### **SOP for Thermco Oxidation Furnace**

Prepared June 10, 2009

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## **EQUIPMENT LAYOUT:**





# **Equipment Location and Handling**

The quartz-ware equipment for the furnace is located in the plastic storage cabinet next to the oxygen furnace. Quartz-ware is made from fused silica which has low thermal expansion properties and exceptionally good thermal shock resistance. While this means that it is protected from most thermal stress, it remains susceptible to physical and chemical damage. As the quartz-ware will be subjected to extremely high temperatures (1000°C+), it is very important to keep it as clean as possible as anything that ends up in the furnace WILL REACT with either the wafers or the quartz-ware (including both the boat and the furnace tube itself). At best, this will result in the tube becoming contaminated and a costly cleaning job. In the worst case, the silica will react with the foreign material and form a compound that does not possess silica's thermal properties which will result in the quartz-ware cracking due to thermal stress. To protect the quartz-ware from any chemicals or skin oils, never touch it with anything other than the tongs provided in the storage cabinet. Not even gloves. If the boat does come into contact with anything other than the bare silicon wafers or tongs, have it cleaned immediately and do not use it in the oxidation furnace.

## Safety and Hazards

There should always be a fire extinguisher located near the furnace. There are also chemical spill kits located near the fume hoods as well as emergency showers located near the entrance. Make sure you know where these things are as they may have been moved. If a fire or chemical spill occurs that is not easily contained, there are emergency numbers posted near the phones. Standard clean room garb should be worn at all times including gloves and eye-protection. When the furnace is powered up (even before running a recipe), parts of it will reach temperatures well above 100°C almost immediately. As long as the furnace is heated above 200°C, there should always be somebody monitoring the system for any abnormal behavior. Make sure that the cooling water is turned on before the furnace is used as well and kept running until the furnace has been turned off and cooled down. When in doubt about the furnace's temperature, leave the cooling water running.

### <u>Material Compatibility</u>

As the oxygen furnace can reach temperatures above 1000°C, ONLY CLEAN SILICON WAFERS ARE ALLOWED IN THE FURNACE as anything else is a contamination source at best and a safety hazard at worst. Any foreign materials will either melt, evaporate, stick to the furnace tube, or react with the furnace tube (making it more likely to crack when changing temperatures). In the worst case, materials previously deposited on a wafer can combust. In any of these cases, the furnace tube will be contaminated and no further work can be done using the oxidation furnace until expensive cleaning and repairs have occurred.

<u>**Preparation**</u> Prior to using the oxidation furnace, the support systems must be set up. This includes gas supplies, cooling water, DI water supply (for wet oxidation only), and powering up the furnace.

Step 1: Gas S	upplies
Overview	Check level of nitrogen and oxygen supplies
	Route gases from the tanks to the furnace
Detailed Steps	<ul> <li>Koute gases from the tanks to the furnace</li> <li>Check the valves on the oxygen tanks and the wall. They should match up with the diagram below.</li> <li>Nitrogen <ul> <li>Open the valves according to the diagram below.</li> <li>1) Open the vent valve slightly to remove any air from the line.</li> <li>2) Close the vent valve.</li> <li>3) Open the cylinder valve on the top of the nitrogen tank by turning it counter-clockwise until it stops.</li> <li>4) Turn the valve to route the nitrogen flow through the regulator. Check the tank pressure to ensure that there is an adequate supply to complete the furnace run. If the line pressure is not at 30 psi, turn the furnace.</li> <li>If the tank pressure is not enough for a full cycle of oxidation, there is a second tank hooked up in parallel to the right of the main nitrogen tank that can be used to supplement the first tank without removing the first tank.</li> </ul> </li> </ul>
	with the oxygen supply.
Explanation	Oxygen is required for the oxidation reaction (water as well for wet
	oxidation). However as oxygen can be dangerous in high
	other chemicals are present to decrease the purity of the formed oxide.



Step 2: Cooli	Step 2: Cooling Water					
Overview	Turn on the cooling water.					
Detailed Steps	<ul> <li>Check that the valves on the cooling water pipes are horizontal (off). If they are both vertical, then the cooling water is already on.</li> <li>If the valves are off, first rotate the RETURN valve (right) to the area position. Then energy the SUPPLY valve (left).</li> </ul>					
<b>T</b>	open position. Then open the SUPPLY valve (left).					
Explanation	The oxidation furnace reaches temperatures of over 1000°C and could easily turn the entire clean room into an oven and destroy the ventilation system. By cooling the hot air rising from the furnace, the ventilation system and the clean room are both protected from these extreme temperatures.					





Step 3: Oxyge	en Flow (Wet or Dry)
Overview	Route the oxygen flow to provide either wet or dry oxygen into the
	furnace tube.
Detailed Steps	For DRY oxidation:
	<ul> <li>The oxygen flow goes directly into the furnace, bypassing the water in the flask. This configuration is shown in the picture below on the left.</li> </ul>
	<ul> <li>The oxygen flow should pass through the DI water in the flask. This flask should be refilled with fresh DI water before the oxidation process as DI water does not remain DI when left stagnant.</li> <li>Set the temperature on the thermometer/heater (located in the frontleft of the DI water cabinet) to below 100°C to heat the water up but not boil yet. Before the final oxidation step of the recipe, the temperature should be set to 110°C to ensure the water boils.</li> </ul>
Explanation	While wet oxidation allows a faster oxide growth rate, it also creates a slightly lower quality oxide than dry oxidation does. Because of this, dry oxidation is typically used to grow thin layers of oxide while wet oxidation is reserved for growing thicker layers of oxide.



Step 4: Furna	ce Power
Overview	Turn on the power to the furnace.
Detailed Steps	<ul> <li>Flip Tube 1 "Element Breaker" switch shown in left picture below to power up the furnace. This is located at the base of the furnace near the open ends of the furnace tubes. The power status light will activate and the furnace will start to warm up.</li> <li>Flip the blower and lamp switches shown in the right picture below. These are located at the base of the loading area of the furnace near the control computer.</li> </ul>
Explanation	The furnace uses electricity to heat up to the high temperatures
	necessary for oxidation to occur. The blower and lamp are for the
	loading area.





Step 5: Recip	Step 5: Recipe Preparation (Optional)						
Overview	Prepare a recipe for running the oxidation furnace.						
Detailed Steps	Open a previously prepared Recipe file.						
	Review the Recipe's steps						
	• Modify the Recipe as needed.						
	• Verify and Save the Recipe						
Explanation	The oxidation furnace is controlled by a computer to ensure proper						
	operation, timing, and control while protecting the user from having to						
	get too close to the furnace while it is operating at high temperatures.						
	The recipe file allows for process control as well as allowing fine						
	tuning to be done for further process optimization.						

Open the Cell Manager window (may be hidden behind the Process Manager window)



Select View and then select Recipe Manager from the resulting menu.



In the Recipe Manager, you can double-click the recipe that you are interested in modifying or if you want to make a copy, select the recipe and push the copy button (circled in red below). The new recipe will need a unique recipe number which you will be prompted to select.

नमा	Recipe Managei	7									
File	e View Library	Reports	Supervisor DosRecipeList								
][	] D   💐 🖻 🖉   🖨 🚧 🗰   🤋										
12	24W48 Recipe File	Recipe	Name	Date & Time	Library	Supervisor	Tubes				
	#01P0001.RCP	1	Default Tube 1	01-21-2009 14:21:18	Prod	01: SUPER01	T3Zone01				
	#01P0002.RCP	2	Default Tube 2	11-29-1999 13:41:54	Prod	01: SUPER01	T3Zone02				
	#01P0003.RCP	3	Default Tube 3	11-29-1999 13:42:28	Prod	01: SUPER01	(Tube 3)				
	#01P0004.RCP	4	Default Tube 4	11-29-1999 13:42:56	Prod	01: SUPER01	(Tube 4)				
	#01P0005.RCP	5	Default Tube 5	11-29-1999 13:43:24	Prod	01: SUPER01	(Tube 5)				
	#01P0006.RCP	6	Default Tube 6	11-29-1999 13:43:48	Prod	01: SUPER01	(Tube 6)				
	#01P0007.RCP	7	Default Tube 7	11-29-1999 13:44:12	Prod	01: SUPER01	(Tube 7)				
	#01P0008.RCP	8	Default Tube 8	11-29-1999 13:44:36	Prod	01: SUPER01	(Tube 8)				
	#01P0011.RCP	11	WET 0XI 1050	01-20-2009 16:33:36	Prod	01: SUPER01	T3Zone01				
	#01P0033.RCP	33	Temporary Recipe	06-08-2009 13:49:57	Prod	01: SUPER01	T3Zone01				
	#01P0999.RCP	999	WET 0XI 1050	04-13-2009 15:21:12	Prod	01: SUPER01	T3Zone01				

The Recipe Editor/Viewer window will show the individual steps of the recipe. The blue clock icon below indicates that the recipe will prompt the user for a duration for this step before the recipe can be sent to the furnace. In this case, the warm up and cool down stages are the same every time with the only change being how long the wafers are being oxidized for.

<del>[]</del>											
🔀 File Edit View Tables Window Help 🔤 🗵											
🛛   🎒   👗 🛍 🛍   🖻   🛅 🖂   🛏	1	12	8 5 8	?							
	Step		State Name	Lower Time	Time	Upper Time	Temp Row	Load	Center	Source	PLoad
Valves   T Redirect	v	0	IDLE		00:00:00		100.0	100.00	100.00	100.00	100.00
E Hecipe	V	1	BOAT OUT		00:02:30		100.0	100.00	100.00	100.00	100.00
	V	2	LOAD		00:01:00		100.0	100.00	100.00	100.00	100.00
Hecipe Name:	~	3	BOAT IN		00:03:00		400	398.00	399.00	398.20	400.00
WET 0XI 1050	~	4	Ramp 400		00:15:00		400	398.00	399.00	398.20	400.00
· · · · · · · · · · · · · · · · · · ·	~	5	Stab 400		00:15:00		400	398.00	399.00	398.20	400.00
Supervisor: SUPER01 (1)	~	6	Ramp to 800C		00:30:00		800	800.00	800.00	800.00	800.00
T. L. 177. 01 (1)	~	7	RAMP TO 1050		00:30:00		1050	1050.00	1050.00	1050.00	1050.00
Tube: T3ZoneUT(T)	<ul> <li></li> </ul>	8	STAB 1050		00:15:00		1050	1050.00	1050.00	1050.00	1050.00
Temperature Zones: 3	v 🕑	9	OXIDATION	00:02:00	00:03:00	03:00:00	1050	1050.00	1050.00	1050.00	1050.00
	v	10	RAMP TO 800		00:40:00		800	800.00	800.00	800.00	800.00
	<b>v</b>	11	BOAT OUT		00:02:30		100.0	100.00	100.00	100.00	100.00
	<b>v</b>	12	UNLOAD		00:05:00		100.0	100.00	100.00	100.00	100.00
	V.	13	BOAT IN		00:03:00		100.0	100.00	100.00	100.00	100.00
	~	14	SHUTDOWN		00:01:00		100.0	100.00	100.00	100.00	100.00

Double-clicking on any step will bring up the Edit Step window. Various values including temperature, boat speed, and MFC settings are not directly editable during step editing but are merely selectable from values previously entered into the Recipe Table or Master Temp Table:

To access the Recipe Table to set alarms, modify MFC settings, and change available boat speeds: From the Recipe Editior/Viewer window, select Tables and then select Recipe Tables.



To access the Master Temp Table where temperature profiles can be modified: From the Recipe Editior/Viewer window, select Tables and then select Master Temperature Table.

		[n. n. a	[	[	1.0.1		
	Name	Date Profiled	Date Modified	Load	Center	Source	<u> </u>
	100.0	03-05-1999	11-15-1999	100.00	100.00	100.00	10
	400	12-31-1969	01-20-2009	398.00	399.00	398.20	40
😽 124 48K Recipe Editor/Viewer - [#U1PUU33.RLP	600	12-31-1969	01-20-2009	599.00	599.00	599.00	60
Rec esta esta una la consta	700	12-31-1969	01-20-2009	700.00	700.00	700.00	70
🧭 File Edit View Tables Window	800	12-31-1969	01-20-2009	800.00	800.00	800.00	80
	900	12-31-1969	01-20-2009	900.00	900.00	900.00	90
🛛 🔽 🖾 🖓 🖾 Recipe Tables	950	12-31-1969	01-20-2009	950.00	950.00	950.00	95
Master Terraneture Table	1000	12-31-1969	01-20-2009	1000.00	1000.00	1000.00	10
master remperature rabie	1050	12-31-1969	01-20-2009	1050.00	1050.00	1050.00	10
	1100	12-31-1969	01-20-2009	1100.00	1100.00	1100.00	11
	14	12-31-1969	01-20-2009	14.00	14.00	14.00	14 💌
	•						•
			- 1		Г		
	Edit Entry A	dd Entry   Dele	te Entry			UK.	Cancel
					-		

After editing anything in a recipe, it is a good idea to verify the recipe. To do this, from the Recipe Editor/Viewer window, select File and then Verify Recipe from the menu. You should get a "Recipe OK!" message. If not, undo any changes and figure out why they were not valid.



Remember to Save your modified recipe before exiting!

Step 6: Run t	he Recipe
Overview	Select and Start the recipe, then load the boat.
Detailed Steps	• Send the Recipe by pressing the F4 button.
	• Select the Recipe (999 WET OXI 1050).
	• Enter oxidation time.
	• Start the recipe by pushing the F5 button.
	• Pause (Start Hold) the recipe after the carrier is out by pushing
	Ctrl+F5.
	• Load the quartz-ware wafer carrier (boat) onto the center of the
	boat.
	• Resume the recipe (Abort Hold) by pushing Ctrl+F5.
Explanation	The recipe is "Sent" to the furnace's control systems so that they can
	locally monitor and control the furnace. To allow more time to load the
	wafer carrier onto the boat, the recipe can be paused before retracting
	the boat. This way, any unforeseen problems that occur during loading
	can be addressed before the boat goes into the furnace.

Begin the Send Recipe process by pushing F4 or selecting the option shown below.

😪 Process Manager - Supervisor: 1 Tube: 1					
Start/Abort Send View					
- 124W48 Ti	Red	:ipe	F4		
Super 1	Sec	quential Recipes	Ctrl+F4		
	Nev	v Config	Ctrl+F8		
lube  1	Set	Outputs	Ctrl+Alt+F8		

Select the desired recipe and select OK.

Recipe Select	×
1 Default Tube 1 11 WET 0XI 1050 999 WET 0XI 1050	Recipe Library C Engineering Production C Maintenance
	OK Cancel

Enter an oxidation time within the range specified. This time can be calculated from the graphs in Appendix A.

🕵 Recipe Variable Ti	mes Table		×
Step Number	Low Limit	Time	High Limit
9 OXIDATION	00:02:00	00:03:00	03:00:00
ОК	6	<u>}</u>	Cancel

The Status field should now read "Waiting for START switch".

🕵 Process Manager - Supervisor: 1	Tube: 1
Start/Abort Send View	
-124W48 Tube Status	
Super 1 SUPER01	Recipe 999 WET 0XI 1050
Tube 1 T3Zone01	Step 0 IDLE
Status Waiting for START switch	

Either press F5 to start the recipe or select the option below from the Process Manager window.

💀 Process Manager - Superv

N I OCC33 I Idile	iger Superr
Start/Abort Send	View
Login/Logout	
Charle Dianian	FF
Start Recipe	F5
Data Capture	Ctrl+F11
Hold	Ctrl+F5
Profile	F9
Redirect	
Stop Recipe	
Exit	Ctrl+F12

#### Select OK from the pop-up window to start the recipe.

Start Recipe		×
Start Recipe?		
OK	Cancel	Lot Numbers

The Status field will now read "Waiting for boat out" as the boat is removed from the furnace.

Ł	<u></u>		idilidg	<b></b>	aper rison r	Tuber 1			
	Start/Ab	oort	Send	View					
ſ	_124₩-	48 Tu	ube Stal	tus					
l	Super visor	1	SUP	ER01		Recipe	999	WET 0XI 1050	
l	Tube	1	T3Zo	ne01		Step	1	BOAT OUT	
	Status	Wai	ting for	boat O	UT				

When the boat is fully retracted and the system pauses for boat loading, you can either press Ctrl-F5 or select the option shown below. Then press OK to pause the system and allow for more time to load the wafer-laden boat onto the rails.



Load the wafer-laden quartz-ware boat onto the rails as shown below. Make sure that the boat's position on the rails is closest to the center of the furnace tube (when inserted) for the best thickness uniformity of the oxide.



Once the boat is in place, press F5 or select the Hold option from the Start/Abort menu and select OK from the pop-up window to resume the recipe.



Step 7: Monit	tor the Recipe/System
Overview	Monitor the oxygen furnace as it goes through the various stages of the
	recipe.
Detailed Steps	<ul> <li>Watch the Status display and the Set Point values as the oxygen furnace heats up and cycles through the stages of the recipe.</li> <li>Watch the Actual temperature readings to ensure that the furnace is heating up on schedule.</li> <li>Watch the pressure readings to make sure that the gases have sufficient pressure.</li> <li>For wet oxidation, make sure that the DI water is boiling before the system opens the oxygen valve.</li> <li>After the oxidation at 1050°C has finished, the water heater and the Op supply can be turned off</li> </ul>
Explanation	The main program will periodically poll the individual systems of the furnace and update the main display. This will result in delays between changes in the furnace system and changes on the display. It is important to monitor the system in case something does not go as planned. If a temperature reading or gas pressure reading is not correct, you can stop the system by going to the Start/Abort menu and selecting Stop Recipe.

Watch the measurements in the areas marked below for the Gases Tab and Temps Tab. Actual shows the current temperature while Set Point is the temperature or pressure that the furnace is attempting to reach. The Green bars give an idea of how far away the Actual value is from the Set Point.

Referencess Manager - Supervisor: 1	1 Tube: 1		🕵 Process Manage	r - Supervisor: 1	Tube: 1		
Start/Abort Send View			Start/Abort Send !	View			
- 124W/48 Tube Status-			- 124W48 Tube Statu	15			
Super 1 SUPER01	Recipe 33 Temporary Recipe	Time To Go	Super 1 SUPER	R01	Recipe 999 WET	OXI 1050	Time To Go
Tube 1 T3Zone01	Step 1 BOAT OUT	Step Time	Tube 1 T3Zon	ie01	Step 1 BOAT	OUT	Step Time
Status Waiting for boat OUT			Status Waiting for b	oat OUT			
Gases Temps	1		Gases	Temps	1		
Range Unit	Set Point Actual -10 %Deviation	+10	duses	Range Units	Set Point Actual	-10 Degrees Dev. +1	0 Power
N2 20 SLM	3 0.15		Load	1200 C	100 108.3		
02 10 SLM			Center	1200 C	100 50.7		00
Gas_3 0 SLPM			Source	1200 C	100 100.5		5
Gas_4 0 SLPM			PLoad	1200 C	100 42.2		5
02HI 5 SLM			PCenter	1200 C	100 34.5		
Gas_6 0 SLPM			PSource	1200 C	100 50.7		5
Gas_7 0 SLPM							
Gas_8 0 SLPM							

Step 8: Remo	ve the Wafers
Overview	After the furnace has cooled down to 800°C, according to the recipe,
	the boat will come out of the furnace automatically
Detailed Steps	• Monitor the furnace until the boat comes out of the furnace.
	• When the boat comes out, you can optionally pause the recipe by
	pressing Ctrl+F5 and confirming the Hold, as in the end of step 6.
	If you do, remember to push Ctrl+F5 and confirm again to resume
	the cool-down stage of the recipe.
	• Remove the boat from the rails.
Explanation	The furnace must be allowed to cool slightly before the boat is removed
	as the high thermal gradient can cause additional stresses on the
	carefully balanced cantilever holding the boat in the furnace's tube.
	Also, the non-reactive N <sub>2</sub> atmosphere of the furnace will prevent
	further oxidation from taking place as the wafers cool down before
	being exposed to air.

Step 9: Furna	ce Cool Down
Overview	Allow the furnace to cool down.
Detailed Steps	• After the boat has been retracted into the furnace, you may shut off the furnace power from Step 4.
	• When the Shutdown stage (last step of the recipe) finishes, the system will wait for acknowledgement that the recipe is finished. Press F7 to acknowledge recipe completion.
	• At this stage, you can optionally measure your oxide thickness and record relevant parameters in the logbook. These parameters include the date and time, the recipe used, and the oxide thickness measured.
	• Continue monitoring the furnace until the temperature reaches 400C.
	• Once cooled down below 400C, you can turn off the cooling water, SUPPLY valve first (Step 2), and the gas supplies (Step 1). If you did a wet oxidation and have not turned off the water heater yet, you may do so now and re-route the oxygen flow to the "Dry oxidation" state (Step 3).
Explanation	The furnace will eventually cool down on its own but for safety
	purposes, it is best to allow the cooling water to run while the
	temperature is still relatively high. It is also recommended not to leave
	the furnace unattended while the temperature is high.

Press F7 or click Acknowledge(F7) at the top right of the Process Manager Window to confirm recipe completion. When you are done, please leave the computer on and make sure everything else has been turned off.

1	🕵 Process Manager - Supervisor: 1 Tube: 1
	Start/Abort Send View
	124W48 Tube Status
	Visor 1 SUPER01 Recipe 33 Temporary Recipe
	Tube 1 T3Zone01 Step 0 IDLE
	Status Tube is waiting for COMPLETE acknowledge

## Appendix A - Growth Rate for Silicon Dioxide on Silicon

Use the appropriate graph to determine the approximate duration for the oxidation stage.



Growth Rate for Dry Oxidation Growth Rate for Wet Oxidation From S.K. Ghandhi, VLSI Fabrication Principles: Silicon and Gallium Arsenide, 1983.