can pose a tin whisker risk, at least for small spacing distances**
- **Our results also show that changes in environments can restart whisker growth, even after 10 years of storage**

Background

- **Boeing S&IS has a “no tin” policy: >3% Pb required in all Sn-based finishes**
- **Incoming inspection performed on every lot**
  - XRF used for mechanical parts and parts without DPA requirements
  - SEM EDS used for electronic parts with DPA requirements
- **XRF and SEM EDS are both accepted techniques for material identification but can produce different results**
  - EDS looks at an area but is almost all at surface
  - XRF looks at an volume going below the surface
  - If Pb is not homogeneous in material, the two methods results may differ
  - EDS is considered preferable by Boeing

Case of Interest

- **Diodes were barrel plated**
  - Barrel plating inherently has less homogeneity of Pb than does solder dipping
- **XRF results from supplier showed >3% Pb**
- **EDS results at Boeing showed <3% Pb (sometimes virtually no Pb)**
- **Concern about whether parts represented a tin whisker risk**



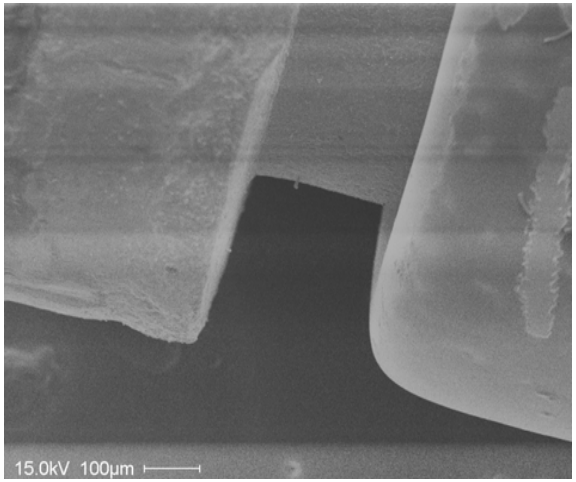
Tin

Lead “clumps”

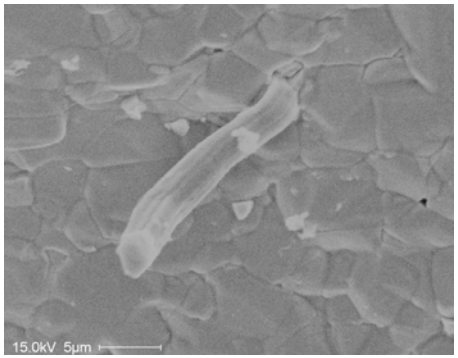
Inspection of Inventory

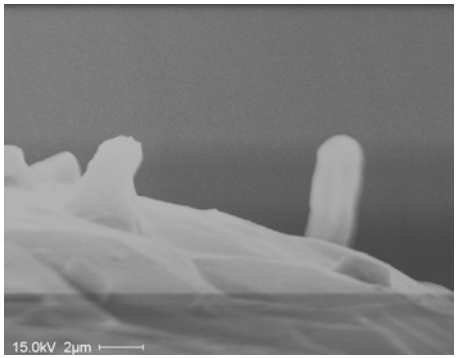
- **History with supplier meant we had many lots of parts with similar plating**
  - Some inventory had already been stored for as much as 10 years
  - Varying XRF and EDS readings of 0% to 2% Pb content
- **>200 parts inspected and one part (10 years old) was found to have 3 whiskers**
  - Longest whisker was about 20 microns, or about 0.8 mils.
  - Per industry standard JESD22A121, this is long enough to constitute a whisker (min 10 microns for whisker)
  - Not long enough to pose a reliability risk

Pictures of As-Stored Whisker

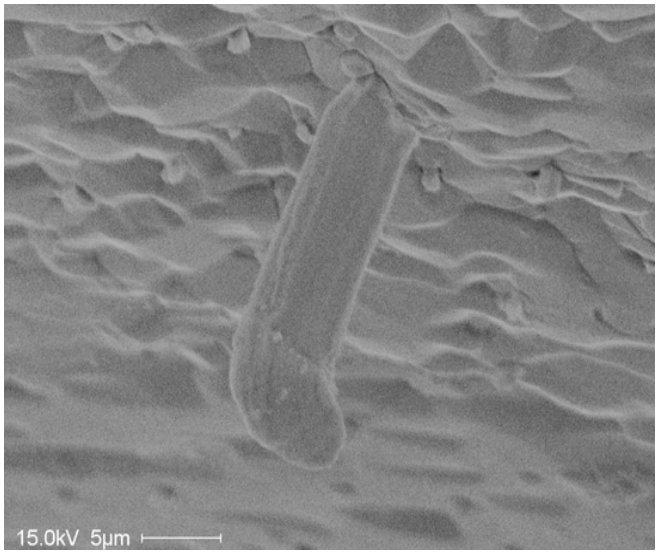


Other Sprouts





Longest Whisker 0.8 mils



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Whisker Growth Experiment

- **Although observed whisker was not long enough to pose a reliability risk, it was unclear whether the growth had saturated**
  - In general, whisker growth is expected to saturate
  - Since part had been in stores for 10 years, whiskers might be as long as they were ever going to get
  - Other old parts might never grow whiskers
- **Took 100 diodes with varying Pb-content and performed steady state growth experiment based on JESD201 and JESD22A121**
  - 57^{o}C, no increase in humidity since space parts will not be in high humidity environment in the field
  - Inspections at 500, 1000, and 5000 hours
- **Results: whiskers were observed to grow during experiment but most were short**

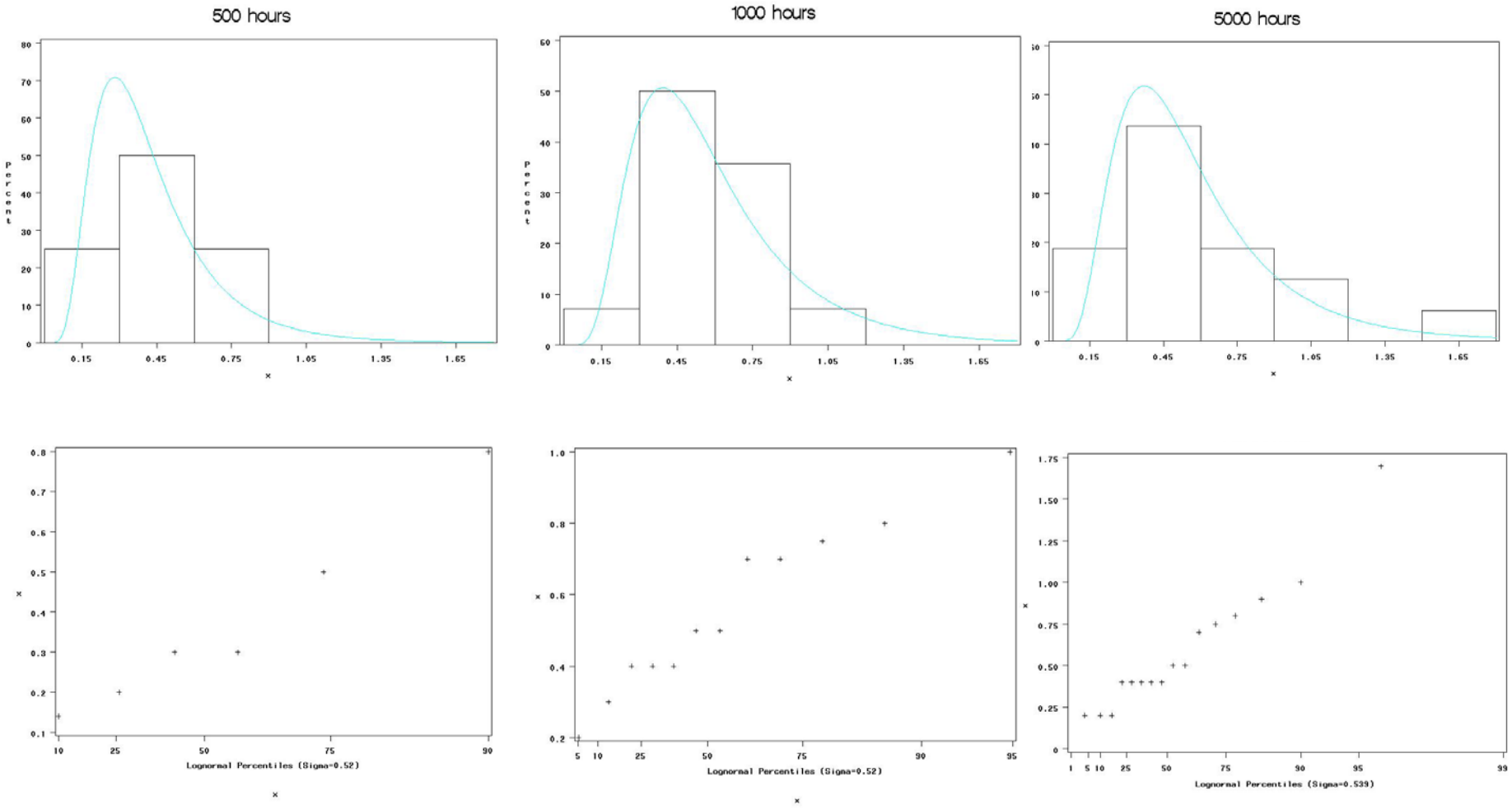
Experimental Results

	500 hrs	1000 hrs	5000 hrs
Part Z	0.15, 0.2, 0.3, 0.3, 0.5, 0.8 (original whisker)	0.5, 0.5, 0.7, 0.75, 0.8, 1 New whiskers: 0.4, 0.2	0.5, 0.5, 0.7, 0.75, 0.8, 1.7, 0.4, 0.4
Part C	No whiskers	0.3, 0.4, 0.4	0.4, 0.4, 0.4, 0.2
Part D	No whiskers	No whiskers	0.2, 0.2, 0.4, 0.4
Part A	No whiskers	0.7	0.9

Modeling Growth

- **Two important aspects to whisker length assessment:**
  - Distribution of whisker lengths at a given point in time
  - Changes in length over time (growth rate)
- **Neither of these aspects is well understood nor do well established models exist**
- **Our experiment**
  - Looked at a sample of parts to try to understand distribution of lengths
  - Took measurements over time to get a sense of growth rate
  - We compared both of these sets of results to work done by CALCE and ESA

Log-Normal Fits of the Data



Confidence Bounds on Lengths at 5000 hours

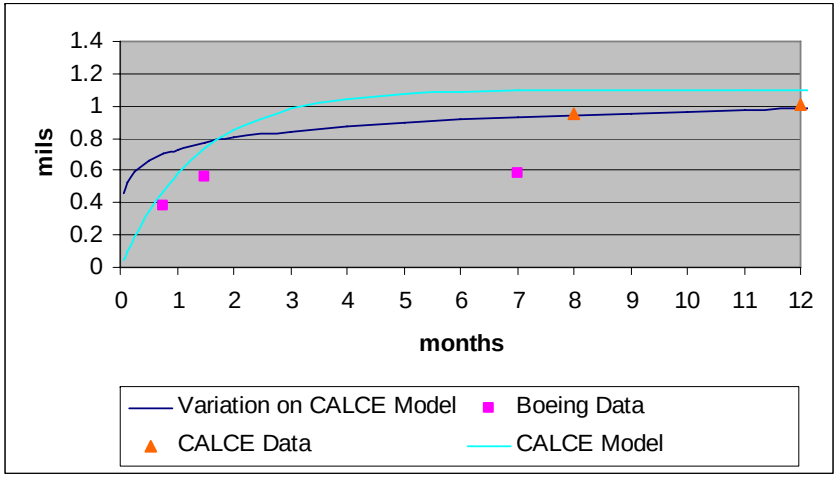
	Median Length	75% Lengths	90% Lengths	95% Lengths	99% Lengths
60% confidence	0.77	1.03	1.35	1.58	2.15
90% confidence	0.86	1.18	1.62	1.96	2.83

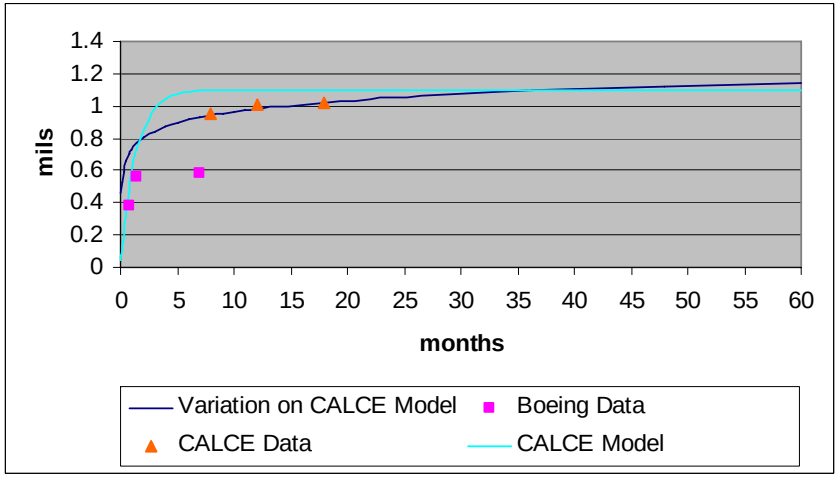
Distributional Results Compared to Literature

- **Our Results:**
  - 500 hours: Mean: 0.38 mils; SD: 0.27
  - 1000 hours (1.5 months): Mean: 0.56 mils, SD: 0.27
  - 5000 hours (7 months): Mean: 0.58 mils, SD: 0.50
- **Fang / CALCE Results (bright tin over brass coupons):**
  - 8 months: Mean: 0.94 mils; SD: 0.5
  - 13 months: Mean: 1.01 mils; SD: 0.45
  - 18 months: Mean: 1.02 mils; SD: 0.45
- **Dunn Results (Bright tin over steel with copper barrier)**
  - 1 month: max: 4 mils
  - 2 months: max: 9 mils
  - 5 months: max 12 mils
  - 22 months: max 24 mils
  - 200 months (15 years): max: 39 mils
  - Note that Dunn's bright tin over brass data shows >50x increase between 1 month and 15 years

Growth Model

Models from the literature predict longer whiskers than we observed.





Boeing Variation of CALCE model is more conservative in long term

Predicted Lengths at EOL

- **Looking at any of the models, 3x growth between end of experiment and EOL would be conservative**

	Median Length	75% Lengths	90% Lengths	95% Lengths	99% Lengths
Point Estimate	2.25	3.01	3.91	4.57	6.12
60% Conf	2.31	3.10	4.05	4.76	6.46
90% Conf	2.57	3.55	4.85	5.88	8.50

Conclusions

- **Specific to Parts Tested:**
  - There is a very low chance of long whiskers on these parts, even after close to 10 years of storage and 15 years of life
- **General Conclusions**
  - Though it has been suggested that >1% Pb is enough to prevent whisker growth, it is possible to have whiskers with 1.5% Pb per EDS.
    - This may be due to the lack of homogeneity of the Pb in the finish for barrel plated parts.
    - These parts would have passed XRF testing (>3% Pb)
  - Even when under normal storage conditions, which has been shown to produce whiskers, whisker growth may not be saturated after 10 years.
    - It may be possible to restart whisker growth under different conditions, suggesting that simply inspecting a large sample of parts before use may not be an adequate tin whisker risk reduction effort.