

# Standard Operating Procedure for the Thermionics E-Beam Evaporation System

## Version: 5 OCT 2023



**Read and understand this SOP completely before attempting to operate this tool. Training by KUNF personnel is required before use.**



### 1. Utility Requirements

- a. System power is supplied through the large switch box on the wall, to the left of the system, as well as by power outlets behind the tool. Disconnect power to the e-beam guns by moving the switch handle to the lower position.
- b. The evaporator currently uses three compressed gasses to operate: Nitrogen, Oxygen and Compressed Dry Air.
  - Nitrogen, the purge/vent gas, is supplied by a UHP/Plus grade (99.9993% pure) T-sized tank located in the chase behind the tool. This gas is internally regulated to 40 psig. Before proceeding, ensure that the tank (not line) pressure is greater than 500 psig (5000 kPa)
  - Oxygen is used as a partial-pressure process gas. It is supplied by a UHP-Plus (99.9993% pure) T-sized tank located in the chase behind the tool. The line pressure is regulated to 5 psig (34 kPa; 0.34 bar) at the tank. Before proceeding, ensure that the tank (not line) pressure is greater than 500 psig (5000 kPa).
  - Compressed Dry Air, which is house-supplied (90 psig), is used to open the various valves and shutters. The gas is supplied by a 1" stainless line located in the chase behind the tool.
- c. Cooling water is house-supplied from lines in the chase behind the tool. This water is filtered internally by a 5 micron sediment filter.

### 2. General Information and Precautions

- a. **The High Voltage Power Supply outputs up to 6000 W (600 mA at 10,000 Volts)!**  
Do not attempt to operate this tool with the interlocks disabled.
- b. In an emergency, pull down on the switch handle—located on the wall to the left of the tool—to disconnect power to the e-beam gun power supply.
- c. The Inficon XTC/2 Deposition Monitor connected to the system is used in this SOP to control the shutters for accurate film thickness deposition. Consult *Appendix A: Servicing and Programming the Inficon XTC/2 Deposition Monitor* when instructed in this SOP.
- d. Materials available for deposition using this tool have different properties that require different settings and techniques for successful evaporation. Consult *Appendix B: Deposition Material Reference Chart* for details.
- e. This E-beam evaporator is fitted with three hearths, and a power supply that can power electron beams to all three hearths simultaneously. The required methods for successful simultaneous material deposition are beyond the scope of this SOP.
- f. Hearth #1 has a turret with four crucible pockets. A knob on the front of the chamber is used to rotate the turret. When loading multiple crucible liners, make note of their positions. **Note:** the knob and turret rotate in opposite directions.

- g. When the electron beam is firing, always use the provided safety goggles when looking into the chamber.
- h. When making “Output Voltage” and “Emission” adjustments, always rotate the dials SLOWLY to avoid arc faults or burning out the filament.
- i. Do not power on the Source Controllers while the chamber is above **5.0 E -5 Torr**. Doing so could possibly result in a burned out filament.

### 3. Putting a Substrate in the Chamber for Deposition

- a. Log in to the logging computer.
- b. Open the cooling water valves. The valves, located in the chase behind the tool, are open when the handles are parallel with the water lines and closed when they are perpendicular.
- c. Power on the system by flipping up the double toggle switch on the front of the machine, located in the middle of the lower panel.
- d. If they are not already on, turn on the bell jar and vacuum pump controls, and the vacuum gauge controller using the toggle switch at the top-left of the machine.
- e. Raise the bell jar:
  - i. Hold the toggle switch in the UP position until the bell jar has reached its maximum height.
  - ii. At the back-left of the tool, insert the lock pin into hoist tower assembly to prevent the bell jar from falling in the case of a mechanical failure.
- f. Remove the sample holder from inside the bell jar:
  - i. push up slightly
  - ii. rotate it counter-clockwise about 30 degrees
  - iii. pull straight down
- g. Secure your sample(s) to the holder, and replace the sample holder in the bell jar.
- h. Check the glass slides in the view ports. If they are difficult to see through, replace them with new ones.
- a. Turn ON the **Inficon XTC/2 Deposition Monitor**, and, according to **Appendix A**, check the **LIFE** of the crystal. Change the crystal if necessary.
- i. Open **Source Shutter A** using the toggle switch on the front of the machine.
- j. Rotate the crucible pocket knob on the front of the lower chamber section until the desired, empty pocket in the **Source A** hearth is available. Then, insert a loaded crucible liner into the selected crucible pocket. Add pellets to the crucible liner if necessary.



**The crucible liner must be at least 20%, but not more than 80%, full. Failure to follow this guidance could result in permanent damage to the source power supply.**



- k. Repeat the step above for each material being deposited.
- l. Close the shutter using the toggle switch.
- m. Clean the bell jar o-ring and the mating surface of the lower chamber section with an IPA-soaked wiper.
- n. Remove the hoist lock pin from the hoist tower assembly, then completely lower the bell jar using the control toggle switch.

- o. Turn on the vacuum pumps by switching the **MECHANICAL PUMP** toggle to the **ON** position.
- p. According to **Appendix A** (Inficon XTC/2), set the film #, final film thickness, layer # and, if necessary, density and z-ratio values for the materials that you have loaded into the hearths.
- q. The system is ready for deposition once the chamber pressure is below 5.0 E -5 Torr. This takes approximately 30 minutes.

#### 4. Deposition of Films

- a. Ensure that the base chamber pressure is less than **5.0 E -5 Torr**, as indicated by the **338 Vacuum Gauge Controller** on the top front panel of the machine. Vacuum levels in the -6 Torr range and lower will ensure better results. **Note:** Some materials *require* a deeper base pressure; consult **Appendix B: Deposition Material Reference Chart** for details.
- b. Ensure that the **EMISSION** knob for **Source Controller 1** is turned fully counter-clockwise.
- c. Ensure that the **OUTPUT VOLTAGE ADJUST** knob on the **SEB-06 e-Gun Power Supply** is turned fully counter-clockwise.
- d. Ensure that the **XYS controller** for Source Controller 1 is powered **OFF** and that the **AMPLITUDE** and **FREQUENCY** knobs are turned fully counter-clockwise.
- e. On the front panel for **Source Controller 1**, turn the **key switch** to the **MAN** (manual) position. Ensure that all of the **INTERLOCKS** LEDs—including the green **READY** LED—are illuminated.
- f. Power on the **SEB-06 e-Gun Power Supply** at the bottom of the source control panel using the **MAINS** triple toggle switch. The **MAINS ON** and **INTERLOCK** LEDs should be illuminated.
- g. Wait 2 minutes for the power supply to warm up.
- h. Turn on Substrate Rotation using the toggle switch next to the shutter controls.
- i. Consult **Appendix B: Deposition Material Reference Chart**, and:
  - i. If you haven't already, according to **Appendix A** set the film #, final film thickness, and layer # values for the materials that you have loaded into the hearth.
  - ii. If necessary, turn on the substrate heater.
  - iii. If necessary, continue to let the system pump down to a deeper base pressure (see the **Notes** column).
  - iv. If necessary, after the prescribed base pressure has been reached, bleed in O<sub>2</sub> using the green-handled needle valve (on the right side of the chamber base) according to the **Notes** column. Open the valve by turning the knob counter-clockwise.



**If you just completed a deposition, wait 5 minutes for the crucible to cool before rotating the turret.**



- j. If necessary, rotate the crucible pocket knob on the front of the lower chamber section until the desired pocket in the Source 1 hearth is exposed.

- k. Check the filament for Source 1 by holding down the **FILAMENT CHECK** button for a few seconds. The filament in the chamber will glow if it is intact.



If the filament does not glow, contact  
KUNF personnel for assistance.  
**DO NOT PROCEED!**



- l. On the **SEB-06**, press the white **HV ON** button, then SLOWLY (pause if brief arcing occurs) turn the **OUTPUT VOLTAGE ADJUST** knob clockwise until the LCD indicates **-6.5 kV**. If an arc fault occurs, turn the output back to 0 V, press the green HV OFF button and start again.
- m. Wait about 1 minute, then, on **Source Controller 1**, press the **ON** button for emission; the red button LED should illuminate.



The scale for the emission needle gauge is 1.0 A!  
**DO NOT TURN THE EMISSION UP TO 0.5 A,  
OR AN ARC FAULT WILL OCCUR!**



- n. SLOWLY turn the **EMISSION** knob to increase the emission current to 50 mA.
- o. On the x-y sweep (**XYS**) **Controller** (to the right of Source Controller 1), flip the **POWER** toggle switch to the **ON** position.
- p. **Put on the safety goggles.**
- q. Look through the viewport and, using the **XYS POSITION** knobs (**HORIZONTAL** and **LATERAL**), position the beam as close to the center of the crucible as possible.
- r. Adjust the **FREQUENCY** knobs to about 10 Hz (~1/4 turn on the potentiometer).
- s. Adjust the **AMPLITUDE** knobs until the beam covers 80-90% of the surface of the material in the crucible. Avoid striking the edge of the crucible liner.
- t. Increase the **FREQUENCY** until the desired temperature distribution is achieved.
- Dielectric materials work better at medium to high frequencies (~40 to 100 Hz).
  - Chrome and high temp oxides work better at lower frequencies (~10-30 Hz).
- u. SLOWLY increase the **EMISSION** to the current value recommended in **Appendix B**. Observe the material through the viewport to ensure that it has begun to melt. Readjust the **XYS POSITION**, **AMPLITUDE** and **FREQUENCY** if necessary. Once the material has melted, proceed.



If arcing is observed, **STOP**, then reduce the emission rate slightly. Allow the source to **SOAK** the material, then resume **SLOWLY** increasing the emission rate.



- v. *If instructed in the **Notes** column in **Appendix B***, turn **OFF** the **XYS controllers**, and readjust **OUTPUT VOLTAGE** to **-5.9 kV**; wait about 1 minute for the system to equilibrate.
- w. Press **START** on the **Inficon XTC/2**; the shutter for Source 1 will automatically open.
- x. Once the final film thickness has been reached, the shutters will automatically close. The Inficon XTC/2 will say **IDLE** on the main screen. Deposition is complete.
- y. Turn **OFF** the **XYS controllers** (if they were not turned off in step 4.u), and turn the **AMPLITUDE** and **FREQUENCY** knobs fully counter-clockwise.

- z. SLOWLY Turn the **EMISSION** knob fully counter-clockwise.
- aa. On **Source Controller 1** press the **OFF** button to turn off the emission.
- bb. If **Substrate Heating** is no longer required, turn off the halogen lamps by rotating the dial to **0%** and flipping the toggle switch to the **OFF** position.
- cc. If **O<sub>2</sub>** is no longer required, close the **Needle Valve** by turning the knob fully clockwise.
- dd. To deposit subsequent material layers, repeat steps **2.i** through **2.cc**, otherwise proceed to the next step.
- ee. Wait 2 minutes for the power supply to equilibrate.
- ff. On the **SEB-06**, SLOWLY turn the **OUTPUT VOLTAGE ADJUST** knob counter-clockwise until the LCD indicates **0 kilovolts**, then press the green **HV OFF** button.
- gg. On **Source Controller 1**, turn the **key switch** to the **OFF** position.
- hh. Power **OFF** the **SEB-06** at the bottom of the source control panel, using the **MAINS** triple toggle switch.

## 5. Venting the Chamber and Shutting Down the System After Deposition

- a. Turn off the vacuum pumps by switching the **Mechanical Pump** toggle to the **OFF** position.
- b. When the turbo pump begins to vent (the **SP4** LED will turn off on the vacuum gauge controller), open the ball valve (on the left side of the chamber base) to bleed in nitrogen.
- c. Wait for the vacuum chamber to reach atmospheric pressure. The vacuum gauge controller will read **7.6 E +2 Torr**.
- d. Close the nitrogen ball valve.
- e. Turn OFF Substrate Rotation.
- f. Raise the bell jar:
  - i. Hold the toggle switch in the UP position until the bell jar has reached its maximum height.
  - ii. At the back-left of the tool, insert the lock pin into hoist tower assembly to prevent the bell jar from falling in the case of a mechanical failure.
- g. Remove the sample holder from inside the bell jar.
- h. Remove your sample(s) from the holder, and replace the sample holder in the bell jar.
- i. Open the shutter.
- j. Remove all of the crucible liners that you installed in the various pockets, and put them back in their cases.
- k. Close the shutter.
- l. Remove the hoist lock pin from the hoist tower assembly, then completely lower the bell jar using the control toggle switch.
- m. Power off the system by flipping down the double toggle switch on the front of the machine, located in the middle of the lower panel.
- n. Close the cooling water valves.
- o. Log out of the logging computer.