The Effects of Partially Activated No-Clean Flux Residues under Component Bodies and No-Clean Flux Residues Entrapped Under RF Cans on Electrical Reliability

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With the predominance of no-clean soldering processes and ever decreasing component standoff, the industry has had to consider the reliability of, what may be, partially activated or "gooey" flux residues under component bodies. Similarly, questions have also risen about the reliability of flux residues resulting from the reflow of no-clean solder pastes that are "entrapped" under RF shields or "cans", where escape of the volatile ingredients of the flux is greatly hindered. In this paper, discussion will be made regarding an experiment designed to mimic the aforementioned conditions and how these conditions affected the SIR performance of the no-clean flux residues. A variety of no-clean solder paste flux residues will be discussed, including a halogen-containing, Pb-free solder paste flux; a halogen-free, Pb-free solder paste flux; a halogen-free, Pb-free solder paste flux with a residue optimized for pin probing; and a halogen free SnPb solder paste flux.

Only the solder paste flux vehicles were used in this experiment, rather than the solder pastes (including solder powder), for two primary reasons:
 1) It insured an excessive amount of flux in order to induce a "worst case scenario".
 2) The presence of the actual solder alloy on the test boards would have led to electrical shorting of the SIR patterns because smearing of the paste (bridging) would have been inevitable.

For these experiments, standard IPC B-24 SIR boards were used. The flux vehicles were printed onto the SIR test patterns using a standard IPC SIR prescribed stencil.
In order to mimic flux being entrapped under a component body, ~1.5" long standard microscope slides were used to cover the flux on two opposing corner patterns of the SIR boards. Two SIR boards were prepared for each flux vehicle. Kapton tape was used to secure the slides in place and created somewhat of a seal along the periphery of the glass slide. The slides were secured in place with the tape throughout the duration of reflow and SIR testing. (See Figure 1 for an example.)
Glass slides were chosen because glass allows for easy inspection of the flux (dendrites) without disturbing the flux. Also, glass has a propensity to attract and hold moisture, further adding to the "worst case scenario" conditions, specifically, promotion of electrochemical migration.

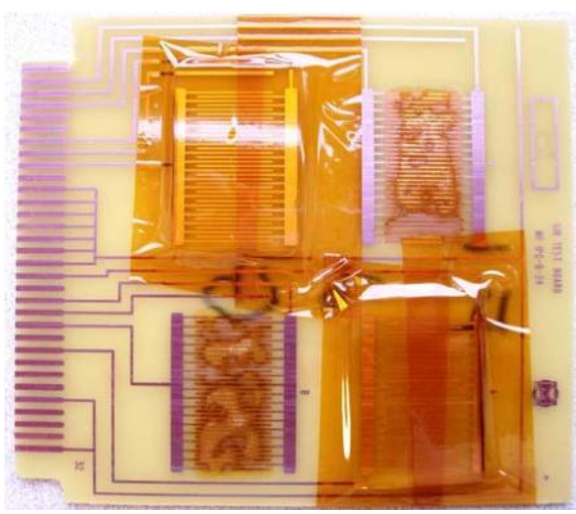


Figure 1 - Example of reflowed SIR board with glass slides secured in place with Kapton tape

In the case of the RF shield scenario, an RF shield was affixed over the upper left SIR pattern (pattern "D"). This was the only location that allowed for placement of the RF shield with minimal risk of contact and shorting to the electrical traces. A little bit of the RF shield had to be removed for the reason of avoiding contact with the electrical traces running down the left side of the SIR boards (Figure 2).

The RF shield was held in place during reflow and SIR testing with Kapton tape creating

somewhat of a seal around the RF shield. Due to a limited quantity of appropriately sized RF shields, only one board was prepared for each solder past flux vehicle.

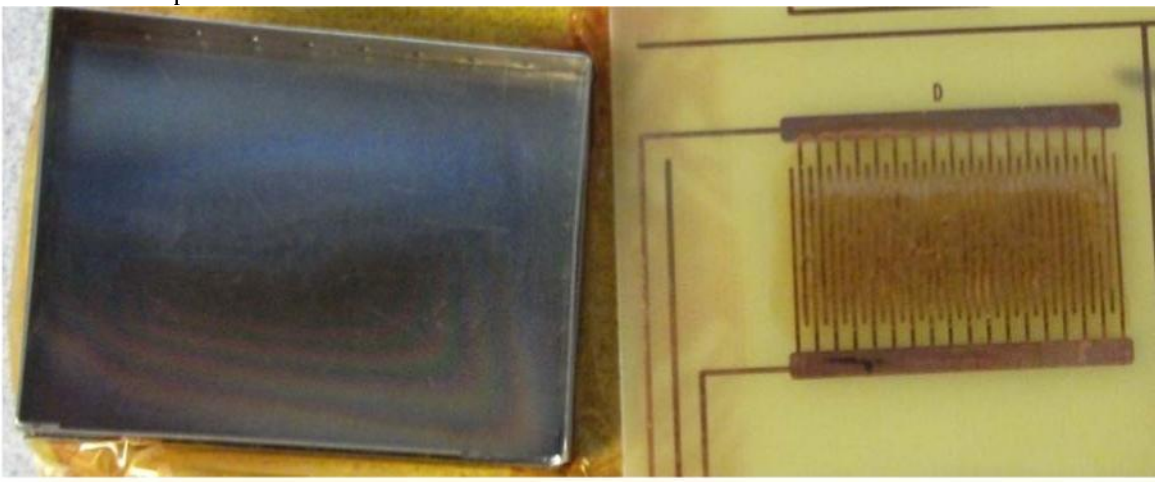


Figure 2 - Example showing RF shield and relative location of electrical traces on SIR board near pattern "D"

The SIR boards prepared with Pb-free no-clean solder paste flux vehicles were reflowed with the following profiles (Figures 3 and 4). On the SIR boards prepared with the glass slides, the bare SIR patterns achieved a peak temperature of -243°C and the patterns with the glass sides achieved a peak temperature of -237°C. On the SIR boards prepared with the RF shield, the bare SIR patterns achieved a peak temperature of -245°C and the pattern with the RF shield achieved a peak temperature of -234°C. The placement of the thermal couples can be seen in Figures 5, 6, and 7.

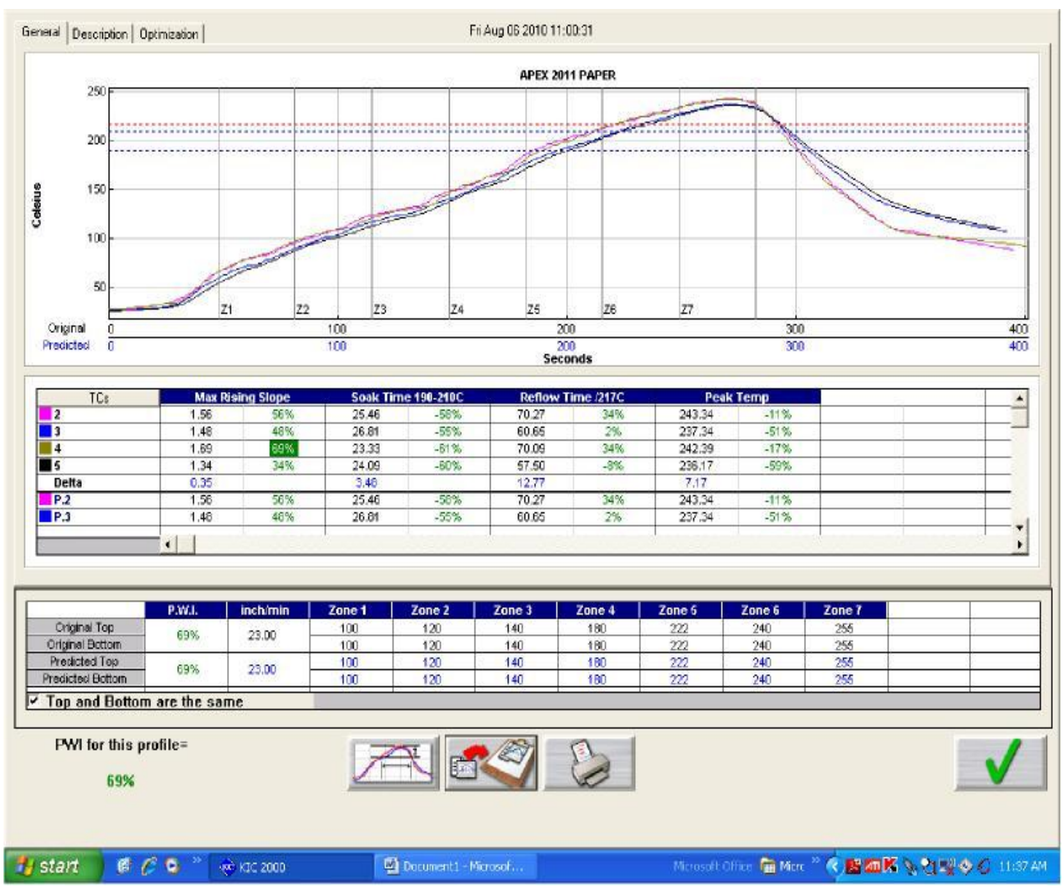


Figure 3 - Reflow profile used for Pb-free fluxed SIR boards with glass slides attached

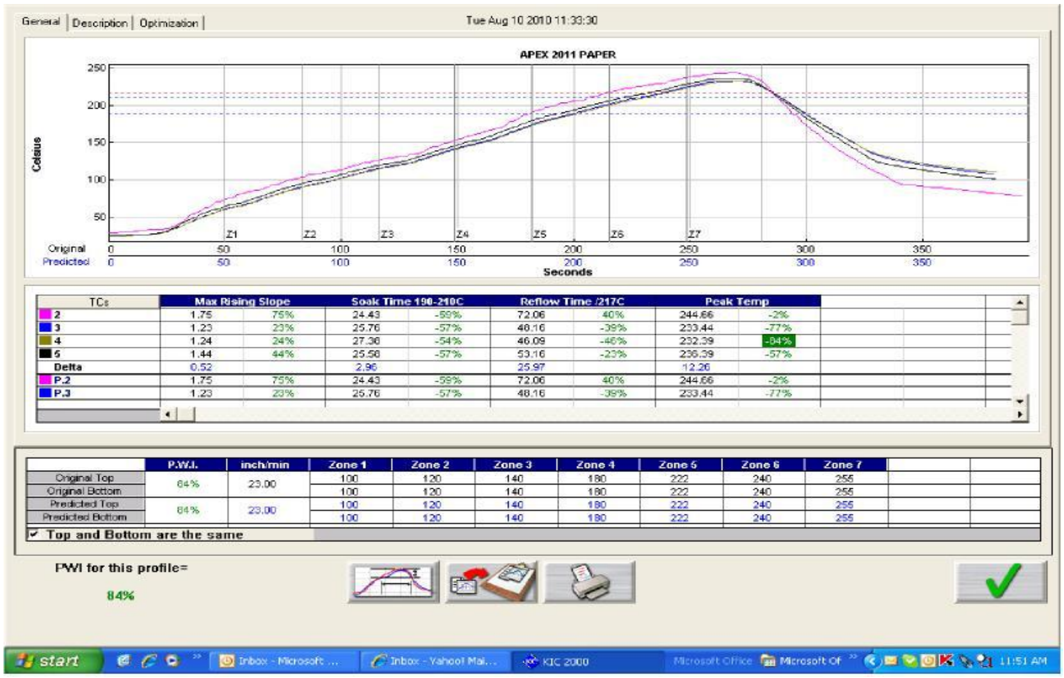


Figure 4 - Reflow profile used for Pb-free fluxed SIR boards with RF shield attached

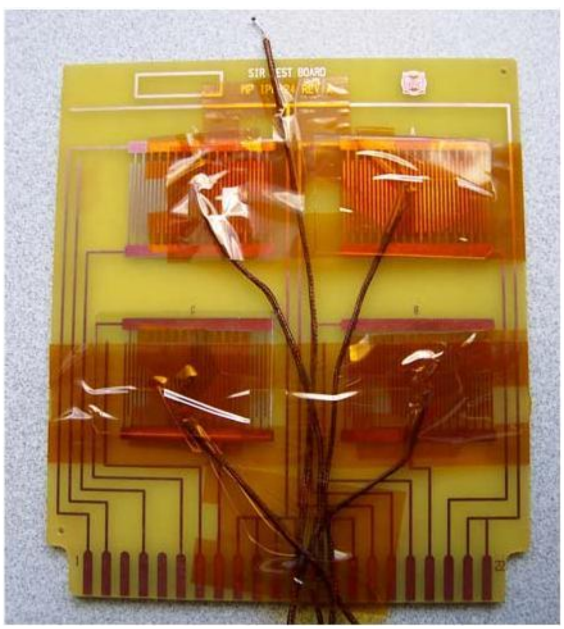


Figure 5 - Location of thermal couples for profiling of SIR board with glass slides


Figure 6 - Location of thermal couples for profiling of SIR board with RF shield

Figure 7 - Location of thermal couples for profiling under RF shield

The SIR boards prepared with SnPb no-clean solder paste flux vehicle were reflowed with the following profile (Figure 8). One board was used for profiling with the upper left pattern covered with the RF shield and two opposite corner patterns covered with glass slides. The bare pattern achieved a peak temperature of ~212°C, the glass slide patterns achieved a peak temperature of ~197°C, and the RF shield pattern achieved a peak temperature of 187°C.

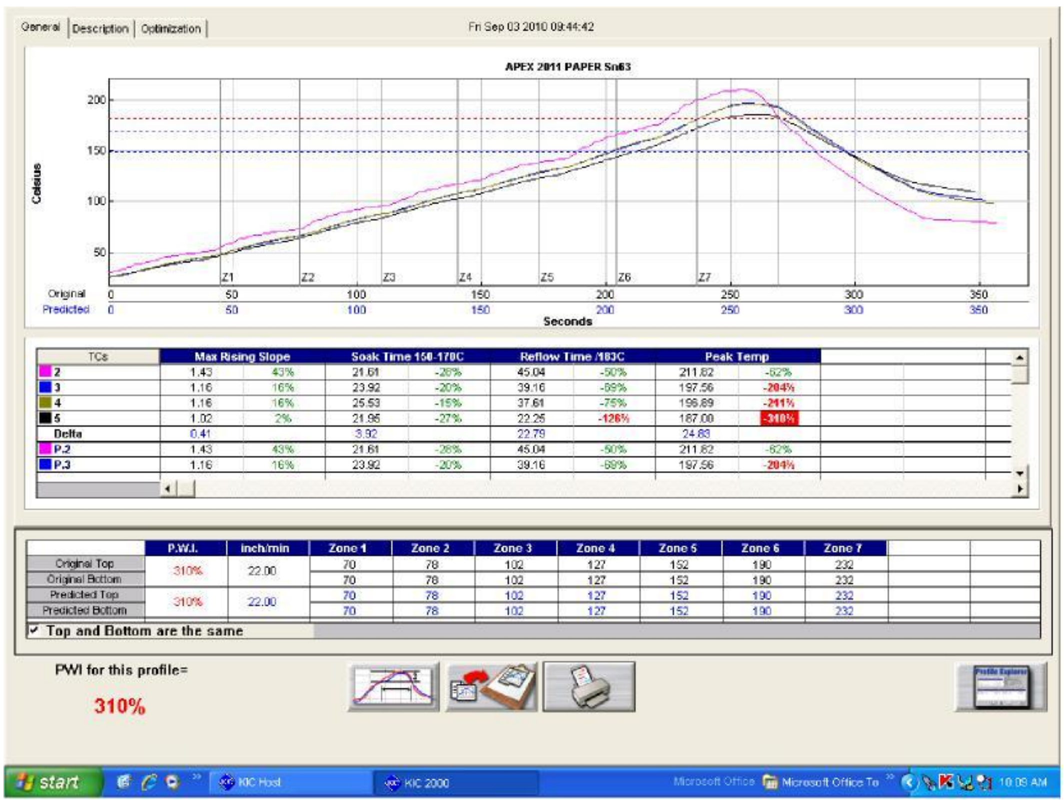
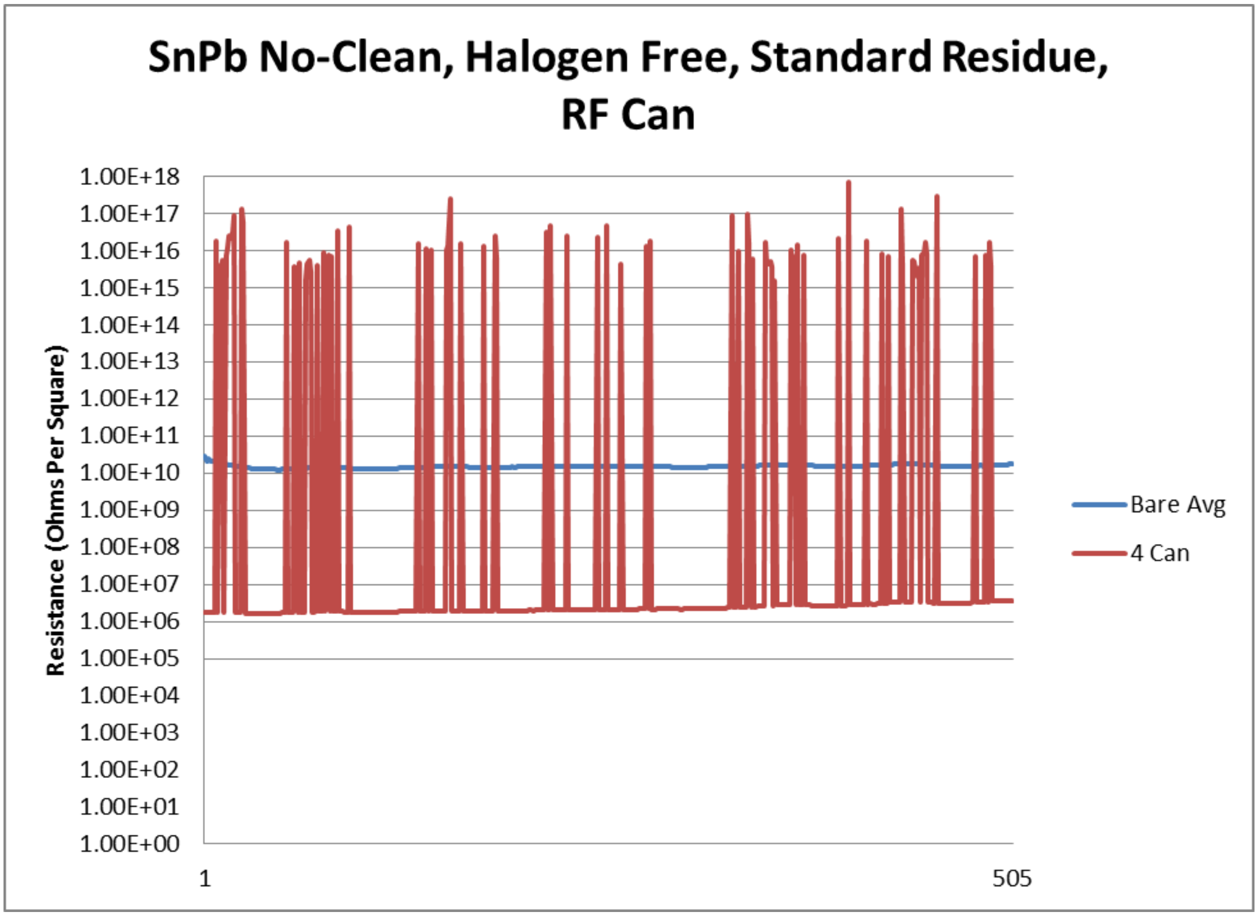


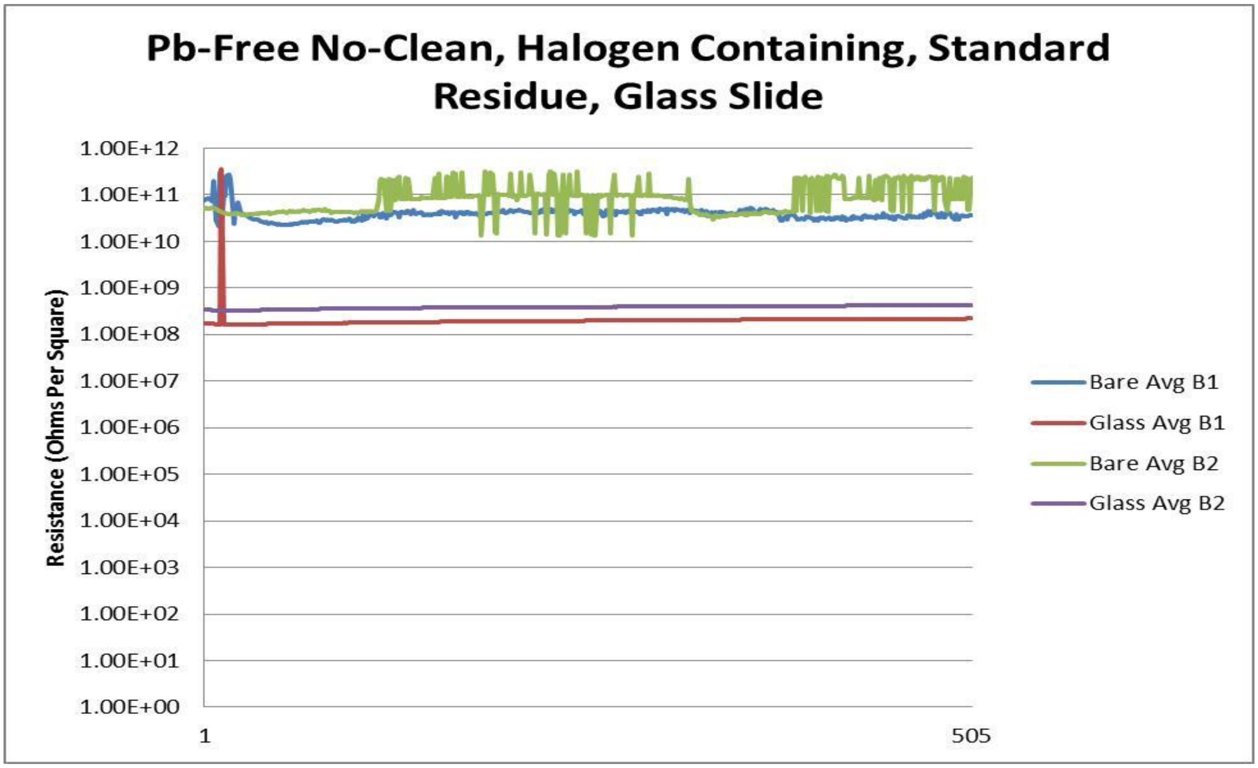
Figure 8 - Reflow profile used for the SnPb fluxed SIR boards with glass slides and RF shield attached

The SIR testing was performed in accordance with J-STD-004B. Following are the results in graphical format. Some of the data shows significant “noise” i.e., large and random upward spikes. This is explained as system noise induced by certain SIR patterns that produced near shorted values (~1.00E+06 ohms per square). These aberrant upward spikes can be ignored.

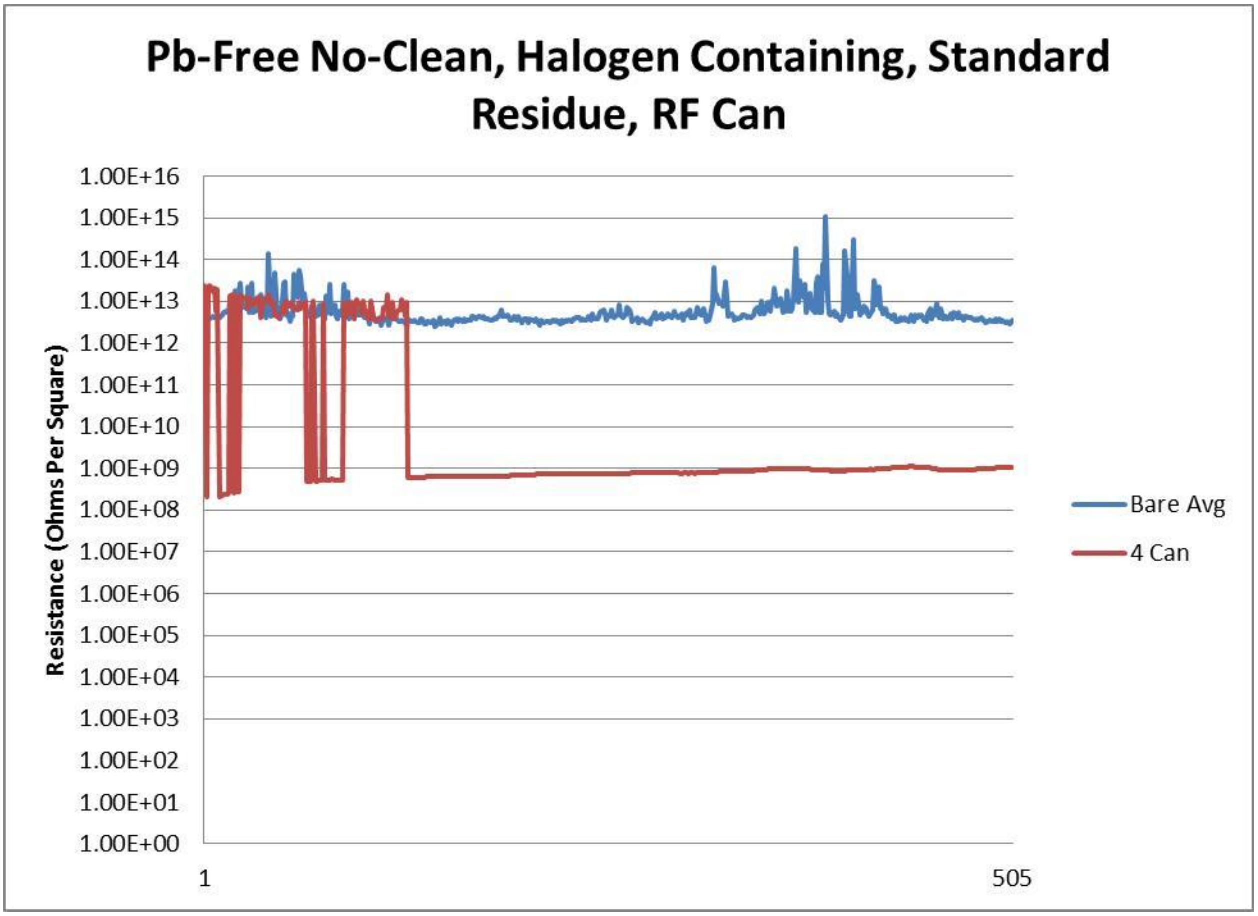
The bare patterns exhibit passing SIR values; whereas, the glass slide covered patterns are virtually shorted. (It is not possible to get readings less than 1.00E+6 because of a 1MΩ current limiting resistor in the circuit.)



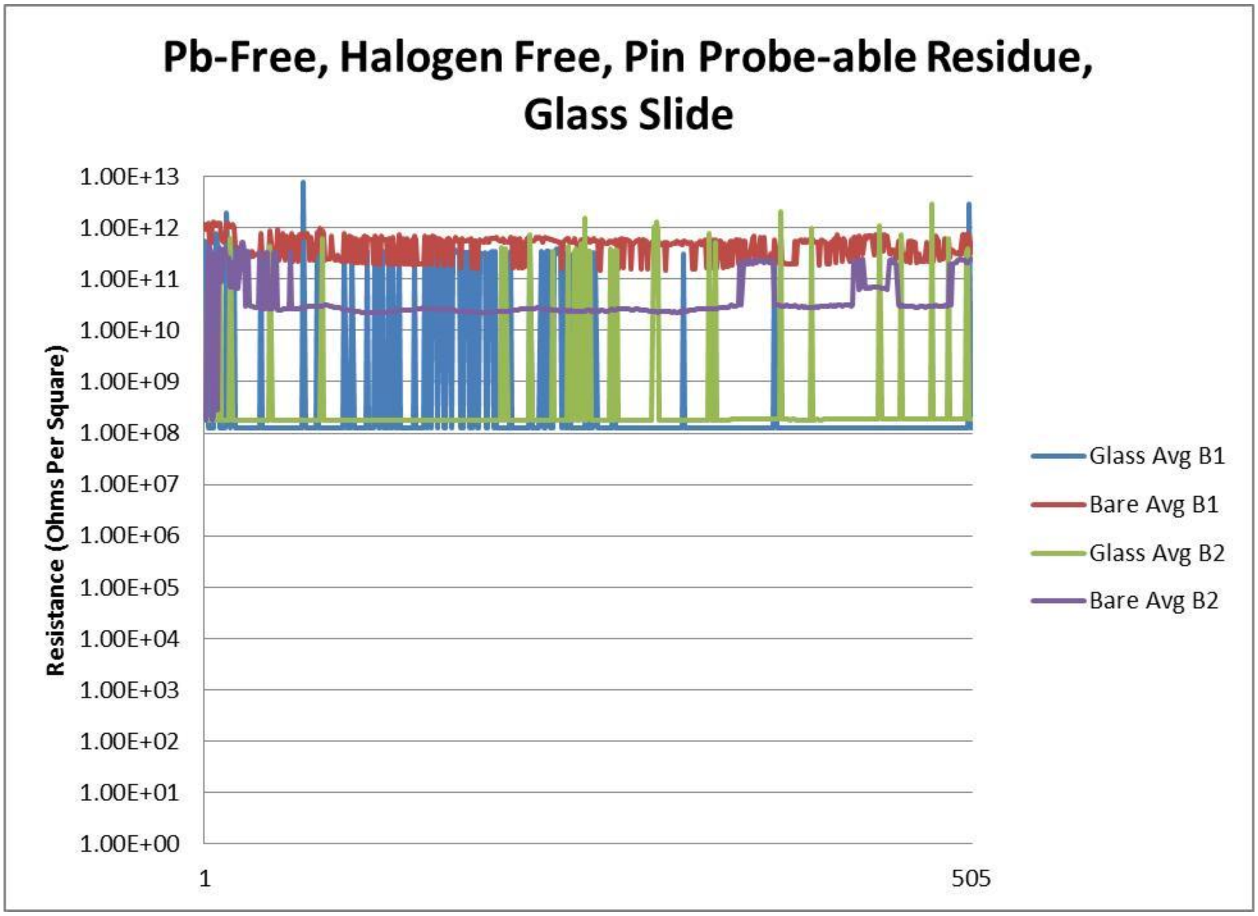
The bare patterns exhibit passing SIR values; whereas, the RF shield covered pattern is virtually shorted. (It is not possible to get readings less than 1.00E+6 because of a 1MΩ current limiting resistor in the circuit.)



Both the bare patterns and the patterns covered with the glass slides produced passing SIR values. However, the patterns covered with the glass slides exhibit lower SIR performance.



Both the bare patterns and the pattern covered with the RF shield produced passing SIR values. However, the pattern covered with the RF shield exhibits lower SIR performance.



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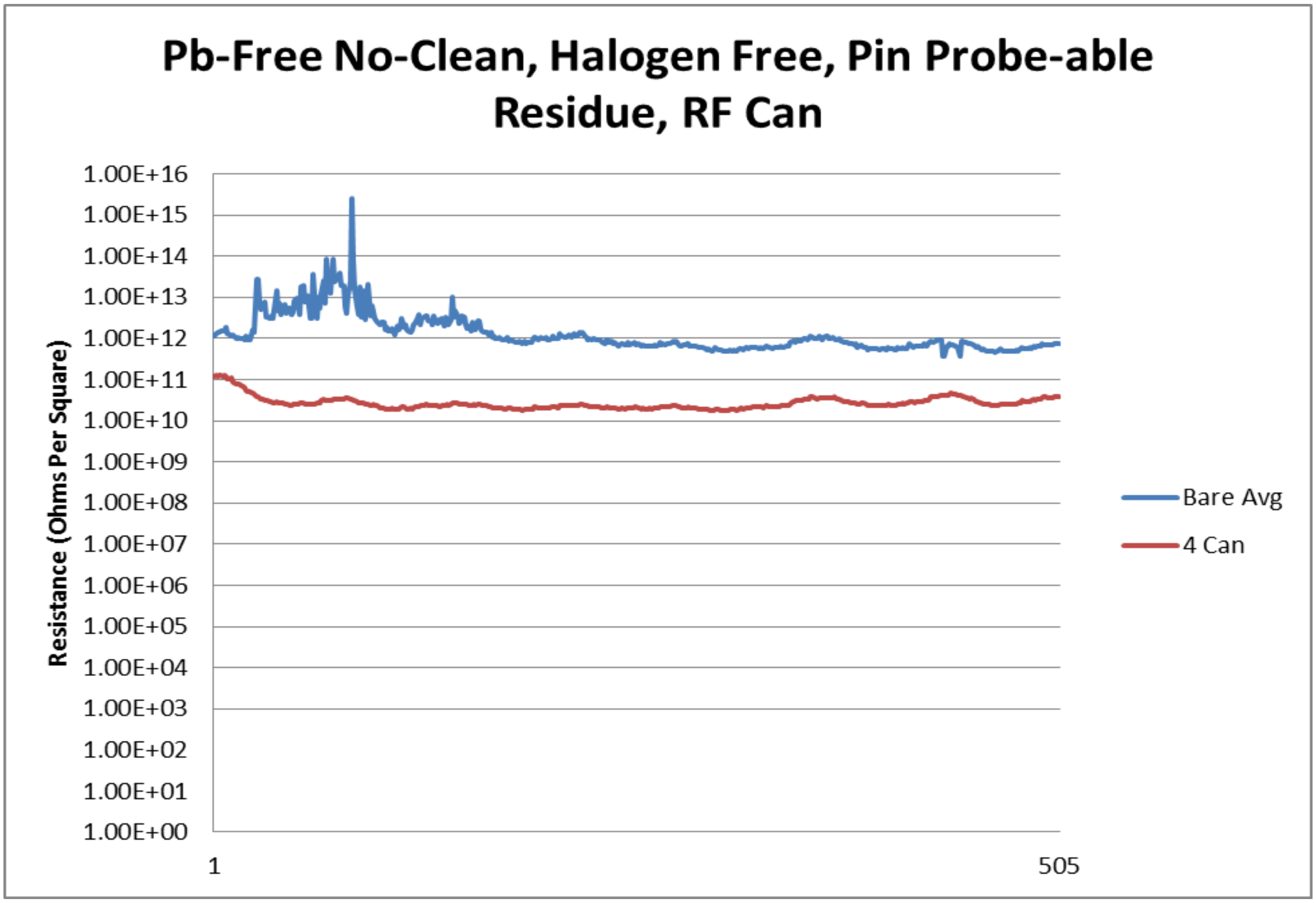
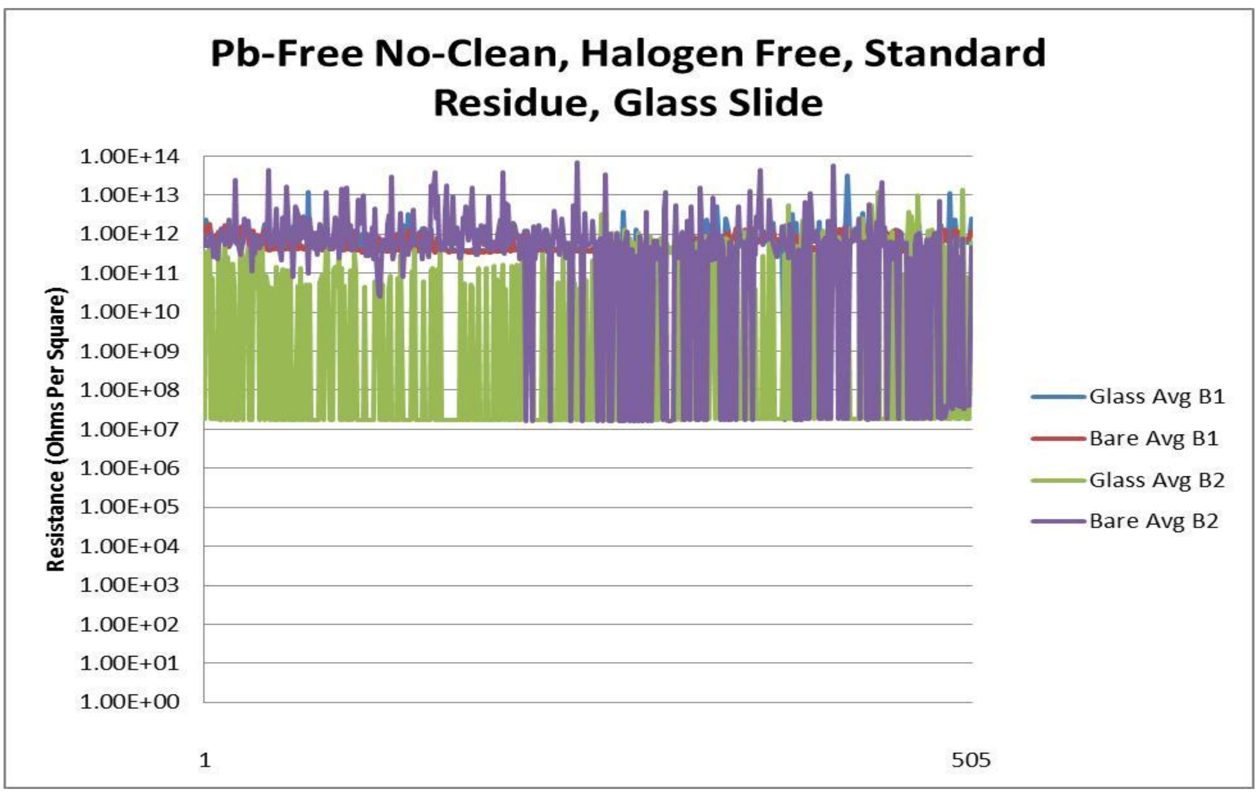
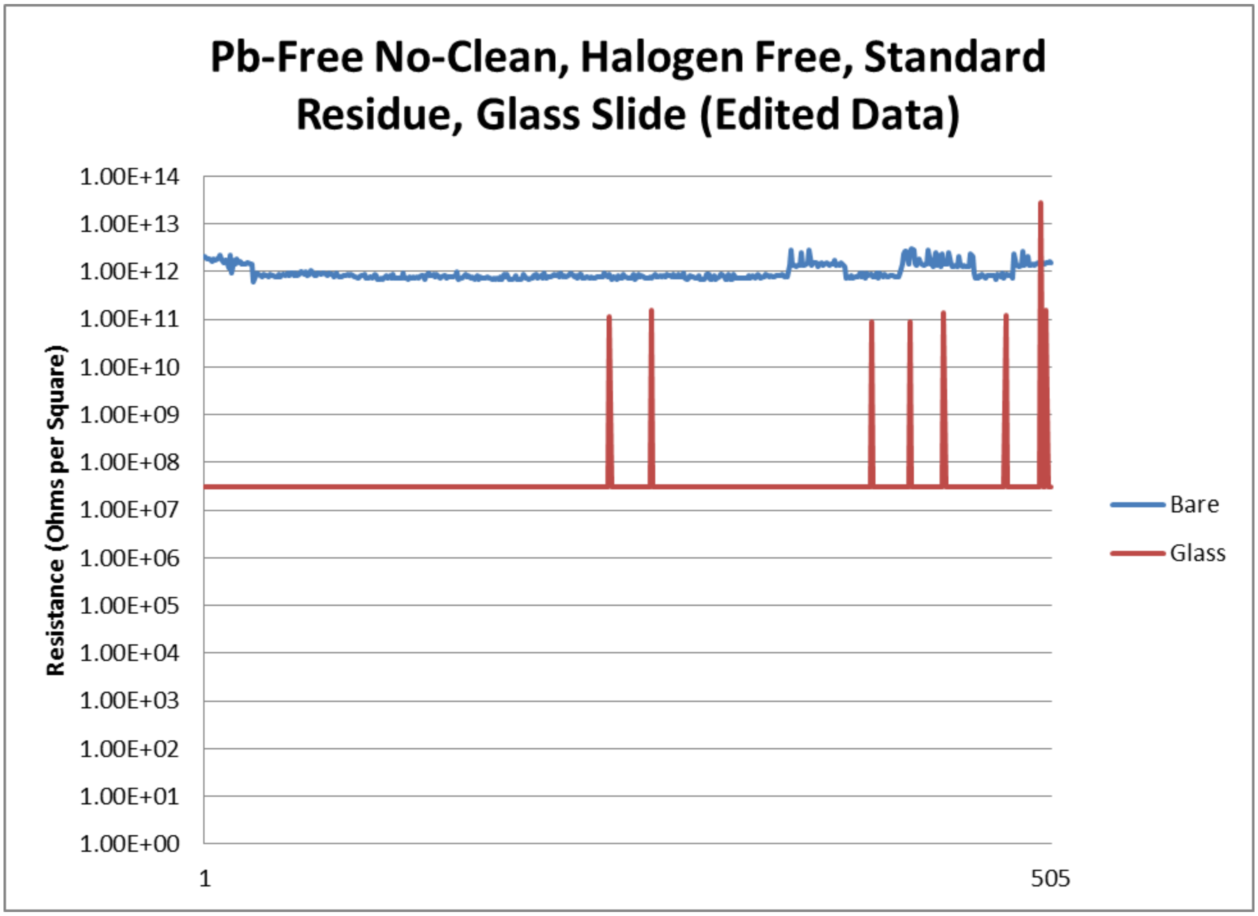


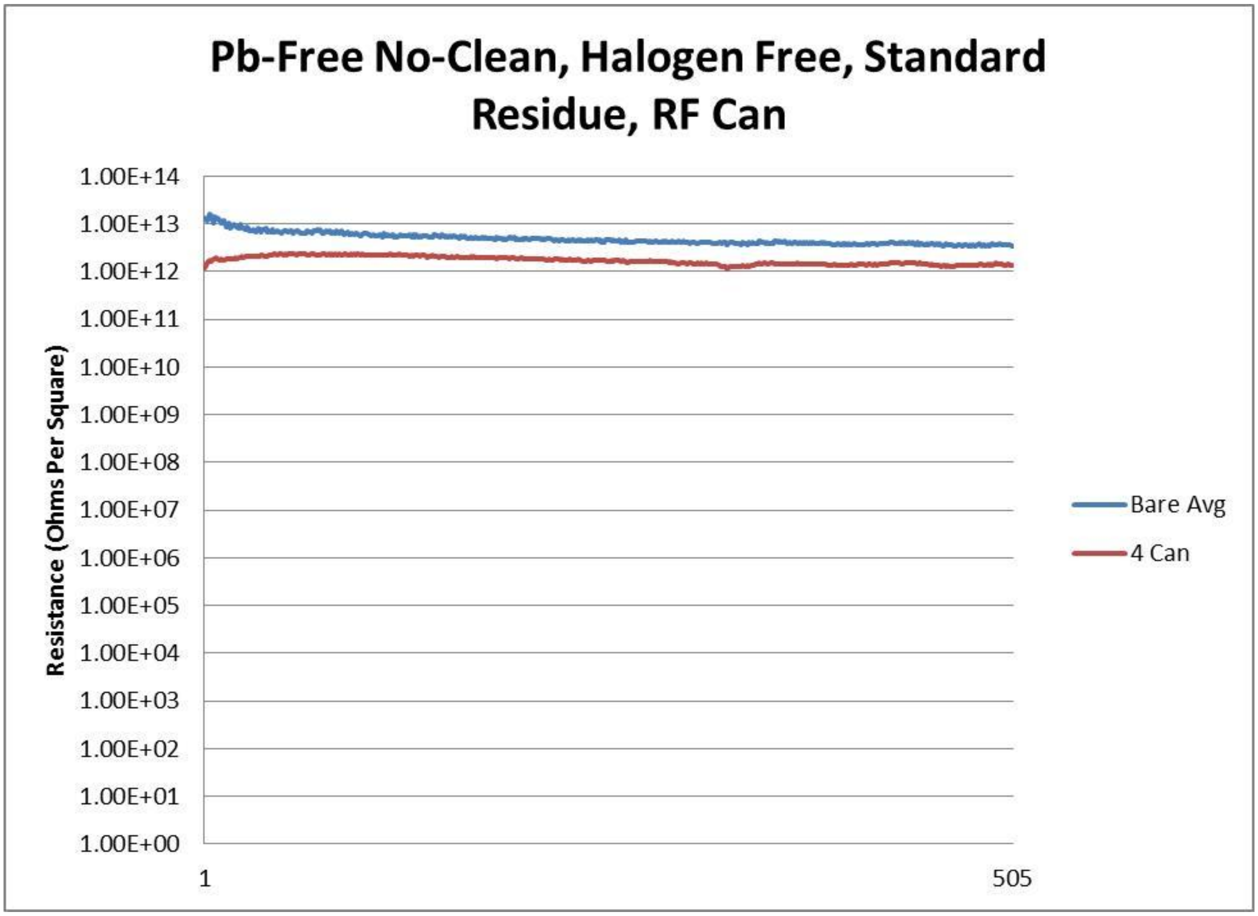
Both the bare patterns and the pattern covered with the RF shield produced passing SIR values. However, the pattern covered with the RF shield exhibits slightly lower SIR performance.



The author was not able to ascertain any meaningful trend from the data produced from these two boards. There seemed to be no rhyme or reason to it. Possible explanations for the aberrant data include condensation, improper wiring, loose connections, etc. Therefore, the author selected data sets that seemed to be in agreement with the typical SIR trend of bare and glass covered patterns. That data is in the following graph.



The bare patterns exhibit passing SIR values; whereas, the glass slide covered patterns exhibit lower and failing SIR values.



Both the bare patterns and the pattern covered with the RF shield produced passing SIR values. However, the pattern covered with the RF shield exhibits slightly lower SIR performance.

Upon completion of the SIR testing the residues were inspected. No dendritic type growth was observed. However, some patterns had notable visual anomalies (Figures 9 – 11). (The bluish coloration is a result of blue LED backlighting.)
All residues under the glass slides were "gooey" and **all** residues under the RF shield were "hard", as observed at the completion of the SIR testing. It can be argued that the "seal", created by the Kapton tape along the edge of the glass slides and RF shields, restricted the moisture of the SIR chamber environment from interacting with the flux residues.

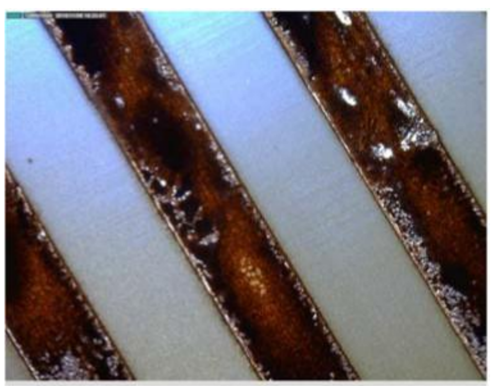


Figure 9 - Pb-free, halide-containing, standard residue, SIR pattern under RF shield

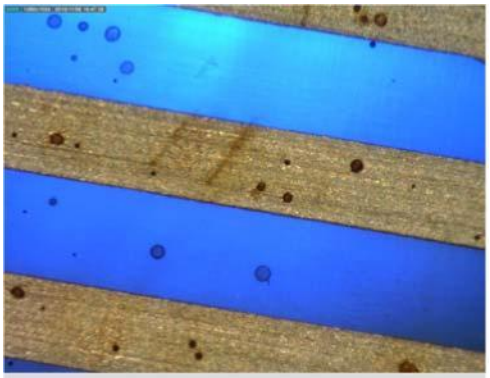


Figure 10 - Pb-free, halogen-free, pin-probeable residue, SIR pattern under RF shield

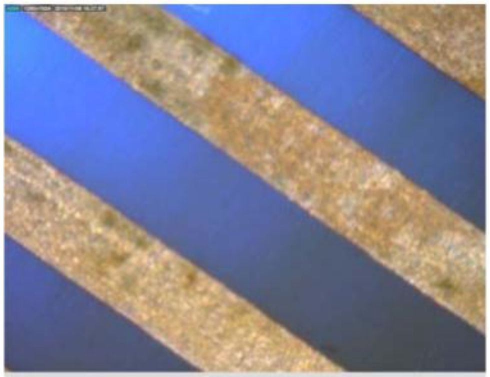


Figure 11 - Pb-free, halogen-free, standard residue, SIR pattern under RF shield

All RF shields exhibited discoloration on their undersides (Figure 12). No noticeable discoloration was detected on any other surfaces of the RF shields. This discoloration was virtually unaffected by wiping with a cotton swab and isopropyl alcohol. It appears to be the result of some sort of chemical interaction between the flux vapors and the metal of the shield.

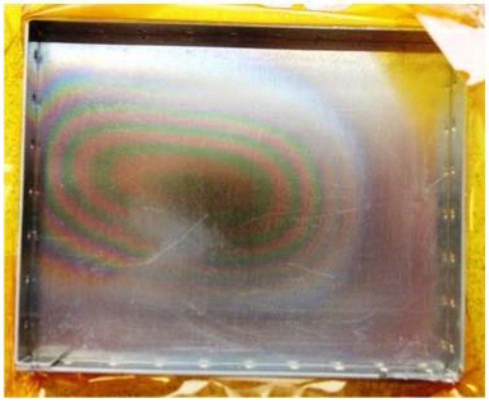


Figure 12 - Discoloration of the RF Shield

It is difficult to ascertain which issue plays a larger role on the SIR performance of a flux residue - an entrapped/covered flux or peak temperature. The ΔT (difference between the peak temperature and melting temperature of the alloy) is high enough in the Pb-free scenarios that any degradation of the SIR values is likely the result of being covered by the glass slides and RF shield; whereas, in the case of the SnPb scenario the ΔT is significantly less (as low as 4°C). In such cases, it could be argued that "incomplete" activation is the over-riding factor in the low SIR values.

Alloy	**SIR Pattern**	**Peak Temp.**	**ΔT (peak temp – melt temp)**
SnPb (183C)	**Bare**	~212°C	**29°C**
	Glass Slide	~197°C	**14°C**
	RF Shield	~187°C	**4°C**
Pb-Free (217C)	**Bare**	~244°C	**27°C**
	Glass Slide	~237°C	**20°C**
	RF Shield	~234°C	**17°C**

The results of this experiment do provide reasonably conclusive evidence that certain characteristics of the flux residue are altered solely as a result of being covered and/or entrapped at varying degrees. Other sensible conclusions can be made as well.

1) All the residues under the glass slides were "gooey" and all of the residues under the RF shields were "hard".
2) All of the fluxes cause discoloration on the underside of the RF shield.
3) Certain fluxes produce residues that have notable visual anomalies when covered with an RF shield.
4) Covered fluxes, be it with a glass slide or RF shield, produce lower SIR values than uncovered, **albeit <u>not</u> necessarily failing readings** (<1.00E+8 ohms per square).
5) Halogen-free flux chemistries **<u>do not</u>** necessarily provide a more electrically "reliable" residue than halide containing residues in these scenarios.

Variations in the SIR performance of a flux, in these scenarios, is likely possible from one flux formulation to another. For example, it may not be wise to anticipate that all halogen-free, pin-probable, Pb-free, no-clean fluxes will perform in the same manner. Some flux formulations may perform better than others under these conditions.