Chapter 6.12

CHA Solution E-beam Evaporator

(cha) (582)

1.0 Equipment Purpose

1.1 The cha e-beam evaporator is a 10 kW high vacuum e-beam evaporation system. One mechanical pump is installed for rough pumping and one cryo pump for high vacuum pumping. The turret can accommodate six crucibles at a time to allow multiple and sequential evaporations. Substrates are held in a rotating dome with wafer rotation capable of maintaining 90 degree facing for lift off geometry. The default substrate is a 6 inch wafer, though 4 inch substrates and chips can be accommodated via adapter plates inserted into the dome. The Inficon IC6 deposition controllers allows for automatically controlled rise and soak of crucible melts, and tightly controlled deposition of films. The system is also equipped with an ionmill for native oxide removal and surface cleaning of substrates.

2.0 Manual Scope

2.1 This document has specific information about the cha e-beam evaporator in 582 bay of the Marvell NanoLab. A list of metals available for deposition in this tool, as well information on correct operation and safety are also provided in this manual.

3.0 Applicable Documents

3.1 6.10 (evapclass) Evaporation Training Workshop

4.0 Definitions & Process Terminology

4.1 PVD Evaporation: A process in which material is heated until it reaches a vapor state, which then emanates via diffusion until contact with a cold source which removes enough heat from the vapor to return it to a solid state.

4.2 E-Beam: A beam of electrons sourced at high voltage (10 kV on cha). The beam heats the material to be deposited. The beam is guided by a series of magnets, which are tuned to focus the beam on the center of the crucible.

4.3 Shunt: A metal bar placed in contact with beam focusing magnets to alter the focus of the beam.

4.4 Beam sweep: A series of electromagnetic coils that offer a tunable magnetic change to the beam positioning magnetics. Used to center the beam and direct the beam in a pattern to avoid localized overheating of the melt.

4.5 Beam Sweep Controller: Sycon beam sweep controller can be programmed with sweep patterns with individual offsets for different materials.

4.6 Base Pressure: The highest vacuum obtained between closing the chamber and beginning the deposition process. 5x10E-6 is the minimum operating base pressure for the cha. 5x10E-7 is required for good film quality.

4.7 E-Gun: The filament and electrical fixturing that fires the e-beam.

4.8 Hearth: The portion of the E-gun that holds the source material.

4.9 Turret: The rotating portion of the hearth used to select pocket positions.
4.10 **Turret Isolation Cover**: Tongue and groove jointed shield used to prevent cross contamination to other pockets during deposition.

4.11 **Pocket**: The machined slots in the turret used to hold crucibles of material.

4.12 **Crucible Spacer**: A machined disk of graphite used to raise the crucible liner off the pocket wall and ensure the crucible liner is centered.

4.13 **Crucible Liner**: Used to both contain the deposition melt and reduce the amount of volume required to build a melt to evaporate films from.

4.14 **Melt**: The molten/sublimating material to be deposited on the wafer.

4.15 **Uniformity Shield**: Used to block some amount of arc length on the wafer rotation path and allow tuning of uniform coatings of material.

4.16 **Shutter**: Scissor type metal plates used to interrupt source to substrate line of sight.

4.17 **Wafer Holder**: 3-wafer lift off dome engineered to be at 90 degrees from source to substrate to allow lift off geometry.

4.18 **Touchscreen**: Siemens touchscreen controls vent/pumpdown/ionmill/beam interlocks. Can run tool in manual mode for process development. Lab Members are not allowed to use manual mode without staff approval.

4.19 **Crystal Monitor**: A 6 MHz gold crystal monitor used to measure the deposition rate.

4.20 **Deposition Controller**: Inficon IC6 deposition controller used to automatically control pre-set deposition parameters.

4.21 **Rise 1 & 2**: Material specific power ramping timers to safely reach Soak 1 & 2 set points.

4.22 **Soak 1 & 2**: Material specific power input parameters to condition melt prior to opening shutter. Soak 1 should achieve melt in most materials, soak 2 should approach desired deposition rate. Soak values in recipes are variable and members should not run processes without checking them.

4.23 **Feed Ramp**: Power ramp for post-deposition.

4.24 **Feed Time**: Time delay before cycling to next layer of deposition. Used to give crucible time to cool to avoid deposition on turret isolation cover.

4.25 **Ion Mill**: Argon based ion source used to clean contacts prior to metal deposition.

4.26 **Ion Gauge 1 & 2**: Ion gauges used to measure high vacuum. Highly sensitive to pressures >10E-4 Torr.

4.27 **Roughing Pump**: Dry pump used to bring chamber from atmosphere to 70 mTorr

4.28 **Cryopump**: CTI cryogenics pump used to bring chamber from <100 mTorr to 5 x 10E-7

4.29 **Vapor Pressure**: The amount of gas pressure a material will generate at a given temperature. Material will evolve gas until vapor pressure is reached.

4.30 **VContamination**: The vapor pressure at which a material reaches contamination level concentrations in contaminated films. In the Marvell NanoLab evaporators, this is defined as 1x10E-7 Torr.

4.31 **VDeposition**: The vapor pressure at which a reasonably fast deposition rate is achieved. In the Marvell NanoLab this is defined as 1x10E-2 Torr.
4.32 **Monolayer Formation Rate:** Rate at which vapor particles will form a monolayer on a given surface. One monolayer ~ 0.5A - 1A deposition. Rate = (Vapor Pressure)/3x10E-4

5.0 **Safety**

5.1 **Molten Metal**

5.1.1 **Radiant Light:**

5.1.1.1 Never look directly at a melt when running more than 50mA into the melt! Molten metal radiates a significant amount of energy from black-body emission.

5.1.1.2 Always use the provided visual shielding to view a bright melt. The effects are similar to staring into the sun.

5.1.2 **Warm Crucibles:**

5.1.2.1 A crucible must cool sufficiently before being removed from the hearth.

5.1.2.2 The crucible liner and spacer combination allows the melt to reach much higher temperatures at much lower powers, but also requires a longer cooling time.

5.1.2.3 Use the provided cooling plate to cool metal melts, and ALWAYS remove metal melts from a hearth with tweezers.

6.0 **Process Data**

6.1

7.0 **Available Processes, Gases, Process Notes**

7.1 **Material Restrictions for cha:**

7.1.1 No materials which reach a vapor pressure of 1x10E-7 Torr at temperatures under 900 °C.

7.1.2 No Ferromagnetic materials: No Cobalt, No Iron, No Nickel, No Gadolinium. Magnetic materials affect beam position due to changing the gauss field in the chamber, and cause rapid process drift.

7.1.3 No Dielectric evaporation

7.1.4 Porous materials such as Sn require members to form melts with shutters **closed** and said members must **always** clean shutters, dome, and mirror ring before disabling the tool. Additionally, members must coordinate with staff when depositing porous materials to schedule a shielding change after their deposition. Failure to coordinate a shielding change for a porous material is grounds for disqualification from tool.

7.2 **Allowed Materials:**

7.2.1 Aluminum, Titanium, Copper, Platinum, Palladium, Silver, Gold, Chrome, Tin, and Nickel (with permission)

7.2.2 Pocket 1 reserved for Aluminum and Tin (Gun Power: LOW)

7.2.3 Pocket 2 reserved for Copper and Silver (Gun power: MID)

7.2.4 Pocket 3 reserved for Titanium & Chrome (Gun power: (MID)

7.2.5 Pocket 4 reserved for Special Applications (Gun Power: (Variable)

7.2.6 Pocket 5 reserved for Gold (Gun Power: MID)
7.2.7 Pocket 6 reserved for Platinum & Palladium (Gun Power: (MID))


7.4 Questions about material policy should be directed to Process Staff.

7.5 Ion Mill Process:

7.5.1 Pressure: 1x10E-4 Torr Ar

7.5.2 Duration: Modified in general recipe

7.5.3 Power:

7.5.4 Etch Rate: Extremely Low. Viable for contact cleaning, otherwise immeasurable.

7.6 Aluminum Process:

7.6.1 Special Notes:

7.6.1.1 Aluminum bonds to carbon crucibles and forms an Aluminum Carbide skin. This skin melts at a much higher temperature than pure aluminum. Soak 2 typically brings the aluminum just above the carbide melting temperature for a short duration and then the auto controller takes over once shutter opens.

7.6.1.2 Do not overfill your melt. Melts with more than 17g aluminum in the crucible risk overtopping and cracking the crucible/forcing tool maintenance.

7.6.2 Crucible: Fabmate coated graphite, 8.2cc volume. Sand edges down to generate sharp lip. Weigh crucible on scale, note weight. All weights are given as melt weight and have subtracted crucible weight.

7.6.3 Melt building procedure:

7.6.3.1 Crucible 1

7.6.3.2 Gun Power: Low

7.6.3.3 Sweep Pattern: 1

7.6.3.4 Rise/Soak 1: 30s, 60%/3min 0sec

7.6.3.5 Rise/Soak 2: 15 sec, 62%/30sec

7.6.3.6 Deposition thickness: 0.000kA (Skips deposition step)

7.6.3.7 Al stage 1: Add ~4g – Fill crucible to 1 layer deep, run recipe

7.6.3.8 Al stage 2: Bring melt to net weight 8g, run melt

7.6.3.9 Al stage 3: Bring melt to net weight 12g, run melt

7.6.4 Deposition Process settings:

7.6.4.1 Bring melt to 12g weight. Do Not Overfill

7.6.4.2 Crucible 1

7.6.4.3 Gun Power: Low

7.6.4.4 Sweep Pattern: 1

7.6.4.5 Rise/Soak 1: 30s, 65%/3min 30sec

7.6.4.6 Rise/Soak 2: 15 sec, 63%/1min 30sec
7.6.4.7 Deposition Rate: 10 A/s
7.6.4.8 Deposition thickness: Determined by member
7.6.4.9 Feed Ramp to 0%: 15 sec, Feed Time: 1min 30sec

7.7 Copper Process:

7.7.1 Special Notes:
7.7.1.1 Process developed for 3.9cc reducing crucible due to copper cost per volume.
7.7.1.2 Copper forms good ball in crucible, but will bond directly to copper hearth. If crucible is damaged, immediately abort process and allow system to cool. Vent and remove melt from crucible and transfer to new undamaged crucible.
7.7.1.3 Copper reaches somewhat high temperatures and requires a longer feed time to cool without damaging melt/crucible.

7.7.2 Crucible: Fabmate coated graphite, 3.9cc volume OR 8.2cc. Weigh crucible on scale, note weight. All weights are given as melt weight and have subtracted crucible weight.

7.7.3 Melt building procedure:
7.7.3.1 Crucible 2
7.7.3.2 Gun Power: Mid
7.7.3.3 Sweep Pattern: 3 (3.9cc) or 1 (8.2cc)
7.7.3.4 Rise/Soak 1: 30s, 38%/5min 0sec
7.7.3.5 Rise/Soak 2: 15 sec, 43%/30sec
7.7.3.6 Deposition thickness: 0.000kA (skips deposition step)
7.7.3.7 Cu stage 1: Add ~7g – Fill crucible to 1 layer deep, run recipe
7.7.3.8 Cu stage 2: Bring melt to net weight 17g, run melt
7.7.3.9 Cu stage 3: Bring melt to net weight 25g, run melt

7.7.4 Deposition Process settings:
7.7.4.1 Bring melt to 25g weight. **Do Not Overfill**
7.7.4.2 Crucible 2
7.7.4.3 Gun Power: Mid
7.7.4.4 Sweep Pattern: 3
7.7.4.5 Rise/Soak 1: 30s, 38%/5min
7.7.4.6 Rise/Soak 2: 15 sec, 43%/1min
7.7.4.7 Deposition Rate: 10 A/s
7.7.4.8 Deposition Thickness: Determined by member.
7.7.4.9 Feed Ramp to 0%: 15 sec, Feed Time: 1min 30sec

7.8 Silver Process:

7.8.1 Special Notes: Process under review by staff.
7.8.1.1 Process developed for 3.9cc reducing crucible due to silver cost per volume.

7.8.1.2 Silver forms good ball in crucible. Does not bond to crucible. If crucible is damaged, immediately abort process and allow system to cool. Vent and remove melt from crucible and transfer to new undamaged crucible.

7.8.1.3 Silver forms a skin and is difficult to melt. Upon piercing skin, deposition rate will increase dramatically (~2 orders of magnitude). Rise/soak 1 should bring melt to 30 A/s of deposition; soak 2 should stabilize power slightly under that amount.

7.8.1.4 Silver requires very low process gain (~5 A/s/%)

7.8.2 Crucible: Tungsten, 3.9cc volume. Weigh crucible on scale, note weight. All weights are given as melt weight and have subtracted crucible weight.

7.8.3 Melt building procedure:

7.8.3.1 Crucible 2
7.8.3.2 Gun Power: Mid
7.8.3.3 Sweep Pattern: 3 (3.9cc) or 1 (8.2cc)
7.8.3.4 Rise/Soak 1: 1 min, 70%/5min 0sec
7.8.3.5 Rise/Soak 2: 15 sec, 60%/30sec
7.8.3.6 Deposition thickness: 0.000kA (skips deposition step)
7.8.3.7 Ag stage 1: Add ~10g – Fill crucible to 1 layer deep, run recipe
7.8.3.8 Ag stage 2: Bring melt to net weight 20g, run melt
7.8.3.9 Ag stage 3: Bring melt to net weight 30g, run melt

7.8.4 Deposition Process settings:

7.8.4.1 Bring melt to 30g weight. Do Not Overfill
7.8.4.2 Crucible 2
7.8.4.3 Gun Power: Mid
7.8.4.4 Sweep Pattern: 1
7.8.4.5 Rise/Soak 1: 30s, 70%/5min
7.8.4.6 Rise/Soak 2: 15 sec, 67%/1min
7.8.4.7 Deposition Rate: 20 A/s
7.8.4.8 Deposition Thickness: Determined by member.
7.8.4.9 Feed Ramp to 0%: 15 sec, Feed Time: 1min 30sec

7.9 Titanium Process:

7.9.1 Special Notes:

7.9.1.1 Titanium creeps up the side of graphite crucibles. It is a relatively high temperature metal and will does not need a full melt to evaporate at an acceptable rate.
7.9.1.2 Process gain for titanium is specified at 7 A/s/%. Do not change. The melt requires a punch through spike on soak 2 and will need to rapidly come down from high temperature to deposition temperature.

7.9.1.3 **Do not overfill your melt.** Melts with more than 25g Titanium in the crucible risk overtopping and cracking the crucible/forcing tool maintenance.

7.9.2 Crucible: Fabmate coated graphite, 8.2cc volume. **Sand edges down to generate sharp lip.** Weigh crucible on scale, note weight. All weights are given as melt weight and have subtracted crucible weight.

7.9.3 Melt building procedure:

7.9.3.1 Crucible 3
7.9.3.2 Gun Power: Mid
7.9.3.3 Sweep Pattern: 1
7.9.3.4 Rise/Soak 1: 30s, 46%/4min 30sec
7.9.3.5 Rise/Soak 2: 15 sec, 50%/30sec
7.9.3.6 Deposition thickness: 0.000kA (Skips deposition step)
7.9.3.7 **Ti stage 1:** Add ~5g – Fill crucible to 1 layer deep, run recipe
7.9.3.8 **Ti stage 2:** Bring melt to net weight 15g, run melt
7.9.3.9 **Ti stage 3:** Bring melt to net weight 25g, run melt

7.9.4 Deposition Process settings:

7.9.4.1 Bring melt to 25g weight. **Do Not Overfill**
7.9.4.2 Crucible 3
7.9.4.3 Gun Power: Mid
7.9.4.4 Sweep Pattern: 1
7.9.4.5 Rise/Soak 1: 30s, 44%/2min 30sec
7.9.4.6 Rise/Soak 2: 15 sec, 48%/1min 0sec
7.9.4.7 Deposition Rate: 4 A/s
7.9.4.8 Deposition thickness: Determined by member
7.9.4.9 Feed Ramp to 0%: 5 sec, Feed Time: 1min 30sec
8.0 **Equipment Operation**

8.1 Vent & Load wafers/melts

8.1.1 Enable cha. Enter materials to be deposited in order of deposition.
8.1.2 Tap touchscreen to wake computer from sleep mode.
8.1.3 Abort pumpdown. Wait for Standby.
8.1.4 Press Auto Vent. Wait 1 min.
8.1.5 Put on vacuum gloves.
8.1.6 Unlock pneumatic door latch. Open door and stand clear for 30s.
8.1.7 Prepare clean loading area for wafer dome.
8.1.8 Use wafer dome removal tool to remove wafer dome. Place in clean loading area.
8.1.9 Inspect dome for flaking films. Open shutter. Inspect chamber (Especially shutters) for flaking films.

8.1.9.1 **Do not rotate the shutters manually – doing so will strip the shafts of the shutters from their mounts and severely damage the tool.**

8.1.10 Use vacuum hose to remove any flakes. If flaking is too excessive to remove, report on mercury.
8.1.11 Remove dummy wafers, load process wafers into wafer dome.
8.1.12 Load dome into tool, remove wafer dome removal tool.
8.1.13 Rotate to desired pocket.
8.1.14 Check for crucible spacer in pocket.
8.1.15 Load melt. Check no sidewalls of crucible touch pocket.
8.1.16 Confirm proper power setting/sweep pattern for melt on touchscreen recipe for the pocket.
8.1.17 Confirm Ionmill time desired in general recipe.
8.1.18 Close Shutter, close door, engage pneumatic latch.
8.1.19 Press Auto Pumpdown. Wait until chamber reaches 5×10⁻⁷

8.2 Manual Mode (Recommended for initial melt stages only!):

8.2.1 Press Manual Mode on the Siemens touchscreen.
8.2.2 Open the High Vac Valve (Be sure to be under 5×10⁻³!)
8.2.3 Press Ion Gauge.
8.2.4 Switch to Ion Gauge #2.
8.2.5 Press Pump.
8.2.6 Press Reset on the IC6.
8.2.7 Select your material as an active process – this allows use of the crystal monitor.
8.2.8 Press Deposit.
8.2.9 Touch the orange motor near the rotary system on the diagram. It should turn green.
8.2.10 Check e-beam gun power setting (LOW, MID, HIGH).
8.2.11 Engage the Filament.
8.2.12 Engage the High Voltage.
8.2.13 Go to Operate on the IC6.
8.2.15 Use hand remote to drive power.
8.2.16 Use beam sweep to assist in pulling pellets in during melt formation.
8.2.17 Finish your melt-up stage.
8.2.18 Ramp the power down and then cut the process by pressing the trigger on the remote.

8.3 Autorun Setup:
8.3.1 Press Menu on IC6 until you reach the screen menus.
8.3.2 Select Material, press menu, and then select your material.
8.3.3 Confirm Pre/Post-dep settings and deposition rate are correct.
8.3.4 Press Menu
8.3.5 Select Process, press menu, and then select your process.
8.3.6 Check deposition thickness, set to desired value. Processes 1-10 are for single layer material processes. Processes 10+ are variable and may be edited by members with staff approval.
8.3.7 Once finished editing process, press RESET, then select Set Active Process.
8.3.8 Wait for pumpdown to complete. Select Autorun. You must attend the cha evaporator at all times while the beam is on. Cruise control does not drive for you, neither does the IC 6.
8.3.9 After run, allow up to 10 minutes for crucible to cool. Never vent if you can see light from the crucible with your naked eye when there is no shield in front of the window.

8.4 Removal of wafers/melt
8.4.1 Press Auto Vent. Wait 1 min.
8.4.2 Put on vacuum gloves.
8.4.3 Unlock pneumatic door latch. Open door and stand clear for 30s.
8.4.4 Prepare clean loading area for wafer dome.
8.4.5 Use wafer dome removal tool to remove wafer dome. Place in clean loading area.
8.4.6 Inspect dome for flaking films. Open shutter. Inspect chamber (Especially shutters) for flaking films.
8.4.7 Clean all shutters, mirror rings, and the deposition dome.
8.4.8 Use vacuum hose to remove any flakes. If flaking is too excessive to remove, report on mercury.
8.4.9 Remove process wafers, load dummy wafers into wafer dome.
8.4.10 Load dome into tool, remove wafer dome removal tool.
8.4.11 Remove melts from pocket with tweezers. Place on cooling plate. Do not directly handle for 3 minutes.
8.4.12 Check crucible spacer is seated in pocket.
8.4.13 Close Shutter, close door, engage pneumatic latch.
8.4.14 Press Auto Pumpdown. Wait until chamber reaches 5x10E-7

9.0 Troubleshooting Guidelines

9.1 Gun will not engage:
  9.1.1 Problem: Interlock likely tripped.
  9.1.2 Solution: Check interlock board – Make sure Ion Gauge 2 is on and key is engaged. If water flow switch is red, report fault.

9.2 Turret Stuck:
  9.2.1 Problem: Turret mechanics jammed
  9.2.2 Solution: This is a red fault. Improper repair can cause considerable wear and damage on system mechanics. Immediately discontinue use of tool and report on mercury. Staff will attempt to resolve.
10.0 Tool Etiquette

10.1 Due to the extreme change in vacuum performance following Sn (Tin) depositions in the CHA system, Sn deposition requires notification of staff (via e-mailing the tool name) with a "Request for Porous Shielding". Staff will coordinate with member regarding a shield change after their deposition.
11.0 Figures & Schematics

11.1 Figure 1: CHA front panel

11.2 Figure 2: Inside of CHA chamber
12.0 Appendices

12.1
NanoLab Qualification Form

CHA Solution E-beam Evaporator

(cha) (582)

Name ___________________________ Office ______________________ Date _______________

Campus Phone _____________________ Home Phone ______________________

Login ___________________________ Trainer ___________________________

Qualification Test Passed (Signed by Front Desk) ___________________________

Oral Qualification Checklist

- Have you taken the Evaporation Training Workshop – Required
- Build a melt – member’s choice
- Which shields are the member’s responsibility
- 

Superuser Login Name ___________________________ Date _______________

Superuser Signature ___________________________