High Gradient R&D Coordinating Committee
September 18, 2001

Agenda

1. NLCTA Operations (Jobe/Ross)

2. Downtime Plans
   Readiness of New Structures (Pearson/Wang)
   Schedule (Jobe/Cornuelle)
   SLED Upgrades?

3. H Structure Fabrication
   Progress (Pearson/Wang)
   Update Etching Studies/Plans (Le Pimpec/Kirby)
   When do we need to specify etching protocol?

4. High Gradient R&D Schedule (Attached)

Some dates:

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-Sept</td>
<td>End T53 run/Begin RA-PIL install</td>
</tr>
<tr>
<td>8-Oct</td>
<td>Begin H bonding - to be confirmed</td>
</tr>
<tr>
<td>23-Oct</td>
<td>Begin RA-PIL run</td>
</tr>
<tr>
<td>21-Dec</td>
<td>End RA-PIL run</td>
</tr>
<tr>
<td>2-Jan-02</td>
<td>Begin H install</td>
</tr>
<tr>
<td>24-Jan-02</td>
<td>Begin H run</td>
</tr>
<tr>
<td>22-Mar-02</td>
<td>End H run?/Begin RX install?</td>
</tr>
<tr>
<td>May-02</td>
<td>TRC Loew Committee Report</td>
</tr>
</tbody>
</table>
Status:

<table>
<thead>
<tr>
<th>Cu - COUPON</th>
<th>Complete to Braze Etching (chemical) time is in s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bare 5 30 (1μm) 60(2μm) 120(4μm)</td>
</tr>
<tr>
<td>T20/T105 KEK Cu</td>
<td>Y     Y     Y</td>
</tr>
<tr>
<td>T20/T105 SLAC Cu</td>
<td>Y LLNL Y LLNL - Y LLNL Y LLNL</td>
</tr>
<tr>
<td>T53 SLAC Cu</td>
<td>Y     Y     Y     Y     Y</td>
</tr>
</tbody>
</table>

Comment on the table from the 1st minute:
Start by the last line (T53 copper) (line3)
Each coupons have 2 sites which are analysed over a surface of 2x2 mm each.
The 4 coupons have been analyzed (backscatter +AFM) and weighted and are back from the etch, they are under analysis.
The data haven’t been looked at yet.
They will be weighted again and then send for the heat treatment.

Middle line (line 2).
Livermore (LLNL) has delivered 9 coupons. They have been degreased Tuesday the 11th September.
3 of them have been (backscatter + AFM) scanned and they will be weighted by Ed Garwin on Thursday 20th.
Next step etching.

First line, KEK machining.
KEK agreed to machine 5 coupons, Disposal boxes have been send to Japan at the beginning of this week.

Ultra Pure Water Cleaning:

4 coupons are currently in installation in the UPW system. The test will be to answer, after 24hour of exposure to a 8gpm flow of water with a speed > V~10cm/s : how many thickness can we remove? According to the results presented last week, we should get 1μm.
One of the coupons is oxidized, this coupon(SN 131) will be simply degreased and mounted, the goal is also to see if we can take off the oxide.

An analyze of the water to determine its chemical composition is also a point of interest.

There is some imperative due to the bonding of the next batch of structures scheduled for the 22 October 2001. It will be extremely great if we can squizz our studies and make them finished at least line 2 and 3 around the 8th of October 2001.
## T20/T105 versus T53 Differences

<table>
<thead>
<tr>
<th>Item</th>
<th>T20/T105</th>
<th>T53’s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper Mill</td>
<td>Hitachi</td>
<td>Hitachi Heat No 91V3523</td>
</tr>
<tr>
<td>Copper Batch/Lot</td>
<td>JIS H3510 C1011BD H62-500 Class 1; 62 mm Diameter Rod</td>
<td>From SLAC ID K2331.1,2</td>
</tr>
<tr>
<td>Part Fabricator</td>
<td>KEB</td>
<td>Robertson</td>
</tr>
<tr>
<td>Cleaning Before Annealing</td>
<td>Isopropyl Alcohol Rinse</td>
<td>Modified Process C01</td>
</tr>
<tr>
<td>Anneal Before Final Cutting</td>
<td>500 °C, 2 Hours, N₂ Atmosphere</td>
<td>525 °C ± 25 °C, 30 Minutes</td>
</tr>
<tr>
<td>Final Lathe Work</td>
<td>Precision Diamond-Turning Lathe</td>
<td>Conventional CNC Lathe</td>
</tr>
<tr>
<td>Final Cutting Tool</td>
<td>Single-Crystal Natural Diamond (IHI Used Synthetic)</td>
<td>Polycrystalline Diamond</td>
</tr>
<tr>
<td>Total Material Removed</td>
<td>40 Microns</td>
<td>125-200 Microns</td>
</tr>
<tr>
<td>Depth of Final Cut</td>
<td>2 Microns</td>
<td>12 Microns</td>
</tr>
<tr>
<td>Cutting Fluid</td>
<td>Air/Kerosene Mist</td>
<td>Petroleum Oil/Water Emulsion “Trim Sol”</td>
</tr>
<tr>
<td>Supplier Degreasing Process</td>
<td>Ultrasonic Ethanol/Acetone</td>
<td>Acetone</td>
</tr>
<tr>
<td>Other Pre-SLAC Cleaning</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>SLAC Degreasing</td>
<td>Not Required</td>
<td>Perchloroethylene (PCE) (2X)</td>
</tr>
<tr>
<td>SLAC Cleaning</td>
<td>Modified Process C01a</td>
<td>Modified Process C01</td>
</tr>
<tr>
<td>Etching Time</td>
<td>Five Seconds</td>
<td>One Minute</td>
</tr>
<tr>
<td>Material Removed During Etching</td>
<td>160 Nanometers</td>
<td>2000 Nanometers</td>
</tr>
<tr>
<td>Couplers</td>
<td>Identical</td>
<td>Identical</td>
</tr>
<tr>
<td>Bonding/Brazing</td>
<td>Identical</td>
<td>Identical</td>
</tr>
<tr>
<td>Comment</td>
<td>All Processing Steps Include</td>
<td>Exposure to Air</td>
</tr>
<tr>
<td>Wet Hydrogen Fire</td>
<td>60 min. at 950 °C</td>
<td>60 min. at 950 °C</td>
</tr>
<tr>
<td>Hold Time Prior to Dry Fire</td>
<td>12 Days T20 / 1 Day T105 in N₂</td>
<td>2 Days VG3 / 3 Days VG5 in N₂</td>
</tr>
<tr>
<td>Dry Hydrogen Fire (Cleanup)</td>
<td>T20: 10 min. @ 980 °C + 2 Hrs @ 955 °C T105: 2 Hrs @950 °C</td>
<td>2½ Hrs @ 950 °C (Orientation flipped 180° between firings)</td>
</tr>
<tr>
<td>Hold Time Prior to Vac Bake</td>
<td>One Day Max. (No Hold) in N₂</td>
<td>1 Day VG3 / 2 Days VG5 in N₂</td>
</tr>
</tbody>
</table>

### Vacuum Bake in Cans

<table>
<thead>
<tr>
<th>Pre-Structure Can Processing</th>
<th>Hydrogen Firing Only</th>
<th>Vacuum Firing (with T20/T105)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Reach 10 x 10⁻⁹ Pressure</td>
<td>12.6 Days</td>
<td>7.3 Days</td>
</tr>
<tr>
<td>Ultimate Pressure Hot</td>
<td>10 x 10⁻⁹</td>
<td>6 x 10⁻⁹</td>
</tr>
</tbody>
</table>

### Nitrogen Purging

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>12 Days</th>
<th>12 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can Opening to In-Situ Bake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen Purging During Final Assembly</td>
<td>4 Hours</td>
<td>8 Hours</td>
</tr>
<tr>
<td>Nitrogen Purging During Cold Test</td>
<td>24 Hours</td>
<td>24 Hours</td>
</tr>
<tr>
<td>Nitrogen Purging During Field Installation</td>
<td>120 Hours</td>
<td>30 Hours</td>
</tr>
<tr>
<td>In Situ Bake Time</td>
<td>325 Hours</td>
<td>92 Hours</td>
</tr>
<tr>
<td>Extensive Waveguide Baking</td>
<td>Yes, at 250 °C</td>
<td>Yes, at 250 °C</td>
</tr>
</tbody>
</table>

### In Situ Bakeout

| Final Pressure at 225 °C | 20 x 10⁻⁷ | 6 x 10⁻⁷ |

Rev. 8  9/20/01 JCC
Proposed Carbon Deposition Mechanism:
During the machining operation, the fluids used in machining are incorporated into the surface of the copper by the stress applied by the tool against the copper surface. This could be into pockets, grain boundary cracks, or dislocations in the crystalline structure that then subsequently close. (According to a super-computer simulation from LLNL that was shown to SLAC some years ago, the chip is released from the cutting edge by the presence of the lubricating fluid. Behind the tool is fresh exposed surface that then has lubricating fluid applied to it. Using proper machining technique there should be no mechanism that traps fluid between layers of the copper as it folds over due to pressure from the tool.) During the firing operations later, this trapped fluid turns to carbon. When RF is applied to cells made from this copper in accelerating structures, this carbon becomes a source of breakdown, either by residing at the surface or exploding from beneath the surface.

Machining Oil Chemistry Factors:
- Whether at KEK or at Robertson Precision, the parts are fabricated with a fluid, kerosene at KEK and a blended commercial product at Robertson that is primarily mineral oil. The fluid remaining on the surface should be removed by the degreasing and cleaning steps routinely performed. Since there has never been an experiment to measure how much if any of the machining lubricant remains on the metal surface after degreasing, this measurement will be incorporated into the coupon cleaning and analysis tests now underway.
- When the parts are heated for the first time for bonding (in a vacuum at KEK, in hydrogen at SLAC), any remaining mineral oil will begin to boil at or below 300 °C. Since this will create a pressure rise by a factor of around 200 at constant volume, only the material that is tightly trapped will not escape.
- While the Robertson fluid is sulfur-free and chlorine-free, it does contain additives that may or may not evaporate and thus could leave residues behind. The kerosene will completely evaporate, but if it contains traces of contaminants they could also be left as a residue.
- When the temperature reaches approximately 700 °C, any completely trapped oil/kerosene will begin to crack into lighter fractions. The peak temperature that the structures reach during bonding and brazing is 950 °C. If some of the mineral oil/kerosene (C₁₂) has cracked down to methane, then it is possible that some methane will proceed back up the chain into ethane, ethylene, ethyne (acetylene), diacetylene, vinyl acetylene, and then carbon. Methane can begin to pyrolyze into this carbon-terminating process around 850 °C. The presence of hydrogen can inhibit the methane to ethane step (the methane needs to shed an H₂ molecule). Since the KEK bonding is done in vacuum, it is possible that the methane to carbon process, if it occurs at all, would occur more readily. At the relatively low temperature of 950 °C, the pyrolysis to carbon reaction will be very slow, spotty, and highly dependent on the presence of a catalyst (carbon), so it is unlikely it will occur to any great or uniform extent.
- During the subsequent brazing cycles in dry hydrogen, 2-10 nanometers of carbon per cycle will be removed from the surface by being converted into hydrocarbons.

Post-Processing Carbon Chemistry Factors:
- During the wet hydrogen firing, any carbon that is exposed to the water/hydrogen gas will turn to CO and disappear. It is not clear the extent to which H₂O can penetrate copper at 950 °C, so the effect on completely subsurface carbon embedded in the first few microns is not known. The mechanism in iron is that the H₂O rapidly depletes the surface carbon resulting in a steep gradient that pulls carbon from the interior, and this same mechanism may apply to copper.
- It is unlikely that there is much native carbon in our copper since it does not readily or at all form a carbide.
• The wet firing does not convert the copper to copper oxide. The parts would have to be almost under water for this to occur.
• The subsequent dry firing is to remove the chromium oxide on the stainless steel flanges produced in the wet firing. Should any be present, it will remove from 2-10 nanometers of carbon from the metal surface also.
• At 950 °C, hydrogen moves quickly through the copper and rapidly saturates it. Any oxygen present in the copper as a contaminant (either as O₂ or as Cu₂O) would be converted completely into water during the hydrogen firing steps. Substantial amounts of oxygen can dissolve in copper, so we are dependent on the quality of the material provided by the supplier. Since we buy OFE Class 1 copper and do not see any damage from the formation of water during brazing, it is unlikely that this reaction occurs to any extent.
• Any carbon present in the same micro-location as the water produced in the previous step would combine with the water to produce CO. This can also create damage to the metal, but we can presume this does not occur because the previous step does not occur.
• Dushman reports that vacuum-melted copper when heated releases primarily CO. The SLAC experience is that hydrogen to some degree may also be present. The CO and hydrogen can come from the grain boundaries, although Dushman also indicates this is not always the case. Therefore, some portion of the CO we see during processing may be an inherent component of the copper, and not only the product of a post-machining reaction.

Other Gases:
• Ethane and acetylene chemically adsorb onto copper, and therefore they could diffuse beneath the surface to some very limited degree based on the atmospheric partial pressure of these gases and a room temperature process. The wet firing would convert the surface gas to CO and hydrogen, and would most likely cause the remaining gas to diffuse out quickly due to the high ambient temperatures and their low partial pressures.
• Nitrogen is insoluble in copper, which is why we do not see it during bakeout or RF processing.

Diffusion in General:
• The surface roughness can have a major impact on the gas diffusion rate by a factor of ten or more - the rougher the surface, the faster the diffusion. This may be a significant factor for the diamond-turned lightly etched versus conventionally-machined heavier etched parts.
• The presence of surface oxide will inhibit diffusion. This should not be a factor due to our hydrogen firing and nitrogen purging.
• Fingerprints on the surface (grease) will greatly increase the diffusion of gas. This should not be a factor due to our cleaning processes and use of gloves.

8/8/01
Attached are charts of the test structure in situ bakeouts from NLCTA for the calendar year to date that I obtained from Marc Ross. I attempted to label the charts to make them easier to read, especially since the color will not copy.

John C.

Copies:
Dave B.
Marc R.
Keith J.
Chris A.
Ron R.
Juwen W.
Sami T.
Roger M.
Daryl S.
Bob K.
Chris P.
Frederic L.
Tor R.
BAKEOUT HISTORY

First data point: 3/1/01 2:24 pm
Last data point: 4/16/01 1:42 pm

Last pressure (Torr): 5.6E-8
Last process temp (degC): 30

Report Printed on: Monday, August 06, 2001 10:26 am

Data Log File Header
- TDL File: U1010301.TDL
- HCG File: 030101.HCG
- RCG File: 030101.RCG
- Controller Title: NLCTA
- Run Title: NLCTA
- Start Time: Thursday, March 01, 2001; 1:23 PM

Points in Graph Window: 50

Data File Source: Load Archived Data
First data point: 5/11/01 3:30 pm
Last data point: 5/14/01 8:12 am
Last pressure (Torr): 2.3E-6
Last process temp (degC): 178

Report Printed on:
Monday, August 06, 2001 9:58 am
BAKEOUT HISTORY

First data point: 5/14/01 11:45 am
Last data point: 5/16/01 8:57 am

Last pressure (Torr): 5.0E-8
Last process temp (degC): 136

Report Printed on: Monday, August 06, 2001 9:58 am
BAKEOUT HISTORY

STATION 2
(T53's) Re-Bake
AFTER VENT

deg C
300
250
200
150
100
50
0

03:00 AM 04:53 PM 06:46 AM 08:40 PM 10:33 AM 12:26 AM 02:20 PM 04:13 AM 06:06 PM 08:00 AM 09:53 PM 11:46 AM 01:40 AM 03:33 PM
07/25/01 07/25/01 07/26/01 07/26/01 07/27/01 07/28/01 07/28/01 07/30/01 07/30/01 07/31/01 08/01/01 08/01/01

Temp.
↑
Pressure
↓

Data Log File Header

TDL File: U1010725.TDL
HCG File: 072401.HCG
RCG File: 072401.RCG
Controller Title: NLCTA Station 2
Run Title: NLCTA Station 2
Start Time: Wednesday, July 25, 2001; 12:38 PM

Data File Source: Load Archived Data

First data point : 7/25/01 12:39 pm
Last data point : 8/1/01 7:27 am
Last pressure (Torr): 1.6E-7
Last process temp (degC): 186

Report Printed on:
Monday, August 06, 2001 9:38 am

pressure (Torr)
process (degC)
setpoint (degC)
TC Ch 1 (degC)
TC Ch 2 (degC)
TC Ch 3 (degC)
TC Ch 4 (degC)