Chapter 5.17

Tystar 17

Low Stress Nitride and High Temperature Oxide LPCVD Furnace
(Non-MOS)
(tystar17 - 386)

1.0 Title
Tystar17 Non-MOS Low Stress Nitride Stoichiometric Nitride and High Temperature Oxide LPCVD Furnace

2.0 Purpose
Tystar17 is a non-MOS LPCVD furnace designed for deposition of low stress Nitride film. It may also be used for deposition of stoichiometric Si$_3$N$_4$ (stress $>$ 1000MPa), High Temperature Oxide (HTO) and Oxynitride films.

Note: non-MOS wafers are not allowed in Tystar9, which is a MOS Si$_3$N$_4$ tube.

3.0 Scope
This document provides operational procedures for Tystar17, recipe loading from the FCS10 furnace computer, and user level troubleshooting.

4.0 Applicable Documents
Revision History
4.1 Chapter 5.0 of the lab manual (Tystar Furnaces - Overview).
4.2 TYTAN Diffusion Furnace System Manual, includes FCS10, TCU, MFS460 (Copy in Office)
4.3 Tystar17 Process Characterization Report (see Memo at the end of this chapter).

5.0 Definitions & Process Terminology
5.1 MOS Furnace: This kind of furnace is used to fabricate MOS devices (IC), whose performance can be greatly impacted by trace contaminants. Wafers processed in MOS furnaces should absolutely be MOS compatible (IC device).

5.2 Non-MOS Furnace: This kind of furnace is used for non-MOS processes such as MEMS. Tystar17 is a non-MOS furnace. Metals allowed in Tystar17 include refractory metals such as W.

Au is NEVER allowed in Tystar17

Requests to process metals other than refractory metals in Tystar17 must be approved by process staff.

5.3 LPCVD: Low Pressure Chemical Vapor Deposition.

5.4 Stoichiometric (Standard) Nitride: Chemically balanced silicon nitride Si$_3$N$_4$ that usually has a tensile film stress of over 1000 MPa.

5.5 Low Stress Nitride (LSN): Si rich nitride, which has a film stress around 300 MPa or lower.
5.6 **Oxynitride**: \( \text{SiO}_x\text{N}_y \). The amount of O, N and its refractive index are determined by the gas flows during the deposition process.

5.7 **High Temperature Oxide (HTO)**: \( \text{SiO}_2 \) formed by the reaction of \( \text{N}_2\text{O} \) and DCS. The oxide property is comparable to thermal oxides, but does not consume the silicon substrate like thermal oxidation.

6.0 **Safety**

Follow general safety guidelines in the lab and the specific safety rules as per follows:

6.1 Tystar17 utilizes **high electric power** (high amperages) heating elements. Do not touch high power electrical part inside panels of the furnace.

6.2 Special care must be taken when the process aborts. In some special circumstances, the tube may go into **SPECIAL HOLD**. In either case, inform process staff immediately. The process staff will decide whether the process can be continued, and/or take proper actions to remedy the situation. **Do not try to open the tube, since there may be toxic hazardous gases in it.**

6.3 All new recipes have to be approved by the process staff, before they can be used on any Tystar furnaces.

6.4 **Burn Hazard**. Furnace cantilevers, boats, and wafers come out of the furnace are very hot. Wear face shield when loading/unloading wafers. Proceed with caution.

7.0 **Statistical/Process Data**

7.1 NanoLab web page.

7.2 Problem and comment section under equipment section of Mercury.

7.3 Enable message for Tystar17.

8.0 **Available Process, Gases, Process Notes**

Non-metalized wafers to be processed in Tystar17 must go through the standard pre-furnace cleaning procedure. This entails a 10 minute piranha dip in Msink8 and Msink6, and an ensuing one minute HF dip for oxide removal if desired. Metalized wafers which can be attacked by piranha should never be processed at Msink8 or Msink6. A clean heated metal bath is available at Msink1 for cleaning metalized wafers prior to entering Tystar17. Photoresist coated non-metalized wafers must initially have their photoresist processed in the Matrix Asher or stripped at Msink1 (PRS-3000 bath). This is required for both MOS and non-MOS wafers. The wafers must then be cleaned in Msink8 and Msink6. Msink6 is the pre-furnace clean step prior to wafer introduction into any furnace. This means photoresist removal from non-metalized wafers requires an additional cleaning at Msink8 regardless of whether the process is MOS or non-MOS. Resist coated metalized wafers will need to get a resist strip, **ash & wet**, plus rinse steps, before going into the Tystar17 furnace. Sometimes the ash strip alone can leave minute particles on the wafer, so a wet strip becomes necessary. For a complete description of pre-furnace wafer cleaning please see Section 1.3 in Chapter 5.00, Tystar Furnaces Overview.

**Available Processes**

8.1 Low Stress Nitride (LSN) Deposition.

8.2 Stoichiometric Nitride Deposition.

8.3 High Temperature Oxide (HTO) deposition normally at temperatures below 850\(^\circ\)C, however, a higher temperature version of HTO process is available that can accommodate thicker films at temperatures above 900\(^\circ\)C (high deposition rate ~ 50A/min).

8.4 Oxynitride Deposition.

8.5 Please contact process staff for any customized processes you may need.
Available Gases

8.6 Dichlorosilane/DCS (SiH₂Cl₂): Used as a source of Si in all Tystar17 processes. Decomposition of DCS supplies silicon for LSN, HTO, Nitride and Oxynitride films.

8.7 Ammonia (NH₃): Used as a source of nitrogen in the nitride process. NH₃ is also used after deposition to neutralize HCl, which is a byproduct of the DCS decomposition.

8.8 Nitrous Oxide (N₂O): Used as a source of O for oxynitride film deposition.

8.9 Nitrogen (N₂): Used for process pressure control, tube purging, and venting the furnace tube back to atmospheric pressure.

Process Notes

8.10 The maximum temperature for Tystar17 is 850°C. Any attempt to go above this temperature will result in damaging the O-rings used for the vacuum sealing.

8.11 The standby temperature for Tystar17 is 650°C. Avoid opening the tube for more than 30 minutes, which will cause the tube temperature to drop significantly. The stress accumulated in the films deposited on the tube’s inner wall will crack the tube.

8.12 All process wafers in Tystar17 should be loaded facing the back of the furnace (pump direction) for better film uniformity. All dummy wafers are loaded facing the door side of the furnace for quality control with respect to particle accumulation.

8.13 Producing particle-free, low stress nitride films, requires a method of limiting volatile compounds that condense in the pump manifold from back-diffusing into the tube during the wafer load step. A special shunt valve with a control orifice is built into the furnace tube gate valve. The orifice allows a small amount of N₂ to flow from the tube to the pump during the load step. A pressure gauge is installed to monitor the shunt’s effectiveness. The orifice is cleaned when necessary.

8.14 All Tystar 17 recipes use 4-letter step IDs, instead of 4-digit numbers used in the past. The commonly used IDs are noted below:

| IDLE: | IDLE state | STRT: | process StaRT |
| LOAD: | LOAD/unload wafers | BTIN: | BoaT moves INto the tube |
| BPP#: | Before nucleation Pump # | BPG#: | Before deposition PurGe # |
| DTEQ: | Deposition Temp EQuilibrium | FNH3: | start Flowing NH3 |
| FDQS: | starts Flowing DCS | DEPO: | DEPosition |
| PNH3: | Post deposition NH3 Purge | APP#: | After deposition PumpP # |
| APG#: | After deposition PurG # | WAIT: | WAIT for user’s action (EVENT) |
| ABRT: | ABoRT sequence | SHLD: | Special HoLD |

Available Process Data:

High temperature HTO process run results, tilted profile, 08/02/2011:

HTOSTDA.017, pressure:400morr,Temperature:910C/920C/930C, N₂O:180sccm
DCS:180sccm; processed for 600 minutes (10 hrs) and oxide thickness measured.

<table>
<thead>
<tr>
<th>Load side Å</th>
<th>Pump side Å</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>34719.3</td>
</tr>
<tr>
<td>C</td>
<td>34900.8</td>
</tr>
<tr>
<td>F</td>
<td>35392.1</td>
</tr>
<tr>
<td>L</td>
<td>34939.6</td>
</tr>
<tr>
<td>R</td>
<td>35113.8</td>
</tr>
</tbody>
</table>

Avg.Thickness: 35013 Å 30400 Å
Deposition rate:
Load side = 58.52 A/min
Pump side = 50.60 A/min

Stress (compressive):
Load side          Pump side
-166.4 MPa          -163.1 MPa

Low Stress Nitride, LSN process run, 01/25/2016, deposition rate,

9.0 Overall Furnace Operation

9.1 General Information and Menu Keypad Definitions

Tystar17 furnace is a five-zone LPCVD furnace. It operates as a stand-alone unit that is made of three modules, wafer load/unload, furnace/process-tube, and gas control. It has its own computer, FCS10, whose display panel and keypad are located on the left side of the wafer load/unload module. The furnace operation is controlled by using menu commands. The furnace temperature is controlled by the TCU computer board which runs a proprietary PID algorithm. The temperature for each of the five furnace zones, Load, Load/Center, Center, Source/Center, and Source, can be independently set. The process gases are regulated by the MFS460 gas flow controller which has five hardware interlocks to ensure safe operation.

9.1.1 Front panel special function buttons and keypad description (see Section 11.1 for the schematics of the front panel):

ABORT: ***USE ONLY IN EMERGENCY***, e.g. fire, toxic gas leak. DO NOT use this key to abort a recipe in progress. If you must stop a recipe, please contact a super-user or process staff. They will know the proper procedure for stopping a process and safely evacuating toxic gases from the furnace. This action requires a password.
MENU: Displays the Main Menu (See the Appendix for the description of all menu commands)

NEXT PAGE: Used to display more information/instructions on the display. Use when prompted, otherwise the computer will freeze and you will need to find a process staff to reboot it.

CMD: Used for certain special functions. (Mostly used with GS commands, Section 9.1.2)

Arrow Keys: Used when prompted to select a recipe. Do not use as a DEL/BACKSPACE key when entering alphanumerical inputs. Otherwise the computer will freeze and you will need to find a process staff to reboot.

Alpha-

Numeric Keys: Used to enter process parameters, e.g. gas flows, pressure, deposition time, and etc.

ENTER: Used to enter the menu command or alphanumerical inputs.

CLEAR: Used to clear an error on the alphanumerical key input.

RUN: Run the recipe loaded in the computer memory.

HOLD: Hold a recipe step at its present process condition. Press RUN to resume the process.

EVENT: Acknowledge the process to go to the next recipe step when the current step time has not finished yet. For instance, after you finish loading your wafers and want to close the furnace door before the 20 minute door open step time. Some process steps cannot be cycled through using the EVENT button.

BOAT IN/OUT: Move the boats in/out of the process tube manually, independent of the recipe. These are toggle switches, i.e. push once to turn on and the second time to turn off. If both are ON at the same time, then the boats stop moving.

ALARM ACK: Silences an alarm, but does not correct the alarm condition. Alarm conditions are displayed on the bottom line of the screen. In most cases, the computer will clear the alarm conditions by itself. If not, report the problem on Mercury.

9.1.2 Commonly used MENU commands (press MENU button, then enter the two letter commands):

DS Displays the current status of the furnace.

DH Displays the process history from the last time the RUN button was pressed until the present time.

DR Displays the contents of the selected recipe.

GS Changes the Display to graphic mode. It shows large characters with only selected process information. Use CMD button to select process parameters to be displayed.

RL Loads process recipes. You will be prompted to use the Arrow Keys to select a recipe. Afterward, press the ENTER button twice. The computer will prompt you to enter process parameters if needed.

9.1.3 Process Gas Flow Interlocks
When any of the following five interlocks turns ON, no process gas, except nitrogen, will flow. If the ANTLK is on, the nitrogen cannot flow either.

**DNTLK** Door interlock. When ON, it indicates that the tube door is not closed properly.

**ANTLK** Above atmosphere pressure interlock. When ON, the tube pressure is above 760 torr.

**BNTLK** Below process pressure interlock. When ON, the process pressure is above 2 Torr.

**VNTLK** Vacuum interlock. When ON, it indicates that the vacuum system is not working.

**GNTLK** Gate interlock. When ON, the gate valve between the vacuum pump and process tube is closed.

### 9.2 Available Recipes

There are four process recipes available on this furnace. Staff should be consulted whenever a new recipe is needed. The UCBKWK1 computer is used for setting up new recipes. No one should ever upload a recipe from the menu driven terminal to the UCBKWK1 computer.

9.2.1 **STANDBYA.017**: Standby recipe. It purges a small amount of nitrogen through the process tube at low pressure to keep it clean.

9.2.2 **LSNSTDA.017**: Standard Low Stress Nitride LPCVD. The deposition condition is fixed (100DCS/25NH3/140mTorr/835°C). Enter only the deposition time, based on your target film thickness, when loading recipe.

9.2.3 **LSNVARA.017**: Variable Low Stress Nitride LPCVD. The process gas flows and pressure are specified by the user, while the temperature is fixed at 835°C. The recommended DCS flow is 100sccm, and you can reduce the NH3 flow to obtain lower stress in the film.

9.2.4 **STDNITA.017**: Stoichiometric Nitride LPCVD. The process condition is fixed (25DCS/75NH3/300mTorr/800°C). The stress can reach above 1000MPa.

9.2.5 **HTOSTDA.017**: High Temperature Oxide LPCVD. Recommended process temperature below 850, unless high deposition is needed can go up to 915°C tilted zone.

### 9.3 Loading a Recipe and Wafers

**Venting the Tube**

Tystar17, and all other LPCVD furnaces, are in STANDBY mode, under vacuum when idle. The furnace tube needs to be vented to atmosphere before the door can be opened. Do not attempt to open the door if the tube is not vented to atmosphere. It will severely damage the furnace. Enable TYSTAR17 on Mercury.

9.3.1 Make sure the recipe **STANDBYA.017** is running, and is at WAIT step. If the VNTLK is ON, do not run any process, as there is a problem with the vacuum system. Report it as a fault on Mercury.

9.3.2 Press **EVENT**, and the process should advance to BKF1 (Back Fill #1). It takes 12 minutes for the venting process to finish. Afterwards, the process ends and the furnace status changes to IDLE mode.

**Load and Run a Process Recipe**

9.3.3 Make sure the process tube is properly vented.
9.3.4 Press MENU button, then enter RL and the screen will show a list of the available recipes. Use the arrow keys to highlight the recipe that you plan to load, then press ENTER twice.

9.3.5 The computer will prompt you to enter some process parameters if needed. Input values of the previous run will be displayed for your reference. You have to enter your value with the same format even if it is the same as what is displayed. Press ENTER after typing each process variable value.

9.3.6 Use the CLEAR key if you need to erase a wrong value, entered. DO NOT USE THE ARROW KEY TO MOVE THE CURSOR! This will cause the software to crash and all the recipes might be lost.

9.3.7 Time is entered in the format of HH.MM.SS. Do not enter 00.00.00 since it will hold the process at the step indefinitely.

9.3.8 Once you have finished entering all of your required values, press MENU, then DS to check that the recipe is loaded properly. Press RUN to start the process. The tube door will open and the boats come out.

9.3.9 Put on the face shield. After the boats move out completely, remove dummy wafers and load your wafers. The boats will remain out for 20 minutes. If the boat start moving in and you have not finish loading your wafers, press EVENT before the door closes, the boat will come out, and you will have another 20 minutes.

*** Do not leave the door open for more than 30 minutes, since it will create a large temperature gradient in the tube and causes the thick film deposited on the tube wall to crack and create particulate problems. It may also crack the process tube.

In case a wafer is broken when loading, and you need to obtain another clean one, press HOLD then BOATIN. After you are ready to load again, press BOATOUT and wait for the boat to come out. Load your wafer, then press RUN.

9.3.10 Press EVENT, and the boats will start moving into the tube. When the door closes completely, the tube will be pumped down and the deposition process start.

9.3.11 If the deposition process completes successfully, the recipe will stop at the HLD1 step and the tube will be purged with nitrogen, held at low pressure at a temperature of 650°C. Press EVENT to start venting the tube.

9.3.12 After 12 minutes, the process will hold at the HLD2 step.

9.3.13 Press EVENT and the tube door will open and the boats will come out.

9.3.14 Press EVENT again, and boats will start moving into the tube. When the door closes completely, the recipe ends. Press ALARMACK to silent the alarm.

Load and Run the Standby Recipe

9.3.15 Press MENU, then enter RL. Use the arrow keys to highlight the standby recipe. Press ENTER twice.

9.3.16 Press MENU, then enter DS. Check and make sure that the recipe is loaded.

9.3.17 Press RUN. You should wait and monitor the furnace until all the interlocks turn OFF. Disable Tystar17 on Mercury when you are done.

10.0 Troubleshooting Guidelines

10.1 The tube is at atmospheric pressure hold (step HLD2). In this case, there is no film deposition on your wafers.
10.1.1 **Cause:** The tube door has not closed properly (DNTLK is ON).
**Solution:** Make sure there is nothing on the track blocking the movement of the boats. Press EVENT three times (The boats will move out, then in, and then the process ends). Run the process again. Press EVENT twice and the door will start moving in. If the DNTLK is still ON when recipe reaches BPP1, the system needs to be checked. Report the problem on Mercury.

10.1.2 **Cause:** The tube failed leak check. (no interlock is ON)
**Solution:** Press EVENT three times (The boats will move out, then in, and then the process ends). Run the process again. When the tube door is completely open, check the door flange and tube’s open-end area for any debris that may result in leakage. Wipe the flange with Technicloth. To prevent burn injury, pay extra attention on the hot spots of the boat loader when doing so.

10.2 **The tube is at abort hold (step APRG).**
In this case, the process was aborted when the process gases were flowing. There is some film deposition on your wafers.

10.2.1 **Cause:** One of the process gas flows was out of tolerance due to a delivery system malfunction or an empty gas cylinder.
**Solution:** Press MENU, then enter DH. Press ENTER when prompted for input. The whole process history for this run will be displayed. Find the root cause for the abort and report on Mercury.

10.2.2 **Cause:** You have not enabled the furnace. In this case, find a member of staff to restart the process.

10.3 **The tube is at special hold (step SHLD).**

10.3.1 **Cause:** When the process hold at SHLD, it indicates some serious system problem occurred, e.g. pump failure, tube leakage, etc.
**Solution:** Report on Mercury or find a staff member immediately. Do not attempt to fix the situation yourself (including super users).

10.4 **The door will not open after the venting**

10.4.1 **Cause:** BOATIN is ON. Someone pressed the button by mistake.
**Solution:** Press BOATIN to turn it OFF. Make sure BOATOUT is ON.

10.4.2 **Cause:** System malfunction. Boat loader has problem.
**Solution:** Report on Mercury.

10.4.3 **Cause:** No N₂ flow and the tube is not vented. On the monitor display, the value of N₂ is 0, instead of 5000.
**Solution:** Report on Mercury.

10.5 **The FCS10 computer does not respond to the keypad input (Computer Crashed)**

10.5.1 **Cause:** Used the Arrow Keys instead of CLEAR to erase an error when entering alphanumeric inputs.
**Solution:** Report on Mercury.
10.5.2 **Cause:** Press NEXTPAGE twice when loading a recipe that requires multi-pages of inputs. Usually, this is caused by an aging keypad, not by the user.

**Solution:** Report on Mercury.

11.0 **Figures & Schematics**

11.1 Front Control Panel of the FCS10 Furnace Computer
11.2 Furnace Status Displayed on the FCS10 Front Panel (step HLD1 of the HTOSTDA.017 recipe)

![Furnace Status Displayed on the FCS10 Front Panel](image)

12.0 Appendix

FCS10 Furnace Computer Menu Commands

**D - Display Sub-Menu**

- **DE**: equipment status
- **DD**: file directory - Lists the recipes in memory. (same as **DI** in Tycom)
- **DH**: process history. In case of recipe abort, error message can be found.
- **DR**: process steps in a recipe file. The system will prompt you to select a specific recipe from memory.
- **DS**: process status that is continuously updated.
- **DT**: temperature history
- **DE** and **DT** should not be used.

**R - Recipe Sub-Menu** (password protected except **RL**)

- **RE**: Allows one to edit recipes. See the Tystar Manual for instructions.
- **RL**: Load a recipe for subsequent use. Usually, this is the only command, which you will need to use from this sub-menu.
- **RM**: Modifies current process parameters.
- **RR**: Renames a recipe. Do not use this either...
- **RX**: Deletes a recipe from memory.

**G - Graphics Sub-Menu**

- **GP**: plumbing diagram
- **GE**: plumbing edit (password protected)
- **GS**: tube status. An abbreviated status summary screen is displayed.

The following sub-menu commands should not be used, but are stated for completeness and to satisfy your curiosity.

**H - Host computer Sub-Menu**

- **HP**: host parameters

**C - Configuration Sub-Menu**

- **CC**: contact closures
- **CM**: MFS460 gases
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CT  TCU temperature  
CS  station options  
CA  alarm selection  

X - Diagnostics Sub-Menu

XM  memory utility

TI (change time, date) and PW (change password) have no submenu. Do not use these commands.