Chapter 5.15

Tystar15 non-MOS 200mm Poly-Si LPCVD Furnace

(tystar15 - 386)

1.0 Equipment Purpose

Tystar15 is a non-MOS Low Pressure Chemical Vapor Deposition Furnace for deposition of poly-Si films. The tube can process small chips and wafers up to 200mm Ø.

2.0 Material Controls & Compatibility

2.1 Si, Ge and quartz wafers are allowed in this furnace. Si wafers with refractory metals on them are sometimes allowed in this furnace. Please talk to staff about which Si wafers with metals are allowed before processing. Once a wafer has been processed in this furnace, it is not allowed in any MOS furnace. There is **ABSOLUTELY NO EXCEPTION** to this rule. For all other materials, please consult staff before using this furnace.

Previously allowed material(s) include: TiN, TiO2

2.2 Process run times exceeding 12 hours must be pre-approved by staff

3.0 Training Procedure & Applicable Documents

3.1 Exam Tool - this tool requires an online exam before qualification. Timeline (estimated time to completion: 1 week)

3.1.1 Get trained by any qualified member.

3.1.2 Take the online test in the Nanolab office (open 8A-12P, 1P-5P).

3.1.3 Arrange a qualification session with a superuser or staff to show competency on the tool.

4.0 Definitions & Process Terminology

4.1 FCS-10: touchscreen control terminal

4.2 Non-MOS Furnace: This furnace deposits non-MOS films.

4.3 Polysilicon Si (poly-Si): poly-Si is deposited under low pressure, ~250mT, and a temperature of ~620°C, using the reaction, $SiH_4 \rightarrow Si + 2H_2$.

4.4 Amorphous Si (a-Si) is deposited with the variable doped recipe at a lower temperature. Contact process staff for recommended parameters.

5.0 Safety

Follow general safety guidelines in the lab as well as the specific safety rules, listed below:

5.1 Electric Shock Hazard: Tystar furnaces utilize high electric power (high current) to generate heat. Do not open the side panels or touch the high power electrical parts in the furnace cabinet.

5.2 Chemical Hazard: SiH_4 is an explosive gas when mixed with air. Do not attempt to open the tube during processing. If there is a problem, contact staff.

5.3 **Burn Hazard**: Cantilevers, boats, and wafers coming out of the furnace are very hot. Always wear a face shield when loading/unloading wafers. Proceed with caution. Avoid touching any furnace quartz ware to prevent burning your hands and/or contaminating the furnace. No flammable chemicals, especially organic solvents, are allowed at the load station when the tube is open.

5.4 **New recipes are not permitted without the express consent of process staff.**

6.0 Statistical/Process Data

6.1 Current problems with the furnace may be found in the fault section, under the equipment menu of and in the enable message for the furnace in Mercury Client.

7.0 Available Process, Gases, Process Notes

7.1 Wafer Cleaning Requirements, before loading them into Tystar furnaces.

7.1.1 Non-metalized wafers to be processed in Tystar15 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. Photoresist coated non-metalized wafers must initially have their photoresist processed in the Matrix Asher or stripped at msink1 (1165 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 Tystar15. This means photoresist removal from non-metalized wafers requires an additional cleaning at msink8 regardless of whether the process is MOS or non-MOS.

7.1.2 Wafers with refractory metals on them must first be cleaned at msink1 in the SVC-14 heated bath before introduction into Tystar15. Photoresist coated metallized wafers must initially have their photoresist processed in the Matrix Asher or stripped at msink1 (1165 bath), then they may be cleaned in the SVC-14 heated bath. Please see Section 7.3 of Chapter 2.1 of the Pre-Furnace Metal Clean Sink manual for more information.

7.1.3 No cleaning steps are necessary when transferring wafers directly from a MOS or non-MOS furnace to the Tystar15 furnace.

7.2 Available Processes

7.2.1 Non-MOS furnace dedicated to poly-Si and amorphous Si deposition: doped and undoped

7.2.2 Check with staff before using the variable recipe if you want to change parameters from our standard Doped Poly-Si recipe.

7.3 Available Gases

7.3.1 **Nitrogen (N_2):** Used to purge tube of atmospheric gases and keep tube in an inert/clean environment during non-oxidation steps.

7.3.2 **Silane (SiH_4):** A highly flammable gas used as the source of the Si for the SiO_2 process.

7.3.3 **Phosphine (PH_3):** A highly flammable gas used for n-type phosphorus doping. The gas used in the Nanolab is a 50% SiH_4/ 50%PH_3 mixture, for all the furnaces. Presently, we are still developing a viable recipe for doping. We hope to have this recipe for member use shortly.

7.4 Special Process Notes

7.4.1 Refractory metals are allowed in Tystar15.

7.4.2 Tystar15 can operate up to 620°C.

7.4.3 NDPOLYVAR.003: variable doped poly and a-Si recipe. Variable temperature, pressure, PH3, SiH4 and time. Use this recipe for amorphous Si **at lower temperatures than 620C** standard poly.

7.4.3.1 Standard Doped Poly Parameters to be used with NDPOLYVAR.003:

7.4.3.1.1 Temperature = 620C

7.4.3.1.2 Pressure = 350mTorr

7.4.3.1.3 SiH4 flow = 100sccm

7.4.3.1.4 PH3 flow = 5sccm

7.4.4 YOU MUST CHECK WITH STAFF before you change parameters in NDPOLYVAR from what's written above!

8.0 Equipment Operation

8.1 General Tystar Furnace Operational Guidelines

Tystar15 is a three-zone low pressure furnace. It operates as a stand-alone unit that is comprised 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 right side of the wafer load/unload module. The furnace operation is controlled using a stylus to press function keys and a series of menu commands. Furnace temperature is controlled by the TCU computer board, which utilizes a proprietary PID algorithm. The temperatures of all 3 furnace zones; i.e. Load, Center and Source can be independently set. The process gases are controlled by the MFS460 mass flow system and the five hardware interlocks it contains to ensure safe operation of the tool.

Front Panel Special Function Buttons and Keypad Description (see Section 11.1 for the schematics of the front panel)

ABORT: ***USE ONLY IN EMERGENGY***, 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 know the proper procedure for stopping a process or evacuating toxic gases from the furnace. This action requires a password.

MAIN 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 member to reboot it.

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

Arrow Keys: Used when prompted to select a recipe. Do not use the arrow keys for **DEL/BACKSPACE** when entering alphanumeric inputs. The computer will freeze and you will need to find a process staff to reboot it.

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 alphanumeric inputs.

CLEAR: DO NOT USE ON THIS FURNACE. This will freeze the computer.

BACKSPACE: Used for correcting alphanumeric inputs.

RUN: Run the recipe loaded in computer memory.

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

EVENT: Acknowledge the process to go to the next step of the recipe when the current step time has not finished yet. For example, after you finish loading the wafers and want to close the furnace door before your 20 minute time limit is up. Note that some process recipe steps do not respond to the EVENT key.

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.

8.2 Computer Terminal **(loading recipes and looking at status of run in progress)**

The Computer Terminal controls and monitors all user accessible Tystar15 Furnace operations.

Commands:

The computer terminal only recognizes CAPITAL letters. You can also use the special function buttons. However, it is suggested that you learn the commands manually as well.

Summary of Commands and Functions.

Commands	Function
DR	Displays all available recipes. Use arrows and double enter to view recipe steps. At the top of the window are instructions on how to view steps in detail. Press the shortcut labeled **NEXT PAGE** to display the next page of steps/sub-steps.
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/when needed.
DS	Displays current process status of Tystar15. The page includes the current step, time to go, and parameters status.
DH	Displays the process history from the last time the RUN button was pressed to present time.
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.

8.3 <u>Available Recipes</u>

STBY.002: Standby recipe to be run post poly-Si deposition run.

POLY.002: poly-Si deposition.

NDPOLYVAR.003: variable doped poly and a-Si recipe. Variable temperature, pressure, PH3, SiH4 and time

8.4 Processing a Run **(Loading Recipe and Wafers)**

Loading a Recipe

Enable Tystar15 in Mercury Client.

Check that no recipe is running in the furnace and that furnace status reads IDLE (status found at center top of **DISPLAY STATUS** sub menu**)**.

Go to **MAIN MENU** and type **RL** (Recipe Load) to display available recipes.

Select the desired recipe using arrow keys and press **ENTER** twice to begin.

Enter desired process parameters when prompted. When done, press **ENTER**, then press **MAIN MENU**, as instructed by the computer, upon variable entry completion. The furnace status should still read IDLE in Display Status.

Load wafers and run a process recipe

Put on the face shield.

Press **RUN**. The furnace door will open and wafer boats will come out. Be aware that the furnace door will automatically close after 30 minutes.

Transfer your wafers from msink6 or msink1 to the furnace in the designated wafer transfer box.

Load your wafers using the non-MOS vacuum wand with black tubing. These vacuum wands **do** work with 8” wafers, no special equipment is necessary. All wafers should be loaded with their flats up for optimal wafer support and consistent gas distribution.

Do not wear poly gloves over nitrile gloves when loading/unloading wafers. The poly gloves are usually too big and slippery for proper dexterity, and the tips of the poly gloves may melt, causing contamination and burns.

Once wafers are loaded, press **EVENT** to start the boat moving into the furnace.

Unload wafers after process ends

No alarm will sound when the deposition is finished. You are in charge of checking the status of your run. POLY.002 is programmed to hold your wafers in an inert environment until you are ready to unload.

To unload your wafers, press **EVENT**. The tube will be gently brought up to atmosphere. Pressing **EVENT** again will open the furnace door moving the boats out. When the boats stop moving, wait at least 5 minutes for the wafers to cool down. Then use the non-MOS vacuum wand to either unload your wafers onto the cooling rack next to the furnace (Tystar15 quartz boats), or into your cassette. Caution, wafers may still be too hot, so you will have to use common sense to determine if you can put the wafers into your cassette.

Press **EVENT** to move the boats back into the furnace. The furnace status will return to IDLE once the door is closed.

Load and run the standby recipe – **THIS IS IMPORTANT, LOAD AND RUN THE STANDBY RECIPE**.

Disable Tystar15 in Mercury Client and be sure to report any faults.

9.0 Troubleshooting Guidelines

9.1 Computer Terminal is blank.

Tap on the far right side of the screen. It should light up.

9.2 Door won’t open/Boat loader stuck

Make sure there is nothing obstructing the movement of the boat loader.

Make sure the cable that pulls the boat loader is not loose. If so, ask staff to adjust the tension on the cable.

If the above steps fail, report the problem on Mercury.

9.3 The tube is at one of the abort sequences (step ABRT) when you come back to unload your wafers.

One of the process gas flows was out of tolerance due to a delivery system malfunction or empty gas cylinder.

Solution: Press MAIN MENU, then enter DH. Press ENTER when prompted for input. The process history for this run will be displayed. Note the last step before the abort sequence and report it on Mercury.

You did not enable the furnace. Find a staff person to restart the process.

9.4 The tube is at special hold (step SHLD)

When the process is in SHLD,an equipment failure has occurred.

Solution: Report as a fault on Mercury. Do not attempt to fix the situation yourself.

10.0 Study Guide

10.1 Maximum temperature.

10.2 MOS vs. non-MOS rule.

10.3 Loading a recipe.

10.4 Troubleshooting the Computer Terminal.

10.5 Cleaning wafers before they go into the furnace.

10.6 Loading wafers.

10.7 Displaying the status of a process.

10.8 Unloading wafers and closing the tube.

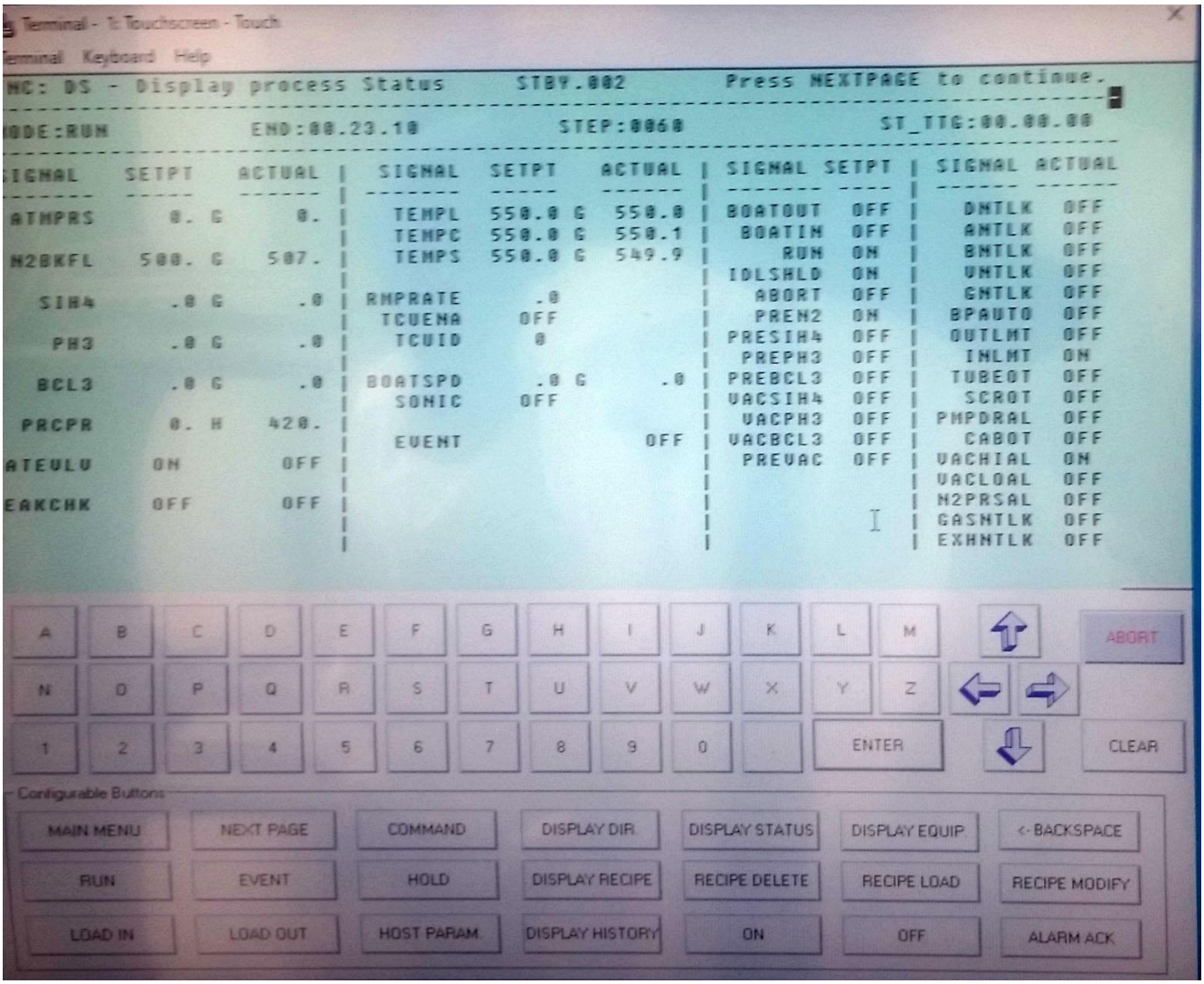
10.9 Which vacuum wand to use.

10.10 Alarms and what to do when you hear them.

10.11 Which gases are used by tystar15.

11.0 Appendices, Figures & Schematics

11.1 Figure 1 – Tystar15 computer terminal Display



11.2 Appendix

FCS10 Furnace Computer Manu Commands

D - Display Sub-Menu

DE equipment status
DD file directory - Lists the recipes in memory. (Same as DI DI in Tycom)
DH process history. In case of a recipe abort, error messages 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. Don't 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 and are for reference only.

H - Host computer Sub-Menu
HP host parameters
C - Configuration Sub-Menu
CC contact closures
CM MFS460 gases
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. Don't use these commands.

11.3 Standard Recipes

1. STBY.003, this is the recipe that the tube should be in when it is not processing a substrate.

2. POLY.003, this is the poly-Si recipe – **6" dep rate ~8.4nm/min**. The dep rate is for a 6" wafer in the 8th slot of the 6" boat. It gives the best uniformity so far.

3. NDPOLYVAR.003 , this is the **DOPED poly-Si** recipe with variable temperature, pressure, SiH4, PH3 flow. YOU MUST CHECK WITH STAFF before you change parameters from the following:

Temperature = 620C

Pressure = 350mTorr

SiH4 flow = 100sccm

PH3 flow = 5sccm

The above parameters results for 8th 6" wafer and 2hr deposition: **1.6nm/min** and resistivity of 0.012Ω*cm before anneal and 0.0009Ω*cm after anneal.

4. a-Si using NDPOLYVAR.003 , this is an amorphous Si recipe with variable temperature, pressure, SiH4, PH3 flow. This has not been tested by staff, but comes from a member process

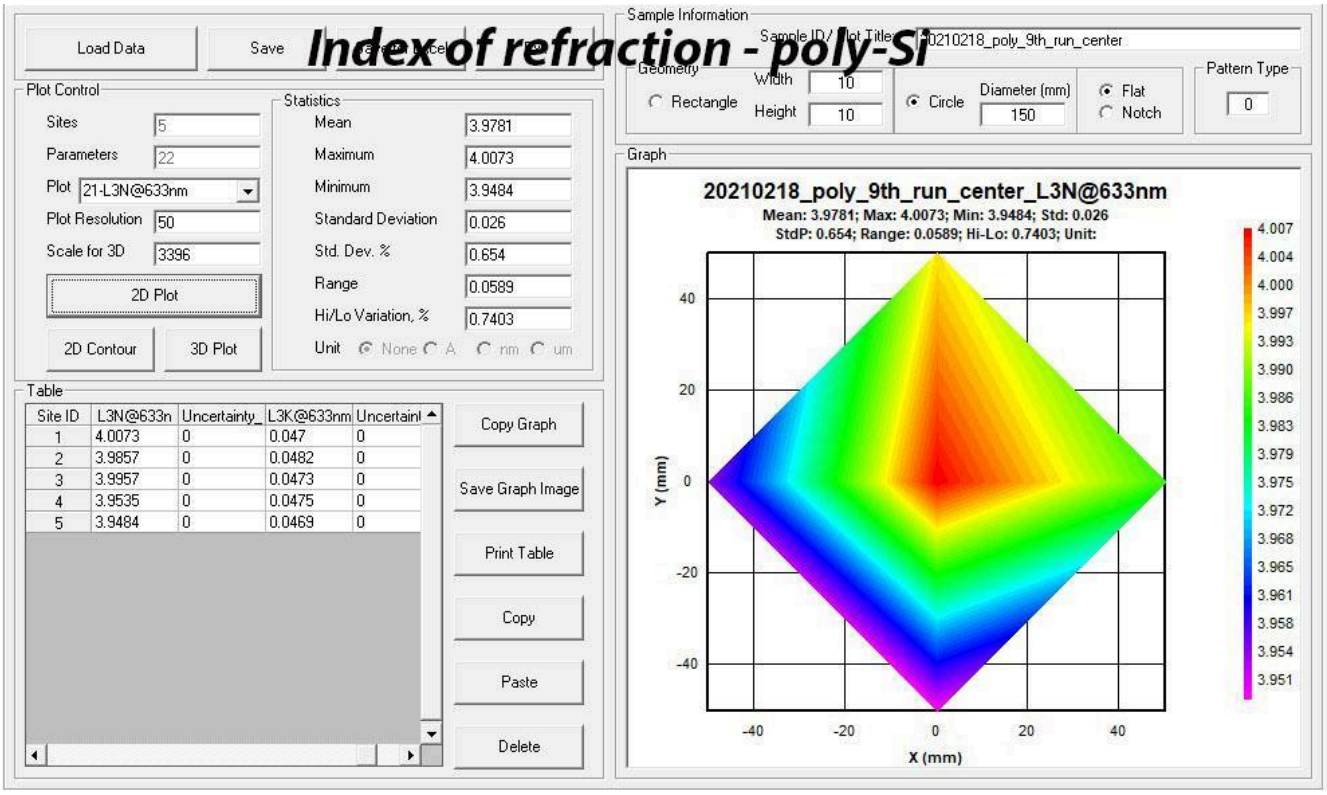
Temperature = 570C

Pressure = 400mTorr

SiH4 flow = 150sccm

PH3 flow = 0sccm

1hr deposition: **4.6nm/min**


Index of refraction - poly-Si
Load Data
Save
Sample Information
Sample ID / Plot Title
20210218_poly_9th_run_center
Geometry
Rectangle
Width
10
Height
10
Circle
Diameter (mm)
150
Flat
Notch
Pattern Type
0
Plot Control
Sites
5
Parameters
22
Plot
21-L3N@633nm
Plot Resolution
50
Scale for 3D
3396
2D Plot
2D Contour
3D Plot
Statistics
Mean
3.9781
Maximum
4.0073
Minimum
3.9484
Standard Deviation
0.026
Std. Dev. %
0.654
Range
0.0589
Hi/Lo Variation, %
0.7403
Unit
None
A
nm
um
Table
Site ID
L3N@633n
Uncertainty_
L3K@633nm
Uncertainl
1 4.0073 0 0.047 0
2 3.9857 0 0.0482 0
3 3.9957 0 0.0473 0
4 3.9535 0 0.0475 0
5 3.9484 0 0.0469 0
Copy Graph
Save Graph Image
Print Table
Copy
Paste
Delete
Graph
20210218_poly_9th_run_center_L3N@633nm
Mean: 3.9781; Max: 4.0073; Min: 3.9484; Std: 0.026
StdP: 0.654; Range: 0.0589; Hi-Lo: 0.7403; Unit:
Y (mm)
X (mm)
40
20
0
-20
-40
4.007
4.004
4.000
3.997
3.993
3.990
3.986
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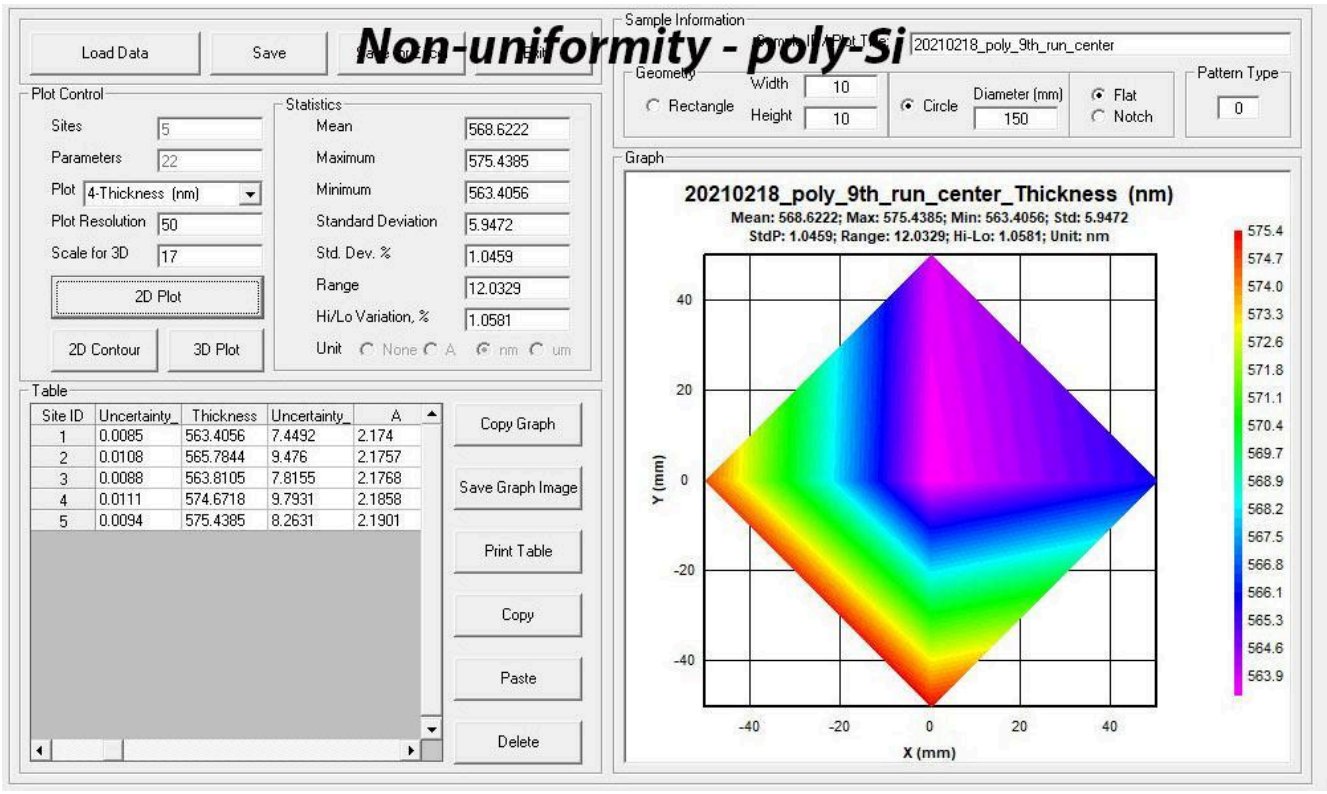
3.961
3.958
3.954
3.951


Non-uniformity - poly-Si
Load Data
Save
Sample Information
20210218_poly_9th_run_center
Geometry
Rectangle
Width
10
Height
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Circle
Diameter (mm)
150
Flat
Notch
Pattern Type
0
Plot Control
Sites
5
Parameters
22
Plot
4-Thickness (nm)
Plot Resolution
50
Scale for 3D
17
2D Plot
2D Contour
3D Plot
Statistics
Mean
568.6222
Maximum
575.4385
Minimum
563.4056
Standard Deviation
5.9472
Std. Dev. %
1.0459
Range
12.0329
Hi/Lo Variation, %
1.0581
Unit
None
A
nm
um
Table
Site ID
Uncertainty_
Thickness
Uncertainty_
A
1 0.0085 563.4056 7.4492 2.174
2 0.0108 565.7844 9.476 2.1757
3 0.0088 563.8105 7.8155 2.1768
4 0.0111 574.6718 9.7931 2.1858
5 0.0094 575.4385 8.2631 2.1901
Copy Graph
Save Graph Image
Print Table
Copy
Paste
Delete
Graph
20210218_poly_9th_run_center_Thickness (nm)
Mean: 568.6222; Max: 575.4385; Min: 563.4056; Std: 5.9472
StdP: 1.0459; Range: 12.0329; Hi-Lo: 1.0581; Unit: nm
Y (mm)
X (mm)
40
20
0
-20
-40
575.4
574.7
574.0
573.3
572.6
571.8
571.1
570.4
569.7
568.9
568.2
567.5
566.8
566.1
565.3
564.6
563.9