University of Minnesota Nano Fabrication Center
Standard Operating Procedure

Equipment Name:	ALD		
Badger Name:	P3 PEALD Ultratech	**Revision Number:**	5
Model:	FIJI	**Revisionist**:	Tony Whipple
Location:	Bay3 PAN	**Date:**	3/27/2020

1 Description

The PEALD is a Plasma Enhanced Atomic Layer Deposition system in the FIJI series from Veeco/UltraTech/Cambridge Nano Tech, inc, deposits thin films. This is done by cycling an individual precursor for a short amount of time. Then a different precursor is cycled. These precursors are alternated to build up a film. The more alternating cycles, or loops that are ran the thicker the resulting film will be. The steps to control the ALD system are few and the machine is easy to run.

2 Safety

a The system uses several gases, and some of the gases are pyrophoric. Pyrophoric means it will burn if exposed to air.

b The system uses electrical power and is under vacuum, so be aware these items. There should be **no** odor whatsoever. If you smell an odor, put system in STANDBY, and leave the area and Contact staff

c As the system is being heated the chamber and other parts can hot so be careful while around the system, do not burn yourself.

d Do not edit the recipe beyond the number of cycles. Do not save the recipe.

e The system does have RF for generating a plasma, beware of this RF power.

3 Restrictions/Requirements

a Must be a qualified user on the PEALD.

4 Required Facilities

a Compressed air
b Nitrogen
c Argon
d Hydrogen
e House Exhaust

5 Definitions

a Precursor – A gas or liquid that is one of the building compounds to make a layer.
b Load lock – the loading chamber to load and unload wafers from the system.
b Recipe – Is the controlling software that makes the process of depositing a film.

6 Operating Instructions

a LOGGING ON

1. Check Badger for other reservations for the "PEALD" system first.
2. Enable "PEALD" on Badger.

b SETUP PROCEDURE

1. The ald system should have been left in a Standby mode with an **Idle** recipe running when it is not in use. Select the operating temperature you want to run at by selecting the correct Idle recipe, and this will set the temperatures to run at the correct operating value. Select the **Idle_xxx** recipe and run it.

Fig 1. Main items of the Fiji ALD system.

2. If the desired temperature is different than the current setpoint the system will take a long time to change. If going for a lower temperature it will take a long time you should plan for this. Use the Idle Cooling Recipes to cool system.

3. Once the system is at the correct temperature then you can load the wafer and select the deposition recipe and run it. The next section will explain how to load a wafer and get the system temperature set. The reason for loading the wafer into the load lock first is to get under vacuum and allow it to degas while the temperature is moving to the setpoint.

A LOADING WAFER INTO LOADLOCK

1. A IDLE recipe most likely will be running when you log in, this is normal. Just press the stop recipe to end it and now you can do the needed steps to run the process.

2. Loading the wafer into the loadlock awhile before moving it into the chamber is a recommended step from the ALD manufacture. Allowing the wafer to sit in the loadlock helps remove water vapor, which helps in making a better film. Removing moisture from the wafer is good and will help in having repeatable results.
3. Vent the Load lock this is done by pressing the Vent Load Lock button. You can tell if the load lock is done venting by looking at the space between the lid and the base, if there is a gap it is vented. Time takes 2 min.

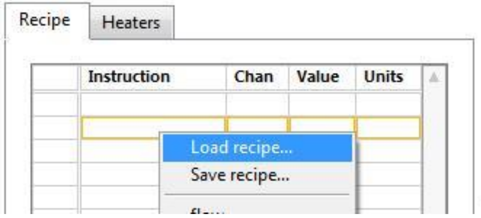
Fig 2. Vented load lock and wafer is in the correct position.

4. Load the wafer in the load lock and position the wafer in the center of the substrate holder. Glass slides can be used to help keep the wafer in place. Using new slides is fine, but make sure that they are cleaned before using them, a solvent rinse and dry is all that is needed. Make sure the lid and O-ring are clean and close lid.
5. Pump down the load lock by pressing the Pump Load Lock button

6. There will be a sound that it makes during the pumping step. If the sound goes longer than 15 seconds without going silent, stop the venting and try again.

B SETTING OPERATING TEMPERATURE

1. Select the temperature you want the process to run at and load the IDLE recipe for that temperature. Right click in the array area to have the menu open up click on the top line – Load recipe - To right click on the touch screen is to touch one area and stay there, after 3 seconds the screen will respond as if a right click was done.



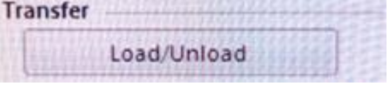
2. Press the button to start the process running.

3. After the temperature of the chamber has been reached or close to it, now stop the current recipe by pressing the button, then select yes.

4. If the time for the temperature change is needed you can log out of Badger while waiting, but make sure you have a reservation for the system during that time. Make sure you reserve the whole time you need. Also include your desired running temperature when you make the reservation so a user can leave have the correct IDLE recipe set for you at the temperature you need.

C TRANSFERRING WAFER INTO THE CHAMBER

1. Transfer the wafer into the chamber by going to the TRANSFER section.



and pressing the Load / Unload Button.

2. The wafer and holder will move from the load lock and will be put in the process chamber. Watch for transfer complete notice on top part of the screen. Look into the lid window to make sure the wafer/holder is in the chamber.

5. If the wafer is NOT in chamber **STOP** and contact MNC staff, and put the system in SHUTDOWN in Badger.

D SELECTING THE DEPOSITION FILM and STARTING

1. Select the recipe for the film that you want by selecting Load recipe... option again from the array area. Select the number of cycles that you want the process to run by selecting the line in the recipe **goto** step for number of loops needed. The **goto** step is close to the end of the recipe

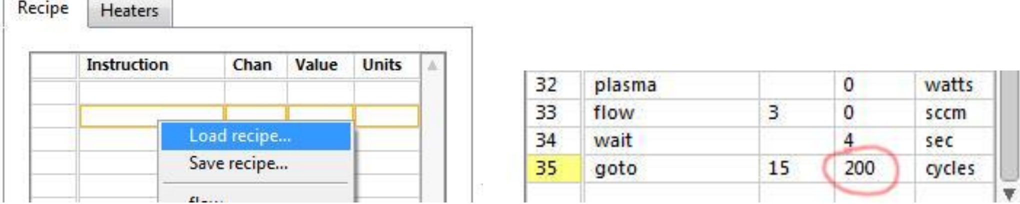


Fig 3. Loading recipe and adjusting the **goto** step for number of cycles.

2. To edit the cycle count you will need the touch screen keyboard to appear. On the left side of the screen is a small tab – touch it with the pointer and pull it to the right, drag it down to be off to the side so you can see the number of cycles to be edited. Remember to hit tab or enter on the keyboard to make your changes stay.

3. For some films it is best to have a longer time before deposition, this helps in improving the film quality. To have the sample waiting in the chamber and warm up for a longer time is good for some films, mainly nitride films. To make the warm up time longer – just do not start the recipe until later. Leave it in there and come back 30 or 60 min later and then start the recipe. This extra time allows the sample to warm up and to also outgas, removing some of the unwanted impurities. You must be logged into the system during this step. Contact MNC staff if you have questions..

Fig. 2. Notice the repeating wave forms, switching between a higher and lower peak.

4 It best to monitor the process from time to time. Making sure the graph looks correct and the temperature of the heaters are at the correct settings.

5 The amount of time left in the process can be checked by looking at the section labeled **Est. Time Remaining** and above that three time options can selected: **Est. Finish Time remaining** displays when the run will be completed.

6 Top line text will say **Process is Complete** when the recipe is done.

E UNLOADING THE COMPLETED WAFER.

1. Check the load lock to make sure it really is empty.

2. Move the wafer to the load lock by pressing the Transfer Load/Unload button. This will move it into the Load Lock. Watch for transfer complete notice on top part of the screen. Look into the lid window to make sure the wafer is in the Load Lock.

3. At this step you might want to leave the wafer in the load lock allowing it to cool. Venting the load lock with a hot wafer might cause the film on the wafer to be changed. Not only does the oxygen in the air might cause a problem but the fast change in temperature might cause film and substrate stresses that are unwanted. If you want to allow it to cool – just leave in there for some time, the hotter the wafer the longer you will need. You must be logged into the system during this time.

4. Vent the Load lock this is done by pressing the Vent Load Lock button. You can tell if the load lock is done venting by looking at the space between the lid and the base, if there is a gap it is vented. Time takes 2 min, do not open before the time is done.

5. Remove the wafer and close the lid and pump the load lock down by pressing the Pump Load Lock button. Make sure it is Pumped down !

6. Load the IDLE recipe with the correct value for the future temperature to be ran. Check Badger to see the temperature listed in the next reservation. Run the recipe by pressing the Start Recipe button to start the process.

7. The START button will change and it will then display ABORT.

8. Log out of Badger.

WARNING:

DO NOT EVER **REMOVE** any precursors from the system.
AVOID PRESSING **ABORT** unless there is a problem or you need to select new recipe.
DO NOT EVER **EDIT** a recipe other than the GOTO step.
DO NOT process any wafers that have been in the PEALD in Bay 1 Keller wet benches
DO NOT touch the screen with anything else than the stylus !

F Problems and Solutions

1. The LoadLock did not vent.

   Check that the normal status of the screen options are correct.
   Is the program running, the top button display " **Running** " ?

2. The normal program is not displayed. How can this be started.
   Contact MNC staff person

3. The system was shutdown, what can be done?
   Contact MNC staff person

4. The precursor is empty, now what?
   Contact MNC staff person

5. The deposit rate is much different than expected.
   Measure the film on another system, check refractive index of the film too. Confirm that the substrate is normal and have had known results. Set the time the graph displays to allow viewing of the whole run, any changes seen?

6. The system was shutdown, what can be done?
   Contact MNC staff person

7. System is waiting to pump below __E-4 while it is below that as in E-6
   It seems to not to clear this notice from the screen, you can just do the next step as normal, as if the notice was not there.

8. Blank
   Contact MNC staff person

G Appendix

Precursors used in the ALD system:

for Hafnium based films = Tetrakis(dimethylamino)hafnium **TDMAH** precursor at 75C

for Alumina based films = trimethylaluminum **TMA** precursor at room temp

for Titanium based films = tetrakis-dimethylamido-titanium **TDMAT** precursor at 75C

for Lanthanum films = [Tris (isopropyl cyclopentadienyl) Lanthanum] [La(iPrCp)3]

Gasses that are used in the ALD system are: O2, Ar, N2 and H2

Common issues to be aware of with the PEALD system ..

Make sure to include a bare Si sample to measure added thickness from ALD. Best to premeasure the Bare Si wafer using ellipsometer.

Lower temperatures process might have a higher deposition rate, see chart. The film quality and step coverage will be reduced, the exact amount has not been measured.

This is a 2nd Generation FIJI tool from Veeco/ UltraTech/Cambridge NanoTech,inc. called **FIJI G2**

To help in making the PEALD system easier to use we are try out something new.

We will NOT charge for any reservation to run the tool. This is to allow users to reserve time for the whole time they will need the system, this includes the time needed to change the temperature.

Rules – Remember – If a wafer is in the system you must be logged in on Badger.

1: Set your time you need for the reservation in Badger, including the time needed for the temperature change.

2: When you run the PEALD system you need to log in to Badger as normal and then if the temperature needs to change run the correct recipe. Log out of Badger when the temperature is adjusting, and put the " Temperature change in progress " sign in front of the monitor.

3: After the temperature has reached its setpoint **log back into Badger** (remove sign) and run the process as normal. When you are done check on Badger to see if another person has a reservation after you in the near future, if so check and see if they recorded the temperature they will be running at. If so select and run the 'Idle_xxx' for the temperature they need. Notice - this procedure might change in the future.

	50C	70C	100C	150C	200C	250C	270C	300C	Temp
Films									
Al_2O_3	1.65		1.5		1.23 to 1.26	1.1	1.08		
HfO_2		1.4	1.33		1.01	0.46			
TiO_2				0.51	0.49	0.45	0.50 to 0.67		
TiN									
AlN			3	1.85		0.65			
HfN						0.37			
La_2O_3					0.19	0.22			

Current dep rate of some of the films, all values are Å (Angstroms) per cycle or loop.
This is for information and help with a starting point of what range to expect.
As always make sure to include a measured native oxide Si sample to measure your ALD deposition results with.