Gold Embrittlement The Causes and The Effects

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- To set the record straight, I am not a chemist nor am I a metallurgist.
- I have experienced the effects of gold embrittlement and as a result I have done some research.
- The results of that experience and research is presented here.

What is gold embrittlement

- Solder joint embrittlement is defined as a change of solder joint durability due to dissolution and/or reaction with a finish such as gold and/or palladium.

What is the Problem?

- Gold, in sufficient quantities, in a solder connection containing tin can fail with time
- This is most common in RF power transistors soldered to a board

What does this mean to us?

- If the gold is not completely dissolved in the solder, in time, with thermal cycling, the solder joint may fracture and fail at the tin/gold interface.
- This could (and has) caused failures in RF power amplifiers where the devices are still fully functional.

What is the Cause for this Problem?

- One possible cause of the problem is gold-tin formation in the joint
- If the saturation rate of gold in the tin is high enough, failure will occur
- Large, weak grains, usually AuSn4, in the gold-tin solder joint add to the problem.

How do we correct for this condition?

- Per IPC J-STD-001G (Requirements for Soldered Electrical and Electronic Assemblies);
- Gold removal is performed to reduce the risk of failure associated with embrittled solder. Gold embrittlement is not a visually inspectable anomaly. In cases where analysis has determined there is a gold embrittlement condition, the gold embrittlement **shall** be considered to be a defect, see IPC-HDBK-001 or IPC-AJ-820 handbook for guidance.

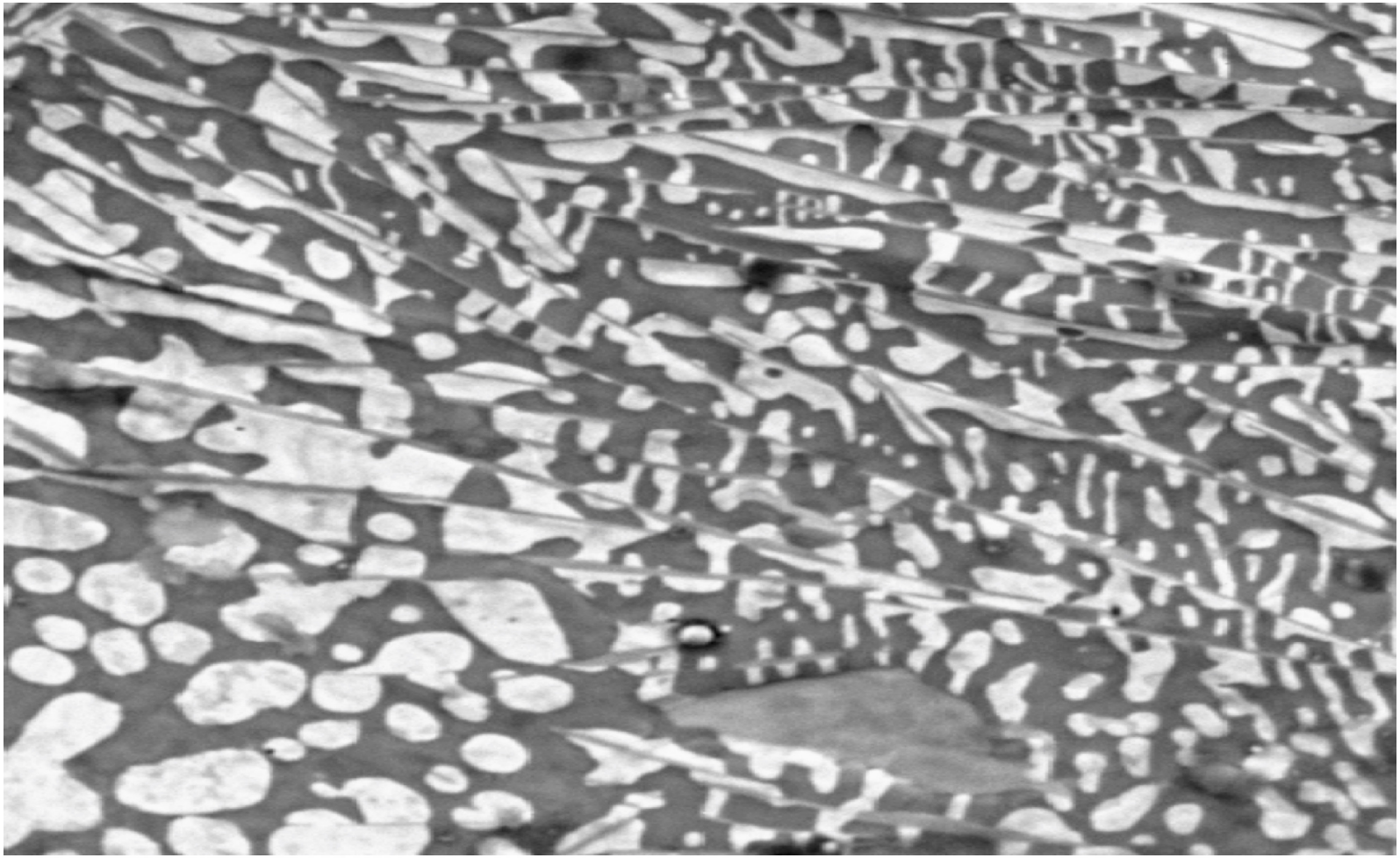
From IPC-J-STD-001G 2017

- Gold **shall** be removed:
- a. From at least 95% of the surfaces to be soldered of the through-hole component leads with >2.54 µm (100 µin) or more of gold thickness and all through-hole leads that will be hand soldered regardless of gold thickness.
- b. From 95% of all surfaces to be soldered of surface mount components regardless of the gold thickness.

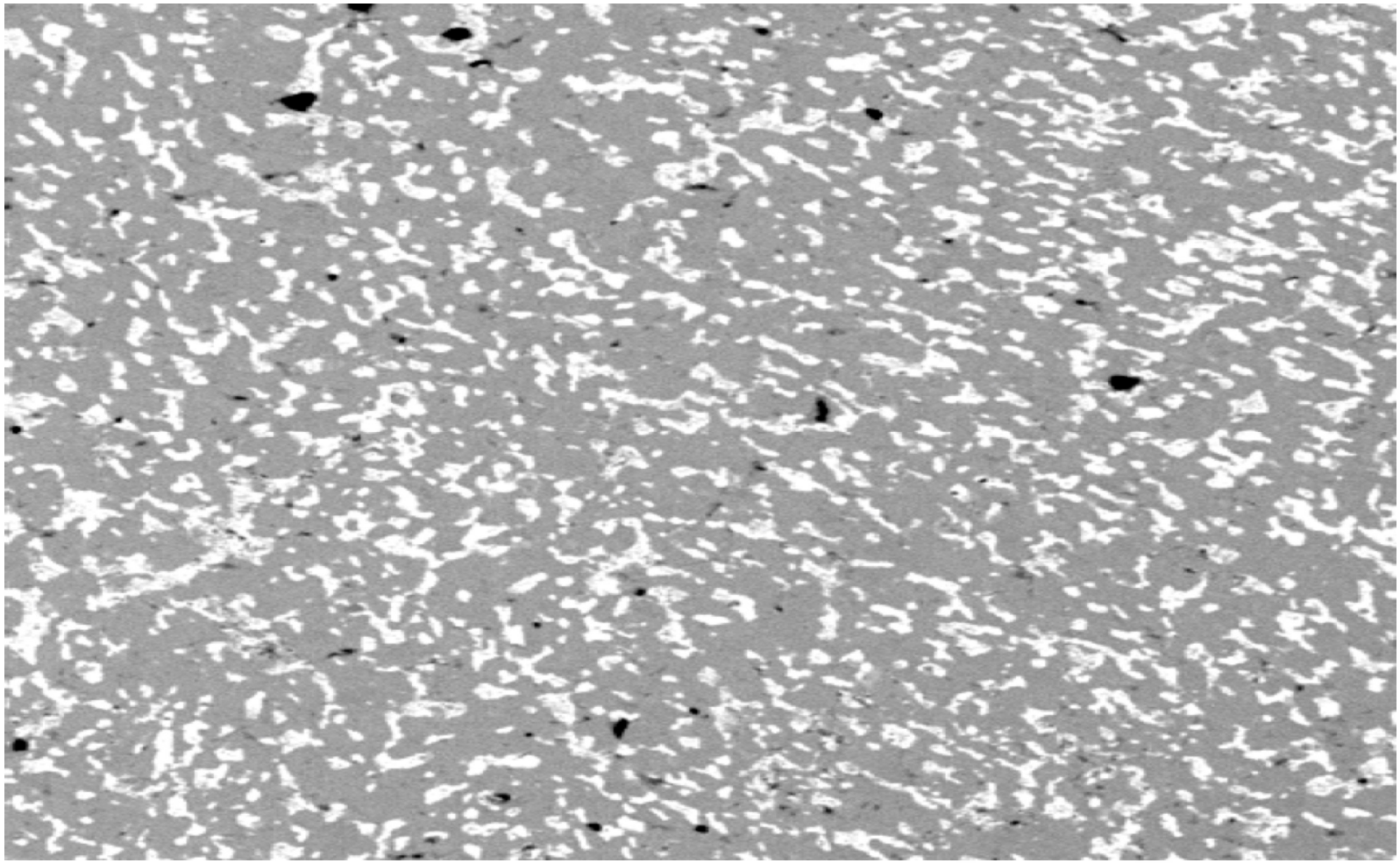
- c. From the surfaces to be soldered of solder terminals plated with 2.54 µm (100 µin) or more of gold thickness and from all solder cup terminals, regardless of gold thickness.
- A double tinning (use of two solder pots) or dynamic solder wave may be used for gold removal prior to mounting the component on the assembly.

- Note: Gold embrittled solder connections can occur regardless of gold thickness when solder volume is low or solder process dwell time is not sufficient to allow the gold to dissolve throughout the entire solder joint.
- The following two slides show an embrittled structure then a normal structure

Gold Embrittlement in Eutectic Tin-Lead microstructure



Normal Eutectic Tin-Lead Solder Microstructure



- When solder cools, different crystalline structures are formed in the cooling process
- When sufficient gold is present, AuSn4 is one of the structures
- This structure is very brittle, where as the other structures formed are more malleable
- It is this brittle structure that causes the problem
- With stress, the solder will fracture at this brittle area

- The fracture will cause a discontinuity in the connection and a failure
- This fracture may take weeks or years to occur
- Thermal cycling, as in a PA heating and cooling, will hasten the joint failure because of differential expansion between the transistor lead and the board material and will put stress on the joint
- This stress will pull the joint apart

- For us, the most probable place for gold embrittlement to take place is on the lead to board interface for a RF transistor
- We usually do not provide enough heat, dwell time and solder to fully dissolve the gold plating because we tend to use minimum heat and solder to protect the transistor
- In time this connection will fail
- Has anyone had a RF power transistor fail and find the bottom of the transistor lead and the board under that lead black?

- If so, you have experienced gold embrittlement.
- I have talked with a RF design engineer about this and his company has seen this same thing, prior to implementing measures to remove the gold plating on the transistor leads.
- The device involved is probably still good.

How Do We Prevent this Problem?

- Remove the gold plating from transistor leads by double tinning the leads
- Use sufficient solder and heat to dissolve any remaining gold when soldering the transistor to the board

How do We Fix Existing Problems?

- Remove the transistor from the board
- Remove the black residue (probably lead and/or tin oxides) from the transistor and the board
- Retin both the board and the transistor
- Verify that the transistor still checks good
- Reinstall the transistor using sufficient solder and heat

References

- IPC J-STD-001G 2017 Requirements for Soldered Electrical and Electronic Assemblies – Available from IPC cost $168.00
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- MACOM Transistor Mounting and Soldering AN3025 – Available here - https://cdn.macom.com/applicationnotes/AN3025.pdf

Questions?