# Effects of room temperature aging on assembled and non-assembled platings

# Whiskers were observed on unassembled Sn, Sn-Cu, and Sn-Bi MQFP leads

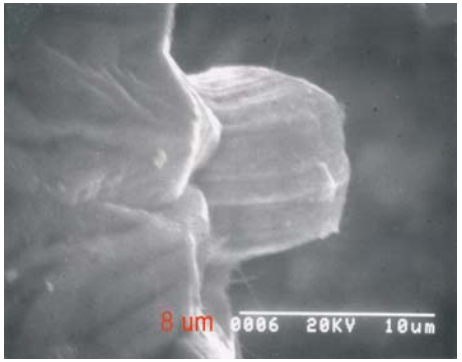
| Plating | Room temp<br>6 months | 55°C<br>7 months |
|---|---|---|
| Sn | Over 15μm whiskers | 0-15μm whiskers |
| Sn-3Cu | Over 15μm whiskers | 0-15μm whiskers |
| Sn-3Bi | 0-15μm whiskers | 0-15μm whiskers |

In this case, room temperature appears more aggressive than 55°C

- –Example of complicated relationship between temperature and whisker formation and growth
- –May be a dependence on lead frame metal

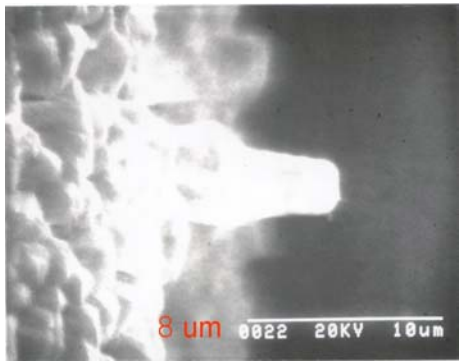
# Examples of whiskers observed on QFPs after constant temperature aging

10 μm




Pure Tin –55°C


Sn/Bi –55°C




Sn/Bi –Room

Whiskers were not observed on assembled QFPs of any plating metallurgy after 8 months of room temperature aging

# Summary of room temperature aging results

| Plating | Room temp. age | Not assembled | Assembled with SAC or Sn-Pb |
|---|---|---|---|
| Sn | 6 months | >15μm whiskers | |
| Sn | 8 months | | No whiskers (bumps) |
| Sn-3%Cu | 6 months | >15μm whiskers | |
| Sn-3%Cu | 8 months | | No whiskers |
| Sn-3%Bi | 6 months | 0-15μm whiskers | |
| Sn-3%Bi | 8 months | | No whiskers |
| Sn-10%Pb | 8 months | | No whiskers |

- Whiskers observed on *un*assembled lead platings, but not assembled lead platings.
- Assembly may hinder whisker growth!

# Limitations of experiment

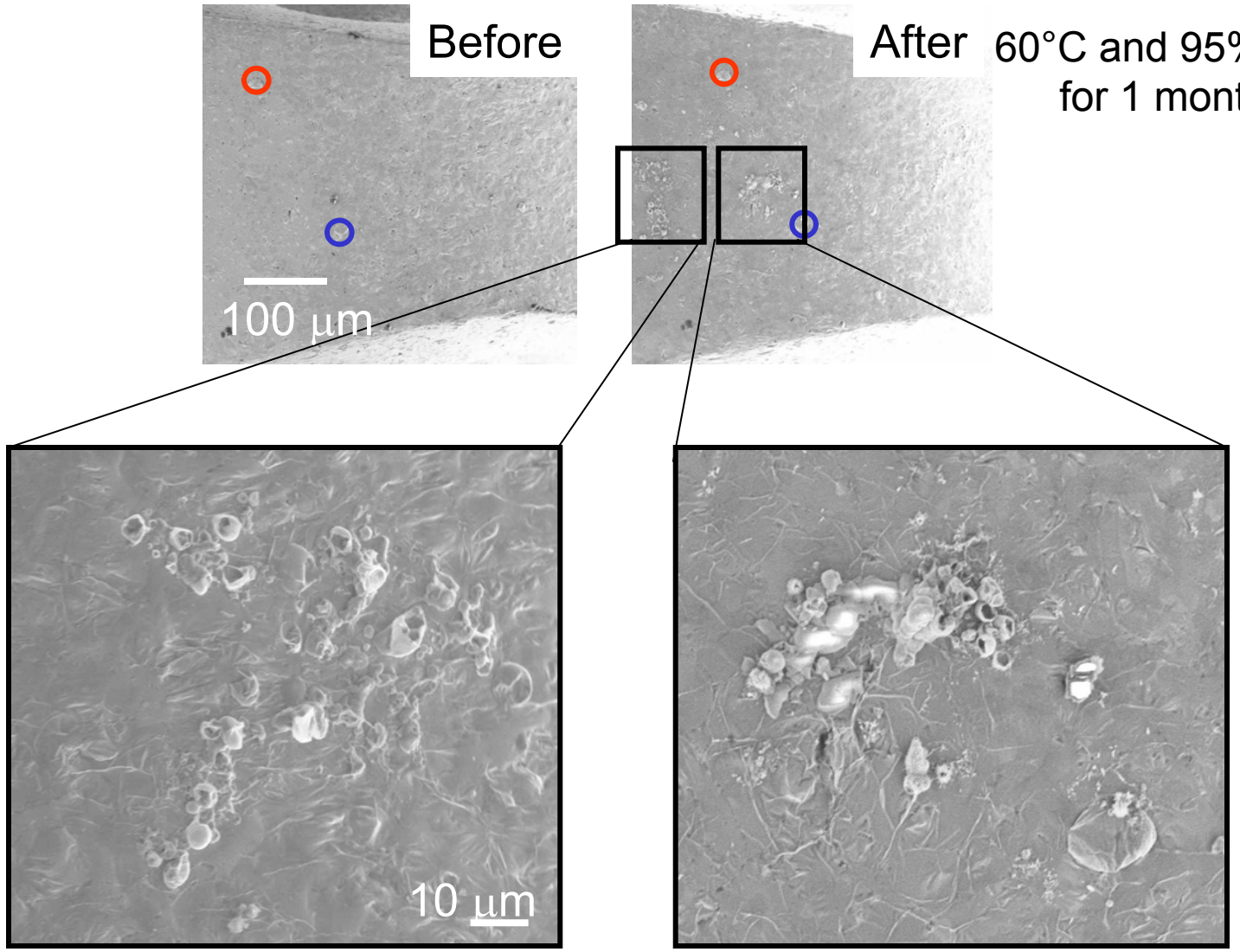
- Unassembled and assembled leads were plated at different times, possibly with different plating chemicals
- Platings were not evaluated directly after assembly (bumps on tin may have formed after assembly)
- QFPs with C7025 leadframe metal showed the lowest propensity to whisker in testing of unassembled components

# Effect of “acceleration tests” on assembled and non-assembled parts

# Assembled and non-assembled QFPs did not whisker after “acceleration tests”

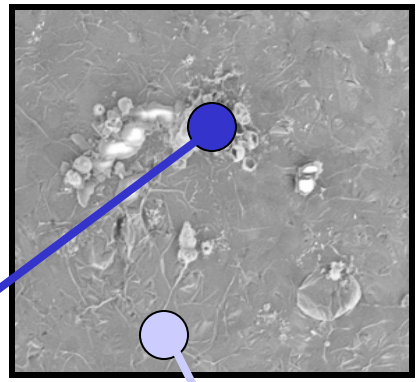
- Thermal cycling – 500 cycles, 20 min./cyc., -55°C to +85°C
- Temperature/humidity aging – 60°C and 95% relative humidity
- Thermal cycling + Temperature/humidity aging

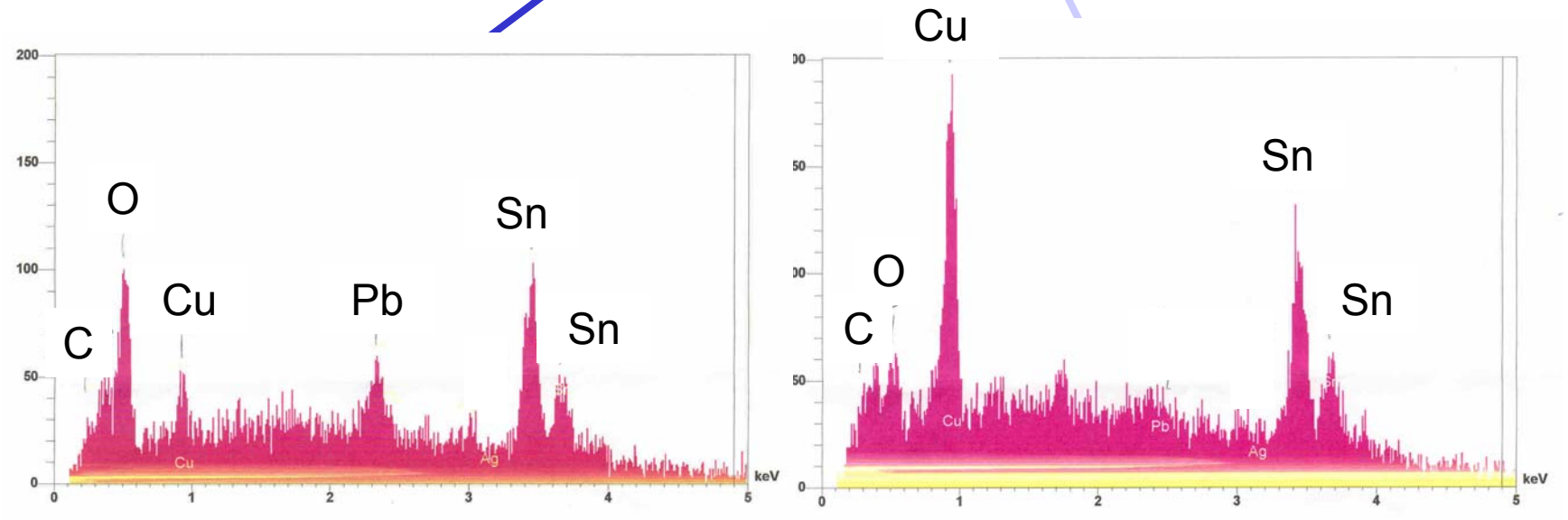
# Tin formations were observed after 60°C/ 95% RH aging that were not whiskers



# Sn formations are likely corrosion products

- Similar formations observed in phase 1
- EDS signal high in oxygen
- Appears black in optical microscope
- Source of Pb unclear





# Summary of “acceleration test” results

| Plating | Assembled | Room temp. age | ATC (500 cyc.) | Temp/RH (4 wks) | ATC + T/RH |
|---|---|---|---|---|---|
| Sn | No | None | No whisk. | No whisk. | No whisk. |
| Sn | Yes | 8 months | No whisk. | Corrosion | Corrosion |
| Sn-3%Cu | Yes | 8 months | No whisk. | No whisk. | No whisk. |
| Sn-3%Bi | Yes | 8 months | No whisk. | No whisk. | No whisk. |
| Sn-10%Pb | Yes | 8 months | No whisk. | No whisk. | No whisk. |

No whiskers observed on assembled or unassembled MQFPs after “acceleration tests.”

# Limitations of experiment

- Unassembled Sn plating did not whisker
- QFPs with C7025 leadframe metal showed the lowest propensity to whisker in testing of unassembled components
- Unassembled and assembled QFPs were plated at different times, possibly with different plating chemicals
- Comparison only to unassembled Sn plating (not Sn-Cu, Sn-Bi, or Sn-Pb)
- Acceleration test conducted after ambient aging for assembled parts

# Possible explanations for "acceleration test" results

No whiskers observed on assembled or unassembled MQFPs after "acceleration tests."

Possible explanations:

- Lead frame base metal (C7025) may be low stress
- "Acceleration tests" may not be effective for C7025

# Leadframe base metal affects plating behavior in whisker "acceleration test"

| Leadframe alloy | Composition | ATC (500 cyc.) | Temp/RH (4 wks) | ATC + T/RH |
|---|---|---|---|---|
| C7025 | 96.2%Cu, 3%Ni, 0.65%Si, 0.15%Mg | No whisk. | No whisk. | No whisk. |
| C151 | Cu, 0.05-0.15%Zr, , 0.005%Mn, 0.005%Fe | Whiskers | No whisk. | No whisk. |
| C194 | Cu, 2.1-2.6%Fe, 0.015-0.15%P, 0.05-0.2%Zn, 0.03%Pb (max) | No whisk. | Whiskers | Whiskers |
| A42 | Fe, 42%Ni | Whiskers | No whisk. | Whiskers |

All matte Sn plating
All unassembled parts

In addition, QFPs grew longer whiskers after room temp aging than after 55°C aging

# Potential acceleration factors for whisker formation and growth

- **Temperature** – High temperatures relieve stress, but enhance diffusion ("sweet spot" of fastest growth believed to be 50-60°C)
- **Humidity** – Oxide formation may constrain film and increase stress, but too much oxide may be difficult to break for whisker growth
- **Mechanical loading** – Compression of the plating expected to increase whisker formation, but conflicting results about actual effect
- **Thermal cycling** – Thermal cycling below 90°C has some effect depending on lead frame alloy, but no clear frequency relationship
- **Mechanical fatigue** – Possible effect in compression, but not well explored in the literature
- **Electrical current** – Whiskering is not believed to be influenced by current, but not well explored in the literature

# The lack of an explanation for the absence of whiskers is a good example of the holes in the proposed whiskering mechanism

We don't understand the mechanism well enough to know

(1) How a design change (e.g. lead frame alloy, plating thickness, plating composition) will impact whisker formation and growth

(2) How to accelerate whisker formation and growth

# Summary

1. A lower incidence of whiskering was observed after room temperature storage on assembled platings compared to non-assembled
2. No whiskering was observed on assembled or non-assembled platings after 1 month 60°C/95%RH or 500 thermal cycles
3. Second level assembly may reduce whiskering by:
   - Covering parts of the plating with solder
   - Completely reflowing the lead plating to reduce residual stresses
   - Reducing stresses in plating that was not reflowed
4. The experiment had drawbacks that limit generalization of any conclusions

# Future work

1. More testing needed to validate the effect of SMT assembly with SAC solder
2. Testing needed to determine the effect of SMT assembly with Sn-Pb solder
3. More testing needed for different lead frame metals
4. Longer and different “accelerated tests” need to be evaluated
5. The whisker mechanism must be understood well enough to construct a predictive model for product design and acceleration testing

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