

Standard Operating Procedure: EBL Elionix

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Hardware Description and Principle of Operation

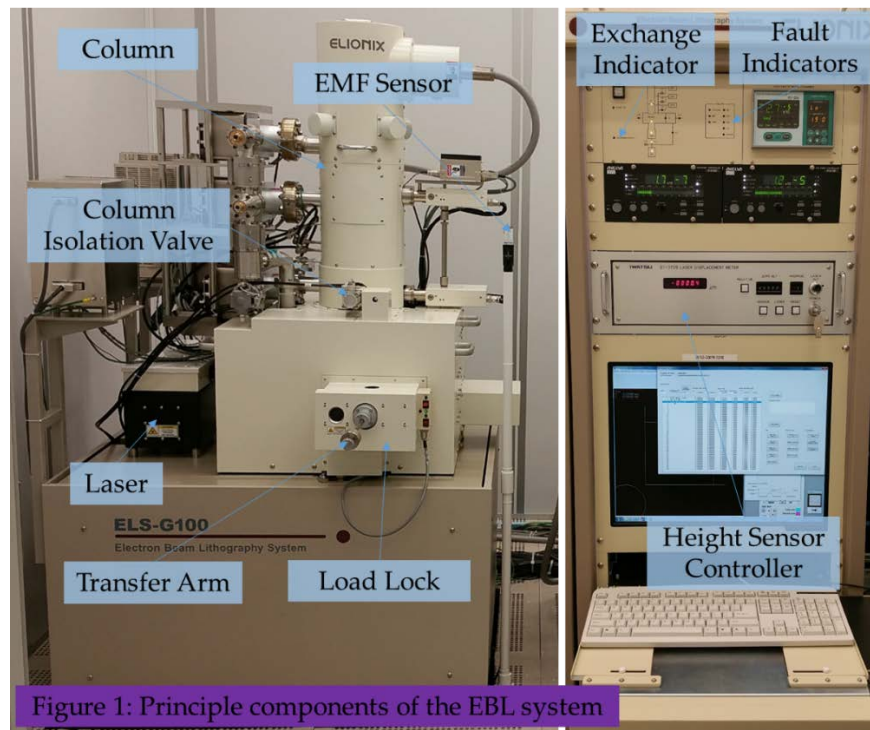
Elionix ELS-G100 Electron Beam Lithography

The Elionix Electron Beam Lithography (EBL) system is a 100 keV electron beam writer that is capable of generating fine patterns with ~ 8 nm resolution, ~ 30 nm stitching accuracy over a six inch wafer. Please note the location of the EMF sensor. The EMF sensor is used to sense electromagnetic fields in the room, which could interfere with the electron beam during exposure. When using the tool users should always exercise caution in the vicinity of the sensor: rotating or displacing it will cause the EMF hardware to malfunction adversely affecting the quality of the exposure.

Material Requirements

Equipment: substrate and tweezers

Personal Protective Equipment: nitrile gloves and face mask





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Procedure

Estimated Time: The time to load the sample and align the beam (without alignment marks) is approximately 10 minutes. If you have alignment marks, then the alignment procedure takes at least 10 more minutes. The above times should be added to the writing time calculated in WeCaS.

Pre-Use Equipment Checks

1. Make sure no fault indicators are illuminated.
2. Ensure that the stage is in exchange position, i.e. the Exchange Indicator is blinking green.

Load Sample

Three sample holders are available for use: a wafer holder that can accommodate 1 to 6 inch wafers, a multi-piece holder that can hold three chips simultaneously and a mask holder that can hold up to a 7 inch photomask or a large square wafer / glass slide.

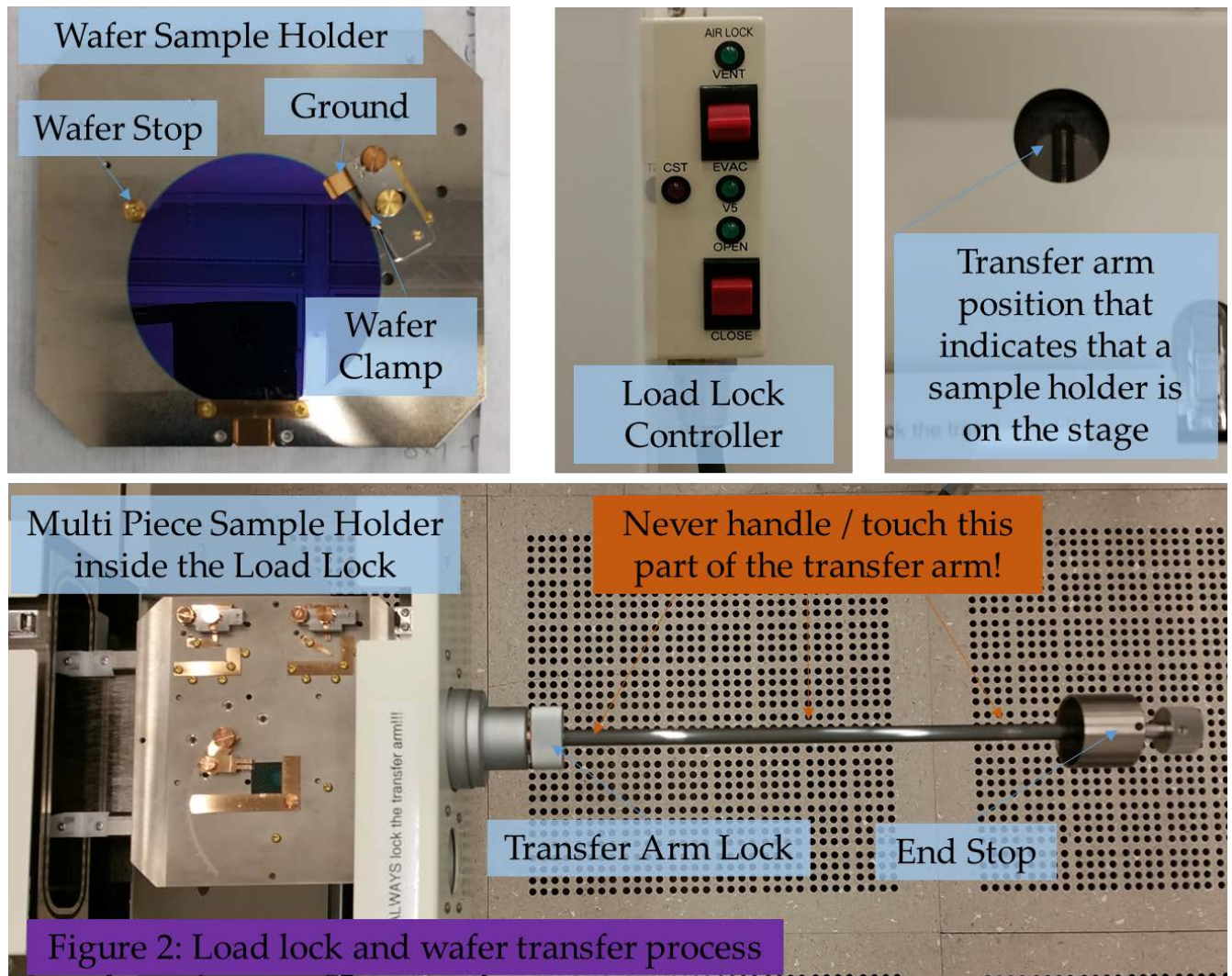
Note: Since the multi-piece sample holder is used most frequently it should always be stored in the load lock in order to minimize the temperature gradient between it and the stage.

When using either of the other two sample holders a 10 minute wait time is recommended to thermalize the holders in order to minimize thermal drift which could be an issue for high resolution exposures.

1. Verify that the stage is in Exchange position.
2. Verify that the gate valve that isolates the load lock from the stage is in the closed position.
3. Vent the load lock.
4. Mount the chip or the wafer to the appropriate sample holder. In doing so, make sure that the wafer stop is in contact with the wafer, the grounding clip is on top of the wafer, and the wafer clamp is fully engaged.
5. Attach the sample holder to the transfer arm by screwing the arm into the sample holder. In doing so, make sure not to over tighten the arm to the point where you may strip the thread.
6. Pump down the load lock, by pressing the toggle switch on the load lock controller down to the EVACUATE position. **For a more detailed explanation of the pumping process please consult the vacuum note at the end of this manual.**

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- Once the load lock is fully evacuated the evacuation LED will be illuminated. At that point you may open the gate valve by pushing the rocking switch on the load lock controller to the open position.
- Loosen the transfer arm lock.
- Insert the transfer arm into the stage until the end stop is in contact with the transfer arm lock and unscrew the transfer arm from the sample holder.
- Retract the arm and lock it in such a way that the transfer spring is visible through the window on the load lock. This indicates that there is a sample on the stage.
- Close the gate valve by pushing the rocker switch on the load lock controller to the close position.
- Now you are ready to set the proper beam conditions and expose your file.



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Setting the Current and Beam Conditioning

1. Click the **Isolation Valve** button to open the valve that isolates the electron beam column from the stage. This is a pneumatic valve that should only be open when you are conditioning the beam or writing.
2. Move the stage to the Faraday Cup, by clicking the **Faraday Cup** button on the stage position tab. At this point you will notice the stage coordinates change in the “Stage Shift (XY)” menu.
3. Once the stage stops moving, release the beam blunker by clicking the **Beam Blunker** button in the top menu.

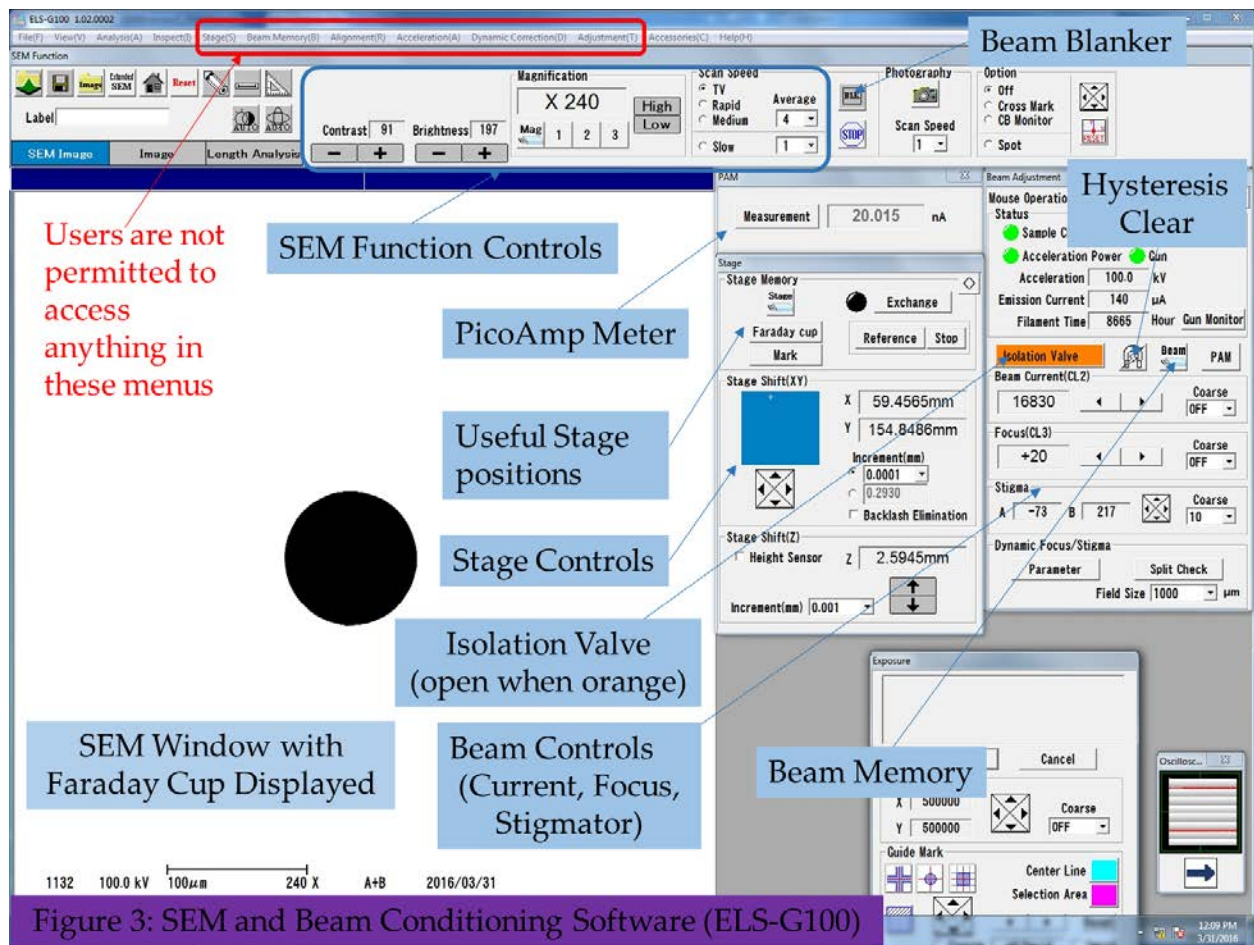
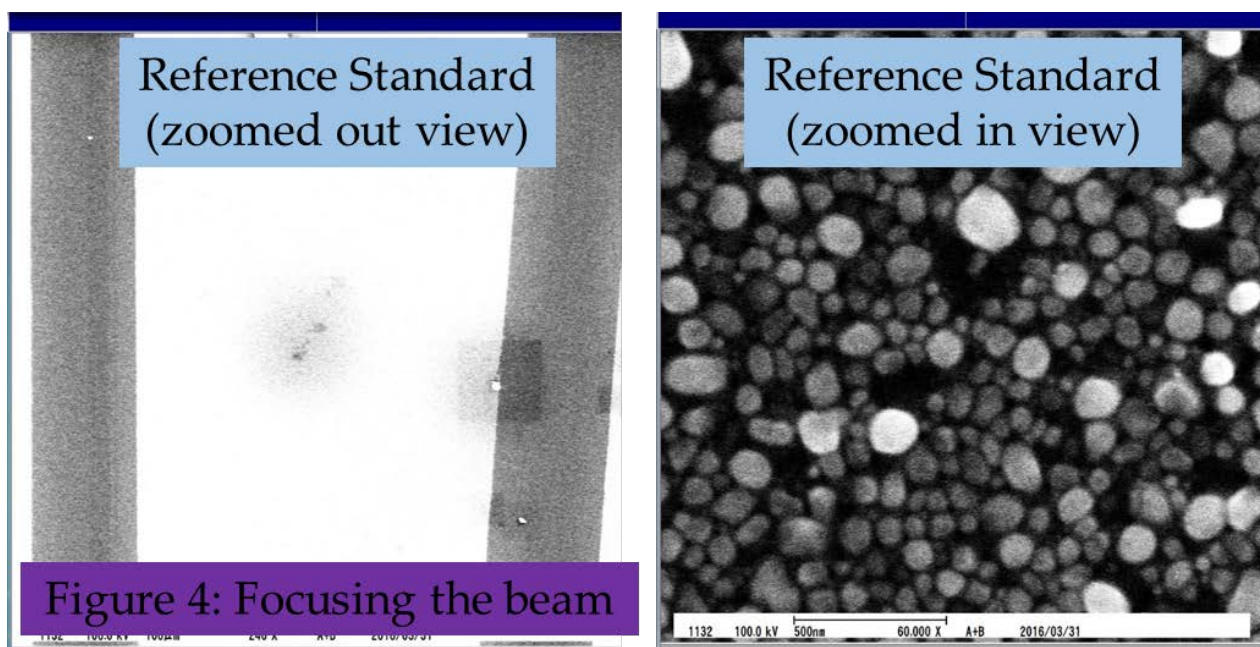


Figure 3: SEM and Beam Conditioning Software (ELS-G100)

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4. At this point you should see an image of the faraday cup. If this is not the case, the most likely cause is that the SEM detector is asleep. You can wake it up by either changing the scan speed and / or by clicking the **Auto Contrast** button at the top of the software.
5. If the PicoAmpMeter (PAM) submenu is not displayed, click the **PAM** button to display it, then press **Measurement** to measure the beam current.
6. If the beam current is not the current you desire then press the **Beam Memory** button and select the proper current.
7. You may also adjust the current by adjusting the beam current lens. This is done by clicking the arrows next to the Beam Current/Condenser Lens 2 in the Beam Adjustment Tab.
 - i. Note: Every time you make an adjustment to the beam current or the Focusing Lens (CL2 or CL3) you should clear the hysteresis which might be caused by these actions. To do so, press the **Hysteresis Clear** button in the beam adjustment tab and wait for the procedure to execute. The hysteresis clear procedure lasts approximately 45 seconds.
8. After setting the beam current, you should focus the beam. This is done by first clicking the **Reference** button in the stage submenu. Doing so will cause the stage to move to the reference target, which is comprised of a set of nanoparticles as shown below.



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9. Zoom in until you see an image of the nano particles.
10. Now adjust the focus until the particles are in focus. This can be done by either changing the value to the focusing lens (CL3) in the beam adjustment tab, or by left clicking on the screen, changing the function of the mouse to focus, then left clicking once to change the focus, moving the mouse until the image becomes focused, and then left clicking again to set the desired focus.
11. Now you are ready to set the stigmation. This is done by following the focusing procedure above, but using the stigmator instead of the focusing controls.
12. For best focus, it is desirable to zoom in to a larger zoom and repeat the above focusing and stigmation procedures. Note: For larger beam currents, the beam spot becomes larger and it might not be possible to easily focus it at a large zoom.
13. In focusing the beam you might have changed the beam current. This might happen since the beam current lens is above the focusing lens in the column, so altering the spot position in the focusing lens, might slightly perturb the spot position in the beam current lens. In order to rectify this, return the stage back to the faraday cup and check the current. If it is unacceptable, then change the current, as described above. Then return the stage to the reference target and refocus and restigmatize the beam. For best results this procedure should be repeated at least twice, or until both the focus and the beam current values converge.

Exposure

Note: if the changes to the beam conditions you made in the previous step are large, for example you changed the current from 50 nA to 100 pA - the beam will be slightly unstable. You may want to wait ten minutes before beginning the exposure. Also if you are not using the piece holder, which is typically stored in the load lock, and your pattern requires high resolution and beam position accuracy, you might want to wait ten to fifteen minutes for the temperature of the sample holder to become equilibrated with the temperature of the stage.

1. Copy the exposure file from the PC where you created it (this is typically the network PC) to the Elionix PC using the network drive.
2. Open the WeCaS software. An overview of this software is given at the end of this SOP.
3. Open your schedule file using the **Edit Schedule Execution** button.
4. Make sure that all the parameters you created are still the same, if they are not, your file might have become corrupted during transfer.

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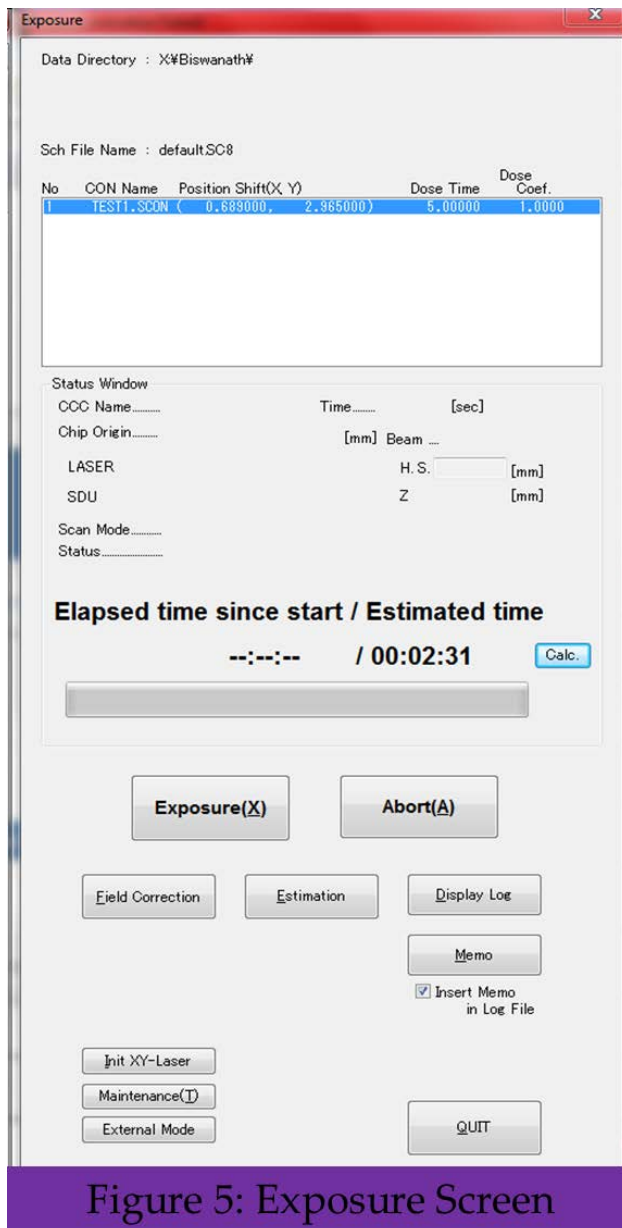


Figure 5: Exposure Screen

5. Click the **Next** button, and ensure that your pattern appears on the desired location on the stage.
6. Click the **Next** button again. Doing so will bring you to the WeCaS exposure screen as shown at the left.
7. Click the **Calc** button to calculate the exposure time. If this is not the same time you calculated when creating the exposure file, then your file is corrupted.
8. Prior to exposing the file you must perform a field correction. This is done by pressing the **Field Correction** button and pressing **Start** in the field correction menu that will open. The field correction takes anywhere between 3 and 10 minutes. If the field correction failed to converge to a value and results in an error, notify NanoFab Staff.
9. If during writing you need to abort the exposure you may do this by either pressing the **Abort** button or by closing the Isolation Valve from the SEM software.

Unload Sample

1. Return to the SEM software.
2. Click the **Exchange** button in the stage submenu. Doing so will automatically close the Isolation Valve and return the stage

to the exchange position.

3. Once the stage has reached the exchange position, the button next to the exchange button will become green. At this point you are ready to remove the sample.
4. Look at the load lock controller to verify that the evacuation LED is still illuminated. If it is not, the stage is not at a sufficient vacuum level to open the gate valve. In this case evacuate the stage again by pressing the **Evacuation Rocker Down** and wait for the evacuation LED to become fully illuminated.

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5. Open the gate valve.
6. Loosen the transfer arm lock.
7. Insert the transfer arm to the stage and rotate it in order to screw it into the sample holder.
8. Pull the transfer arm out.
9. While still firmly holding the transfer arm lock it to the stage again by tightening the lock. Sometimes this may require some force.
10. Close the gate valve.
11. Vent the stage and remove your sample.
12. If you used a sample holder other than the piece holder, place the piece holder back in the load lock and screw it to the transfer arm.
13. Evacuate the load lock. Note: The load lock should be always left under vacuum.

Cleanup and Waste Disposal

1. Please make sure that the area around the EBL system is clean whenever you are done.

Emergency Stop

There are two ways to stop the exposure:

1. Press the abort button in the WeCaS software. Sometimes there is a time delay between the time the “abort” button is pressed and when the exposure is aborted. If that time delay is unacceptable use method 2.
2. Close the “Isolation Valve” in the SEM software. This will prevent the electron beam from reaching your sample. After this is done. Press the “abort” button in the WeCaS software, and wait for the stage to move to the Farady Cup.

Allowed Activities

During routine operation users are allowed to

- Load and unload samples,
- Change current to the beam and adjust the focus and stigmation,

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- Perform field correction,
- Run exposure files.

Disallowed Activities

Users are not allowed to:

- Perform any beam alignments or calibrations other than the ones described above or discussed in the in-person training,
- Interact with any of the electrical controls (i.e., any buttons on the electronics rack or on the tool) other than the ones discussed in this manual or in this training.

What to watch out for during operation

The majority (more than 99%) of all errors that are encountered on the Elionix occur either before or at the beginning of the first writing field. So, prior to walking away from the tool during long writes, make sure that the write started successfully, that is, look at the status indicator during the exposure screen and make sure that it says “exposing.” You can also look at the software oscilloscope on the computer and make sure that the beam is being rastered in accordance with your pattern. If that is the case, most likely there will be no errors.

Common Troubleshooting Tips

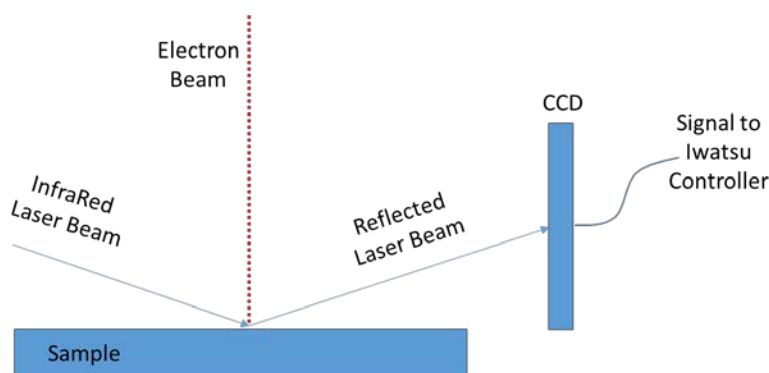
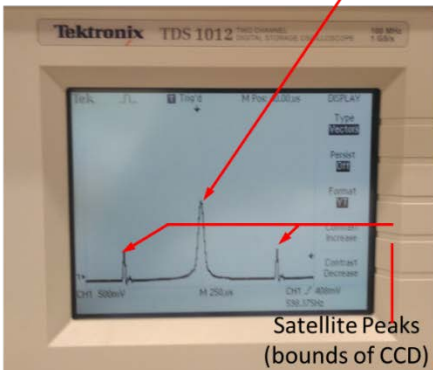


Figure 6: Operating Principle of the Height Sensor

The Majority of the errors on the Elionix tool are caused by a height sensor malfunction. The height sensor is used to raise or lower your wafer into the focal point of the electron beam each time the stage moves to a different field. The tool will not begin exposing unless the surface of the sample is

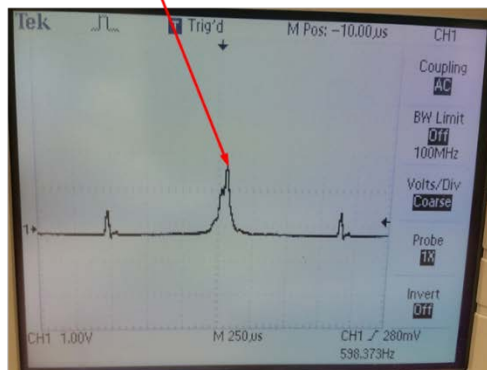
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Reflection of the Laser from the sample
 (should be a Gaussian Beam)



Good Height Sensor Signal

Not a Gaussian Beam
 (the laser power might be too low,
 adjust the laser gain to fix)



OK / Fixable Height Sensor Signal



Laser gain controller

in the focal point of the beam. The height sensor consists of a laser, and a CCD detector. The laser illumination is aligned to the center of the writing field as shown in Figure 6.

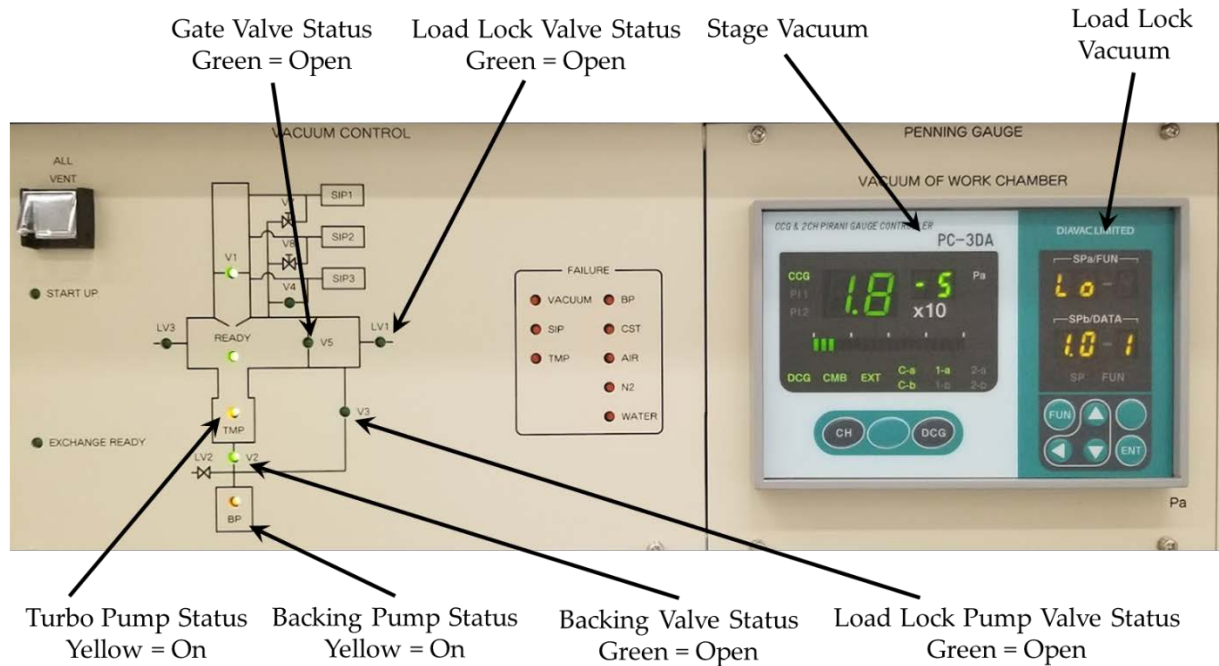
The oscilloscope next to the tool shows the signal that is being read and fitted by the Iwatsu controller

the signal consists of a main peak, which should be Gaussian, and two satellite peaks, which are the bounds of the CCD. See figure below. Each time the elionix performs a stage move, it uses a z-motor on the stage to bring the sample into the focal point of the beam. This is accomplished by moving the stage up and down and centering the Gaussian peak between the two satellite peaks. Several things can go wrong during this process:

1. If your sample is not reflective (i.e., it is made of glass) you will not see a Gaussian peak. In that case you need to think of a different way to adjust the height, such as sputtering some gold on the surface of your sample to make it reflective, or using the SEM to focus on several parts of your wafar and making a height map.
2. If your sample is partially reflective, or it consists of several thin layers that might be causing multiple reflections of the laser beam (a common symptom of this is shown in the figure below), you can try adjusting the laser gain on the Iwatsu controller until your beam becomes Gaussian.
3. The figure below shows a good height sensor signal, and an OK height sensor signal which may be fixed by adjusting the laser gain.

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Vacuum Note



The figure above shows the vacuum diagram of the Elionix tool as well as the pressure gauge controllers / indicators for the stage and load lock vacuum levels. It is important to understand how both the stage and the load lock are pumped in order to avoid mistakenly venting the stage. The stage and load lock pumping system consists of a turbomolecular (turbo) pump and a backing pump. In order for the turbo pump to function properly the backing pump must be on and the backing pump valve (V2) must be open.

When the load lock is vented the load lock vent valve (LV1) is opened for a brief period of time in order to allow for nitrogen to enter the load lock and to vent it. When the load lock is pumped, the load lock pump valve (V3) is opened and the backing valve (V2) is closed. In this state the backing pump is pumping on the load lock and not the turbo. When this happens you should observe the pressure in the load lock rapidly decreasing. This can be seen on the load lock vacuum gauge. Once the load lock reaches the proper cross over pressure, the load lock pump valve (V3) is closed, and the backing valve (V2) is open once again to return the system to the state shown in the figure above. The process of closing V3 and opening V2 is controlled by pressure. That is the system will wait for the load lock to be pumped to a sufficiently low base pressure before it closes V3 and opens V2. Sometimes, if the door to the load lock is not properly closed, a leak will occur, in which case the load lock will never reach the proper cross over pressure. After some

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time, the turbo pump will sense a loss of vacuum, and spin down, causing the entire stage to vent. If that happens, all the pumps will have to be restarted manually. In order to prevent this from happening, please make sure that once you started pumping the load lock, the load lock is actually pumping. You can ensure that the load lock is pumping by verifying that the pressure is decreasing on the load lock vacuum gauge (see the figure above for the location of the gauge). At some point the load lock vacuum gauge will read “Lo;” this means that the load lock is under vacuum and that the vacuum level reached is below the readout capability of the gauge.

When to call staff?

- If any of the failure LED's are illuminated and you hear and audible alarm.
- If you get an error during the field correction procedure before you begin the exposure.
- If you notice something atypical with the tool during operation. In that case, please try to take a photograph of the malfunction if you can.
- If there is a vacuum issue
- If a sample gets stuck

Badger Criteria

Report Problem:

- Issues Focusing or Stigmating the beam.
- Issues related to obtaining proper current.
- Historically over 99.95% of all issues that arose during alignment or height sensor are either user mistakes, or sample related, do not report those on badger.

Shutdown:

- Any Vacuum issues / errors.
- A sample that is stuck either in the stage or in the space between the stage and the load lock.
- A “fault indicator” LED are blinking (see figure 1 for the location of the fault indicator LED's).

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Revision History:

- a. March 2016 – Original SOP Created
- b. November 2017 – Slight Updates, and added the Height Sensor Troubleshooting Guide
- c. May 14, 2018 – Added vacuum note that describes the procedure to ensure that the load lock is pumped properly