High Gradient R&D Coordinating Committee
June 26, 2001

Agenda

1. High Gradient R&D Schedule (Attached)

2. Update on NLCTA Run (Jobe/Ross)

3. July - August Plans (Burke/All)
   T53VG3R 400ns Test
   SLED 400 MW Test
   T53VG3RA Plans
   Glow-Discharge Readiness
   S20PIL Readiness
   Staffing Through Snowmass

Upcoming:
   July 3   July Progress Review (Cornuelle)
   July 10  ??? (???)
   July 17  ??? (???)
• We will bypass SLED in Station 2 and run the T53VG3R now installed at 400 ns pulse width and as high in power as we can go prior to the next install.
  o We will leave Station 1 running so we need another set of the bypass parts we used for Station 1. Per Keith at the meeting this is an E-plane bend with two flanges, and we need to bring the drawings to Chris Pearson’s attention.
  o We will need to bypass the T53VG5R structure, but that part should already be available. We will also need to bypass/remove the attenuator in front of the T53VG3R, which may require new parts.
  o On July 24, we will meet to assess where we are on the standing wave and travelling wave structure testing (many of us will be away until 7/23 at the Snowmass meeting).
  o Assuming that nothing significant has occurred, we will take Station 2 down and convert it over starting 7/30/01 to 8/3/01. We will start up without an in-situ bake. If this does not work, we will shut down and do the bake.

• 400 MW Upgrade/Test
  o During the July 24 meeting, we will determine if and when we will do the 400 MW test on Station 1. The tradeoff is whether the time needed for the 400 MW test can be obtained without unacceptably delaying the structure-testing program. Keith reported that the 400 MW installation alone may require four or five in-situ cold tests that could take on the order of five days each.
  o Based on load tree part availability (yet to be confirmed), we could begin this work anytime after July 24. It is estimated that it will take a minimum of 30 days to do the installation and testing into the load tree. Doing the SLED head upgrade but not the load tree testing could shorten this time.

• Next Installation:
  o The T53VG3RA will be part of the next install. The coupler is in the queue at the mill. It will be ready for installation into NLCTA on 8/30/01. It is the critical path for the install. It is form/fit the presently installed T53’s except for the 12” wingspan on the input coupler.
  o The T53VG3F will also go into the next install alongside the T53VG3RA. This structure was bonded by KEK and is in its shipping container in Chris Pearson’s furnace area. It is 61 mm in diameter and has an integral (61 mm) coupler. It needs water-cooling and waveguides. It may have other small form/fit differences from the presently installed T53’s.
  o The two S20PIL standing wave structures will also go into the install. They were bonded earlier. Their couplers need to be brazed and then re-machined. There may be a modification to add an RF monitoring port (feedthrough) radially at one end (reduced ID section). They should be ready before the T53VG3RA.
• Other:
  o Chris Adolphsen proposed that we could effectively double-pulse the SLED system to get twice the pulse width (but at half the power). No action at the present time.
  o Keith resurfaced the idea of adding delay line to the SLED system to go up to the 400 ns pulse width. Initially he proposed moving the SLED-head eastward down the building, but the difficulty was perceived to be high. Keith will look at going westward (shorted end) and wrapping the SLED line around the corner using bends to get the length required. The line could also be bent 180° and routed back down the roof.
High-Pressure Water-Rinse Cleaning of Copper†

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Abstract

Copper, niobium and stainless steel surfaces were cleaned by high-pressure water-rinsing spray. Surface chemical and topographic analyses show that the HPWR process is neither a contaminating nor a significantly eroding process.

1 Introduction

Cornell University, CERN, KEK and Jefferson Lab use high pressure water rinsing (HPWR) in preparing superconducting cavities for ring installation. Work in those labs show that HPWR is useful in eliminating particles which can lead to high field breakdown during cavity operation. Although, at this date, particles alone do not appear to be the source of breakdowns in NLCTA test accelerating structures, it is useful to evaluate HPWR as a final cleaning step on the assembled structures, where the overall structure size and complexity prevents the use of other types of cleaning. Something resembling a spray-wand could be “snaked” down the completed structure, followed by filtered nitrogen gas drying.

To test this possibility, copper (Cu) coupons were cleaned by Greg Werner at Cornell’s Newman Lab using HPWR after prior extensive surface analysis and characterization at SLAC, consisting of weighing by microgram balance, measuring for contamination with x-ray photoelectron spectroscopy (XPS), measuring surface topography by atomic force microscopy (AFM) and assessing surface particle density by secondary electron microscopy (SEM) and energy-dispersive x-ray spectrometry (EDX). The measurements were repeated after return. The principals of these techniques are briefly described in the Appendix. For comparison, stainless steel (S/S) and niobium (Nb) coupons were also tested. Nb sheet for the coupons was kindly provided by H. Padamsee, Cornell.

The surface finish was deliberately left “as-machined”, rather than polished, to follow the surface roughness, through rinsing, in the event that the high pressure water flow caused material erosion. Erosion is of concern because material loss in the accelerating structure iris apertures would lead to a resonant frequency tune shift.

†Work supported by the U.S. Department of Energy under contract number DE-AC03-76SF00515.

2 Experimental Details

Test coupons (Figure 1) were produced from class 1 OFE copper, 304 stainless steel and niobium. All coupons were machined with conventional HSS tooling, and engraved on the backside with “134” and “135” for Cu, “S-1” for S/S and “N-1” for Nb. They were subsequently cleaned chemically in the SLAC Plating Shop, and stored in clean polypropylene wafer boxes. Care was taken to preserve the state of the coupon surface from that point on. The SLAC chemical cleaning recipes were C01A for Cu, C02A for S/S and C54A for Nb.

Figure 1. NLC cleanliness study test coupon. The central 0.375” square “mesa” was the area of study.

Analyses were performed in the sequence “least-surface-modifying first” of weighing, XPS, AFM, SEM.

Each sample was HPW-rinsed in a raster-scan pattern. The nozzle, containing four water jets, turned at one rotation/45 seconds as it descended 2 cm in 5 minutes toward each coupon. The coupon was covered with a mask that exposed only the central “mesa” to the water rinse. The coupons were dried in the clean room face-up for 15-2.5 hours and were then re-packaged in the wafer carriers, and sealed in a bag filled with filtered argon. Between measurements at SLAC, the coupons were stored in their individual wafer containers in a dry-nitrogen flushed dessicator.
3. Results

Weighing:

The material thickness loss, \( t \), is given by:

\[
\frac{t}{\text{mass}} = \frac{\text{density}}{\text{area}}
\]

The densities are roughly the same for Cu, Nb and S/S, with the thickness per \( \mu \)gram, on the mesa, about forty atomic layers or 10 nmeters of material.

The weight gain/loss as a result of the water rinse is:

- 134 – 4 \( \mu \)gram loss
- 135 – 4 \( \mu \)gram gain
- S-1 – 37 \( \mu \)gram gain
- N-1 – 2 \( \mu \)gram gain

The accuracy is about ± 30 \( \mu \)gram, so there appears to be no measureable weight loss/gain as a result of HPWR.

X-Ray Photoelectron Spectroscopy:

After weighing, the coupons were loaded into the UHV XPS unit. XPS is non-destructive and the least-contaminating technique for measuring surface composition, particularly contamination layers. Figure 2 is a spectrum of Cu coupon 135, prior to HPWR processing.

![XPS spectrum of Cu coupon #135, prior to HPWR](image)

Figure 2. XPS spectrum of Cu coupon #135, prior to HPWR. Atom% values refer to concentration of each element present in the information layer (~5nm), normalized to 100%.

Basically, these pre-HPWR spectra show that the coupon surfaces are UHV-quality clean from the SLAC Plating Shop. The coupon results for each element are summarized in Table 1, both for pre- and post-HPWR. The changes observed are rather small. The Cu coupons have gained a bit of C and lost some O. The C gain is consistent with the reactivity of Cu, compared to S/S.

Oxygen-free water strips small amounts of oxide from some surfaces. But, in general terms, not much has happened to the coupons as a result of the rinsing.

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Nb</th>
<th>Fe</th>
<th>Cr</th>
<th>Mn</th>
<th>Ni</th>
<th>O</th>
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<td>134</td>
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<td>S-1</td>
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<td>16</td>
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<td>3</td>
<td>43</td>
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Table 1. XPS atomic percentages of elements on Cu, Nb and stainless steel coupons, prior to HPWR.

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Nb</th>
<th>Fe</th>
<th>Cr</th>
<th>Mn</th>
<th>Ni</th>
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<td>2</td>
<td>2</td>
<td>45</td>
<td>22</td>
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</tbody>
</table>

Table 2. XPS atomic percentages of elements on Cu, Nb and stainless steel coupons, after HPWR.

Atomic Force Microscopy:

It was anticipated that the HPWR process might remove native material from the coupons, particularly on the rather soft Cu, so the surface finish was measured with an atomic force microscope. The scan area is rather small, about 70 \( \mu \) x 55 \( \mu \), but a representative area was chosen for scanning using an optical microscope for the setup. The scanning tip is silicon, as shown in Figure 3. The tip was imaged separately in the electron microscope to ensure the it did not wear and bias the results. The same tip was used for all the coupons in this study.

![New silicon AFM tip, used for coupons](image)

Figure 3. New silicon AFM tip, used for coupons.

Figures 4-6 are 3-dimensional AFM images of the surface topography of three of the coupons. Tables 3 and 4 give the vital statistics of average roughness, \( R_m \), and maximum peak-to-peak height of the coupon's surfaces,
R_p, before and after rinsing. The exactly same areas on the coupons were probably not scanned before and after HPWR, but were reasonably close.

The AFM images themselves, before and after HPWR, looked similar. The average roughness in the two cases is very close, rising slightly for Cu and dropping slightly for Nb and S/S. For Nb and S/S, the peak-to-peak roughness also drops, suggesting that the improving smoothness came at the cost of exposed machining ridge-tops. The Cu result is a wash – one has higher peak-to-peak, the other lower. The Cu surface is more open and, consequently, more exposed to erosion in valleys as well as peaktops. But the overall change, due to HPWR, is very small for all coupons and on the order of a few tenths of a micron average roughness – consistent with no measurable change in the weights.

<table>
<thead>
<tr>
<th>Cu134</th>
<th>Cu135</th>
<th>N-1</th>
<th>S-1</th>
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<tbody>
<tr>
<td>R_p</td>
<td>0.07</td>
<td>0.15</td>
<td>0.12</td>
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<tr>
<td>R_p</td>
<td>0.54</td>
<td>1.07</td>
<td>0.98</td>
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Table 3. Average roughness factors from AFM, before HPWR. Values are in microns.

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<thead>
<tr>
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<th>N-1</th>
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<tbody>
<tr>
<td>R_p</td>
<td>0.10</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>R_p</td>
<td>0.73</td>
<td>0.97</td>
<td>0.81</td>
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Table 4. Average roughness factors from AFM, after HPWR. Values are in microns.

Particle Searches:

Finally, the SEM was used to look for residual particles on the coupons. HPWR removal of particles was not the focus of this study. A proper search requires smooth surfaces for the automated particle-searching software to distinguish particles from background. Such a search is based on backscattered elastic electron signal contrast and brightness levels – virtually impossible on machined surfaces. The focus of this study was to look for signs of surface erosion and it was thought that detecting such erosion would be easiest with a rougher, rather than smoother, surface. The Cu coupons, although not smooth, had a rather featureless surface due to the lack of machining lines. They (134 and 135) were searched with the automated software. The Nb and S/S coupons were highly featured, and their search results could not be unambiguously interpreted. Cu 134 and 135 results are presented below.

Searches for particles >1 μ diameter were done by rejecting found-particles for which the EDX Cu signal was >97%. The assumption is that any non-Cu particle will have >3% of the total EDX signal. The purpose of this construct is to avoid counting, as particles, surface features of native Cu. No attempt was made to find and correlate individual particles found before and after HPWR. The search results were separated for predominant particle content, namely, dust/concrete constituents (Class A) and, everything else.

Class A: Ca or Al or Si or Mg or O
Class B: Other

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<th>Cu 134 Statistics</th>
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<tbody>
<tr>
<td>A  B</td>
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<tr>
<td>Before HPWR 47 33</td>
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<td>After HPWR 37 22</td>
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<tr>
<td>A  B</td>
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<tr>
<td>Before HPWR 151 38</td>
</tr>
<tr>
<td>After HPWR 150 36</td>
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Result: One reduced, one no change.
5. Conclusion

The primary purpose of this first test with HPWR was to look for signs of water erosion and contamination. Five minutes of rinsing removed a few tenths of a micron of surface at most. Contamination-wise, there is no significant change. Further work in that area requires the use of carefully-contaminated samples of known surface composition to test the ability of HPWR to remove the "dirt".

Looking at particle removal on the Cu coupons, it appears that there may be some effect on >1μ diameter particles, but further work on smoother surfaces is necessary to establish firm numbers. Rounding off the total results of the measurements suggests that HPWR is benign and may have particle-removal benefits.

6. Appendix

X-Ray Photoelectron Spectroscopy (XPS)

Energy-Dispersive X-Ray Analysis (EDX)

Atomic Force Microscopy (AFM)