Marvell Nanofabrication Laboratory *University of California, Berkeley* Berkeley Microfabrication Laboratory

Lab Manual

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Revision History

Chapter 5.00

Tystar Furnaces Overview

1.0 General Information

There are a mixture of 19 atmospheric and sub-atmospheric (low pressure vapor deposition) furnaces available in the Nanolab. All furnaces are manufactured by Tystar Corporation and are computer-controlled. They can process 4” and 6” wafers, with Tystar 5-7 capable of processing 8” wafers also. There are specific guidelines regarding processing wafers and preventing cross contamination. This includes performing a mandatory pre-furnace clean step on all wafers entering any furnace(s), as well as following the rules for MOS fabrication vs. non-MOS fabrication such as MEMS, all of which are explained in this and other pertinent furnace chapters. For the information regarding recipe management, process/temperature control, gas delivery, software and hardware control information, please refer to the Appendix of this chapter and other furnace chapters posted on our web site.

1.1 Atmospheric Pressure and Low Pressure Chemical Vapor Deposition Furnaces

There are two types of furnaces available in the Nanolab distinguished by their operating pressures and the type of processes they offer. These are the **Atmospheric Pressure** (AP) and **Low Pressure Chemical Vapor Deposition** (LPCVD) furnaces.

The AP furnaces provide dry/wet oxidation, dopant diffusion, annealing, and sintering process, which are transport dominant, i.e. the reaction rate is controlled by the transportation and/or diffusion of reactants into the substrate. This means the reaction rate is usually not linear, and most often decreases with time. A high temperature oxidation in an AP furnace requires a Si surface to form a SiO_2 layer.

The LPCVD furnaces provide us with silicon nitride, poly, amorphous silicon, low temperature oxide, silicon carbide, and silicon/germanium alloy deposition capability. Unlike the AP processes, the reaction rate does not depend on the transportation of the reactants. Therefore, it is usually constant over time. Films are deposited through breakdown and/or reaction of process gases. Therefore, a silicon surface is not necessary and desired films can be deposited on various surfaces (film layers), including metal layers. During the deposition process, gas species react at the surface, and by-products quickly get pumped away out of the furnace tube. Process control is achieved by proper control of reaction temperature, pressure and the amount of reacting gases.

Standby recipes must be run when LPCVD furnaces are not in use to keep the quartz-ware clean in an N_2 ambient atmosphere.

1.2 MOS and Non-MOS (MEMS) Clean Furnaces

The Nanolab furnaces are divided into **MOS** or **Non-MOS** furnaces. This division is made to prevent MOS clean furnaces from getting contaminated by non-MOS clean processes/wafers or any other possible source of contamination (contaminated sinks, transfer box, and so on). A great deal of care must be taken to keep our MOS-Clean furnaces free of mobile ion, metallic and III-V compound contamination by following the rules defined in this and pertinent furnace chapters.

MOS Clean processes: Only MOS devices are allowed in a MOS clean furnace. This implies that MOS clean wafers stay in these furnaces for all furnace process steps. Migration to a non-MOS clean furnace at any point during the process sequence will change the run status to non-

MOS. Therefore, the remaining furnace steps in the fabrication process must be performed in non-MOS furnaces.

Non-MOS Clean Processes: Non-MOS runs must be exclusively processed in a non-MOS clean furnaces. You may begin a non-MOS process sequence such as a MEMS run, in a MOS clean furnace. Prime or test grade Si wafers straight out of the vendor's box are considered MOS clean. However, once the wafer experiences a non-MOS process step, it may only be introduced into a non-MOS furnace.

In summary, transition from a MOS clean to a non-MOS clean process is allowed, but the reverse transition is not. Once a run is exposed to a non-MOS clean furnace, it should stay in the non-MOS clean furnaces until it has completed all its furnace processes.

III-V compounds such as GaAs wafers do not fall into any of the above noted categories. Therefore, they must not be processed in any of the furnaces (MOS or Non-MOS). These types of wafers have their own designated equipment located in specific areas of the Nanolab.

Please note: Since most of the non-MOS processes are used for the fabrication of MEMS, the non-MOS and MEMS terminologies are used interchangeably in this manual.

1.3 Pre-Furnace Wafer Cleaning (Rules/Procedure)

A 10 minute piranha dip in Msink6 is required as the last step prior to processing non-metal coated wafers in any Tystar furnace. A one minute HF dip often follows the piranha clean. This can remove small amounts of oxide, a reason one may opt out of an HF dip as part of the overall pre-furnace clean process. Metal coated wafers which can be attacked by piranha, should never be processed in Msink6 or Msink8. A clean heated metal bath is available at Msink1 for cleaning metal coated wafers prior to entering selected furnaces as per defined in the Chapter 1.7 - Material & Process Compatibility Policy.

If you are cleaning non-MOS wafers for furnace use, an additional 10 minute piranha dip followed by an HF dip in Msink8 is required prior to using the Msink6 pre-furnace clean step noted earlier. Again an HF dip can be skipped depending on your process. In general, MOS clean wafers only require Msink6 cleaning, but non-MOS clean wafers must first get cleaned in Msink8, and then cleaned in Msink6 before introduction into the furnace.

After Msink6 cleaning, wafers must be moved to the furnaces in specially designated 4” or 6” black transfer boxes located at the Msink6 station. Do not take designated Msink6 black cassettes directly to the furnace. Transfer your wafers from the Msink6 black cassette to the Msink6 black transfer cassette located in the Msink6 transfer box. Also, as was described earlier, metal coated wafers, which cannot tolerate piranha clean must not be cleaned at Msink6. They should be cleaned at Msink1 and carried to the furnaces in the red Msink1 designated transfer box.

Photoresist coated wafers without metal layers must initially have their photoresist stripped at Msink1 (PRS-3000 bath) or in the Matrix Asher. This is required for both MOS and non-MOS wafers. Next, these wafers must be cleaned in Msink8 before moving onto Msink6, the pre-furnace cleaning step prior to introduction into any furnace. This means photoresist removal requires an additional cleaning at Msink8 regardless of whether the process is MOS or non-MOS.

Photoresist coated wafers with metal layers should first have their photoresist stripped before processing them at Msink1 in the Matrix Asher and PRS-3000. Sometimes the ash strip alone can leave minute particles on the wafer, so a wet strip becomes necessary also. The wafers must then be cleaned in the metal clean bath at Msink1 before putting them in the specific furnace where metals are allowed. There must be no Msink6 or Msink8 acid exposure for wafers with metal layer/s on them.

Photoresist can be adequately removed from wafers (including wafers with metal layers on top) by various methods – Msink1 PRS3000 (wet strip) to ensure complete resist removal, OR after using the Matrix or Technics-C Ashers.

1.4 Furnace Training and Qualification Procedure for Lab Members

It is recommended that new lab members first learn how to use AP type furnaces, Tystar1-4. Once they are familiar with the basics of this type of furnace operation including wafer loading/unloading, they can advance to the more complicated LPCVD type furnaces. It is not recommended that new lab members learn about Tystar17-20 LPCVD furnaces at the same time you are getting trained on the other LPCVD furnaces, Tystar9-13 and Tystar13-16. Their operations are different and may be confused. All furnaces require an online and oral test. The online tests are sometimes grouped together:

Online tests: Tystar1-4 (group), Tystar5-7, Tystar9-20

All members need to pass an online and oral test to get qualified on Tystar1-7 and 9-20.

Note: Furnaces with a common online test require an individual oral test for each furnace. For instance, being qualified on Tystar1 does not allow you to use Tystar3 even though you have passed the written test for Tystar1-4. You must also be orally qualified on Tystar3.

1.5 Process Monitoring Data

For Tystar1,2,9,10,11,12,16,17, process monitoring data such as deposition rate and non-uniformity are acquired on a monthly basis and statistical process control charts (SPC) are generated. This information is posted on the web at the following link:

http://nanolab.berkeley.edu/ProcessMonitor/index.html

Members are encouraged to use this data as a starting point before performing their own tests to determine exact deposition rates, uniformity or other parameters needed for their process steps.

2.0 Atmospheric Furnaces in Bank1 (Tystar 1-4)

All furnaces in Bank1 are Atmospheric furnaces, where Tystar1 is specifically reserved for IC device Gate Oxidation processes.

2.1 **Tystar1** – Dedicated for gate oxidation of MOS devices. A TCA clean recipe is available that utilizes TCA vapor to clean the tube quartz ware. The cleaning process runs at 1100°C for eight hours to remove the metallic/organic contaminations and to ensure good quality oxide. This is required prior to performing any gate oxidation process in the tube.

2.2 **Tystar2** – General dry/wet oxidation and annealing for MOS clean processes (devices), and a back up to Tystar1 for gate oxidation, if/when Tystar1 goes down. This furnace uses TLC vapor for tube cleaning. The TLC process runs faster than TCA, but may not be as effective. However, it is required before performing any gate oxidation process.

2.3 **Tystar3** – General dry/wet oxidation and annealing for Non-MOS application.

2.4 **Tystar4** – General dry/wet oxidation and annealing for Non-MOS application. This furnace also has forming gas (10%H_2 in N_2) for sintering processes at elevated temperatures. Specific metals are allowed in this tube, refer to Chapter 1.7 - Material Compatibility & Process Compatibility Policy, and Chapter 5.4 - Tystar4 or process staff for more details.

Table 1 - Tystar Bank 1 Furnaces Summary (4" and 6" Capable)

	Tystar1	**Tystar2**	**Tystar3**	**Tystar4**
Furnace Cleanness	MOS	MOS	Non-Mos (MEMS)	Non-Mos (MEMS)
Process type	Atmospheric MOS Gate Oxidation	Atmospheric Oxidation Diffusion	Atmospheric Oxidation Diffusion	Atmospheric Oxidation Diffusion
Heater				
Type	High Mass	High Mass	High Mass	High Mass
Controller	DTC	DTC	DTC	DTC
No. of Indep. Zones	3	3	3	3
Temperature Range	400 - 1050°C	400 - 1050°C	400 - 1050°C	400 - 1050°C
Boat				
Type	Open Quartz Boat	Open Quartz Boat	Open Quartz Boat	Open SiC and Quartz Boat
Load/Unload Speed	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min
Wafer Capacity				
4" wafer	50	75	50	50
6" wafer	25	25	25	25
Process				
Recipe Loading	TYCOM	TYCOM	TYCOM	TYCOM
Recipe Storage	Floppy Diskette	Floppy Diskette	Floppy Diskette	Floppy Diskette
Standard Processes	MOS Gate Oxidation N_2 anneal	Dry Oxidation Wet Oxidation N_2 Anneal	Dry Oxidation Wet Oxidation N_2 Anneal	Dry Oxidation Wet Oxidation N_2 Anneal H_2/N_2 Sinter
Oxidation rate	Note1	Note1	Note1	Note1
Available Gases				
N_2	10 SLM	10 SLM	10 SLM	10 SLM
N_2/ H_2 (10%)	-	-	-	5 SLM
O_2	10 SLM	10 SLM	10 SLM	10 SLM
Ar (as request only)	-	10 SLM	10 SLM	10 SLM
H_2O (Steam)	3 ml/min DI H_2O fixed	3 ml/min DI H_2O fixed	3 ml/min DI H_2O fixed	3 ml/min DI H_2O fixed
Cleaning	TCA	TLC	-	-

Note1: Oxidation rate is not constant (not linear) and varies with time (refer to oxidation charts).
Tystar1: 1GATEOX recipe (dry oxidation) at 950ºC for 60 minutes yields ~ 300 Å of SiO2.
Tystar2: 2WETOXA recipe (wet oxidation) at 1000ºC for 42 minutes yields ~2700 Å of SiO2.

3.0 Atmospheric Furnaces in Bank2 (Tystar 5-7)

This bank can accommodate 6” and 8” wafers. Tystar5-7 each have their own FCS30 computer and plasma display for more advanced process control. Recipes are stored in the computer’s EPROM instead of on a floppy diskette. For safety reasons, the process will go to a pre-programmed abort sequence if/when the process parameters are out of tolerance. Only staff and super-users can re-direct the process back to normal after trouble-shooting the problem and making sure it is safe to proceed (there may be unreacted toxic gases present in the tube). A PC is dedicated to Bank 2 for real time process data acquisition and advanced recipe management.

3.1 **Tystar5** – General dry/wet oxidation and annealing for MOS clean processes. This furnace uses TLC vapor for tube cleaning, which is required before performing any gate oxidation process.

3.2 **Tystar6** – $POCL_3$ liquid doping for non-MOS clean processes.

3.3 **Tystar7** – B doping using BCl_3 doping gas for non-MOS processes.

Table 2 - Tystar Bank 2 Furnaces Summary (6" and 8” Capable)

	Tystar5	Tystar6	Tystar7
Furnace Cleanness	MOS	Non-MOS	MOS
Process Category	Atmospheric Oxidation Diffusion	Atmospheric Oxidation Diffusion	Atmospheric Oxidation Diffusion
Heater			
Type	High Mass	High Mass	High Mass
Controller	TCU	TCU	TCU
# of Zones	3	3	3
Temperature Range	400 - 1050°C	400 - 1050°C	400 - 1050°C
Boat			
Type	Open Quartz Boat	Open Quartz Boat	Open Quartz Boat
Load/Unload Speed	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min
Wafer Capacity			
6" wafer	25	25	25
8" wafer	25	25	25
Process			
Recipe Loading	FCS30	FCS30	FCS30
Recipe storage	EPROM	EPROM	EPROM
Standard Processes	Dry Oxidation Wet Oxidation N_2 Anneal	P Doping Dopant Drive-in Dry Oxidation N_2 Anneal	B Doping Dry Oxidation N_2 Anneal H_2/N_2 Sinter

Available Gas

N_2	0.2 - 10 SLM	0.2 – 10 SLM	0.2 – 10 SLM
O_2	0.2 – 10 SLM	0.01 – 5 SLM	-
Ar	0.2 – 10 SLM	-	0.2 – 10 SLM
H_2O (Vapor)	0.2 -10 ml/min	-	-
Cleaning	TLC	-	-
$POCl_3$ (carried by N_2)	-	On/Off	
NH_3	-	-	0.004 – 0.2 SLM
BCl_3He	-	-	0.004 – 0.2 SLM
N_2/H_2 (10%)	-	0.2 – 10 SLM	0.2 – 10 SLM

-

4.0 LPCVD Furnaces in Bank3 (Tystar9-12)

All furnaces on this bank are LPCVD. Oil-Sealed Mechanical pumps are used to set the pressure for standard processes. For customized processes with pressures lower than the standard process, the total process gas flow must be lowered in order to have the process pressure sufficiently set.

Because the operating temperatures of Bank 3 furnaces are lower than the AP furnaces, low mass heaters are used to make the temperature response faster. Do not attempt to run your process with a temperature higher than the standard process. It will not only damage the heater, but also flake the film previously deposited on the process tube and create a particle problem.

4.1 **Tystar9** – MOS clean furnace for the stoichiometric silicon nitride and high temperature oxide (HTO) processes. Due to the high stress, over 1GPa, in the nitride film, the maximum thickness for one process run is limited to 5000 Å. HTO has similar properties to thermal oxides produced in AP furnaces but does not consume any Si on the substrate. Tystar9 can also deposit Oxynitride film with different refractive index by adjusting the NH_3 and N_2O gas flows upon process staff's approval.

4.2 **Tystar10** – MOS clean furnace for poly and amorphous Si film. The film can be doped with PH_3 in situ.

4.3 **Tystar11** – MOS clean furnace for Low Temperature Oxide (LTO). The film can be doped with PH_3 in situ to form phosphosilicate glass (PSG).

4.4 **Tystar12** – Same setup as Tystar11 for non-MOS applications.

Table 3 - Tystar Bank 3 Furnaces Summary

	Tystar9	**Tystar10**	**Tystar11**	**Tystar12**
Furnace Cleanness	MOS	MOS	MOS	Non-MOS (MEMS)
Process Category	Low Pressure Chemical Vapor Deposition	Low Pressure Chemical Vapor Deposition	Low Pressure Chemical Vapor Deposition	Low Pressure Chemical Vapor Deposition
Vacuum System				
Pump	Oil-Sealed Mechanical	Oil-Sealed Mechanical	Oil-Sealed Mechanical	Oil-Sealed Mechanical
Pressure Control	Closed loop PID	Closed loop PID	Closed loop PID	Closed loop PID
Pressure Range*	100 - 2000 mtorr	100 - 2000 mtorr	100 - 2000 mtorr	100 - 2000 mtorr
Std Process Pressure	300 mtorr	375 mtorr	300 mtorr	300 mtorr
Heater				
Type	Low Mass	Low Mass	Low Mass	Low Mass
Controller	DTC	DTC	DTC	DTC
# of Zones	3	3	3	3
Temperature Range	600 - 800°C	500 - 650°C	400 - 450°C	400 - 450°C

Boat

Type	Open Quartz Boat	Close Quartz Boat	Close Quartz Boat	Close Quartz Boat
Load/Unload Speed	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min

Wafer Capacity

4" wafer	25	26	26	26
6" wafer	12	13	13	13

Process

Recipe Loading	TYCOM	TYCOM	TYCOM	TYCOM
Recipe storage	Floppy Diskette	Floppy Diskette	Floppy Diskette	Floppy Diskette
Standard Processes	Standard Si_3N_4 High Temp Oxide Oxynitride	Phosphorous Doped/Undoped Poly/Amorphous Silicon	Phosphorous Doped/Undoped Low Temp Oxide	Phosphorous Doped/Undoped Low Temp Oxide
Dep. Rate (Aº/min)	Nitride ~45	Doped poly ~21	LTO ~150	LTO ~155

Available Gases

SiH_4	-	200 SCCM	100 SCCM	200 SCCM
SiH_2Cl_2 (DCS)	100 SCCM	-	-	-
NH_3	100 SCCM	-	-	-
O_2	-	-	200 SCCM	200 SCCM
N_2O	200 SCCM	-	-	-
50% PH_3 / 50% SiH_4	-	10 SCCM	40 SCCM	40 SCCM
N_2	5 SLM	5 SLM	5 SLM	5 SLM

*Actual pressure range depends on the total process gas flow

5.0 AP and LPCVD Furnaces in Bank4 (Tystar13-16)

There are two AP (Tystar13 and 14) and two LPCVD (Tystar15 and 16) furnaces available in this bank.

5.1 **Tystar13** – $POCl_3$ doping. This furnace uses $POCl_3$ vapor and O_2 to dope a wafer with P. The process produces a thin layer of SiO_2, which needs to be stripped off in dilute HF as part of the P diffusion process.

5.2 **Tystar14** – Solid source B doping. This furnace uses solid source disks to dope B into the substrate. The main purpose of this process is to form a B rich layer down to a certain depth on the wafer. A compound layer on the silicon substrate is formed. It is wet oxidized in an AP furnace, and then stripped off using diluted HF.

5.3 **Tystar15** – Polycrystalline SiC in-situ doped with N, are grown by LPCVD using methylsilane with ammonia and dichlorosilane as precursors.

5.4 **Tystar16** – Non-MOS doped/undoped poly and amorphous polysilicon film deposition. There are two mass flow controllers for PH_3 on this LPCVD furnace that can be used to fine-tune the amount of poly-Si P doping and the stress level in the film. Glass wafers are allowed in this furnace for low temperature amorphous Si process only.

Table 4 - Tystar Bank 4 Furnaces Summary

	Tystar13	Tystar14	Tystar15	Tystar16
Furnace Cleanness	Non-MOS (MEMS)	Non-MOS (MEMS)	Non-MOS (MEMS)	Non-MOS (MEMS)
Process Category	Atmospheric Pressure Oxidation Diffusion	Atmospheric Pressure Oxidation Diffusion	Low Pressure Chemical Vapor Deposition	Low Pressure Chemical Vapor Deposition
Vacuum System				
Pump	-	-	Double Stage Dry Pump	Double Stage Dry Pump
Pressure Control	-	-	Closed loop PID	Closed loop PID
Pressure Range*	-	-	100 - 2000 mtorr	100 - 2000 mtorr
Std Process Pressure	-	-	Variable	375 mtorr
Heater				
Type	High Mass	High Mass	Low Mass	Low Mass
Controller	DTC	DTC	DTC	DTC
# of Zones	3	3	3	3
Temperature Range	400 - 1050°C	400 - 1100°C	450 - 650°C	450 - 650°C
Boat				
Type	Open Quartz Boat	Open Quartz Boat	Close Quartz Boat	Close or Open Quartz Boat
Load/Unload Speed	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min
Wafer Capacity				
4" wafer	25	26	26	26
6" wafer	12	13	13	13
Process				
Recipe Loading	TYCOM	TYCOM	TYCOM	TYCOM
Recipe storage	Floppy Diskette	Floppy Diskette	Floppy Diskette	Floppy Diskette
Standard Processes	Phosphorus Doping Dopant Drive-in Dry Oxidation N2 Anneal	Boron Doping (Solid Source) Dopant Drive-in N2 Anneal	Doped/Undoped SiC	Phosphorus Doped/Undoped Poly/Amorphous Silicon
Dep. Rate Aº/min	N/A	N/A	N/A	Doped poly ~35
Available Gases				
SiH_4	-	-	-	200 SCCM
NH_3	-	-	10 SCCM	-
O_2	500, 5000 SCCM	200 SCCM	-	-
50% PH_3 / 50% SiH_4	-	-	-	3, 10 SCCM
N_2	10 SLM	10 SLM	5 SLM	5 SLM
$POCl_3$ (carried by N_2)	1000 SCCM	-	-	-
N_2/H_2(10%)	-	10 SLM	-	-
Methylsilane (MS; H_3SiCH_3)	-	-	100 SCCM	N/A

Dichlorosilane (DCS; H_2SiCl_2)	-	-	100 SCCM	-
H_2	-	-	500 SCCM	-

*Actual pressure range depends on the total process gas flow

6.0 Bank 5: Advanced Furnaces – Tystar17-20

Tystar17-20 each has its own FCS10 computer and plasma display for more advanced process control. Recipes are stored in the computer's EPROM instead of on a floppy diskette. For safety reasons, the process will go to a pre-programmed abort sequence if the process parameters are out of tolerance. Only staff and super-users can re-direct the process back to normal after trouble-shooting the problem and making sure it is safe to proceed (there may be unreacted toxic gases present in the tube). A PC is connected to the Bank 5 for real time process data acquisition and advanced recipe management.

6.1 Tystar17 – LSN

Tystar17 deposits "Low Stress Nitride" (LSN) film on the wafers, which is a Si rich type film. The stress level in the film is adjusted by the process gas ratio (DCS: NH_3). The film stress can be controlled by this ratio from below 100 to 300 MPa. The Standard recipe has a 4:1 gas ratio, and the stress level measures 250 MPa for a 1000Å LSN film.

Tystar17 has a high throughput pumping system and a customized device plus a shunt and a self-cleaning orifice to prevent particle back streaming. The furnace can also deposit standard nitride and high temperature oxide for MEMS applications.

6.2 Tystar18 – Sintering

This furnace is dedicated to MOS Al sintering, using customary forming gas (10%H_2 in nitrogen). It can also be used for Al sintering in 10% deuterium in nitrogen, as well as low temperature N_2, O_2 anneal.

6.3 Tystar19 – Silicon/Germanium

Tystar19 deposits Si/Ge alloy film for MOS applications. The film can range from pure Si, a mixture of the two, to pure Ge. Either B or P can be used for in-situ doping of a deposited film.

6.4 Tystar20 – Silicon/Germanium

Tystar20's setup is identical to Tystar19, however, it is dedicated to deposition of Si/Ge alloy films in non-MOS applications. B can be used for in-situ doping of a deposited film. Metals allowed in Tystar20 include Al, Ti and W.

Table 5 - Tystar Bank 5 Furnaces Summary

	Tystar17	Tystar18	Tystar19	Tystar20
Furnace Cleanness	MEMS	MOS	MOS	MEMS
Process Category	Low Pressure Chemical Vapor Deposition	Atmospheric Pressure Sinter/Anneal	Low Pressure Chemical Vapor Deposition	Low Pressure Chemical Vapor Deposition
Vacuum System				
Pump	Double Stage Dry Pump	-	Double Stage Dry Pump	Double Stage Dry Pump
Pressure Control	Closed loop PID	-	Closed loop PID	Closed loop PID
Pressure Range*	100-2000 mtorr	-	100-2000 mtorr	100-2000 mtorr
Std Process Pressure	140 mtorr	-	Variable	375 mtorr
Heater				
Type	High Mass	Low Mass	Low Mass	Low Mass
Controller	TCU	TCU	TCU	TCU
# of Zones	5	5	5	5
Temperature Range	650 - 850°C	400 - 600°C	300 - 650°C	300 - 450°C
Boat				
Type	Open Quartz Boat	Open Quartz Boat	Close or Open Quartz Boat	Open Quartz Boat
Load/Unload Speed	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min	5 - 25 inch/min
Wafer Capacity				
4" wafer	25	25	26	-
6" wafer	12	25	13	26
Process				
Recipe Loading	FCS10	FCS10	FCS10	FCS10
Recipe storage	EPROM	EPROM	EPROM	EPROM
Standard Processes	Low Stress Nitride Standard Nitride Hi Temp Oxide	N_2/H_2 Sinter D_2/H_2 Sinter N_2 Anneal	Phosphorus/Boron Doped/Undoped Silicon/Germanium	Boron Doped /Undoped Silicon/Germanium
Deposition Rate	LSN ~35 Aº/min	N/A	N/A	N/A
Available Gas				
SiH_4	-	-	200 SCCM	200 SCCM
Si_2H_6 (Disilane)	-	-	200 SCCM	200 SCCM
SiH_2Cl_2 (DCS)	200 SCCM	-	-	-
GeH_4 (Germane)	-	-	200 SCCM	200 SCCM
NH_3	100 SCCM	-	-	-
N_2O	200 SCCM	-	-	-
50% PH_3 / 50% SiH_4	-	-	10 SCCM	-
B_2H_6	-	-	-	-
BCl_3	-	-	100 SCCM	100 SCCM
N_2	5 SLM	10 SLM	5 SLM	5 SLM
$H_2(10\%)/N_2$	-	10 SLM	-	-
$D_2(10\%)/N_2$	-	10 SLM	-	-
O_2		10 SLM		

*Actual pressure range depends on the total process gas flow.

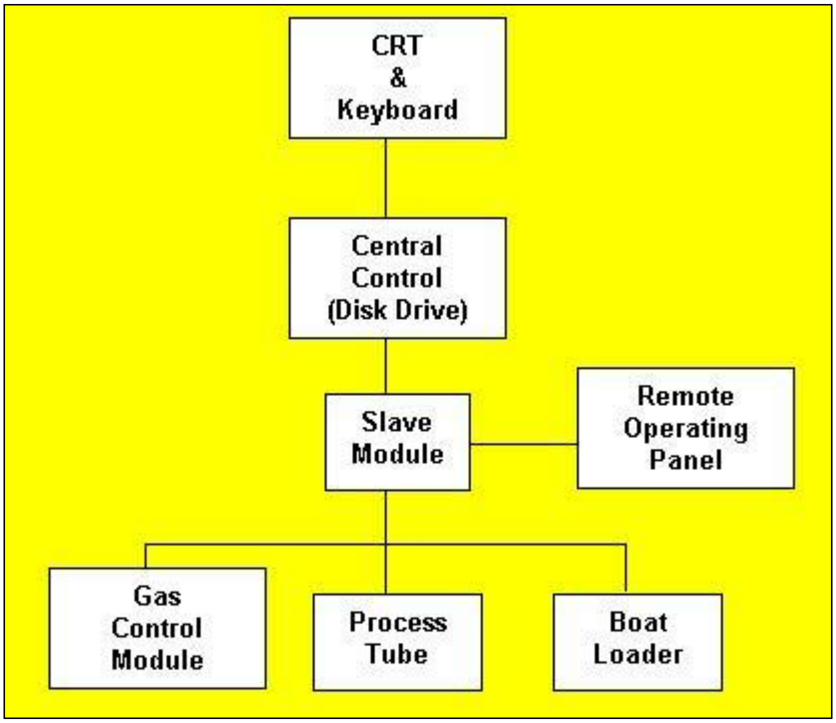
APPENDIX

Recipe Management, TYCOM Commands and Furnace Control

1.0 Control System For Bank 1,3 and 4 Furnaces (TYCOM microcomputer)

Banks 1,3 and 4 furnaces are controlled by a centralized microcomputer called the TYCOM Microprocessor Control System. The instructions for furnace processes are executed by computer programs called process recipes that are loaded into the slave module of each furnace. Each slave module provides individual control over its associated process tube and components, such as the boat loaders and gas panels.

The TYCOM CRT, keyboard and disk drive are used to input recipes into the slave module, execute commands, and display information such as gas flow and temperature for a process run. The TYCOM has its own operating system, and commands to load, run and edit recipes. An abbreviated listing of TYCOM commands can be found in the Appendix of this manual. The slave module can also take input commands from the remote operating panel located on front side of each furnace. The relationship between TYCOM component subsystems is shown below.



1.1 TYCOM

TYCOM consists of a CPU with two floppy disk drives, a CRT monitor and a keyboard. Process status and run history can be monitored in detail on the TYCOM CRT screen. TYCOM is also connected to the Nanolab UNIX server, which enables members to remotely access the content of the TYCOM screen, and check on the status of a process run in progress.

Nanolab standard recipes are stored on 5.25 inch floppy diskettes at the TYCOM station. The recipes are loaded for the furnace microprocessor using the floppy disk drive on the TYCOM computer. Standard recipes for each furnace are stored on a floppy diskette labeled with the furnace name, e.g. Tystar1. Do not alter the contents of the furnace recipe diskettes. If you need to develop a special recipe consult staff. Keep your recipes on a separate diskette at the back of the furnace diskette caddy.

1.2 Glossary of TYCOM Commands

MKC>	**Prompt in command mode**
DI ST SY	**Display status of system**
DI ST SY C	**Display status of system continuously (every 20 sec)**
CTRL-C	**To get out of continuous mode**
DI ST tube#	**Display status of tube tube#**
DI ST tube# C	**Display status of tube tube# continuously**
DI DI	**Display directory on disc currently in disc drive**
DI RE name	**Display recipe of given name**
LO name tube#	**Load recipe into tube tube#**
RU tube#	**Start to run recipe in tube tube#**
AC tube#	**Acknowledge at end of run when alarm goes on**
AB tube#	**Abort process in tube#**
FORMAT	**Initialize new disc before writing on it; or to completely erase an old disc (password is needed)**
COPY name	**To copy recipe from one disc to another: First put in disc with recipe, type: COPY recipe name, then follow prompt.**
DELETE name	**Delete whole recipe from disc (password needed)**
ED name	**Edit recipe (password needed); the prompt in edit mode is EDT>**
LI	**List recipe**
LI ST	**List recipe header**
IN ST	**Insert new recipe header; all 5 lines must be retyped; process I.D. should be same as recipe name.**
LI step#	**List step**
IN step#	**Will overwrite one line in step - hit return twice to get out of insert mode**
DE step#	**Delete one line in step**
DE ST #	**Delete entire step**
EX	**Exit edit mode**
EX newname	**Exit and give new recipe name**
VE name tube#	**Verify that recipe will properly compile for tube#**
ACT PR	**Activate printer**
DEACT PR	**Deactivate printer immediately after printout is obtained.**

1.3 Rebooting the TYCOM

Occasionally the TYCOM crashes and must be rebooted. If you see the TYCOM screen blank, hit any key and see if the screen is restored. If the screen is still blank, you will need to contact staff to reboot the system.

2.0 Control System For Bank2 and Bank5 Furnaces (DCS-30, FCS10 and Tystar PC)

Every furnace in Bank2 has its own computer and plasma display with a DCS-30 user interface. The recipes are stored in EPROM and can be loaded directly for each process run. A PC is connected to the three furnaces on this Bank. It collects process data and displays the data graphically in real time. It also performs process recipe management.

There are four Bank5 furnaces utilizing user interface FCS10 to store, load, process recipes and display process data in real time.

3.0 Temperature Control for Bank1-4 and Bank5 Furnaces

3.1 DTC – Bank 1, 3 and 4 furnaces use a microprocessor-based circuit board, DTC (Direct Temperature Control), to control the temperatures of 3 independent heaters (Load, Center, and Source). The DTC board sends electric pulses into the heater coils and the heat power dissipated is determined by the pulse frequency. The temperature is controlled through a closed loop PID. There are 43 PID parameters that can be specified in the process recipe to optimize furnace temperature in each process operating range.

3.2 TCU – Bank 2, 5 furnaces use TCU (temperature control unit), with a proprietary temperature control algorithm. It maximizes the temperature ramping rate with minimum overshooting. The furnaces for Bank 2 have three independent heaters (Load, Center, Source). Bank 5 has five independent heaters (Load, Load-Center, Center, Source-Center, and Source). This allows the possibility of a furnace tilted temperature profile.

4.0 Process Gas Delivery and Pressure Control for Bank1-4 and Bank5 Furnaces

All furnaces use the MFS460, a microprocessor based unit, to control the mass flow controllers (MFC) and pneumatic valves for all process gas deliveries. Because most of the process gases used in these furnaces are toxic and/or flammable, the MFS460 has several built-in safety mechanisms that will stop the gas flow if unsafe conditions are detected.

4.1 Process gases flow in an opposite direction for the AP furnaces as compared to the LPCVD furnaces. In the AP furnaces, process gases flow into the process tube through the backside of the furnace (source zone), and exit through a small opening in the front, near the loading door (load zone). In the LPCVD furnaces, process gases enter the furnace tube through a gas ring at the loading door (front side of the furnace), and exit through the backside of the tube into the pump.

4.2 All the LPCVD furnaces are equipped with mechanical pumps for vacuum operation. Bank 3 furnaces use oil-sealed rotary pumps. Due to the low throughput of these pumps, the total process gas flow should be limited to 200 SCCM or below. All other LPCVD furnaces use a roots-blower in series with a multistage dry pump. This arrangement can achieve low pressure with high process gas flow throughput.

4.3 A closed-loop PID circuit built into the MFS460 controls the process pressure in the tube. The PID parameters are entered manually. They are optimized for different pressure operating ranges, and can be changed by staff only.