STANDARD OPERATING PROCEDURE
FOR TUBE "B1-Au" furnace in TRL.

INTRODUCTION

Tube "B1-Au" is an Atmospheric furnace designed to grow thermal SiO_2 in the temperature range of 800- 1050C, on Silicon wafers up to 6" inch in diameter. Other thermal processes can also be run. The system is operated in manual mode. Three Eurotherm temperature controllers provide a 20 inch long, flat profile in the Center Zone; they are arranged in a master/slave configuration and the temperature profile is set up in manual mode. The gases are introduced through a Hydrogen injector, located at the Source Zone and specially designed to allow the generation of water vapors by Pyrogenic reaction. The gas control is provided by the Argus 581 Gas Control Module, which allows to set up and monitor the Mass Flow Controller flow for each gas, and also manages the safety hardware interlocks. The gas control could be manual or in a programmed sequence by using the Argus 771 Sequencer.
The system has 5 MFCs with the following maximum flow ranges:

Nitrogen	10 SLPM
Oxygen	5 SLPM
Hydrogen	10 SLPM
TCA	1SLPM
Ar	10 SLPM

The Hydrogen MFC has three safety hardware interlocks for wet oxidation processes:

- master/slave interlock configuration with Oxygen MFC, in a specific ratio range (< 2:1);
- Pyrogenic thermocouple temperature value interlock (> 600 C);
- Nitrogen flow interlock (> 50%, >10 minutes, alone), to clear the furnace of Oxygen.

and other 3 hardware safety interlocks for using a mixture of Hydrogen and Nitrogen:

- master/slave interlock configuration with Nitrogen MFC in N_2:H_2 ratio range of 8:1 to 16:1
- Nitrogen master MFC high flow set up (> 90%) to match the H_2 MFC range/ratio.
- H_2/Burn ON, for more than 5 minutes to assure the burning of exhaust H_2 in the N_2/H_2 mixture

The wafer handling is manual: the quartz boat is introduced in the flat zone and extracted from the furnace with the help of quartz rods.
The system can be used for wet or dry thermal oxidation, anneal, film densification, wafer bonding, sinter in an in situ prepared n2/H_2 mixture, etc.

SAFETY.

The system has hardware safety interlocks, to prevent any Hydrogen related hazard.
High temperature: many furnace parts can be hot. Use the special heat resistant gloves to handle those parts

PROCEDURE.

1) "ENGAGE" the machine in CORAL for TRL tube "B1-Au"machine, before you start. Tube B1-Au is designated to run wafers that have been exposed to GOLD processing. The wafers must be free of photoresist and other organic products, and your process should have been approved by PTC
2) Load the wafers into the tube:
   - place the wafers into the assigned quartz boat for tubeA1, with the flat up and front side to face the clean room side, when introduced into the furnace. Place the boat on the quartz half shell handler.
   - check if the tube temperature is bellow 600C and remove the furnace end cap using the heat resistant gloves; place it face down on the SS wafer transfer table.
   - transport the quartz boat with the boat handler to the tube opening, and push the boat with the short quartz rod into the tube.
   - using the long quartz rod push the boat to the Center Zone of the flat temperature profile; the quartz has a mark that should be aligned to the edge of the tube scavenger, when the boat is in the Center Zone.
   - replace the end cap: take care not to push it too hard, and align its exhaust to the scavenger opening.
   - set the Nitrogen flow to 50%:

* select channel 1 using the Channel toggle switch on the Argus GCM, in MAN mode.
* increase the MFC set point to 50% by moving upward the Set Point toggle switch.
* push twice the Set Point button located bellow the display, to activate the set point, and the actual flow value will be displayed.

3) Set the process temperature profile:

- on the Central Zone Eurotherm controller, adjust the set point to the process temperature value by using the arrow keys. The set point is for the heater thermocouples located outside the quartz tube and should be lower than 1065C. Adjust the set point for the Load and Source zone controllers to a value between 10 and 20; these set points are relative to the Central zone controller set point .
- on the main Omega DSP display, select channel # 14 that correspond to the Central Zone profile Tc located inside the quartz tube, and wait for the temperature ramp up and stabilization.
- on the Omega display check the Load zone (channe l3) and Source zone (channel 15) temperature values and manually adjust the respective controllers set points to get a flat temperature profile; repeat these adjustments until all temperature values are within 2 degrees.

4) Edit the process recipe on the 771 Sequencer:

a) Wet oxidation example:

- on the main tube panel, turn the key to PYROGENIC
- on the 771 Sequencer turn the key into the program position, and push the MAN button, you are in program edit mode now.
- push the PROG SELECT button, and use the toggle switch to select the program number address (up to 5 programs) that you want to program. Use the TIME SELECT switch to set the time base, and push RESET button to reset to program step # 1.

Bellow is a program example.

Lets assume that you want to grow a 1 um thermal SiO_2 film on a <100> Si substrate, with the electrical resistivity value in the 0.1 - 50 Ohm-cm range, at 1050 C, using the following gas flow sequence: (each step will be explained bellow)

1 min N_2 + 20 min O_2 + 11 min N_2 + 200 min(H_2O & O_2) + 20 min O_2 + 20 min N_2 / end,

then on the 771 Sequencer set the time values and push the active buttons specified bellow

STEP #	TIME (MIN)	DESCRIPTION	ACTIVE BUTTONS	COMMENTS
1	1 .0	N2 FLOW 51%	1 ,10, LOAD,STEP	RECIPE START
2	20.0	O2 FLOW 60%	3, 10,LOAD, STEP	DRY OXIDATION
3	11.0	N2 FLOW 51%	1,10,LOAD,STEP	SAFETY INTERLOCK FOR H2 FLOW ENABLE.
4	99.9	H2 40 % & O2	2,3, 10,LOAD,STEP	WET OXIDATION USING PYROGENIC REACTION
5	99.9	H2 40% & O2	2,3,10,LOAD,STEP	H2 MFC SETS THE O2 MFC SET POINT
6	20.0	O2 FLOW 60%	3,10, LOAD, STEP	DRY OXIDATION
7	20.0	N2 FLOW 51%	1,,10, LOAD, STEP	ANNEAL
8	0.0	N2 FLOW 51%	1,10,HALT,LOAD,RESET	RECIPE END.

Explanations:

The buttons 1,2,3,10 on the 771 Sequencer correspond respectively to the N_2, H_2 , O_2 and N_2 Bypass channels on the Argus 581 Gas Box , LOAD button stores the step settings into the memory, STEP button moves the program edit control to the next step and the RESET button brings the control to the first step. HALT stops the program control movement to the next step. The timer allows maximum 99.9 minutes per step; more identical step are needed for longer process steps. The 771 Sequencer controls the on/off time sequence of the gas "objects" with their attributes (set points) already defined and set up, on the corresponding Argus 781 Gas Box. Check and adjust the following channels: N_2 =51%, H_2=40%, O_2= 60%, H_2:O_2 Ratio = 1.5, Pyro TC = 610C, on the Argus 581 Gas Box.

- when you finish the program, turn the key to LOCK and push the MAN button to exit the edit mode,

and check each program step.

b) Sinter H_2 alloy example:
- set the process temperature in the 300-600C range only !
- on the main tube panel turn the key to ALLOY
  on the Argus 781 gas box:
- push the channel # 5 button: " H2/BURN" . Must run more than 5 minute before turn on H2/FORM
- set the N_2 (channel 1) flow to 99%
- set the N_2:H_2 ratio = 8.00 : 1 (channel 12)
- push the channel # 4 button : "H2/FORM" and monitor the H_2 flow on the channel 4 display; when the flow stabilized at 12%, toggle fast to N_2/H_2 ratio channel 12, and change the set point to 16.00:1
  If the H_2 alarm went on, push RESET button, bring the gas system in idle mode and start again.
  If the alarm shows up the second time , stop and ask help from the staff.
- when your run ended, turn off the H2/FORM, wait 5 minutes and then turn off H2/BURN and reduce the N_2 flow to 20%

5) Start the program
Check if the system temperature profile is the one you need, and if it is stable.
There is no programmable connection between the gas flow sequence and the temperature time variation.

- on the 771 Sequencer push the ENABLE button
- on the 581 Argus Gas Box push the AUTO button
- on the 771 Sequencer push the RUN button (be sure the program was reset in step 1)

The program starts and the timer display will show the time remaining in each step.

* You have to wait until the program goes into step 4, to be sure that H_2 and O_2 flows are OK
  Push RESET button on the Argus 781 Gas Box if it was a H_2 alarm, and call the staff if the alarm didn't clear.

6) To unload the wafers do the following:

When the program ends, the system will remain at the process temperature with Nitrogen flow at 51%, and a buzzer will be on signaling the end of the run.
You must ramp down the temperature bellow 600 C before unloading the wafers, and you must put the system controller in manual mode, and finally let the tube in idle state at 600C with 20 % N_2 flow.
- push the following buttons quickly on after other, to silence the buzzer and reset to manual mode:

ENABLE on 771 Sequencer
MAN on Argus 781 box
Channel 1 on Argus 781 box
Channel 10 on Argus 781 box

after these steps the buzzer went off and the controller was switched from auto to manual mode.

- on the Eurotherm Central zone controller push the down arrow key to bring the tube temperature set point to 600C; wait aprox 1 hour for the temperature to reach that level.
- check if the tube temperature is bellow 600C and remove the furnace end cap using the heat resistant gloves; place it face down on the SS wafer transfer table.
- using the long quartz rod bring the quartz boat to the tube edge, then using the short quartz rod pull the quartz boat onto the boat handler and move them to the transfer table.
- install back the end cap with its exhaust aligned to the scavenger opening, and take care not to push it too hard as it may get stacked and difficult to remove later.
- set the N_2 flow to 20 %.

7) End your session in CORAL, by "DISENGAGE" the machine after you input the measurement data in the comments section.

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