Practical Solutions for Successful Pb-Free Soldering

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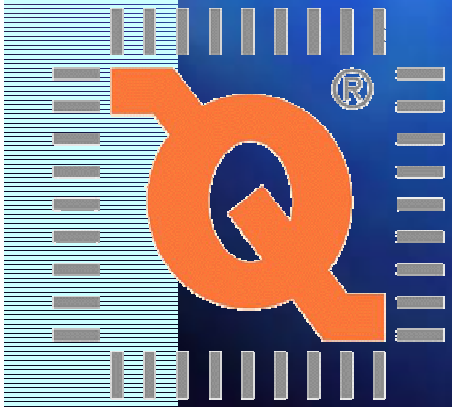


Challenges/Barriers to Lead Free

- Cost
- Material Availability
- Process Modifications
- Material Compatibility
- Standards
- Inspection
- Rework and Repair
- Historical Data

Cost

- 2½ to 3 times more expensive than Sn/Pb solders

Material Availability

- Tin, (Sn) is the major element in Pb-Free soldering alloys and there is sufficient worldwide supply
- Silver, (Ag) although expensive, there is a sufficient worldwide supply
- Copper, (Cu) relatively inexpensive and a sufficient worldwide supply

Process Modifications

- Higher temperatures required
- I/R reflow ovens may not be suitable
- Wavesolder baths require upgrading
- Higher solids fluxes required
- Cleaning flux residues difficult
- In Circuit Test more difficult

Material Compatibility

- Research data so far has indicated that the reliability of solder joints made with Pb-Free board finishes and Pb-Free component termination finishes, when soldered with the SAC alloy family of Pb-Free solders, to be similar to solder joints made with Sn/Pb alloys

Standards Currently Available

- IPC-J-STD-001D Requirements for Electrical and Electronic Assemblies
- IPC-A-610D Acceptability of Electronic Assemblies
- 1066 Marking, Symbols and Labels
- 1065 Material Declaration Handbook

Standards Currently in Draft Format

- IPC-J-STD-002: Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires
- IPC-J-STD-003: Solderability Tests for Printed Boards
- IPC-J-STD-004: Requirements for Soldering Fluxes
- IPC-J-STD-005: Requirements for Soldering Pastes
- IPC-J-STD-006: Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders
- IPC/JEDEC J-STD-020C: IPC/JEDEC Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Device
- IPC/JEDEC J-STD-033A: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices

Inspection

- Pb-Free solder joints look dull and grainy
- Pb-Free solder has high surface tension therefore wetting spread will be less than that seen with Sn/Pb solders
- Inspection personnel will require re-education

Rework and Repair

- It is advisable to use the same alloy as originally used for making the solder joint being reworked
- Care should be taken with components and board substrate in the area to be reworked
- Pb-Free solders will wear out soldering iron tips faster than Sn/Pb solders

Historical Data

- Studies are still ongoing to determine the long term reliability of Pb-Free soldering alloys. However, all testing so far has indicated that the reliability of solder joints made with Pb-Free alloys are similar to those made with Sn/Pb alloys

Alloy Selection

- There are many Pb-Free alloys to choose from but, in the opinion of most commentators, the Sn/Ag/Cu (SAC) combination of elements is the industry preferred choice.
- Other "exotic" elemental combinations will be either too expensive, will have reliability issues or there could be supply availability issues

Pb-Free Alloys

- Sn99.3/Cu0.7
- Sn96.5/Ag3.5
- Sn42/Bi58
- Sn/Ag/Cu

Sn99.3/ Cu0.7

- High Melting Point 227ºC
- Poor wetting characteristics
- Lower capillary action
- Lower fatigue resistance
- However, copper is cheaper than silver therefore, this alloy could be considered for wavesoldering of commercial electronic equipment

Sn96.5/Ag3.5

- High melting point 221ºC
- Longest history
- Peak reflow temperature 240ºC-260ºC. This is considered to be too high for reflow soldering
- May not have adequate thermal reliability

Sn42/Bi58

- Low melting point 138ºC
- Poor thermal fatigue
- Possible formation of Sn/Pb/Bi (96ºC) low melting phases
- Poor wetting characteristics
- Questionable mechanical properties

Sn/Ag/Cu

- Industry preferred alloy
- Melting point 217ºC
- Eutectic alloy with no low melting phases
- Can be used for reflow, wave and hand soldering processes
- Reliability is similar to Sn62 and Sn63 alloys

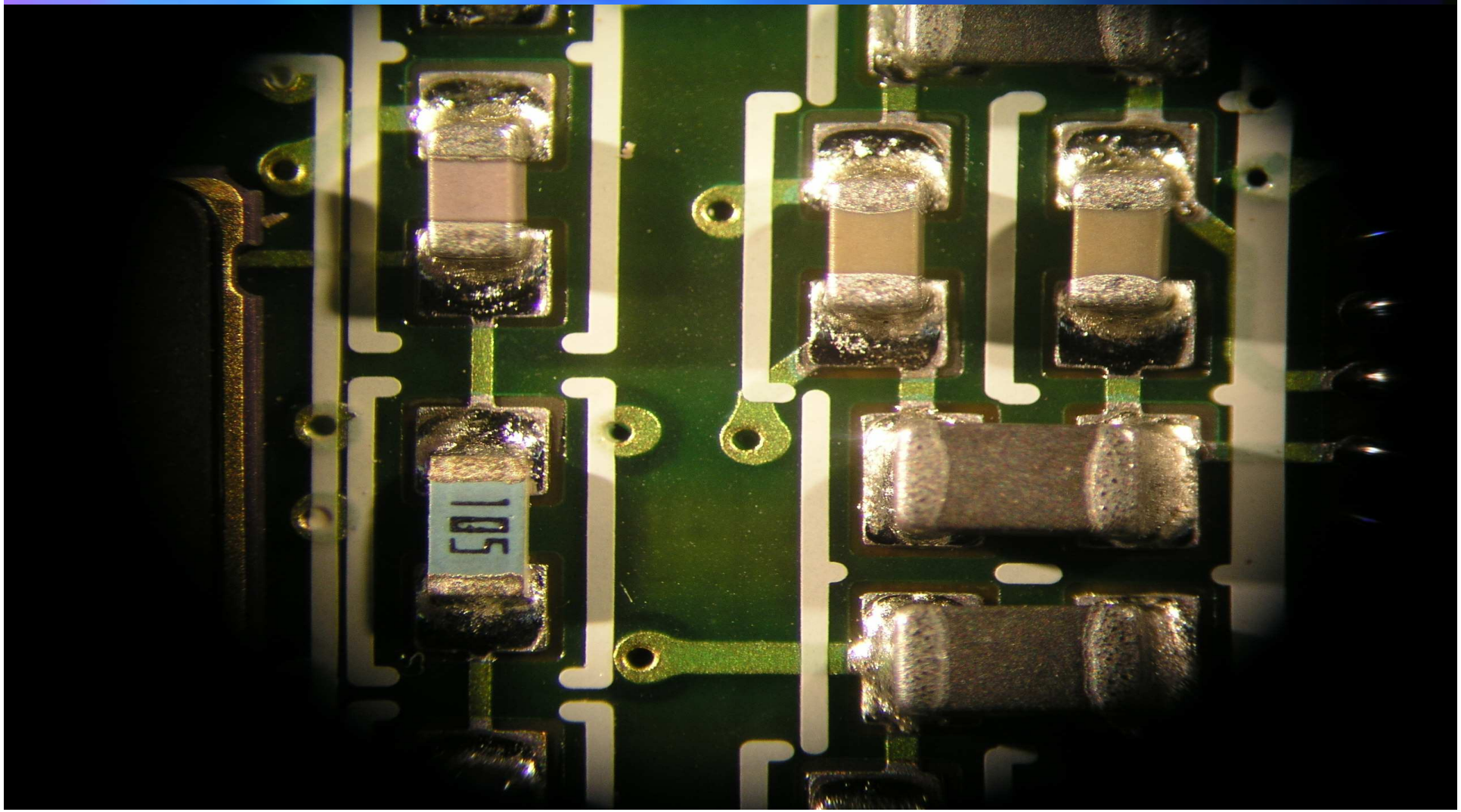
Circuit Board Finishes

- Immersion Tin
- Immersion Silver
- OSP
- Au/Ni
- HASL - Sn/Cu0.7 (Sn100C with Nickel stabilization)

Component Terminations

- Precious metals
  - Au
  - Pd
  - Pd/Ni
- Lead Free Alloys
  - Sn/Ag
  - Pure Sn

Pb-Free solder joints on Au/Ni surface finish 1st side reflow



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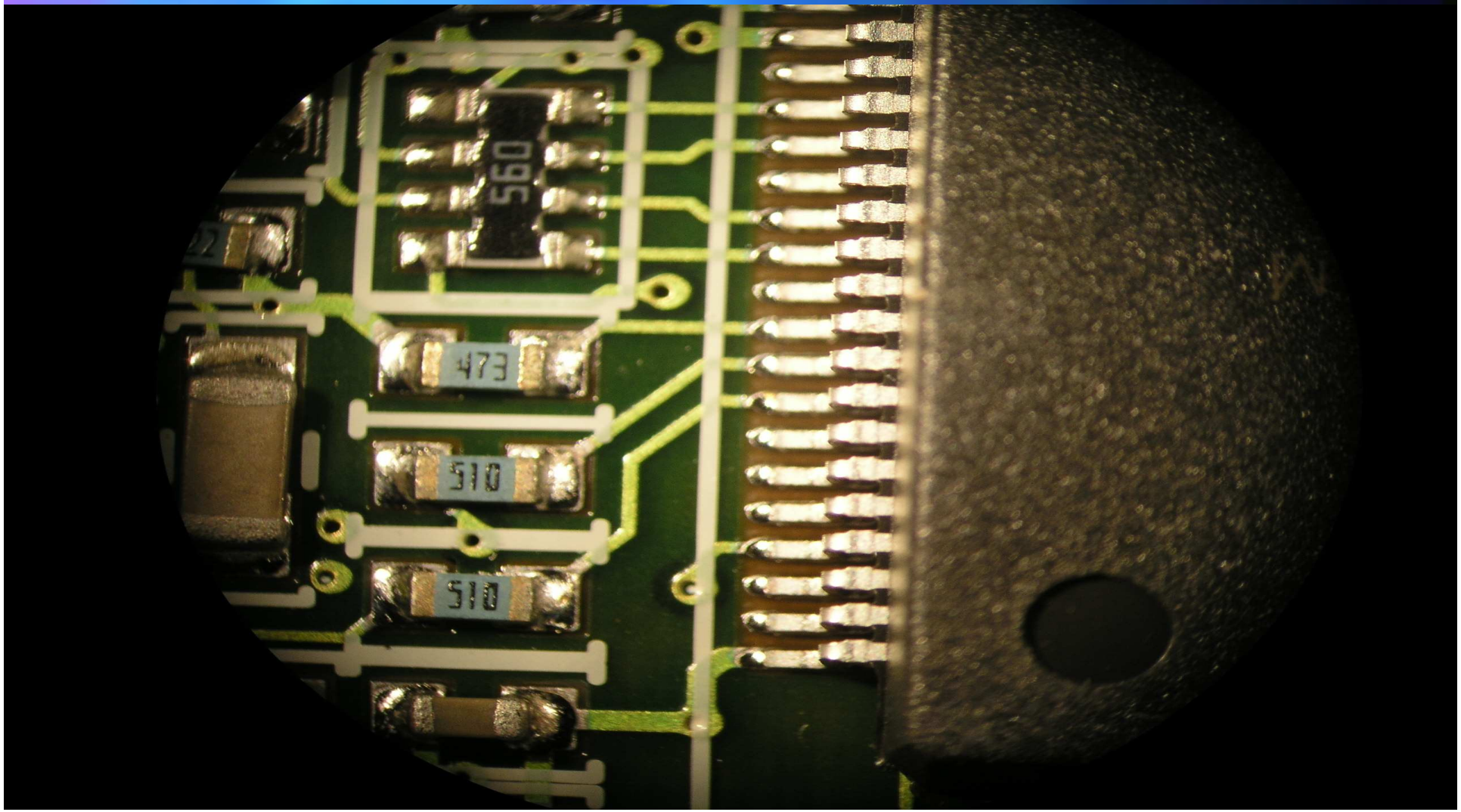
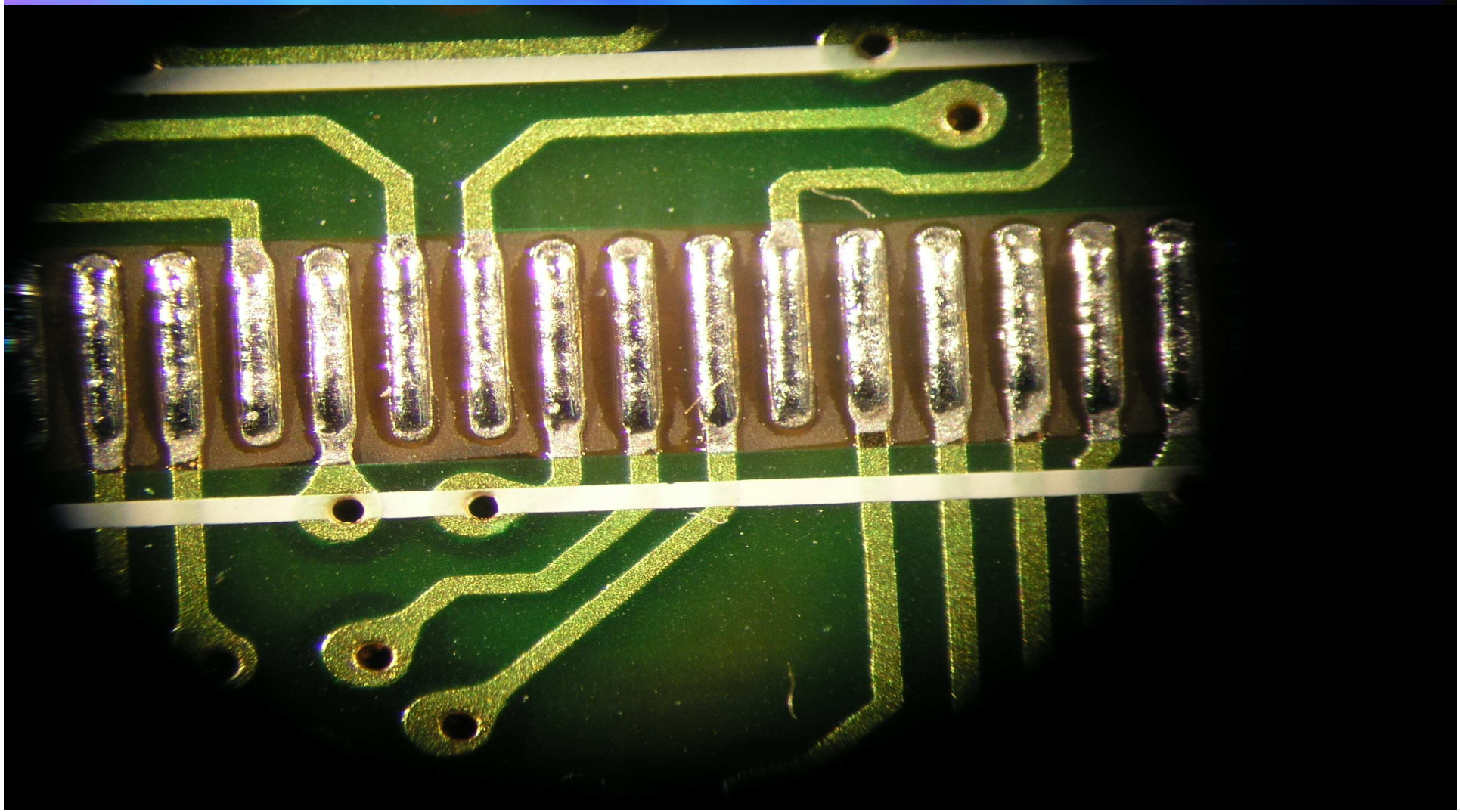


Pb-Free solder joints on Au/Ni surface finish 2nd side reflow



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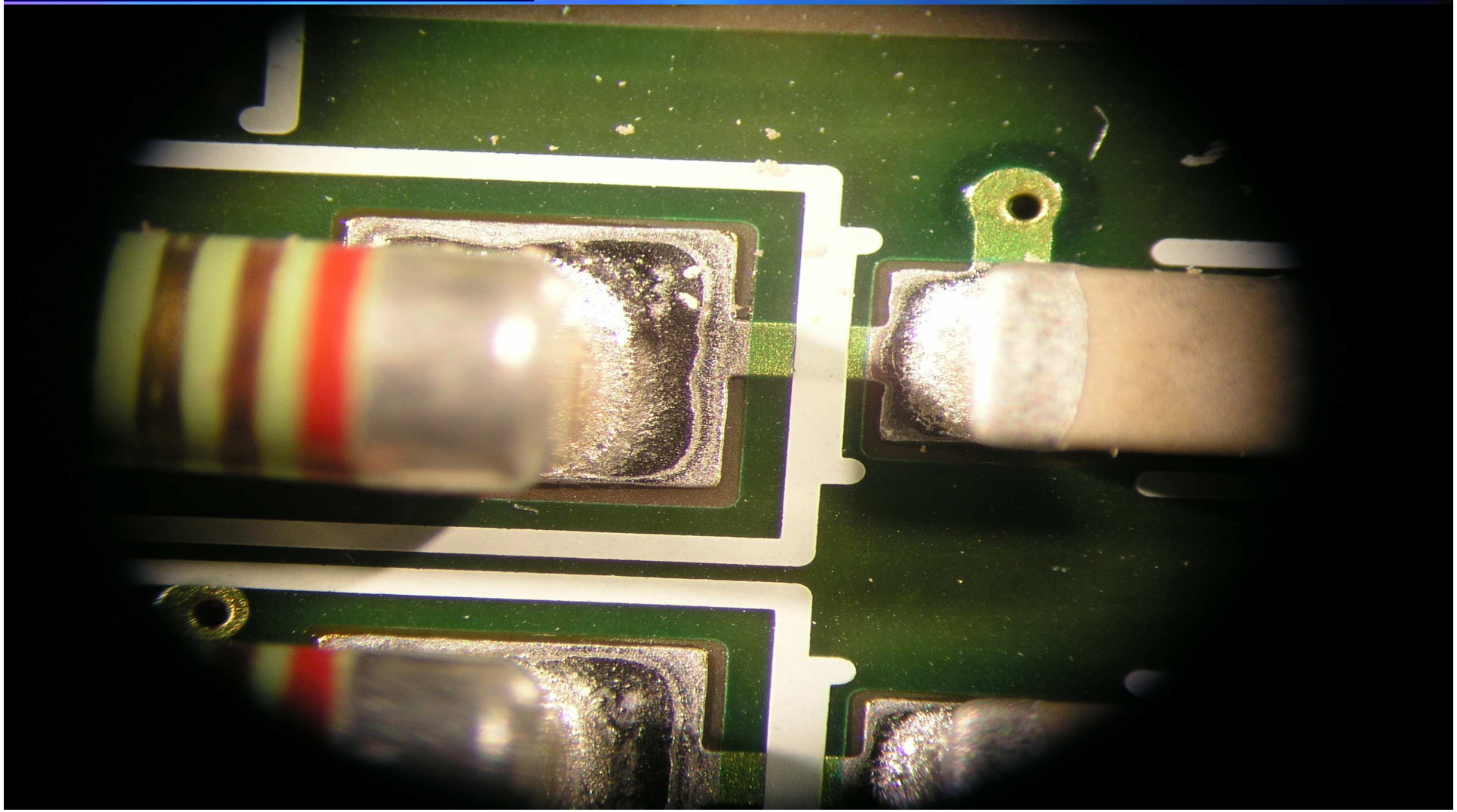
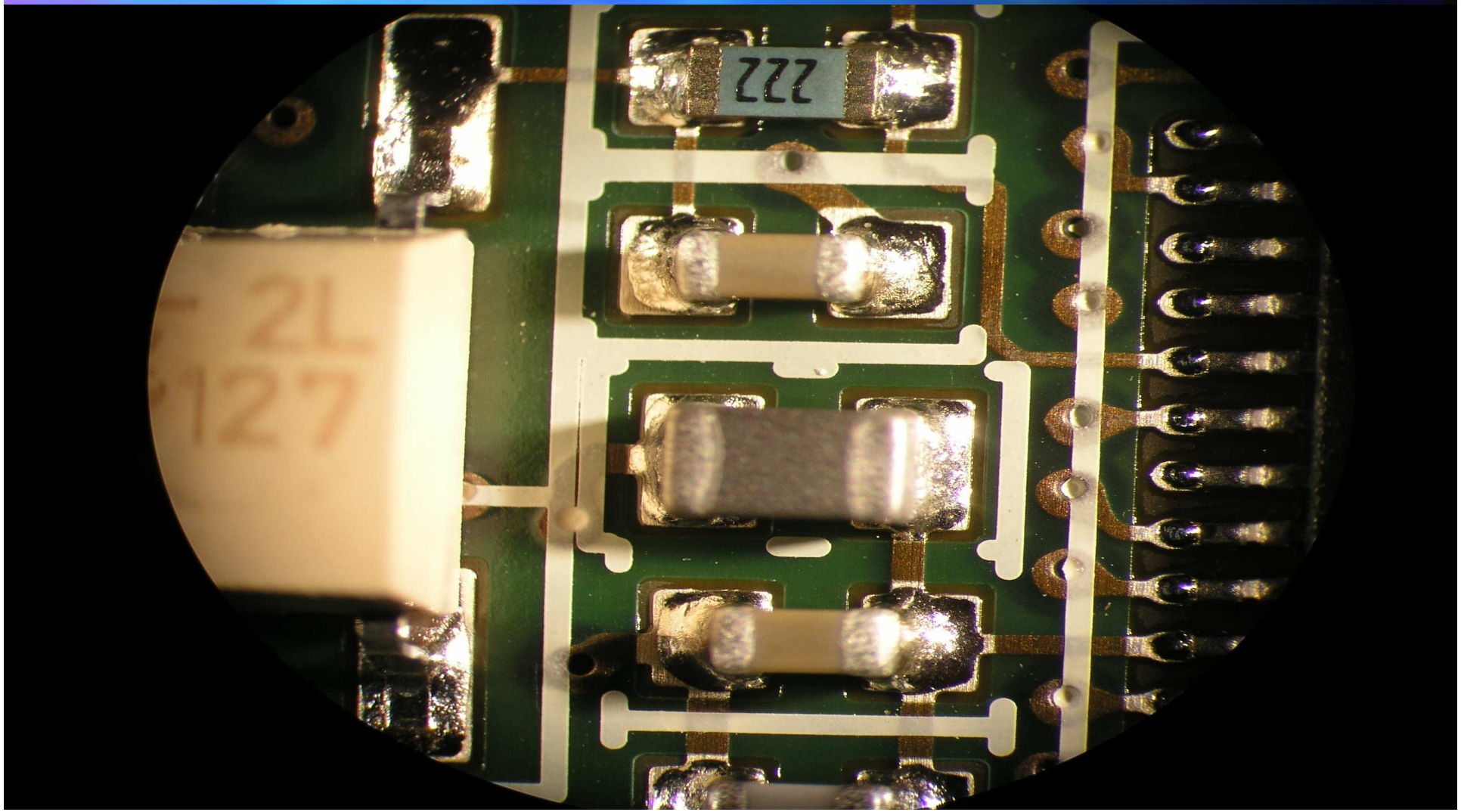


Pb-Free solder joints on Imm Ag surface finish 1st side reflow



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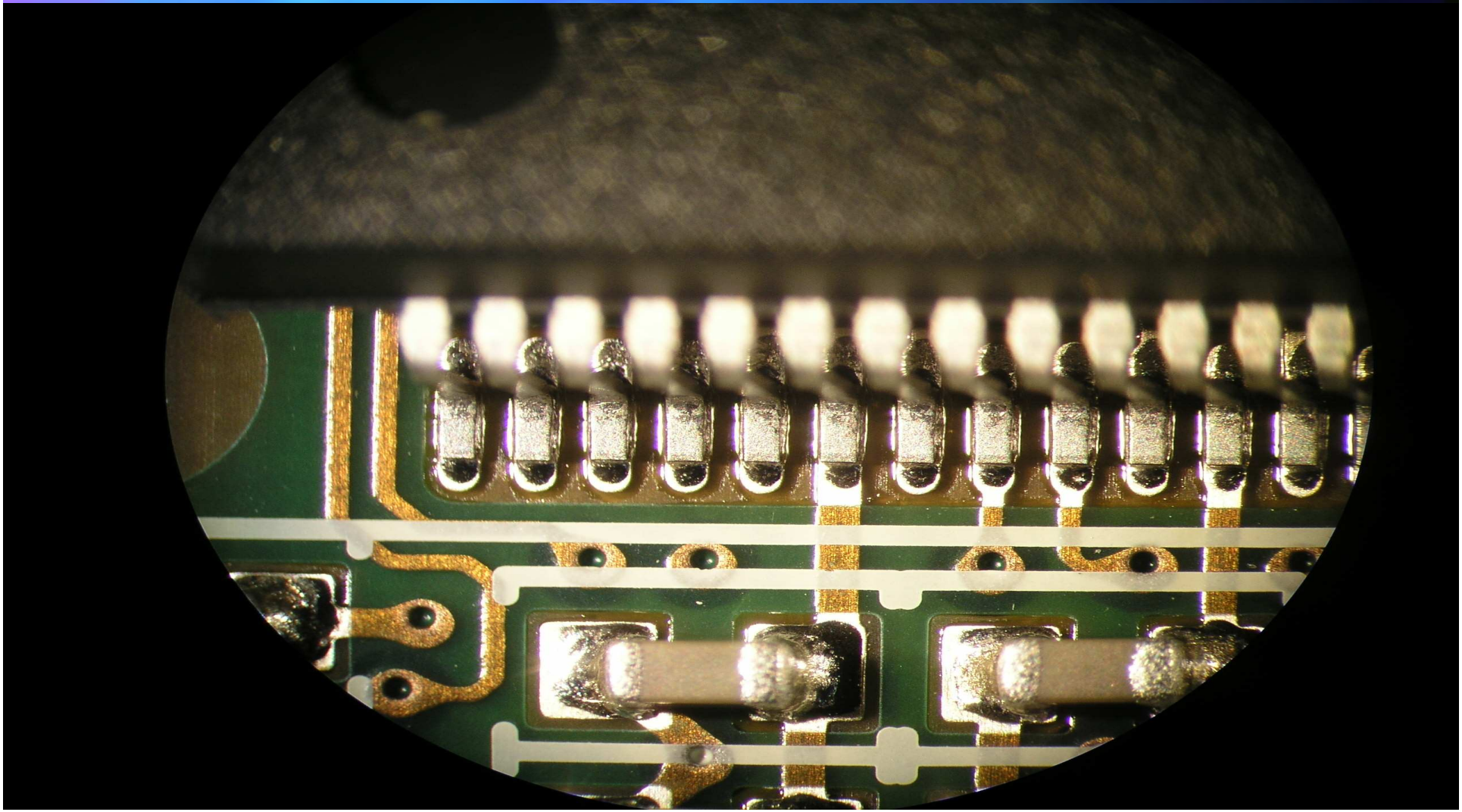
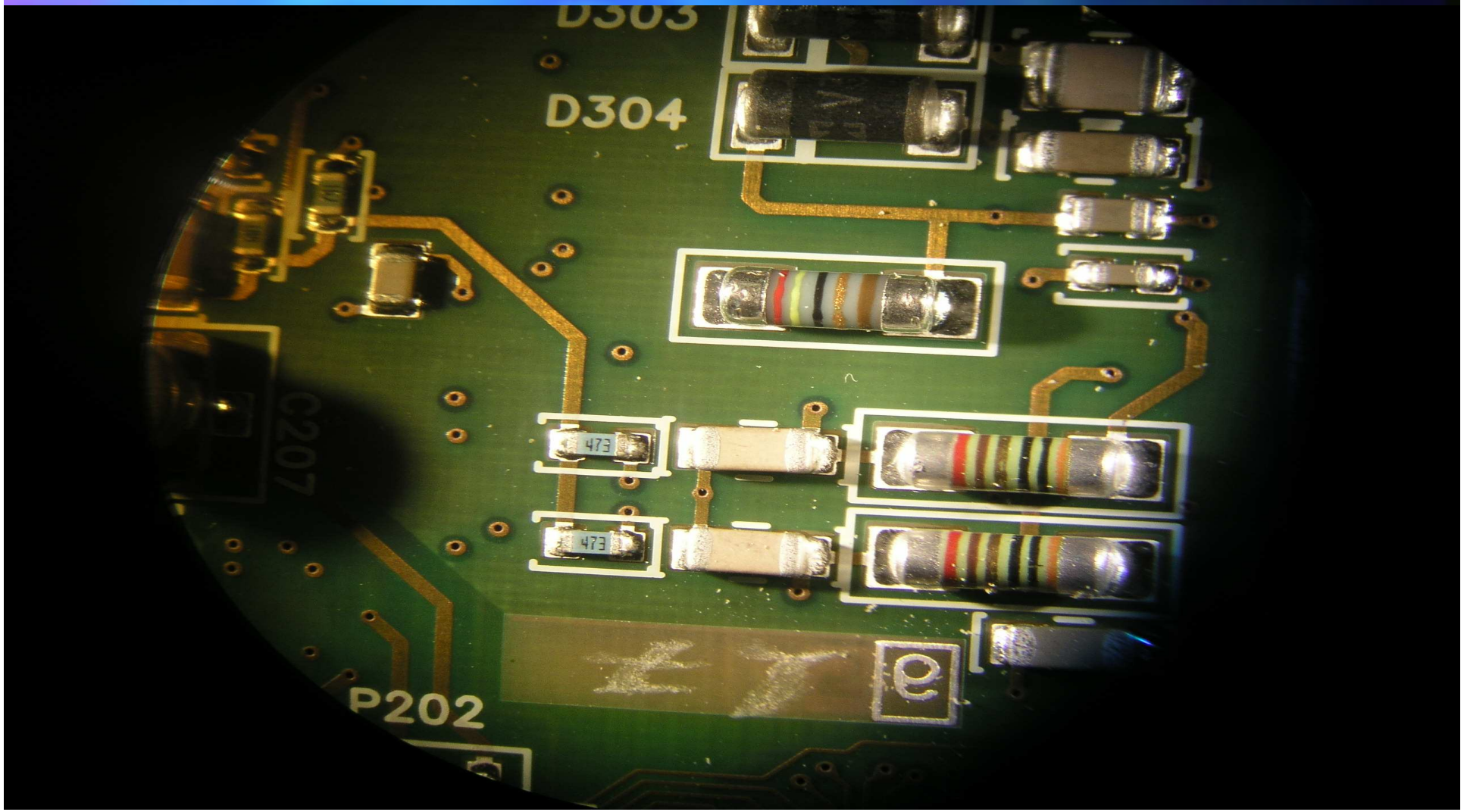
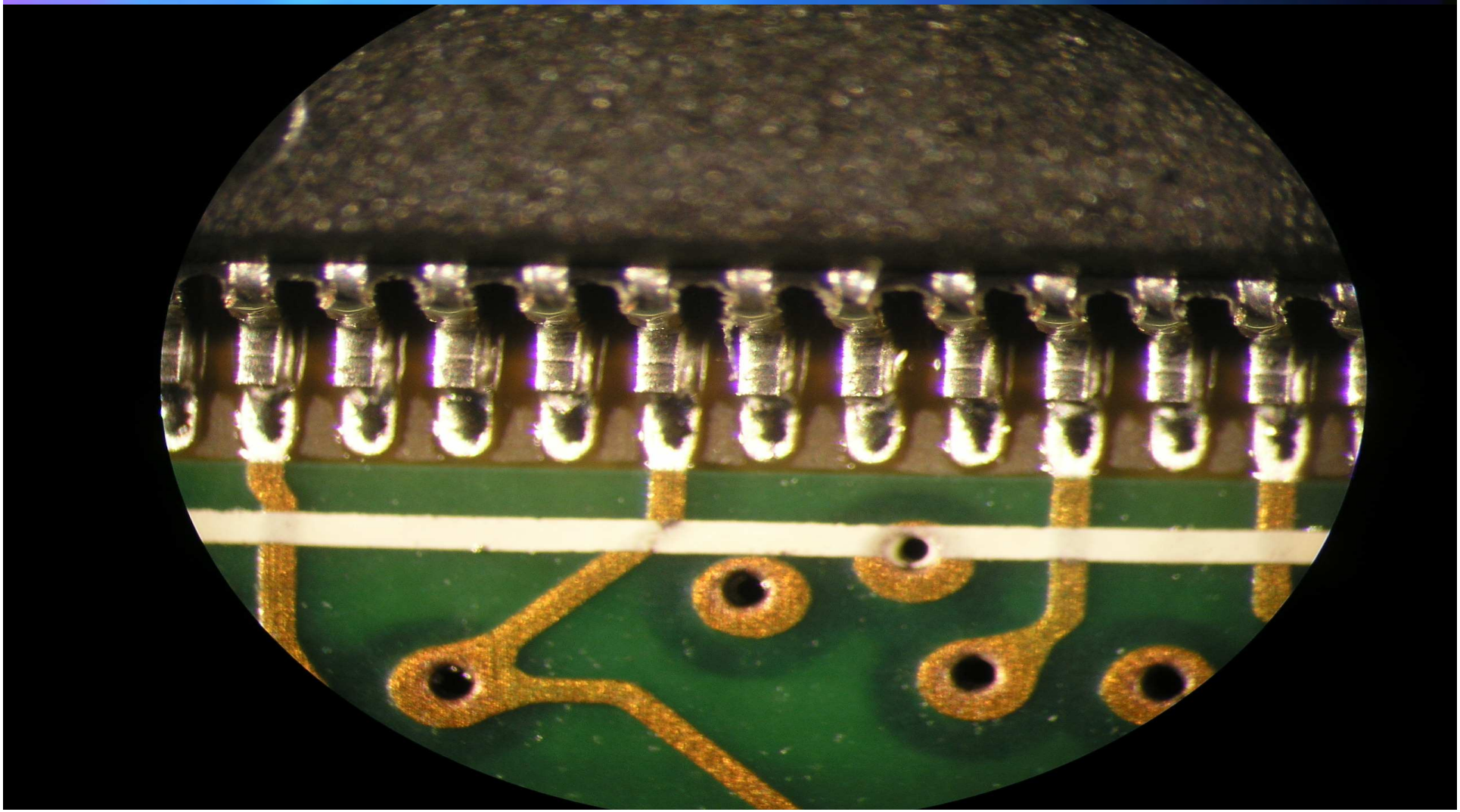


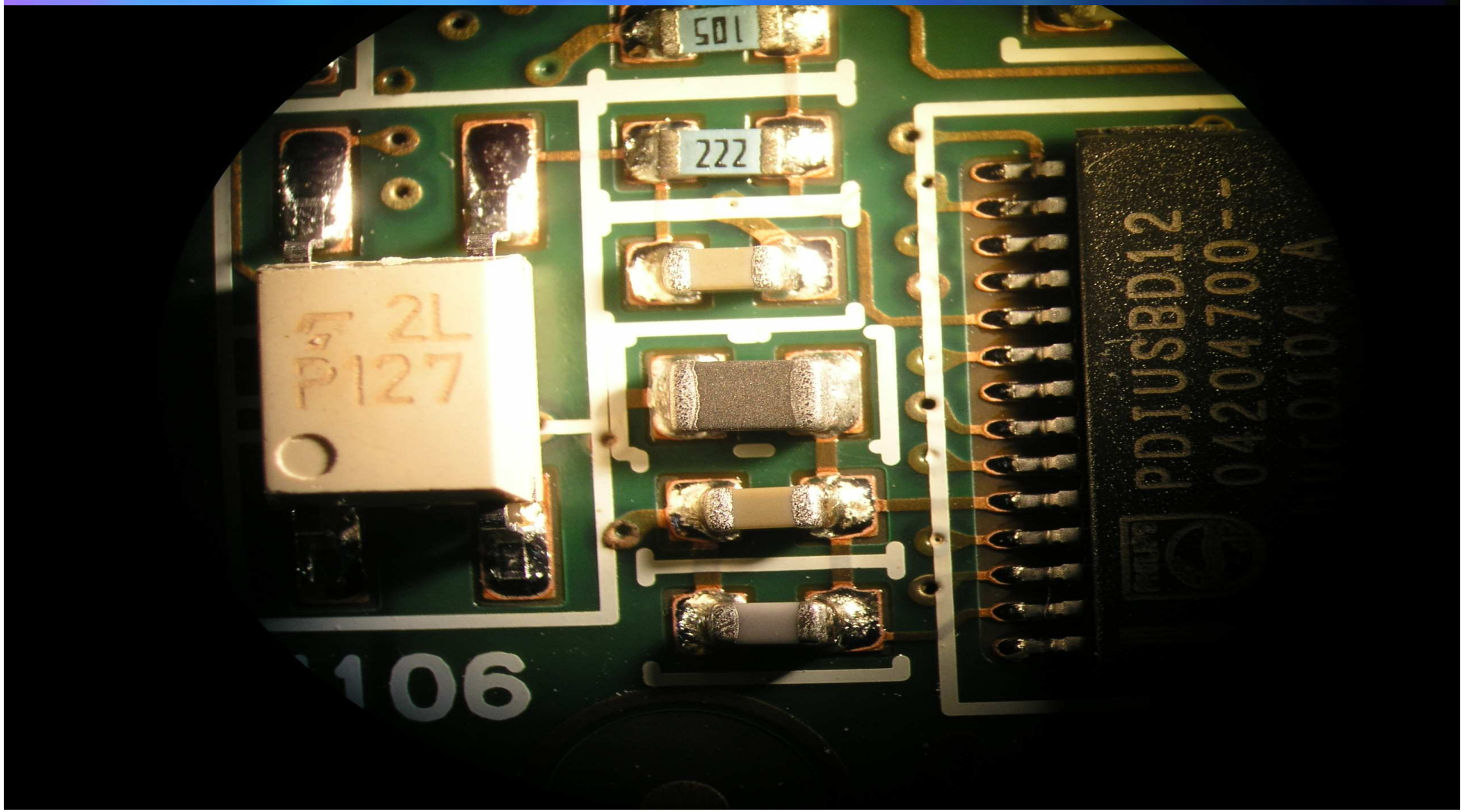
Pb-Free solder joints on Imm Ag surface finish 2nd side reflow



Pb-Free solder joints on Imm Ag surface finish 2nd side reflow



Pb-Free solder joints on OSP surface finish 1st side reflow



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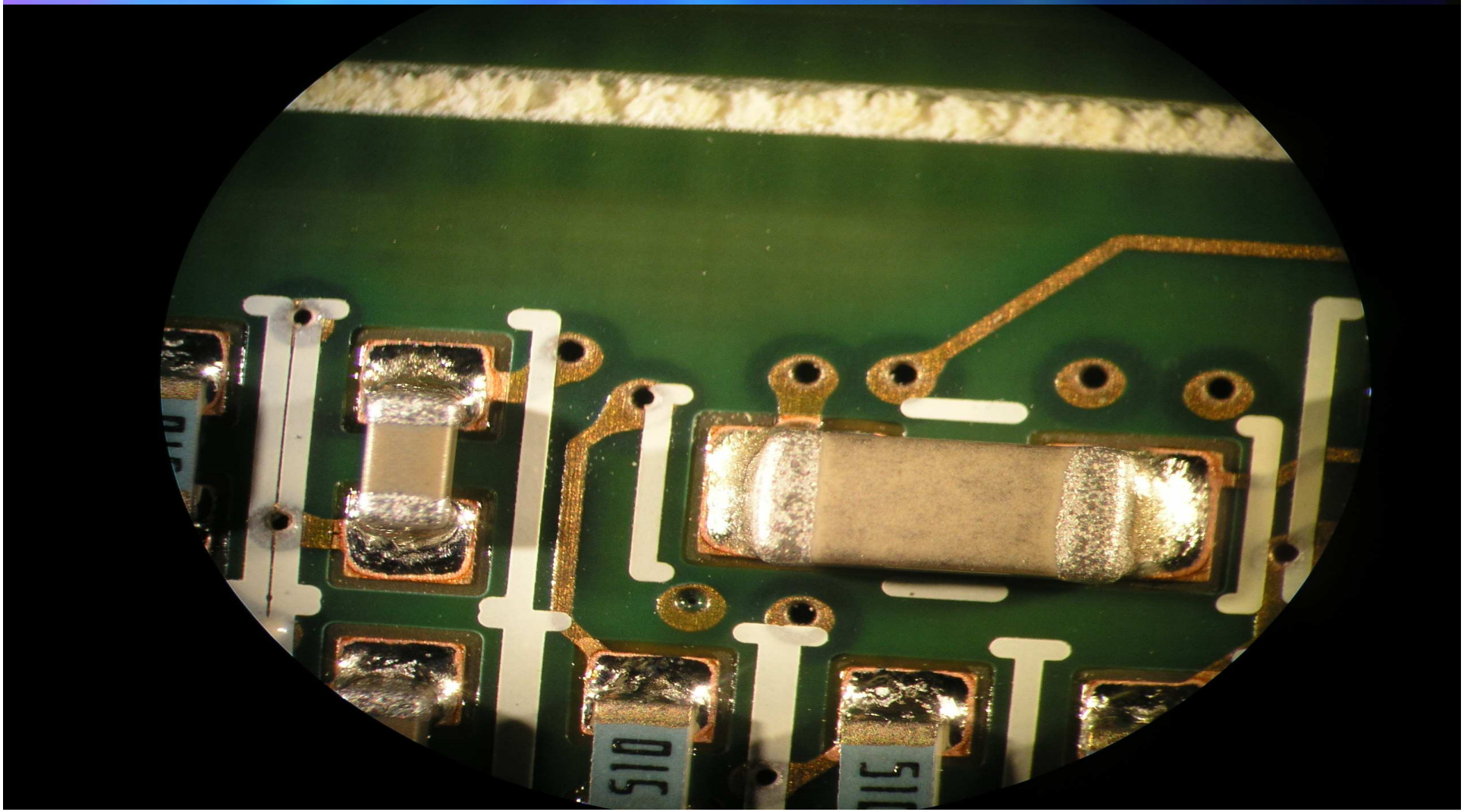

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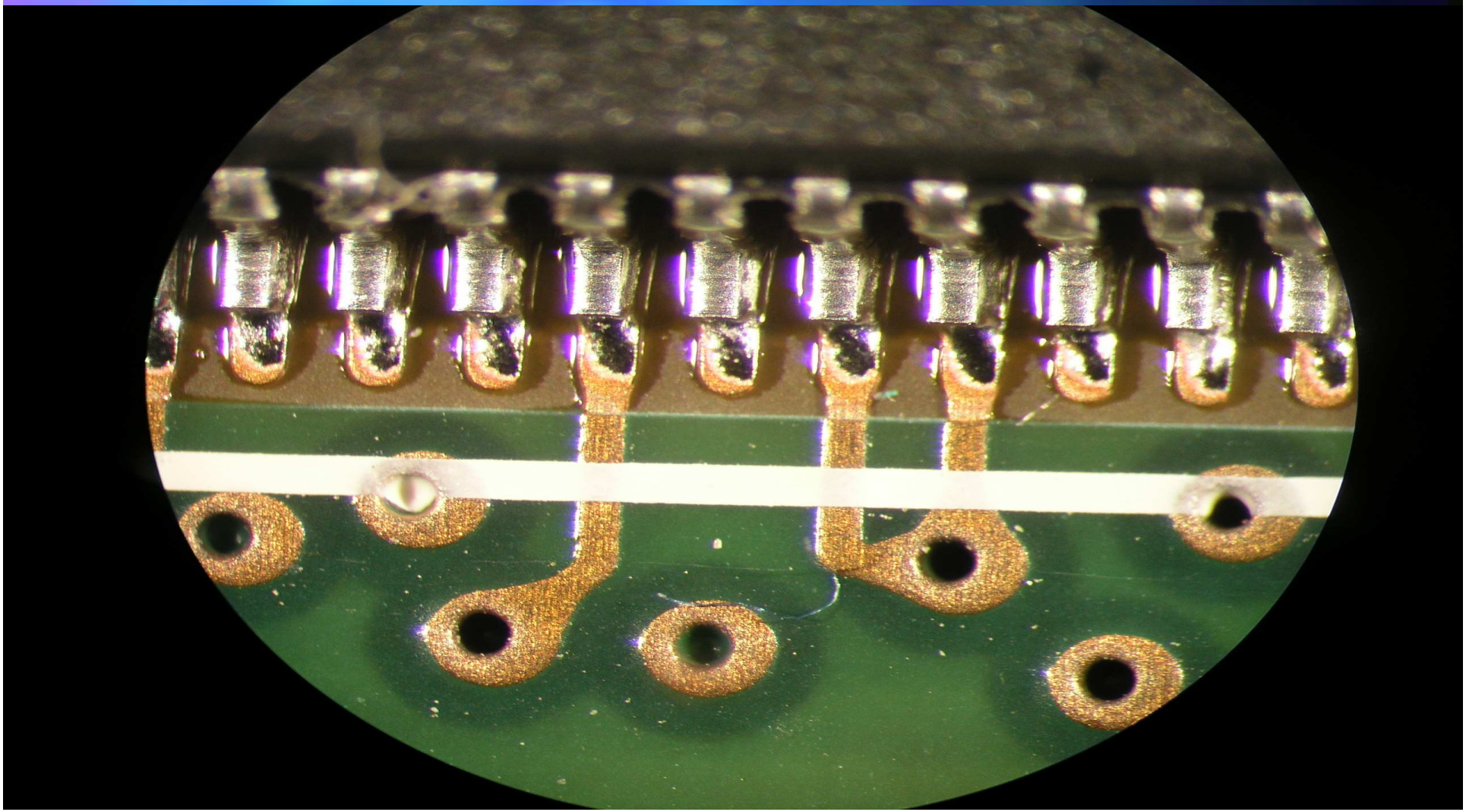

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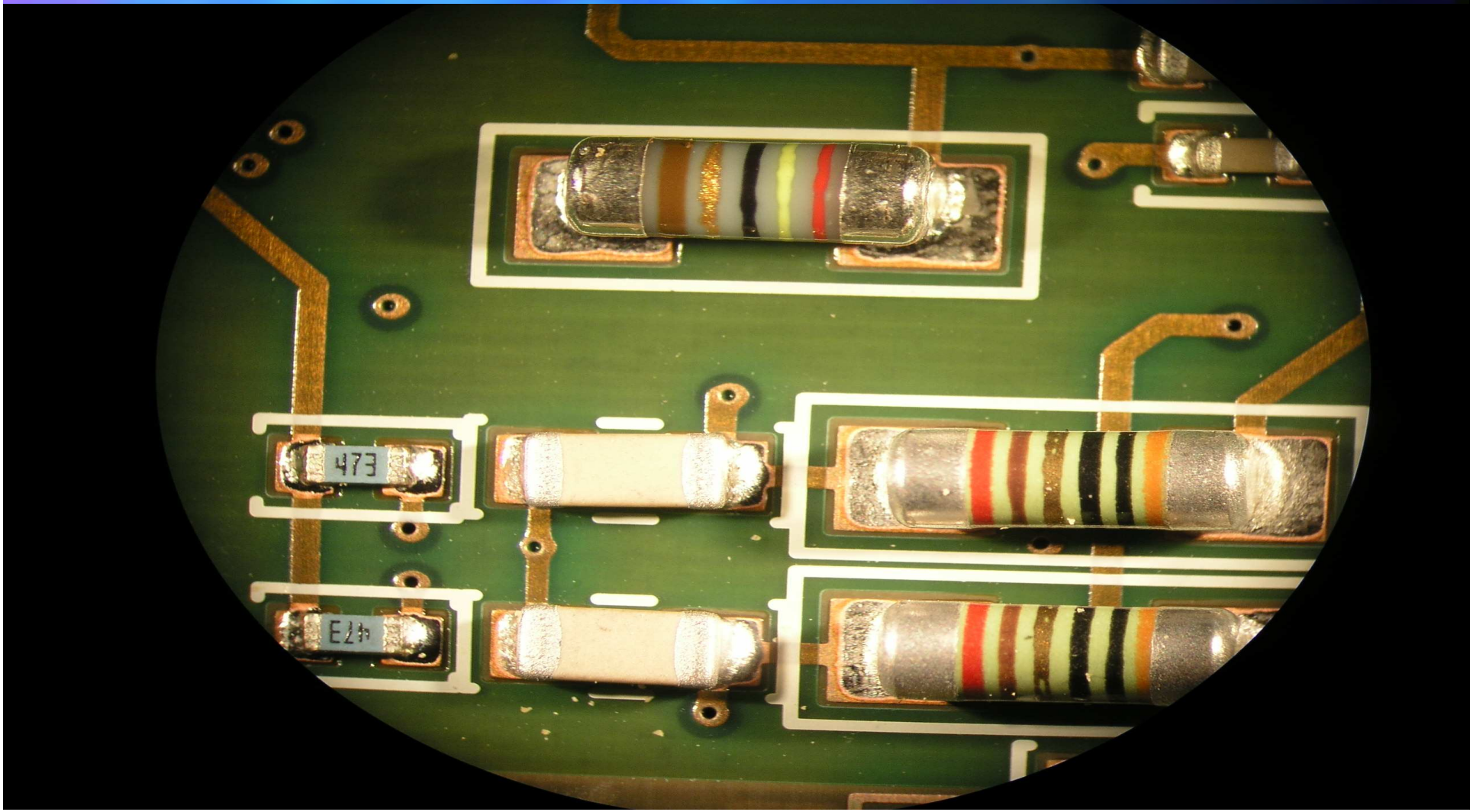
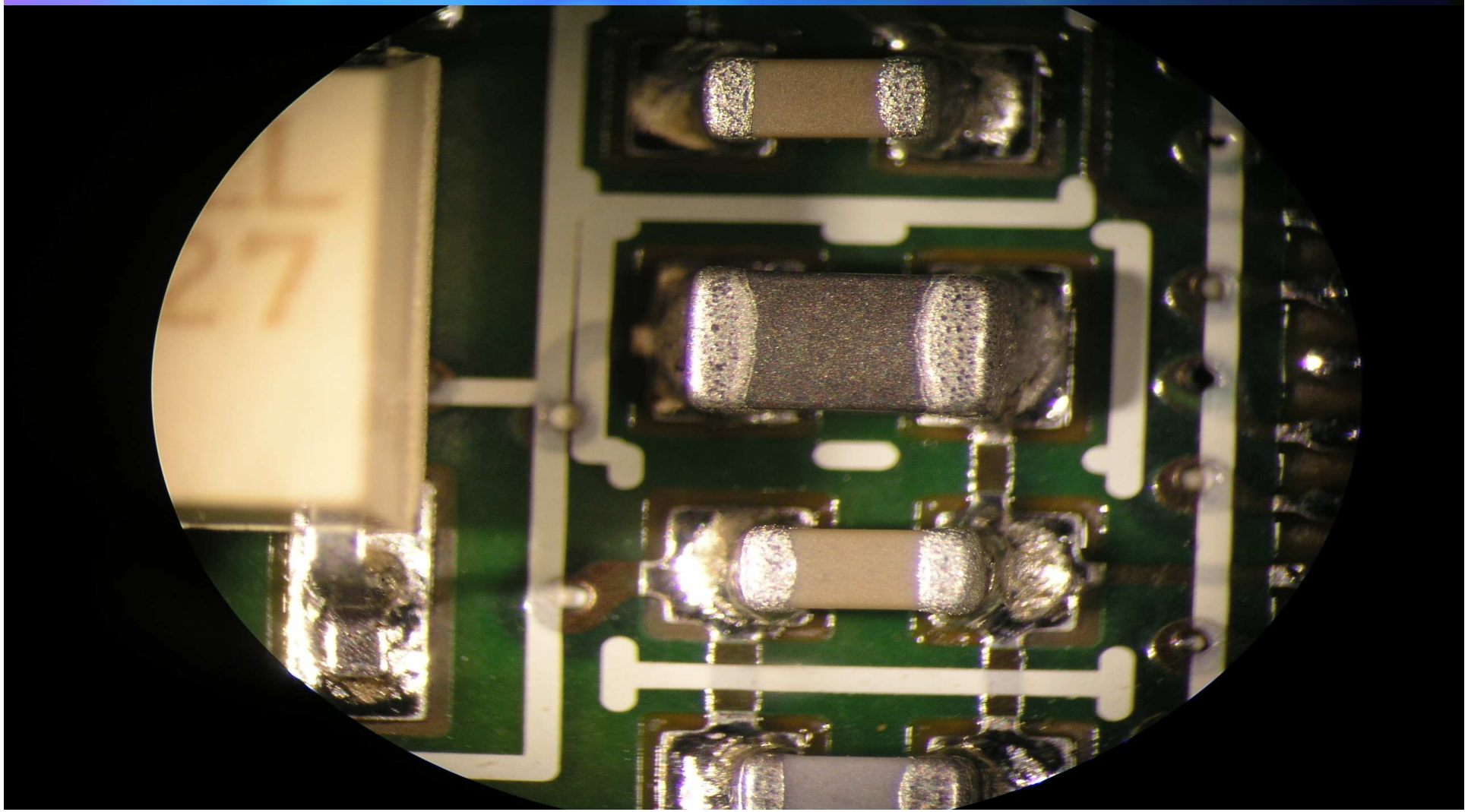


Pb-Free solder joints on HASL surface finish 1st side reflow



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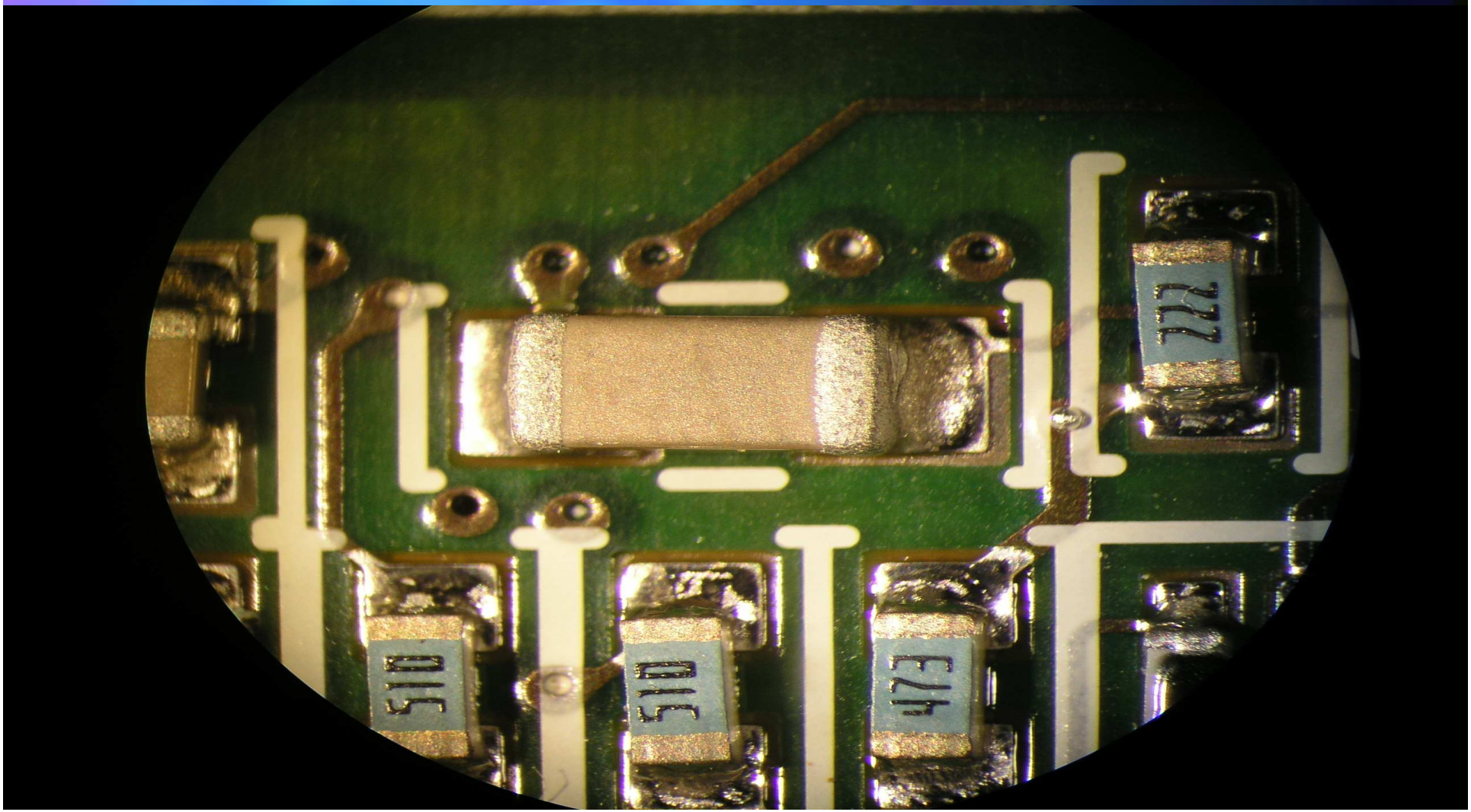

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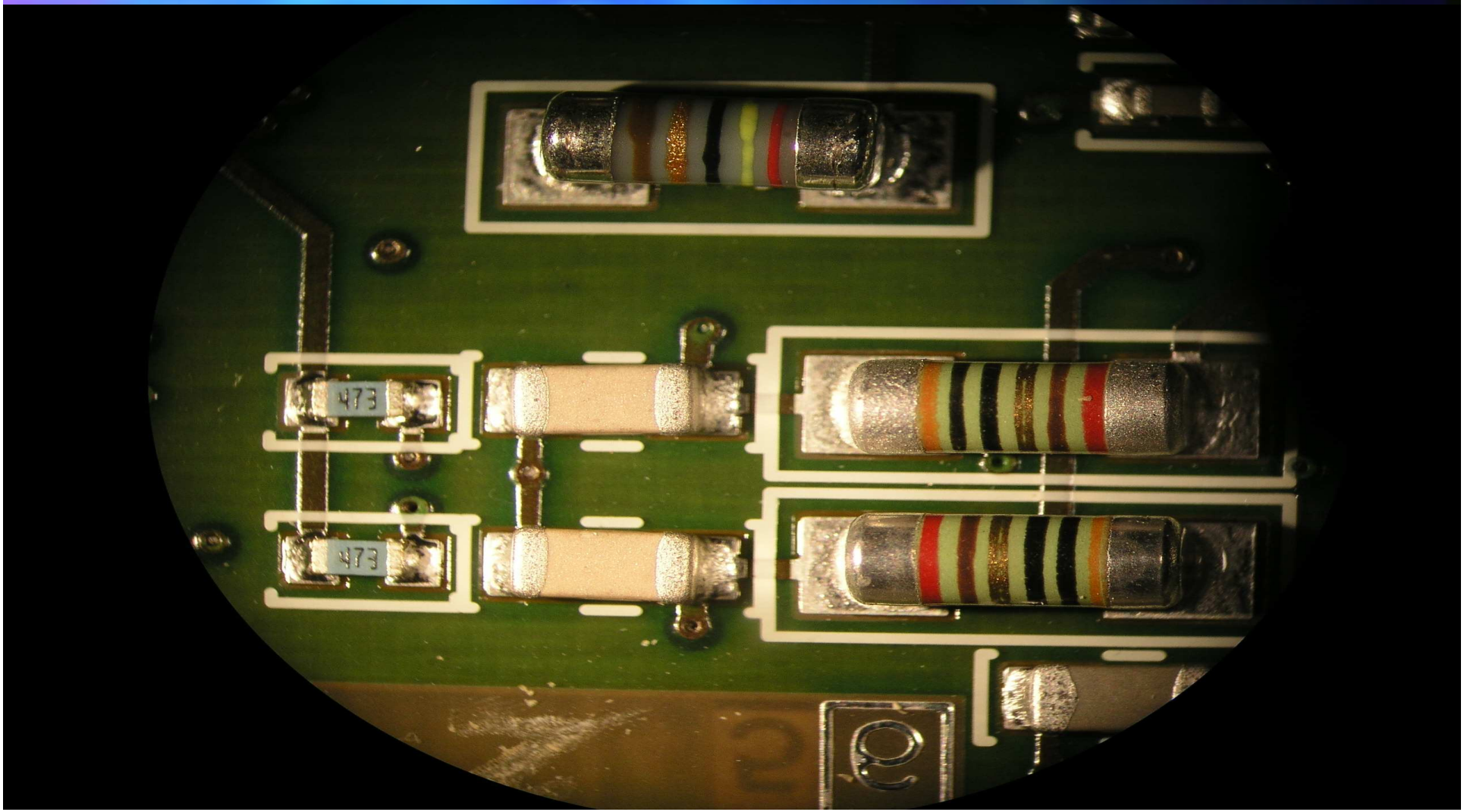

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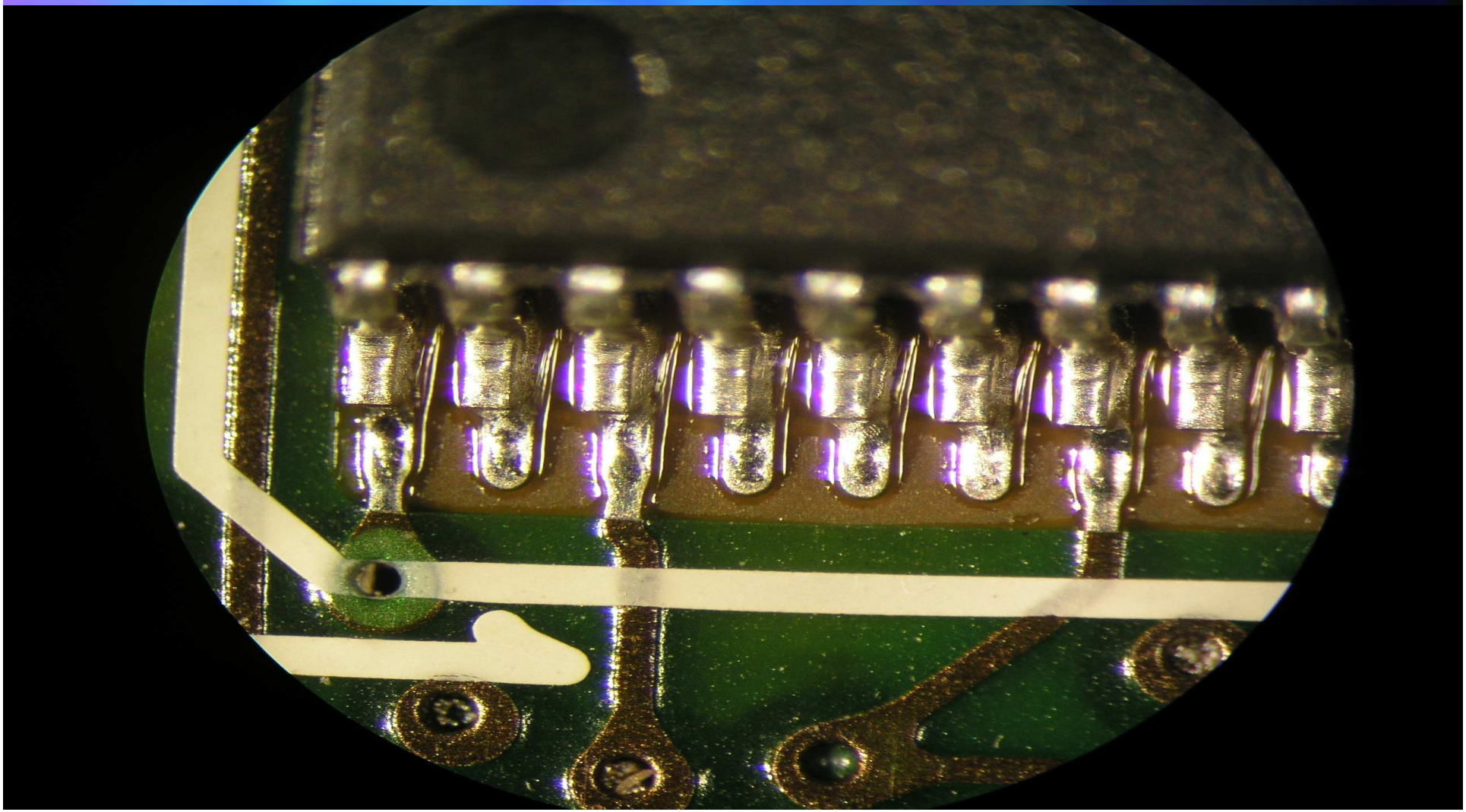


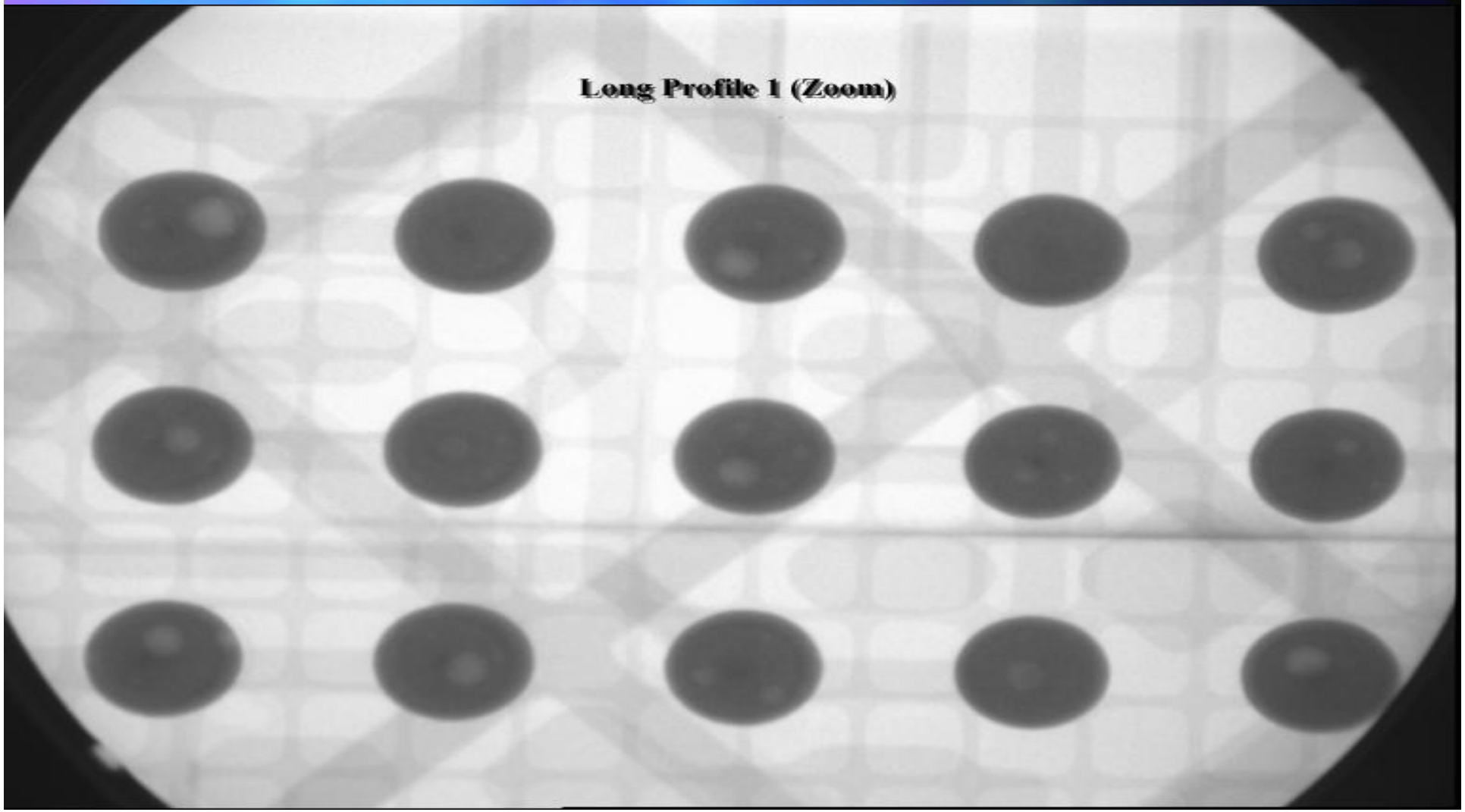
Flux Chemistries

- Water soluble - Excellent
- RMA Fluxes - Good with higher solids
- Most current low solids fluxes are inferior. New versions available soon
- VOC-Free need more development with the possibility of higher solids

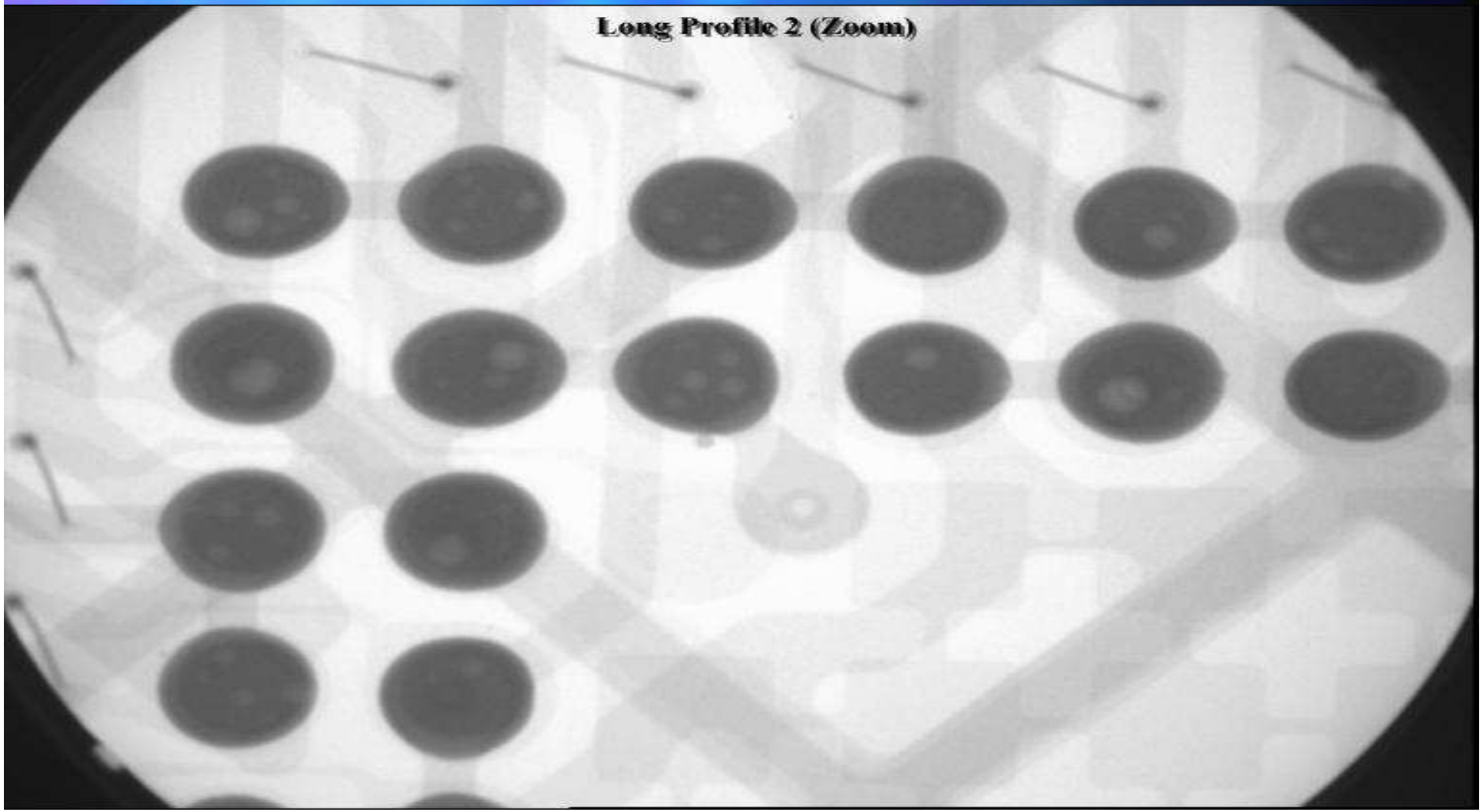
Solderability Issues

- Wettablility
  - Pb-Free alternatives are inferior to Sn/Pb
- Joint Appearance
  - Dull
  - Coarse structure
- Voiding
  - Increased
  - Dependent on flux chemistry

X-Ray Images of BGA Voiding



X-Ray Images of BGA Voiding



Rework/Repair

- Caution with temperature sensitivity of components
- Operators must be re-trained
- Possible using conventional equipment
- Cored solder wires are available in Pb-Free alloys

Wave Soldering Issues

- Higher dross formation with increased tin content
- Higher copper dissolution leading to the formation of Cu_6 Sn_5 Intermetallic
- Smaller process window
- Wave soldering fluxes
- Sn/Cu alloy attacks stainless steel solder baths and wave nozzles that are in contact with wavesoldering fluxes

Wavesoldering Issues

Reflow Soldering Issues

- Increased peak temperatures which could lead to component damage
- Higher levels of flux contamination build-up inside reflow oven
- Increased tendency for voiding especially with BGA and µBGA components
- Incomplete pad coverage - exposed Cu and Au around pads

Current Proposals

- Component Lead Finish
  - Sn, Sn/Cu, Ni/Pd, Sn/Ag/Cu
- Board Finish
  - Immersion Ag, Immersion Sn, HASL Sn/Cu0.7, Au/Ni, and OSP
- Wave Soldering Alloys
  - Sn/Cu, Sn/Ag/Cu
- Solder Paste Alloys
  - Sn/Ag/Cu, Sn/Ag,

Conclusions - 1

- Lead-free wave and reflow soldering of electronic assemblies is feasible
- Legislation in Europe ***1st of July 2006***
- No "drop in" replacement for eutectic Sn/Pb solder
- Sn/Ag/Cu eutectic is the most likely, safe global, solution for both reflow and wave.
- Most current equipment can be used
- Solder bath temperature 265°C
- Reflow temperature (joint interface) 235°C

Conclusions - 2

- Tests have shown that the reliability of Sn/Ag/Cu to be similar to Sn/Pb alloys
- Lead-free PCBs, bar, cored solder wire, and solder pastes are available now
- Components with Pb-Free finishes are gradually becoming available
- Component damage and dull joints are the main issue in reflow soldering
- Reflow tolerates some lead in finishes, but wave soldering **DOES NOT!**

Thank you for your Attention

Any Questions

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