AJA Hybrid Evaporator

Standard Operating Procedure; Rev. 04; Aug. 2019

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System overview

The AJA (Fig. 1) is an ultra-high vacuum (UHV) hybrid tool equipped with Physical Vapor Deposition (PVD) systems such as electron-beam evaporation and DC/RF magnetron sputtering, and ion/plasma sources for cleaning/etching the samples. The AJA has a load-lock (LL) that allows users to quickly load/unload their samples without compromising the vacuum in the Main Chamber (MC). Samples up to 4" in diameter can be processed. The system has two sample tables, one water-cooled and one with heating capability (up to 400^{o}C). Both tables can be fixed at any angle (0-360^{o}) with respect to the table cradle axis (coincides with that of the red cylinder on Fig. 1) and allow continuous in-plane sample rotation.

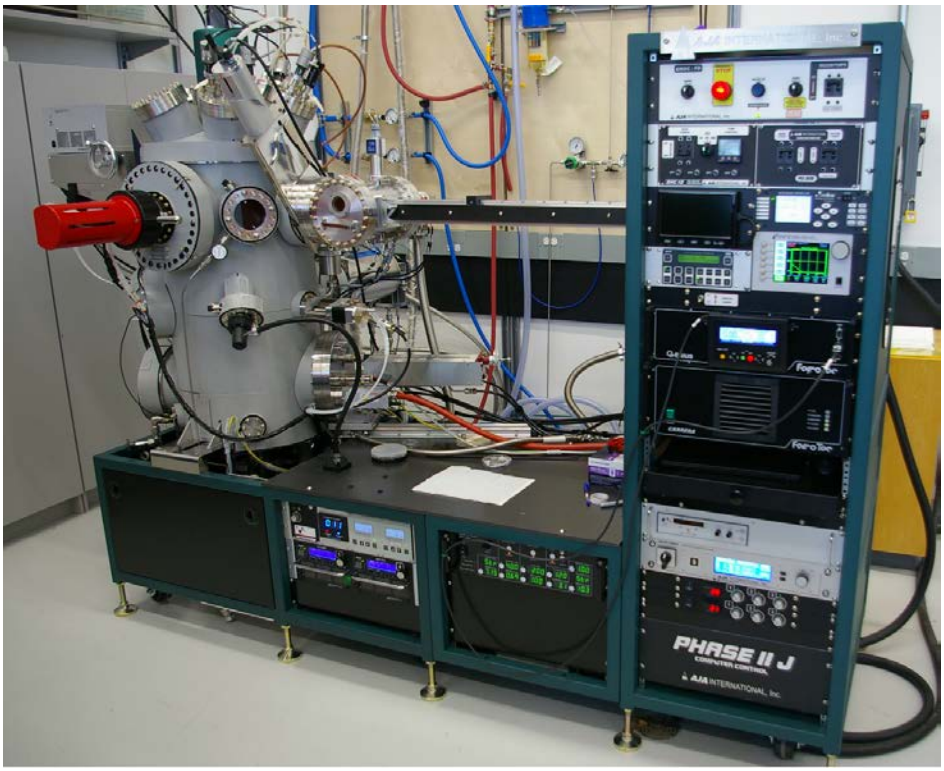


Fig. 1. AJA hybrid evaporator.

The vacuum system of the AJA consists of two sub-systems. The LL is evacuated by a Turbomolecular Pump (LL TMP) backed by a roughing scroll pump. The MC vacuum sub-system consists of a Turbo-Pump (MC TMP, backed by a separate dry pump) and a Cryogenic Pump (CP). Both MC pumps can be isolated from the MC volume by gate valves; the CP gate valve can only be closed or opened, the MC TMP gate valve can, additionally, be set to any intermediate position or operated, with feedback, in a

pressure control mode. The MC gate valves (TMP and CP) are controlled by the PHASE II J software, the LL gate valve is manually operated.

The AJA dashboard (Fig. 2) has a number of switches, controls, and monitors.

The upper level of the dashboard panel (A) is not intended to be used by operators, except, in case of an emergency, the emergency shutdown button.

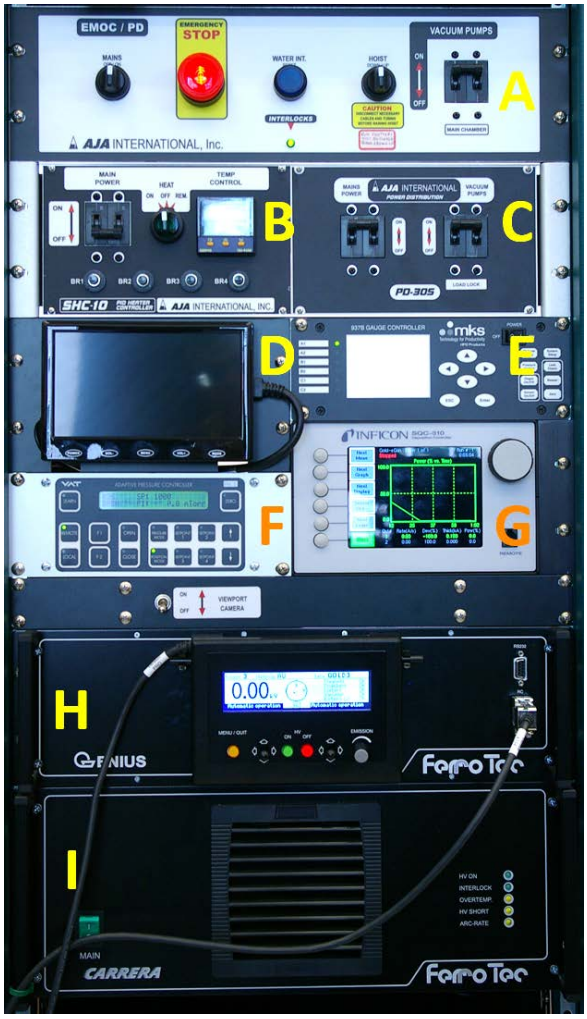


Fig. 2. AJA dashboard.

The second level of the dashboard panel contains the controls for sample holder heaters on the left (B), the main power switch (in the middle), and the switch for LL vacuum system on the right (C).

At the next level, a viewing monitor is located on the left (D, connected to a camera outside the MC, currently not in use), and the pressure gauge controller (MKS 937B) on the right (E).

On the bottom level of the dashboard, a MC TMP gate valve (VAT) controller (F) and the e-beam deposition controller (Inficon SQC-310, G) are situated.

Below the dashboard, the remote e-gun controller (FerroTec Genius, H) is mounted and, at the very bottom, the e-gun power supply switch is located (FerroTec Carrera, I).

The vacuum pump controllers are located at the bottom left of the rack (Fig. 3). For the CP, its temperature is indicated. For the TMP's, their status and current rotation speeds are displayed. On the left side of the CP monitor, table rotation controller is situated. It has a toggle switch to switch between the local and remote control modes, and a rotation speed knob.

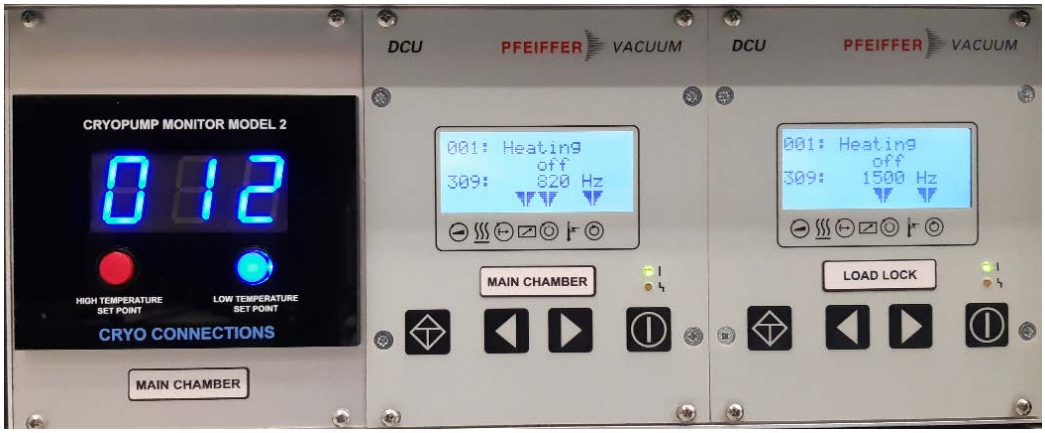


Fig. 3. Cryo pump monitor, MC and LL TMP controllers.

The vacuum inside the MC is measured by three vacuum gauges covering the pressure range from 760 Torr to 10^{-10} Torr: Convectron Pirani (from atmosphere to 1 mTorr), Baratron Capacitance Manometer (from 0.1 Torr to 10^{-5} Torr), and Ion Gauge (below 10^{-5} Torr). All gauge readings are displayed on a gauge controller (Fig. 4) in the following order (top to bottom): Ion (A1), Convectron (B1), Baratron (C1).

Fig. 4. MKS pressure gauge controller.

Please note that, to prevent the Ion Gauge filament burnout at high pressure, the Ion Gauge must be turned off when any gas is supplied to the MC (for example, for sputter deposition or for MC venting purposes). To turn it off/on, use the up/down arrows on the control panel to place the green light at the corresponding line, and push the "Sensor On/Off" button to toggle the gauge (Fig. 4).

Sample loading/unloading

Running any process on the AJA requires loading and unloading the sample(s) inside the LL and, later, the MC. The loading mechanism consists of a sample holder (can house wafers up to 4”) mounted on loading arm that can move it in and out of the MC. Rotation is used to fix it onto or separate it from the table. To load your sample:

1) Vent the LL. To do this, turn the LL pumping off using the switch on the corresponding panel (Fig. 5).

Fig. 5 Load Lock vacuum switch.

2) The LL TMP controller will indicate an error and, after some time, will turn off. You will also hear the clicking sound of a venting valve that injects small portions of venting gas into the LL. Wait until the pressure in the LL equals 1 atmosphere (750-760 Torr), as indicated by the gauge (Fig. 6).

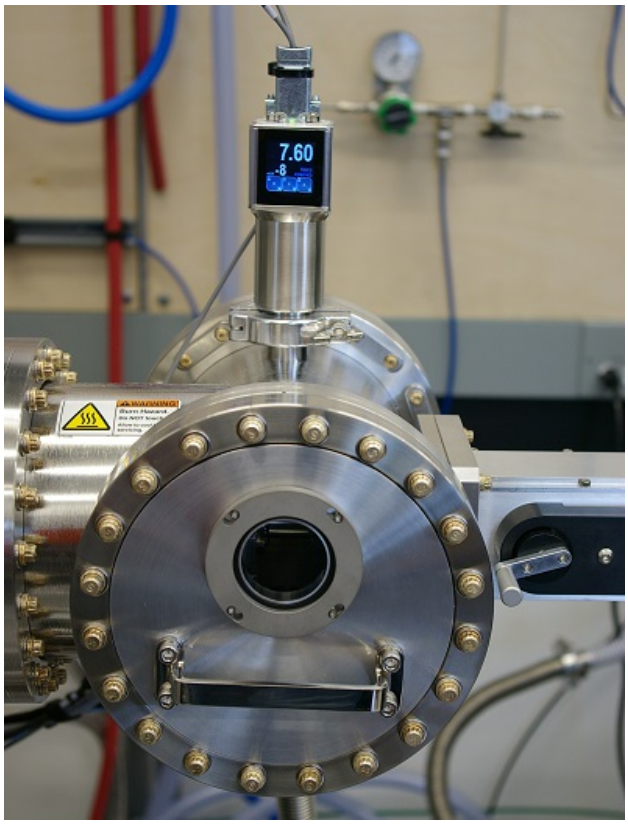


Fig. 6. Load-lock (closed, lid on). The pressure gauge is on top, the arm moving handle on the right.

3) Take the LL lid off. Take the sample holder out.

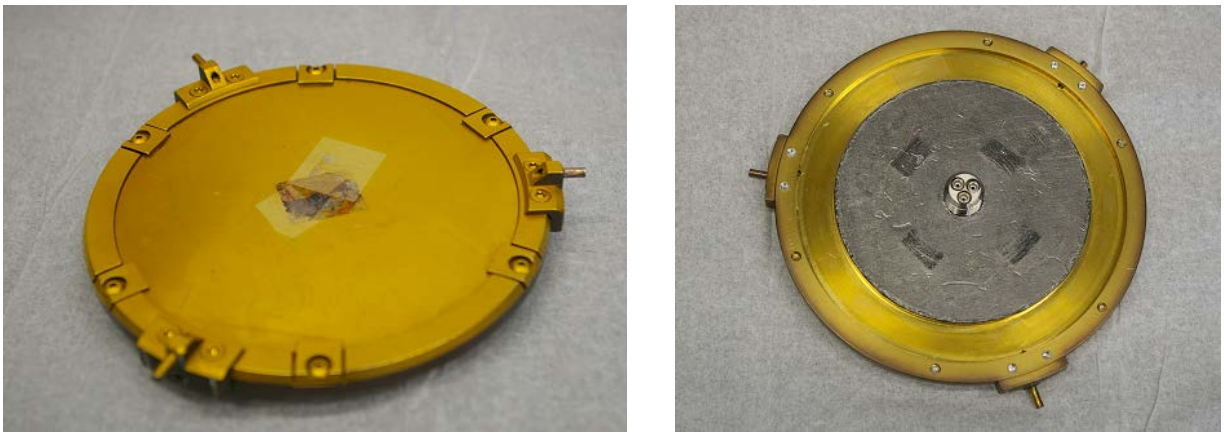


Fig. 7. Sample holder, front (left) and back (right) sides. On the back side, a mounting screw is seen; it is used to fix the holder on sample table, and is surrounded by grey Indium foil for thermal contact.

4) Mount your sample. Load the sample holder back into the LL. Be careful when doing this, do not scratch the sample surface. Make sure each of the three sample holder pins sit between the four white rolls on the arm (Fig. 8).

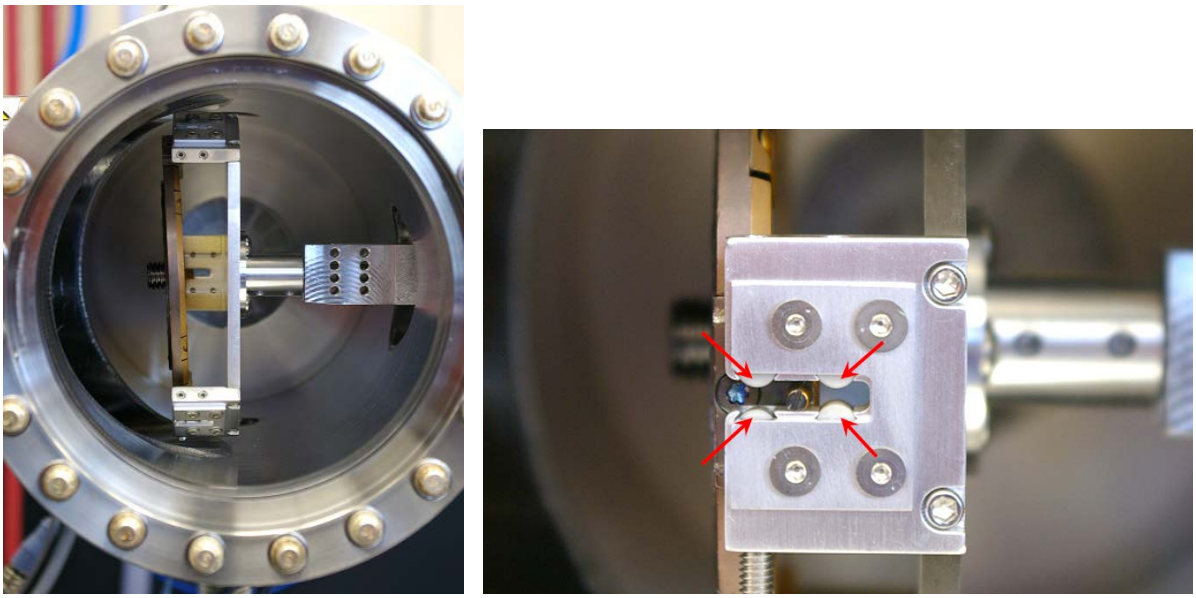


Fig. 8. Arm that grabs the sample holder inside the LL. Arrows show the white rolls that hold the pins of the sample holder in place when transferring into the MC.

5) Close the LL lid and evacuate the LL by pulling up the switch in Fig. 5 .
6) While the LL is pumping down, open the electronic Logbook on the computer and start recording. Make a note of the base pressure and other parameters, as required.
7) When the vacuum in the LL reaches $1*10^{-5}$ Torr, open the manual gate valve between the MC and LL. Only rotate the handle until you start to feel resistance!

Fig. 9. Manual gate valve (isolates MC from LL). The pin is in “CLOSED” position (at slit bottom).

8) Make sure the table in the MC is facing to the right (270^{o} on the scale, Fig. 10) and move the arm with the sample holder inside the MC. The threaded pin on the holder should go inside the threaded hole in a table (Fig. 11).

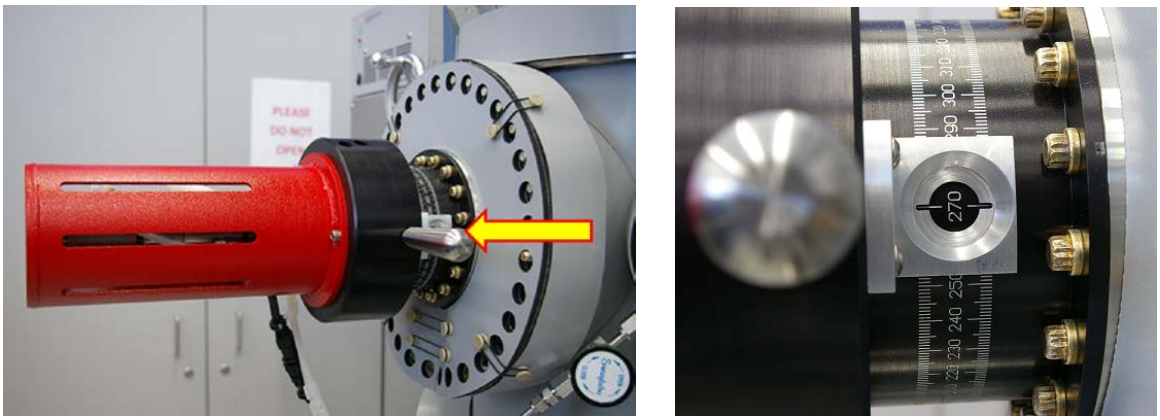


Fig. 10. Rotating sample table (outer part) with handles and scale. For sample transfer, the angle should be set to 270^{o}.

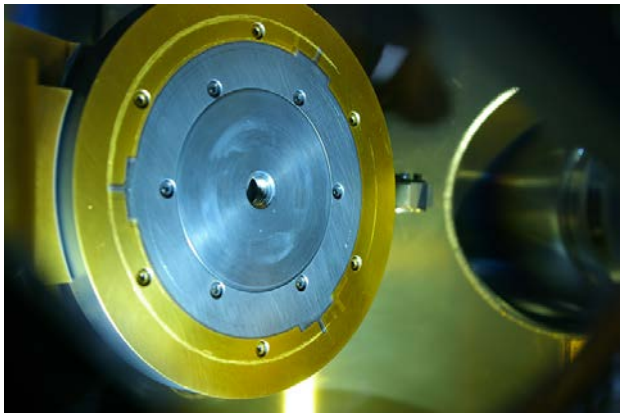


Fig. 11. Sample table (inner part) inside the MC; the tapped hole (center) is where the sample holder pin screws in.

9) Fix the holder by rotating the black handle (Fig. 12) counter clockwise (the sample holder rotates clockwise). Stop as soon as you feel more resistance than normal!

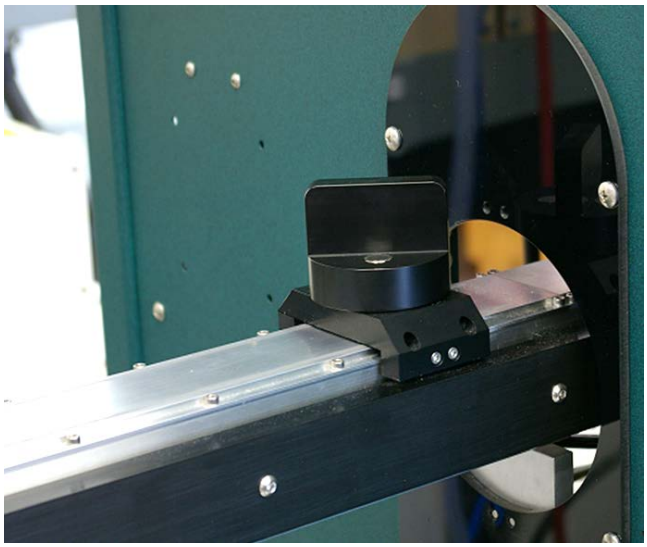


Fig. 12. Sample holder rotation handle. NOTE: the holder rotation direction is opposite to the handle rotation direction.

10) Retract the arm back to its original position, all the way out from the MC.
11) Close the manual gate valve. Stop rotating the handle immediately after you feel the click and the position indicator pin “drops” to the lowest position. Overtightening the handle will damage the valve eventually leading to its failure!

To unload the sample:

1) Rotate the table to 270 deg. position (facing to the right).
2) Open the manual gate valve. Only rotate the handle until you start to feel resistance!
3) Move the arm into the MC. Adjust the arm rotation angle such that it can grab the three pins on a sample holder. If you can’t grab the pins, rotate the table using the rotation controller.
4) When all three pins of the sample holder are caught, rotate the black arm handle clockwise to unscrew the holder from the table. Make many turns to make sure that the sample holder got separated from the table.
5) Retract the arm all the way and close the manual gate valve. Stop rotating the valve handle as soon as you feel a click and the pin jumps down.
6) Vent the LL.
7) Open the LL lid and carefully take the sample holder off the arm and out of the LL. Take care not to scratch the sample surface in the process!
8) Take your sample off the holder and clean the holder.
9) Install the holder back in the arm and make sure each of the three sample holder pins sits between the four white rolls on the arm.
10) Evacuate the LL by pulling up the LL TMP switch (Fig. 5).

E-beam evaporation

Process basics.

Electron-beam evaporation (EBE) is a PVD technique used to deposit thin films of various materials in high vacuum (HV) environment. During an EBE process, current is first passed through a tungsten filament (cathode) which leads to joule heating and electron emission. High voltage is applied between the filament and the hearth to accelerate the emitted electrons towards the crucible containing the material to be deposited (anode). A strong magnetic field focuses the electrons into a unified beam; upon arrival, the energy of this beam of electrons is transferred to the deposition material, causing it to evaporate (or sublimate) and deposit onto the substrate.

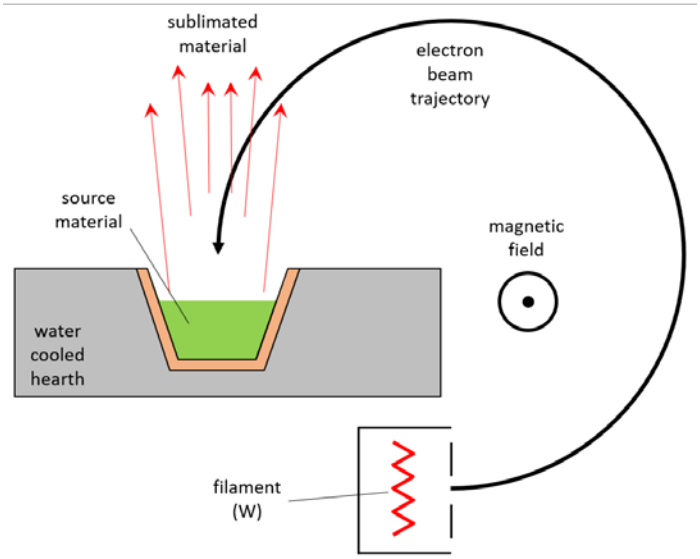


Fig. 13. Schematic of e-beam evaporation process.

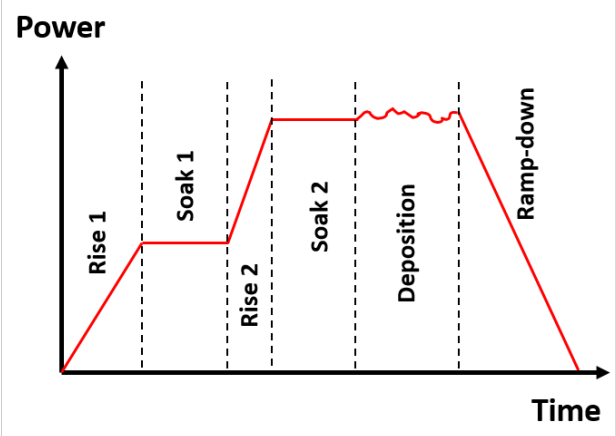


Fig. 14. Power vs. time profile of a typical EBE process.

The typical EBE process consists of several phases (Fig. 14): power ramp-up (Rise 1, Soak 1, Rise 2, Soak 2), deposition, power ramp-down. Gradual increase of gun power is required to preheat the target and distribute the electron energy evenly, while Soak stages allow the target and evaporated plume to

equilibrate after the power ascension. The exact process parameters depend on the material to be deposited and machine type used.

The AJA is equipped with an EBE deposition controller that automatically completes all process stages and, when in deposition mode, maintains the specified deposition rate with high accuracy, based on the readings from the quartz crystal monitor (QCM). Because the process parameters (in particular, the Rise 1/Rise 2 power levels) may differ significantly for various materials, it is critically important that the material selected on the deposition controller is the same as the real material in a crucible.

To deposit a layer of any material using e-beam evaporation:

1) Load your sample.
2) Rotate the table such that the sample faces down (or set it to a desired angle if, for example, a tilted sample is a requirement of your process (side walls need to be coated, etc.)).
3) Use the material selector wheel to choose the required material crucible. Note that the pin of the selector must exactly align with the mark on the panel as shown on Fig. 15.

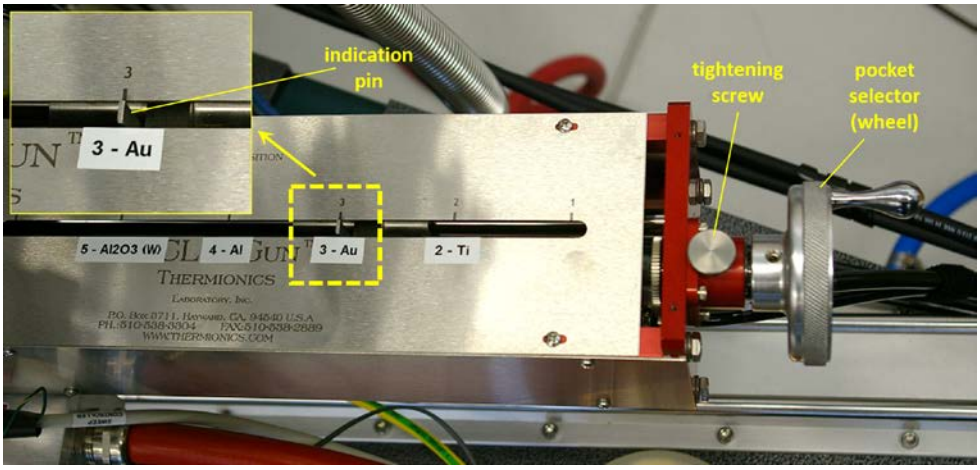


Fig. 15. Material selector.

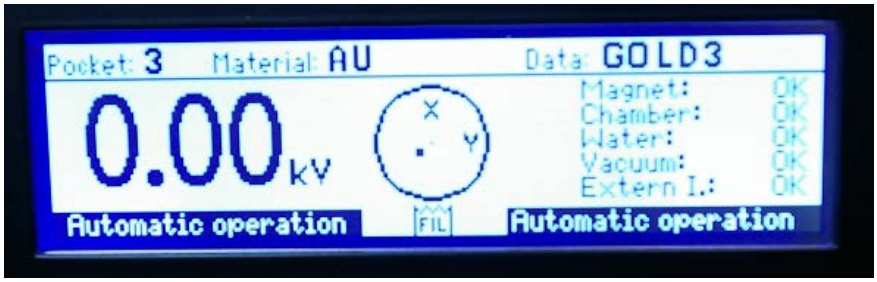
4) Set the gun controller (Fig. 16) to the material you'll be depositing. To do so:

Fig. 16. Electron gun controller (FerroTec Genius). Left to right: Menu Enter/Quit button, left joystick, HV on and off buttons, right joystick, emission current knob.

a. go into Menu (press yellow MENU button)
b. enter the Auto/Manual sub-menu (one click down of the left joystick, Fig. 17b)

c. change the operation mode from Auto to Manual (one click of the right joystick up to activate Manual, DO NOT MOVE THE JOYSTICK TO THE RIGHT/LEFT!)
d. go into Set Pocket sub-menu (one click of the left joystick up, Fig. 17c)
e. select the proper material (use the right joystick to select the pocket (up and down) and set it with one click to the right)
f. return into Auto/Manual sub-menu (one click down of the left joystick)
g. switch to Auto mode (click down of the right joystick)
h. exit Menu (press yellow button)

(a)

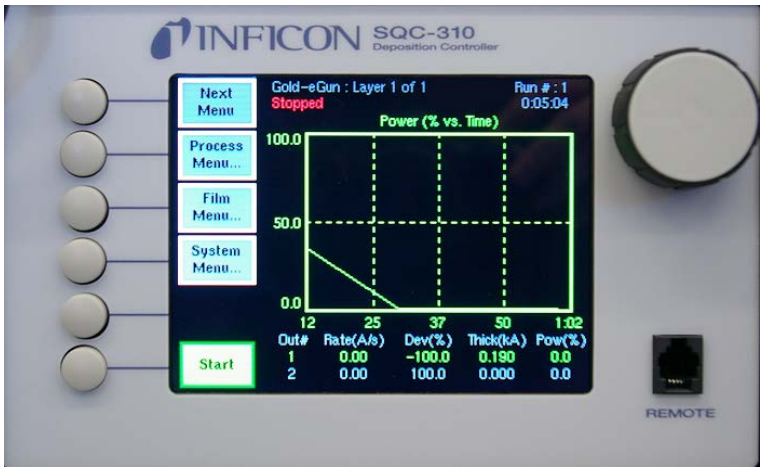


(b)

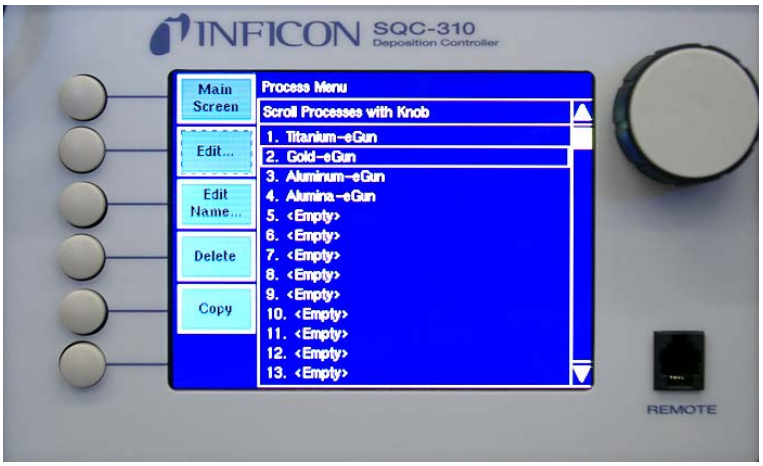
(c)

Fig. 17. Gun controller. Main screen (a) and sub-menus: Auto/Manual mode (b), Set Pocket (c).

5) Set the deposition controller (Inficon, Fig. 18) to the corresponding material. To do so:
   a. go into Process Menu



b. use the wheel to select the process, then click “Edit”;



c. layer menu will be displayed. Select the corresponding layer and click “Edit”

d. Set the required deposition rate (in A/s) and film thickness (in kA, 1 kA = 100 nm), confirm by pressing “Enter”, and return to the main menu.

Fig. 18. Deposition controller (Inficon). Main screen, process menu, Layer menu and Layer settings are shown.

6) Make sure the proper material is selected: on the material selector, on the gun controller, and on the deposition controller.
7) Turn ON the e-gun power supply ("MAIN" button on FerroTec Carrera panel).
8) Turn ON the high voltage (HV) on e-gun remote controller (green button). The screen should display 8.60 kV.
9) In the PHASE II J software, in e-beam deposition section (Fig. 19), make sure the regime button is set to REMOTE, then select desired process, and click Run Process. The deposition will start in fully automatic mode.
10) **!!! IMPORTANT !!!:** If the gun is approaching the Soak 2 stage and you see zero or extremely low deposition rate, you should immediately abort the process, turn OFF the e-gun power supply, and contact the cleanroom staff. Failure to do so may result in the tool damage.
11) During deposition, make notes of the gun power (in %) and emission current (in mA) in a log file.
12) After the deposition is complete and message "Deposition process complete" pops up in PHASE II J, turn the HV OFF (red button on the gun controller) and wait until the HV reading drops to zero.
13) If you need to deposit another layer on the same sample, repeat steps 3-11 for a new material.
14) Turn OFF the e-gun power supply.
15) Complete the log by writing the sensor life and save it.
16) Unload your sample.

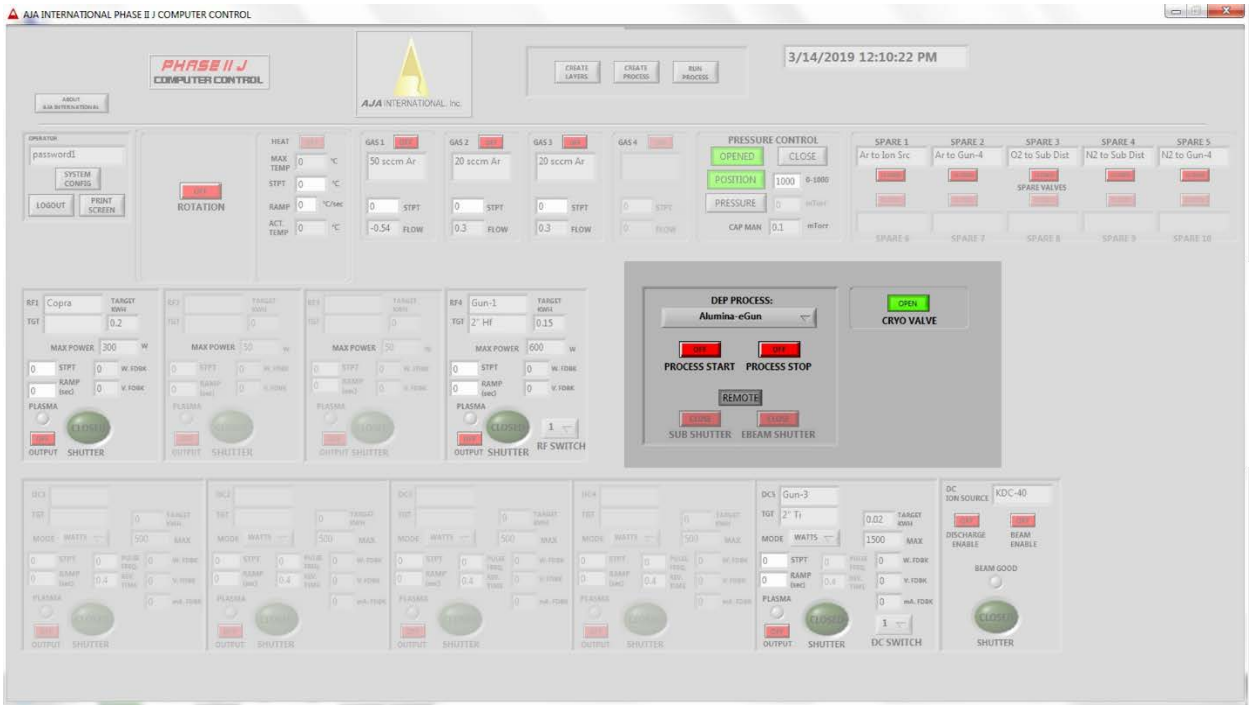


Fig. 19. Phase II J software. Ebeam deposition controls and cryo valve switch are highlighted.