

University of Minnesota Minnesota Nano Center

Standard Operating Procedure

Equipment Name: CHA Evaporator

Coral Name: ebevap-cha

Revision Number: 12

Model: SEC 600

Revisionist: L. von Dissen

Location: PAN Bay 3

Date: 04/13/2018

1 Description

The CHA Evaporator is a single source electron beam evaporator. It has a lift-off fixture and a planetary fixture for 4" wafers. It can run up to six different materials in a run. The lift-off fixture holds 9 wafers, and the planetary fixture holds 6 wafers each; since there are 3 planetary fixtures that can be used, a total of 18 wafers can be run at one time.

Note: For users that desire to run 6" wafers, MNC has a fixture available which can accommodate up to three 6" wafers at once. Ask appropriate MNC staff for details.

2 Safety

- a. Use the dark tinted, welder's glass provided when looking directly at the beam if it is too bright, or alternatively you can use tinted safety glasses.
- b. Take care when loading wafers and crucibles. Use a step stool if needed.
- c. The crucibles may be hot when unloading. Be careful when handling.

3 Restrictions/Requirements

- a. **DO NOT** leave the system during deposition for more than 10 minutes at a time and **ONLY** after the beam is verified to be in the pocket.
- b. During a FIRE or lab GAS alarm press **F12** on the SEIMENS computer to abort a run if the system is running. You can also press the **STOP** button on the Inficon computer to stop the process. The red **EMO** button should only be pressed if there is obvious danger such as fire, smoke, or a water leak.
- c. **Materials are restricted to those listed on the CHA Materials Parameter Sheet located in the CHA Log Book. See Staff for approval of other materials.**
- d. **The first 3 pockets are dedicated to Aluminum, Chromium, and Gold.**
- e. **Do not put scotch tape in the CHA! Only use "Kapton" (polyimide) tape**

4 Required Facilities

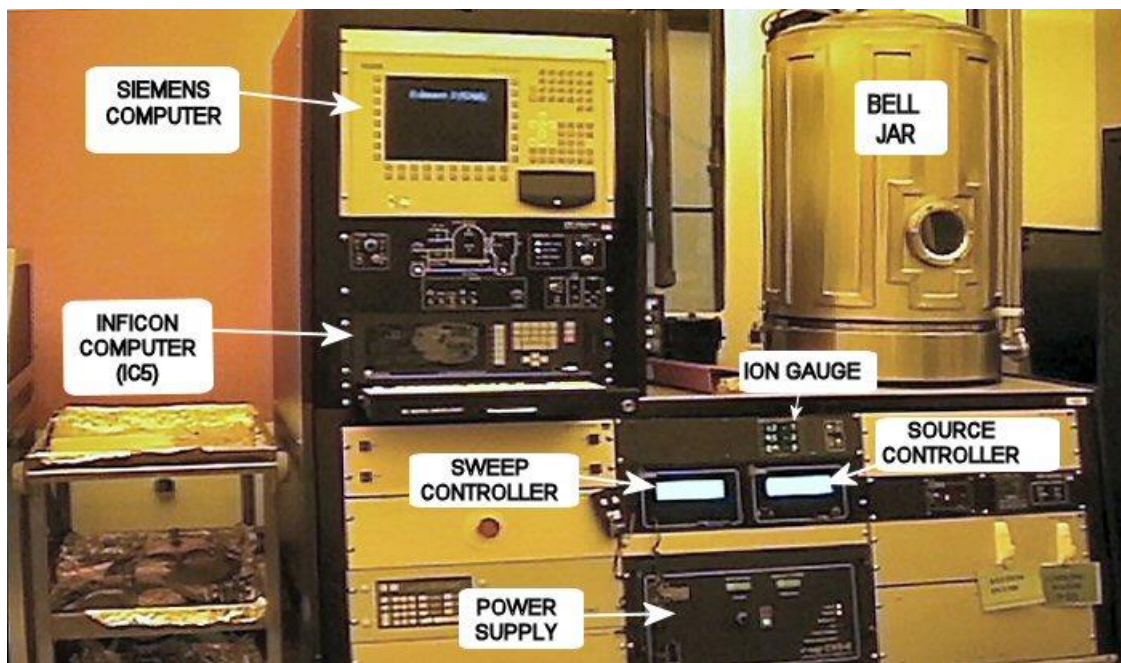
- a. Compressed air 80-90 psi
- b. Process water
- c. Nitrogen gas
- d. Electrical 208/240 VAC
- e. House Exhaust

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5 Definitions

- a. **INFICON:** The computer where recipes are written and stored.
- b. **SEIMENS:** The computer that is the operator interface. It is controlled by the keyboard and mouse pad as well as the touch panel surrounding the monitor. It has a picture of the bell jar as well as all the fixturing and major valves within the system. Buttons that are displayed are used to operate the system.
- c. **Gun:** This refers to the copper hearth that holds several metals to be evaporated.
- d. **Crucible:** This is a name used to describe each “gun” position (1 through 6).
- e. **Pocket:** This is another name used to describe each “gun” position (1 through 6).
- f. **Crystal / QCM:** This is the deposition monitoring crystal (QCM: Quartz Crystal Microbalance) which is used to monitor the deposition rate and thickness of the depositing film.
- g. **Equipment Overview:**



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6 Setup

- a. **Enable** the CHA with the Badger system.

7 Operating Instructions

a. VENT THE CHA

1. If the system has been pumping down for a while, and the pressure in the main chamber is at or below _____ Torr, a window will be on the screen that says “PUMPDOWN COMPLETE”.



If this “PUMPDOWN COMPLETE” message is not on the screen, then there should be a blue banner that reads:

“IG2 SETPOINT 1 IS BEING MADE”

In either case, to vent the system, press **F4** to go into standby. Click “**OK**” (or press **A**) to acknowledge the standby message when it appears.

2. Press **F3 (VENT)** to begin venting the CHA. The chamber animation on the screen will gradually fill up with a blue/green color indicating that the system is venting.
3. When the system has vented, a window will pop up saying that the vent cycle has completed. Left click on the “**RETURN TO STANDBY**” button (or press **A**). Wait about 10 seconds, and then click “**OK**” (or press **A**) when the “**SYSTEM IN STANDBY**” message appears.
4. An option will appear on the screen allowing you to raise the bell jar:



Press and hold **F5** to raise the bell jar. Keep holding/pressing **F5** until the bell jar is all the way up (it will stop moving when it is all the way up).

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5. When the bell jar has moved up, the “**BELL JAR DOWN**” option pops up, which will be used after you are finished loading/unloading the chamber.

BELL JAR DOWN F4

b. LOAD SAMPLES

1. With the bell jar open, load wafers onto the LIFT-OFF dome. Secure the wafers / holders to the dome with the clips. Fill any empty spots on the dome with samples holders. If using the PLANETARY fixture, the PLANETS should be loaded **before** hanging them on the planet pole fixture, and the load should be evenly distributed around the planet (i.e. equal spacing and weight distribution of wafers if possible).

c. LOAD SOURCE MATERIAL – POCKETS

1. The CHA has 6 pockets in the gun. The first 3 pockets have been dedicated to particular materials. **These dedicated pockets should always have the dedicated materials in them.** Verify that those dedicated materials are in the CHA if you are going to use them during your run. If the aluminum or chromium sources look low, there should be aluminum and chromium pellets in the cabinet to the left of the bell jar in their own labeled drawers. Place a couple of pellets in the appropriate pocket if needed (do not overfill beyond the height of the pocket). Contact an MNC staff member if you need help refilling or replacing any material.
 - Pocket 1: Solid Aluminum (no liner)
 - Pocket 2: Chromium disks (in graphite liner)
 - Pocket 3: Gold (Tungsten liner with two buttons underneath)
 - Pocket 4-6: Open for use, and can be loaded with any of the allowed materials.
2. When the system is vented, the gun will automatically rotate to pocket 1. Press **F7** to open the scissor shutter.
3. Every user must weigh the gold source (and the two buttons that normally lay underneath this gold source) before any run is performed. Press **F6** to rotate the gun to a different pocket. A window will pop up with different pocket numbers. Since the gold source is dedicated in pocket 3, select pocket 3 by pressing the number 3 on the keyboard/keypad or by clicking on “Pocket 3” on the Siemens computer screen using the mouse/track-pad. The gun will slowly rotate to the pocket you selected.

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4. Turn on the scale located to the left of the bell jar. Remove the gold source (and the two buttons that are underneath the gold source) from pocket 3 and place it on the scale. Record the combined weight of the gold source and the two buttons in the CHA log book. Place the two buttons back in to the center of pocket 3. Place the gold source back on top of the buttons in the center of pocket 3. If you plan to use platinum or palladium, weigh those sources as well and then record those weights in the log book (record the combined weight of the metal source and the two buttons).
5. If you plan to load or evaporate materials from other pockets in the gun, select those pockets on the Siemens computer screen and physically load them with the desired materials as needed. Left click on **DONE** (or press **A**) when finished loading all desired pockets.
6. Check the status/percent-life of the deposition monitoring crystal (QCM) on the **IC/5 Deposition Controller**. To do this, from the main "Operate" screen, press **F2 (Sensors)**. This will take you to the "Sensors" screen.

You will notice two similar rows of information. Generally, the top row pertains to the default QCM crystal, which is most often used (Crystal # 1). Within that first row of information, you will see whether or not the crystal is "ON" or "OFF". Whichever row has this "On" indication pertains to the crystal sensor that is currently being used. Under the column labeled "Life", you will see a number listed that pertains to the percent-life of that QCM crystal. This is a quality metric for the crystal which **INCREASES** over time as the crystal is coated with evaporated material. When the crystal life reaches 15 (%) or higher, it is generally changed at that time. To the right of the column labeled "Life", you will notice another column that shows the "Activity" of the QCM crystal. This is another quality metric for the crystal which tends to **DECREASE** over time.

If the crystal life is greater than or equal to "15", or if the crystal activity is less than "400", replace the QCM crystal. Change the QCM crystal as instructed by MNC staff (or ask MNC staff for assistance). Press **F6 (Operate)** to return to the main "Operate" screen on the **IC/5 Deposition Controller**.

7. Look in the bottom mirror of the periscope assembly to make sure that the pocket in the gun is visible in the reflection off the mirror. You want to do this to ensure that you can see the pocket with this mirror before closing the chamber and pumping down as the pocket visibility is critical once the e-beam is turned on.

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8. Check the chamber's internal hardware for peeling/flaking metal and inform MNC staff if there is a significant amount of build-up. The most important areas to check for metal peeling/flaking are the bottom of the scissor shutter and the area surrounding the pockets themselves. If the shutters or pockets are peeling/flaking, ask MNC staff for assistance so the shutters can be changed out and/or so the pockets can be quickly cleaned prior to pumping the system down. Peeling/flaking metal can contaminate the metal sources, so any cleaning needed must be taken care of BEFORE pumping the system down and running a deposition.
9. Press **F7** to close the scissor shutter.
10. Press and hold **F4** to lower the bell jar. Keep holding/pressing **F4** until the bell jar is all the way down and stops moving.

d. Run Recipe in Automatic

1. Press **F2 (PUMPDOWN)** to start the pump-down sequence. The chamber will pump down trying to reach the setpoint of **Torr**. Once this pressure is reached, the system will continue to pump, but you will now have the option to start your run. When this pressure has been reached, the following message will appear:



2. While you are waiting for the pumpdown to complete, you can program your recipe in the Inficon computer (IC/5 Deposition Controller).
See the “Appendix: IC5 Recipe Writing” on page 9 for instructions on how to program your process recipe.
3. Zero out the X and Y offsets on the MDC sweep controller for a safe initial beam position. The Program button, ‘**PRM**’, should already be highlighted (if not, press PRM). The beam position can be adjusted by pressing the corresponding X or Y axis button on the MDC sweep controller. Use the hand controller to adjust the X and Y offsets as needed during the run. For now, adjust them both to 0.0

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When the pumpdown has completed and you are ready to start, first make sure that all four interlock conditions have been met. You can verify this by checking to see that all four “Interlock Status” LEDs (located below the computer monitor) are lit. If any of them are not lit, please report a problem in Badger and do not use the tool.

4. Press **F1 (Automatic)** to start an automatic process run. If a lower pressure is desired, wait until that pressure has been reached before pressing F1.
5. A window will pop up asking for the IC5 process number that you want to run.



6. Click on the **UP** or **DOWN** arrow to select the recipe you want to run. Click **“OK”** (or press **A**). The process will start automatically. The gun turret will rotate to the correct pocket. Check to confirm that the pocket number is correct by looking at the “hearth controller” which is located to the right of the “Sweep Controller” and the “Source Controller”. There should be a red digital number displayed (1 through 6).
7. Observe the beam inside the chamber. If it is too bright, use UV protective glasses or a piece of tinted glass (located on the CHA metal supply cabinet). The Program button **‘PRM’** should already be highlighted (if not, press **PRM**). Adjust the beam position as needed using the MDC sweep controller. The beam can be adjusted by pressing the corresponding X or Y axis button on the MDC sweep controller. Use the hand controller to adjust the beam by pressing the up or down arrow buttons. Be sure to look inside the chamber at the beam while you are changing the X or Y axis settings to determine where the beam is moving.

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8. When the target thickness has been reached, the shutter will close automatically and the beam will shut off. A message will pop up asking if you want to vent the chamber. Wait at least 10 more minutes for the sources to cool before venting.

After you are finished cooling the metal source, vent the chamber by left clicking on **YES** or pressing **F9**. When the system is vented, a message will pop up saying "PROCESS COMPLETE". Press **F4** (or press **A**) to enter standby. Wait about 10 seconds, and then click "**OK**" (or press **A**) when the **SYSTEM IN STANDBY** message appears. Press and hold **F5** to raise the bell jar, and then unload your wafers.

9. If you loaded any sources in to pockets 4, 5, or 6, remove them from the system. To do this, press **F7** to open the scissor shutter. Then press **F6** to rotate the gun to a different pocket. A window will pop up with different pocket numbers. Select the desired pocket(s) by pressing the appropriate number on the keypad or by clicking on the desired pocket number on the Siemens computer screen using the mouse/track-pad. The gun will slowly rotate to the pocket you selected.

Note: If you used the gold source during your run (or platinum or palladium), you need to weigh the precious metal source (and the two buttons) one more time before closing the bell jar. Record these weights in the CHA log book.

e. Idle State: The CHA is ALWAYS to be left pumped down.

1. Press and hold **F4** to lower the bell jar. Keep holding/pressing **F4** until the bell jar is all the way down and stops moving. Then press **F2** (**PUMPDOWN**) to pump the system back down. The system will do a soft roughing pump-down for 1-2 minutes, and then it will switch to a regular roughing pump-down for several minutes. The chamber animation on the screen will gradually change from green to gray indicating that it is pumping. When the cross-over pressure setpoint is reached, the roughing valve will close automatically and the system will then measure the "rate of rise" (i.e. leak-up rate). If the system is satisfied with the "rate of rise" test, it will automatically cross over into high vacuum and you will hear the high vacuum valve open.
2. Stay with the system until "**IG2 SETPOINT 1 IS BEING MADE**" is displayed on the screen. (If this does not happen within 10 minutes after starting the pump-down, contact an MNC staff member). After this, you can disable the CHA in the Badger system. If you did use the gold source during the run, you will need to calculate how much gold you used (in milligrams). An example is listed in the table at the top of the next page.

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Beginning Weight	172.53 grams
Ending Weight	170.41 grams
Total Gold Used (in milligrams)	2.12 grams = 2120 milligrams

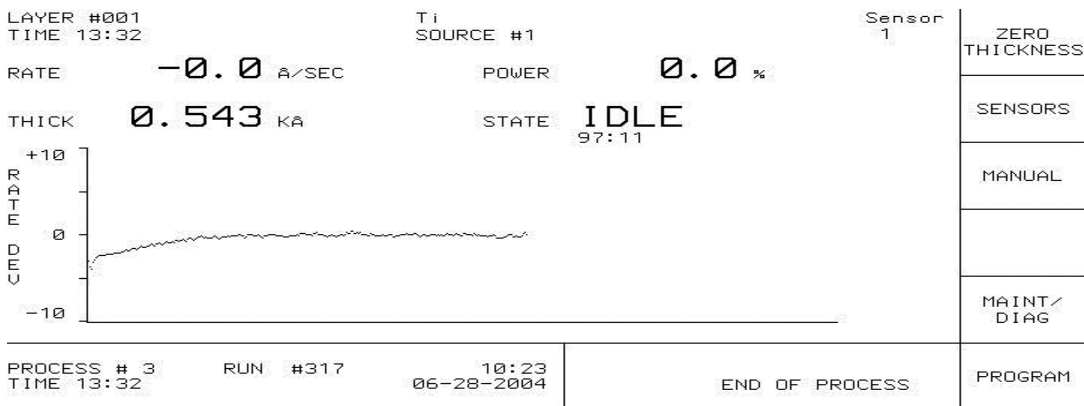
In Badger, click on the “**Supplies**” menu, and select “**Check Out**”. You will then notice a supply list that appears on the left side within the Badger window. Scroll down the list and click on “evap gold” (or “evap platinum” or “**evap palladium**” if those were used). Then you will see that supply name appear in the “**Supply**” field box. In the “**Quantity**” field box, enter the number of milligrams of gold (or Pt or Pd) that was used (which was 2120 mg in the example above). Click on “**Save & Close**”.

3. Finish filling out the log book (e.g. your name, the date, your materials, pocket numbers, deposition rates, thicknesses, percent crystal life, etc.).

8. Appendix: IC5 Recipe Writing

a. WRITING A PROCESS RECIPE (INIFICON COMPUTER)

1. Shown below is the INFICON main “Operate” screen. After programming the INFICON, pressing **F6** repeatedly will eventually return the USER to this main “Operate” screen.



b. Defining Materials

1. To check or modify the parameters; from the main “Operate” screen (which looks like the image on page 9), press **F6 (PROGRAM)** to enter the “Program” screen. Press **F1 (MATERIAL DIRECTORY)** to access the “Material Directory”, which should look similar to the following image (at the top of the next page).

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MATERIAL DIRECTORY				DELETE MATERIAL
1. Cr	7. Pd	13. Ge	19.	
2. Ti	8. Pt	14.	20.	
3. Al	9. Au	15.	21.	
4. Ni	10. Ag	16.	22.	
5. USER	11. Cu	17.	23.	
6. Ti	12. Mo	18.	24.	MATERIAL
0. 0 Å/SEC 0. 546 kA 0. 0%				END OF PROCESS
				PROGRAM

- Move the cursor to the material that you want to edit or check values for. Press **F5** to access that material's parameters which will bring you to a screen that looks similar to the following image (below). **Do not add or delete materials.** MNC staff will do this if needed.

MATERIAL 6 - Ti			Page 1 of 3	PAGE FORWARD
Density	4.500	GM/CM^3		
Z-Ratio	0.628			
Source	1	(1-6)		
Control Loop	0	(0=Non-PID, 1=PI, 2=PID)		
Process Gain	10.000	Å/SEC/%PWR		
Master Tooling	26.1	%		
Recorder Output	0	(1-6, 0=None)		
Recorder Function	0	(0=Rate 100Å/S, 1=Rate 1000Å/S, 2=Thick 100 Å, 3=Thick 1000 Å, 4=Rate Dev ±50Å/S, 5=Power)		
Crystal Quality	0	(0-9)		MATERIAL LIBRARY
Crystal Stability	0	(0-9)		
-0. 0 Å/SEC 0. 546 kA 0. 0%			END OF PROCESS	MATERIAL DIRECTORY

- Modify or check the parameters:** Move the cursor to the parameter you want to edit; enter the value desired using the keypad and then press **'E'** to save the number. The values below are the default values for page 1 of all materials. The Density and Z-ratio values will be different for each material. The **Source** is always set to '1'. The tooling factor (i.e. "Master Tooling") may be adjusted if needed although it should be very accurate. Check the "Material Parameters Sheet" for the current value. All of the other parameters (on page 1) should already be set to zero.

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- Press **F1 (PAGE FORWARD)** to access page 2 which will look similar to the following image (below).

MATERIAL 6 - Ti			Page 2 of 3
Maximum Power	25.0	%	PAGE FORWARD
Soak Power 1	7.0	%	PAGE BACK
Rise Time 1	1:30	MM:SS	
Soak Time 1	1:00	MM:SS	
Soak Power 2	9.0	%	
Rise Time 2	1:00	MM:SS	
Soak Time 2	1:00	MM:SS	
Auto-Soak2	NO	YES/NO	
Delay Option	0	0=None,1=Shutter,2=Control,3=Both	
Feed Power	0.0	%	
Feed Ramp Time	0:30	MM:SS	
Feed Time	00:00	MM:SS	
Idle Power	0.0	%	
Idle Ramp Time	5:00	MM:SS	
0.0 A/SEC 0.546 kÅ 0.0%			END OF PROCESS
			MATERIAL DIRECTORY

See the Materials Parameter Sheet (located on the first page of this SOP booklet) in order to verify that the following parameters are set properly:

Maximum Power, Soak Power 1, Rise Time 1, Soak Time 1, Soak Power 2, Rise Time 2, Soak Time 2

The **Auto-Soak 2** should be set to NO. The **Delay Option** is not used, so it is set to 0. **Feed Power** refers to the power that the CHA will ramp down to after your thickness is reached. Set this to 0. The **Feed Ramp Time** is the time allotted for ramping down the beam power when finished with that layer in the process (should be set to 00:30). The **Feed Time** should be set to 00:00. **Idle Power** should be set to 0.0. **Idle Ramp Time** is the time allotted for cooling the source prior to advancing to the next step in the process. See the “Material Parameters Sheet” to check this value, since different materials require different cooling times.

- If any of the parameters do not match those listed in the Material Parameters Sheet, move the cursor to the parameter that needs to be changed, then enter the correct value using the keypad, and then press ‘**E**’ to save the number entered. Press **F6 (MATERIAL DIRECTORY)** to return to the “Material Directory”.

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c. Defining a Process

- From the “Material Directory” screen, press **F6 (PROGRAM)** to enter the “Program” screen. From the “Program” screen, press **F2 (PROCESS DIRECTORY)** to access the “Process Directory” which will look similar to the following image (below).

PROCESS DIRECTORY		Active Process is 3 Layer to Start is 1	PAGE FORWARD
PROCESS 1:	Au		
PROCESS 2:	Ge, Au, Ni, Ti, Au		
PROCESS 3:	Ti		
PROCESS 4:	Cr, Ge		
PROCESS 5:	Cr, Au		
PROCESS 6:	Cu		SELECT ACTIVE PROCESS
PROCESS 7:	Cr		
PROCESS 8:	Ti, Cu		PROCESS
PROCESS 9:	Ge		
-0.0 Å/SEC 0.546 kÅ 0.0%		END OF PROCESS	PROGRAM

- Move the cursor and/or press **F1** or **F2** as needed to scroll to the desired process number (1 through 50). You can pick any process number that you want and program or change it as needed. Once the cursor is on the process you want to edit, press **F5 (PROCESS)** to access that “Process” recipe, and then you will see a screen that looks similar to the image (below).

PROCESS 4		Page 1 of 2 Layers Defined 2				PAGE FORWARD
		Layer 1	Layer 2	Layer 3	Layer 4	
Material Index	(1-24)	Cr 1	Au 9			
Rate	Å/SEC	2.0	2.0			
Final Thickness	kÅ	0.050	0.500			
Thickness Limit	kÅ	0.000	0.000			
Time Limit	MM:SS	00:00	00:00			
Co-Deposition	YES/NO	NO	NO			
Ratio Control	%					
Cal Status						
Cross Talk	%					
RateWatch Time	MM:SS	00:00	00:00			LAYER EDITING
RateWatch Accuracy	%	2	2			
Crucible	(1-64)	1	3			
0.0 Å/SEC 0.141 kÅ 0.0%		END OF PROCESS				PROCESS DIRECTORY

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3. Move the cursor to the parameter you want to edit; enter the value desired using the keypad and then press '**E**' to save the number. Each layer in the process requires you to program the following four parameters: "**Material Index**", "**Rate**", "**Final Thickness**", and "**Crucible**".

The "**Material index**" refers to the material you are going to evaporate and it is represented by a number (1 through 24) which corresponds to the material number in the "Material Directory". This "Material Index" is also listed as the "Material number" on the "Material Parameters Sheet" located on the first page of the SOP booklet.

The "**Rate**" refers to the deposition rate that you want for that material (in Å/sec).

The "**Final Thickness**" is the desired film thickness in units of kÅ.
(e.g. 54 nm = 540 Å = 0.540 kÅ).

The "**Crucible**" parameter refers to the pocket number (1 through 6) that the material is located in (i.e. where it is stored in the gun/hearth). If more than one process layer/film is desired, use the arrow keys to move the cursor over to the next column in the process and continue programming until all desired layers are programmed in the process.

4. To delete a layer, press **F5 (LAYER EDITING)** and this will move the cursor up to the layer number. Use the left or right arrow keys to move the cursor over to the layer you want to delete, and then press **F5 (TAG)** to "tag" (i.e. select) the layer. Press **F2 (DELETE)** to delete the layer. Press **F6 (PROCESS)** to exit the layer editing option and return the cursor down below to the process parameters.
5. Press **F6 (PROCESS DIRECTORY)** to return to the "Process Directory". You should notice that the process number that you just programmed is now up-to-date with your current film layers displayed. Press **F6 (PROGRAM)** to return to the "Program" screen. Press **F6 (OPERATE)** to return to the main "Operate" screen.
6. Now that you are finished programming your recipes, go back to the middle of **page 6** and continue reading and following those instructions (waiting for the pumpdown, etc.)