SAND2020-3194PE

Assessment of Isolator Units Following Shock Testing

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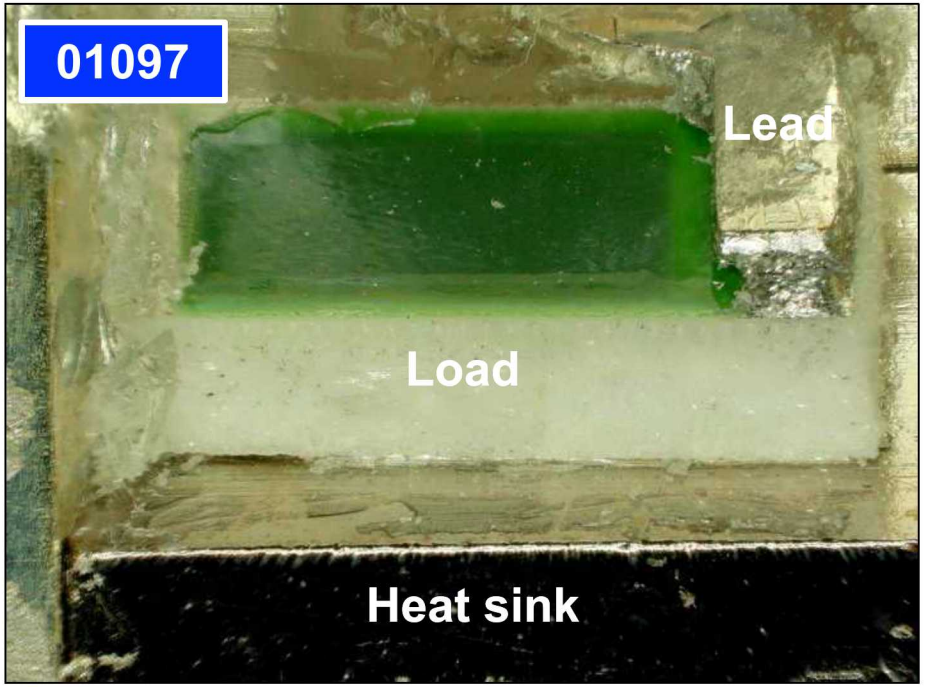
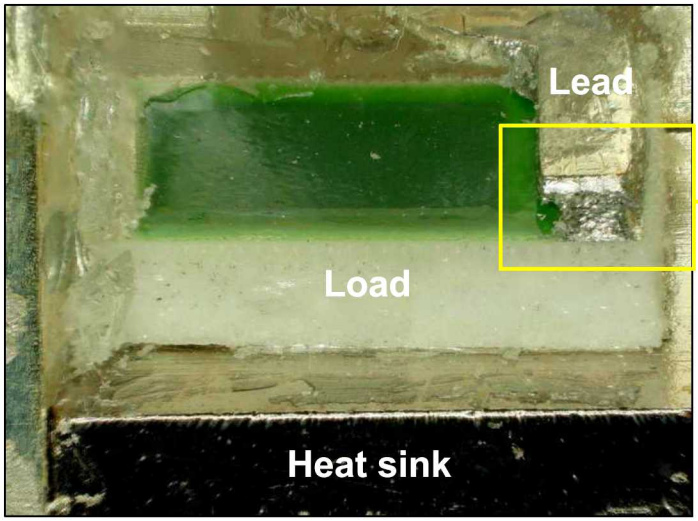
Outline

- **Problem**: The isolator S/N01097 failed electrical testing following mechanical shock testing (qualification) at the supplier:
- **Objective**: Determine the root-cause of the failure in order to resolve the qualification status of the product lot.
- **Approach**: Perform microanalysis on the failed unit as well as on "sister" components and assess their materials reliability status.
  - Two other units, S/N 01080 and S/N 00913, originated from the same shock test lot and passed the electrical test. An analysis of those units provided baseline construction information with respect to a shock response.



Analysis

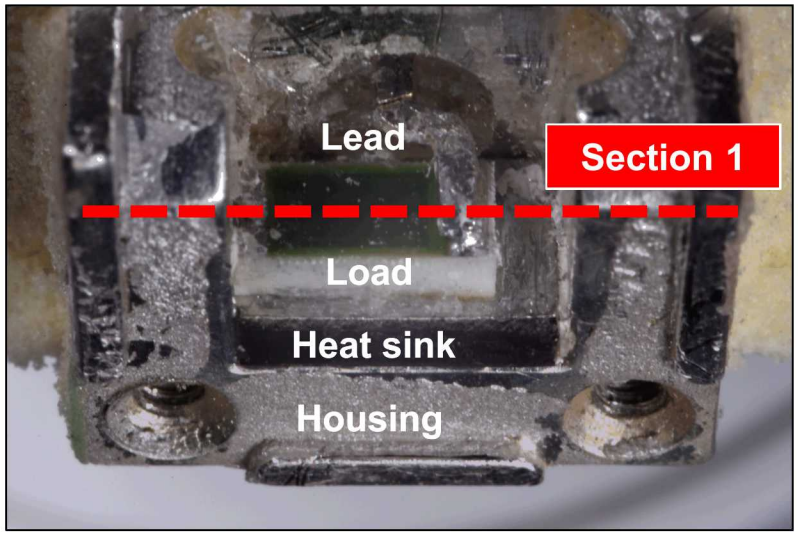
- The high-magnification photograph shows a crack (magenta arrows) in the solder fillet, which pinpointed the potential anomaly that was responsible for the electrical failure.



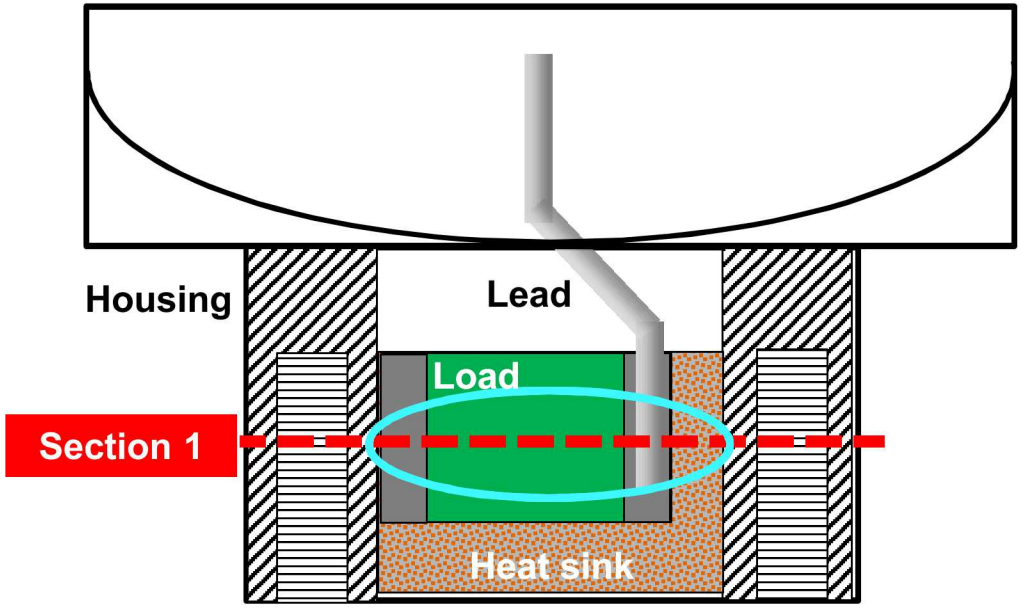
The vendor's technique for removing the RTV was particularly harsh, leaving many artifacts on critical areas of the solder joint.

Cross Section Method

- **Photograph (angle view) and schematic diagram (top-down view) show the isolator and the location of the cross section.**



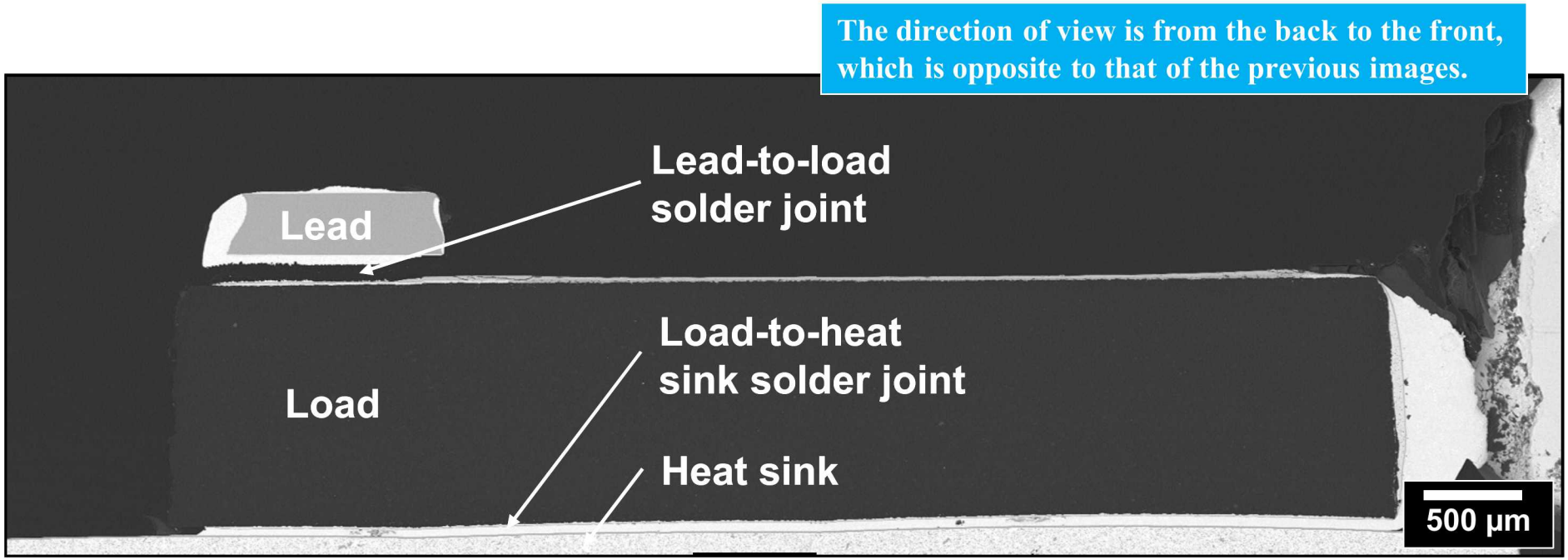
Photograph (angle view)



Schematic (top-down view)

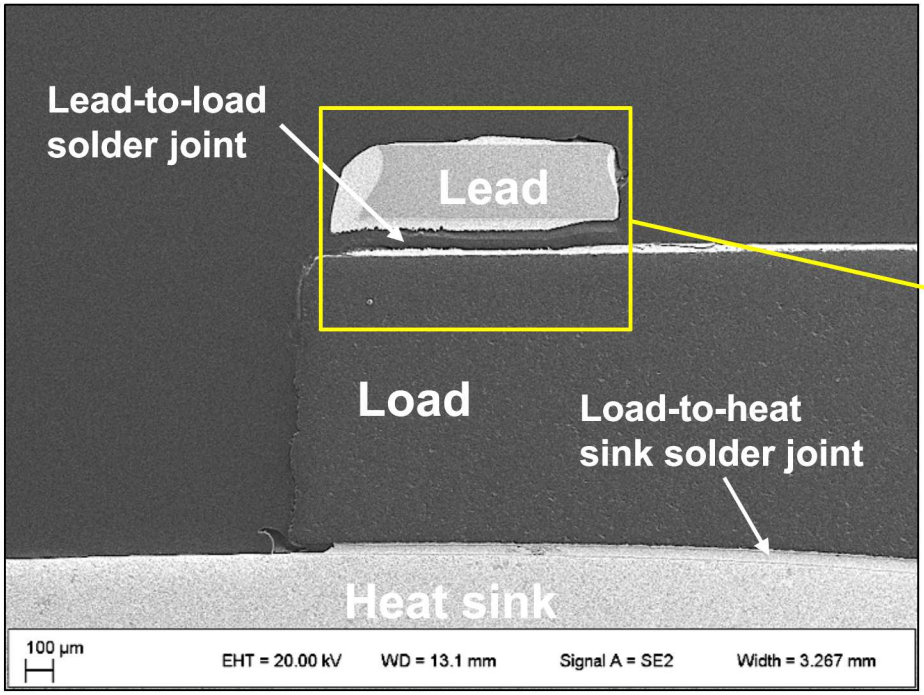
Analysis: S/N 01097, *Failed Unit*

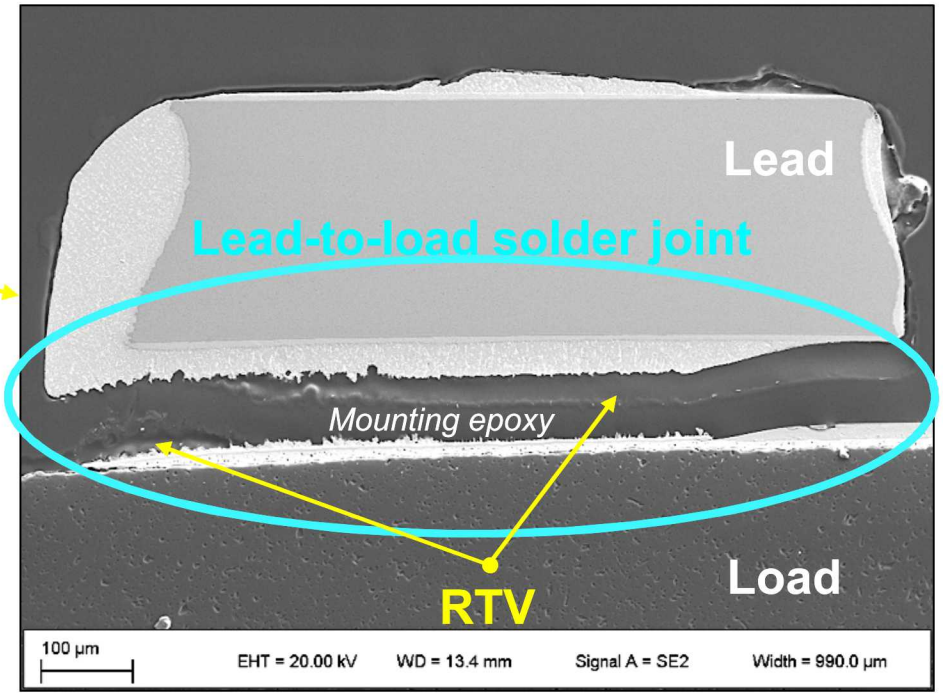
- **The SEM montage shows the lead, the load, and the heat sink as well as the lead-to-load and load-to-heat sink solder joints.**
  - **The lead-to-load solder joint has failed, completely.**
  - **The load-to-heat sink solder joint showed excellent integrity.**
  - **Damage was not observed to the lead or to the load component.**



Analysis: S/N 01097, *Failed Unit*

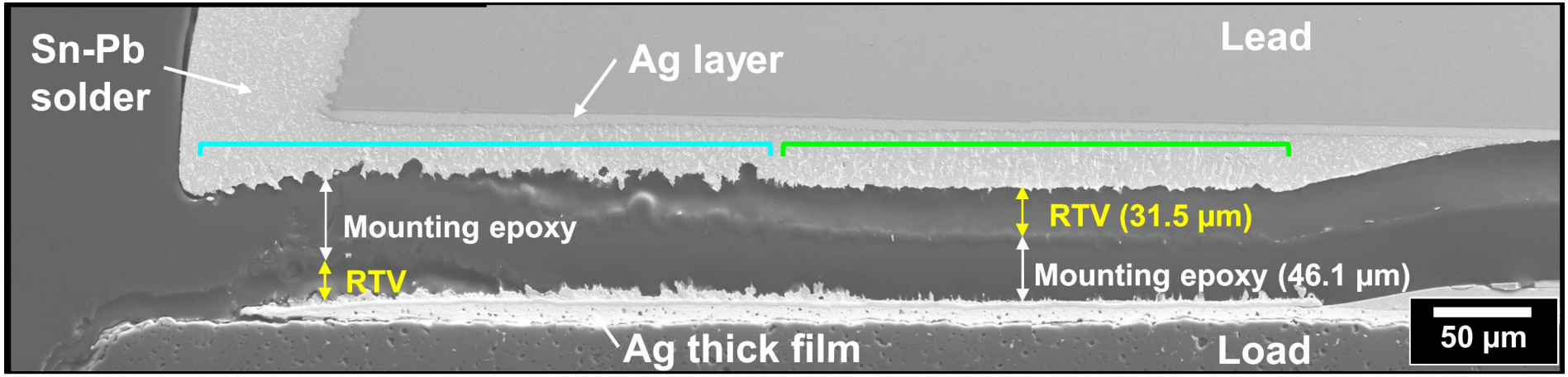
- The photographs show the failure of the lead-to-load solder joint.
- Of particular note was the presence of RTV in the gap.
  - The RTV was distinguished from the mounting epoxy that flowed into the gap during the pre-potting, sample preparation process step.





Analysis: S/N 01097, *Failed Unit*

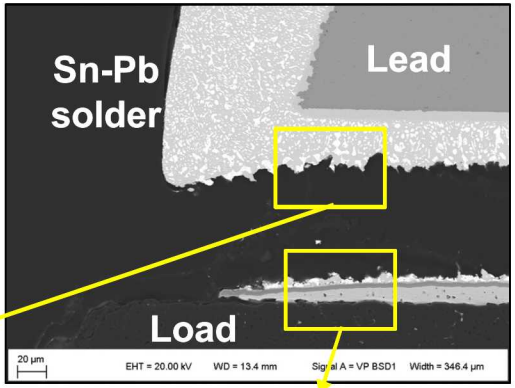
- **Two morphologies were observed for the fracture surface both of which, indicated a *tensile overload stress* placed on the joint.**
  - **Green bracket: relatively fast stain rate due to the crack path being located at the immediate solder/thick film (Ni layer) interface.**
  - **Cyan bracket: relatively slow stain rate indicated by the crack path moving towards the center of the gap and increase plastic deformation.**

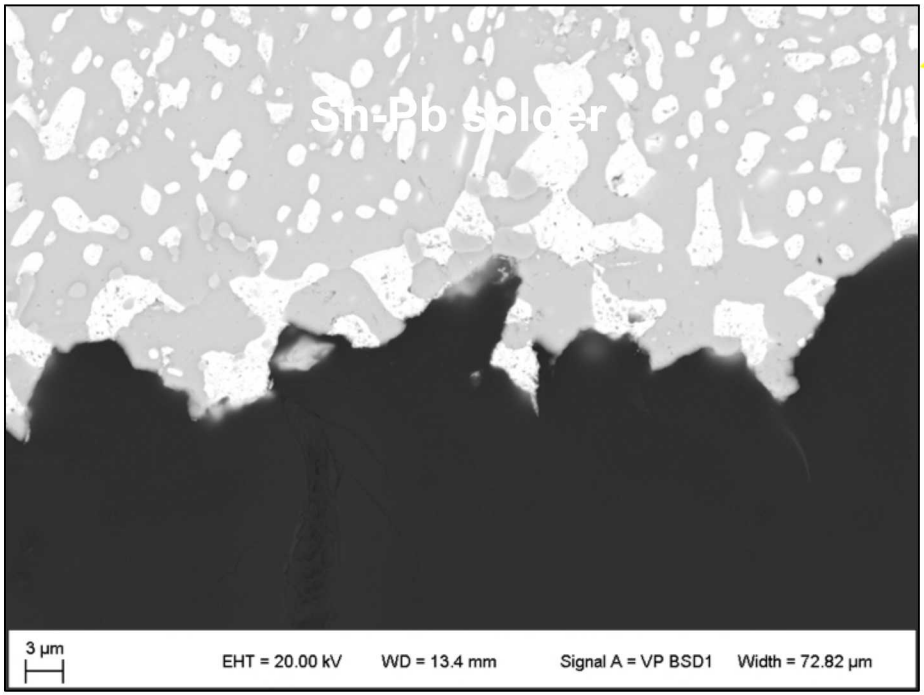


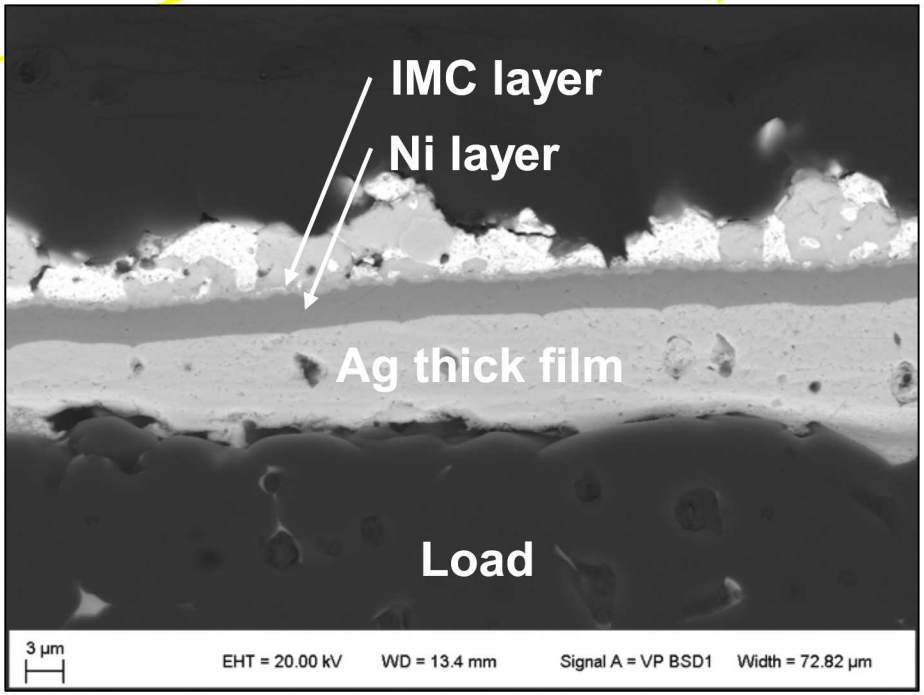
- **Assuming that the RTV thickness represents the original gap created by the separation, *the crack propagated right-to-left*.**

Analysis: S/N 01097, *Failed Unit*

- **A closer examination did not detect a defect in the materials set or solder assembly process.**
- **The Sn-Pb solder showed significant ductility and negligible Pb-rich coarsening, confirming *time-independent deformation*.**

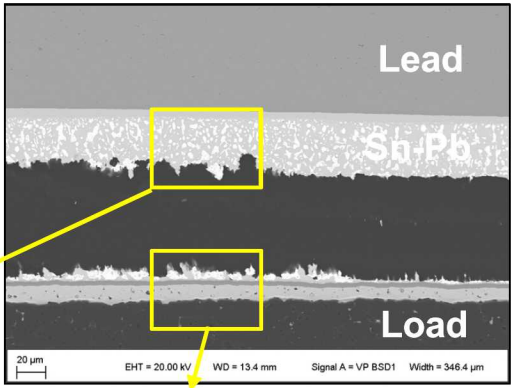


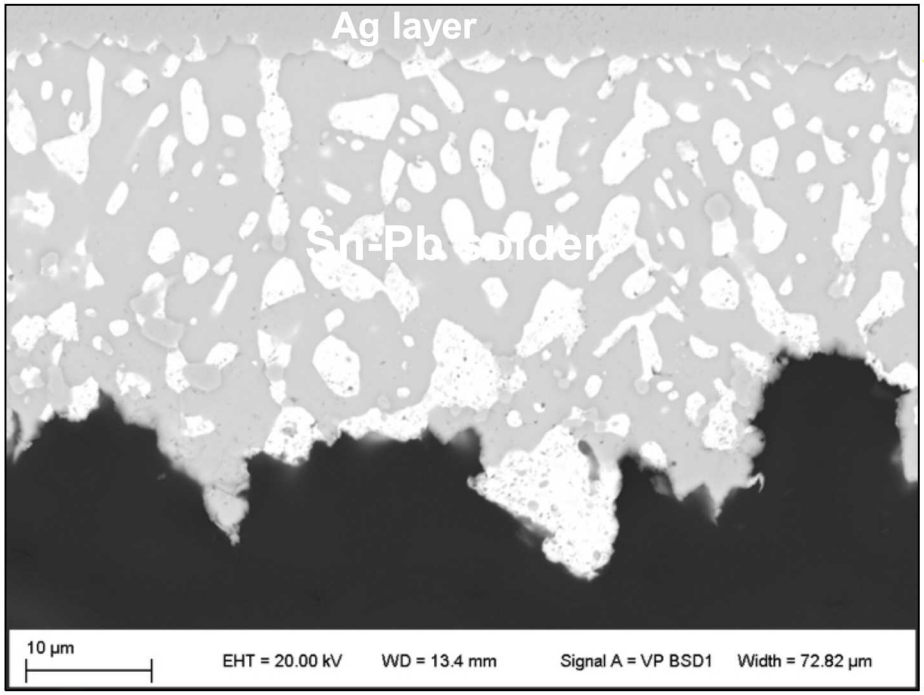


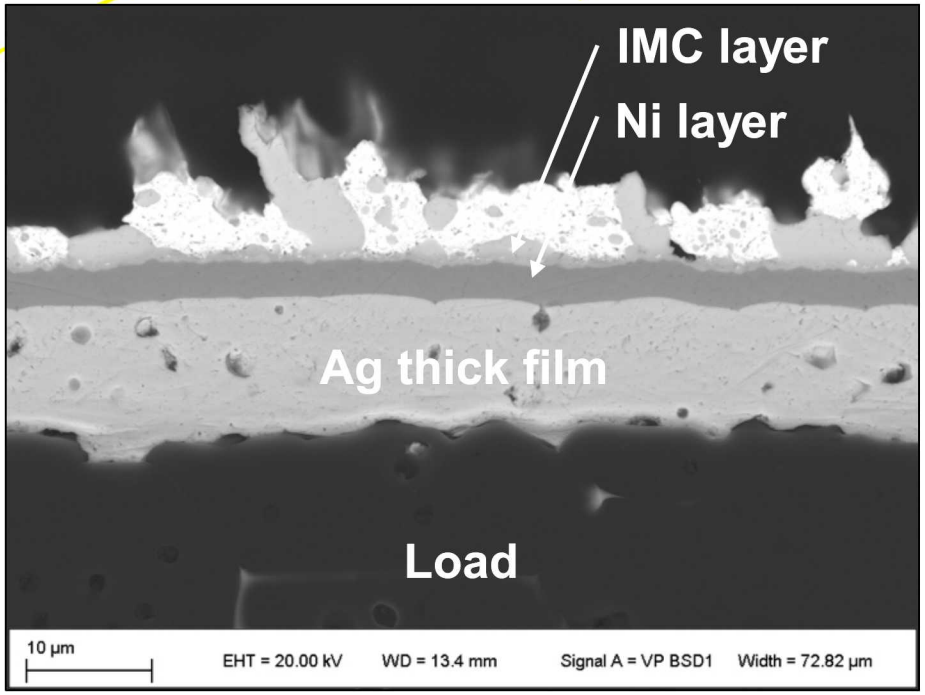


Analysis: S/N 01097, *Failed Unit*

- **A similar conclusion was drawn at this location of the fracture path, which marked the transition between the two morphologies.**

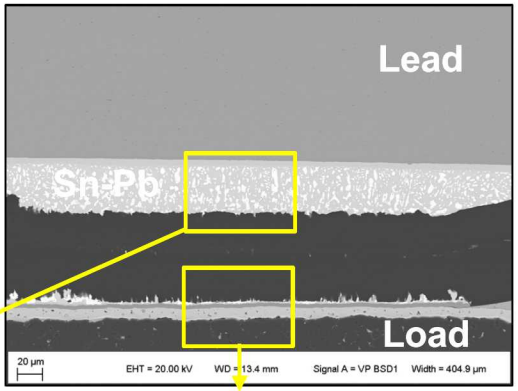


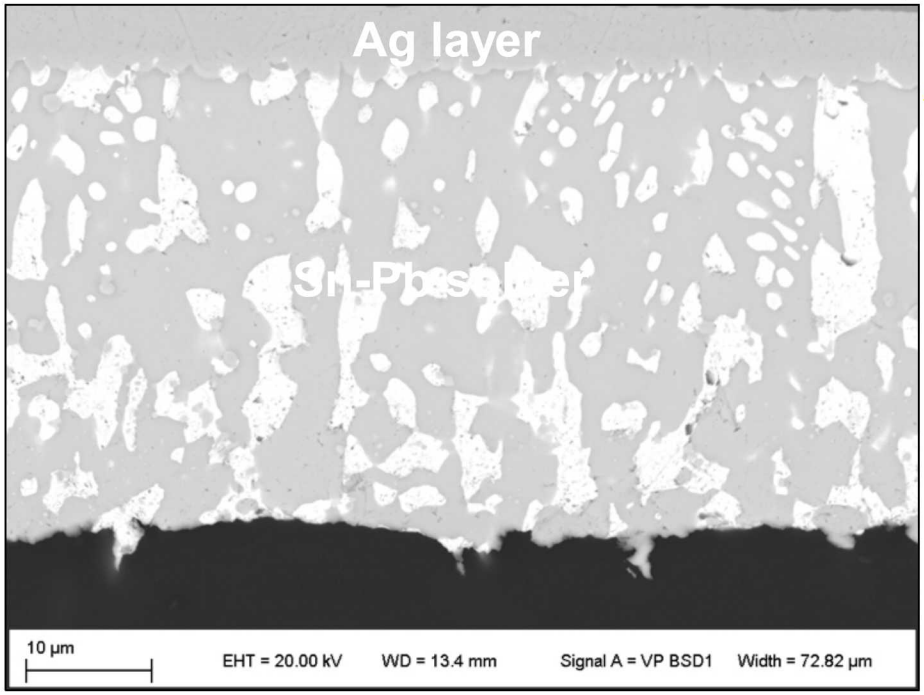


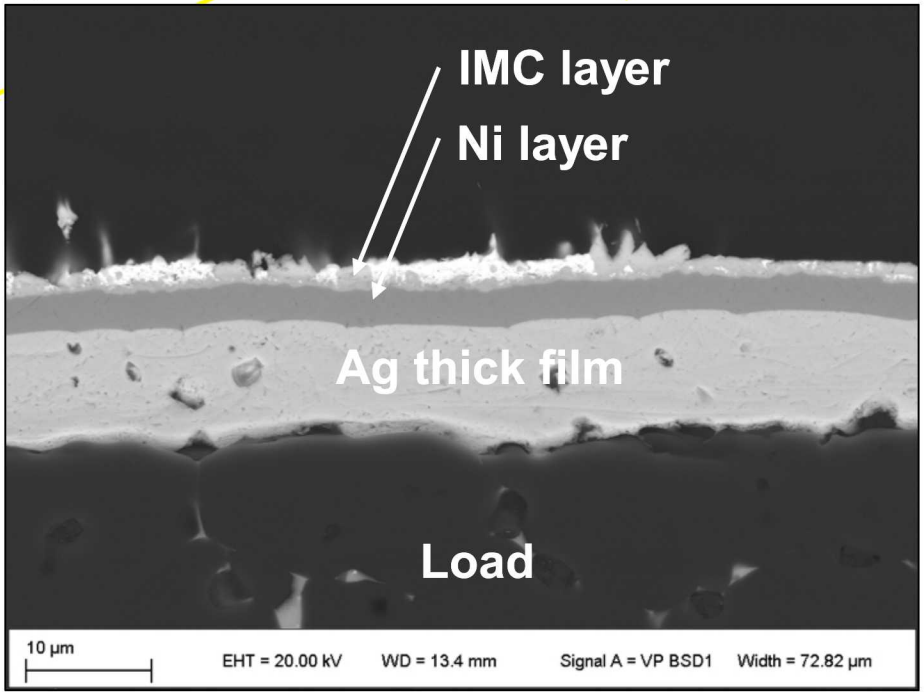


Analysis: S/N 01097, *Failed Unit*

- The failure mode, although still based upon time-independent deformation, occurred at a faster strain rate.
- Although positioned closer to the interface, the fracture was not augmented by the presence of the intermetallic compound (IMC) layer.

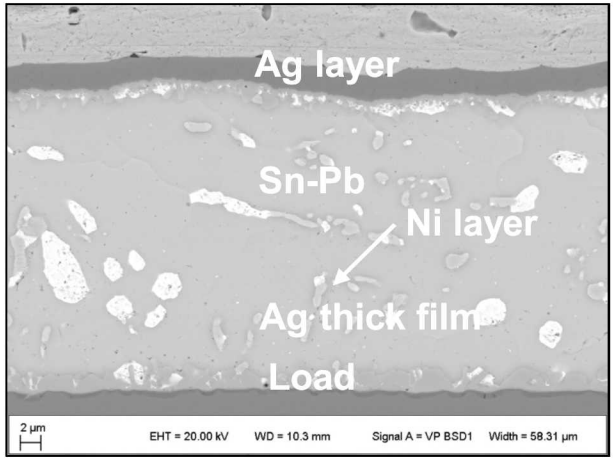


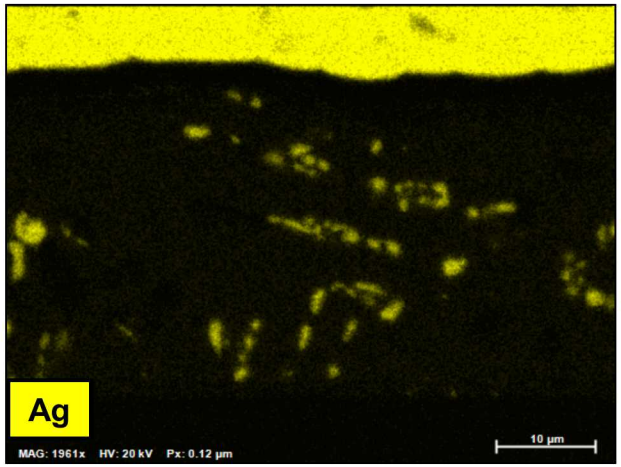


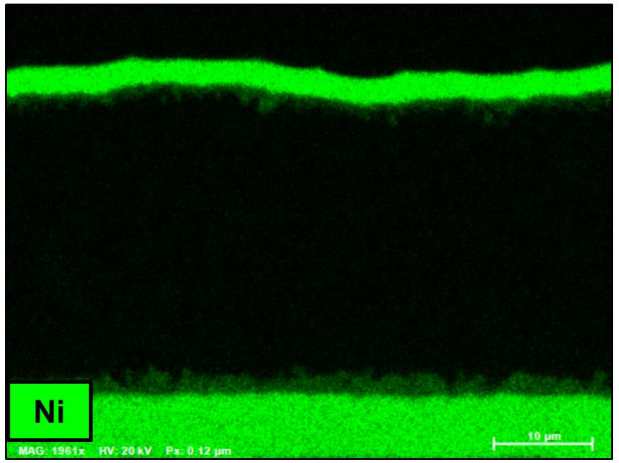


Analysis: S/N 01097, *Failed Unit*

- **The load-to-heat sink solder joint exhibited *excellent integrity.***
  - **The Ni layer did not experience delamination from the the heat-sink.**

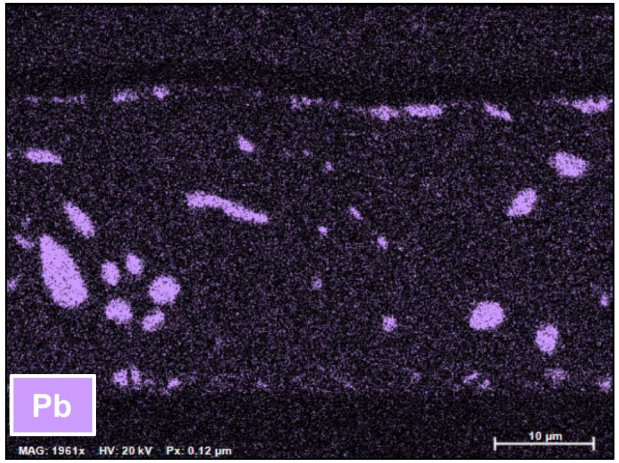


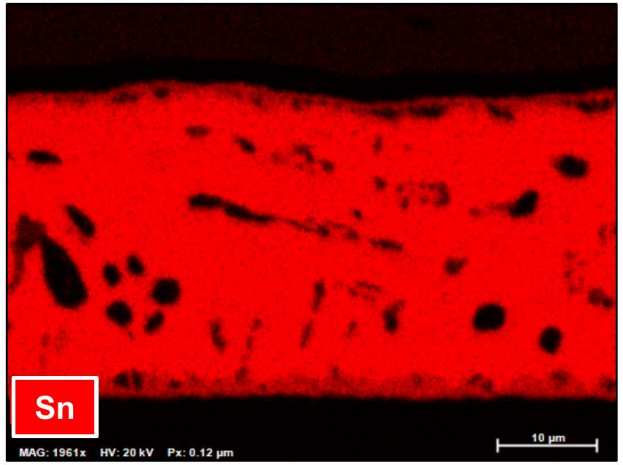




The Sn-Ag solder was contaminated with Pb from the soldering iron.

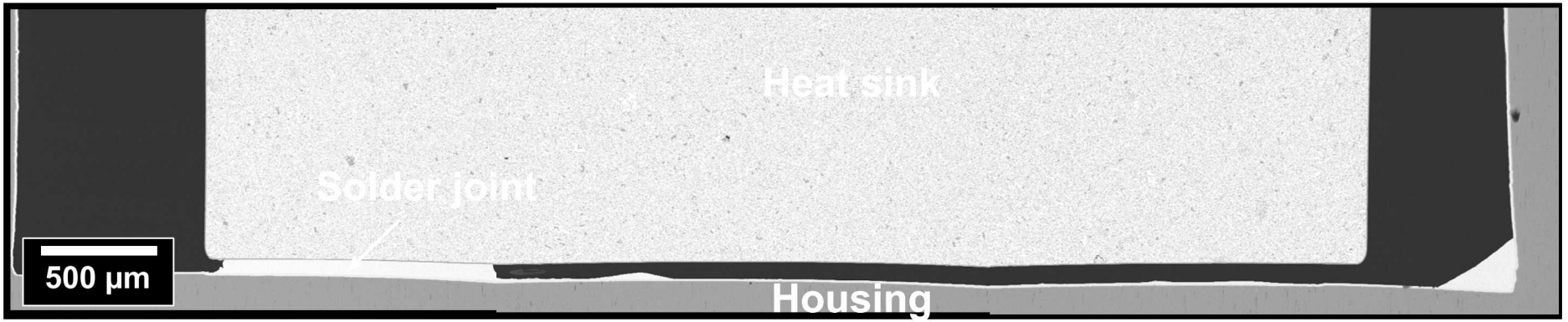
The extent of Pb *will not* degrade the long-term reliability of the joint.





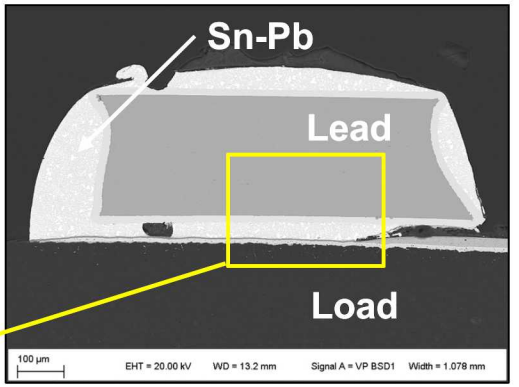
Analysis: S/N 01097, *Failed Unit*

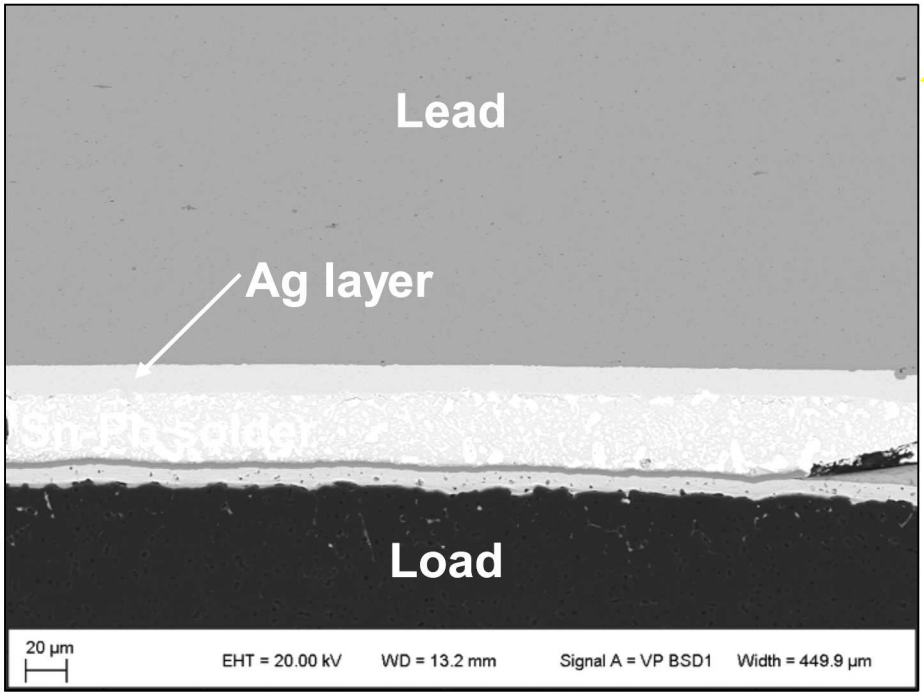
- **A significant extent of filler metal was missing from the the heat sink-to-housing solder joint.**
  - **The portion of the solder joint, which was present, showed good solderability and an absence of defects.**

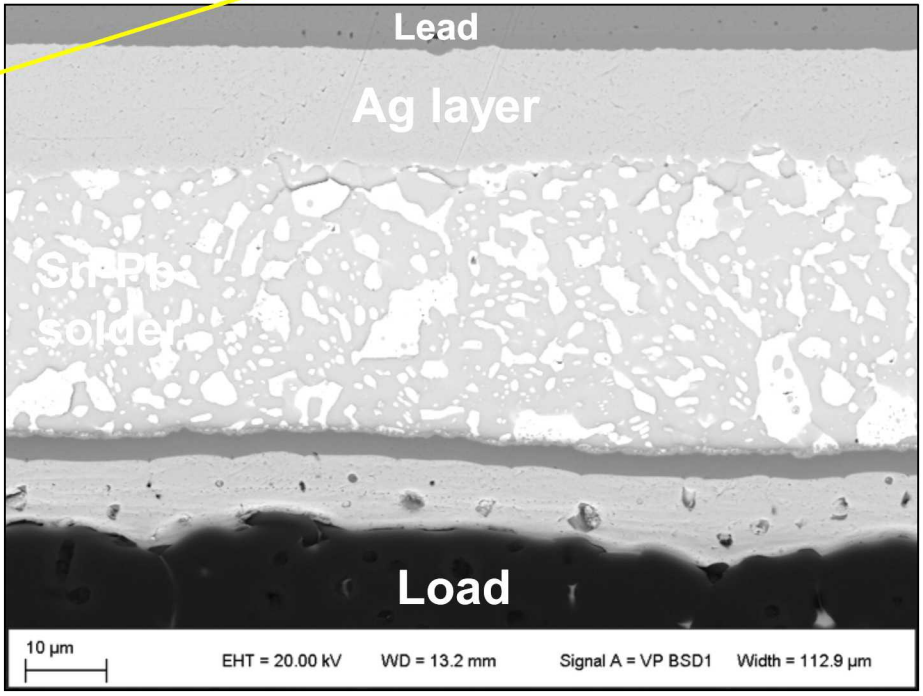


Analysis: S/N 01080 and S/N 00913, *Baseline Units*

- **The microstructures were documented for these two "baseline" units. The focus was placed on the S/N 01080 unit.**

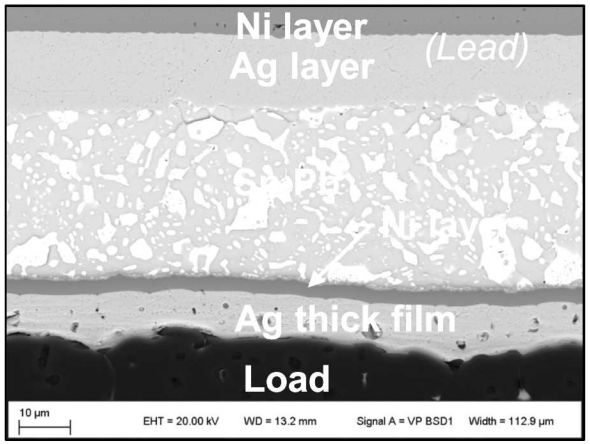


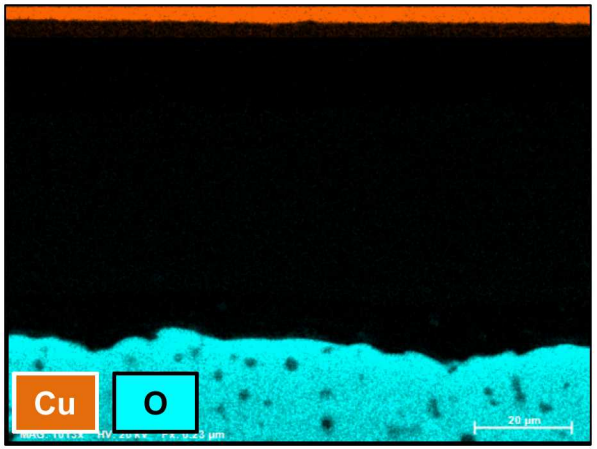


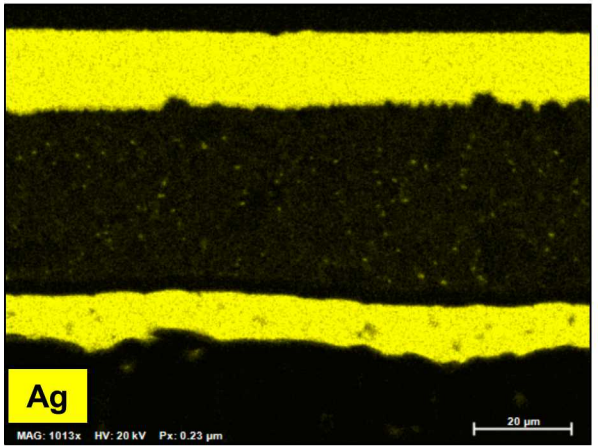


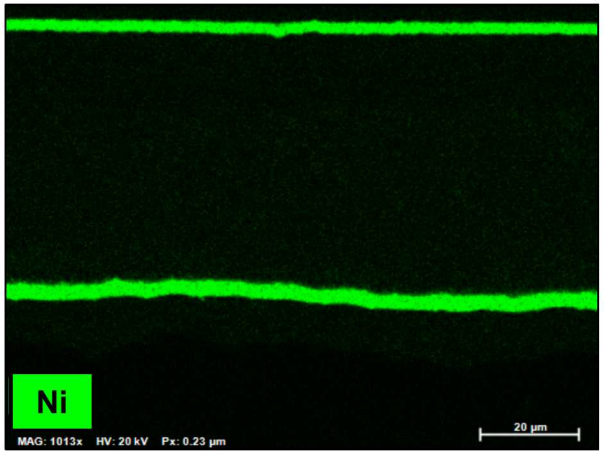
Analysis: S/N 01080, *Baseline Unit*

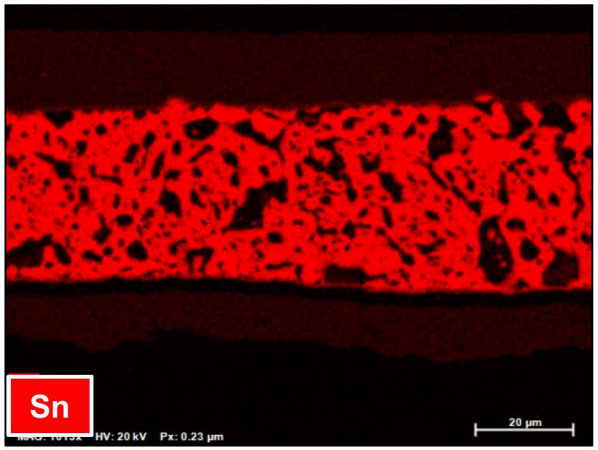
- **The EDX analysis confirmed the composition of the solder joint structure between the lead and the load.**

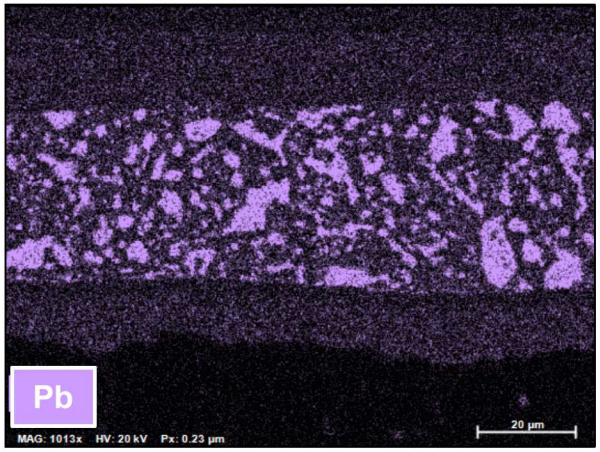






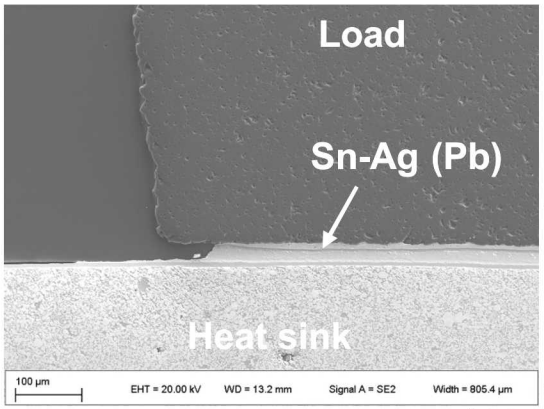


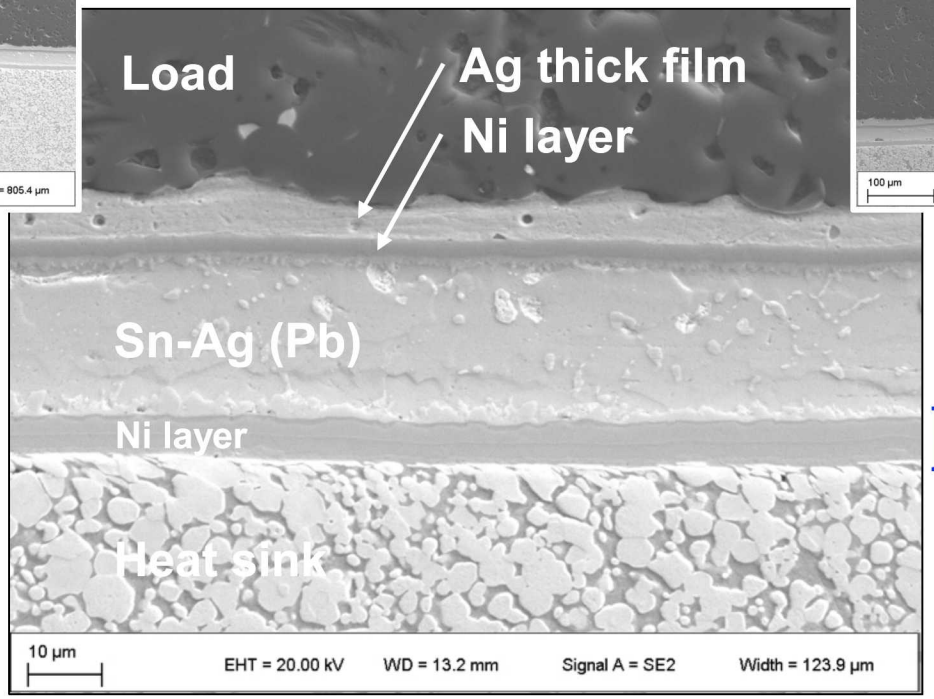


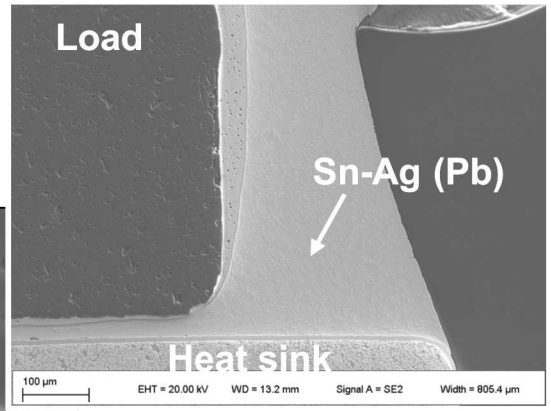


Analysis: S/N 01080, *Baseline Unit*

- **The load-to-heat sink solder joint showed excellent integrity.**
  - **Past problems have been remedied with respect to poor Ni plating adhesion to the heat sink surface.**





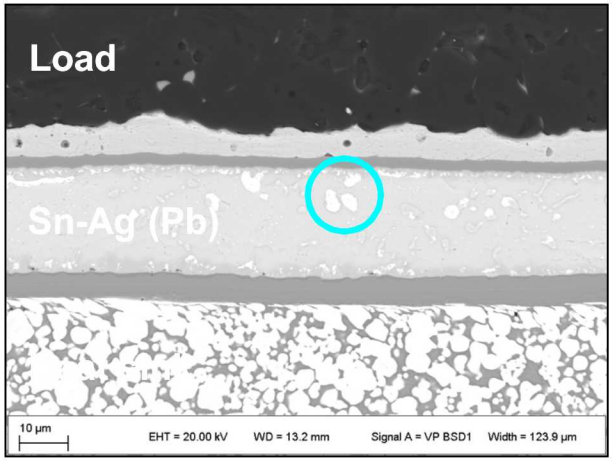


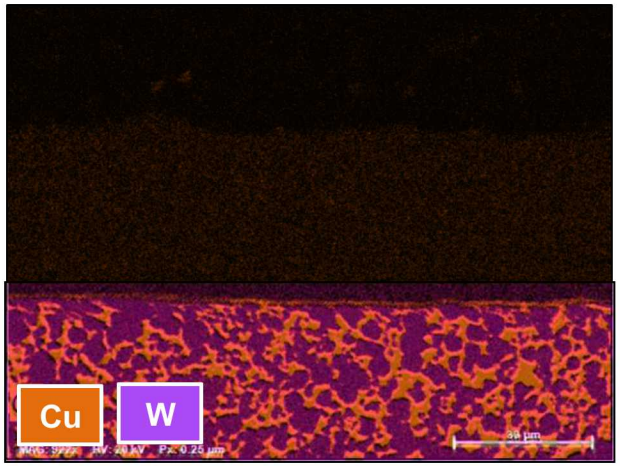
The Ni finish is comprised of three individual layers:

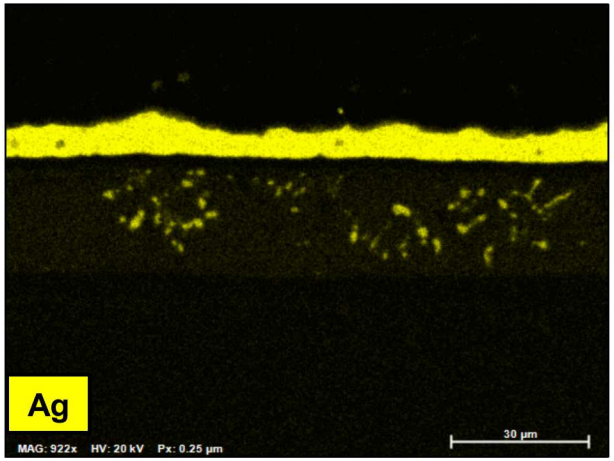
- **Electroless Ni**
- **Electroplated Ni**
- **Electroless Ni *flash***

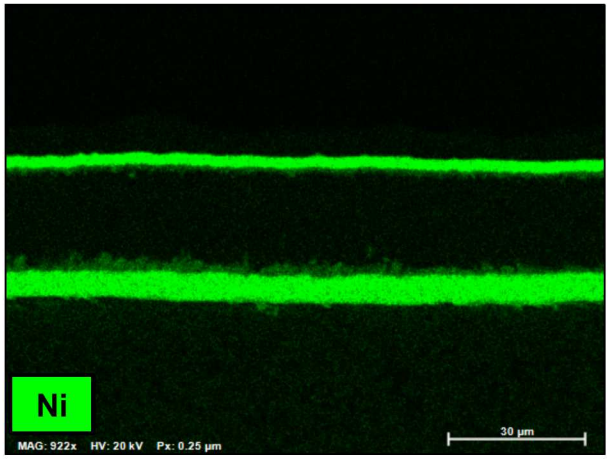
Analysis: S/N 01080, *Baseline Unit*

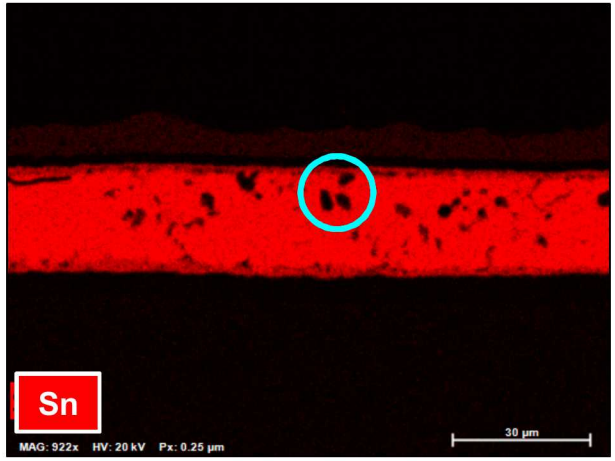
- **The solder appears to be a Sn-Ag or Sn-Ag-Cu alloy that was contaminated with *traces of Pb* (cyan circle) from the soldering iron.**

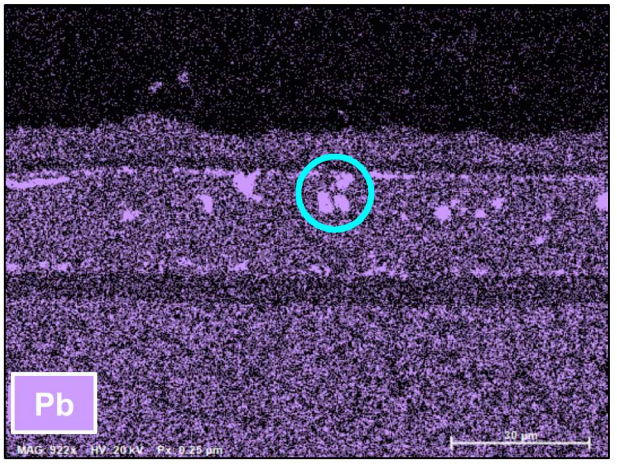






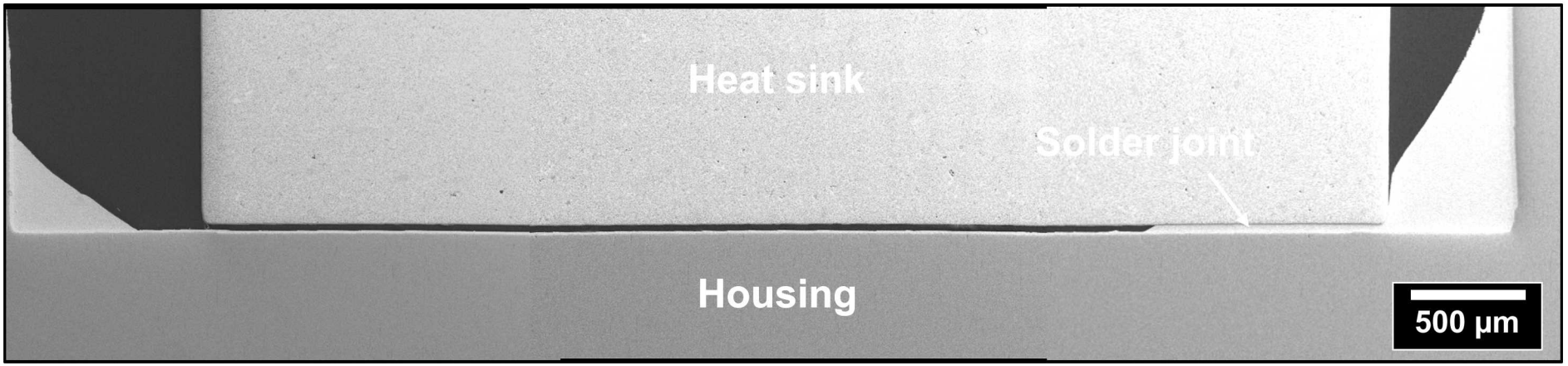






Analysis: S/N 01080, *Baseline Unit*

- **A significant extent of filler metal was missing from the the heat sink-to-frame (housing) solder joint.**

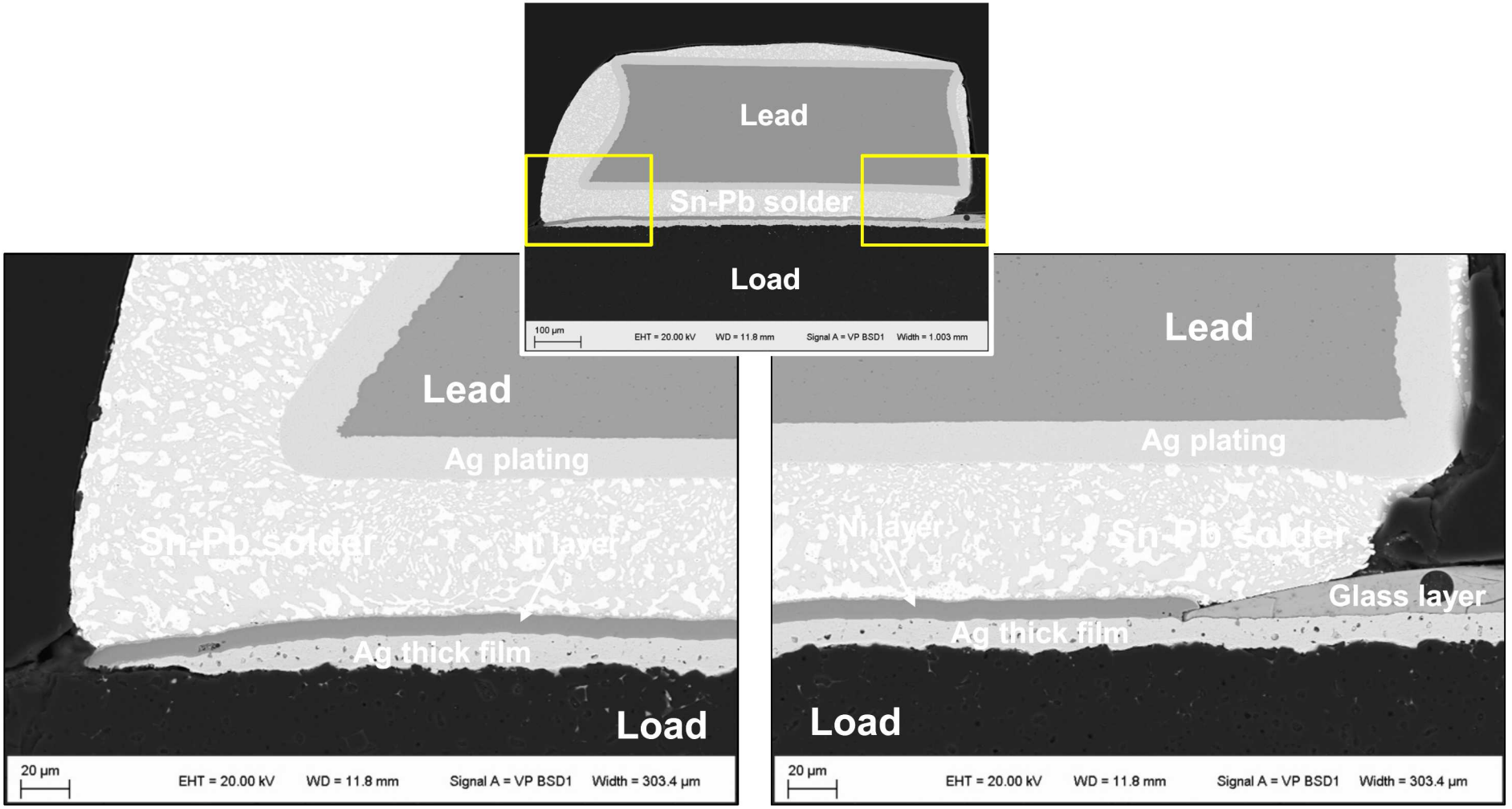


- **The second baseline unit, S/N00913, showed the same defect.**

All three instances of an incomplete heat sink-to-housing solder joint indicated simply *a lack of filler metal supplied to the joint* – evidence was not apparent at this point that there was a solderability problem with the surfaces of either the heat sink or the housing, which both had Ni solderable layers.

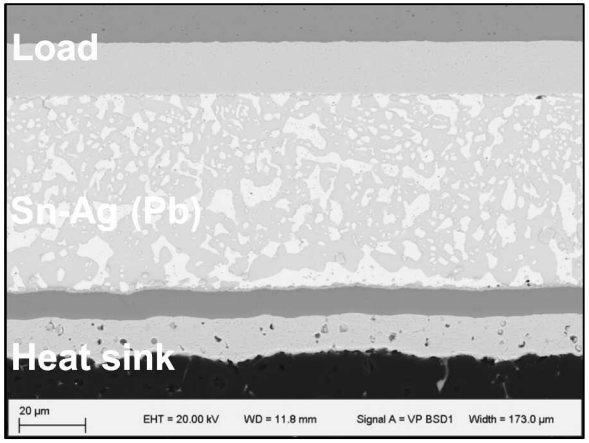
Analysis: S/N 00913, *Baseline Unit*

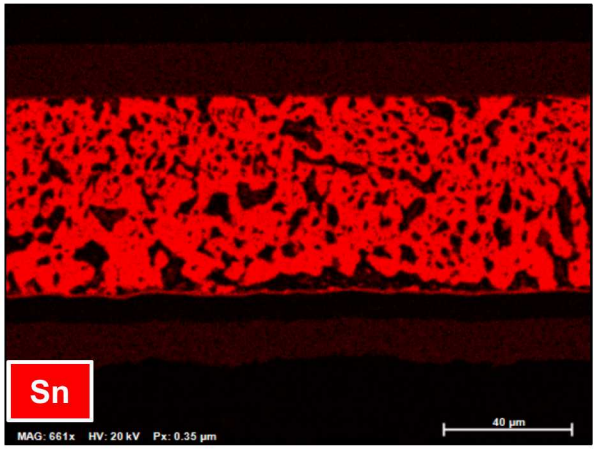
- **The lead-to-load solder joint exhibited excellent integrity.**

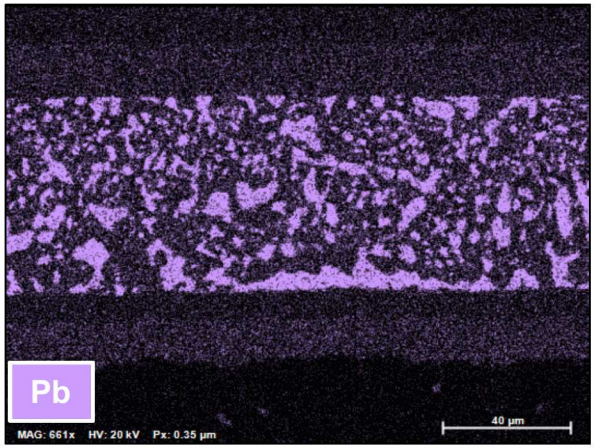


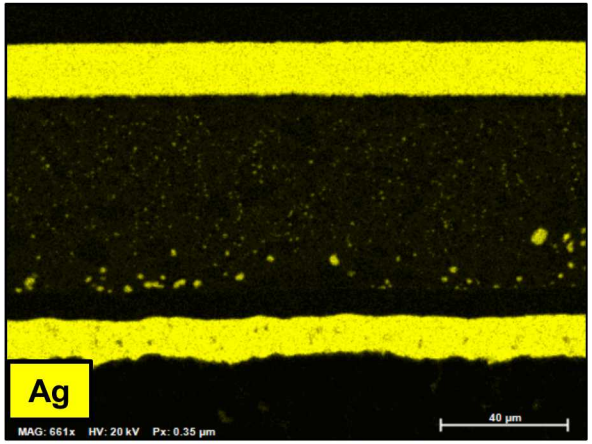
Analysis: S/N 00913, *Baseline Unit*

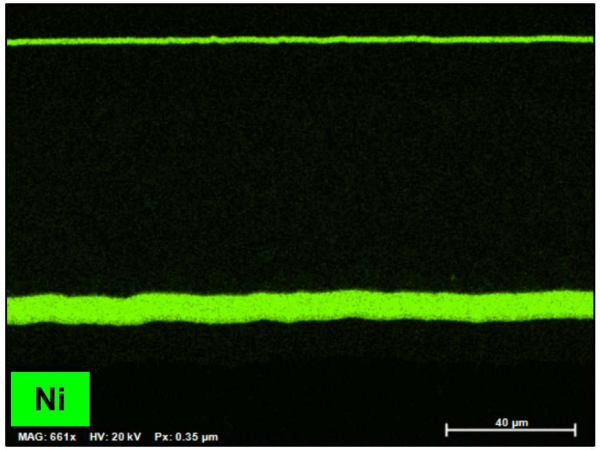
- **An anomaly was the presence of an *electroplated iron (Fe) layer* between the Ni layer and the Ag thick film layer on the load.**

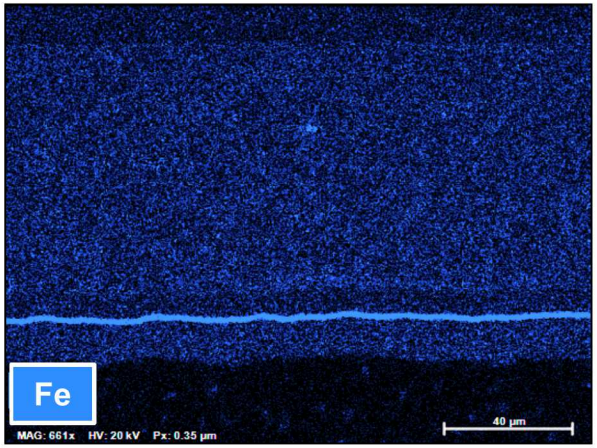












Summary

- **The isolator S/N01097 that failed an electrical test after having been subjected to a mechanical shock environment (in-plane to the device footprint).**
- **The load "room" was opened up and the RTV encapsulant removed at the supplier's facility. Inspection revealed *a crack between the lead and the load at the Sn-Pb solder joint*.**
- **A failure analysis was performed at SNL to answer the following points and thus render an accept/reject decision on the lot:**
  - **Root-cause**
  - **Material's performance and reliability impact**
  - **Prevalence in the lot**
  - **Mitigation strategy**
- **Two additional units, S/N 01080 and S/N 00913, experienced the same test sequence without failure, were also evaluated, here.**

Summary

- **Root-cause: The solder joint was subjected to a tensile, overload stress that failed the Sn-Pb solder.**
  - **The presence of RTV in the solder joint gap implies that the overload stress and failure occurred prior to the introduction of RTV into the "room."**
  - **The separation was widened further by the test regiments.**
  - **Note that metallographic cross sections represent a single plane; therefore, electrical conductivity (DC) could have been maintained at an unseen location into/out-of that plane.**
  - **The defect, or any evidence that would support a high likelihood of its recurrence in the future, was not detected in the other two units.**

Summary

- **Materials performance and reliability impact:** The materials set, which was used in the component design, will meet the intended performance and reliability characteristic for the device.

- **Prevalence in the lot:** The materials set, which was used in the component design and consistently applied across the three units, will meet the intended performance and reliability characteristic for the device.

- **Mitigation:** A mitigation strategy is not warranted with respect to altering materials performance of reliability by the unit design or testing parameters.

The recommendation is to accept this lot of isolators, based upon the findings of this failure analysis.