Standard Operating Procedure
BNC
OAI 206 Lithographic Mask Aligner (Aligner 4)
Version 2020 June 2 Rev 1

I. Purpose
This Standard Operating Procedure (SOP) outlines requirements to be considered by an authorized user of the top loading mask OAI 206 Lithographic mask aligner (Aligner 4) as well as describes the normal operation of the aligner and any hazards that may be encountered during normal operation. Finally, the SOP explains how to minimize any hazards and how to respond in an emergency. This document is to be reviewed one year from the date of approval or as conditions warrant, whichever is the shorter time period.

II. Personnel
A. Authorized Personnel: The Aligner 4 may be operated only by authorized personnel who are fully cognizant of all safety issues involved in the operation of such a device. These personnel are to ensure that the aligner is only operated in the manner laid out in this document. To become an authorized user, one must:
   1. Complete Environment, Health & Safety (EH&S) training class.
   2. Take the baseline BNC Safety Orientation class
   3. Read and fully understand the SOP
   5. Sign the authorized user sheet to affirm that the above steps have been completed.

B. Unauthorized personnel: No unauthorized personnel may enter the BNC clean room facility unless accompanied by an authorized user. All visitors must be briefed on proper safety protocol and must wear appropriate protective eyewear located on the premises.
III. Hazards
A. Electrical Hazards: electrical shock or electrocution could result from direct contact with high voltage. Such hazards are typically interlocked by the aligner system. High voltage electrode and conductors are located inside the light source system chassis. In addition, the external power supply unit has connections behind the power supply chassis. Do not disconnect the external lines. Use normal precautions with external house (110VAC) connections behind the aligner and light source chassis.

C. Chemical: N/A.

D. Pressure Hazards: Pressurized house gases are used with the aligner. Do not disconnect or tamper with gas and vacuum lines behind the aligner. Contact lab management for information.

E. Other: UV radiation is generated and emitted through the light source housing and mask exposure location. Wear protective eye wear when looking at the mask exposure locations.

IV. Hazard Controls
A. Electrical
   1. Enclosures for protection against the high voltages of the power supply may only be removed after the power supply has been unplugged from the outlets and after following the safety procedures outlined in the safety and operations manual provided by the manufacturer.
   2. Only qualified personnel may perform all internal maintenance to the aligner and more than one user must be present when performing said maintenance.
   3. Every portion of the electrical system, including the printed circuit cards, should be assumed to be at dangerous voltage level.

C. Chemical and Pressure
   1. Enclosures for protection against valves and internal gas plumbing may only be removed after the system has been turned off and gases have been valving off and relieved of line pressure.
   2. Only qualified personnel may perform all internal gas maintenance to the aligner and more than one user must be present when performing said maintenance.

D. Other
   1. Proper eye protection must always be worn in the clean room and while operating the aligner.
V. Normal Operation

A. Inspect all electrical, gas, and vacuum connections for damage and connectivity. The vacuum pump typically operates in the range (-20mmHg to -30mmHg). When the main vacuum valve on the instrument front panel is turned OFF, the vacuum pump pressure should be in the range of -20mmHg to -30mmHg. The gauge can be found on the vacuum Venturi pump located in the back room (Hint: Locate where the hissing noise is).

B. Complete the “check-in” log and record the lamp hour meter reading (6-digit numbers). This will help monitor the lifetime of the UV bulb. Log ALL problems encountered.

C. Set up Operations

1. Turn on the Venturi vacuum for the machine (Air valve (CDA) at the vacuum pump on the wall in the service corridor next to the back door of Room 146.
2. Turn on the compressed air on the wall in the service corridor next to the back door of Room 146. It should be set at 60 PSI minimum (valve on the wall in the service corridor).
3. Turn on the Nitrogen, if it is not on. The valve is located on the wall next to the back door of Room 146. It should be set at 20 PSI.
4. Turn on the illumination intensity controller, if lamp is NOT on yet. The controller can be turned on by switching up the circuit breaker located on the right side of the instrument front panel. (See Figure 1a)
   IMPORTANT: The lamp MUST be turned on before the entire aligner power. Otherwise, there is a possibility of damaging the aligner electronics. LAMP ON FIRST BEFORE ALIGNER POWER.
5. Turn on the lamp by depressing the Start switch momentarily; verify that the lamp turns on. (See Figure 1a) Note that both the voltage and current rise.
6. Wait 10 minutes for the lamp to warm up and check the Lamp power. It should be (between 350W to 625W). Typical is around 450 Watts. Warning: If the lamp power has been turned off recently, you need to wait at least 30 minutes to allow the lamp to cool sufficiently before turning it back on. Not doing so, can be very dangerous.
7. Turn the entire aligner on by the toggle switch labeled Power on located on the instrument front panel. (See Figure 1b)
8. Turn on the video instruments by switching on both (2) power strips located behind the aligner. The video display monitors should turn on.
D. Initial Lamp Power Measurement and Exposure Time Calculation:

1. The initial exposure should be with a power meter. You will take the mJ per centimeter square measurement and divide it by your mW per centimeter square resist exposure requirement and arrive at the time (seconds) of exposure you need to provide.

E. Load Mask

1. (Top Loading Mask Holder – the wafer chuck is within the holder cavity)
   a. Inspect the mask. Make sure it is clean and oriented such that the chrome (brownish) or black pattern side is facing down. The pattern makes contact or comes close with the photoresist. The pattern should be on the wafer side of the mask. Light traveling pathway from the lamp is air, mask glass, pattern, resist, then wafer. The wrong side will result in a defocused pattern.
   b. Removed the mask frame by loosening the black knobs (6 places) on top of the mask frame holder. Turn the Mask Vac. OFF. (Similar to Figure 2, but screws are on top) The two mask clamps can be removed and the mask can be inserted with the contact surface of the mask facing the wafer.
   c. Make sure the vacuum slots on the mask plate are also aligned flush against the photomask surface.
   d. Replace all the screws holding down the clamps on the photomask. Make sure the photomask is secured and (eyeball) aligned with the wafer as required.
   e. Turn the Mask Vac. ON. (See Figure 3a)

F. Load Substrate:
1. Press the button on the black handle on the front of the alignment module and slide the alignment module all the way to the right side. (See Figure 2)
2. Move the microscope all the way back by pressing on the release button located on the main supporting arm and pushing the whole stage back.
3. Switch the “Mask Close” toggle to “Mask Open”. (See Figure 3b)
4. Place your wafer in the middle of the vacuum chuck. Align to the small shiny steel pins on the vacuum chuck.
5. When the substrate is properly positioned, switch on the “Sub. Vac.” Toggle. (See Figure 3a)
6. Switch the “Mask Open” toggle to “Mask Close”. The mask will be lowered onto the wafer.

![Images of control panels and height dial](image)

Fig 3 (a) Toggle switch on panel (b) black height dial for raising mask. **WARNING: DO NOT FORCE THIS BLACK HEIGHT DIAL! EXCESSIVE TURNING WILL DESTROY THE Z AXIS DRIVE MECHANISM. IF IT GOES NO FURTHER, IT HAS REACHED A PHYSICAL LIMIT. The magnetic strength of the clutch is a function of the electrical current setting “Chuck Z adjust”.

G. Alignment

1. Move the microscope back over the mask by pressing in on the button on the main supporting arm and slide the stage toward you. (See Figure 2)
2. Turn on the illuminator power and focus the microscope on the mask structure. (See Figure 4) The illuminator intensity level is already set and should turn on with the power strips.
3. Flip the “Ball Vac.” switch to the “Unlock” position. (See Figure 3a)
4. You will need to raise the substrate toward the sample by turning the Z axis black height knob located on the alignment module. (See Figure 3b)
5. Set “Chuck Z’ Adjust” to 12 mA. **WARNING: DO NOT EXCEED 14 mA.** The current controlled here feeds an electronic clutch that engages a belt on the `Z' adjust knob (the big black one on the front of the alignment module). We want the smallest current that allows us to raise the substrate up into contact with the mask. Turn the black knob clockwise until the reading on the ammeter is about 10-20. (See Figure 3a)
6. Adjust the video microscope so that you can see the mask on both monitors. Use low zoom magnification for set-up and for locating any alignment features because low magnification provides the greatest depth of field and field of view.
7. Observe the substrate raising and leveling process on the monitor.
8. Slowly turn the numbered black height dial (See Figure 3b) clockwise on the front of the alignment module to raise the substrate into contact with the mask. Stop when you feel a significant resistance while turning the black knob and the belt will stop moving. When the belt stops moving, the magnetic clutch has released because the wafer has contacted the mask. You should be able to observe optical fringes at the wafer to mask interface.
**WARNING: DO NOT FORCE THIS BLACK HEIGHT DIAL! EXCESSIVE TURNING WILL DESTROY THE Z AXIS DRIVE MECHANISM. IF IT GOES NO FURTHER, IT HAS REACHED A PHYSICAL LIMIT.** The magnetic strength of the clutch is a function of the electrical current setting “Chuck Z adjust”.
9. Switch the “Ball Vac.” toggle to the “Lock” position. (See Figure 3a)
10. Lower the substrate a little to have small gap between mask and substrate by rotating the numbered black height dial counterclockwise and align the features using the micrometers (The wafer position is controlled with the three micrometers. The one in the middle is Y axis. The one on the right is X axis. The one on the left is theta (rotation)). It will be easier if the video microscope is properly adjusted on the monitors. (See Figure 2)
**WARNING:** DO NOT FORCE THIS BLACK HEIGHT DIAL! EXCESSIVE TURNING WILL DESTROY THE Z AXIS DRIVE MECHANISM. IF IT GOES NO FURTHER, IT HAS REACHED A PHYSICAL LIMIT.

11. When you are satisfied with the alignment, raise the substrate by rotating the numbered black height dial clockwise until it contacts the wafer to the mask and you feel the belt slipping. You are now in “soft contact”, and ready to expose. For higher resolution toggle **hard contact** “on”. (See Figure 5a) More pressure will be exerted between the mask and substrate. This can cause sticky resists to stick to the mask but will give finer resolution. For 2-5 micron features, hard contact should be sufficient.

12. **SPECIAL INSTRUCTIONS ON WAFER TO MASK CONTACT METHODS:**

   a. **Review of Wafer to Mask Planarization.** The instruction steps explain the process of obtaining uniform surface contact between the wafer mask and substrate surface. By Unlocking the BALL VAC, you will allow the wafer chuck to wobble and rock in all directions. The wafer chuck can conform to the mask top, center, bottom, left, and right surface locations. Locking the BALL VAC, freezes the wafer chuck to mask surface contact position. The initial step is to release the wafer chuck by unlocking the BALL VAC. Next you will raise the wafer chuck with a silicon wafer in the upward Z axis direction by turning the Z axis dial. The wafer should rise until it contacts the wafer mask. As the wafer comes in contact with the mask, optical fringes should appear on the wafer mask surface interface. Reverse the Z axis dial direction as to slowly back the mask away from the wafer. The fringes should all disappear from the surface. Raise the wafer to contact the mask again. Repeat this process several times to optimize the exact planarization position. The Z axis should be set at the point where the axis setting is at the onset of uniform appearance of fringes. Note the Z axis dial setting. Lock the BALL VAC. Your wafer and mask are now set at its optimal wafer to mask planarized uniformity setting. You should never change this setting unless you change masks.

   b. **Hard Contact Exposure wafer to mask.** This method uses nitrogen gas channeled through the wafer chuck to drive the wafer onto the mask plate. The photoresist on the wafer is forced against the mask surface. **CAUTION:** If the photoresist is “tacky”, it may either adhere to the mask or result in resist residue on the mask. This may require photomask cleaning to prevent photomask defects.

   The first thing that must be done is photomask to wafer planarization as discussed in **section a.** Upon seeing fringes on the mask surface, back off the Z axis (separating mask from wafer) by approximately 50 to 70 units on the Z axis dial. This will provide a very short distance of separation.
between mask and wafer. The wafer to mask interface fringes will
disappear. Next turn OFF SUBSTRATE VACUUM which frees the wafer
from the substrate chuck. Then turn ON HARD CONTACT. Nitrogen gas
will be routed to the wafer chuck holes and lift the wafer onto the mask
plate surface. At this moment, exposure can be performed.

To release and return the wafer to the chuck for removal, return the wafer
stage to the far-right position for unloading, turn OFF HARD CONTACT
and turn ON SUBSTRATE VACUUM, and turn ON N2 PURGE to separate
the wafer from the photomask plate.

c. **Contact Vacuum or Vacuum Contact wafer to mask.** This method of
exposure requires the installation of the wafer chuck vacuum seal. For the
Model 206, a smaller diameter silicone seal is required. The mask plate
must be securely fastened to the mask plate holder stage. The procedure for
wafer to mask plate planarization in section a. must be performed. This
method uses vacuum between the wafer and mask plate to remove all
ambient air and pulls the wafer and mask plate securely together. Turn ON
SUBSTRATE VACUUM. Check the wafer to wafer mask fringes. Back off
the Z axis dial by 30 to 50 dial units. Turn ON CONTACT VACUUM, the
CONTACT VACCUM GAUGE which measures the amount of vacuum
within the space between the wafer and mask should be approximate 5
inches of Hg. At this moment, an exposure can be performed. Note that
turning OFF SUBSTRATE VACUUM may help improve exposure
resolution. But it must be turned ON immediately after exposure to assist
wafer to wafer mask separation before turning OFF CONTACT VACUUM.

To release and separate the wafer to the chuck for removal, return the wafer
stage to the far-right position for unloading, turn OFF CONTACT
VACUUM and turn ON N2 PURGE to separate wafer from the mask. The
N2 flow should be set at 3 SCCM and turn ON N2 PURGE to separate the
wafer from the photomask plate.
Fig 5 (a) Hard contact and N2 flow meter (b) Exposure time set-up

H. Exposure
1. Check or set the desired exposure time (in seconds) on the left of the front panel of the aligner. Be aware of the “decimal point” LED setting below the thumb wheel switches. (See Figure 5b) This is adjusted with either the 100 Sec or 1000Sec selection.
2. Press the button on the handle of the alignment module and slide it under the lamp housing. After about one second, the shutter will automatically open, expose your sample and close.
3. After exposure, slide the alignment module back to the alignment position (right most).
4. Important note for using Negative Photoresist: It may be necessary to use Contact Vacuum method and turn ON N2 PURGE momentarily as to purge air out of the sealed wafer to mask space prior to exposure. Consult your respective photoresist manufacturer guidelines for N2 purge requirements.

I. General Unload Substrate Instructions
1. Toggle the hard contact switch to the “Off” position if being used.
2. If your substrate sticks to masks, you may need to switch on the “Nitrogen purge” toggle and open the “Nitrogen purge flow valve” to blow some air between wafer and mask for 5 seconds. Adjust the flow rate to somewhere mid-range on the N2 flow meter. Turn off the N2 purge when it is done. Note that the Nitrogen Purge is very useful in preventing both vacuum release of the mask from the wafer and ensuring separation between mask and wafer “sticky resist” problems.
3. Lower the substrate out of contact with the mask using the black knob.
4. Slide the alignment optics to the back of the tool as done earlier (back most position).
5. Open the mask frame (Open Mask Frame) and turn off the substrate vacuum (sub. vac.). You can now remove the wafer from the substrate.
6. Close the mask frame.

J. Unload mask
1. Loosen the thumb screws on either side of the mask frame, remove black screws and swing the mask clamps out of the way.
2. Turn OFF the mask vacuum toggle and remove the mask.
K. Shut down the system
   1. Turn OFF the alignment optic illuminators by switching OFF both (2) power strips behind the aligner.
   2. Turn OFF the main power to the unit on the front left. (See Figure 1b)
L. Shut off the lamp (If no one is going to use the aligner after you)
   1. Turn OFF the power on the front panel of the lamp intensity controller. The lamp should shut OFF. (See Figure 1a)
M. Turn OFF aligner vacuum pump in the service corridor by shutting off compressed air in the service corridor.
N. Turn off the Nitrogen in the service corridor.
O. COMPLETE THE LOGBOOK INFORMATION.

VI. Emergency Procedures

A. Aligner accidents: Notify lab management and PI immediately.

B. Power outage: If there is a power outage, turn off the aligner per the aligner shut down procedure (Section J, K and L in Shut down the System) to avoid a hazardous situation when power is restored. If there is an emergency, leave laboratory immediately and either return after emergency to shut down aligner or contact lab management.
Authorized Users:
I have read and understood the Standard Operating Procedures for OAI 206 Lithographic Mask Aligner (Aligner 4)

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Appendix A – In case of medical emergencies, consult lab safety protocol or lab safety plan.

In the event of an aligner accident, follow the procedure below:

1. Ensure that the aligner is shut off per Section J, K, and L in **Shut down the System**.
2. Provide for the safety of the personnel (first aid, evacuation, etc.) as needed.
3. Obtain medical assistance for anyone who may be injured.

| UC Optometry Clinic (Normal Hours)       | 642-2020 |
| UC Optometry Clinic (24 Hour Emergencies) | 642-0992 |
| University Health Services (Emergency)   | 642-3188 |
| Ambulance (urgent medical care)          | 9-911    |

4. If there is a fire, pull the alarm, and contact the fire department by calling 9-911. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.

5. Inform the Office of Environment Health, & Safety (EH&S) as soon as possible.

6. During normal working hours, call the following:

| EH&S Office                     | 642-3073 |
| BNC Safety Officer (Paul Lum)   | 666-3356 |
| EH&S Health & Safety Manager    | 642-3073 |

After normal working hours, call 642-6760 to contact the UC Police Department who can contact the above using their emergency call list.

7. Inform *(PI NAME)* and the BNC safety officer (BNC Management) as soon as possible. If there is an injury, *(PI NAME)* will need to submit a report of injury to the Worker’s Compensation Office.

8. After the incident, do not resume use of the aligner system until the BNC lab manager and EH&S has reviewed the incident and approved the resumption of research.