QNFCF

Quantum Nano Fabrication
and Characterization Facility

Standard Operating Procedure (SOP): **Angstrom Engineering Indium Evaporator in RAC1 Cleanroom (ANGSTROM-InEvap-R1)**

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Summary:

This document summarizes the safe operating practices to be followed when working with Angstrom Engineering Indium Evaporator located in the RAC1 Cleanroom (Angstrom-InEvap-R1)

Important:

The Angstrom-InEvap-R1 chamber is specifically designed for the evaporation of Indium material. No other evaporation materials are allowed in the system. Please follow standard vacuum system cleanliness protocols. For equipment issues, report them in Nemo for the fastest response from QNFCF staff.

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2. EQUIPMENT DESCRIPTION AND FEATURES

The Angstrom Indium Evaporator is designed for thin- and thick-film Indium deposition. It utilizes a large-volume 28 cc Indium thermal source that produces a highly collimated deposition flux, making it ideal for Indium bump processes. The system supports deposition rates ranging from 1 Å/s to 100 Å/s and film thicknesses up to 20 µm. A temperature-controlled substrate stage enables precise control of surface diffusion and eliminates condensation during venting. The 12-crystal QCM indexer allows extended operation without frequent crystal changes. The evaporator is controlled through AERES software, which supports recipe-based automation.

Features:

- 28CC alumina coated crucible evaporation source generating a highly collimated disposition flux.
- Deposition rates: 1 Å/s to 100 Å/s
- Maximum film thickness: 20 µm
- Automated Z-axis stage height control
- Rotating substrate stage (10–30 RPM)
- Temperature-controlled substrate stage (-30 °C to 125 °C)
- Substrate holders: Ø4”, Ø6”, Ø8”, or custom clip plate
- Water-cooled resistive thermal source with molybdenum crucible
- QCM multi-crystal indexer (12 crystals per sensor)
- Vacuum system:
    - Edwards CTI-8F Cryopump
    - Pfeiffer ACP40 roughing pump
    - Ultimate base pressure: 1×10^{-7} Torr
    - Pumping speed: 1500 L/s
- Automated recipe execution via AERES software

2.1. GENERAL LAYOUT

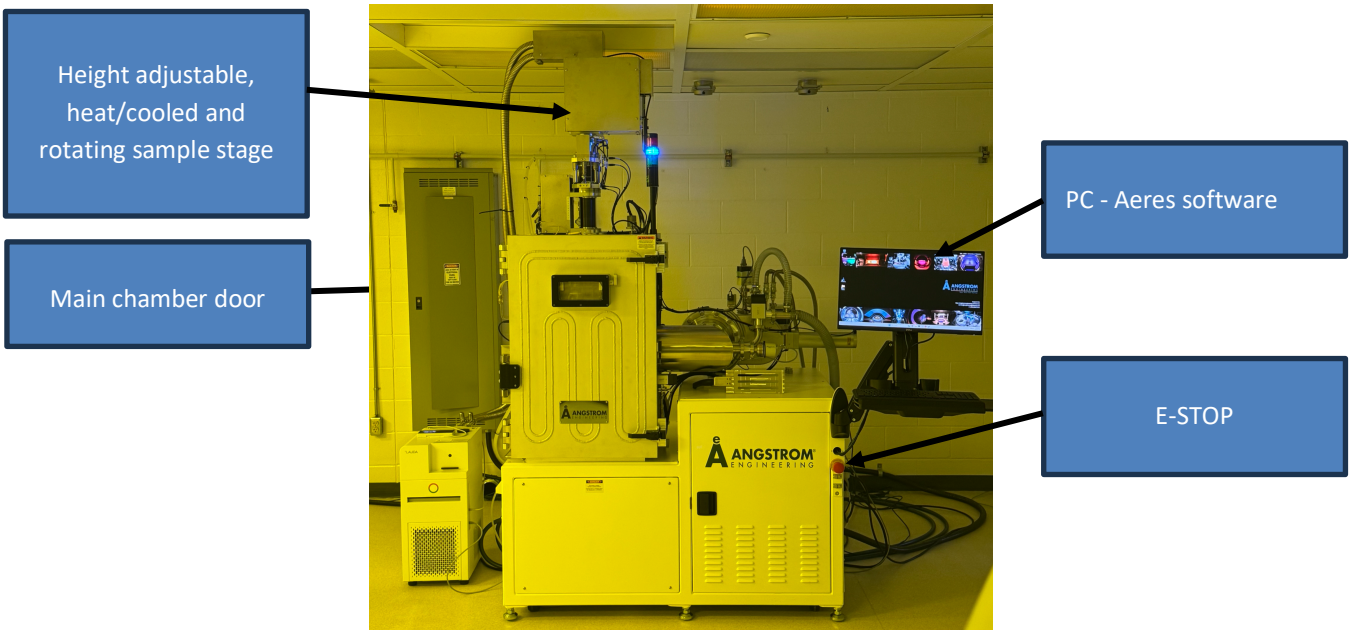

Figure 1 - System layout

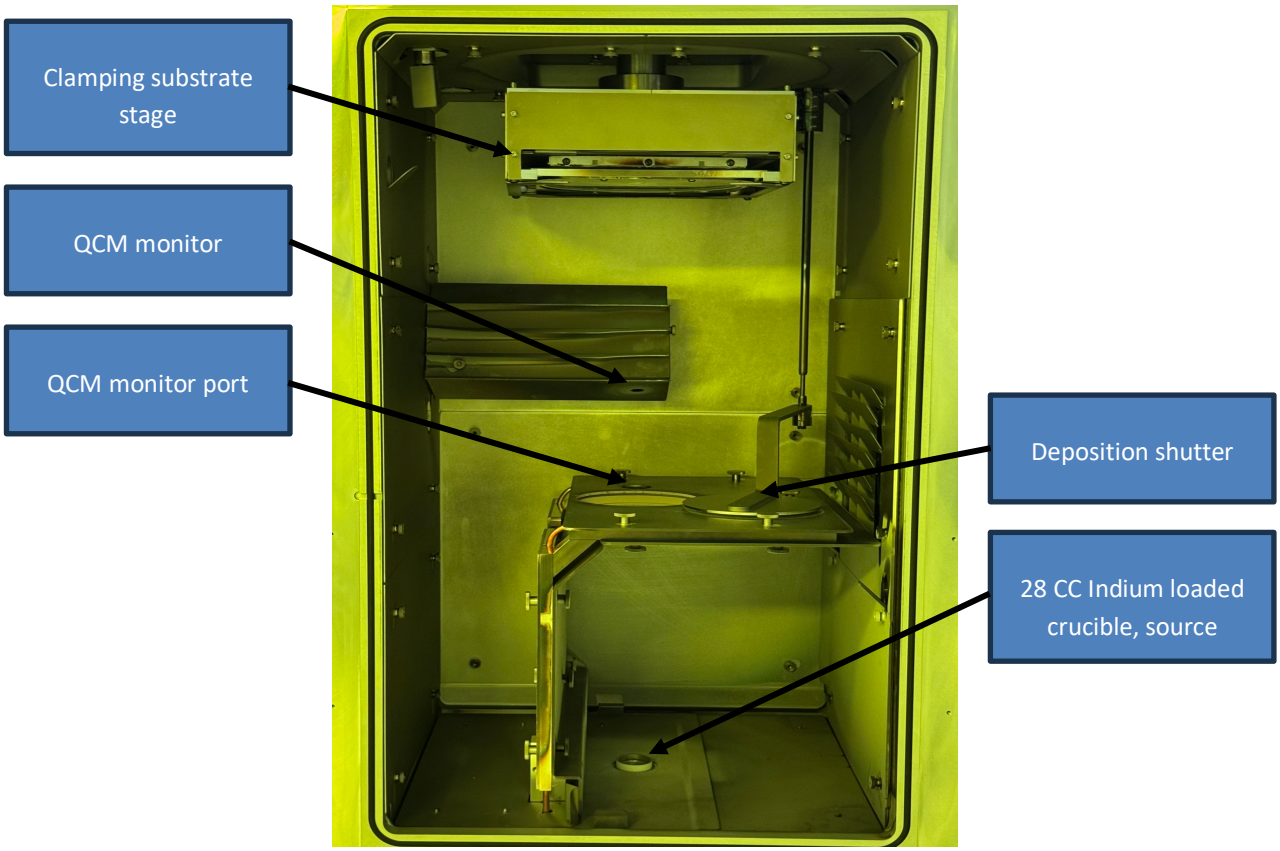

Figure 2 - System Chamber layout

3. REFERENCE DOCUMENTS

- Safety data sheet (SDS) for chemicals to be used. SDS are located in the labeled binders by the RAC cleanroom lab entrance. Electronic copies are also available in the QNFCF website (login required) https://qnfcf.uwaterloo.ca/data/safety-data-sheets
- Cleanroom Safety Protocols listed online (login to your account first): https://qnfcf.uwaterloo.ca/policies/safety-policies
- Emergency contact numbers listed online (login to your account first): https://qnfcf.uwaterloo.ca/data/general/safety-policies/emergency-phone-list
- Process recipes for the chemical solution needed. These PROC documents are available online in the "*Process Info*" folder under each piece of equipment in the *Equipment Info* section.

4. MINIMUM REQUIREMENTS BEFORE USE

Before using this equipment independently, you must have completed the "*Becoming a Lab Member*" requirements listed on the facility website, the major elements of which include:

- Completing and passing all required Safety & Cleanroom training
- Submitting a *Process Review Request* (one for each of your unique process flows)
- Submitting an *Equipment Authorization Request* (one for each equipment needed)
- Receiving one-on-one equipment training by an authorized staff member

Additional requirements specific to this equipment:

- Reserve time on this equipment through the facility's NEMO scheduler well in advance of your session. When you arrive to use the equipment you must remember to "enable" the tool prior to beginning work and "disable" the tool when you are done.
- Review and become familiar with the risks and the emergency response procedures listed in the *safety data sheets* (SDS) for the chemicals you plan to use.
- NOTE: Make sure there is another lab member with you in the cleanroom should you plan to also use any wetbench or fumehood. This person will be there to provide assistance or seek help in the event of an emergency.

5. HEALTH, SAFETY & ENVIRONMENT

Please **do not handling the Indium thermal source and evaporation materia**l. Temperatures around the source can exceed 200°C after deposition, posing a serious burn risk.

5.1. MANDATORY PERSONAL PROTECTIVE EQUIPMENT (PPE)

Standard cleanroom attire including nitrile gloves and safety glasses.

5.2. IN THE EVENT OF AN EVACUATION ORDER (FIRE ALARM, ETC.)

Leave the cleanroom immediately. Do not waste time removing your cleanroom gear.

6. MATERIALS & SUPPLIES NEEDED

You will likely need some combination of the following items when using this equipment:

- Sample tweezers
- Allen key 3/32
- Phillips head screwdriver (provided at tool)

7. VERIFICATIONS BEFORE STARTING

- Enable system in Nemo.
- Ensure the alarm beacon is not illuminated “RED” and no alarms are displayed on the system status bar.
- The chamber pressure is below 1.0e-7 Torr.
- Verify the QCM’s remaining life capacity, ideally at least 80%.

Note: Report any system malfunctions to QNFCF staff.

8. GENERAL INFORMATION

Substrate and substrate stage. It is important that your sample is clean and suitable to use in a vacuum environment and under variable heat loads (-30 to 125°C), otherwise you risk the contamination of vacuum chamber or damaging your sample. The substrate is mounted to a plate that can be configure to a 4, 6 or 8” diameter wafer holder or a custom clip and plate setup. Plates are clamped to the substrate stage, where they directly contact a heat exchanger plate controlled by an external fluid chiller. The temperature, rotation speed, and Z-distance are all controlled by the user’s recipe.

Vacuum and the vacuum system. This system operates under a high vacuum of 1e-7 Torr, which allows films to grow in a mean free path that produces high-quality, high-purity films. It uses an Edwards CTI-8F Cryopump and an Adixen ACP40 rough vacuum pump to achieve the

necessary vacuum pressure. The system requires operators to vent it to atmospheric pressure for loading and unloading samples, and it can be controlled via the software user interface.

Indium evaporation and resistive heat evaporator system. Indium has a low melting point (156.6 °C) and a relatively high vapor pressure at moderate temperatures, which makes it well suited for thermal evaporation. While many thermal evaporation systems use a resistively heated boat, this system uses a shielded box heater with a large-capacity, alumina-coated crucible. This design improves temperature stability and material handling. For safety, users do not handle the source directly; all refilling is performed by QNFCF staff. During operation, indium is heated above its melting point inside the crucible. As the temperature increases, its vapor pressure rises. When this vapor pressure exceeds the chamber pressure, indium begins to evaporate and deposit onto the substrate.

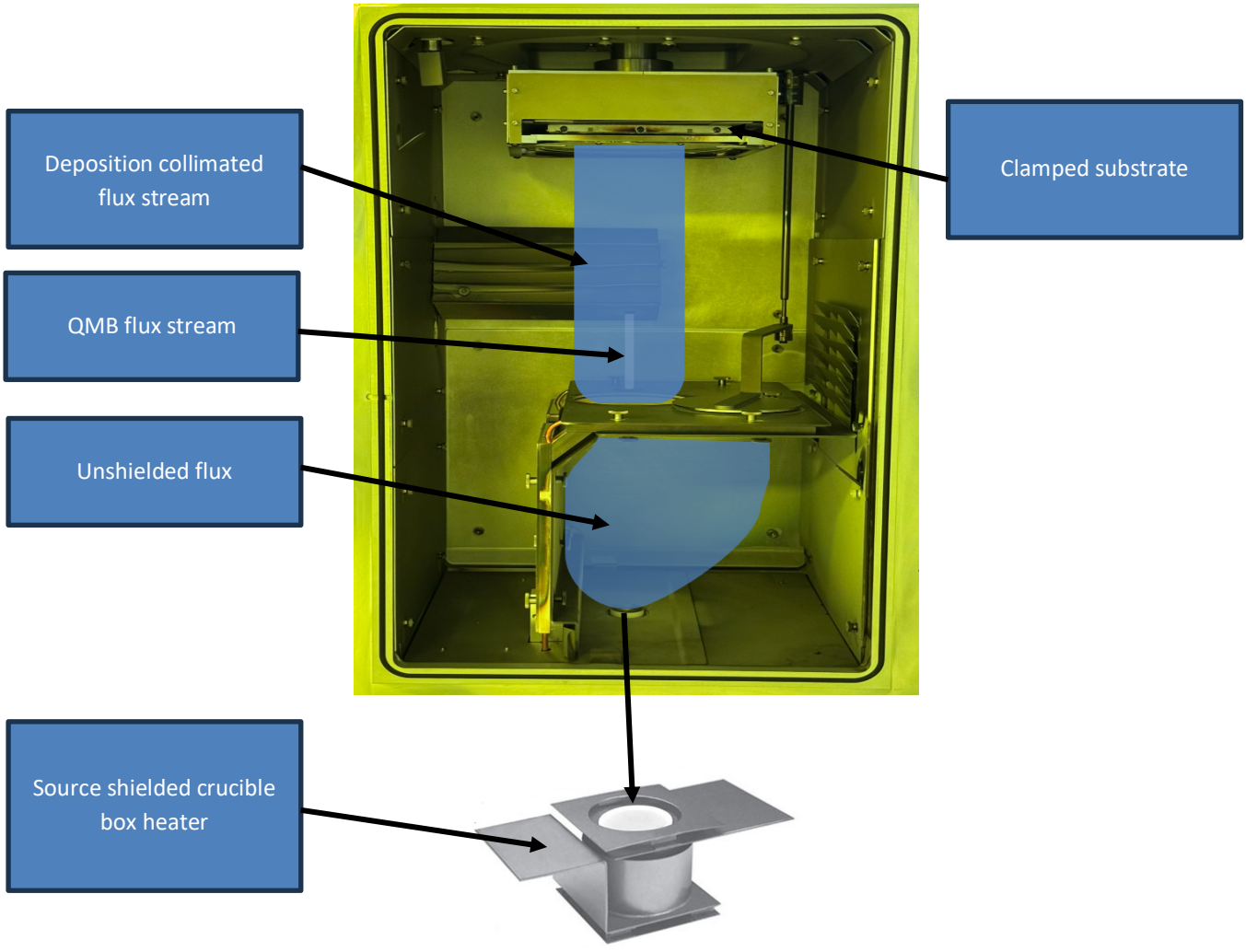

Figure 3 - Indium flux stream

Software and controls. All deposition-related tasks in the ANGSTROM-InEvap-R1 evaporator are recipe-driven. These recipes are written, loaded, and executed through the AERES software interface.

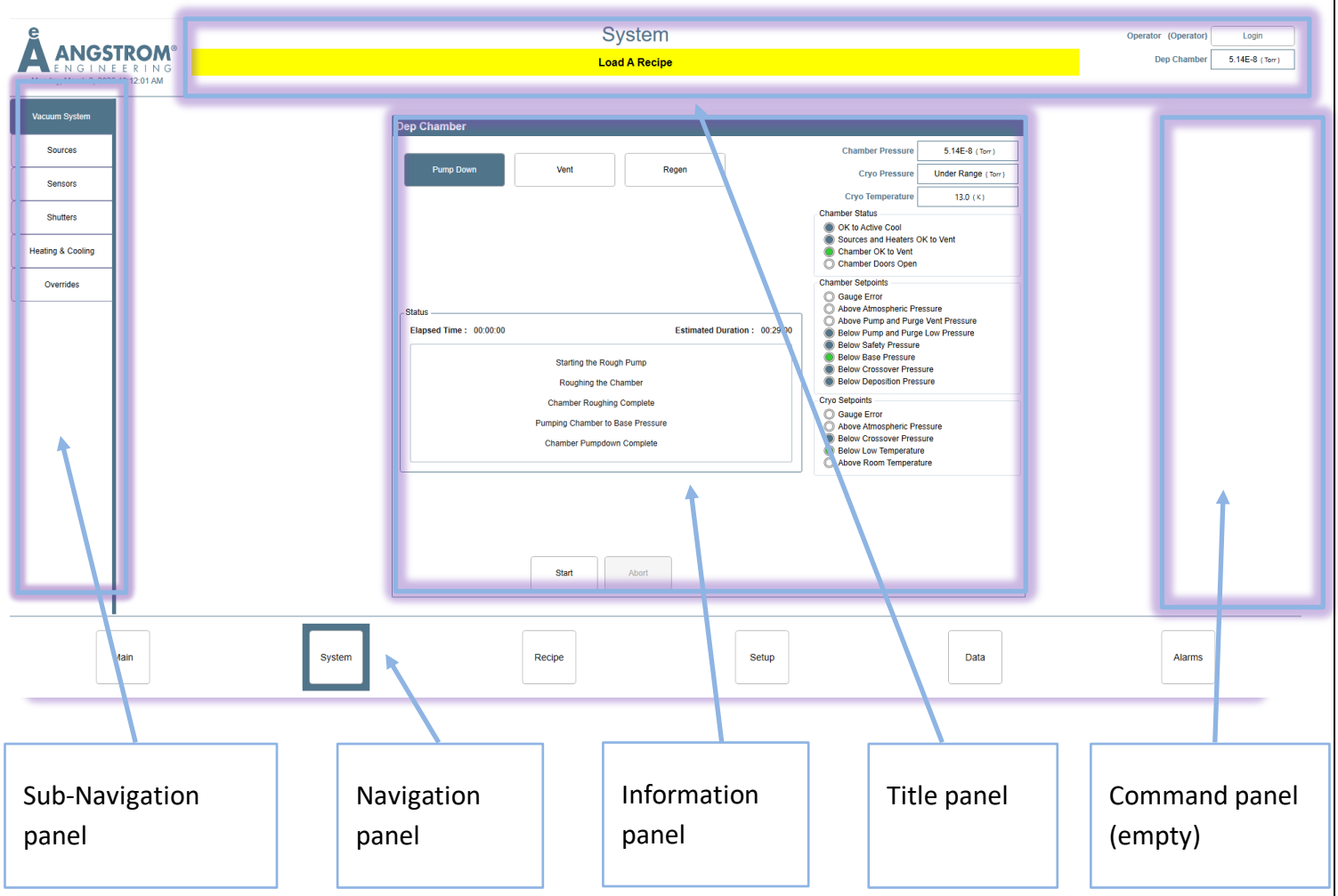

Figure 4: Main screen of AERES software

The Navigation panel functions are described below:

- Main - load, run and monitor pre-programmed recipes
- System - Equipment functions such as pumping and venting tool, monitoring crystal feedback, actuating shutters or changing material/source assignments
- Recipe - Writing of and editing of recipes
- Setup - Contains information relating to PID feedback and material tooling factors.
- Data - Permits loading of run data from previous depositions
- Alarms - Contains information regarding process or equipment alarms

ARIES recipes consist of four main steps: **pre-condition, stabilize, deposition, and post-condition.**

During **pre-condition**, power is gradually increased to a set level (based on the source and material) and held for a short soak period. Deposition rate is not used to control power in this stage. Substrate temperature is set.

During **stabilization**, the deposition rate is monitored, and power is adjusted to achieve the target rate within a specified tolerance. However, in Indium recipes, stabilization is often skipped to avoid power increases adjustments that cause "spitting" during disposition.

During **deposition**, the substrate shutter opens, exposing the substrate to the vapor flux. The system maintains the set deposition rate using feedback from the crystal monitor until the desired film thickness is reached, after which the shutter closes.

Finally, in **post-condition**, power is gradually reduced to allow controlled cooling of the source and material. Substrate is set to an ambient temperature.

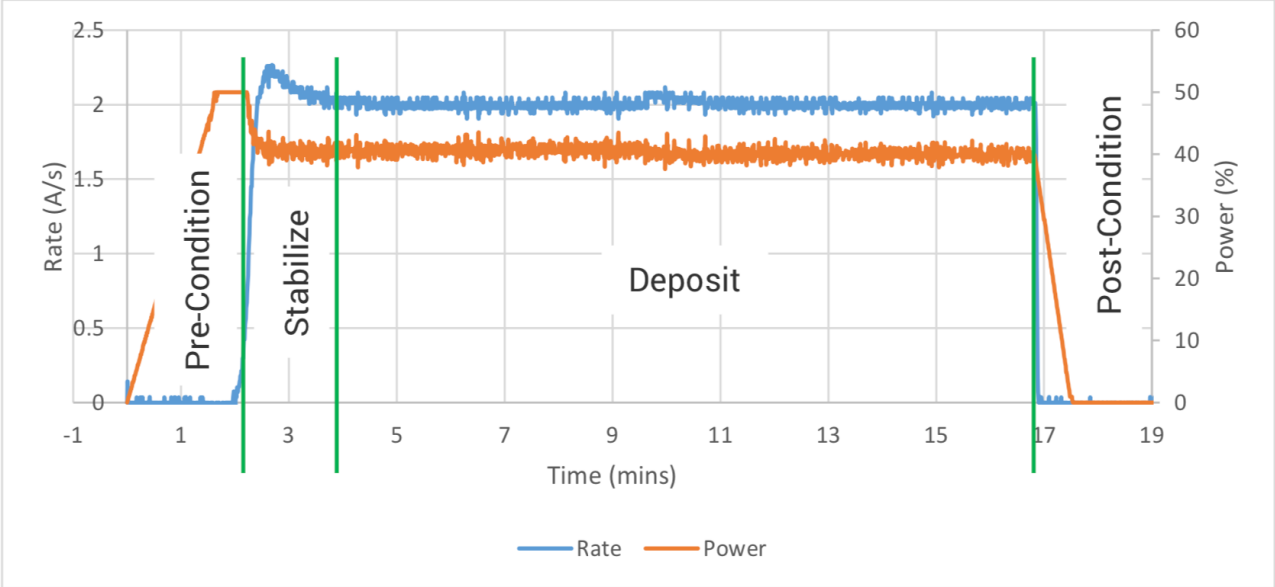

Figure 5: Typical deposition profile graph for thermal evaporation

9. STANDARD OPERATING PROCEDURE

Typical operation of this equipment can routinely be divided into the following steps:

- Venting, loading, and pumping down system
- Loading recipe with minor edits
- Deposition
- Vending, unloading, and pumping down system
- Clean up

9.1. VENTING, LOADING AND PUMPING DOWN SYSTEM

To initiate the vent sequence, enter the System panel by selecting the System button (1.), then click the Vacuum system button (2.) and the Vent button (3.). Finally, press the Start button (4.). See figure 7. Once the chamber is vented, the main door can open.

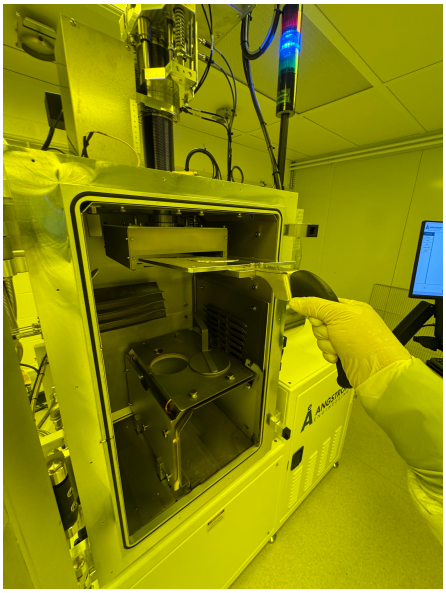

Figure 6 - Loading tool

Carefully remove the substrate plate through the clamp opening. You may need to manually rotate the substrate stage by hand to face the door. Use the correct plate for your substrate, which comes in 4, 6, or 8” diameter wafer holders, or a custom clip and plate. Install the plate the same way you removed it. Be careful not to touch the substrate as you feed it through the clamp opening. A loading tool is available for your convenience, as shown in figure 6.

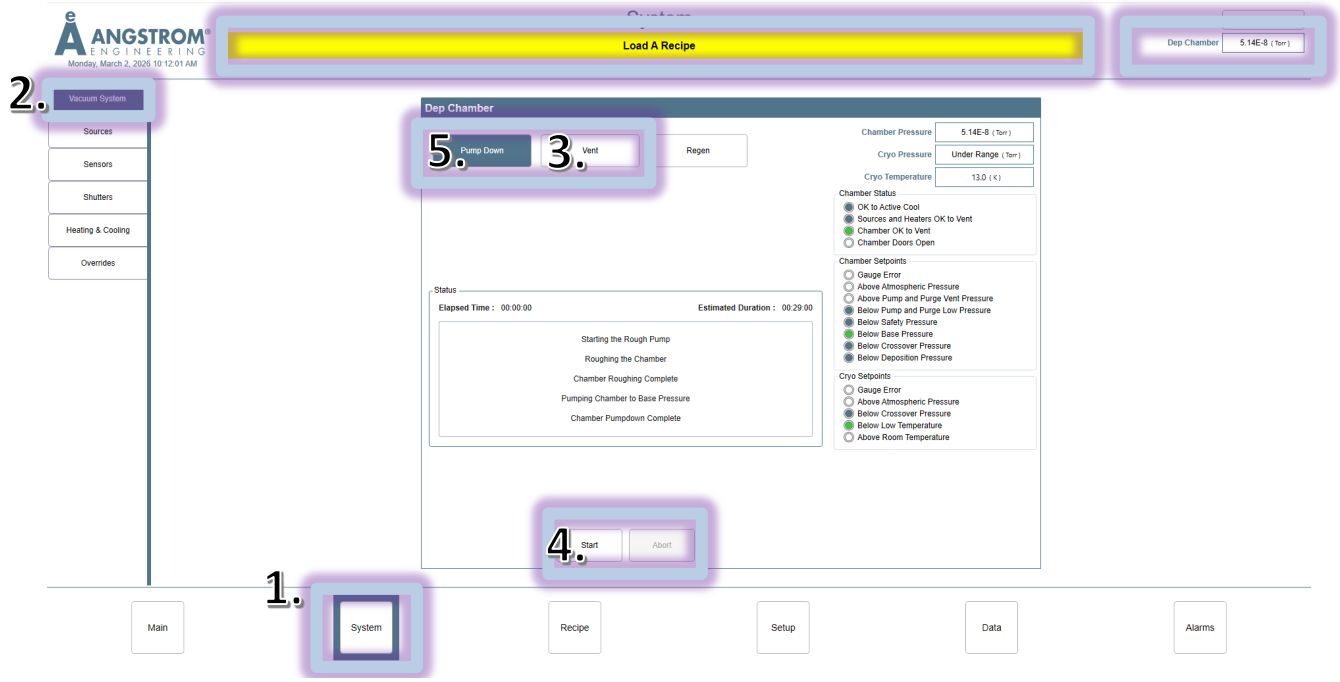

Figure 7 - System screen

Once your substrate is loaded, visually inspect the Indium crucible to ensure adequate material is available. Danger: Do not touch the crucible as it may be hot from previous depositions. Notify QNFCF Staff if Indium material levels are low. Close the main chamber door and start the pump down process by pressing the Pump Down button (5.) followed by the start button (4.). Note the vacuum levels in the upper right side of the Title panel display. Once the system has met base pressure of 1.0e-7 Torr, then the “System Is Ready” message will be displayed in the Title panel display.

While the system is pumping down, you should inspect the QCM remaining life. Click the Sensor button in the Sub-Navigation panel and ensure the Remaining life is at least 80%. If the life is below the threshold, you can index to a new sensor by clicking the Next Crystal button to cycle to the next available crystal. If all crystals are consumed, please contact QNFCF Staff to replace the crystals.

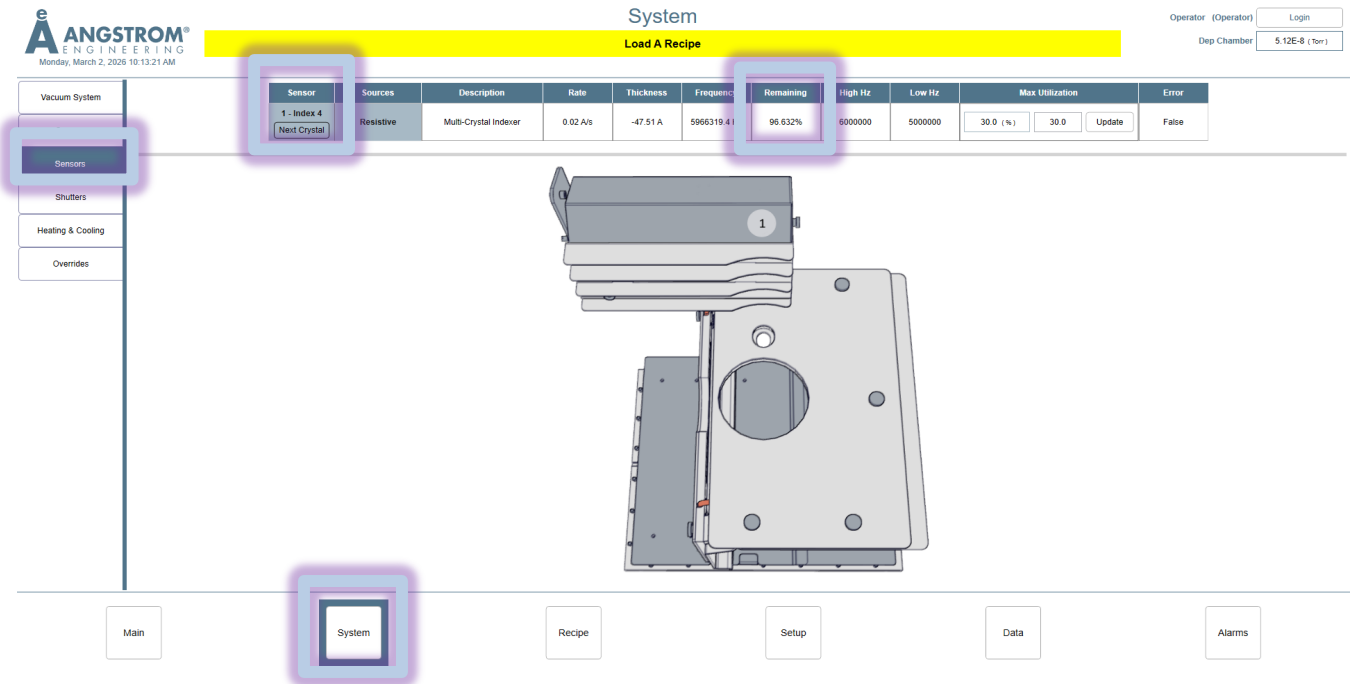

Figure 8 – Sensor life

9.2.LOADING RECIPE

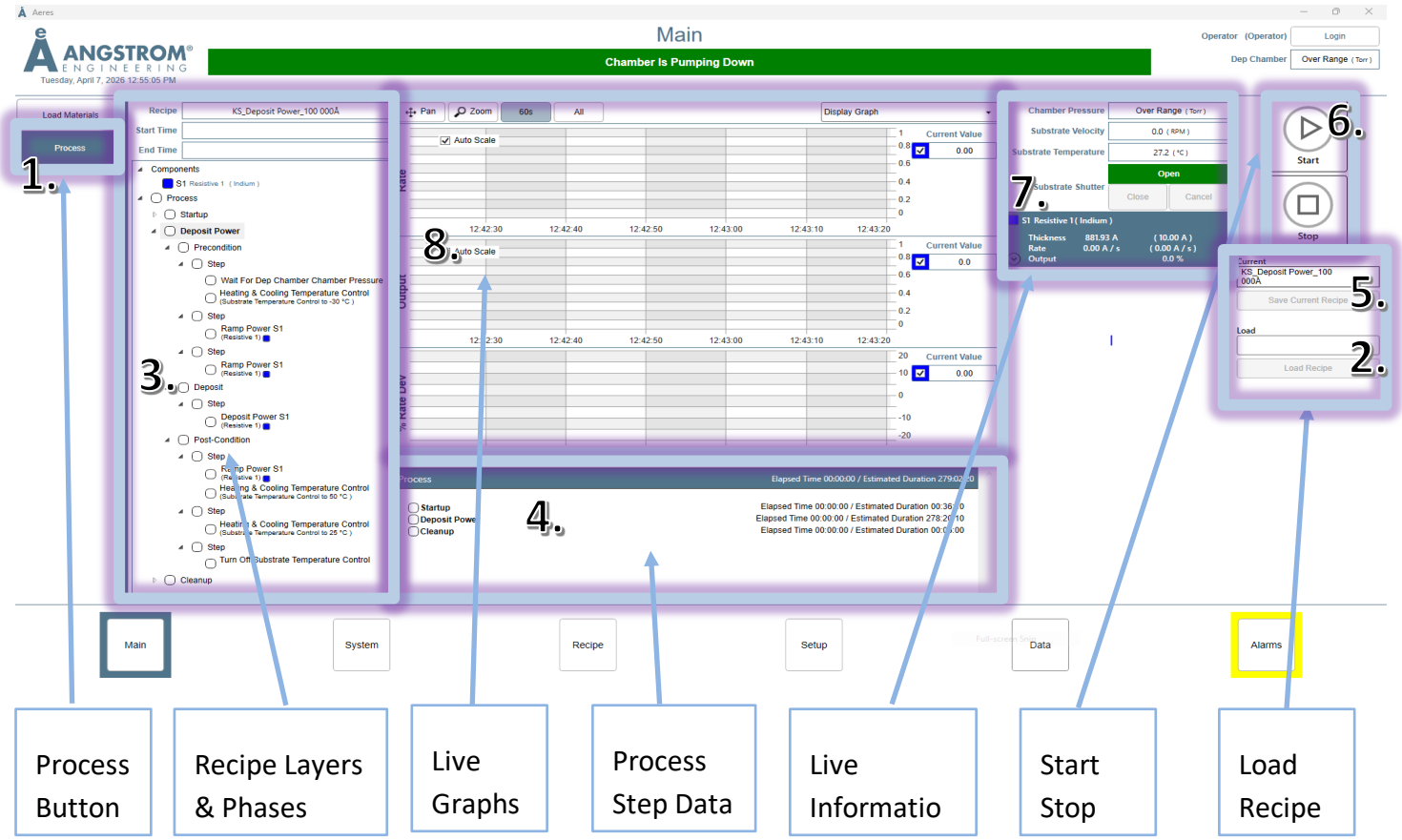

Figure 9 – Process screen

Since the system is only set up with Indium material, the only two variables that need to be considered are **Deposition rate Å/s** and **Deposition thickness Å**. Recipes for the ANGSTROM-InEvap-R1 are preconfigured for your convenience. Recipes are created for various deposition rates: 5 Å/s, 10 Å/s, 20 Å/s, 30 Å/s, and 50Å/s. The deposition thickness can be altered in the Main screen once a recipe is loaded.

To load a recipe, navigate to the Main screen and confirm that the Process screen (1.) is selected. Then, in the Load Recipe section (2.) of the Command Panel, click the dropdown menu and select “>>>.” Once the recipe is highlighted in the dropdown, click the Load Recipe button. The recipe name will now appear in the Current text box, and the entire recipe will populate the Layers and Phases section (3.).

To edit thickness parameters, click the Process Phase and expand the Deposit Step. Now in Process Step Data (4.), you can edit the thickness parameters. You can save this personalized recipe in the Load Recipe section by clicking the Save Current Recipe button (5.).

Now you can start the deposition by pressing the Start button (6.) in the upper right corner. You can monitor your growth rate and thickness in the Live Information section (7.) and observe real-time graphical information for Rate % Deviation, Output Power %, and Rate Å/s in the Live graphs section (8.). Additionally, you can monitor the active steps in the recipe in the Layer and Phase section. Each Layer, Phase, or step will have a coloured icon to represent its current state.

- Green - completed
- Yellow - currently running
- White - next in sequence
- Red - an error has occurred

Once the recipe is complete all steps will have a green icon and a complete graph of the process will we available to view. A complete Data set will be available to export can be demonstrated during the one-on-one equipment training.

9.3.VENTING AND UNLOADING

Follow the instructions in the section 9.1 to vent and unload the sample and place system back into vacuum.

9.4.CLEAN UP

At the end of your session:

1. Ensure the system is in a vacuum.
2. The work area is clean.
3. The system is disabled in NEMO.

10.TYPICAL PROBLEMS & SOLUTIONS

11.TECHNICAL DATA

APPENDIX