

University of Minnesota Nano Fabrication Center

Standard Operating Procedure

Equipment Name: Temescal E-Beam Evaporator

Coral Name: ebevap-temescal

Revision Number: 3

Model: Temescal

Revisionist: L. Matzke

Location: Bay 3

Date: 05/13/08

1 Description

The electron beam evaporator is used to deposit thin films onto substrates. Evaporation is done under a high vacuum in a belljar chamber. Evaporation is achieved by heating a source with an electron beam. As the source material evaporates, it forms a thin film on the samples.

2 Safety

- a. If the building alarm sounds anytime during a run, TURN OFF THE POWER SUPPLY CIRCUIT BREAKER and leave immediately.
- b. When viewing the e-beam inside the chamber, wear UV glasses or use the chamber window Polarizer to minimize the light, to prevent eye damage.
- c. If there is water leaking out of the machine, or any immediate danger, press any of the red EMO buttons (one located on the bottom of the equipment control board stack, and one built in on the front-left of the temescal)

3 Restrictions/Requirements

- a. Must be a qualified user on ebevap-temescal.
- b. Materials are restricted to those found on the material parameter sheet. Any other materials besides those listed must be approved by NFC staff.
- c. Fill out the log sheet before/after your run.

4 Required Facilities

- a. Process chilled water

5 Definitions

- a. Ion gauge -- measures the pressure of the chamber while under high vacuum (While using the Cryo Pump)
- b. Thermal Couple 2 (TC2) -- measures the chamber pressure while under low vacuum (while using the Roughing Pump)
- c. Hearth -- located inside the chamber consisting of 4 pockets which holds the materials to be evaporated.
- d. Lift-off Fixture -- the fixture that holds your substrates inside the chamber (rotation optional).
- e. Shutter -- A metal paddle that either exposes or blocks the source metals from your samples.
- f. View Shutter -- A shutter located by the front of the bell-jar that, when open, allows you to see the source through the chamber window.

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Setup

- a. Close the **CRYO ISOLATION** valve, then wait at least 5 seconds.
- b. Turn the **ION GAUGE FILAMENT** off by ‘bumping’ the switch up (assure it is off by checking that the LED by the switch is not lit).
- c. Open the **VENT** valve.
- d. The bell jar will reach atmospheric pressure and be ready to open in approximately 5 minutes. Monitor the pressure on the vacuum gauge located to the left rear of the chamber. When the vacuum gauge has reached zero, wait a minute or two then lift the bell jar cover fully open (Note: it can be very heavy to lift, so if necessary, ask assistance from another user or staff member).
- e. Close the **VENT** valve (you can do this as soon as the chamber lid can open).
- f. Open the **SHUTTER** (by flipping shutter toggle switch up on control board).
- g. Load the sources to be evaporated into the **HEARTH**. There are 4 pockets available for use (Note: you can choose/indicate the pocket number by using the hearth rotation controller located to left of the chamber). To make things easier to remember, I would load the sources in the order they will be deposited (i.e. Layer 1 in Pocket 1, Layer 2 in Pocket 2, etc.).
- h. Close the **SHUTTER**.
- i. Load the substrates onto the **LIFT-OFF FIXTURE** with the samples facing down. There are various holders/clips available to accommodate different sized substrates, located in the black plastic boxes on top of the Power Supply stack.
- j. Turn on the **PROGRAM BOARD**. The **T/X** light should blink 2 or 3 times, and then stop. If the light continues blinking, the thickness monitoring crystal needs to be replaced. To confirm this, press and hold down the **T/X** light, and check the second group of numbers displayed in the center (if >25, replace the crystal).
- k. If needed, prior to closing the bell jar, align the markings on the very top of the lift-off fixture then lower slowly. If the chamber doesn’t close all the way, raise the bell jar cover and readjust the lift-off fixture to the markings and try again.
- l. Make sure the **VENT** valve is closed (if it was still open, close it, wait 5 seconds to be sure). Flip up the **ROUGHING PUMP** valve toggle switch to open the roughing valve and start the initial pump down.
- m. Wait until the pressure on the TC2 gauge reads 200 (μm - Hg) or less.
- n. Once 200 μm -Hg (a.k.a. 200 mTorr) has been reached, close the **ROUGHING PUMP** valve, wait 5 seconds, and then open the **CRYO ISOLATION** valve.
- o. Turn the **ION GAUGE FILAMENT** on by ‘bumping’ the switch up (the LED by the switch will now be lit)
- p. Wait until the pressure drops to at least 6.0×10^{-6} Torr prior to deposition (while you are waiting for the desired pressure, you can program your parameters).
- q. The word **PROGRAM** should be lit up near the right of the program board.
- r. The **CONTROL POWER** should be set to **AUTO**.
- s. **Layer 1** will be lit to the right of the ZERO/START/STOP buttons. This indicates you will be entering parameters for this particular layer number.
- t. You **MUST** press the red **ENTER** button after each parameter value is entered.
- u. **RISE TIME**: is the time spent to ramp from zero power to **SOAK 1 POWER**.
- v. **SOAK TIME 1**: is the time spent at **SOAK 1**.

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- w. SOAK TIME 2: half of this time is spent ramping from SOAK 1 POWER to SOAK 2 POWER, the other half is spent at SOAK 2 POWER.
- x. RATE: this is the evaporation rate in Å/sec. Do not go above 5.
- y. TOOLING: A calibration ratio for proper thickness measurement by the crystal. This number is posted on the front of the chamber; Tooling = 67.0%
- z. SOAK 1 POWER: should be set 1 – 2% below SOAK 2 POWER. The purpose of both SOAK 1 and SOAK 2 are to evenly/gradually heat the source. This will allow the metal to outgas and also heat evenly, so when the evaporation begins, it will be uniform.
- aa. SOAK 2 POWER: should be set 1 – 2% above SOAK 1 POWER.
- bb. MAX POWER: this setting prevents the beam from exceeding this power set point (even if the desired deposition rate is NOT achieved), to prevent damaging the equipment, or your metal source.
- cc. IDLE POWER: always set at zero (0).
- dd. GAIN: this controls the rate stability. The lower the gain, the more stable the deposition rate (but lower GAIN values may take up more time in your process if you have a material that is hard to stabilize like Pt). Typical gains range from 1 to 10, with 2 being used the most often.
- ee. THICKNESS 1: This is the thickness that you wish to evaporate in kilo-angstroms. Example: 5.000 = 5000Å. THICKNESS 2 is not used.
- ff. DENSITY and Z-RATIO are characteristics of the evaporate. These numbers are posted on the equipment control board stack. For all other films, see the process technician to check their Film Evaporation Reference.
- gg. SOURCE/ SENSOR: always set at 1/1.
- hh. If you have 1 or 2 more layers to program, you can program them by pressing **Layer 2**, and/or **Layer 3**, and program the parameters for each layer, etc. If you use this option, you should program the layers in the order they will be deposited to avoid making mistakes. Using the **Layer 1, 2, and 3** option can allow you to save time by programming/saving up to 3 layers at once.
- ii. Press the KEYBOARD switch to LOCK. The PROGRAM light will turn off.
- jj. Wait for the belljar to pump down to the desired vacuum by observing the Ion Gauge. Maximum allowable pressure for deposition is 6.0×10^{-6} Torr, so we recommend going to a lower pressure if time permits ($\leq 2.0 \times 10^{-6}$ is ideal).

7 Operating Instructions

- a. Make sure the Hearth is set to the correct pocket. Switching the Hearth Rotation Controller dial to the desired number will determine this.
- b. Open the water valve located inside the left door under the Belljar. Turn the lever up.
- c. Flip the circuit breaker to the **H.V. POWER SUPPLY** up.
- d. Turn the **SOURCE CONTROL** power on.
- e. All four interlocks should light GREEN. If not, the beam cannot be turned on.
 - Water
 - Transformer
 - Vacuum
 - Doors (closed)

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- f. Turn the **SWEEP CONTROLLER** on, located on the back panel of the unit.
- g. Turn the **HIGH VOLTAGE** on. Press the **H.V. ON** button.
- h. Turn the **FILAMENT CURRENT** on. Press the **FIL-ON** button.
- i. Turn on the sweep controller current by pressing **ON**.
- j. To change any of the parameters, press **PGM**. Press the corresponding parameter you wish to change and press the up or down arrow until the desired value is selected. Zero out the X and Y offsets for a safe, initial position for the beam.
- k. 'Pattern' should be set to 1 (circle)
- l. Change the sweep amplitude to the value listed on the material parameter sheet.
- m. Turn the **ROTATION** on (Toggle switch up on equipment control board stack).
- n. Start the AUTO CYCLE by pressing **START**.
- o. Open the View Shutter to see inside the bell jar. Once the beam is visible (definitely at SOAK 2), center the beam on the SOURCE by adjusting the X and Y offsets on the **SWEEP CONTROLLER**. The beam should not touch the crucible. If evaporating nickel or copper, do not turn the amplitude above 0.4 – nickel is very volatile and will spark, etc. *You can use the handheld control to adjust the sweep parameters while you are looking in the chamber (this is advised)*. Check the source periodically, as it should not be bubbling or moving around. If it is, it means the source is about to EXPLODE (if this is the case, hit the **STOP** button, and get an NFC staff member for assistance).
- p. When the cycle reaches the **DEPOSIT** step, OPEN the **SHUTTER** to expose the samples to the source evaporate. If this is not done, the shutter will be destroyed.
- q. After the desired thickness is reached, the beam will automatically stop. Close the **SHUTTER** and press **STOP** on the **DEPOSITION CONTROLLER**.
- r. If you are going to evaporate from another source, wait 5 minutes before rotating the hearth to a new pocket, to allow the source to cool and prevent any damage to the o-ring. You can enter the parameters for the next source on the PROGRAM BOARD and begin evaporation. Or, if you already programmed the other layers in **Layer 2**, or **Layer 3**, then press **Layer 2 or 3** to select that programmed layer and hit **START** (Be sure to re-adjust the SWEEP CONTROLLER parameters for this new material such as X/Y offsets, sweep amplitude, etc.).
- s. Turn the **PROGRAM BOARD OFF** when done depositing all layers.

8 Shutdown

- a. Press the **FIL-OFF** on the **SOURCE CONTROLLER**.
- b. Press the **H.V. RESET** on the **H.V. POWER SUPPLY**
- c. Turn the Circuit Breaker off located on the **H.V. POWER SUPPLY**.
- d. Turn the **SOURCE CONTROLLER** off.
- e. Turn the **SWEEP CONTROLLER** off.
- f. Turn the **ROTATION** off.
- g. **IMPORTANT: WAIT 10 MINUTES BEFORE YOU TURN THE COOLING WATER OFF!!! DO NOT VENT** until the cooling water is off!!!
- h. Close the **D.P. Isolation** valve.
- i. Open the **VENT** valve (Assure the water is turned OFF before doing this!).
- j. The bell jar will reach atmosphere and be ready to open in approximately 5 minutes. You may monitor the pressure on the vacuum gauge located to the left rear of the belljar.

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- k. Remove the substrates and the sources.
- l. Prior to closing the belljar, align the markings on the lift-off fixture then lower slowly. If you meet any resistance, raise the belljar and readjust the lift-off fixture to the markings and try again.
- m. Pump down the belljar by following the PUMP DOWN procedure (Section 6- L, M, and N).

9 Problems/Troubleshooting

- a. The system is not pumping down- If the samples have moisture on them, i.e. water or photoresist, the chamber will take longer to reach the desired pressure. If the samples are dry, there may be particles on the O-ring preventing a good seal. Vent the system and wipe off the O-ring with a wipe soaked with either methanol or IPA (DO NOT USE - ACETONE) and try to pump down the chamber again.
- b. The T/X light keeps on flashing when the Program Board is turned on- This indicates that the crystal that monitors the thickness needs to be changed by a staff member or the replaced crystal has been installed improperly.
- c. The chamber lid will not close- If you meet any resistance, raise the belljar and readjust the lift-off fixture to match up the indicated markings and try again.
- d. The metal will not evaporate- This may happen for a number of reasons:
 1. Check to see if the hearth has been rotated to the correct pocket/material.
 2. Re-check the parameters entered on the program board. Flip the rocker switch back to Program and press the corresponding white buttons and check the original entries. If an entry is not correct and needs to be changed, press the CLEAR button. Enter the correct parameter and press the red **ENTER** button. (Flip the keyboard switch to **LOCK** to save these new parameters).
 3. If the cooling water has been left on for an extended period of time without evaporating any metal, the source metal may be too cold. Turn off the cooling water for at least 30 minutes to allow the metal to warm up and retry the evaporation process again.
- e. There is no beam visible when program board has reached SOAK POWER2- This may happen for a number of reasons:
 1. The **SWEEP CONTROLLER** has most likely been set too far in either the X or Y position. On the **SWEEP CONTROLLER**, press **PGM**. Press the X offset and return it to 0.0 by moving the arrow in the up or down direction. Return the Y offset to 0.0. At this point, the beam should be in view and any further X/Y offset adjustments should be minimal (you should NEVER have to exceed ± 2.0 on the X/Y offsets to center the beam). If problems persist, press the **STOP** button on the **DEPOSITION CONTROLLER** and notify the process staff for assistance.
 2. With the **View Shutter** open, advance the old, metallized shutter film by rotating the dial **CLOCKWISE** so there is new, clean, transparent film covering the inside of the view shutter (you should NEVER have to turn the dial more than a whole 360° turn; if you do, you are wasting film).
 3. Make sure that the polarizer on the chamber window is not rotated to minimize the light coming through; try rotating it 45°.