A Practical Investigation Into the Use of No Lead Solders for SMT Reflow

Heller Industries and Soldering Technology
David Heller and Jim Raby

Forces Mandating the Change to Lead Free

- ISO 14000
- European Community Directives
- WEEE – Waste from Electronic and Electronics Equipment (Jan 1, 2008)
- Danish Environmental Agency
- Green environment = lead free / halide-free
- Japanese companies driving quick implementation
- Market Demand – Consumers will opt for lead free products

No Lead Solder is Coming

QUESTIONS

- How well does it work?
- What do I have to do differently?
- What profile shape, peak temperature, liquidous time?
- What atmosphere, air or nitrogen?
- Should I be concerned?

ANSWERS

- Lead Free solders offer the same performance as Tin/Lead (better in some cases).
- Modify existing process – no radical change
- Profile shape is similar with slightly higher peak temperatures.
- Both Nitrogen and Air atmospheres can be used with equal success. (Depends on paste formulation and manufacturer's recommendation).
- No cause for concern, embrace the change and utilize lead free as a marketing tool to increase business.

PROPRIETARY AND CONFIDENTIAL INFORMATION

Candidate Alloy Melting Temperatures

ALLOY COMPOSITION, wt%	MELTING TEMPERATURE OR RANGE, °C
Sn100	232
SnCu0.7	227
SnAg3.5	221
SnAg3.8Cu0.7	217
SnAg3.88Cu0.7Sb0.25	217
SnAg2.5Cu0.8Sb0.5	210-216
SnBi5Ag1	203-211
SnBi5Ag1+	209-217

No Lead Characteristics

- Slightly Stronger
- Comparable Fatigue Life to 63/37
- Coarser Grain Structure – Joints Look Ugly but are fine
- Bismuth – Reduces melting point but joints can be brittle depending on formulation
- Antimony –
  - Gives better stability at low temperatures when used with tin
  - Less expensive than Silver

Eutectic Vs. Lead Free Process window comparison

	Eutectic (Tin Lead)	Lead Free
Melting Point	183°C	216°C – 220°C
Typical Peak Temperature Range	205°C - 215°C	225°C – 235°C
Max PCB Temp	230°C – 240°C	230°C – 240°C
“True” Process Window	15°C – 35°C	5°C - 15°C

Conclusions

- The true process window for Lead Free Solder is 10 - 20°C less than standard eutectic tin lead
- Delta T on the PCB becomes critical
- Process repeatability is most important – Example: If process window is 10 °C and Delta T is 10 °C, the process would be running with 0 margin of error

Other Considerations

- Components and Boards
  - Problems with electrolytic caps / connectors / IC’s – Some can’t take the heat
  - Component availability is limited in no lead versions
  - No drop-in universal no lead paste – work with vendors is critical
  - Void formations can be an issue in no leads

Soldering Technology International

Investigation

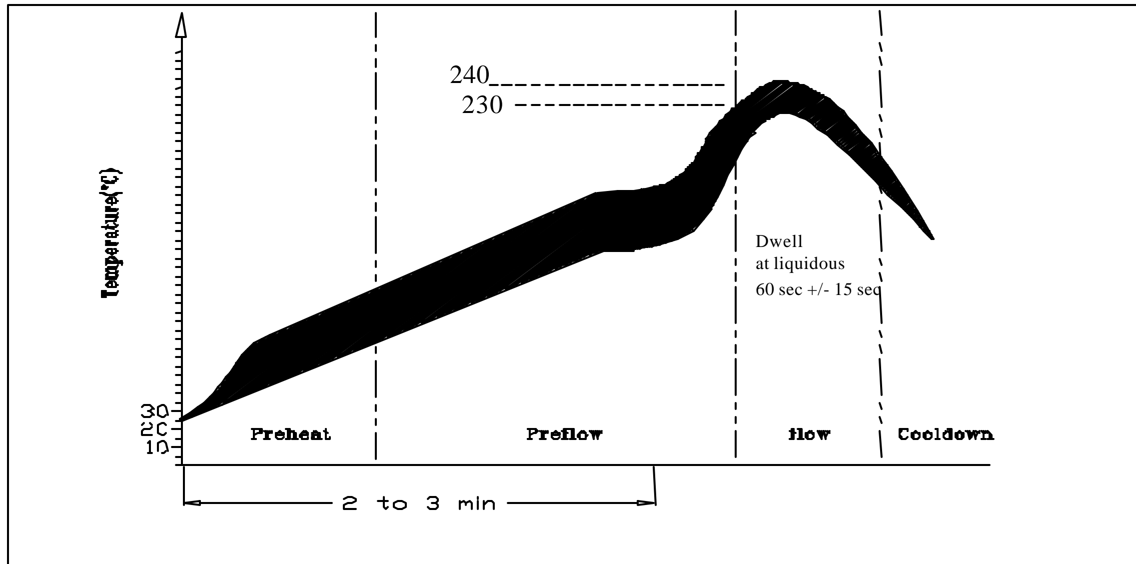
- The testing was conducted at Soldering Technology International – a world renowned 3rd party laboratory and training center.
- A variety of board and component types were run through different profiles and atmospheres to determine what worked and what did not.
- Procured specially prepared components with no lead metalization. Either tin, palladium silver or nickel.
- For BGAs, removed tin/lead balls and re-balled with tin/silver balls.
- Procured test board with bare copper pads protected with OSP. (Future testing to be run with HASL Lead Free Pads)
- Tested 2 pastes:
  - 96.5% Sn/3.5% Ag with RMA flux melt point 221°C
  - 96.2% Sn / 2.5% Ag / .8% cu .5% Sb with no clean flux melt point 216°C

Differences –
Tin Silver Vs. Tin Silver Copper Antimony

- With .5% Antimony
  - Cold temperature stability is enhanced
  - Reduced Copper intermetallics
  - Improved thermal fatigue
  - 20% less expensive than Tin Silver

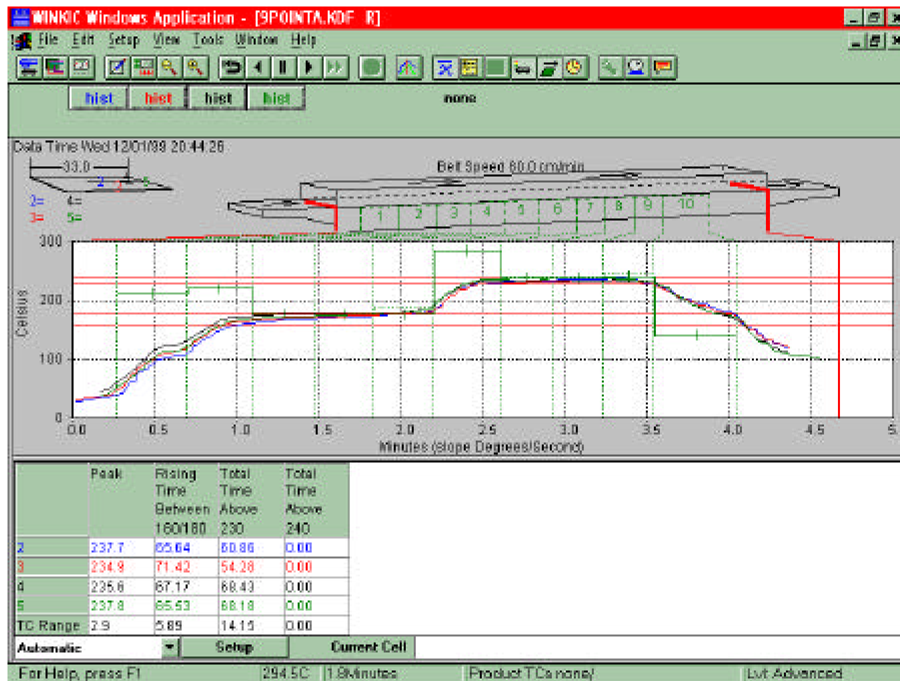
Investigation

- Ran in Both Nitrogen and Air
- Nitrogen Testing Utilized 1000 PPM O2
- Tested Peak Temperatures of both 240°C and 230°C to determine if lower temperatures could be used to protect components



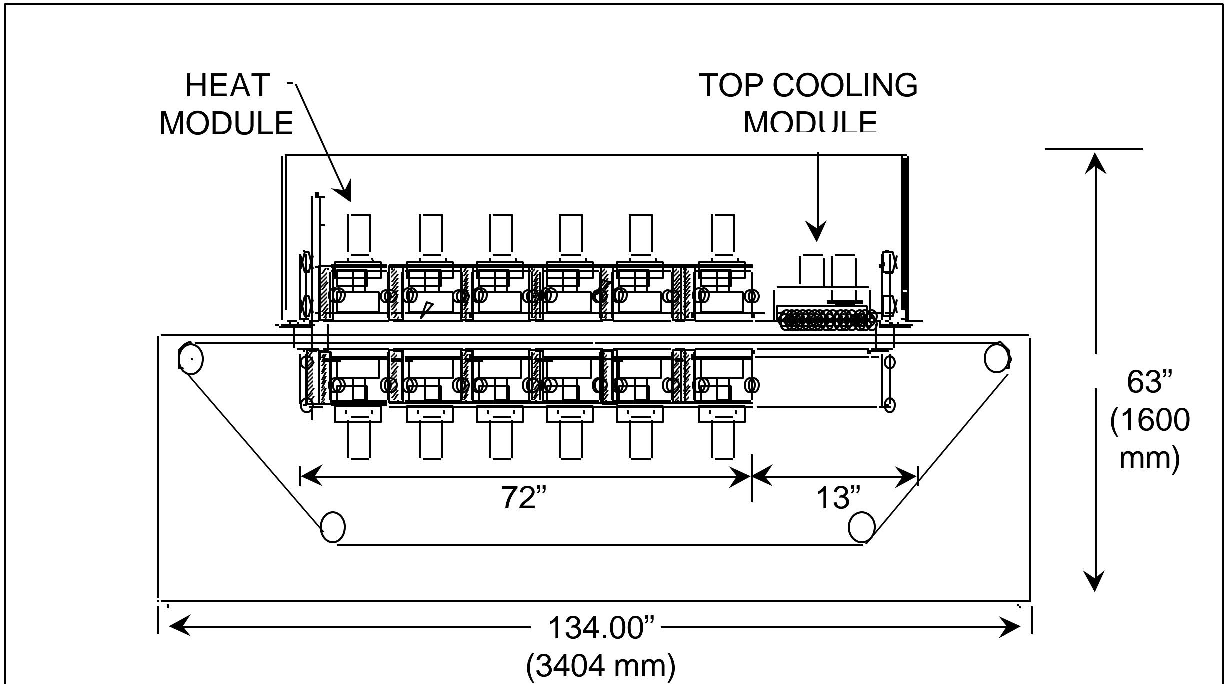
- **Reflowed recommended profiles of 240°C max temp and 60 seconds liquidous. Also tested at 230°C maximum temperature to evaluate process latitude. Tested in Air atmosphere and Nitrogen at 1000 ppm oxygen using a tent shaped profile**

No Lead Solder Paste Profile (Alternative Approach – Preferred in Japan)

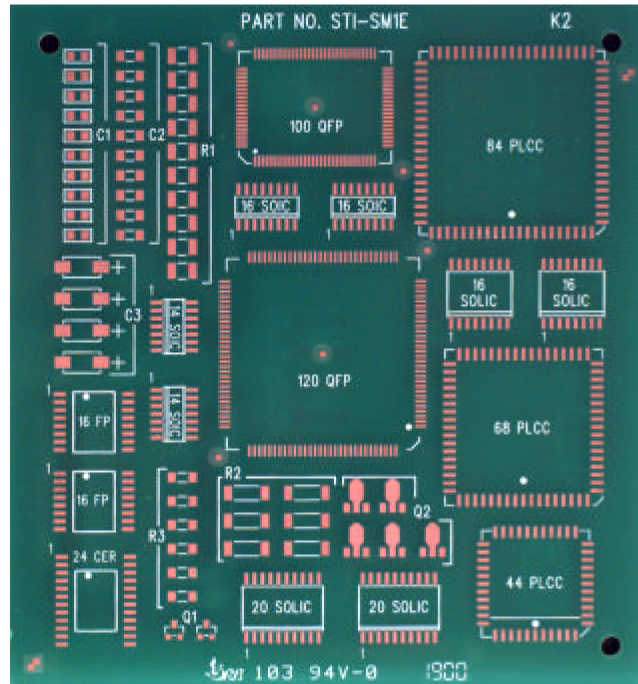


	Peak	Rising Time Between 160/180	Total Time Above 230	Total Time Above 240
2	237.7	65.64	60.86	0.00
3	234.9	71.42	54.28	0.00
4	235.6	67.17	68.43	0.00
5	237.8	65.53	68.18	0.00
TC Range	2.9	5.89	14.15	0.00

Used a Heller 1700S with 6 zones heating, 1 zone cooling.

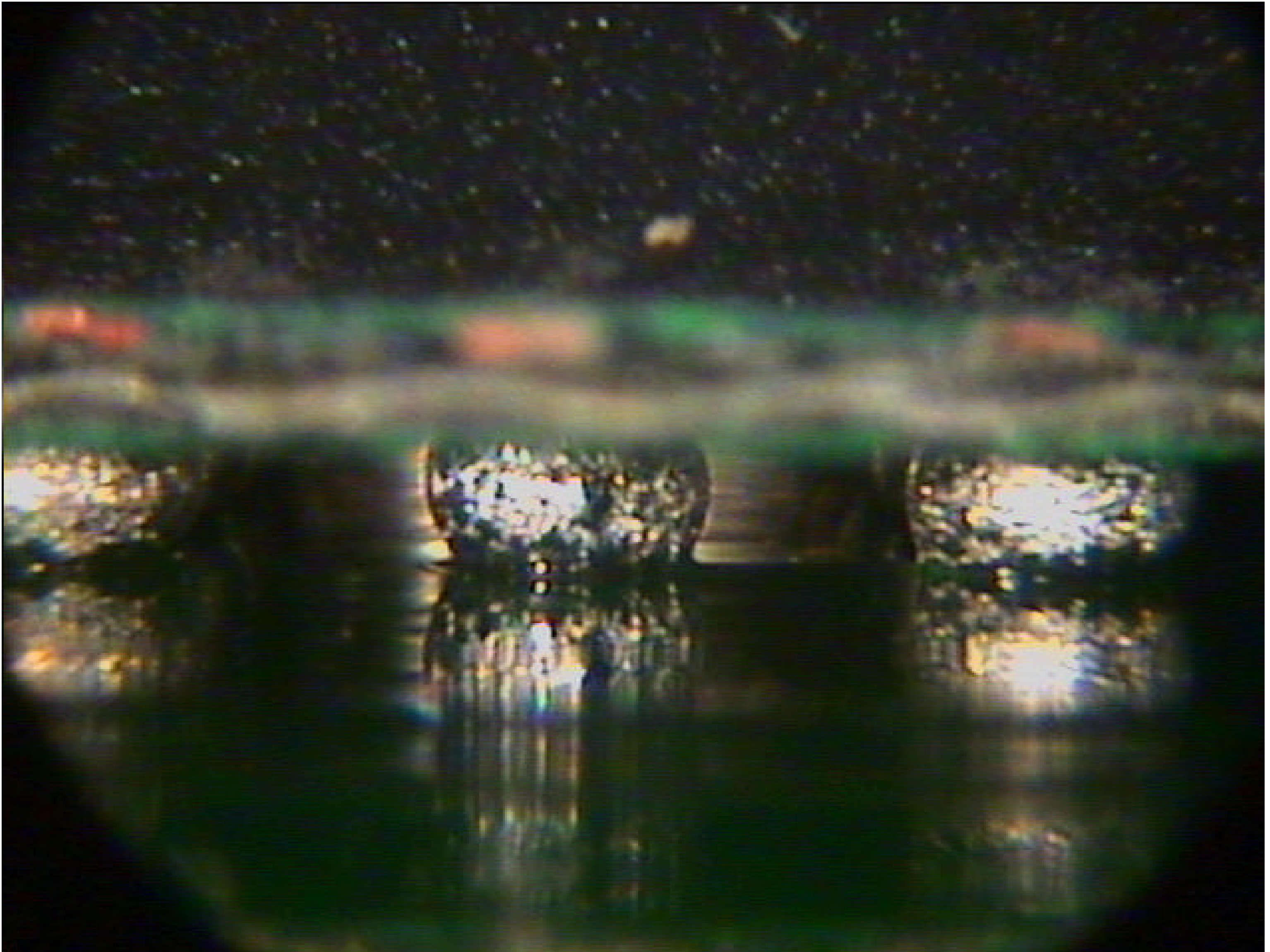


SMT Board



Test # 1

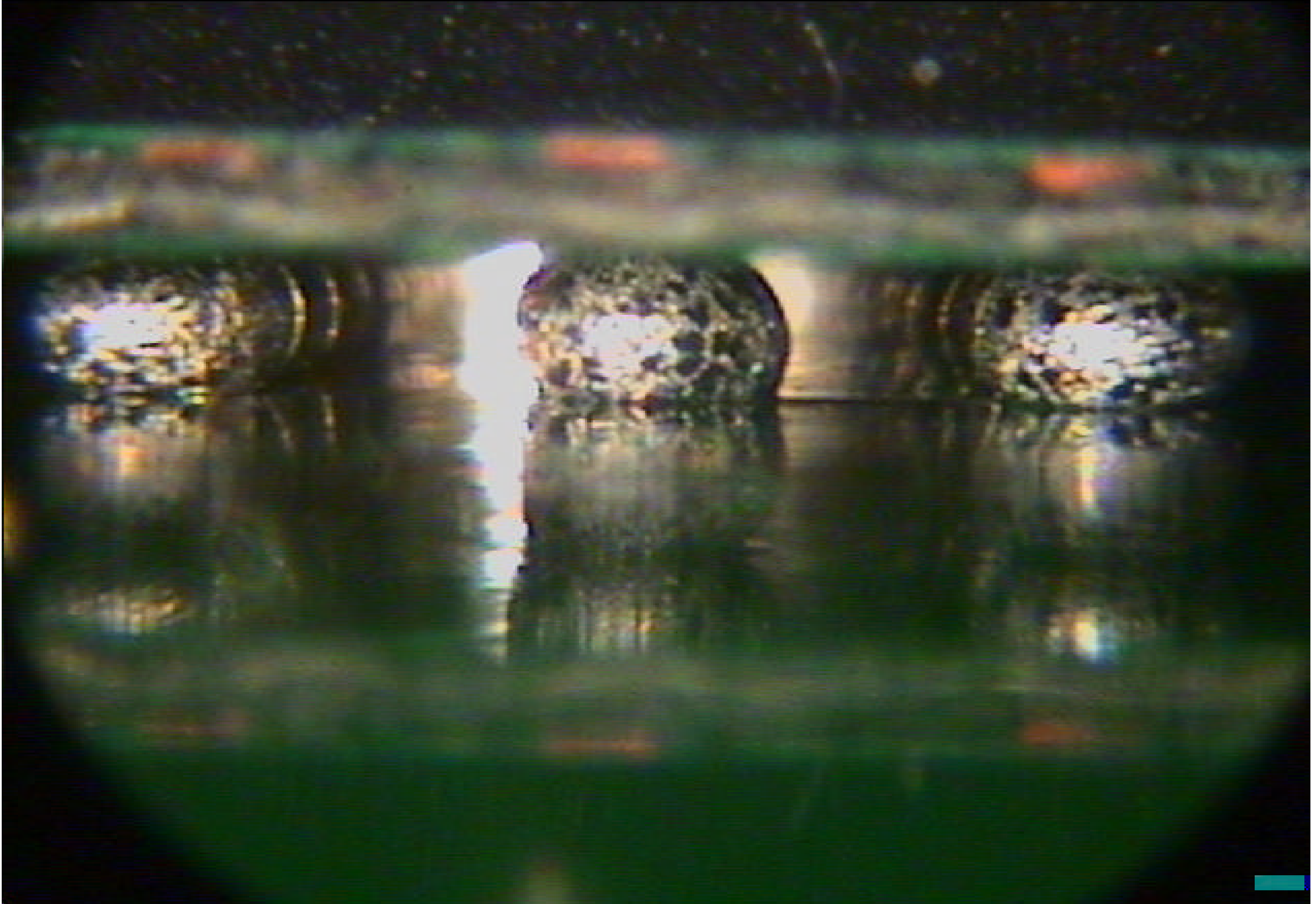
Tin Silver, BGA 230°C N2



Good Wetting but Surface Finish Looks Grainy
(Acceptable ball formation)

Test # 2

Tin, Silver Copper, Antimony, BGA 230°C N2



Good Wetting with Grainy Surface Finish

Test # 3

Material: Tin Silver Atmosphere: Nitrogen Temperature: 240°C

Thin Intermetallic Layer   No Voids

BGA Cross Section

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Test # 4

Material: T, S, C, A **Atmosphere: Nitrogen** **Temperature:240°C**

Thin Intermetallic Layer No Voids

BGA Cross Section

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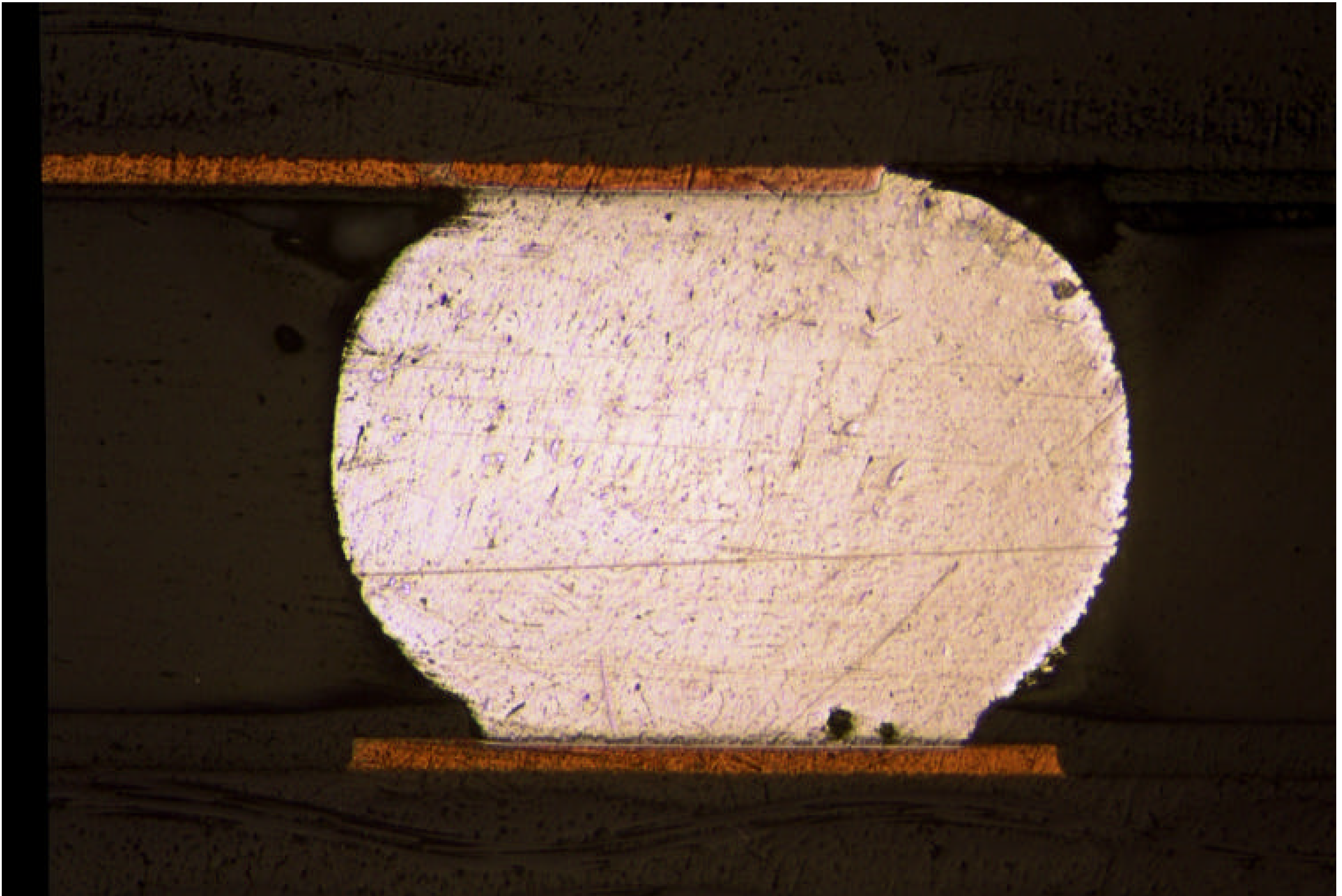
Test # 5

Material: Tin Silver   Atmosphere : Air   Temperature:240°C

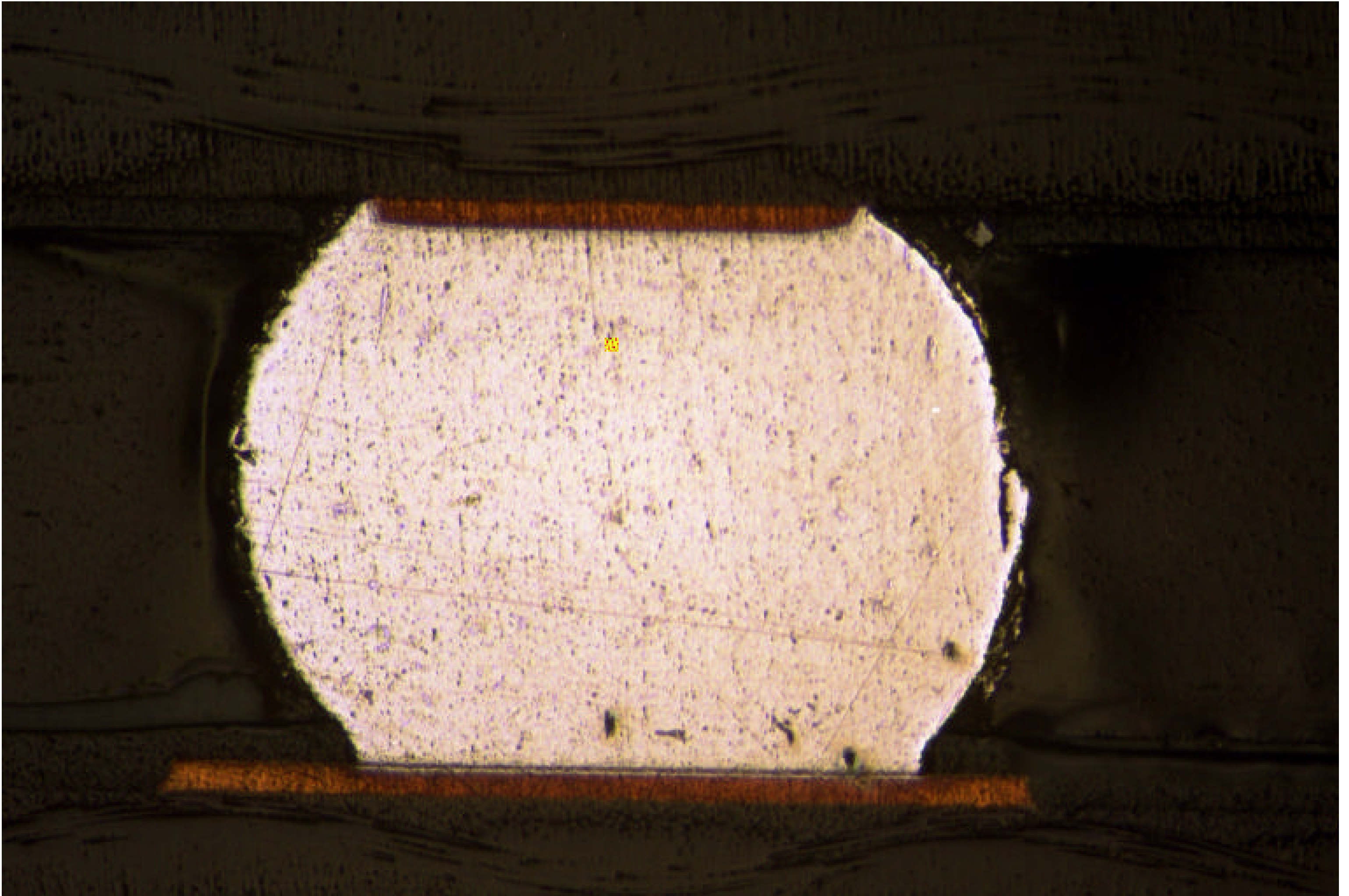


Small Voids Seen but within IPC Spec

BGA Cross Section

Test # 6

Material: T, S, C, A **Atmosphere: Air** **Temperature:240°C**

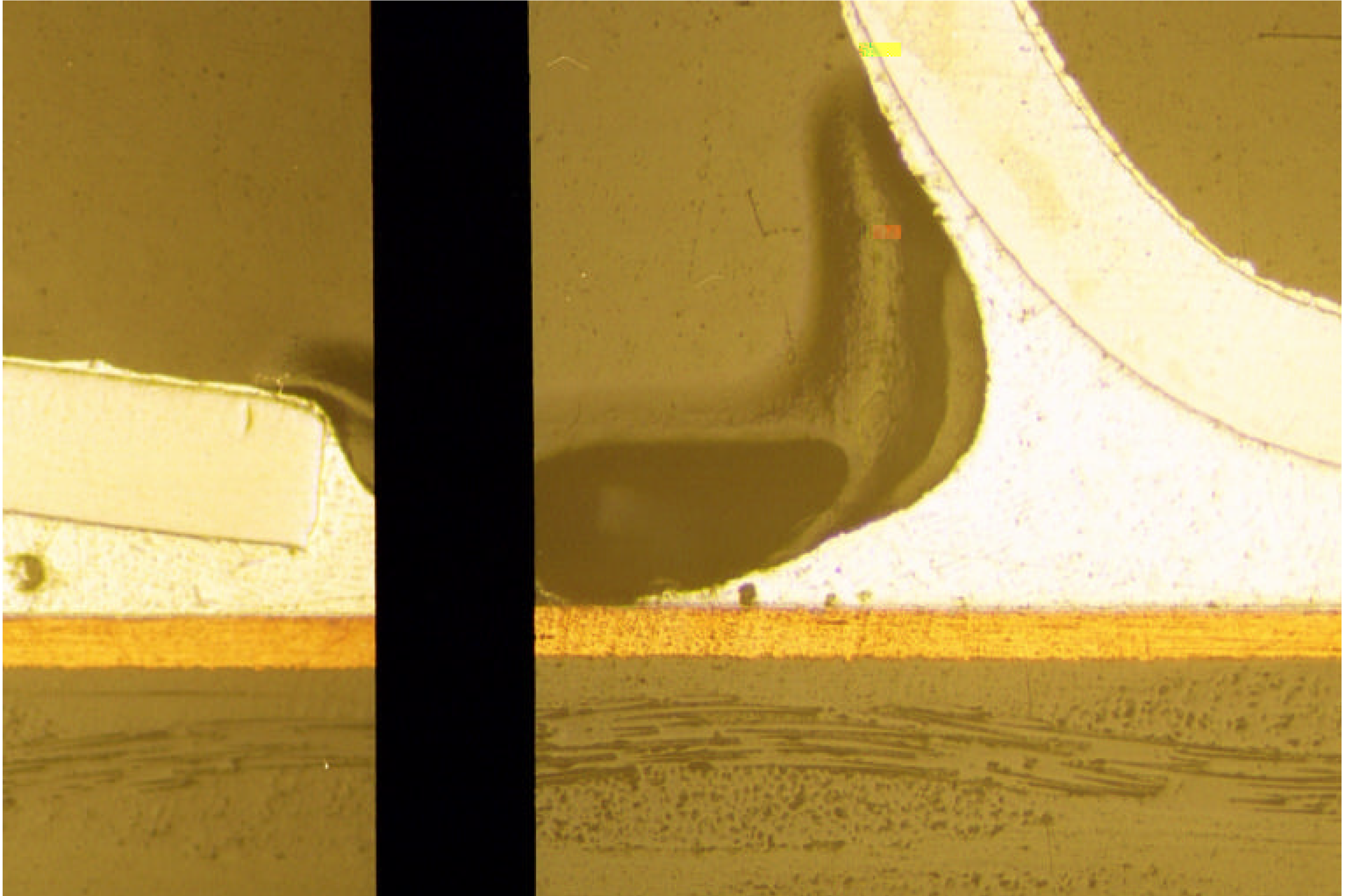


Small Voids but within Acceptable Limits

BGA Cross Section

Test # 7

Material: Tin Silver   Atmosphere: Nitrogen   Temperature:240°C

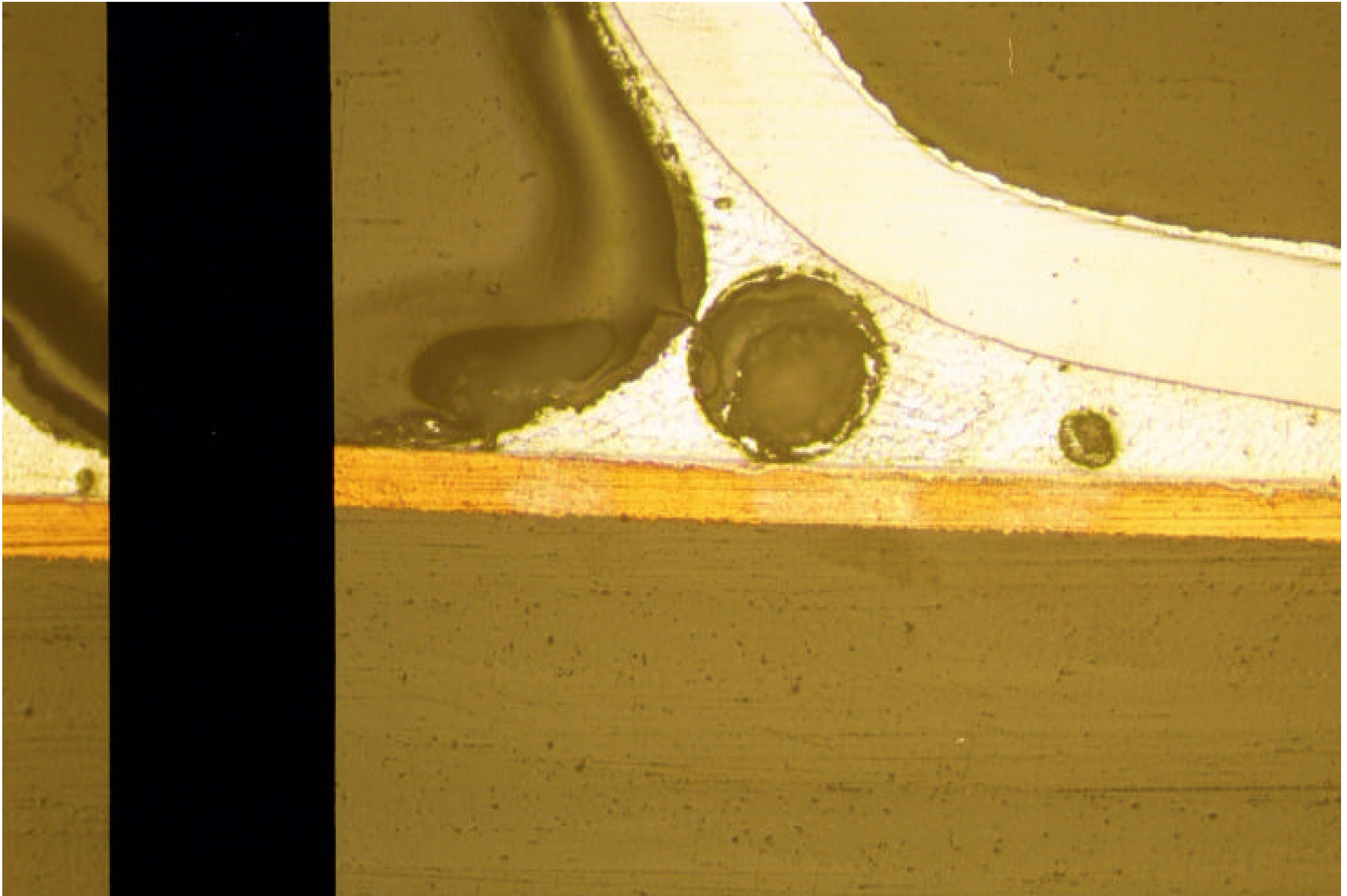


Excellent Wetting in Toe and Heel – Small, Acceptable Voids

Cross Section of QFP Solder Fillet

Test # 8

Material: T, S, C, A   Atmosphere: Nitrogen   Temperature:240°C



Large Unacceptable Void – Likely Due to Bad Wetting
(Lead Free HASL Candidate)

Solder Fillet with Void

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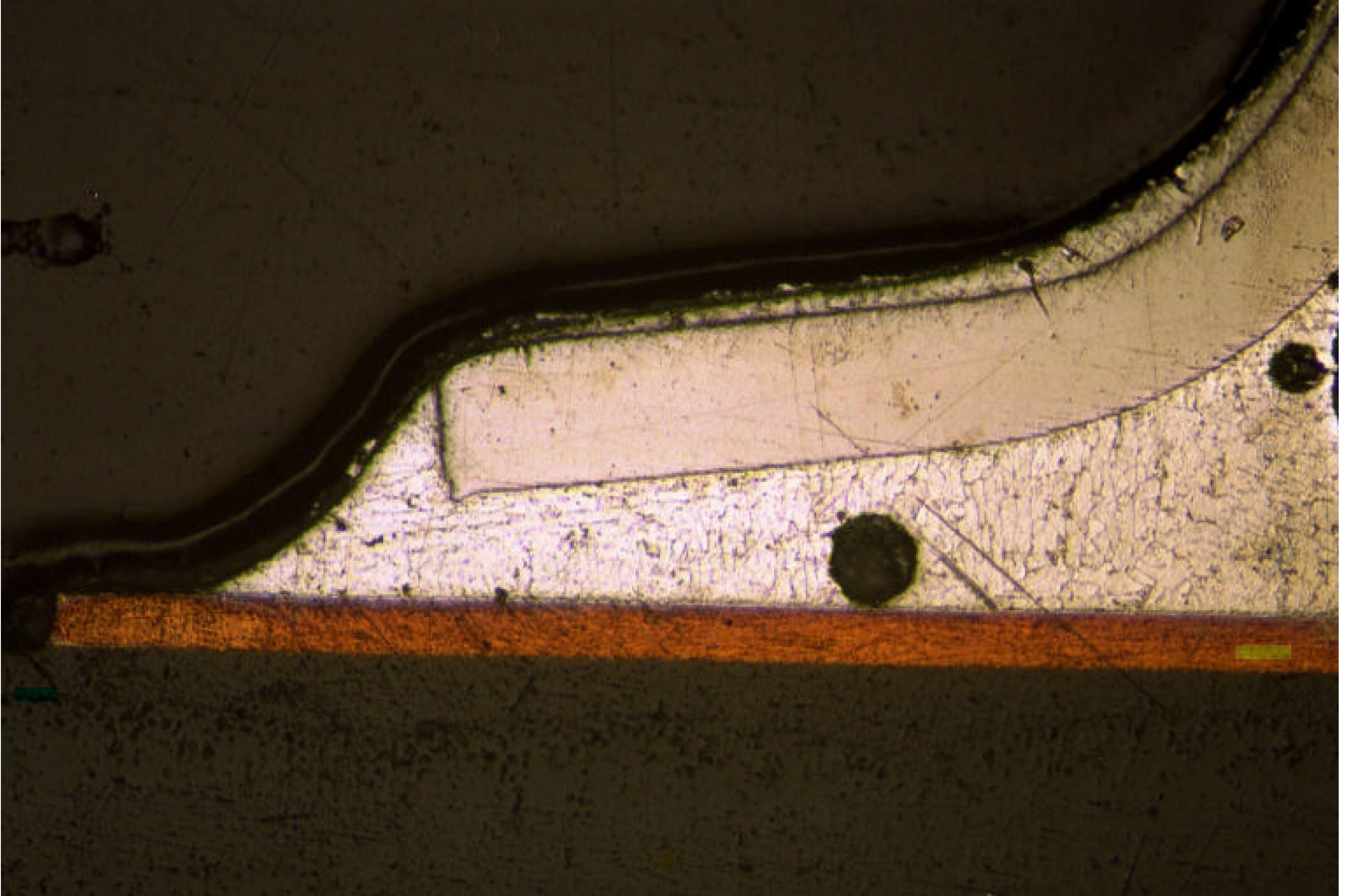
Test # 9

Material: Tin Silver   Atmosphere:Nitrogen   Temperature:240°C



Excellent Wetting at Toe Due to Nitrogen   Small, acceptable voids

20 mil QFP Lead

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Test # 10

Material: T, S, C, A   Atmosphere: Air   Temperature:240°C

Reduced Toe and Heel Wetting in Air   Acceptable Joint

20 mil QFP Lead

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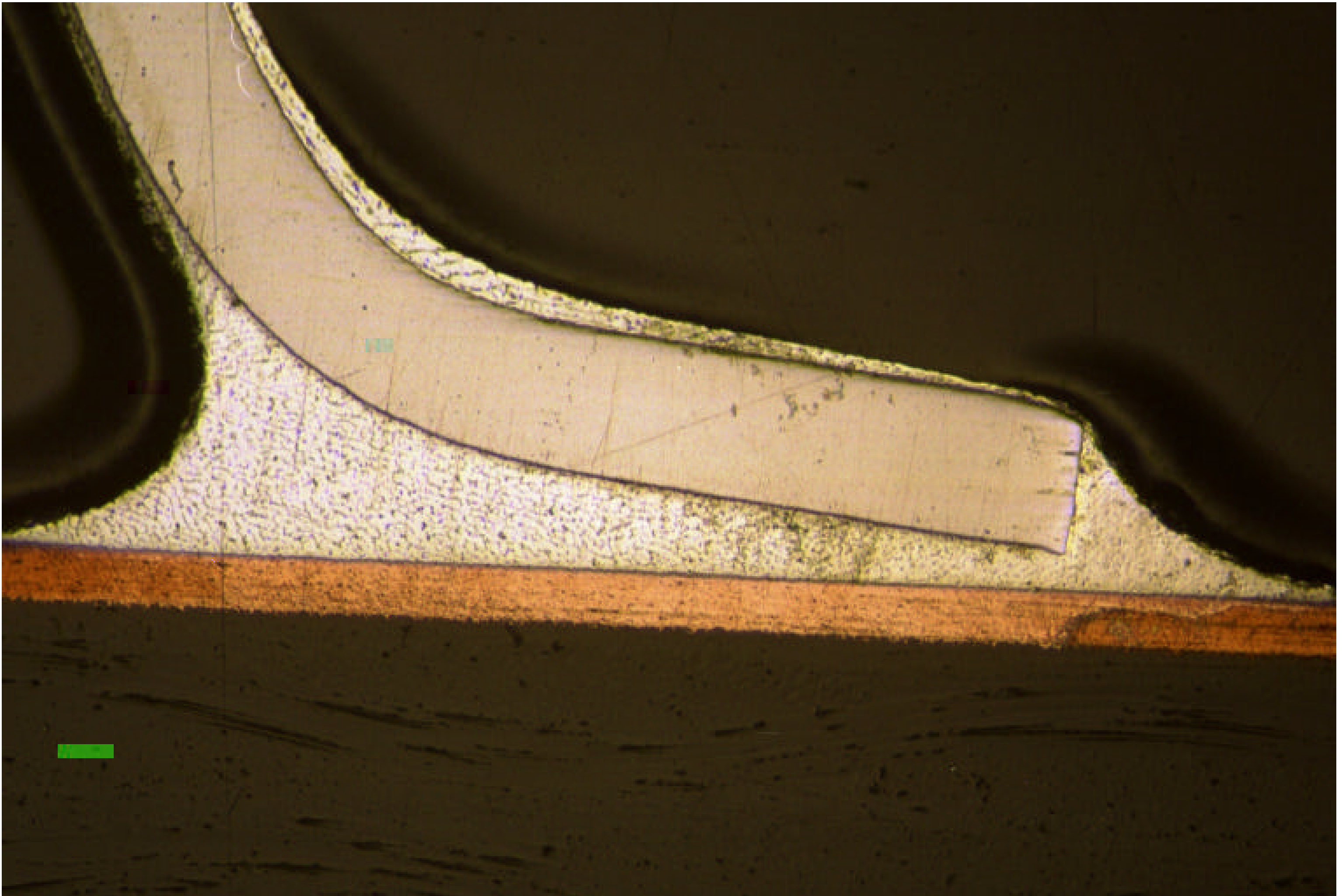
Test # 11

Material:T, S, C, A   Atmosphere:Nitrogen   Temperature:230°C



Excellent Wetting, Reduced Temperature Shows
No Effect on Joint Formation

20 mil QFP Lead

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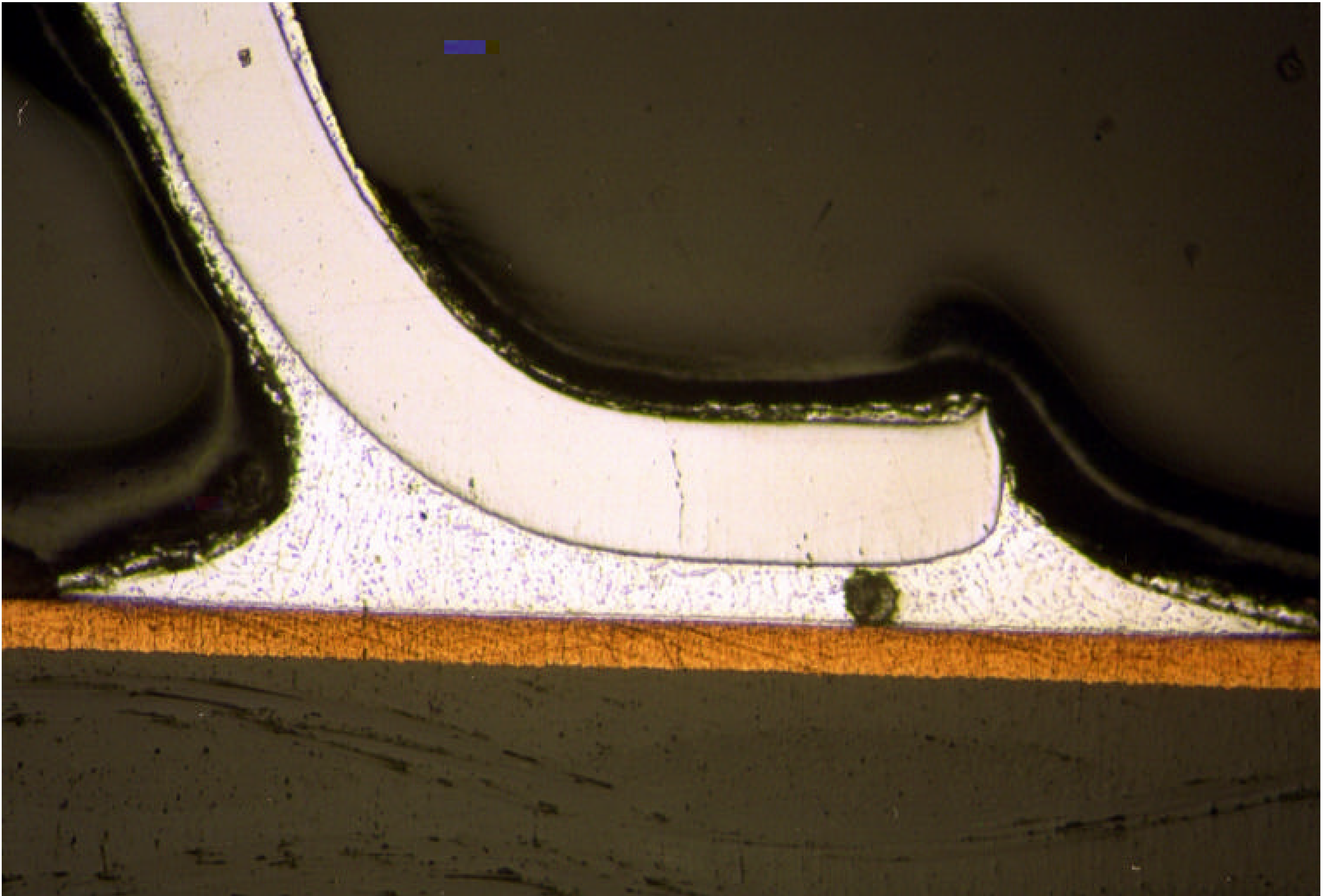
Test # 12

Material: T, S, C, A **Atmosphere: Air** **Temperature:230°C**



Reduced Wetting in Air, Small Void but Acceptable Joint

20 mil QFP Lead

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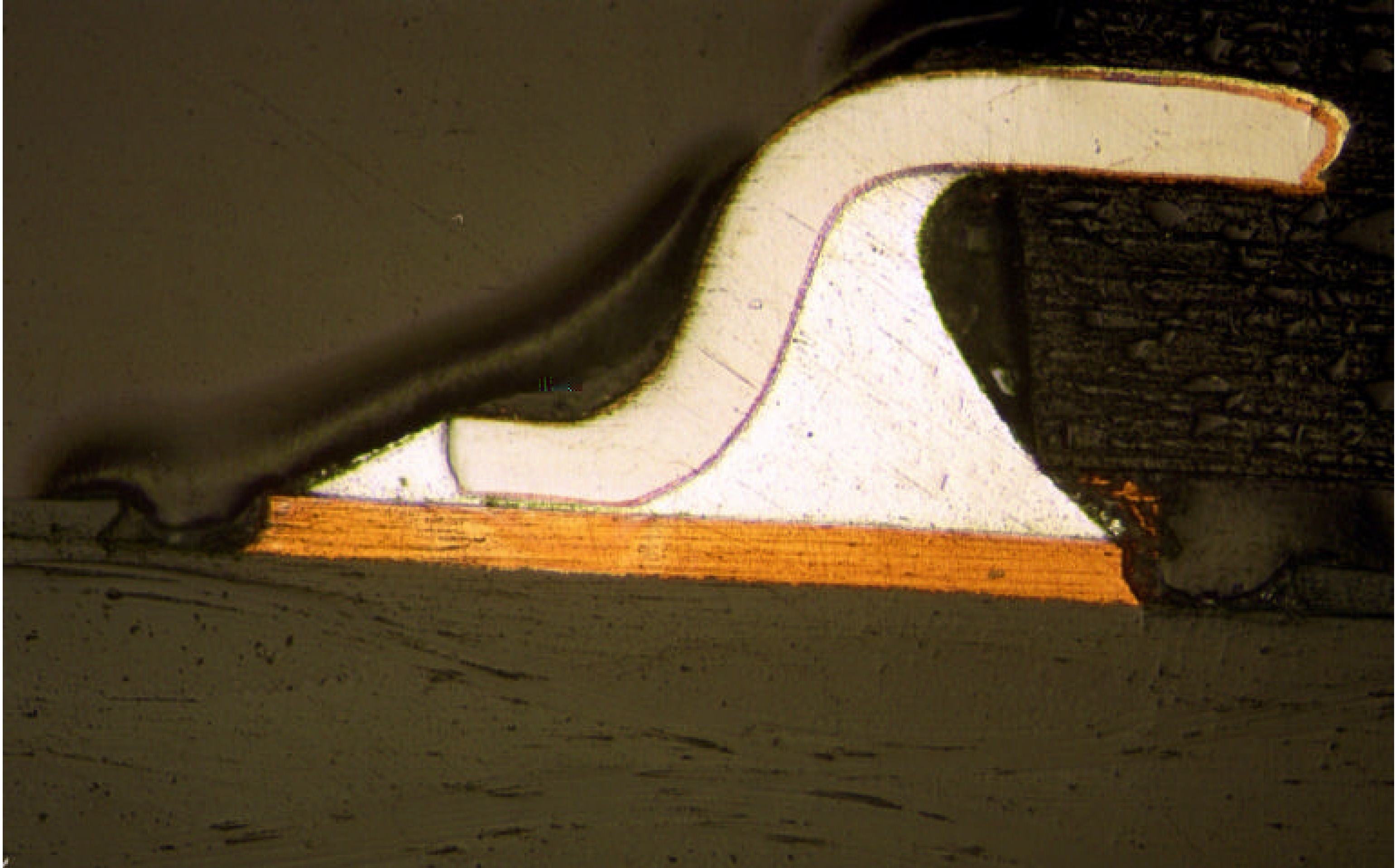
Test # 13

Material: T,S C, A   Atmosphere: Nitrogen   Temperature: 240°C



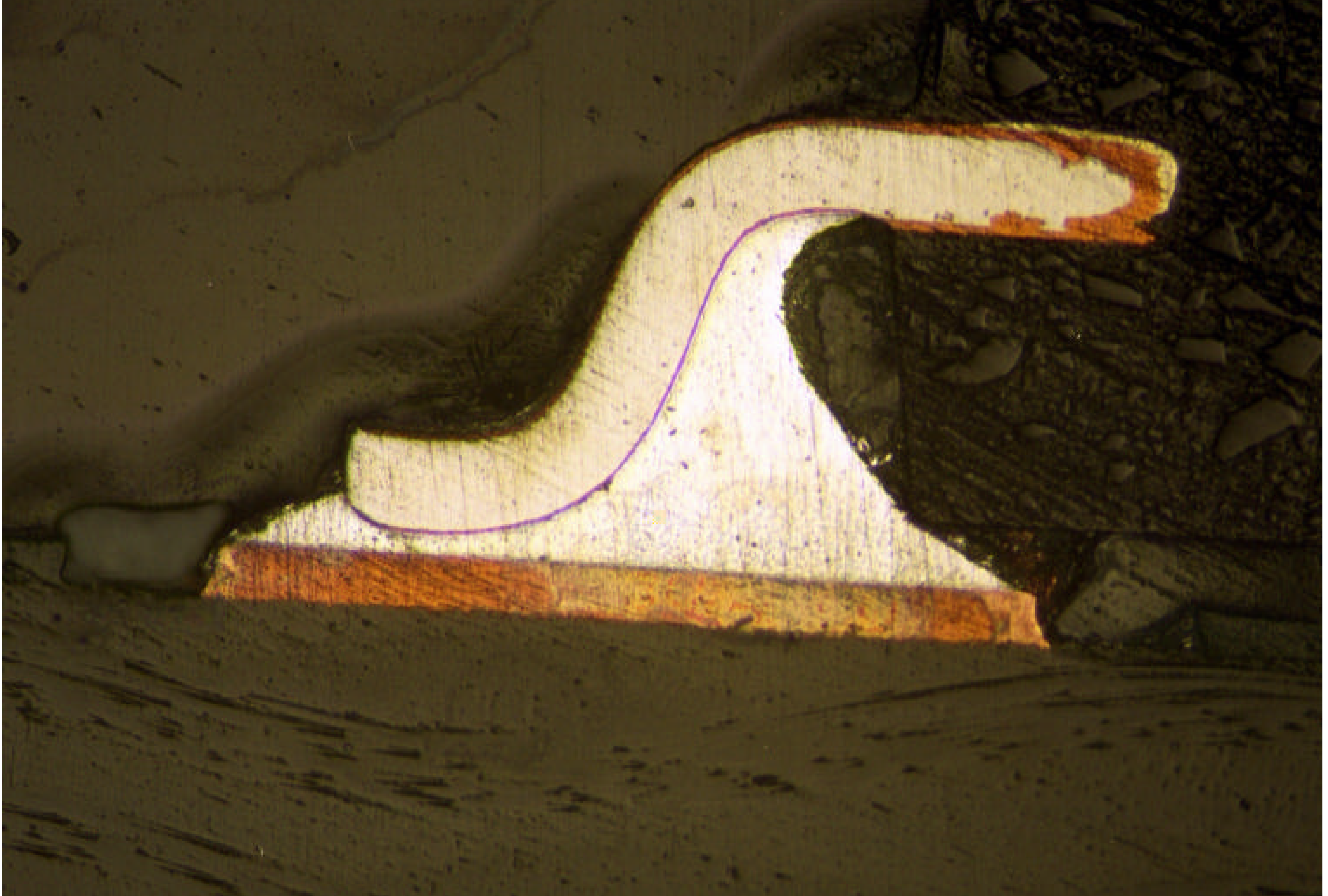
Visually Good Joint but…

… too much solder in heel is a potential failure point

SOT Lead

Test # 14

Material: T,S C, A **Atmosphere: Air** **Temperature: 230°C**



Exhibits Reduced Wetting Due to Air but Still Has Too Much Paste

SOT Lead

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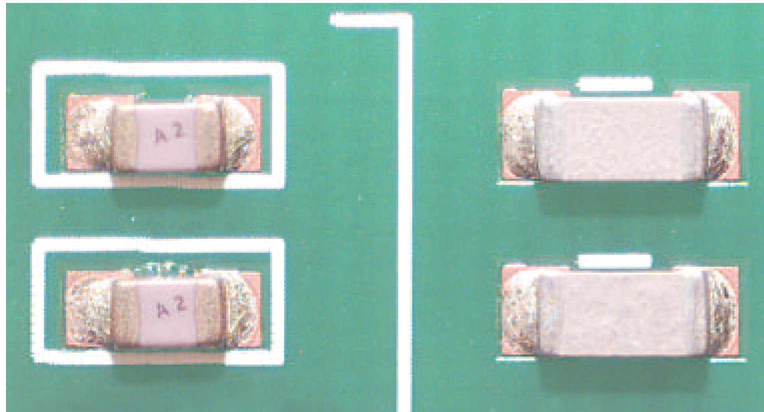
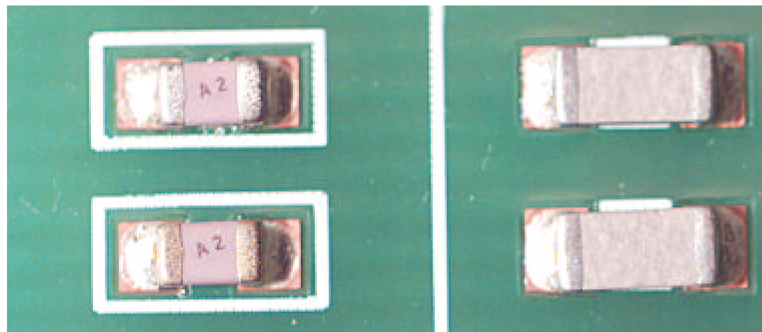
CAPACITORS WITH N2



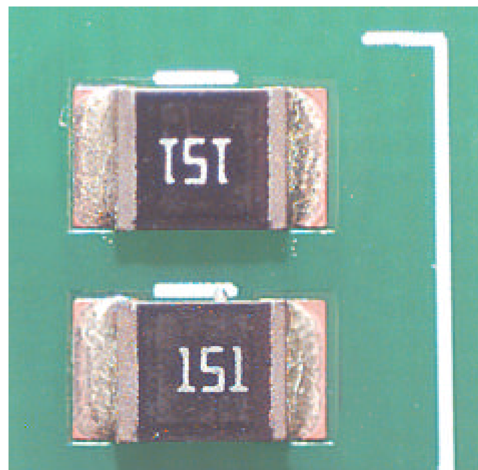
Grainy joint – no wetting to entire pad

CAPACITORS WITHOUT N2



No difference between Air and Nitrogen

Resistors With N2



Grainy joint – no wetting to entire pad

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Conclusion

- No lead solders provide a robust process, excellent results at all soldering conditions considered
    - Potential concern – Voids. May require more aggressive Flux and/or No lead HASL finish
- Drop in process for existing reflow equipment
- Nitrogen cover gas will enhance wetting and appearance, but is not essential for adequate results
- Good results at both 230°C and 240°C peak temperature - Confirms that lower temperatures can be utilized to protect boards and components.

Other Considerations

- Certain Components cannot survive the thermal excursion
- Component Availability is limited in certain cases
- Higher Reflow Temperatures can lead to board warpage
- Center Board Support may be required

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