Stanford | SNF Stanford Nanofabrication Facility

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1. Equipment Purpose

1.1. The Savannah is a Cambridge Nanotech S200 Thermal ALD tool.

2. Equipment Specifications

2.1. Maximum sample diameter: 8 in

2.2. Minimum sample diameter: Samples smaller than 4” must use a carrier wafer to prevent being falling into vacuum lines

2.3. Maximum thickness: 50nm

2.4. Chamber Temperature Range: 24-250C

2.5. Monitor Frequency: Monthly HfO2 for uniformity and growth rate

3. Cleanliness Standard

3.1. Savannah is classified as flexible. The following materials are not allowed:

- Polymers, unless approved by staff
- Wet samples
- Anything with a melting point or ignition point below 250C
- Plastic, including Teflon
- Non-encapsulated polymers
- Samples small enough to fall in the exhaust line

3.2. Note on III-V materials:

- Traditionally III-V materials are classified as gold contaminated. However, due to the low operating temperature of the Savannah, III-V materials can be used under certain conditions
    - The III-V material must not violate any of the above conditions
    - You must speak to a SNF staff member about your plan before introducing your sample into the MVD
    - The III-V material should never touch the inside of the deposition chamber. Tweezers used on III-V materials are also considered contaminated and should not contact the deposition chamber

4. ZnO Deposition

- Due to the electrically conductive nature of ZnO films, there are special operating procedures in place for ZnO depositions

4.1. Contamination of the pressure sensor by conductive ZnO deposition must be prevented by following the procedure below

4.1.1. You must turn on the pressure sensor purge MFC, by switching the toggle switch to “Control” **Figure 1.**

4.1.2. Verify the MFC value is 10+/-1. You will see the base pressure of the chamber increase with the additional N2 flow

4.1.3. Turn Joystick to “Close” after the run

Figure 1: MFC Controller Must be in “Control” Position During ZnO Deposition

4.2. Zn atom migration can easily damage subsequent processes, so care must be taken to coat the inside of the chamber to stop migration.

4.2.1. Once your ZnO coated sample has been removed from the chamber, run 100 cycles of the standard HfO2 recipe to coat the chamber and prevent Zn atom migration

5. Processing Capabilities

5.1. See “**13. Process Data”** for complete list of films

5.2. Deposit high quality oxide films

5.3. Tightly controlled thickness through monolayer growth

5.4. Ultra conformal deposition

5.5. The Savannah cannot deposit thick films. Thicker than 50nm requires staff approval. This is due to the slow deposition rate and high cost of precursors.

5.6. Selective ALD is difficult and an ongoing research topic. It should be expected that the material **will** deposit on the entire substrate

6. Becoming a User

6.1. Read all documentation on the SNF website pertaining to the Savannah
6.2. Shadow a current Savannah user until you become familiar with the operation of the tool. If you do not know a Savannah user, check the upcoming reservations on Badger and see if they would be willing to let you shadow
6.3. Contact Staff for a copy of the written quiz.
6.4. Pass an in person practical exam with Staff. You may bring a sample, or a dummy wafer will be provided
6.5. Additional training is required to become an “Engineer” level user with the ability to modify temperature set points and recipes. Contact Staff for details

7. Safety

7.1. Never open the Savannah box or tamper with precursors! This is for staff only.
7.2. Use caution when near the chamber, it is hot
7.3. The sample plate is maintained at an operating temperature between 100-200C, do not use anything that melts at low temperature when loading your sample. Use metal or teflon coated tweezers. Do not use clear vinyl gloves.

8. Required equipment

8.1. Metal or Teflon coated metal tweezers
8.2. Cleanroom Garments as necessary for room SNF cleanroom
8.3. Double latex or nitrile gloves, not clear vinyl glove as the vinyl will melt

9. Operating Procedure

9.1. Reservations
  9.1.1. Maximum reservation window is 4 days
  9.1.2. Maximum length of primetime reservations on weekdays is 4 hours
  9.1.3. Maximum reservation length is 24 hours.
9.2. Precursor Requests
  9.2.1. Check the current precursors installed by logging in to badger and checking the “precursor status” comment
9.3. Initial Checks
  9.3.1. Check if the precursor you would like to use is available, and up to temperature if applicable. **Figure 2.**
9.4. Verify Standby Condition
  9.4.1. The chamber should be pumped down to <200mTorr with a carrier gas flow of 5sccm

9.4.2. Verify the precursors and chamber are up to temperature by checking if the temperature set point matches the actual value

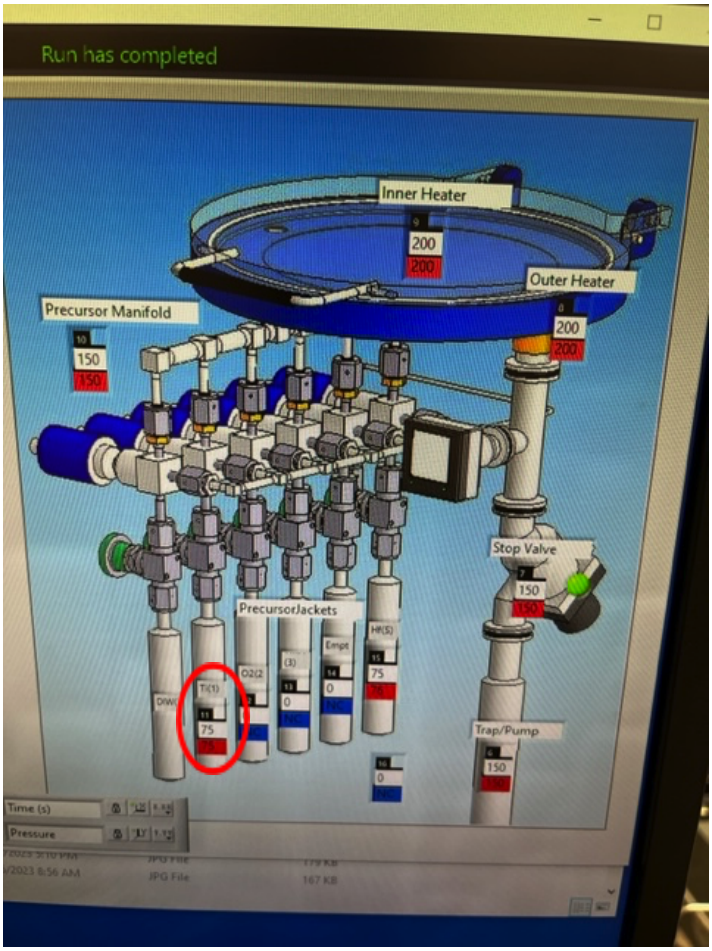

Figure 2: Verify Precursor Temperature

9.5. Loading Samples

9.5.1. Click “Vent Chamber” **FIGURE 3**

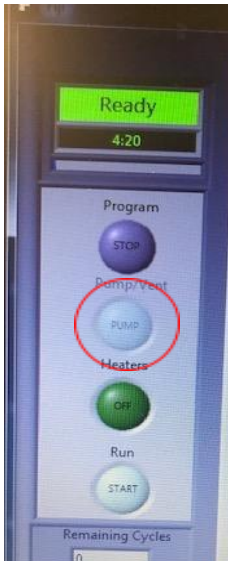

Figure 3: Pump/Vent Chamber Button

9.5.2. When the chamber has vented, remove the protective shield. The shield can be placed directly behind the user, on the metal table near Fiji 1 and 2. **Figure 4.**

Figure 4: Protectie Foil Cover

9.5.3. Open the chamber, keeping in mind the chamber will be hot. **FIGURE 5.**

Figure 5: Chamber Closed

9.5.4. Place samples in the chamber. ALD is a very uniform process, but it is good practice to place samples in the same position in the chamber every deposition.

9.5.5. Close the chamber and replace the protective foil shield

9.5.6. Select “Pump” **Figure 6.**

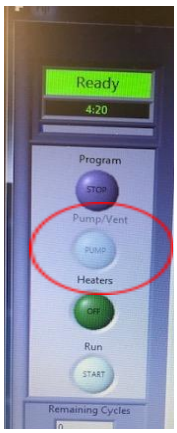

Figure 6: Pump Button

9.5.7. Chamber pressure should drop to <300 mTorr within 30 seconds.

9.6. Running the Recipe

9.6.1. Right click in the white field, and select “load recipe”. **Figure 7.**

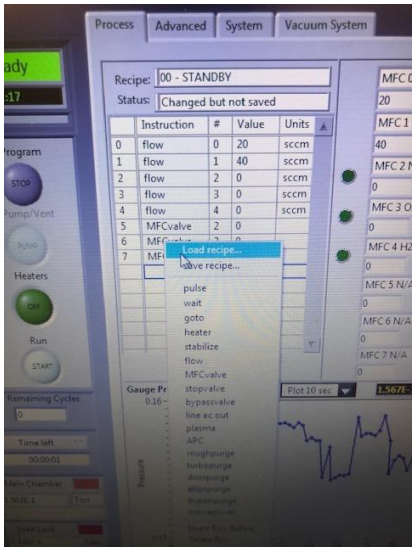

Figure 7: Right click in recipe area to access drop down menu

9.6.2. Select the recipe you would like to run. **Figure 8.**

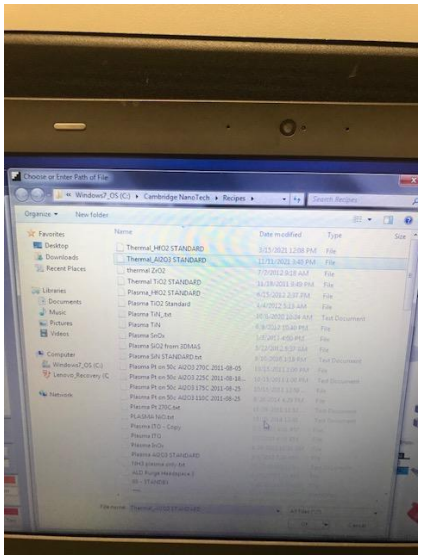

Figure 8: Recipe Window

9.6.3. Once the recipe is loaded, ensure the “pulse” and “goto” steps are set correctly for your process.

9.6.3.1. Pulse: in the # column, this value must match the position of the precursor inside the Savannah. Precursors move regularly, so

make sure to check this value. Precursor position can be seen in **Figure 9.**

9.6.4. Edit the “go to” step to change the number of times the cycle repeats.

9.6.4.1. go to: in the value column, this controls the number of deposition cycles. Ensure the number of cycles is correct for your target thickness.

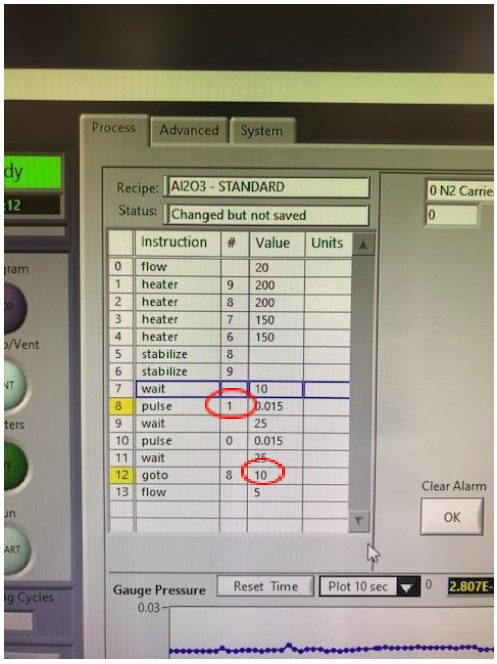

Figure 9: Recipe parameters to verify/modify before starting a deposition

9.6.5. With the sample loaded, temperatures verified, and recipe validated, you can now click the “Start” button. **Figure 10.**

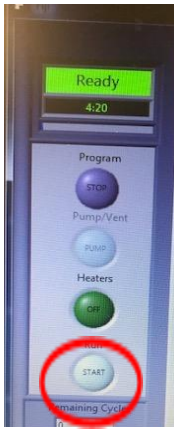

FIGURE 10: Recipe Start Button

9.7. Unloading Sample:

9.7.1. When the run has completed, select “Vent”

9.7.2. Remove the protective foil cover and open the chamber

9.7.3. Remove the sample from the chamber, remembering the chamber will be hot!

9.7.4. Close the chamber, and cover with protective foil cover

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Savannah ALD

10. Operating Guide

10.1. Request Precursors on Badger at least 24 hours before deposition

10.2. Reserve Savannah on Badger

10.3. Enable Savannah on Badger

10.4. Verify the precursor you would like to use is at the correct operating temperature, as found in section 13.

10.5. Remove heat shield, place on table directly in front of Savannah, near Fiji tools

10.6. Click “Vent” to vent the chamber

10.7. Open the chamber lid, be careful as it will be hot

10.8. Place sample in center of chamber using metal tweezers

10.9. Close chamber lid

10.10. Click “Pump” to pump down chamber

10.11. Right click in recipe field, and select “Load Recipe”

10.12. Select the recipe you would like to run

10.13. Make sure the “Pulse” step is pulsing the correct precursor

10.14. Make sure the “Go-to” step is the correct number of cycles you would like to run

10.15. Make sure the precursors are at the correct temperature

10.16. Click “Start Run”

10.17. Watch the process for a few cycles to verify precursors are pulsing normally

10.18. When process is finished, click “Vent” to vent chamber

10.19. Remove sample from chamber using metal tweezers

10.20. Close chamber lid

10.21. Click “pump” to pump down chamber

10.22. Load and run “00-Standby” recipe

11. Pre-Run Checklist

- Verify precursor temperature using the table in **"13. Process Data"**
- Verify chamber pressure is less than 200 mTorr with 5 SCCM N2
- Verify "pulse" step in recipe is pulsing the correct precursor position
- Verify "go to" step is the correct number of cycles

12. Recipe Parameters

- Standard recipes are maintained in the C://Recipes/ folder.
- Below are the parameters in the users control, and a comment about each:

Parameter	Notes	User Modify?
Chamber and Manifold Heaters	An increasing temperature gradient must exist between the precursor and the chamber.	Advanced Users only, consult staff if unsure.
Precursor Heater	User must verify temperature before running process, correct temperature can be found in section 13. Process Data.	Yes
Flow	The MFCs control the plasma and process gasses. It is defined in sccm. Do not adjust the standard flow settings. The MFCs for H_2, N_2, and O_2 have a hard off state and should be set to zero and then closed. This is already established in all recipes on the tool.	No
Pulse	This command is for pulsing a precursor line. It requires an ALD valve number and the amount of time you want the valve open in seconds. The shortest possible pulse is roughly .015 seconds. Even if you define a shorter time, the pulse will still be .015s. (The time in seconds needs a digit to the left of the decimal place; thus you should use "0.015" instead of ".015" for the minimum duration pulse.)	Should change/check valve number agrees with precursor you would like to use
goto	"goto" defines the loops in the recipe. This command takes the step to return to as an input. The value for this command defines how many times the loop will run.	Should change number of cycles based on target thickness
stabilize	This command is used to hold a recipe until a	No

	heater has reached the desired value. It takes as input a heater ID number and will wait until that heater demonstrates the set temperature with a degree C over a few seconds.	
Wait	This command takes as input a value in seconds that you would like the system to wait before proceeding to the next command. (The time in seconds needs a digit to the left of the decimal place; thus you should use "0.1" instead of ".1")	No
Stop Valve	This command will close or open the output valve for the reaction chamber depending on a Boolean input. This command is currently not used in any of the standard recipes, but development is beginning for recipes using this feature.	No

13. Process Data

Film	Process	Recipe Name	Deposition Rate @ 200C chamber temp unless otherwise noted (A/cycle)	Thickness Non Uniformity across chamber	Precursor Label	Precursor Temp In Use	Precursor Temp Not In Use
Al2O3	Thermal	Thermal_Al2O3 STANDARD	1	1.00%	TMA	Unheated	Unheated
HfO2	Thermal	Thermal_HfO2 STANDARD	1	1.00%	Hf	75C	75C
Pt	Thermal	Thermal Pt	0.4	??	Pt	50C	85C
Ru	Thermal	Thermal Ru	??	??	Ru	135C	135C
Ta2O5	Thermal	Thermal Ta2O3 STANDARD	??	??	Ta	120C	60C
TiO2	Thermal	Thermal TiO2 STANDARD	0.8	1.00%	Ti	75C	75C

ZnO	Thermal	ZnO Standard	??	??	DEZ	Unheated	Unheated
ZrO2	Thermal	Thermal ZrO2	0.8	1.00%	Zr	75C	50C

14. Troubleshooting

Symptom	Issue	Resolution
Can't open loadlock	• Not enabled in Badger • Chamber failed to vent	• Enable in Badger • Under "Vacuum" tab, select "Vent LL" again
No precursor pulse seen on pressure gauge	• No Issue • Out of precursors • Low precursor temp	• Some precursor pulses are weak, and cannot be seen over the baseline gas flow • Contact staff for replacement precursor • Consult Process Data table, check temp settings on precursor
Erratic deposition	• Wafer Cleanliness • Chamber Temperature • Base pressure	• Consult Staff • Consult Staff • Consult Staff

15. Revision Block

Revision	**Date**	**Description of Change**	**Author**
A	2/16/2023	Initial Release	A. Denton