

Standard Operating Procedure (SOP)

Lesker PVD75 E-beam Evaporator

(PVD-04)

In case of fire or injury please call 911 (511 from campus phones)

If there is an error with the system/tool, please report it using NEMO, and the staff will take care of it.

Please *DO NOT* run diagnostics without a staff member present or with their approval!

Common Errors and What To Do If You See Them:

- 1) **Crystal quality (Q) is below 30%:** If $Q < 30\%$ before your deposition, please do not proceed and report this as a problem through NEMO. You may proceed with your deposition if Q is slightly above 30% prior to your deposition, but if $Q < 30\%$ afterwards, please report this as a problem through NEMO. Notify the next scheduled user.
- 2) **"Rate below setpoint" error followed by a recipe abort:** This is a crucible issue. Do not try running the recipe again. If during regular business hours, unload your sample to the load lock, and email or call staff. If outside of business hours, remove your sample entirely from the system and report the issue in NEMO.
- 3) **"Crucible not in position" error:** You will get this error if you forget to login, as the interlock prevents hearth rotation when logged out. To resolve this error, (i) login on NEMO, (ii) open the door behind the tool computer, (iii) and click through the error message of the remote controller using the yellow button (usually two clicks). You can now rerun your recipe. If the error persists, please contact staff.
- 4) **Odd looking crucible/melt:** If you think the crucible doesn't look right, please report it as a problem to staff.

PVD-04 Training Video:

In YouTube, search:

“qnf pvd-04”

Link:

<https://www.youtube.com/watch?v=OxkmP7Lr9Lo&t=0s>

QR code:



Lesker PVD75 E-beam Evaporator



- Primary tool owner: Dan Sabrsula
- For processing questions, contact Jason: dsabr@seas.upenn.edu
- Problems with the tool **MUST** be reported on NEMO. Do not contact primary tool owner with tool issues directly.
- This tool can be used for deposition of Au, Cr, Pd and Ti only.
- For other deposition needs, please check the QNF Wiki: <https://wiki.nano.upenn.edu/wiki/index.php?title=Equipment>

Tool Policy:

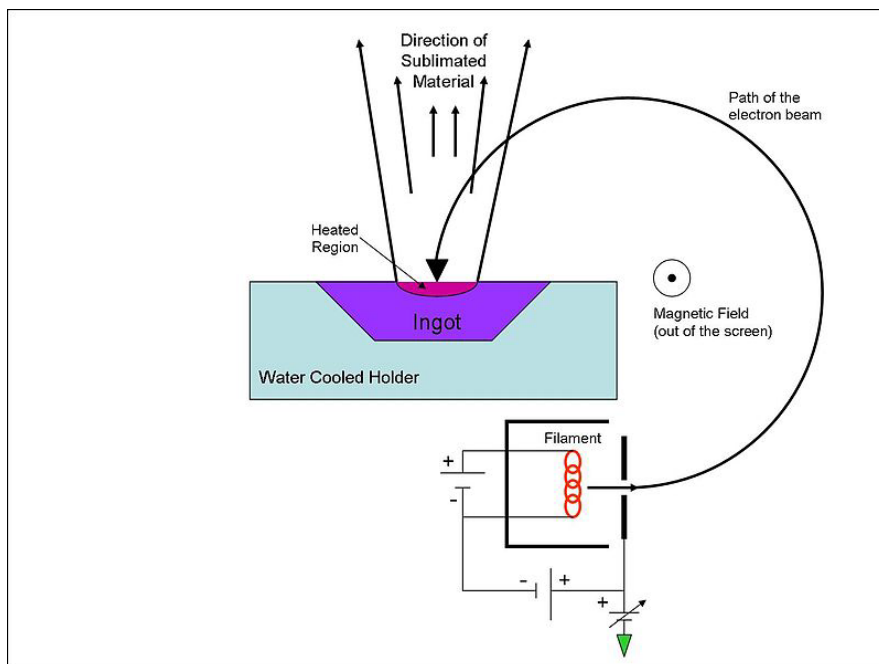
- If a deposition recipe is running, you must be by the tool while that recipe is running (unless there's an emergency, i.e. a fire alarm or toxic gas alarm).
- Check the crucible in the chamber periodically during the deposition: Check that the melt looks correct, and that the melt level is not getting too low (crucibles should ideally be two thirds to half full).
- You must pump down the load lock when you're done using the tool.
- Only trained users can use the tool! You cannot book the tool for your lab mate to use, and they cannot operate the tool under your supervision.

Procedure Overview

- 0) Before you begin
- 1) Mount the sample to the platen
- 2) Vent the load lock
- 3) Load sample(s) into the load lock
- 4) Pump the load lock and load sample into chamber
- 5) Run deposition recipe
- 6) Unload sample to load lock and vent load lock
- 7) Unload sample from load lock
- 8) Pump down load lock
- 9) Check crystal monitor quality and log out of NEMO

Tool Overview:

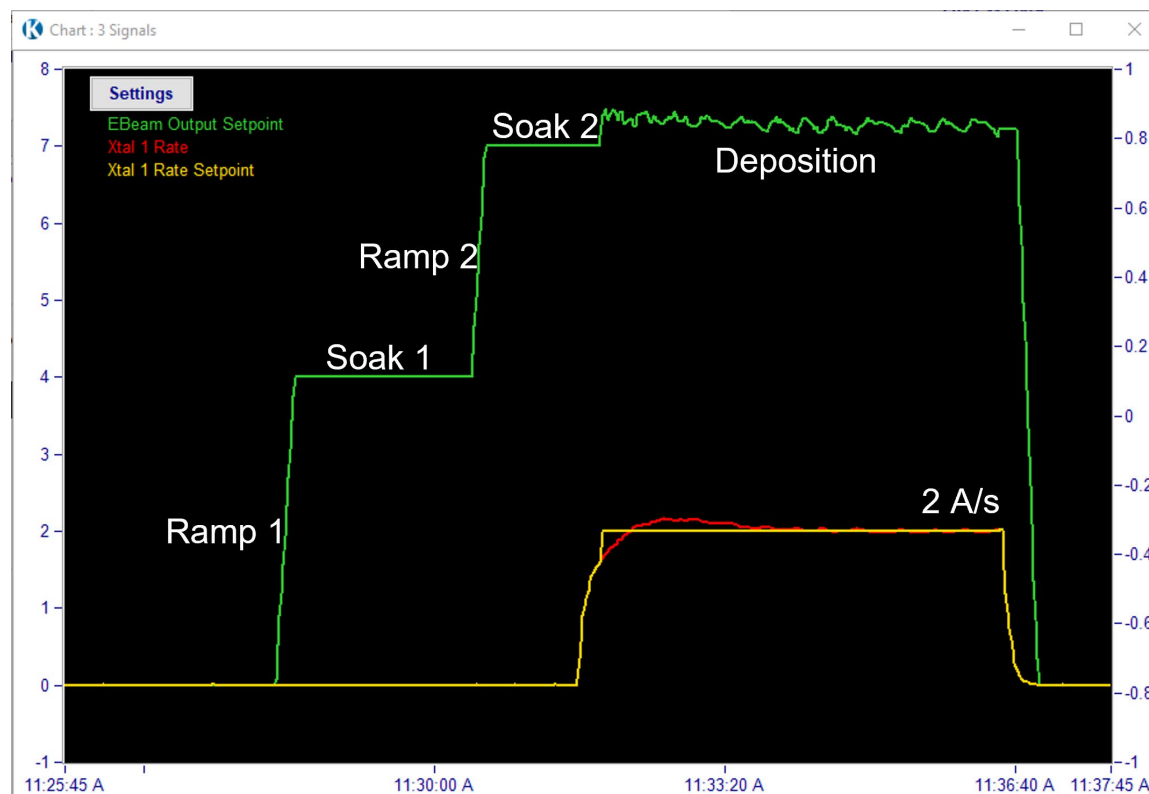
The PVD75 E-beam (PVD-04) Evaporator is an electron-beam (e-beam) evaporation tool. In e-beam evaporation, an electron beam is used to heat up the source metal to the point where it will evaporate. As the figure below shows, a voltage is applied to a filament, resulting in emitted electrons. A magnetic field is used to steer these electrons and raster them across the source metal. This results in heating. The metal subsequently evaporates and travels towards the substrate placed above and deposits there. E-beam evaporation allows for deposition of materials with very high melting points, which is not possible with thermal evaporation.



E-beam evaporation is a vacuum deposition tool. The system operates under high vacuum ($< 5 \times 10^{-6}$ Torr), resulting in relatively high mean free paths of both the emitted electrons and the evaporated metal particles within the chamber, resulting in minimal interactions with unwanted N_2 , O_2 , and H_2O gas particles. This allows for a highly directional deposition (suitable for lift-off processes) and results in high-quality metal films.

An evaporation recipe follows a number of steps that are crucial for a successful deposition. Prior to the actual deposition, the tool will warm up the metal during the “ramp and soak” phases (as shown in the figure below). The power will “ramp” up, and the beam is swept over the sample to warm it up during the “soak” phase. This process is repeated for a second “ramp and soak” phase, where the power is increased closer to the power used during the deposition. These steps ensure that the melts are adequate for the deposition. The source and crystal monitor shutters will subsequently open, and the deposition rate is measured by the crystal monitors. The tool adjusts the power to dial in the deposition rate (2 Å/s for most depositions), and the deposition begins. The tool uses the crystal monitors to track the thickness of the deposited material (which is why it is important that the Q lifetime is noted before and after a deposition, as the crystals need to be replaced frequently). Once the desired thickness has been deposited, the tool will close the shutters and ramp down the power to complete the recipe.

The figure below shows the set power of the e-beam (green), the target rate (yellow), and the measured deposition rate (red) of a typical deposition.



Full procedure:

0. Before you begin

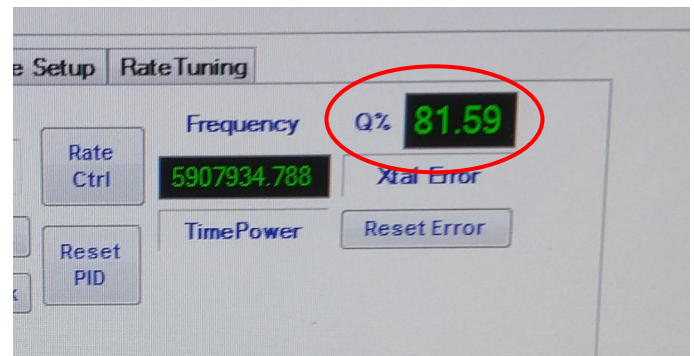
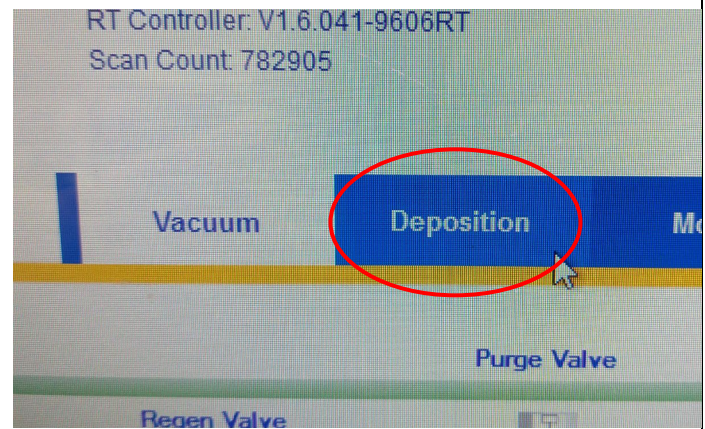
- 0.1. Log into the tool via NEMO
- 0.2. Ensure that you're logged into the tool software as a basic user.

Username: user

Password: user

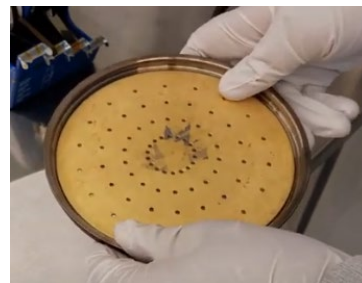
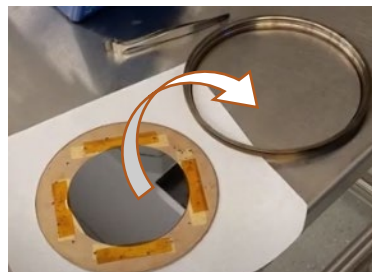
- 0.3. Check the crystal quality under the "Deposition" tab. If the crystal quality is less than 30%, please do not begin your deposition and report it as a problem in NEMO.

Attention: If you proceed with your deposition with $Q < 30\%$, this will be considered tool misuse.



1. Mount the sample to the platen

- 1.1. The sample holder (ring and platen), can be found on the stand on the table to the right of the tool. Keep the sample holder on the stand as you're mounting your sample.
- 1.2. If your sample is a 6" wafer, it may be placed in the ring directly, without the use of the platen. *Go to 1.4.*
- 1.3. If your sample is smaller than 6", you can mount your sample onto the platen using the screws and clips in the tray next to the tool, or you can use Kapton tape.
- 1.4. Your sample goes into the tool facing downwards! Flip the platen/wafer upside down on the stand.

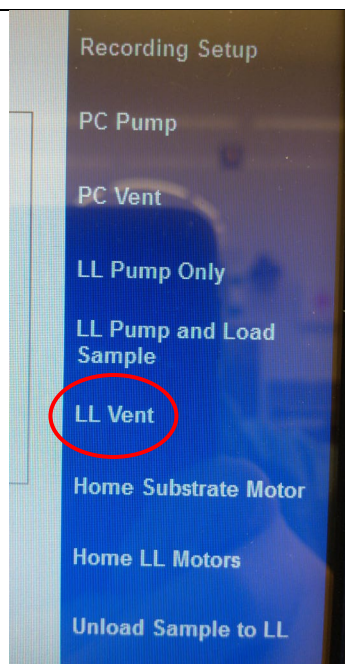


2. Vent the load lock:

- 2.1. Click the “LL Vent” button to vent the load lock to atmospheric pressure. This button can be found on the right-hand side of the screen.

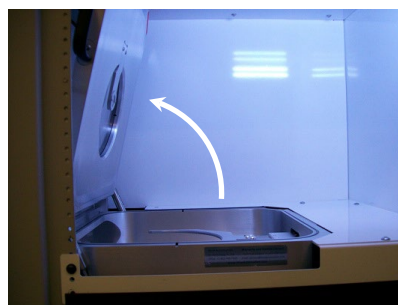
Attention: If you cannot see these buttons, make sure you’re logged into the tool software (*step 0.2*)

- 2.2. When the “LL Vent” recipe is complete, the recipe window will turn green. This is true for all recipes.

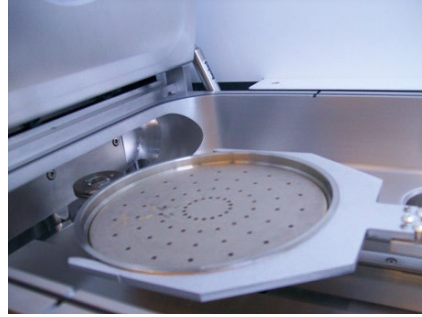


3. Load sample(s) into the loadlock:

- 3.1. Open the panel that the computer is on (it's a door), and open the load lock.



3.2. Place the sample into the load lock.
Ensure that the sample is face-down.



3.3. Close the load lock lid and close the door.

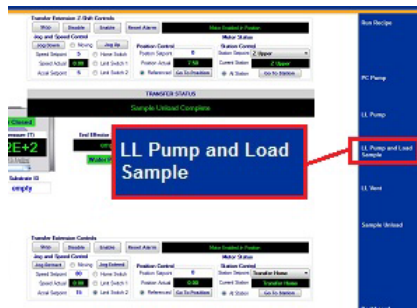


Note: If the lid is not closed, the software will tell you to close the lid before you're able to pump down the load lock.



4. Pump down the load lock, and load sample into chamber

4.1. Click "LL Pump and Load Sample".



4.2. The recipe will prompt you to enter a sample ID. The Recipe Monitor will show you this →

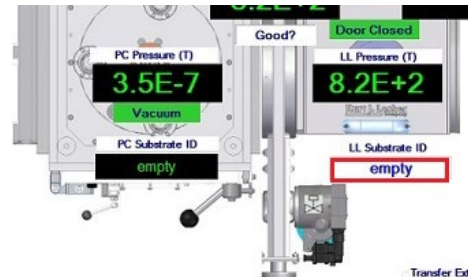
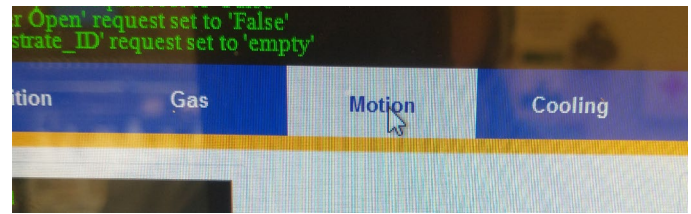


- 4.3. Click the “Motion” tab, and type [your PennID] in the LL Substrate ID (anything but “empty” will work) and press Enter on the keyboard.

Note: Pressing “Enter” on the keyboard is required. If you don’t press “Enter” after typing in the LL Substrate ID, the tool’s software won’t register the sample ID, and won’t run the recipe. You can hear a faint sound when you press enter, and the software will notify you in the notification box at the top of the screen.

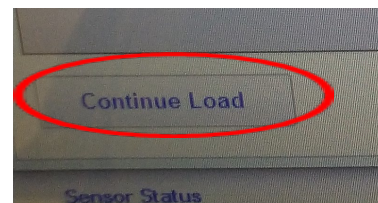
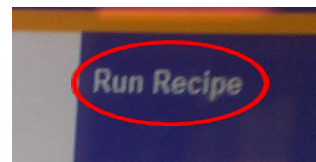
- 4.4. Click the “Resume” button on the Recipe Monitor.

- 4.5. Allow the recipe to run and finish before proceeding. **This step typically takes 5-6 minutes.**



5. Run deposition recipe(s)

- 5.1. Run a deposition recipe. To do this: click the “Run Recipe” button, select the deposition recipe that you’d like to run, and click “Run Recipe.”
- 5.2. The tool is programmed to work with deposition thicknesses in units of kilo angstroms (kA), and not nanometers (nm). **1 kA = 100 nm.**
- 5.3. Enter your thickness target in kA, then hit “Enter” on the keyboard. Click “Continue Load” to start the recipe.



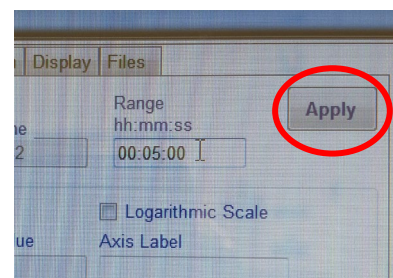
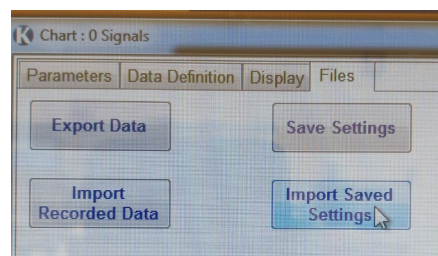
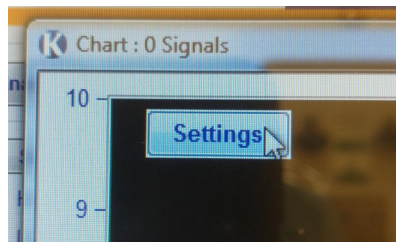
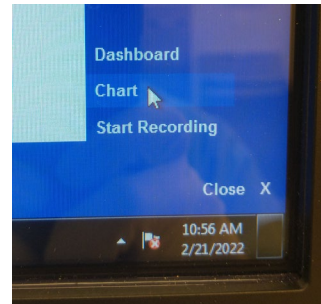
5.4. Throughout the deposition process, you need keep an eye on the deposition rate, the power being used by the tool, and the melt in the crucible through the window in the process chamber. The deposition rate and power can be monitored on the chart.

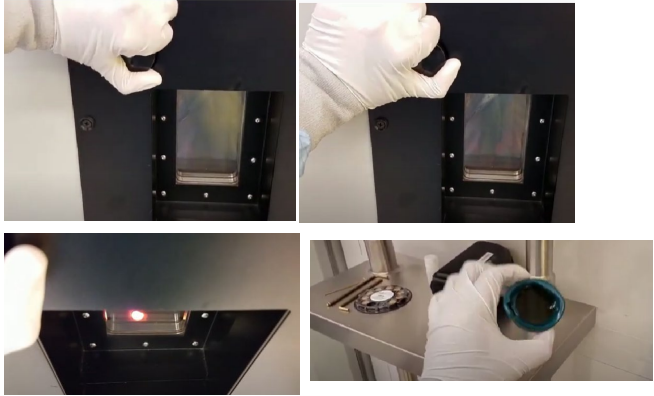
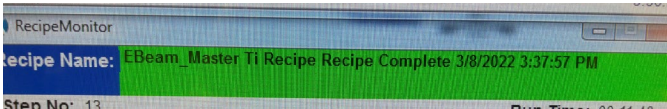
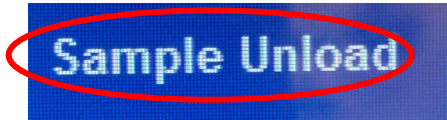
5.4.1. This is especially important during the shutter delay and deposition steps. If, during these steps, the power greatly increases while the rate continues to drop, or the power begins to oscillate with an amplitude more than 1-2%, you should abort the recipe and report a problem on NEMO.

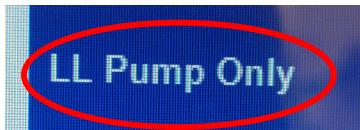
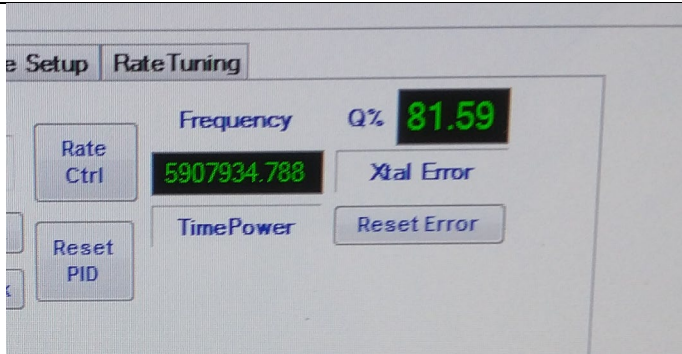
5.5. If the chart is not visible, you can bring it up by clicking the “Chart” icon at the bottom-right of the screen.

5.5.1. Click Settings, Files, Import saved settings, and open “master ebeam chart.ini”.

5.5.2. We recommend setting the time scale on the chart to 5 minutes. To do this, open the chart and click Settings, Parameters, set the Range to 00:05:00, and click “Apply”.



5.6. Look at the melt in the crucible periodically (every 2 minutes or so) to monitor the melt state and level, and to ensure that the e-beam is rastering over the metal and isn't drilling into the crucible. To do so, hold open the shutter next to the tool. Be sure to use an eyepiece to protect your eyes – some of the metals (especially Ti) will glow very brightly, which could damage your eyes. 5.7. Wait for the deposition recipe to finish. If you'd like to deposit another metal (i.e. Au after depositing Ti), you may do so. Attention: Wait for the melt in the crucible to cool before running another deposition recipe or unloading your sample. Look at the melt through the window. You can proceed if the crucible is no longer visible.	 
6. Unload the sample to the load lock, and vent the load lock 6.1. Run the Sample Unload to LL recipe to unload your sample to the loadlock. Wait for the recipe to finish. 6.2. Run the LL Vent to vent the loadlock. Wait for the recipe to finish.	
7. Unload the sample from the load lock 7.1. Take out your sample and close the load lock.	

8. Pump down load lock 8.1. Run the LL Pump Only recipe to pump down the loadlock. Please wait for the LL Pump Only recipe to finish before logging out and leaving the tool.	
9. Check crystal monitor quality and log out of NEMO 9.1. Check the crystal monitor. If the quality is below 30%, please report to staff! 9.2. Log out of the tool via NEMO once the pump-down recipe is complete.	

Feel free to contact the staff members with any questions about your process and the tool.