SLAC FPC Cleaning and Assembly Process

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

SLAC TTF3 Coupler Overview

TTF3 Coupler Overview:

- SLAC coupler processing facilities
- TTF3 Coupler processing
  - Metrology
  - Cleaning
  - Assembly
  - Baking
  - Processing
  - Shipping
- TTF3 Coupler Lessons Learned
- Summary

SLAC Coupler Processing Facilities

TTF3 Coupler Assembly Cleanroom at SLAC

- ISO 4 (Class 10)
  - 15’ 6” x 16’ area
- ISO 5 (Class 100)
  - 12’ x 15’ 6” area
- Gowning area
  - 11’ x 8’ area
- Air Shower
  - 8’ x 4’ 6” area ISO 5 (Class 100)
  - An air shower is an effective way to remove surface-deposited particles from personnel and parts, before they enter into the cleanroom.
- Remote particle counters (0.5 & 10.0 μm) with temperature/relative humidity in all areas of cleanrooms.
- Portable particle counter for validating hardware cleanliness (0.3, 0.5, 1.0, 3.0, 5.0 & 10.0 μm).
- UHV Pump/leak tester (Pfeiffer SmartTest HTL 565)
  - Smallest detectable leak rate for He (Vacuum leak detection 1.0×10^{10} mbar l/s)
- Ultra pure nitrogen taps (0.02μm) in both ISO 4 &5 areas.

SLAC Coupler Processing Facilities cont.

TTF3 Coupler Assembly Cleanroom at SLAC cont.

- All the benches are electro-polished 304 stainless steel with perforated tops to maintain a laminar flow in the work areas.
- The majority of the construction material to fabricate the cleanroom is static dissipative to minimize particle attraction and ease of cleaning.
- The flooring material complies with ANSI/ESD-S20.20 for Electrostatic Discharge (ESD) static dissipative material.
- A 7.5 ton chiller system maintains the facility air temperature at 20ºC (68°F).

SLAC Coupler Processing Facilities cont.

SLAC

Cleanroom ISO 4 (Class 10)

- Rinsing station
- Assembly area
- Particle counter
- Nitrogen purge box

Cleanroom ISO 5 (Class 100)

Ultrasonic washing station

Vacuum pump down station

Vacuum bag heat sealing

Tool box

SLAC Coupler Processing Facilities cont.

Ultra Pure Water System:

- Millipore water system designed to produce up to 700 liters/day of Type I purified water to a 350 liter reservoir.
- Primary distribution equipment includes pump, Super-Q System, 254 UV, 0.22 micron membrane filtration to deliver up to 3.8 GPM of Type I purified water.
- 316 S.S. supply and return (closed loop system) to wash and rinse stations.

SLAC Coupler Processing Facilities cont.

Ultrasonic wash station ISO 5 (Class 100) area

- 56 gallon tank 40“ L x 18“ W x 18“ D
- 1,600 Watt 40 kHz power

Rinse station ISO 4 (Class 10) area

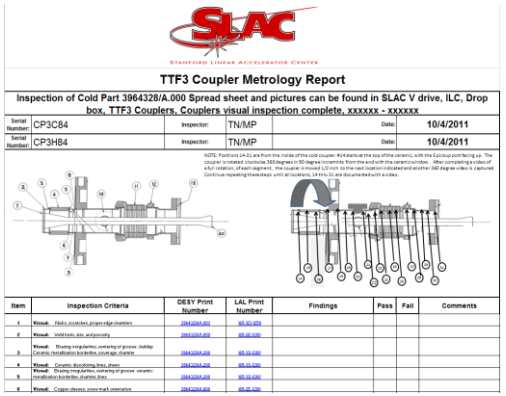
- Filtered nitrogen ionizing gun (0.02 µm) to blow parts dry
- Omega conductivity/resistivity controller (probe in P-trap)

TTF3 Coupler Processing

Metrology:

Each coupler went through a rigorous metrology inspection to validate compliancy prior to processing.

- Done in ISO 7 (class 10,000) cleanroom
- Full metrology report for both Cold & Warm
- Borescope 100% of inside of couplers
  - Teflon V-block support parts during inspection for ease of rotation
- Any out of spec tolerances was captured on a NCR (Non-Conformance Report) and disposition appropriately.

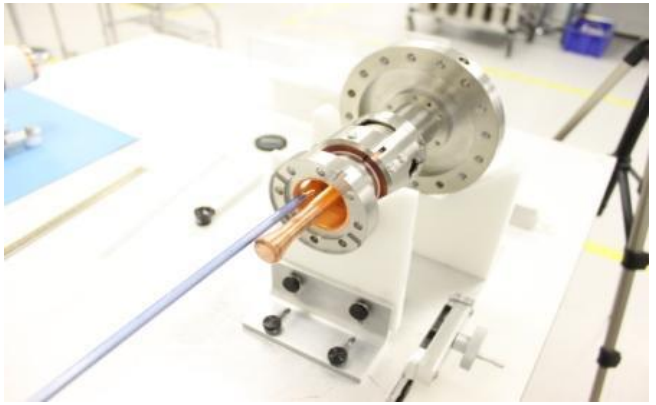


TTF3 Coupler Metrology Report

Inspection of Cold Part 3964328/A.000 Spread sheet and pictures can be found in SLAC V drive, ILC, Drop box, TTF3 Couplers, Couplers visual inspection complete, xxxxxx - xxxxxx

Serial Number:	CP3C84	Inspector:	TN/MP	Date:	10/4/2011
Serial Number:	CP3H84	Inspector:	TN/MP	Date:	10/4/2011

Item	Inspection Criteria	DESY Print Number	LAL Print Number	Findings	Pass	Fail	Comments
1	Visual:						
2	Visual:						
3	Visual:						
4	Visual:						
5	Visual:						
6	Visual:						

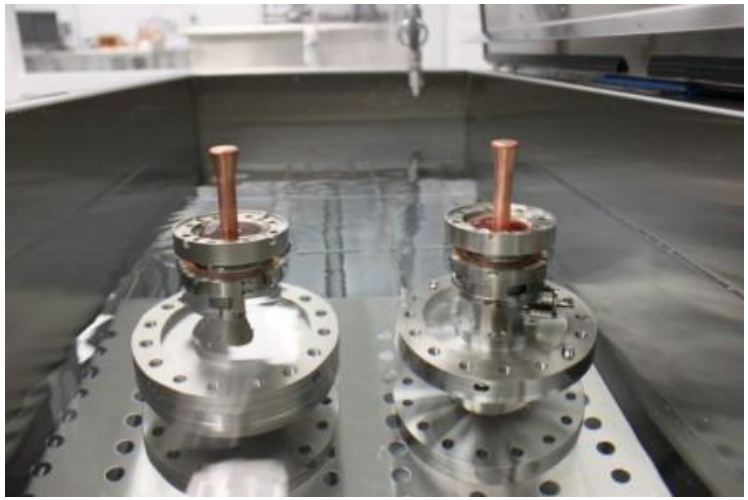


TTF3 Coupler Processing cont.

SLAC

Cleaning Process:

- All parts are blown off prior to entry into the ISO 5 cleanroom (all parts that can be UHV cleaned are done so prior to ISO 4 cleaning).
- The parts are then placed in an ultrasonic cleaner for 15 minutes that is filled with 40-50 °C ultrapure water and a diluted (1:100) cleaning agent (Liquinox).
- Production verification of cleanliness is done using Millipore fluids contamination analysis kit (grid membrane filter 0.45µm).



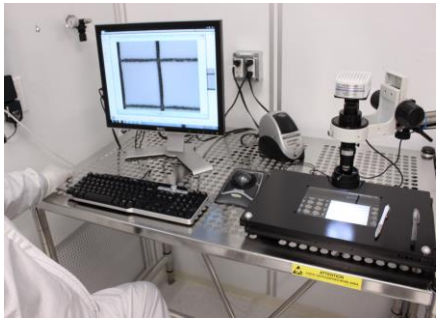
TTF3 Coupler Processing cont.

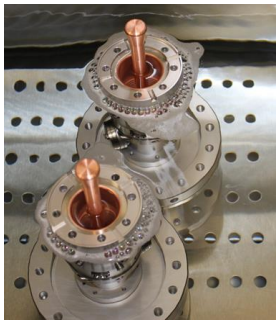
UPW filters verification process cont.:

An initial cleanliness verification process is performed for production of FPC by using a filter sample after each ultrasonic bath and rinse cycle on several FPC to determine that the Washing and Rinsing process is working correctly.

- Filter is a Millipore Membrane, mixed cellulose esters, Hydrophilic, 0.45 µm, 47 mm diameter, white, gridded.
- Particle counting: Each filter had a picture taken using the VZM-200 Digital Video Measurement System.
- Particle counting was done by hand, no program was used to determine amount (time consuming and labor intensive).

Normal particle counting with filtered Nitrogen is done to baseline the verification process.



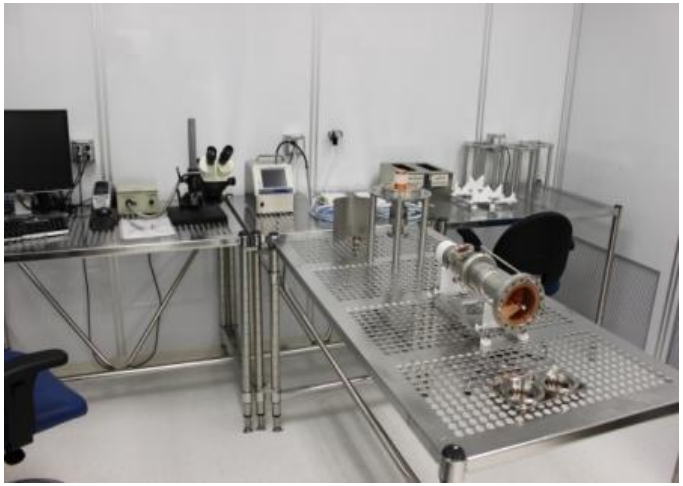


TTF3 Coupler Processing cont.

SLAC

Rinse:

- Afterwards, they are rinsed off in the ISO 4 area using a 40-60 psi hand-held spray nozzle.
- A resistivity meter is used to determine if the part is clean enough, and it usually takes 5-7 minutes of rinsing to achieve an acceptable level (> 14 MΩ/cm) also verification of cleanliness is done using Millipore fluids contamination analysis kit (grid membrane filter 0.45μm) and viewed in the class 10 area real-time for verification.
- Filtered and sterile denatured ethanol is then sprayed through the warm and cold sections to help remove water, especially that in the bellows, and all parts are blown dry with filtered nitrogen.
- The parts are then placed in a nitrogen purge box (48 hours) to ensure dryness and minimize oxides.

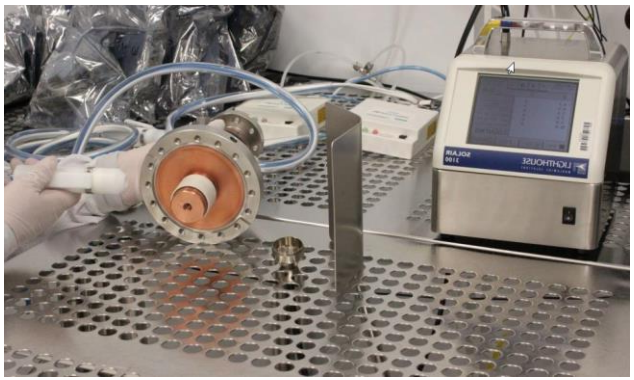


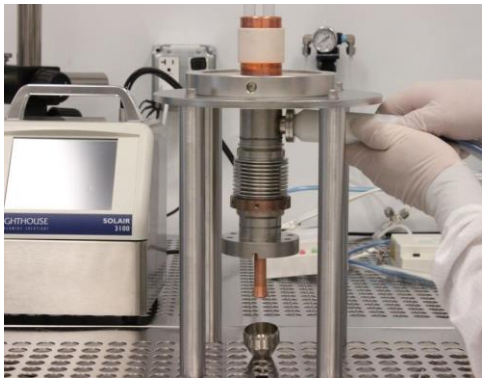
TTF3 Coupler Processing cont.

Particle verification (Nitrogen):

All parts are verified using Nitrogen and particle counter to verify parts are within specification.

Particle Size	0.3µm	0.5µm	1µm	3µm	5µm	10µm
Internal Surface Counts	10	5	0	0	0	0
External Surface Counts	100	50	10	5	5	2

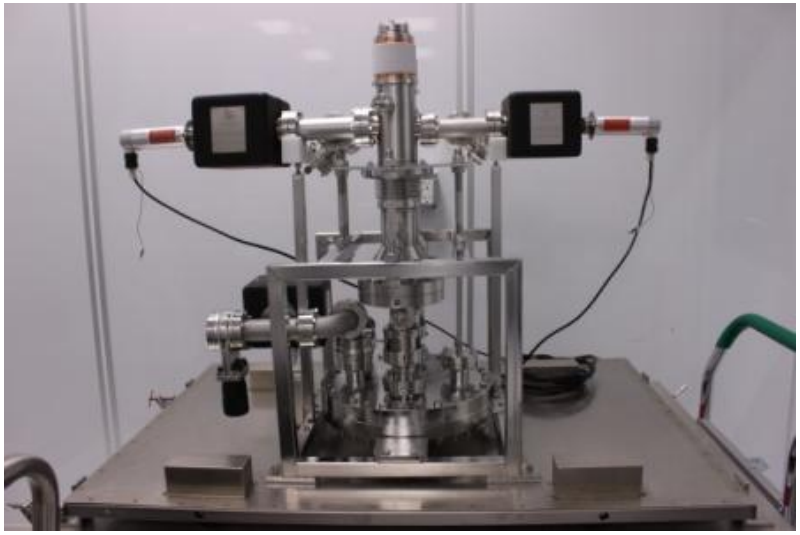




TTF3 Coupler Processing cont.

Assembly:

- The TTF3 assembly is done in the ISO 4 area and built to a Technical Speciation document. Each coupler build has this unique document to capture all aspects of the assembly, baking & RF processing.
- During assembly filtered nitrogen is blown in one of the e-pickups for a positive pressure to keep contamination out of the couplers.

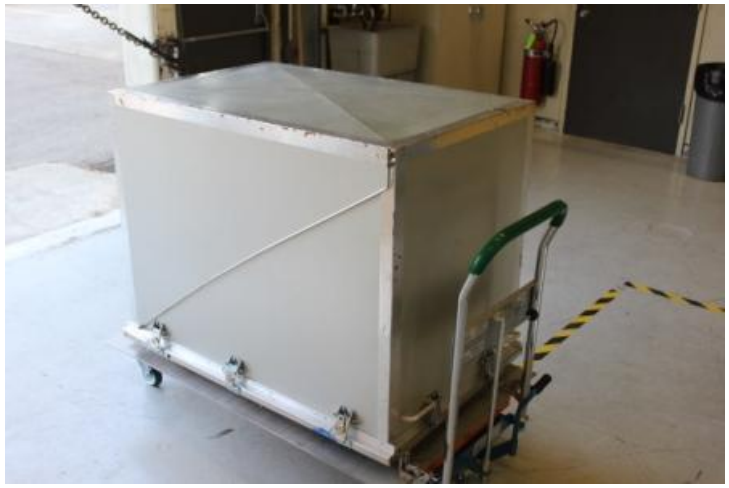


TTF3 Coupler Processing cont.

Bake-out:

Bake-out of the couplers
are done prior to RF processing.

- 100 C ramp up for around 8 hours
- 150 C for 48 hours
- Bake-out oven I.D.
  35" high x 33" wide x 46" deep
- Bake-out oven Nitrogen purge box
  30.5" high x 27" wide x 40.5” deep
- Temperature and vacuum are
  monitored during bake-out.



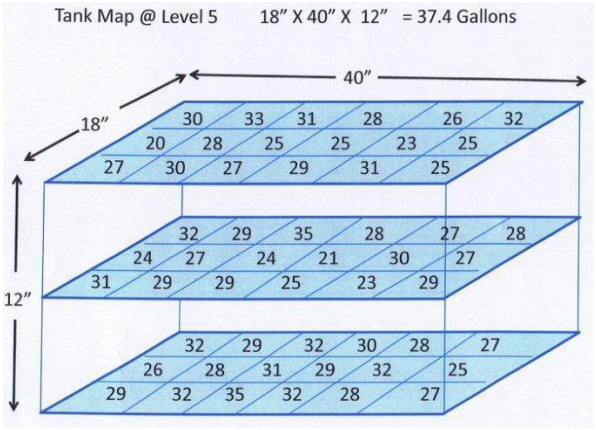
TTF3 Coupler Processing cont.

Shipping of Couplers:

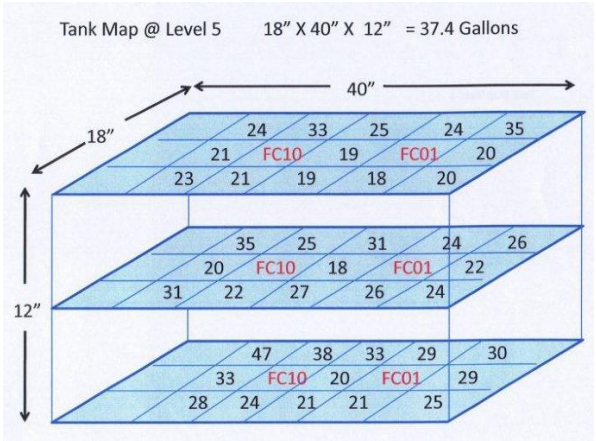
- Used ATA foamed filled shipping containers with custom cut inserts for hardware. Foam was lined with ESD bubble wrap.
- Each is custom fitted for each configuration with polyethylene foam (closed cell, white and 2.2 lbs. per cubic ft. rated for safety of hardware).
- All hardware is doubled bagged (vacuum heat sealed), Colds are tripled bagged.
  - Bag material meets ANSI/ESD S20.20 MIL-PRF-81705D Type III
- Cold parts are shipped in RF processing cavity assembly (under vacuum).

TTF3 Coupler Lessons Learned cont.

Ultrasonic Bath Power Level cont.

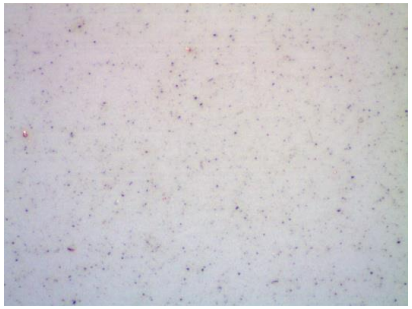


POWER LEVEL WITHOUT COUPLERS

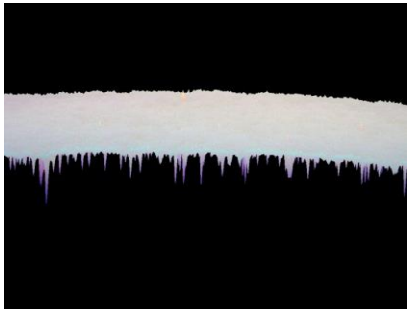


POWER LEVEL WITH COUPLERS

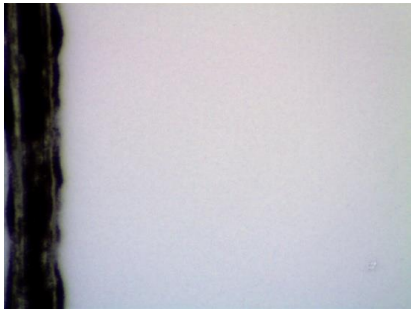
Finding: Copper particle count weakly dependent on power level



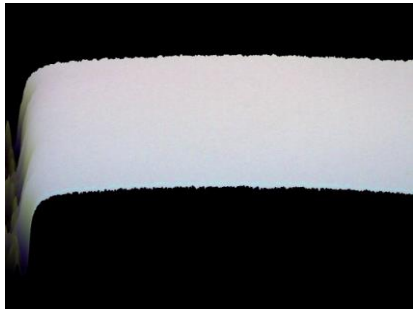
Bath 5 15 min



Bath 5 3D



Rinse 5 5 min



Rinse 5 3D

TTF3 Coupler Lessons Learned cont.

Galling of S.S. hardware & contamination control:

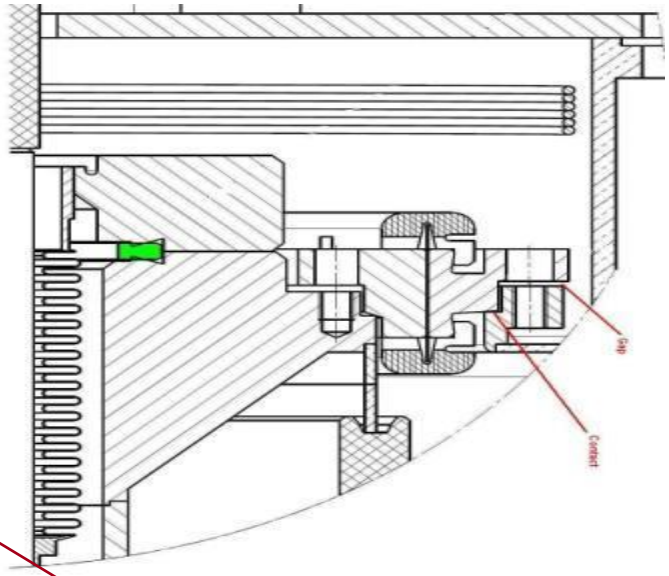
- All of the hardware was changed from the 316 S.S. to Nitronics 60 do to galling between the hardware.
- Nitronics 60 Magnetic Permeability is as follows:
  - Annealed 1.003
  - 25% Cold Drawn 1.004
  - 50% Cold Drawn 1.007
  - 75% Cold Drawn 1.010

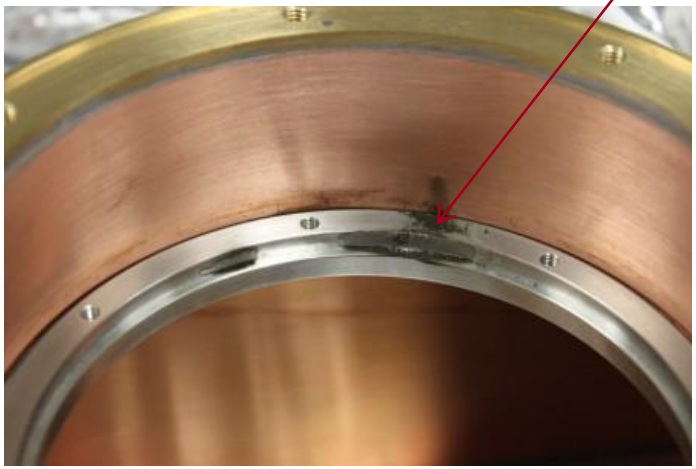
- Contamination tests performed on cut bolts vs. rolled bolts showed an order of magnitude of less particles on rolled bolts. Tests done with both bolts being electropolished.
- All bolts are Nitronics 60 electropolished then UHV degreased and ISO 4 cleaned before use.

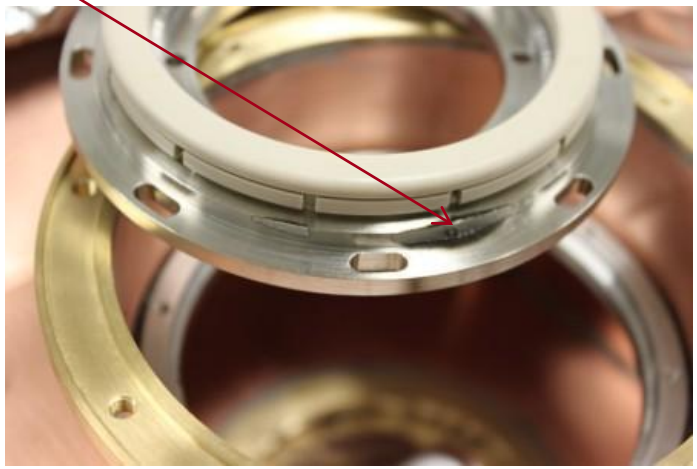
TTF3 Coupler Lessons Learned cont.

TTF3 Capacitor arcing:

- Waveguide to warm assembly arcing was observed in several couplers.
- Out of tolerance gaps between waveguide and ‘capacitor.’





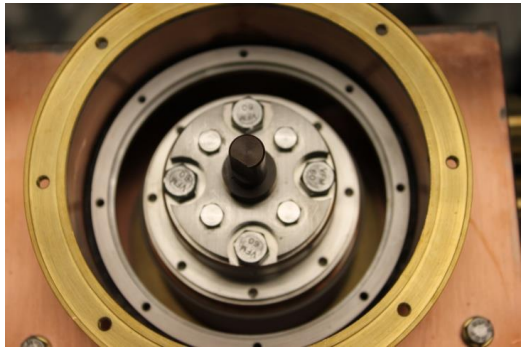


TTF3 Coupler Lessons Learned cont.

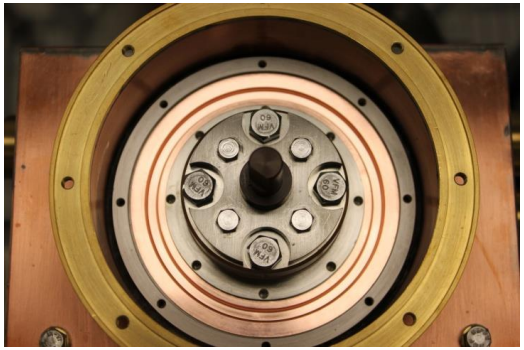
SLAC

Arcing cont.

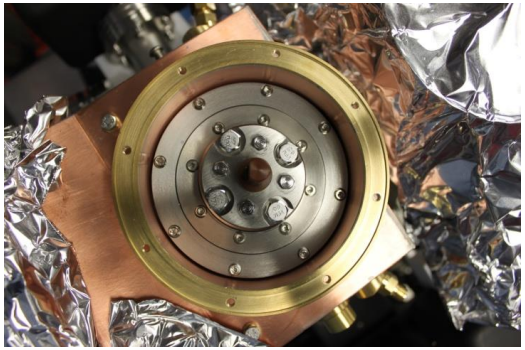
Designed a more flexible mating assembly using 304 S.S. outer and inner rings and a thin Cu middle ring to seal gap (does not allow HV bias)



SK-GB-100212



SK-GB-100211



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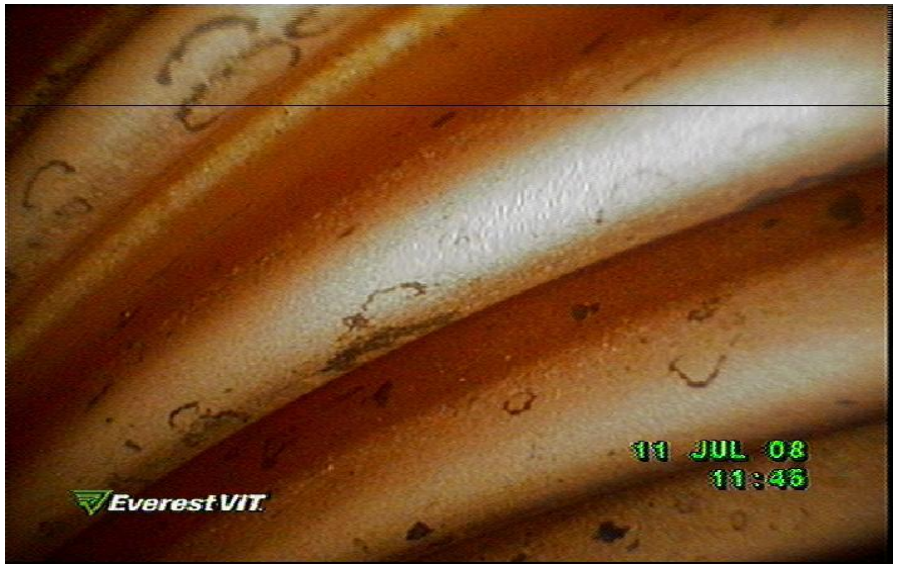
TTF3 Coupler Lessons Learned cont.

Some couplers that failed incoming inspection:

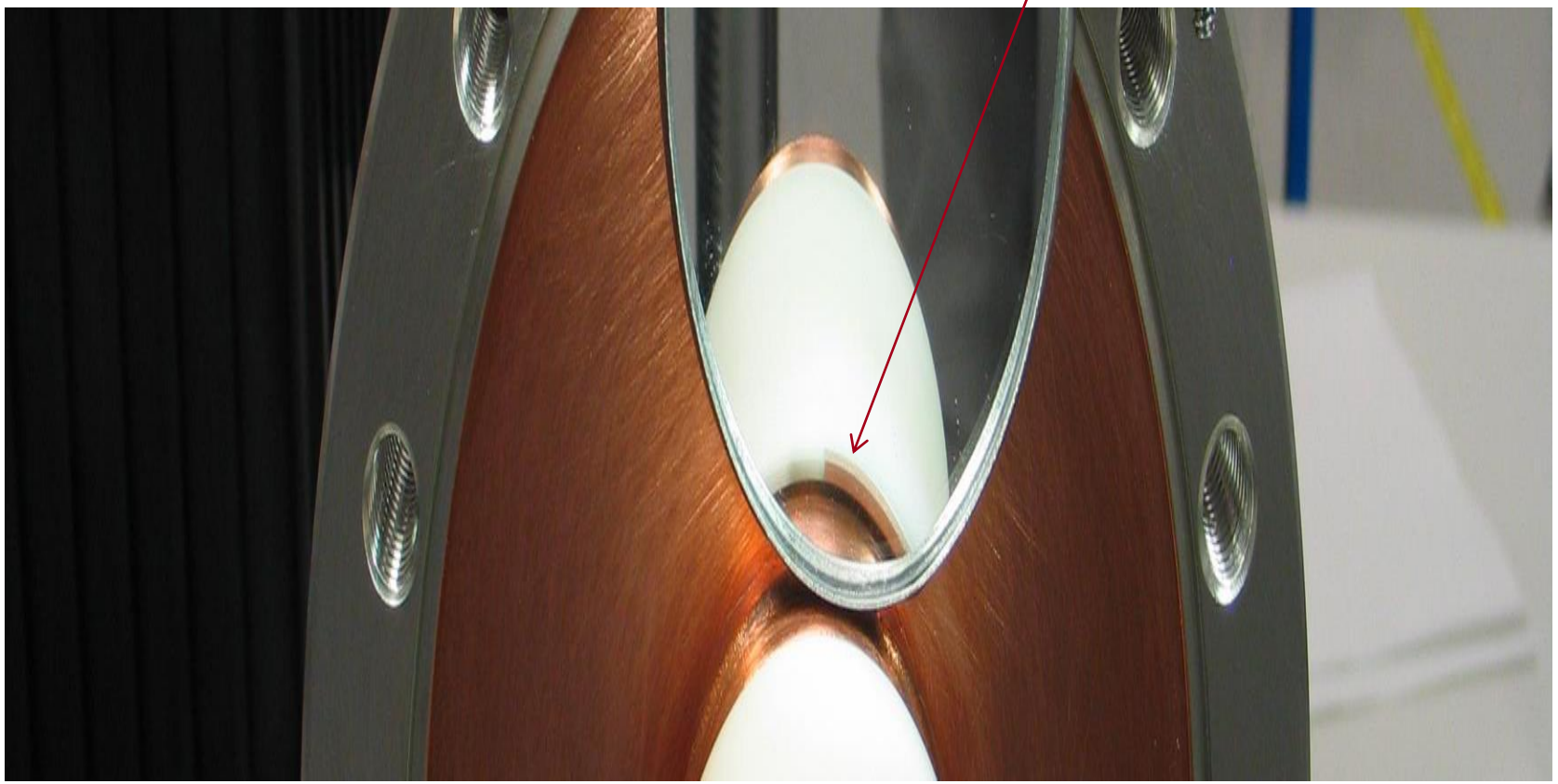
Warm inner conductor with extensive oxidation (two different couplers).



TTF3 Coupler Lessons Learned cont.

NCR cont.

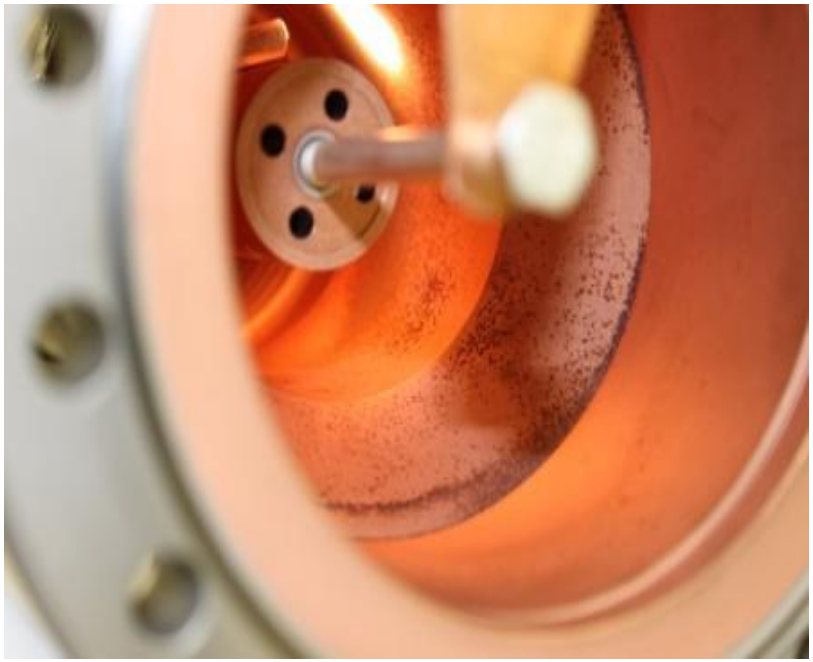
Here the window has copper plating on the ceramic, which must be free of metallization.



TTF3 Coupler Lessons Learned cont.

NCR cont.

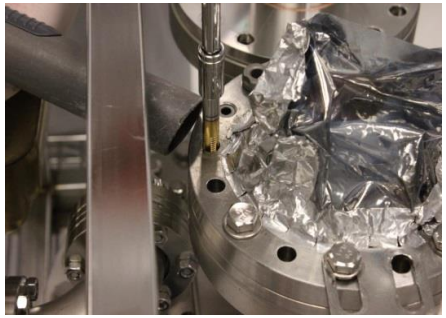
- Badly dented bellows on Warm section
- Oxidization on Warm outer wall copper plating.



TTF3 Coupler Lessons Learned cont.

M8 holes had insufficient holes tapped on several CF-100 flanges (Colds). During removal of bolts (drilling) the window delaminated from the copper ring assembly. Analysis of de-metallization is still under investigation.





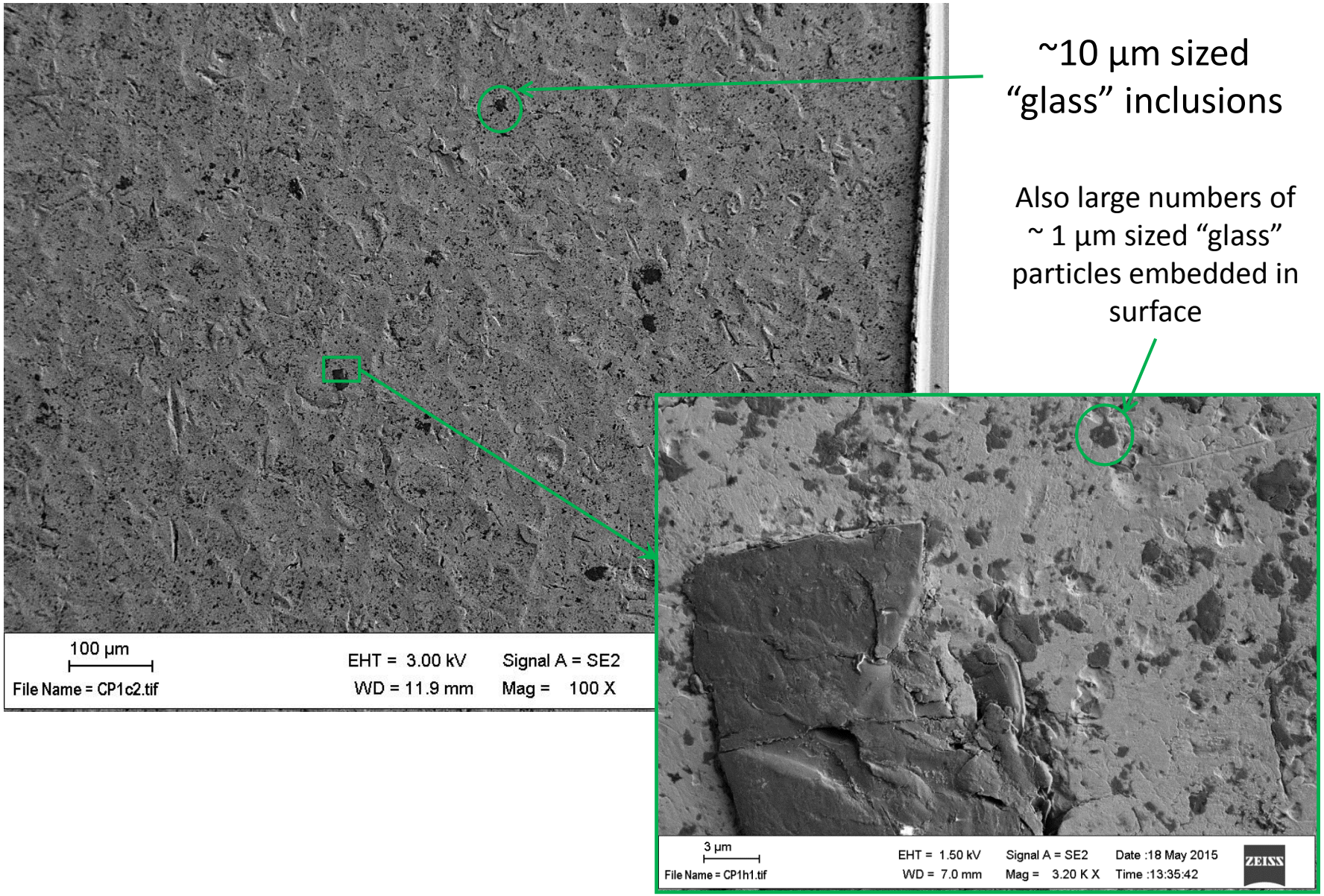

TTF3 Coupler Lessons Learned cont.

For the TTF3 ILC Coupler we had 30 NCR reports out of 44 Couplers for the ILC development program from minor to major non-conformance.

NCR #	Part # / Serial #	Part Description	Brief Summarry	Current Status
1	3964328/A.000 / FC01	Cold Part	Copper on ceramic	Repaired
2	3964328/A.000 / FC02	Cold Part	nick in copper	Repair here/Done
3	3964328/A.000 / FC04	Cold Part	Copper on ceramic/dent in antenna	Repaired
4	3964328/A.000 / FC05	Cold Part	fix scratches on antenna	Repair here/Done
5	3964328/A.000 / FC06	Cold Part	fix scratches on antenna	Repair here/Done
6	3964328/A.000 / FC10	Cold Part	Concentricity is out	Repaired
7	3964328/A.000/CP3C41	Cold Part	Excessive Oxidation	Send to Ali
8	2988356/A.000 / FH02	Warm Part	Excessive Oxidation	Repaired
9	2988356/A.000 / FH07	Warm Part	Bent bellows	Repaired
10	2988356/A.000 / FH09	Warm Part	Cf-100 dented/ Plating not uniform	Repaired
11	2988356/A.000 / FH10	Warm Part	Cf-100 dented/ Plating not uniform	Repaired
12	FH03	Warm Part	nick in copper	Repair here/Done
13	FC04, FC05	VACUUM LEAK	Gate Valve Failure	Repair here/Done
14	FC06, FH06 FC07 FH07	BAKEOUT	ION PUMP POWER FAILURE	CORRECTED
15	FH07	ANTENNA TUNING ROD	SEEMS TO BE NOT LOCKED IN	CORRECTED
16	FH09	RF IN WARM PART	SHORTED H.V. CABLE ON ION PUMP	REPLACED
17	CP3H75	WARM PART	SIGNIFICANT OXYDATION	RETURN TO VENDOR
18	CP3C75, CP3C76,CP3H76, FH01	MARK ON CAPACITOR	AFTER R.F. TEST SAW MARK ON CAPACITOR	CLEANED
19	CP3H79 / CP3K77	MARK ON CAPACITOR	AFTER R.F. TEST SAW MARK ON CAPACITOR	CLEANED
20	CP3C91	GALLED BOLTS	AFTER R.F.TESTING BOLTS GALLED	THREADS/BOLTS CHASED
21	CP3C83	cold part	Threaded holes	return to vendor
22	CP3C84	cold part	Threaded holes	return to vendor
23	CP3H87	Warm Part	PLANE OF PUMP PORT FLANGE	USE AS IS
24	CP3H92	Warm Part	PLANE OF PUMP PORT FLANGE	USE AS IS
25	CP3C91	WARM Part	ADDITIONAL LEAK CHECK	
26	CP3H89/CP3C87	WARM Part	R.F. BREAK DOWN	
27	CP3H101	WARM Part	R.F. BREAK DOWN	change with H02
28	CP3H102	WARM Part	R.F. BREAK DOWN	Repair and retest
29	CP3H94	WARM Part	R.F. BREAK DOWN	Repair and retest
30	C97/H97/C98/H98	COLD PARTS	COLD COUPLERS R.F. BREAKDOWN	

Recent SEM Study of Vendor Bead-Blasted and Non-Bead-Blasted Copper Plated Surfaces

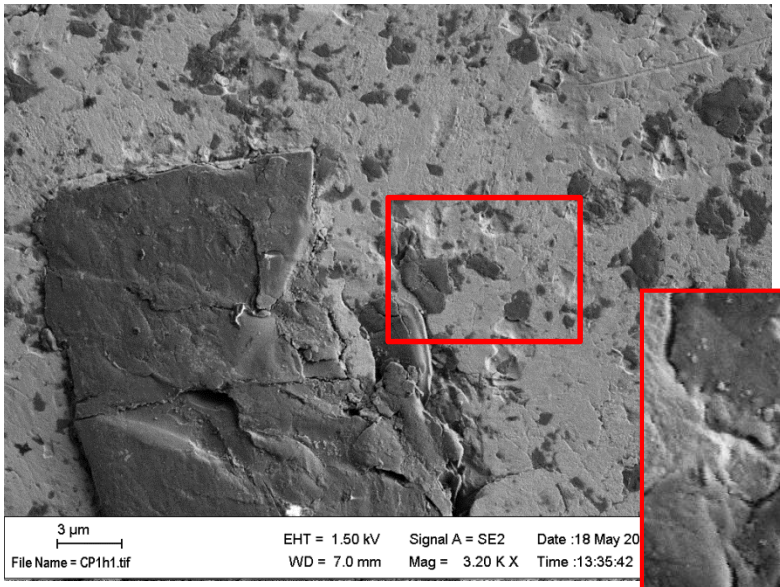
Vendor – 10 microns, Bead blasted, ISO 4 cleaned



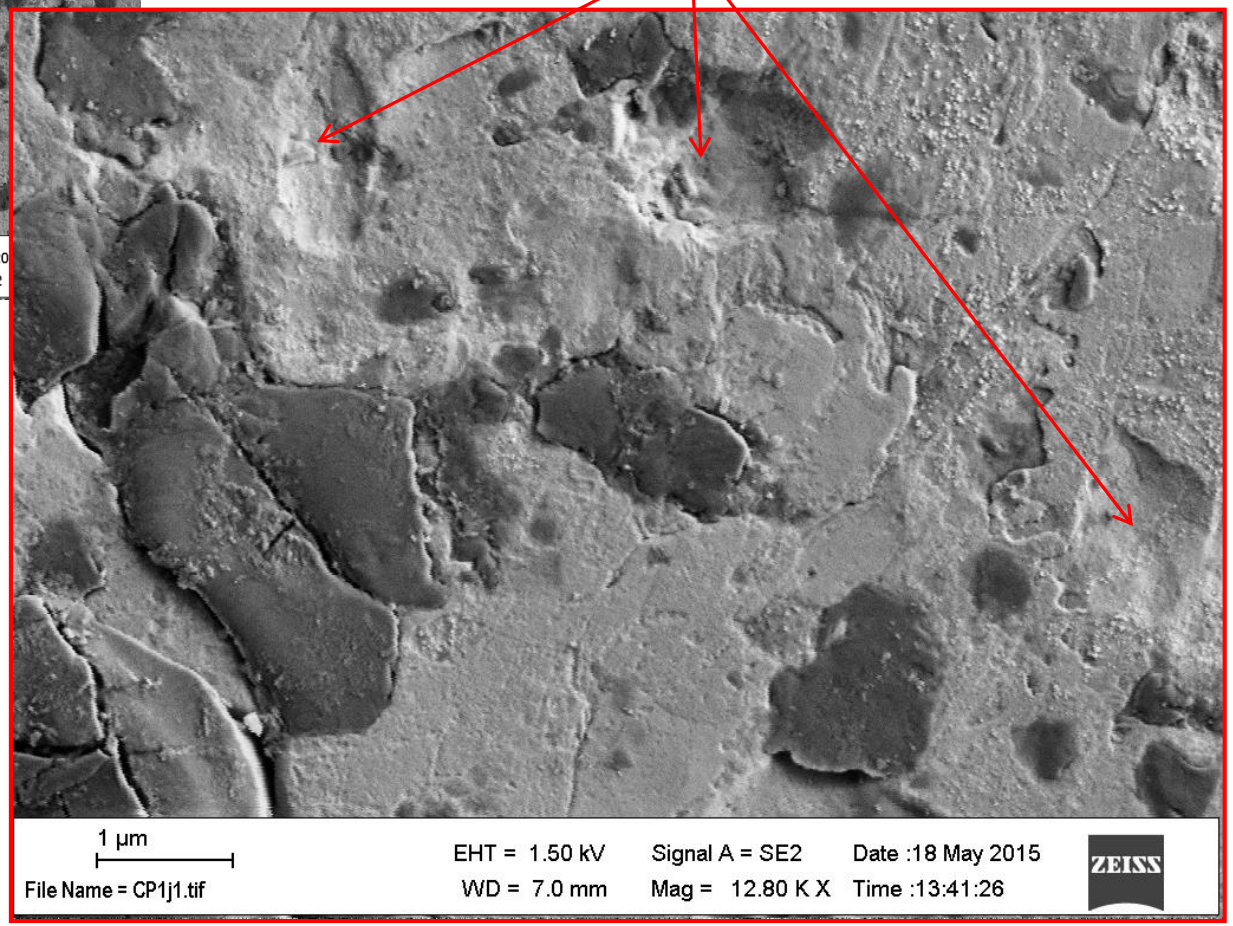
~10 µm sized "glass" inclusions

Also large numbers of ~ 1 µm sized "glass" particles embedded in surface

Vendor – 10 microns, Bead blasted, ISO 4 cleaned

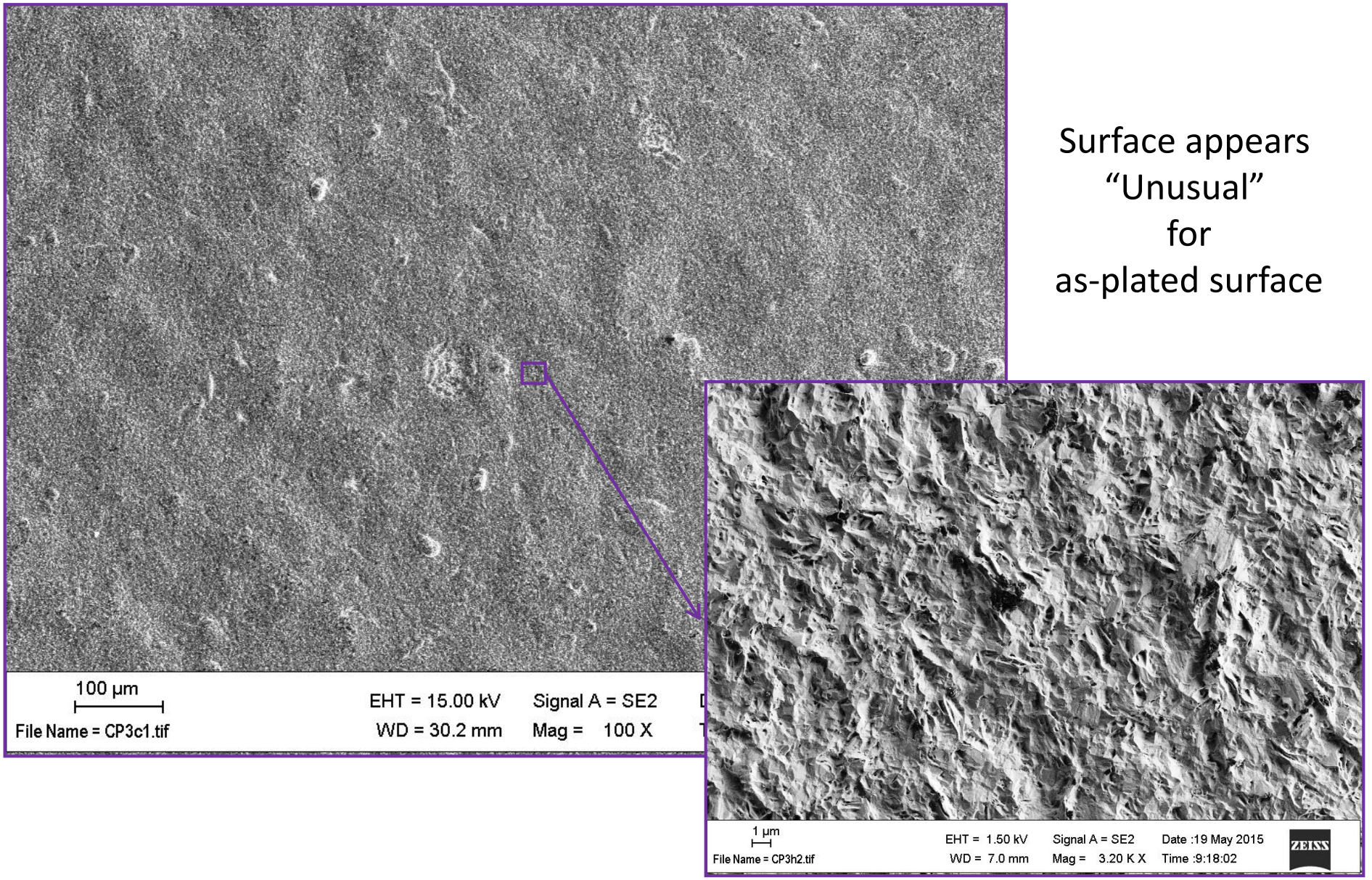


Close examination reveals areas where embedded particles may have been removed by ultrasonic cleaning



Many sub-micron embedded particles and also present

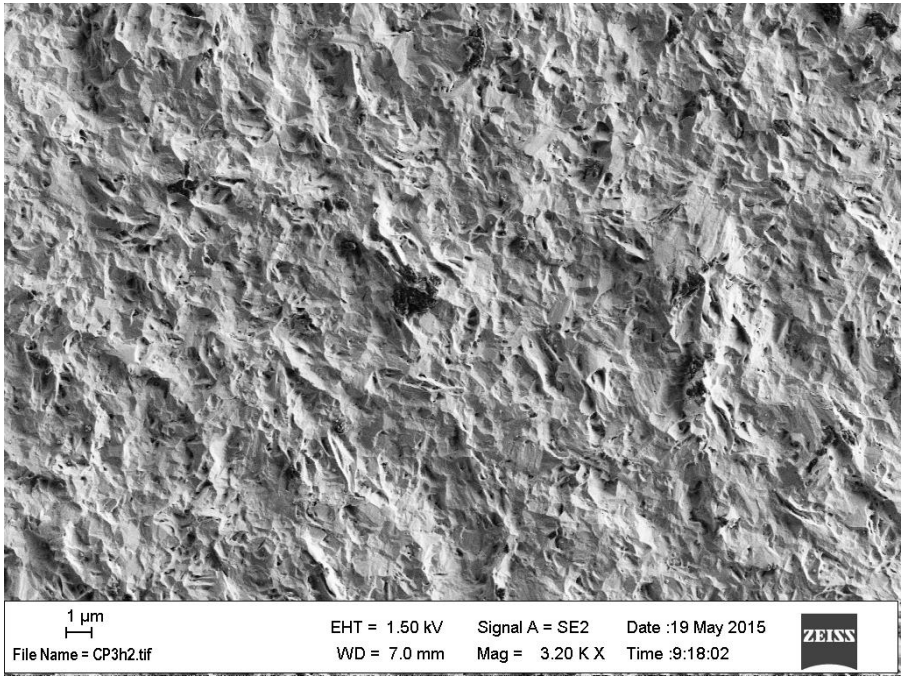
Vendor – 10 microns, Not Bead blasted



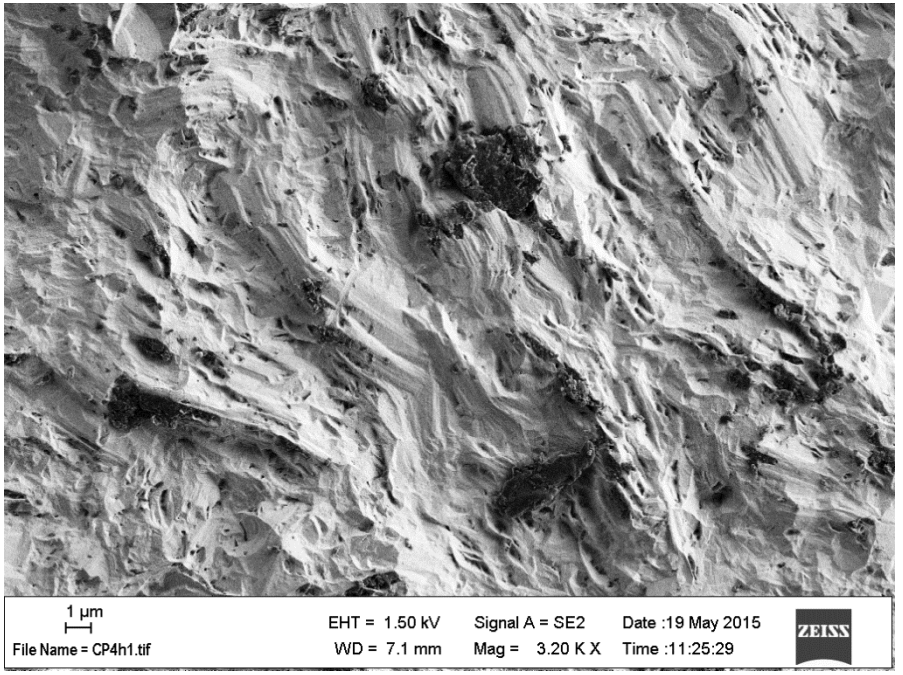
Surface appears
"Unusual"
for
as-plated surface

Vendor -Not Bead blasted

10 µm not blasted



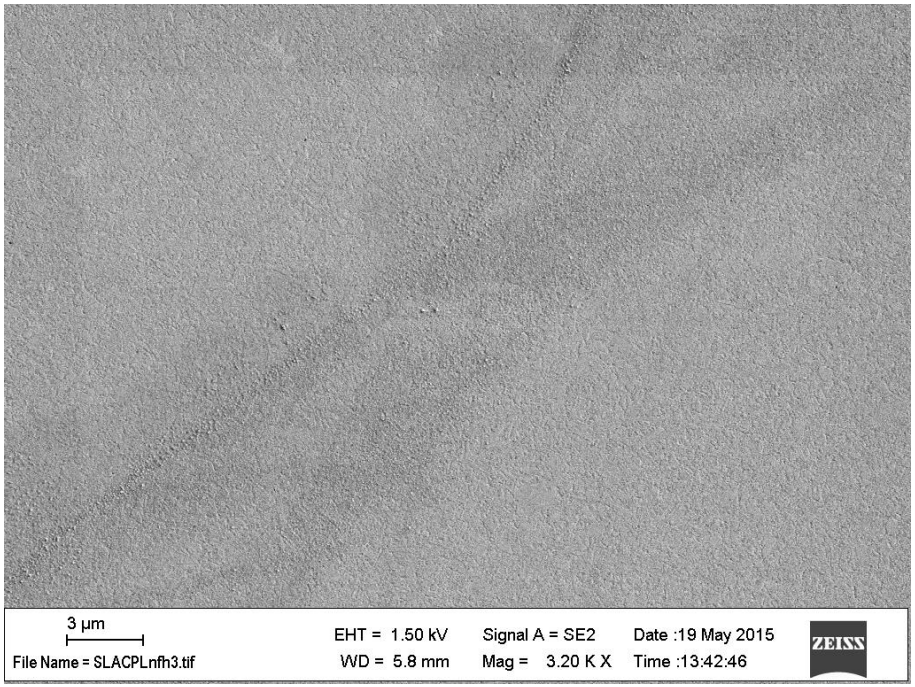
150 µm not blasted



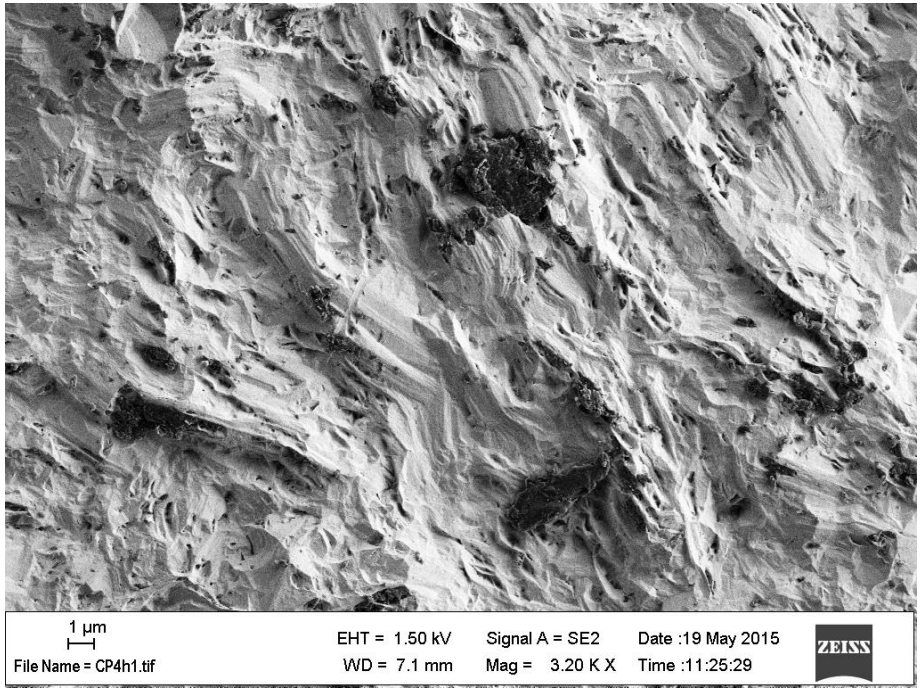
Both Images at 3.2 KX

Ref- Comparison with SLAC Plating

SLAC Sample
As plated, not bead blasted
(from Cu plated rf flange routine production)



Vendor Sample 4
As plated, not bead blasted



Both Images at 3.2 KX

Summary

SLAC has cleaned and processed:

- 44 (ILC) TTF3
- 16 EuXFEL
- 13 LCLS-II (TTF3 modified)

Fundamental Power Couplers are not easy to fabricate, clean, assemble, bake and RF process to support SRF projects. Many steps are needed to get to a compliant part.

- Oversight of vendor's
- Quality Assurance from vendor's to Labs.
- Labor intensive processes.
- Complicated parts.

We need to keep smiling when it comes to Couplers work!