



The Use of Design of Experiments to Determine the Impact of Conductive Particles on Electrical Properties of Alumina for Electronic Applications

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Armida J. Carbajal, M.S. Statistics

Graduate Student Intern SNL for Dept 2736 & Dept 0415

University of New Mexico

Cognitive Psychology Doctoral Student

PI: Loren Espada, PhD Physics Dept 2735

SEM/Imaging: Gary Zender, Dept 1822

Background

Alumina ceramics are used as electrical insulators in vacuum applications, such as vacuum tubes for:

Rectification: converts AC current to DC current

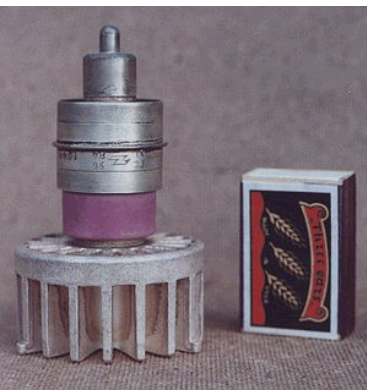
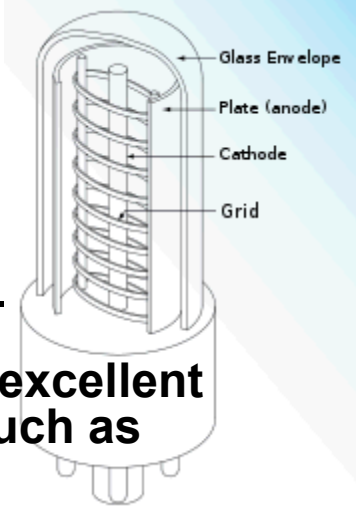
Amplification: converts voltage or a current to Audio, IF, RF or VHF signal

Switching: electrical component that can interrupt current and divert it from one conductor to another

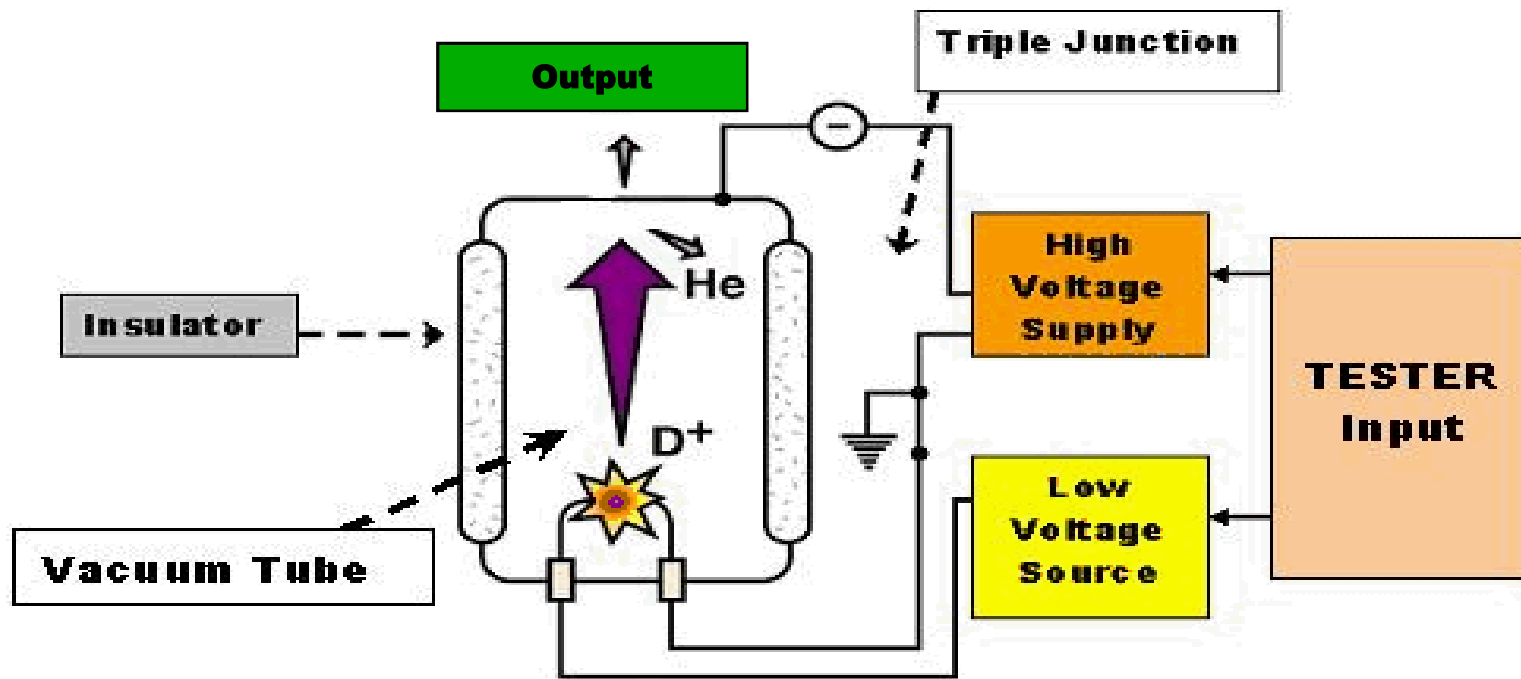
because of their excellent properties such as

- high mechanical strength
- high resistivity at high temperatures
- and less gas emission.

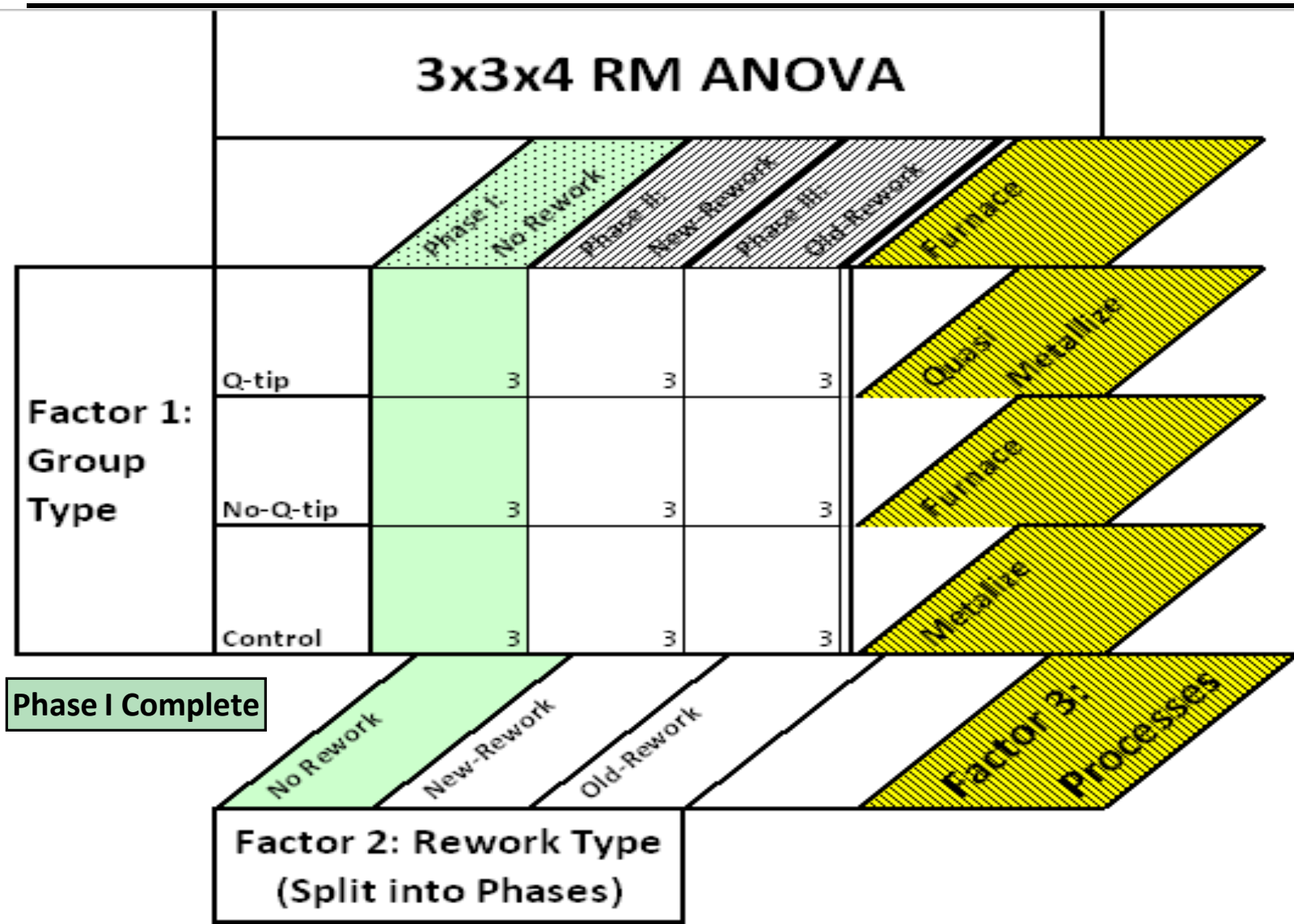
This work will focus on measuring the effects of electron irradiation on these ceramic materials as a function of surface contamination such as conductive particles.



Schematic of Vacuum Tube Function



Identification → Potential Factors Contributing to Conductive Particle contamination





Design of Experiments

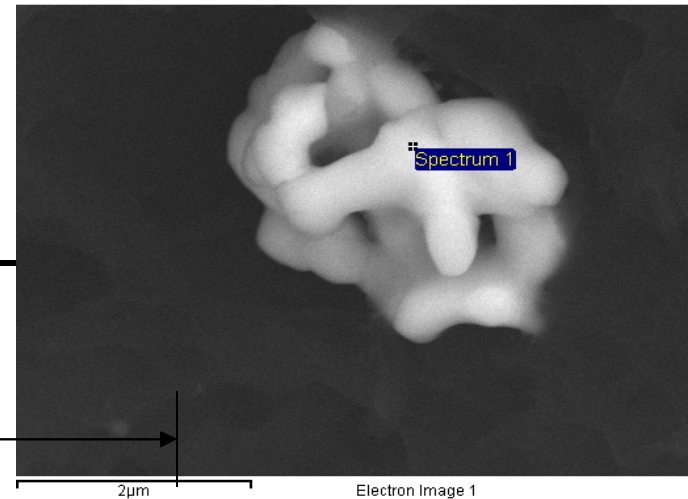
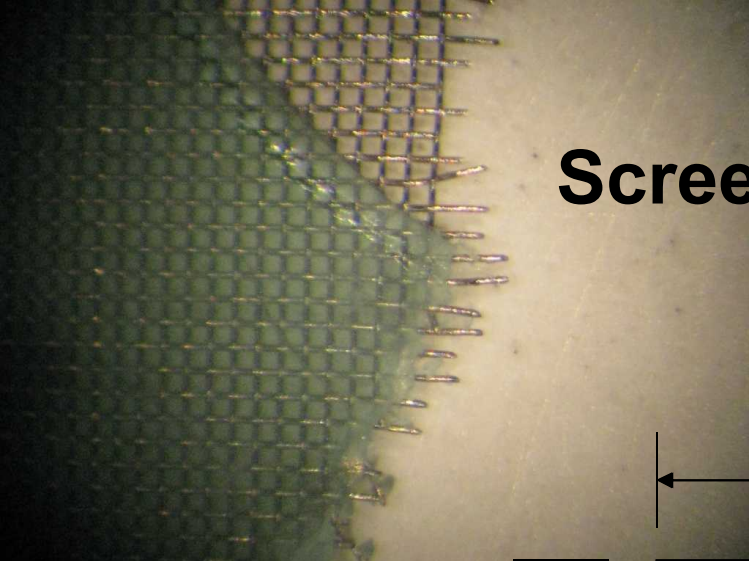
Response Variables

- Secondary Electron Emission
- Surface Resistivity
- High Voltage Strength
 - (Measured by Surface Flashover)
- Percent Particle Concentration
 - (Measured by SEM and Image Processing)

Experimental Factors

- **Factor 1: Group Type**
 - Q-tip
 - No-Q-tip
 - Blank
- **Factor 2: Rework Type**
 - No Rework
 - New Rework
 - Old Rework
- **Factor 3: Processes**
 - Metalize
 - Furnace
 - Quasi-Metalize
 - Furnace

Screen Print Mask



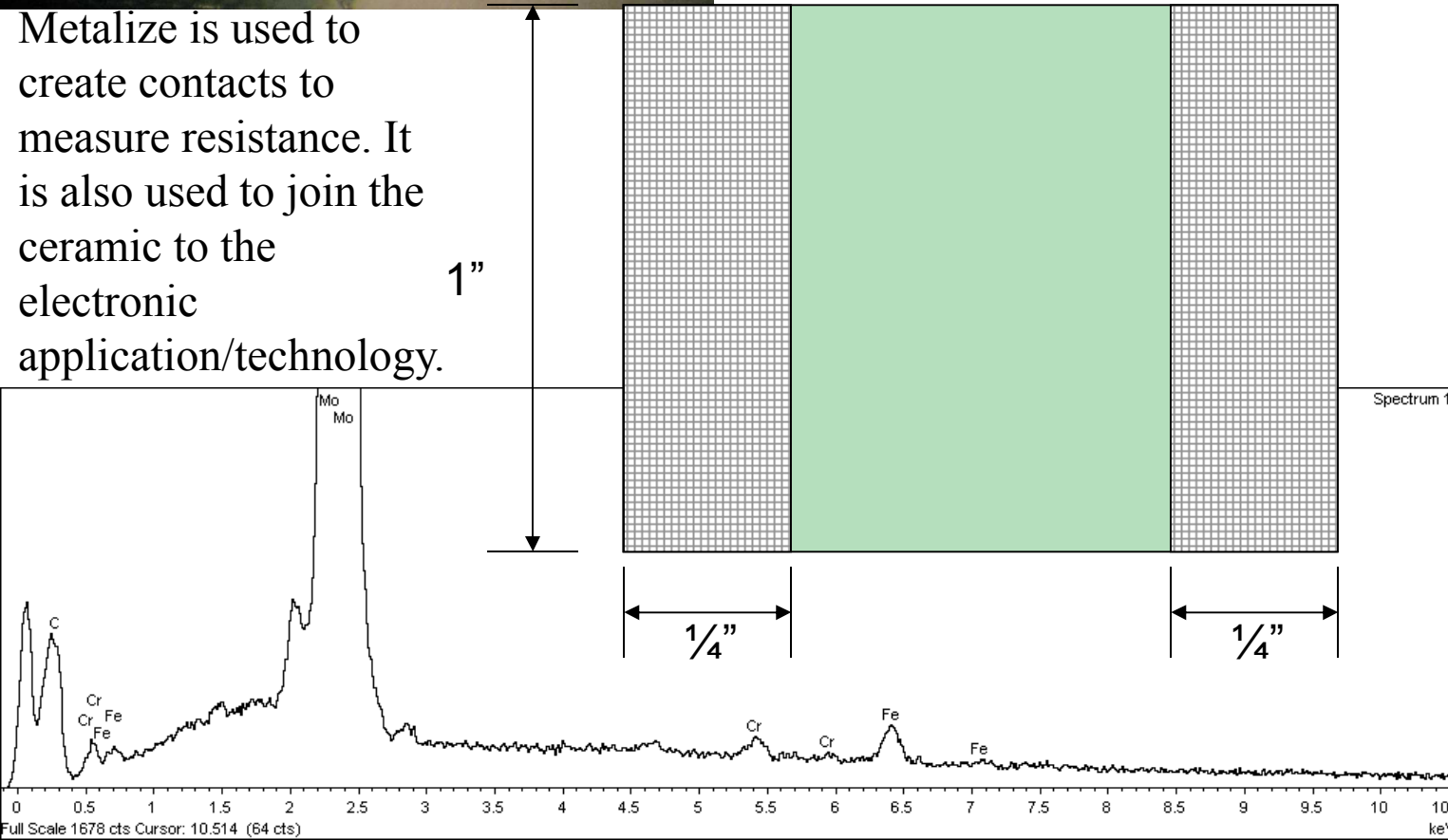
1"

2μm

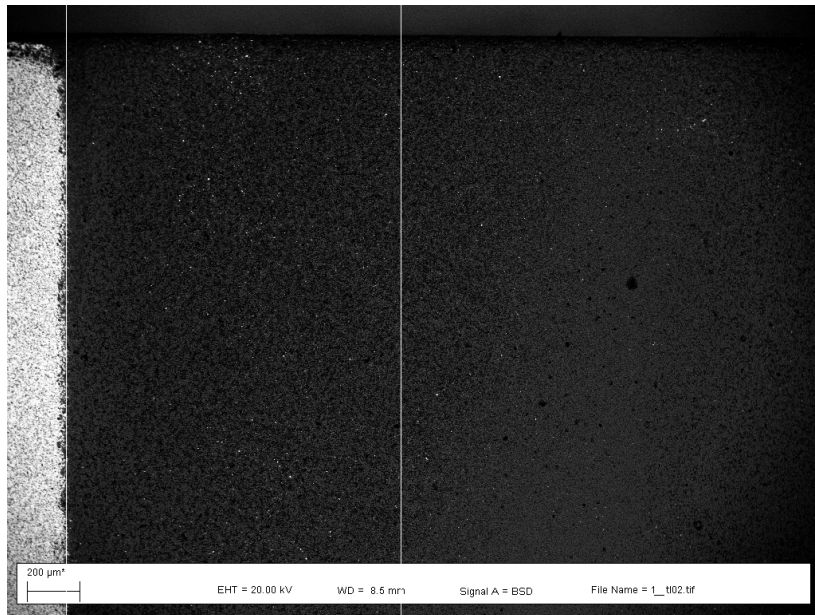
Electron Image 1

Metalize is used to create contacts to measure resistance. It is also used to join the ceramic to the electronic application/technology.

1"



Phase I Results



Identified the
Screen Print Process
i.e. Application of Metalize is
the *main contributor* of
Moly onto vacuum tubes
via the coupon study

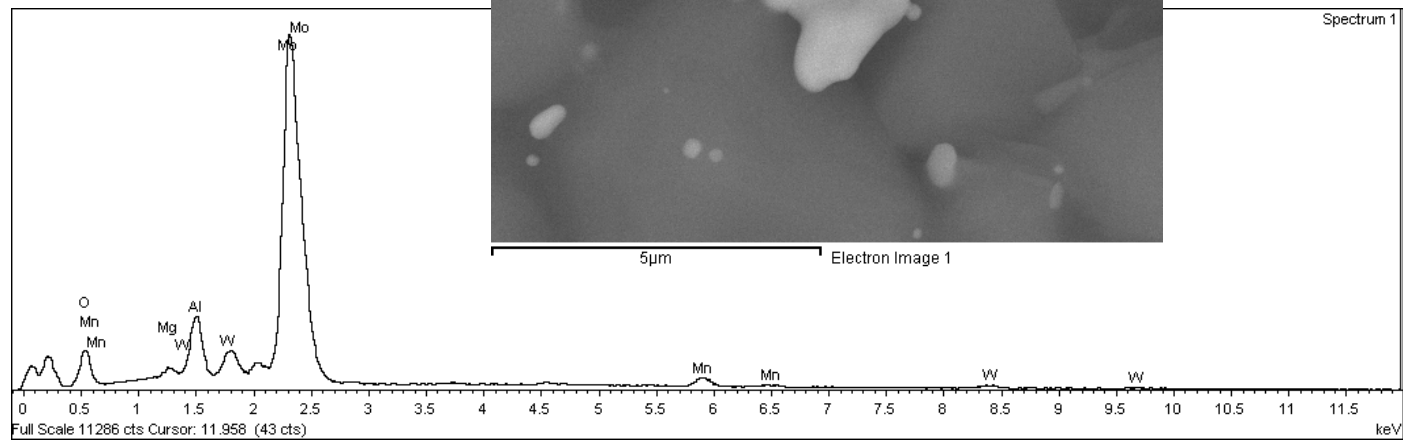
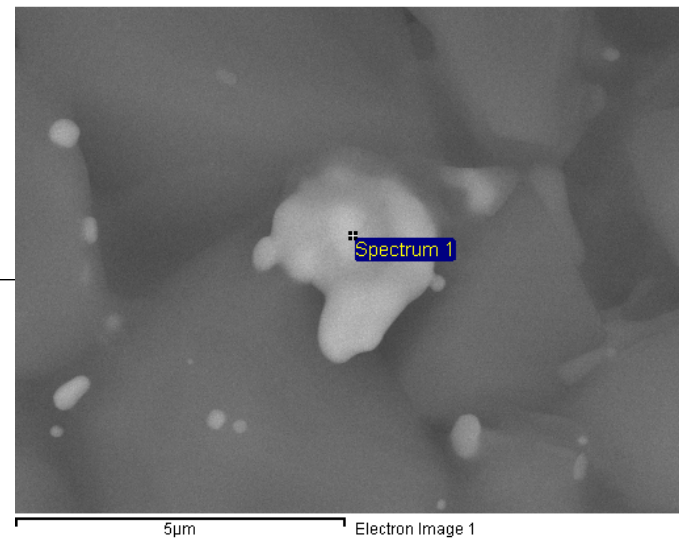
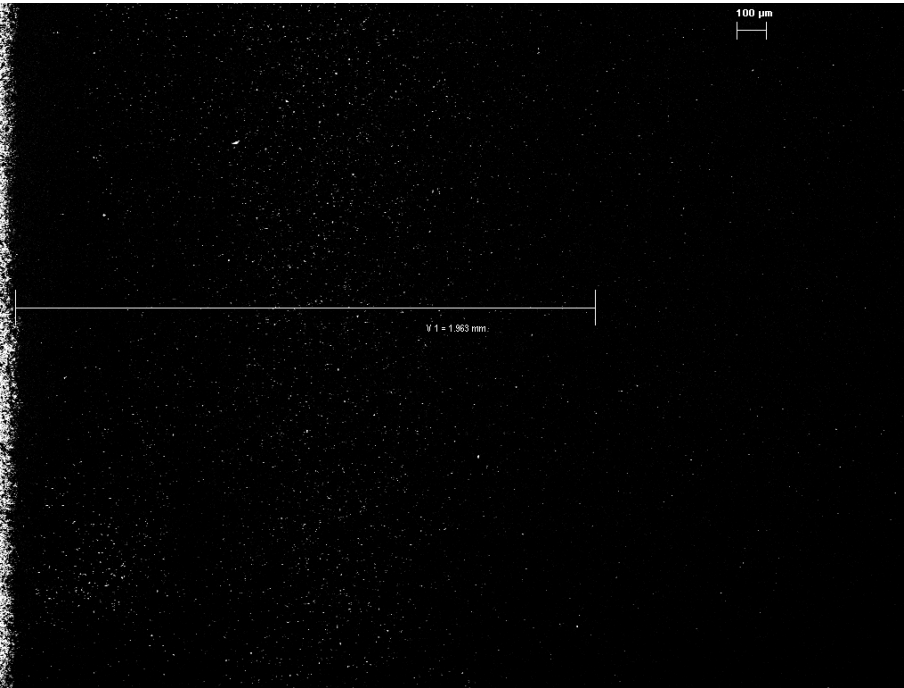


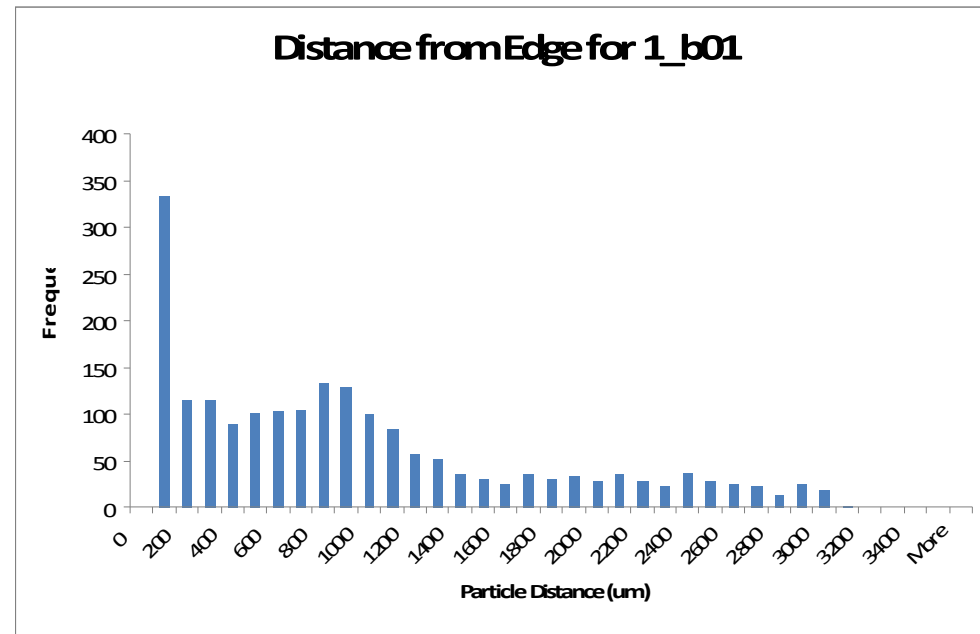
Image Processing



In order to determine the particle concentration, image processing was used on the SEM images of the tiles. This is an edge of one of the Q-tip tiles. This data has not yet been summarized for the analysis.

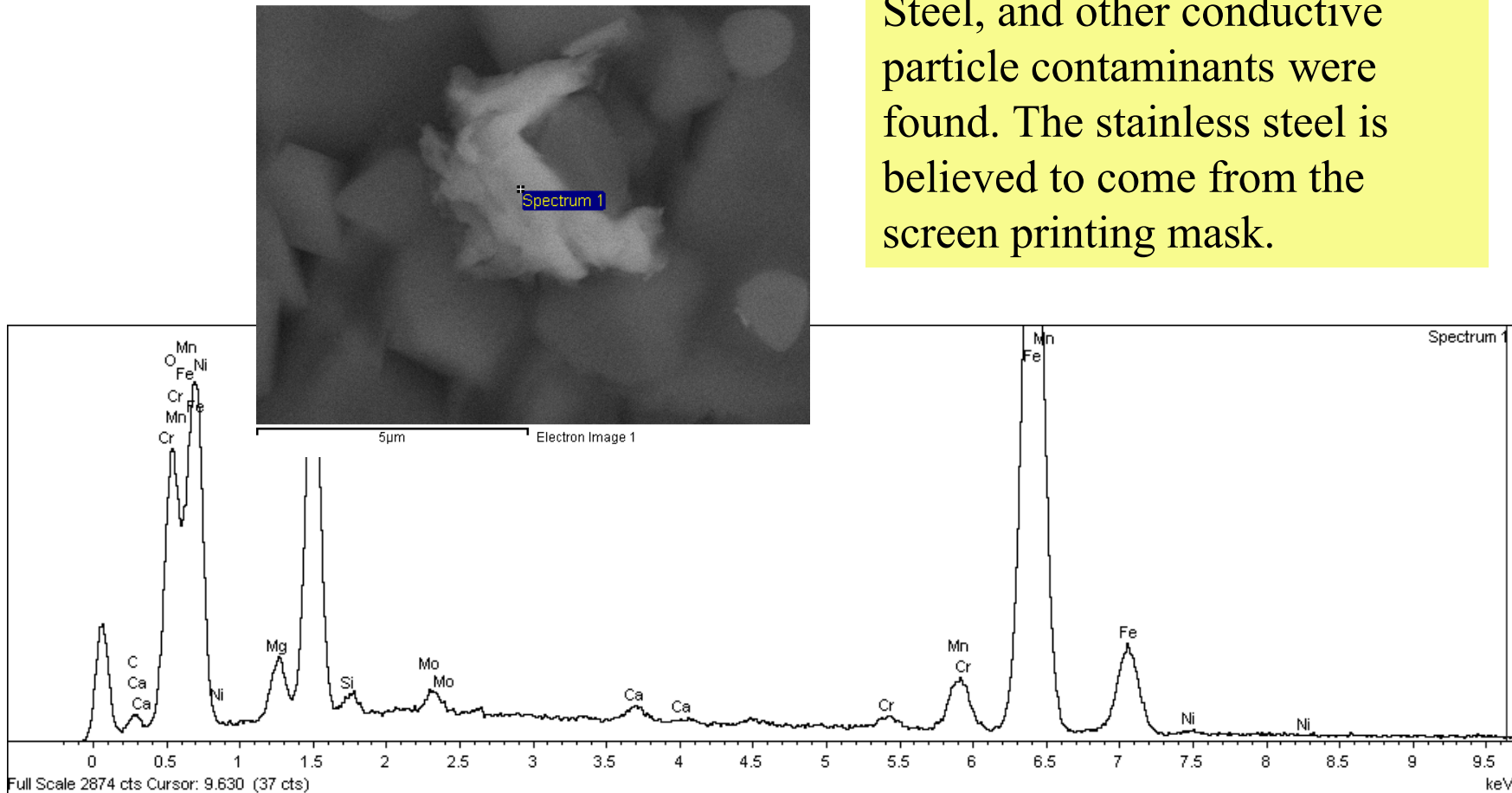
Image Processing was done by:

Alice Kilgo
and
Zahra Ghanbari
Dept 1831



Q-tip Coupon

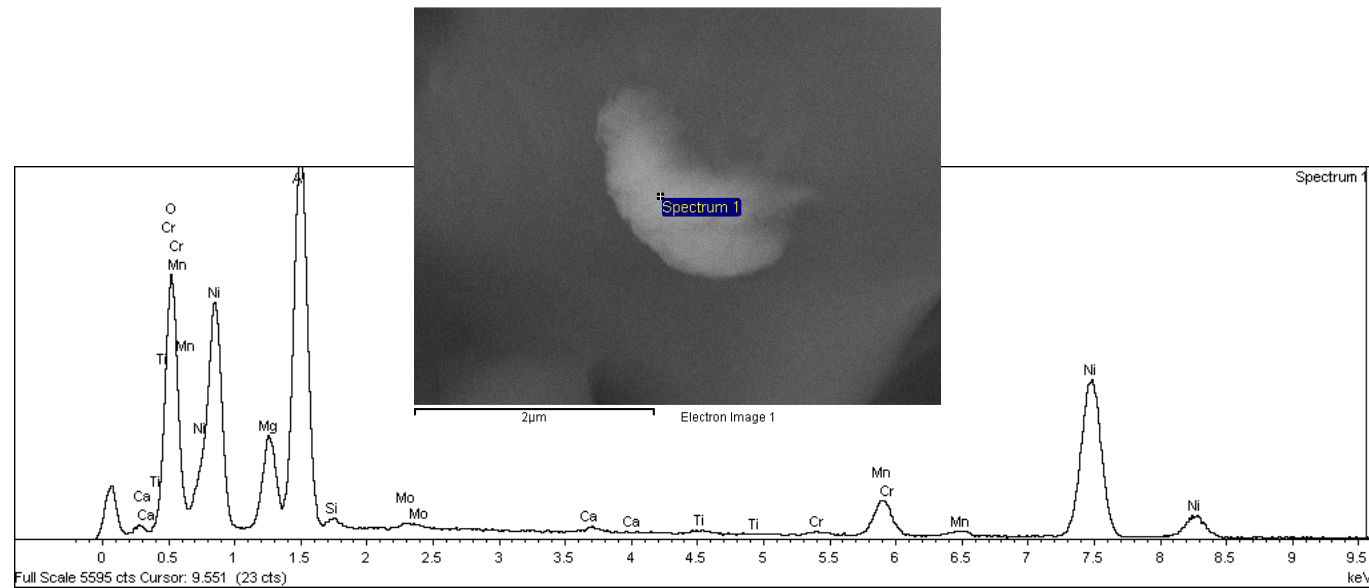
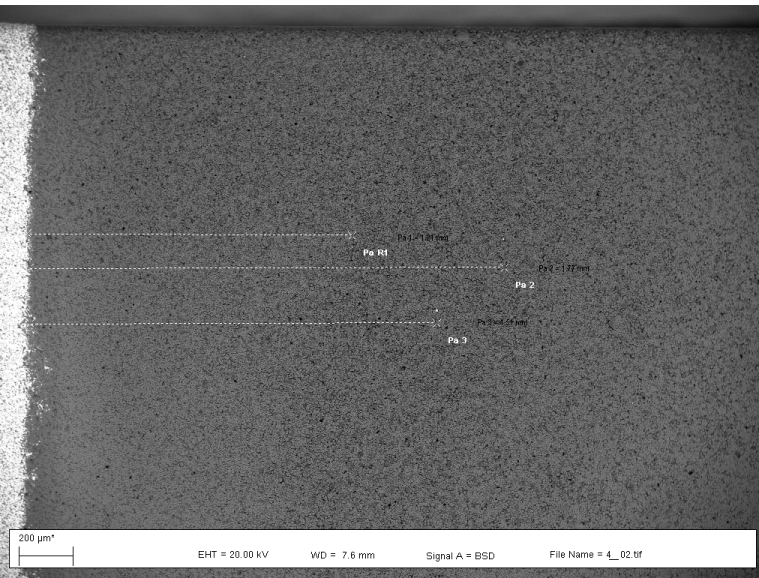
In addition to Moly, Stainless Steel, and other conductive particle contaminants were found. The stainless steel is believed to come from the screen printing mask.





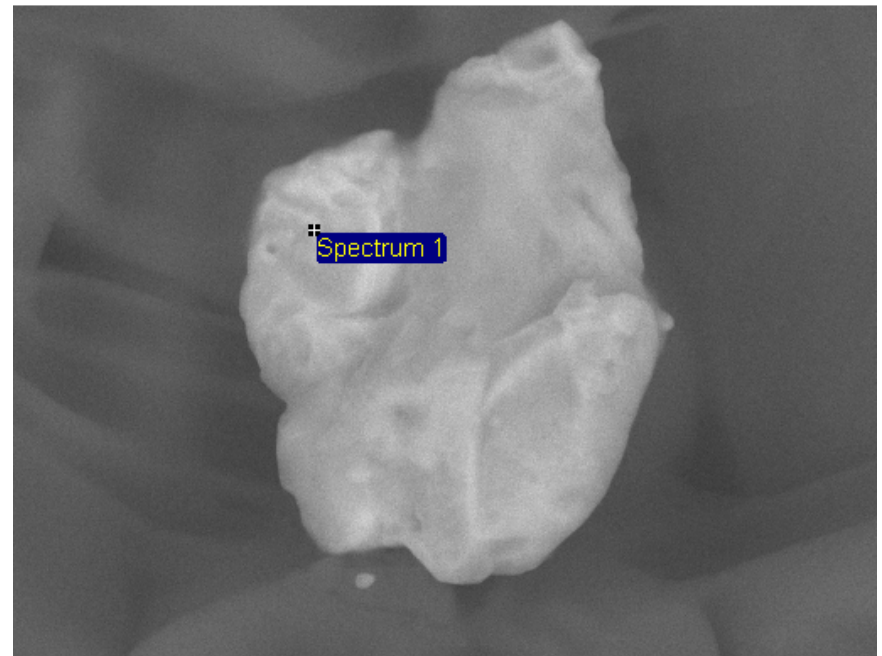
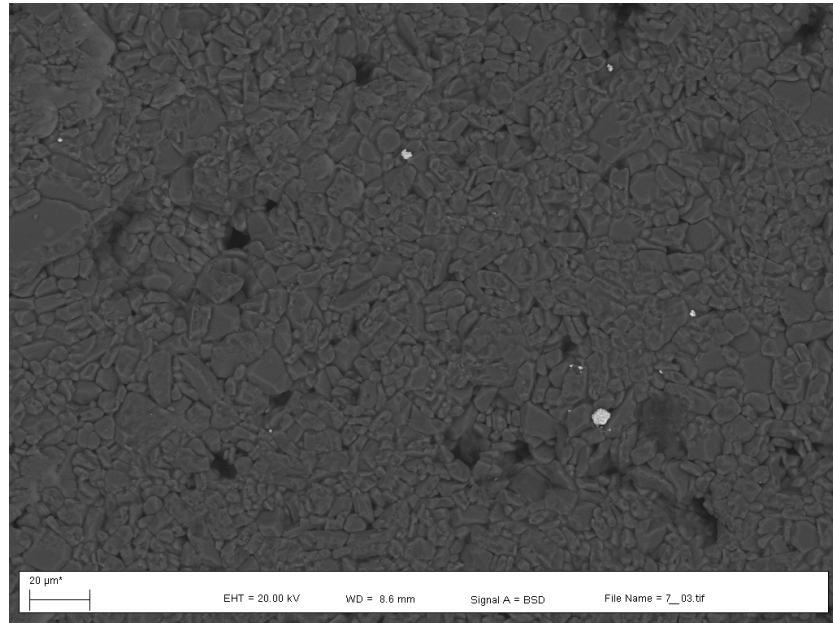
No-Q-tip

Several other conductive particles were found on several tiles, including Mo, Stainless Steel, Ni, Na, K, and Ti.





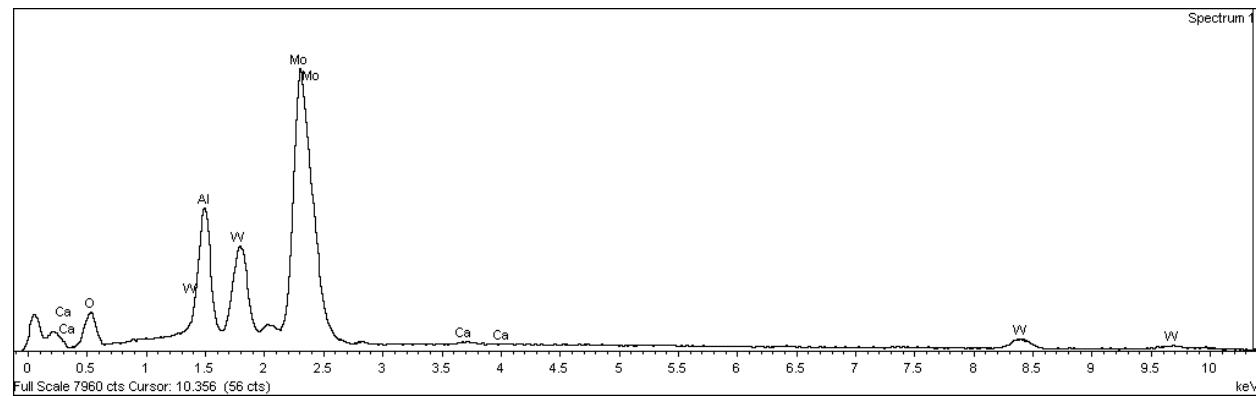
Blank Coupon



6 μm

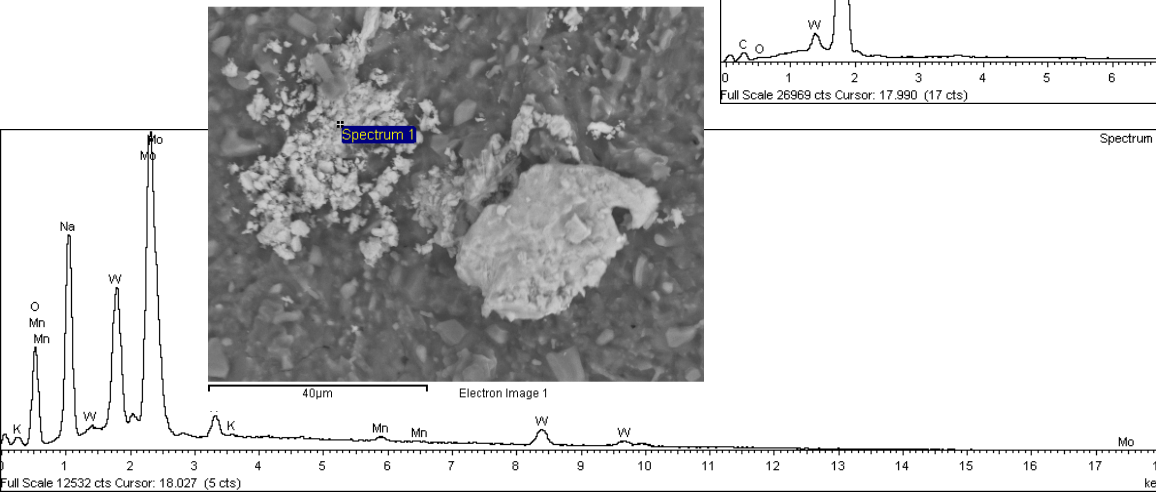
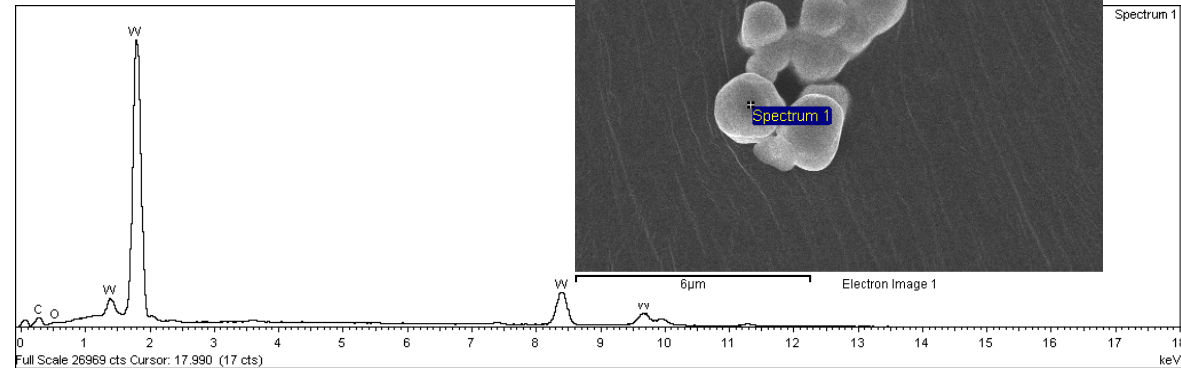
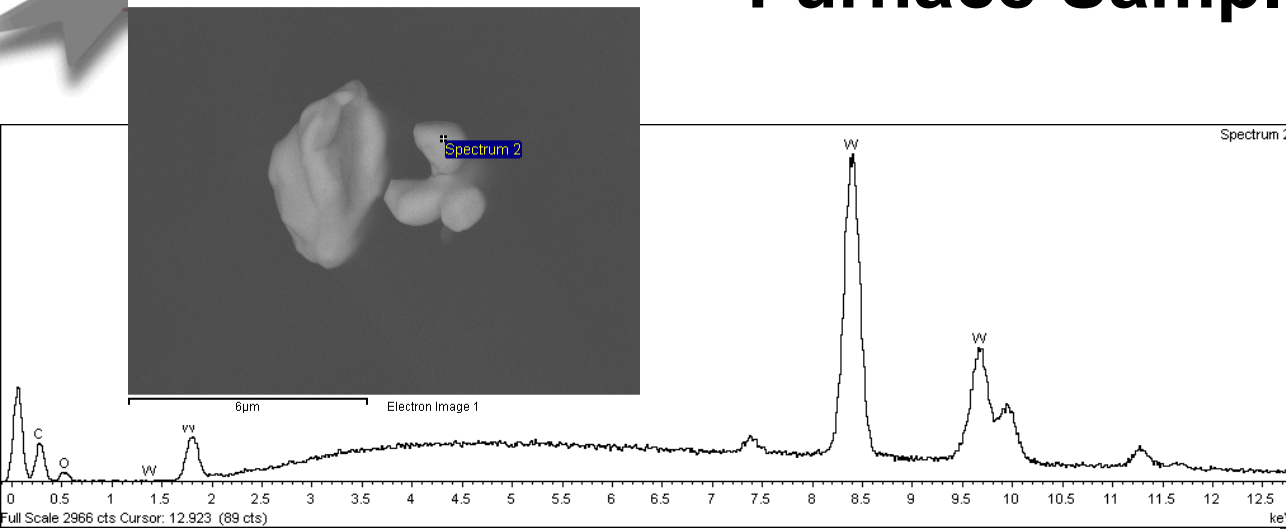
Electron Image 1

Moly on the blanks is indicative that during the Screen Printing Process Moly Particles become airborne and land on surrounding surfaces.



Furnace Samples

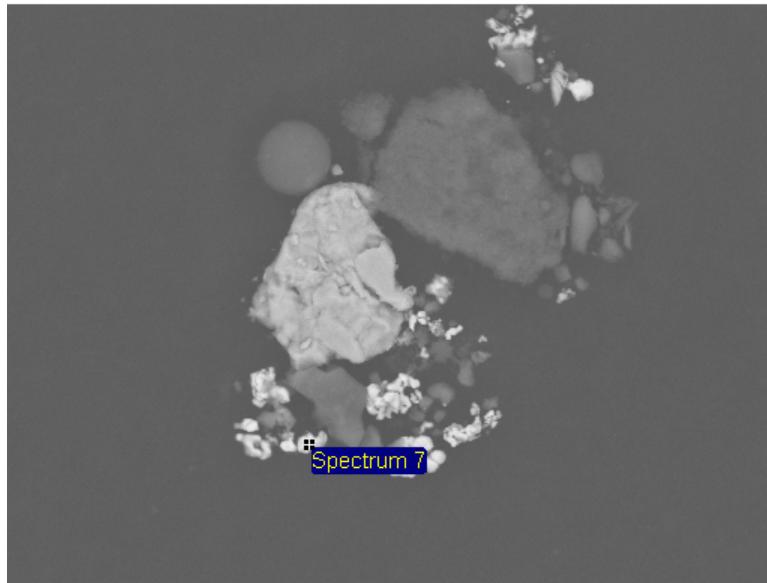
Another Conductive particle, Tungsten was found to be introduced during the Furnace process. This process permanently adheres the Metalize to the Alumina Ceramic.



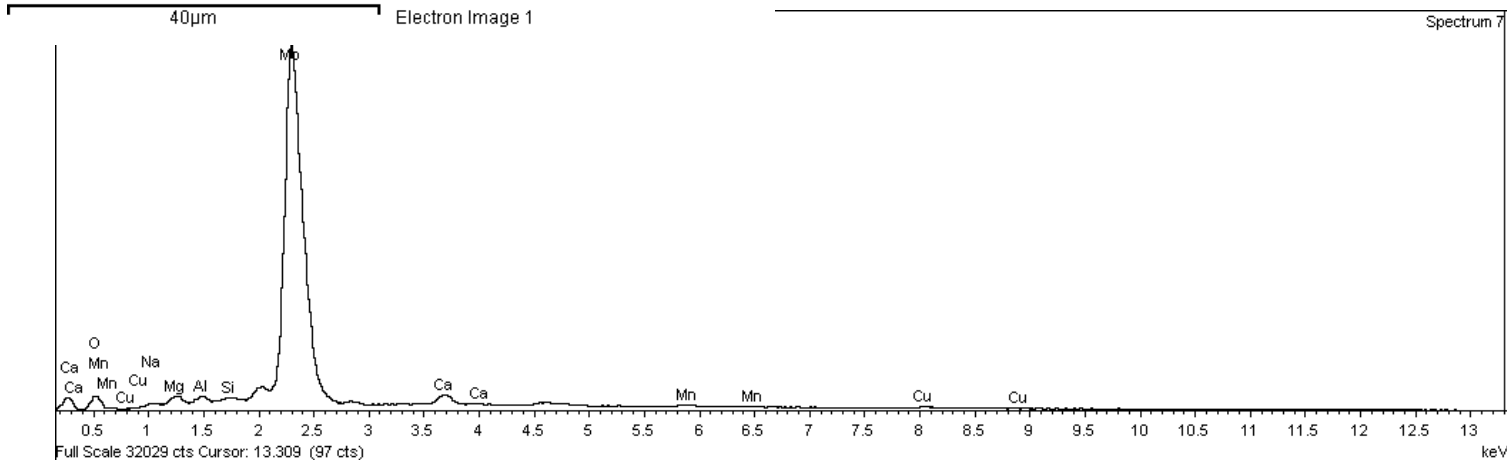
Additionally, Moly particles contaminate the shelves in the furnace especially at the bottom. Tungsten, Na, K were also found.

Phase II

Rework Bath Sample



In Phase II, step 1, was to apply Metalize, then rework by using a (5-bath system). This is the new method of reworking, which is an improvement to the original 3-bath system, however, Moly was found in the final bath.





Resistivity Measurements

Surface Resistivity (Ω)		
	Coupon	Point to Point
Q-tip	1	7.36E+10
	2	1.421E+11
	3	1.436E+11
No-Q-tip	4	1.874E+11
	5	1.4E+11
	6	5.1E+11
Blank	7	n/a
	8	n/a
	9	n/a

The higher the concentration of conductive particles the lower the surface resistance. This decreases the dielectric properties of the insulator.



Conclusion

- **Particle contamination in the walls of the tube insulator decrease the resistivity (by increasing the resistance). In turn this decreases the dielectric properties of the insulator. It is believed this has an impact on high voltage hold-off of the vacuum tube.**
- **Recommendation: improve the screen printing process to reduce/eliminate the need for q-tipping and rework.**
- **Research is being conducted on different methods to improve the screen printing process.**
- **Research is being conducted to determine where the Furnace contaminants come from and how to decontaminate.**