This instruction covers the capabilities, operation, and compatibilities of the ProTemp Furnace system. This system is located in the R bay of the cleanroom and is only to be operated by trained and authorized users.

1 SAFETY REQUIREMENTS

1.1 Safety Information

- When the furnace tubes are open, there is a thermal hazard due to the high idle temperatures of the tube interior. Heat and gasses are expelled from the tube openings, which can burn your hands if you get too close. Thermal gloves are available in R bay.
- Take care not to touch the internal quartz components including cantilevers, boats, and tube openings to avoid burns as well as to avoid contaminating the tube.
- Safety glasses must be worn whenever in the cleanroom, except when using a microscope or when wearing protective goggles.
- Be mindful of cross-contamination of controls, equipment, and tools.

2 PROCESS MATERIALS

2.1 Equipment

- Wafer handling tweezers (no rubberized or low melting point)
- Thermal Gloves
- Cleanroom Wipes
- Isopropyl Alcohol Squeeze Bottle
- Aluminum Foil

2.2 Gasses

Table 1 - Process Gasses

Symbol	Name	Hazard	Tube
N_2	Nitrogen		All
Ar	Argon		5
O_2	Oxygen		1,3,4,7
N_2/H_2	**Forming Gas (96% N2 / 4% H2)**	Flammable over 4% H_2	5
H_2	**Hydrogen**	Flammable	1,4,7
NH_3	**Ammonia**	Flammable, Corrosive, Toxic, Environmental	2
$SiCl_2H_2$	**Dichlorosilane**	Corrosive, Pyrophoric, Toxic	2
SiH_4	**Silane 100%**	Flammable, Pyrophoric	3,6

3 System Overview

3.1 System Capabilities

The ProTemp furnace system is capable of a variety of thermal processes including oxidation, LPCVD nitridation, low-temp oxide, annealing, and polysilicon. The processing gasses, pressure, and temperature vary widely between each tube. Each tube is supported by a Tymkon process sequencer, various regulation valves, exhaust ventilation, process gasses, and thermal controllers. Some tubes also have vacuum pumps, throttle valves, cooling flanges, toxic gas monitoring, sealing o-rings, and gas mixing injectors. Each process tube is fully constructed of fused quartz including all internal cantilevers, boats, and slides.

Table 2 - ProTemp Processes

Tube #	Name	Max Temp °C	Gasses	Pressure	Notes
1/4/7	Wet & Dry Oxidation	1100	N_2, O_2, H_2	ATM	Tube 1 – RCA Only
2	LPCVD Nitride	800	N_2, NH_3, $SiCl_2H_2$	50mTorr	Si_3N_4
3	Low Temp Oxide	400	N_2, O_2, SiH_4	5-300mTorr	
5	Anneal	1100	N_2, Ar, FG (N_2+H_2 4%)	ATM	
6	LPCVD Polysilicon	650	N_2, SiH_4	150mTorr	Amorphous & Polysilicon
8	Phos. Drive	1100	N_2	ATM	Permission Req'd

3.2 Theory of Operation

3.2.1 TymPlex Software

The individual furnace tubes are controlled by real-time sequencing processors that execute the processes even when the TymPlex software is shut down. The TymPlex software uploads recipe files to the controllers and allows you to select and execute a process. Tubes 1-6 are controlled by the system on the right, and tubes 7-8 by the system on the left. The tubes all run independently, so don't worry about disrupting someone else's process by working on your own.

3.2.2 Wet & Dry Oxidation (Tubes 1/4/7)

Wet Oxidation – Wet growth of SiO_2 on Si substrates by combining H_2 and O_2 gasses in-situ at 1100°C.
Dry Oxidation – Dry growth of SiO_2 on Si substrates by exposing the Si wafer to O_2 at 1100°C.

3.2.3 LPCVD Nitride (Tube 2)

Nitridation - Si_3N_4 is deposited on a substrate by mixing Dichlorosilane with Ammonia at 800°C in an unregulated vacuum of approximately 50mTorr.

3.2.4 Low Temperature Oxide (Tube 3)

LTO – SiO_2 is deposited onto a substrate by mixing Silane and Oxygen at 400°C while pressure is throttled to 300mTorr. The substrates are enclosed within a fused quarts caged boat.

3.2.5 Anneal (Tube 5)

Anneal – Samples are subjected to temperatures ranging from 200-1100°C in the presence of various gasses including Nitrogen, Argon, and Forming Gas at atmosphere.

3.2.6 Polysilicon (Tube 6)

Amorphous Silicon – Deposition of Amorphous Silicon exposes the sample to Silane at 550-600°C and 150mTorr.
Polysilicon – Deposition of Polysilicon exposes the sample to Silane at 600-650°C and 150mTorr.

3.2.7 Phos Drive (Tube 8)

Special annealing tube.

4 Operation

4.1 Getting Started

- Enable a tube in iLabs. This allows the motors to open and close the furnace cantilever arm.
- Go to the ProTemp furnace console and start the TymPlex software.
- When TymPlex opens up, click on the green “Log In” button on the left side of the screen.
- Your login name and password are set at the time of your training. Enter them now.

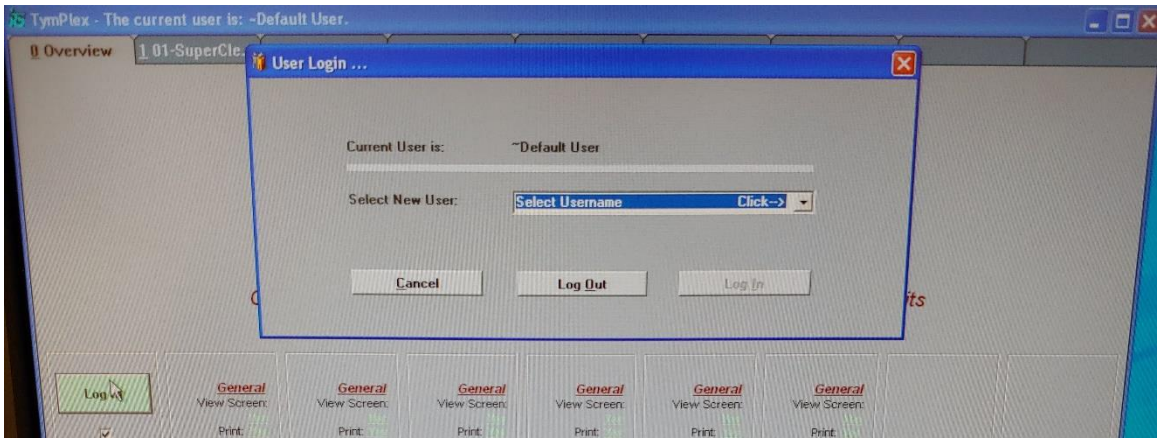

Figure 1 - Login Screen

- The screen that appears after logging in will display all furnace tubes controlled by this console from left to right.
- The permissions assigned to you during training should be reflected by green ‘Yes’ entries in the specified columns.
- If you do not think these permissions are accurate, contact the furnace core research engineer.
- Each tab at the top of the screen represents a specific tube. Find the tube of interest and click on the tab.

Figure 2 - Tube Status Screen

- Figure 3 describes some of the things you'll see on the ''Operate" tab of the tube.
    - The top half is for sensors and indicators which the controller uses to execute the process.
    - The lower right hand side includes the recipe selection and display panel.
    - The lower left hand side contains the recipe controls, status, and error indicators.

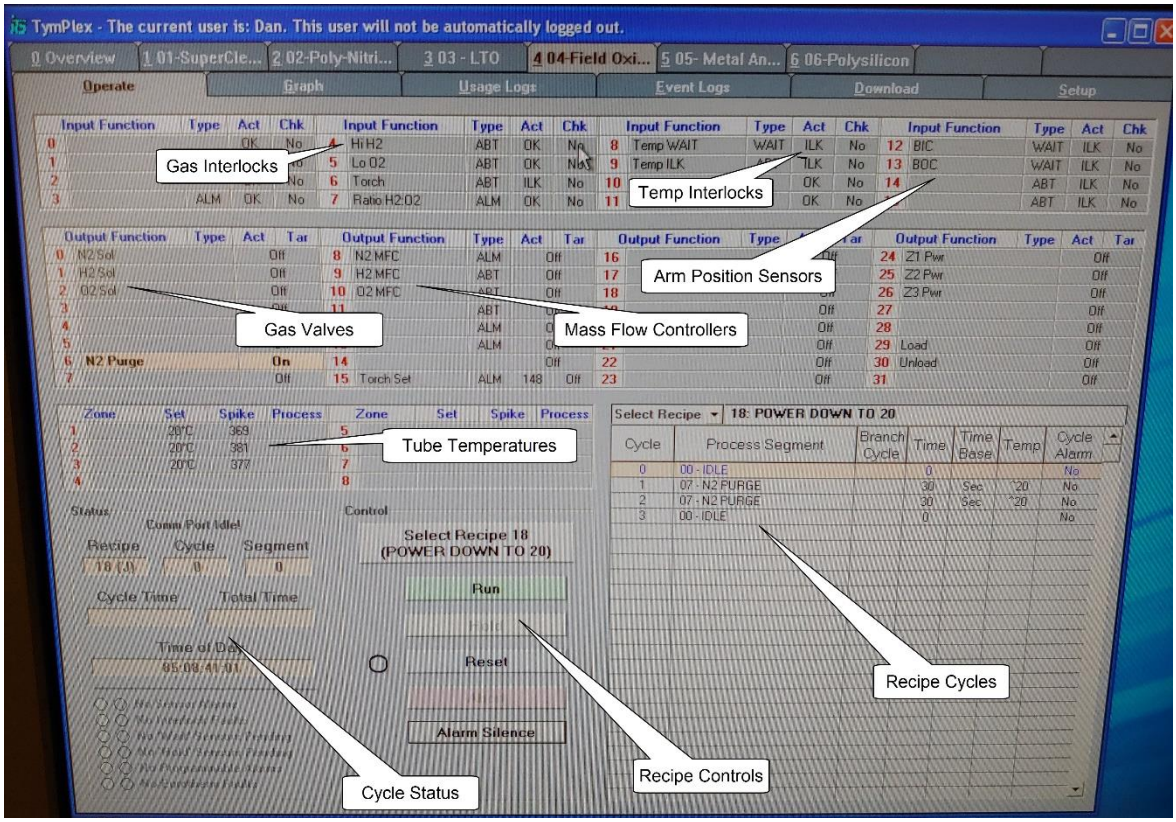

Figure 3 – Tube Control Dashboard

4.2 Loading a Recipe File

- Click on the 'Download' tab in the 2nd level underneath the tube in question.
- ***INSTRUCTIONS ON HOW TO LOAD FILE WITH A PICTURE HERE***

4.3 Choosing a Recipe

- At this point you are ready to begin the recipe. Each standard recipe will perform the functions of opening and closing tube door automatically, so that you shouldn't need to use any manual controls to load and unload a sample.
- Click on the 'Operate' tab and then click the 'Select Recipe' button in the middle of the screen. This will give you a selection of different standard recipes that are approved for the tube. Click on the recipe you would like to run.

4.4 Starting the Process & Loading Samples

- Click 'Run', which will begin the recipe. Any vacuum will be backfilled and the tube door will begin to open. The software will go to the 'Program Hold' step.
- Program Hold is a special command that effectively pauses the sequence and waits for you to complete a manual step, such as loading or unloading your samples onto the boat.
- If you are using tubes 2 or 3 you will need to remove the o-ring from the boat door after the door has opened completely. Take care not to touch the cantilever or boat with the o-ring during removal.
- Clean the o-ring with a cleanroom wipe and IPA, removing any particles that can be identified visually.
- Replace the o-ring back onto the door channel carefully in the reverse order.
- When you have finished loading the sample, click on 'Run' to advance the recipe.

4.5 Processing & Unloading

- The system will now execute the process according to the chosen recipe. The tube temperature is gradually elevated to the target temperature, while process gasses are flowing and any pressure control is regulated.
- Typical processes are between 4-8 hours and the total estimated time can be seen in the cycle status box in the lower left hand side of TymPlex.
- After the processing steps are over temperature is gradually brought back to idle and gasses are purged from the system. The 'program hold' step will then pause and wait until you come in to pick up your sample before opening the door. This is to prevent the sample and furnace from being exposed to the open air for longer than necessary.
- Click 'Run' to open the door and remove your sample, taking care with the hot sample and letting the sample air cool for a few seconds before placing it into your sample container.
- If you are using tubes 2 or 3 you will need to remove the o-ring from the boat door after the door has opened completely. Take care not to touch the cantilever or boat with the o-ring during removal.
- Clean the o-ring with a cleanroom wipe and IPA, removing any particles that can be identified visually.
- Replace the o-ring back onto the door channel carefully in the reverse order.
- Click 'Run' to allow the boat to close and complete the recipe. When the door is closed and any vacuum steps have been executed, the 'Complete' button will be available.
- Click 'Complete' to silence the alarm and terminate the recipe.

5 Standard Processes

5.1 Standard Process Recipes

SiO_2 Dry Oxidation (Tube 1/4/7)

Target (Å)	Time (min)	Temp °C
50	125	825
100	66	900
250	38	1000
500	15	1100
750	28	1100
1000	42	1100
2000	176	1100
3000	341	1100

SiO_2 Wet Oxidation (Tube 1/4/7)

Target (Å)	Time (min)	Temp °C
2500	13	1100
3000	17	1100
3500	22	1100
5000	39	1100
6000	54	1100
7000	71	1100
10000	160	1100
12000	189	1100
15000	287	1100
17500	385	1100
20000	497	1100

Nitride (Tube 2)

Target (Å)	Time (min)	Temp °C
100		800
500		800
1000	23.5	800
1250		800
1500		800
2000	51	800
2200		800
2500		800
3000		800

LTO (Tube 3)

Target (Å)	Time (min)	Temp °C
500		400
1000	12	400
1500	16	400
2000	25.1	400
3000		400
4000		400
5000	80	400
10000	230	400

Amorphous Silicon (Tube 6)

Target (Å)	Time (min)	Temp °C
3000		605
3500	70	605
4000	90	605
4500		605

Polysilicon (Tube 6)

Target (Å)	Time (min)	Temp °C
		630
		630
		630
		630

Special Anneal (Tube 8)

Gas	Time (min)	Temp °C
N_2,Ar,FG	30-120	500-1100

General Annealing Matrix (Tube 5)

Gas	Time (min)	Temp °C
N_2,Ar,FG	30-120	500-1100

Maintenance Recipes

Name	Time (min)	Temp °C
Ramp to 20C	90	20
Ramp to Idle	60	Idle
Backfill	5	Idle
Door Open	3	Idle
Door Close	3	Idle

6 Troubleshooting

6.1 Problem: The system won't pump down to correct vacuum levels on tubes 2/3/6.

Solution: Unload the boat and check that the o-ring seal is fitted correctly and free of particles. This I the primary cause of pressure issues.

7 References

7.1 Birck Nanotech Wiki – Cleaning Page

8 REVISION RECORD

Reason for Revision	Date of Revision	Person Responsible
Initial Release		Rich Hosler