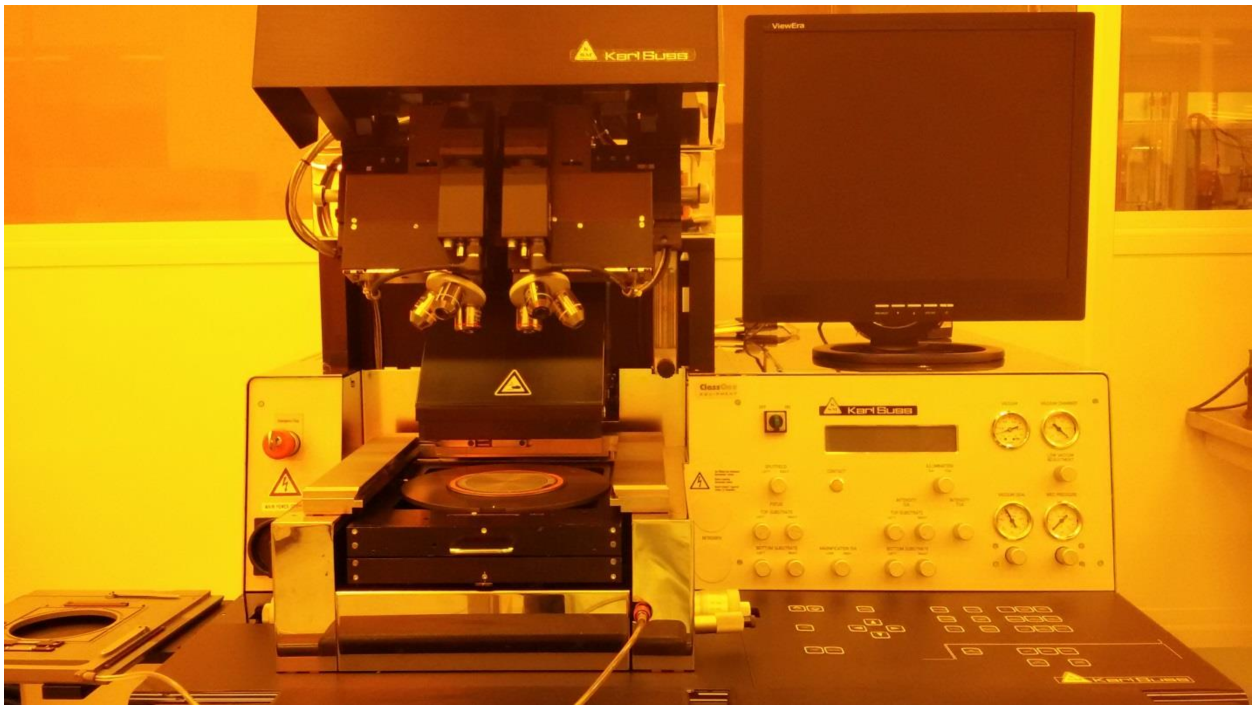
University of Minnesota Nano Fabrication Center

Standard Operating Procedure

Equipment name:	Karl Suss Mask Aligners		
Badger name:	MA6-P	**Revision number:**	0
Model:	MA6	**Revisionist:**	Paul Kimani
Location:	Bay 4 PAN	**Date:**	September 17, 2015

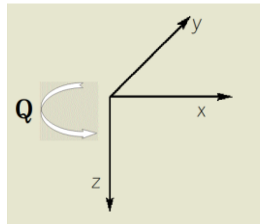
1. **Introduction**

   The Karl Suss **MA6-PAN** is a contact aligners used for optical lithography down to 1 micron. It can be used with 4-inch, 5-inch and 7-inch mask plates and is capable of processing pieces, 4 inch and 6 inch substrates. Wafers and substrates up to 6mm thickness can be processed. It is equipped with a 350 watt, UV 400 mercury arc lamp (350nm – 450nm wavelength range) capable of operating in constant power or constant intensity mode. MNC operates its aligners in constant intensity mode, where the power to the lamps automatically adjusts to maintain a constant intensity. The MA6-PAN is ideal for exposing broadband positive and negative resists. The machine is used for front side alignment with Top Side Scopes



2. **Description**
   a. A 350 watt mercury arc lamp with smart power supply capable of operating in constant power mode or constant intensity mode. The lamp is run in constant intensity mode, whereby as the lamp ages, power is adjusted automatically to keep the intensity constant.
   b. Front-side alignment is achieved using top-side microscope, mask and wafer placed on their respective seats.

c. Six lithographic modes for exposure. They include: **SOFT CONTACT**, **HARD CONTACT**, **LOW VACUUM CONTACT**, **VACUUM CONTACT and PROXIMITY**.
d. 4-inch, 5-inch and 7-inch masks can be used in any of the aligners
e. Three chuck sizes can be used with the aligners: piece chuck, 4-inch and 6-inch.
f. Alignment can be done using one or two objectives. Positional memory lock allows one to fast scan between two locations quickly.
g. Coordinate system: The length units for the x and y- direction are in mm. The z- direction length unit is in µm. The origin is in the center of the alignment stage unit. The origin in the z-direction is at the mask or upper substrate plane.



h. LED on: Key selected or function active
i. LED off: Key not selected or function deactivated
j. LED flashing: Most applicable key to continue.

3. Safety

a. Do not look directly at the ultraviolet light or its reflection. The aligners' lamps output 365nm, 405nm and 436 nm wavelengths light.
b. Beware of moving parts on the aligner. The microscope assembly moves up and down. The exposure tool will move forward when exposing a wafer. Be careful to avoid putting any body part, clothing, or other material in the path of the moving parts.

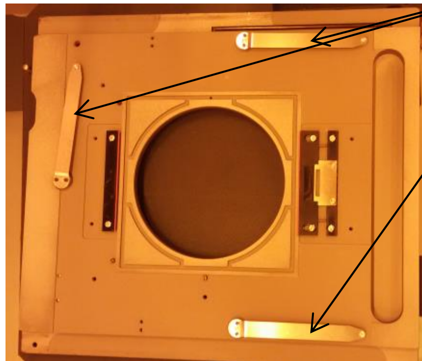
4. Restrictions/Requirements

a. Do not place heavy or sharp objects on the touch panel
b. Do not lean on the anti-vibration table
c. Do not turn any knobs more than a few degrees at a time. Turn all knobs with care. Handle all equipment gently and with care.
d. Do not use acetone to clean the chuck. If needed, use a cleanroom towel with some methanol or IPA. If you are having repetitive issues with wafer chuck vacuum, report the problem on Badger and/or contact staff.
e. Any chucks not in use should be placed in the chucks cabinet for safe keeping
f. When handling the mask plate, take care not to damage the proximity flags
g. Enable the aligner on **Badger** before each use.

5. Required facilities

a. Compressed air - 5 bar
b. Vacuum (< -0.8 relative to ambient pressure or 0.2 bar absolute)
c. Nitrogen gas – 1bar
d. Electrical power

6. **Definitions**
   a. **Mask Holder -** holds masks in place. Avoid tampering with the 3 metal proximity flags.



   b. **Chuck** - holds wafer in place

   c. **WEC** – Wedge Error Compensation. It occurs after loading the substrate. In this procedure, the wafer is leveled so that it is as close as possible to being parallel to the mask. The WEC-pressure is used to compensate for the higher gravitation force of a bigger chuck. There are two WEC options; contact and proximity. Contact WEC achieves parallelism by utilizing the flatness of the mask/wafer contact. Proximity WEC uses three proximity flags (see a & m) for parallelism adjustment. Of these two, the contact WEC has less error and is preferred unless circumstances dictate otherwise. If you need to use proximity WEC, use only the MA6-P. If you experience regular over-current errors, reduce the WEC-pressure to 0 (zero). At 0 bar pressure, the force during WEC is about 7N - 8N.
   d. **Micrometer knobs X**- and **Y-** Located on left and the right side of the alignment stage respectively, they are used to move the microscope along the x- (maximal travel ± 10mm) and y-axis (maximal travel ± 5mm).
   e. **Stage θ-movement Micrometer:** This is a small knob at the right side of the alignment stage. Maximal travel is ± 5°.
   f. **Fast key** – when activated (LED is on), it allows the microscope to move rapidly in either the x- or y-axis
   g. **SEP keys** – These keys enable the alignment position of the chuck to be changed in finite steps of 1µm along the z-axis. The keys are active with the wafer loaded and in alignment

position. When used, they increase or decrease the alignment gap between the mask and the wafer.

h. **ALIGN CONT/EXP Key** – Enables the operator to change the position of the exposure chuck between alignment gap and contact position with the mask (or proximity if the selected exposure program is proximity). This places the wafer in contact position (proximity) without exposure. Pressing the key again returns the wafer back to its original alignment position.
i. **ALIGNMENT CHECK key** – This triggers all parameters of an exposure program except the exposure. The key only works for Hard Contact, Vacuum contact and Low Vacuum Contact. Using this key allows one to check their final alignment before pressing the exposure key.
j. **EXPOSURE Key** – After completing the alignment process, press this key to start exposure.
k. **TSA Key** – Top side alignment. The top microscope is used to align the mask to the top/front of the wafer. The topside of the substrate is then exposed.
l. **Multiple Exposure Key** – This key allows for the overall exposure to be broken down into equal shorter exposure intervals with defined wait times during which the substrate is not exposed. It may be useful in exposure of thick photoresists that have long exposure requirements.
m. **Proximity Flags** – The three pneumatically actuated flags located on the mask holder sides. They serve as spacers between the mask and substrate during proximity WEC.
n. **Overcurrent Error** – This error may occur when you press the exposure key. However, its cause emanates from bad WEC procedure that causes the motor which brings the mask and wafer into contact, to draw excessive current. The problem manifests itself when the exposure procedure is triggered. *Often observed when using a standard mask and little substrate pieces placed off-center on a carrier wafer.*

7. <u>**Exposure Programs**</u>

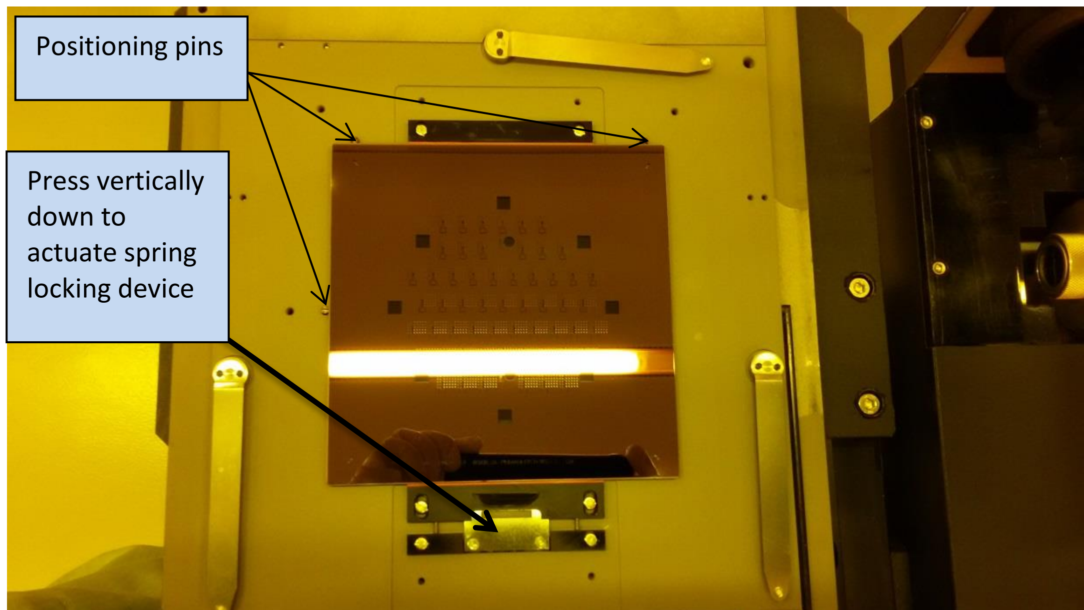
a. **Soft Contact** – One of the six possible lithography modes. The substrate is brought into contact with the mask by a preset force exerted by the WEC head, during exposure. This mode is suitable for feature sizes 2 μm or larger.
b. **Hard Contact** – Similar to soft contact mode with an additional pillow pressure provided using nitrogen. This exerts an additional upward force on the wafer. This mode is suitable for feature sizes 1 μm or larger
c. **Vacuum Contact** - The rubber seal on the chuck inflates to form a chamber, which is then evacuated. The parameters PreVac or Full Vac time in this mode allow the vacuum to proceed slowly. This aids in preventing alignment shift. The vacuum in the chamber cannot be adjusted (in contrast to Low Vacuum program). To diminish the vacuum, nitrogen is bled into the chamber after exposure. This mode is suitable for features sizes of 1 μm or less.
d. **Low Vacuum Contact** – Similar to vacuum mode except that the contact force can be reduced by bleeding a small amount of N_2 within the evacuated chamber. The vacuum is adjusted by opening an N_2 leak valve. Open the vacuum restrictor LOW VACUUM ADJUSTMENT below the gauge counter clockwise. Close it by turning the knob clockwise. This mode is suitable for features sizes of 1 μm or less.

e. **Proximity** - The mask and wafer are separated by an exposure distance specified by the user. There is no contact between the mask and the wafer.

8. <u>**Mask loading:**</u>
   a. Enable **MA6-P** on **BADGER**
   b. If the mask holder is already out and placed on the shelf on the left, proceed directly to e
   c. If a different mask holder is needed, disconnect the vacuum hose at the machine. Push in on the knurled knob and gently pull on the hose. Store the removed mask holder in the Karl Suss parts cabinet. Connect the vacuum hose for your new mask holder.
   d. If the mask holder is in the inserted position, gently pull it out taking care not to hold the proximity flags. Flip the mask holder and place it on the loading tray to the left of the machine.

e. Place the mask in the mask holder (chrome side up) and align mask position against the fixed plate and positioning pins. Press the flashing **ENTER** key to turn the vacuum on.

Gently press the silver tab to engage the spring locking mechanism. This serves as an additional protection should the vacuum grip fail.

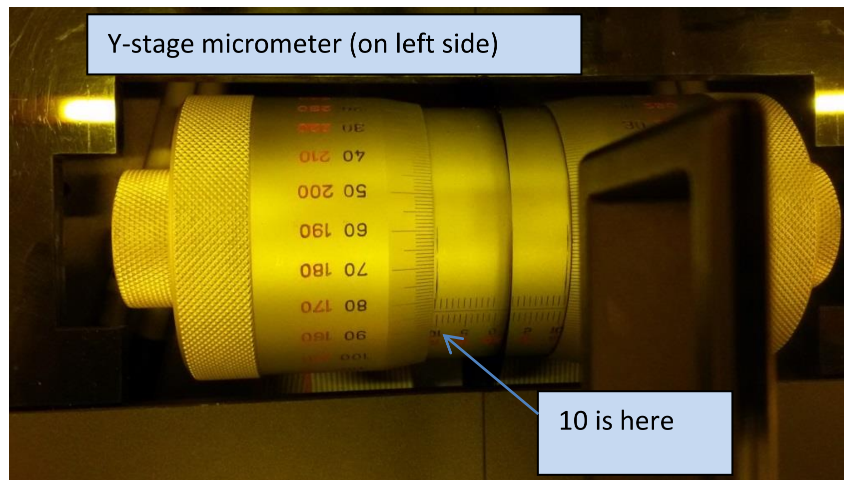


f. Turn the mask holder upright (the mask will now have the chrome side facing down), insert it onto the dovetail guide of the alignment stage and push it in all the way. Clamp the mask holder in the alignment stage by pressing the **CHANGE MASK** key. A **Ready for Load** message will appear on the LCD display.

9. Substrate Loading

Three types of wafer chucks can be used; one for pieces that are at least 1 cm^2 area, one for 4-inch and one for 6-inch size substrates. Use the 4-inch wafer chuck with a 5-inch mask holder and a 6-inch wafer chuck with a 7-inch mask holder. The vacuum grooves on the chuck need to be fully covered by the substrate. Care has to be taken when handling the chucks as replacements are pricey and not easily obtained.

a. Set the **X**- and **Y**-stage micrometers to "**10**" and the stage rotation knob to "**0**" to ensure that the resulting image is centered on the wafer.



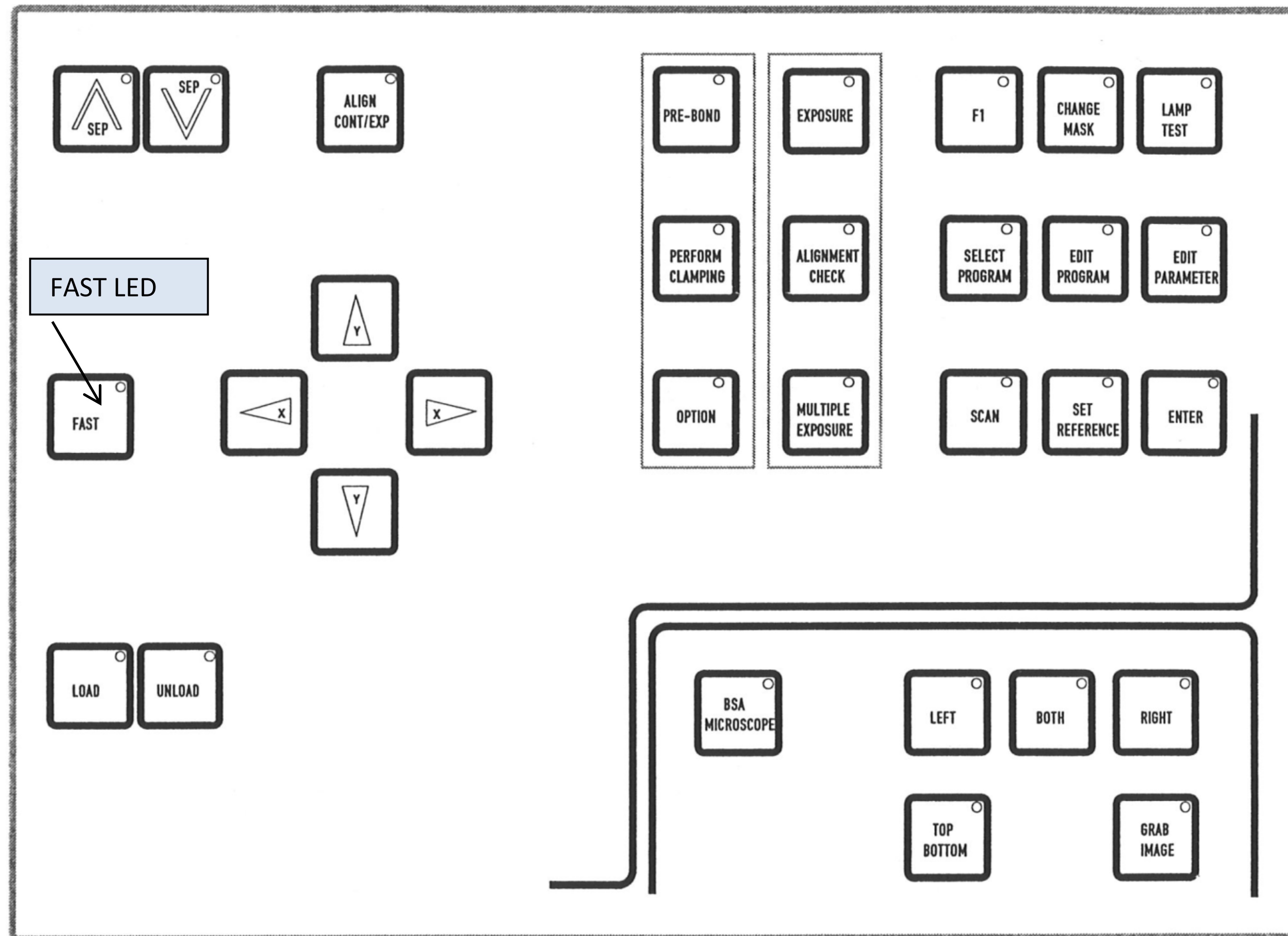
b. Confirm that you have the right-sized chuck for your alignment/exposure needs. If you need a different chuck, carefully lift off the chuck from the slide and place it in the Karl Suss parts cabinet. Place you desired chuck on the slide opening aligning the white mark on the chuck with the projecting pin on the slide.
c. Press the **LOAD** key. Pull the slide all the way out. Place the wafer on the chuck with the flat facing the user and ensure that the wafer aligns against the three steel alignment pins. Press enter to turn the vacuum on the wafer on.
d. Push the slide all the way into the machine. Press **ENTER**. **WEC** is performed and then the substrate is ready for alignment.

10. Selecting and editing a program

a. Press **SELECT PROGRAM** key to choose an exposure program. Doing so will select one of the five lithography modes defined in 7 above. On the MA6-P, use the y-key pad to scroll through the six-program choices and then press **SELECT PROGRAM** again to load your choice.
b. **EDIT PARAMETERS** key allows one to change the existing program's option.
   - Press **EDIT PARAMETERS** key. **EXP TIME** will be displayed. Press **Y**-up/down key to increase/decrease the exposure time.
   - Press **X**-key until **AL GAP** is displayed. Press **Y**-up/down key to set the **AL GAP** value.
   - Press **EDIT PARAMETERS** key again to save the recipe.

Karl Suss
IDLE

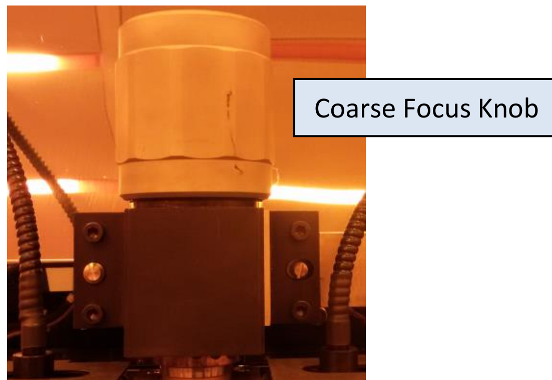
ClassOne EQUIPMENT
OFF
ON
Karl Suss
VACUUM
VACUUM CHAMBER
LOW VACUUM ADJUSTMENT
SPLITFIELD
LEFT
RIGHT
CONTACT
ILLUMINATION
ISA
TSA
Vor Öffnen des Gehäuses Netzstecker ziehen.
Before opening disconnect mains.
Avant d'ouvrir l'appareil retirez la fichemâle.
FOCUS
TOP SUBSTRATE
LEFT
RIGHT
INTENSITY ISA
INTENSITY TSA
TOP SUBSTRATE
LEFT
RIGHT
VACUUM SEAL
WEC PRESSURE
NITROGEN
BOTTOM SUBSTRATE
LEFT
RIGHT
MAGNIFICATION ISA
LOW
HIGH
BOTTOM SUBSTRATE
LEFT
RIGHT
TSA Illumination



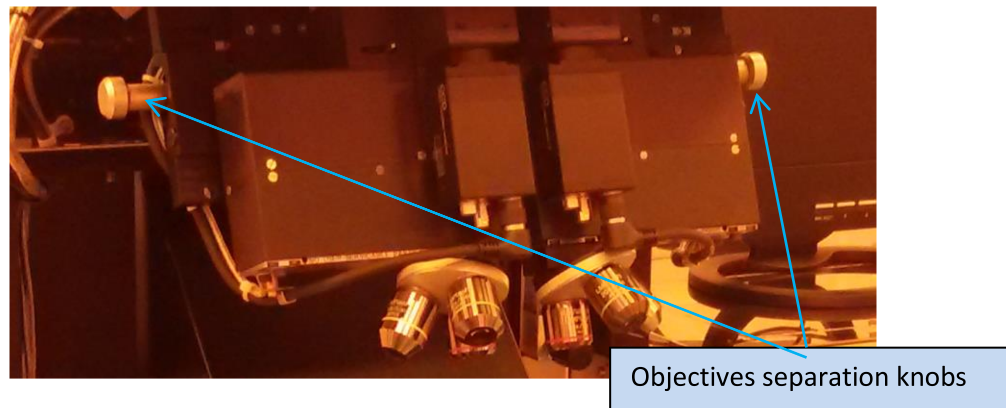
Lower Panel Controls of the MA6 / BA6

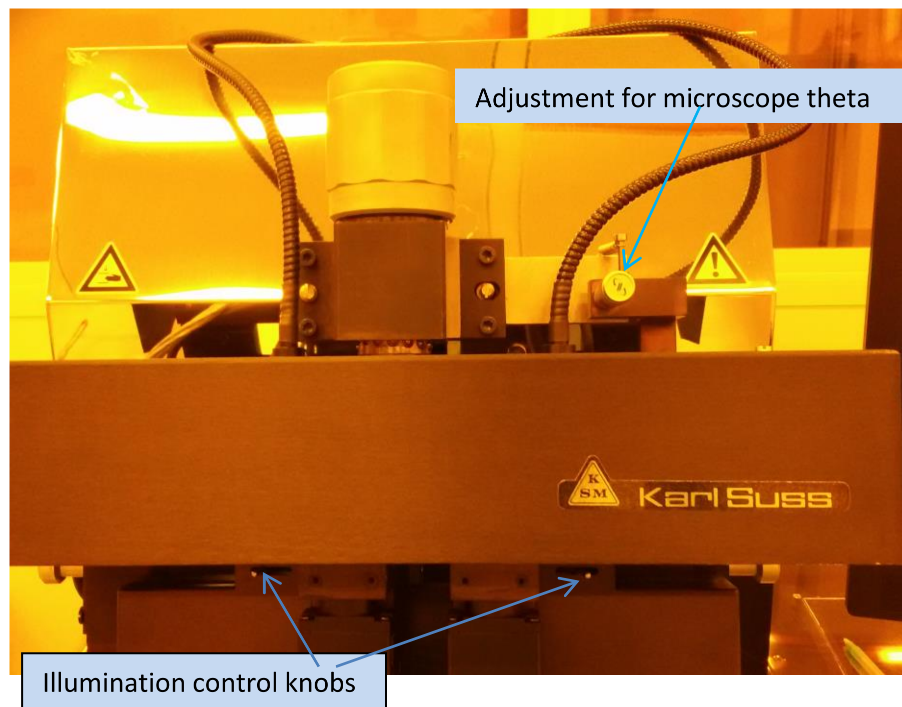
TSA Setup

a. The top objectives can be moved over the mask using the **X**-and **Y-** arrow keys. If the **FAST** key Led is lit green, the objectives move much more rapidly than when the **FAST** Key Led is toggled off.
b. One can view the left side and the right side images simultaneously, if SPLIT FIELD knob is centered. Alternatively, one can view a full image provided by the Left or Right side objective, if left or right side mode are toggled.
c. The intensity of illumination may be adjusted using the illumination control knobs (see diagrams above)
d. The Coarse focus is used to bring the objective's depth of focus into the fine focus range. Fine focus is adjusted using the fine focus knobs. The Top Substrate focus knobs are used to focus on the mask. The Bottom Substrate focus knobs are used to focus on the wafer. Focus control key allows one to switch between focusing on the mask and focusing on the wafer. When Top Substrate Key Led is lit green, one can manipulate the Top Substrate focus knobs. When the Led is off, one can manipulate the Bottom Substrate knobs.



e. You can use the **SET REFERENCE** key to remember the microscope's position. Position the microscope to your first reference position. Press the **SET REFERENCE** key to activate it. Move the microscope to the second position. Press **SCAN** Key. The microscope moves to the first reference point. Pressing the **SCAN** key again moves the microscope to the second reference position. This allows one to easily locate dual positions for quick alignment.
f. The objectives separation knobs (see diagram below) are used to adjust the distance between the objectives. To prepare for alignment, use **X-** and **Y-** keys and move objectives over the mask and locate mask alignment marks. To move rapidly, toggle the **FAST** key, so that the Led is lit green. Use an objective separation knob to find the other alignment mark (if using split field). Use the "adjustment for microscope's theta" to keep the images on both sides parallel to each other. The "adjustment for microscope theta" allows the rotational angle of both objectives to be adjusted relative to each other. Use the illumination control knobs to control the amount of light going through each objective. Adjust **TSA** illumination if needed.

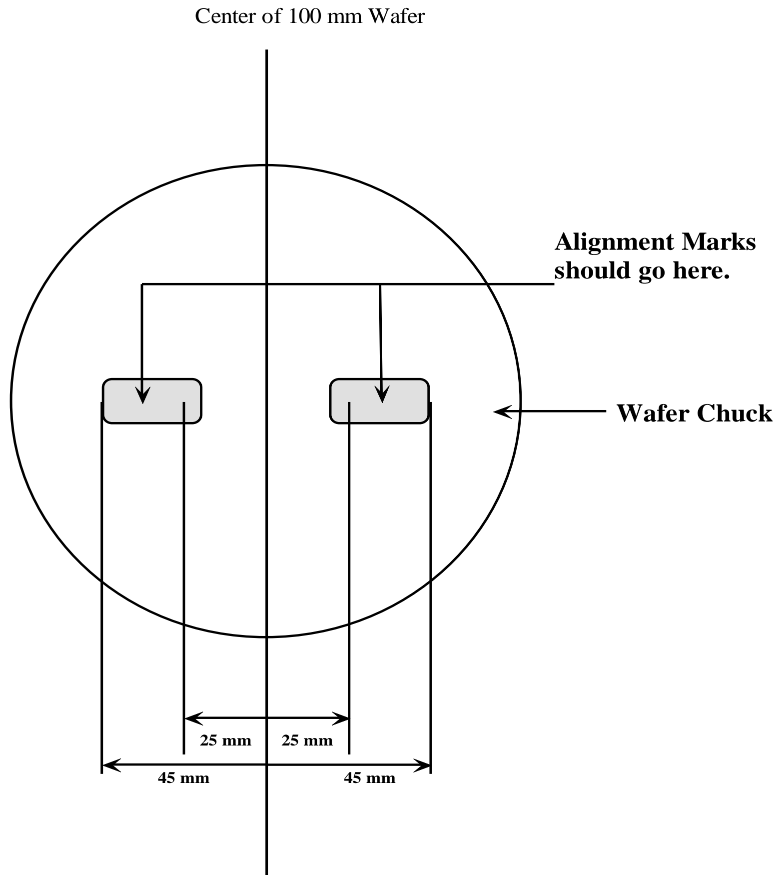




g. Use (rarely) the large coarse focus knob to bring the objective's depth focus into the fine focus range. Fine tune the focus on the mask using the two focus knobs under the **TOP SUBSTRATE**. Focus control using **TOP SUBSTRATE** left and right knob is available when the Top/Bottom key is lit green. If it is not, toggle it so that it is illuminated green.

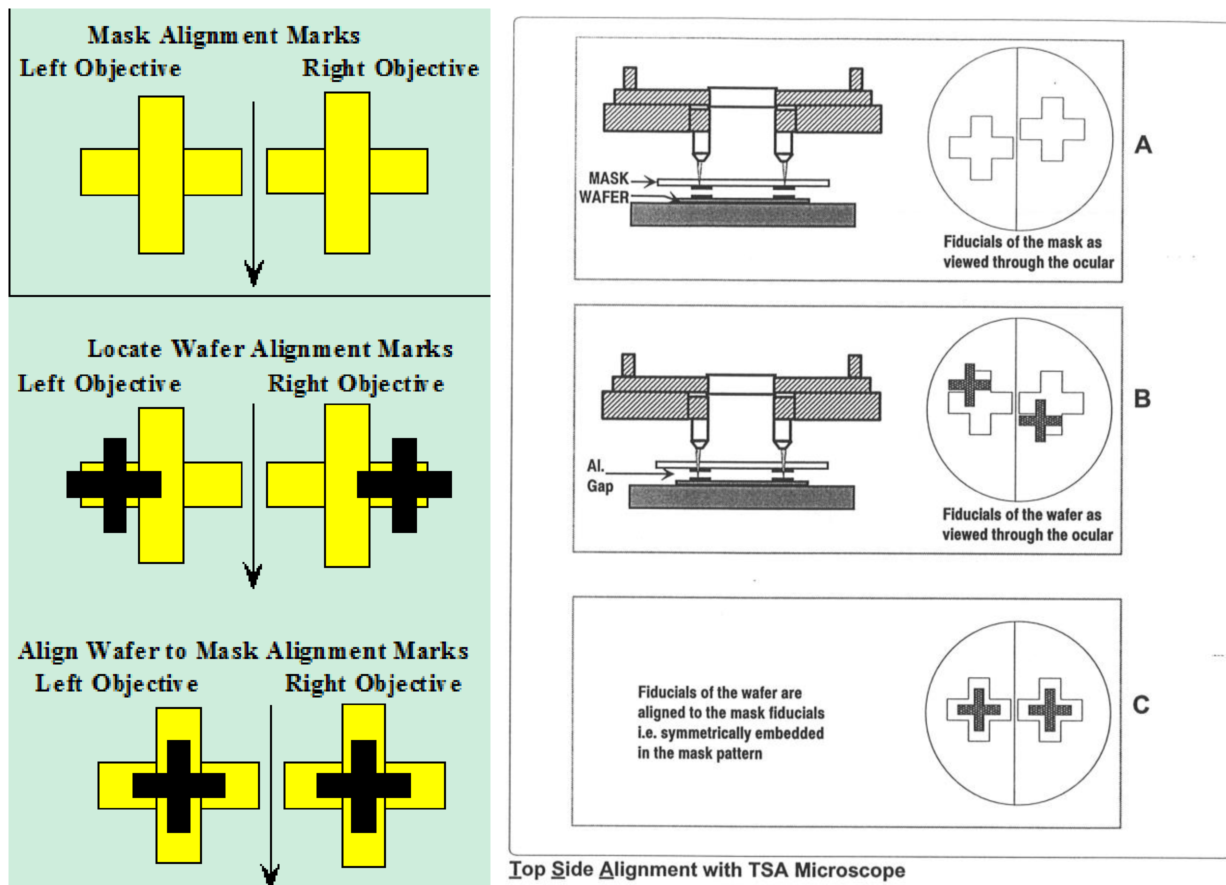
11. Wafer Alignment

a. **Alignment Marks:** Below is the suggested alignment mark placement when designing a mask. It will allow the user to use both the MA6 and the MA6/BA6 contact aligners. Refer to the Mask Design SOP for further questions on how to design a mask.



b. Ensure that the machine is in alignment mode. The **ALIGN/CONT** key is illuminated when the machine is in alignment mode. Use the **X-**, **Y-** and **θ** micrometers to manipulate the wafer relative to the mask. The two **SEP** keys can be used to increase/decrease the alignment gap if wafer is too close to or too far from the mask.

c. Align the wafer to the mask using the **X-**, **Y-** and **θ** micrometers. Adjust wafer focus by toggling the **TOP/BOTTOM** key off. The focus is now on the bottom substrate and the focus control is on the **BOTTOM SUBSTRATE** knobs.



Top Side Alignment with TSA Microscope

d. Check alignment using either the **ALIGN/CONT** key or the ALIGNMENT CHECK key. **ALIGN/CONT** key brings the wafer and the mask into contact without exposure and the **ALIGNMENT CHECK** key will activate all the steps in the contact program except the exposure. Check for any shift or misalignment. If further adjustment is required, toggle the **ALIGN/CONT** key or the **ALIGNMENT CHECK** key to separate the wafer and mask. **SEP ^** or **SEP** ∨ keys can also be used to decrease/increase the mask-wafer gap to check for alignment. If no change is needed, exposure can take place. **ALIGNMENT CHECK** is not available in Soft Contact or Proximity modes.

12. Wafer Exposure

a. Press **EXPOSURE** key. The top side microscope assembly lifts and the exposure lamp housing slides forward over the mask. Exposure takes place for the selected amount of time, then the exposure lamp housing retreats to the back of the machine and the microscope assembly drops back.
b. The exposed wafer can now be removed. Pull the slide out all the way, press **ENTER** to turn the wafer vacuum off, then remove the wafer and slide the wafer holder back into the machine.
c. For resists that need long exposure, you can break down the exposure duration into short exposure periods with cooling periods, using **MULTIPLE EXPOSURE** key. To use this option, press **MULTIPLE EXPOSURE** key on the console. Use **EDIT**

PARAMETERS to enter the exposure time, the duration when there is no exposure and the number of exposure cycles needed. If you need to expose for a total of 60 seconds in three cycles, then set your exposure time as 20 seconds and the number of cycles at 3 cycles.

13. **Unloading a wafer after exposure**
    a. After the wafer has been exposed, pull the wafer slide all the way out. Unload the wafer and press enter to confirm you action. Push the slide back into the machine.

14. **Unloading a wafer before exposure**
    a. To unload the wafer, before exposure, press the **UNLOAD** key. Pull the slide out and press enter to release wafer vacuum and unload the wafer. Push the slide back into the machine.

15. **Mask Unloading**
    a. Press **CHANGE MASK** key.
    b. Pull the mask holder out and place it upside down on the loading tray positioned at the left of the machine. Press **ENTER** to turn the vacuum off. Pull back on the spring loaded locking device to separate it from the mask and lift the mask out. Leave the mask holder on the loading tray.

16. **Problems/troubleshooting**

    a. Mask features cannot be focused
    1. The mask may be upside down. Reload mask correctly. The chrome (darker side) should be facing the wafer.
    2. The mask may not be properly loaded onto the tray. Reload the Mask
    3. The mask may not be resting flush against the tray. Possible particle or photoresist is on the mask. Clean the mask and reload

    b. Wafer is out of focus
    1. The alignment gap may be too large. Adjust with the SEP keys or unload and set the alignment gap to a lower value
    2. The WEC may have not taken place correctly. Unload the wafer and try again

    c. Wafer sticks to the mask either before or after exposure
    1. If this occurs before exposure, increase the alignment gap. The mask should be cleaned before trying to expose another wafer.
    2. If this occurs after exposure, either the mask may be dirty or the resist may not be baked enough.

    d. Loss of wafer vacuum
    1. The wafer may still be held by vacuum. If so continue with the run. If there is no vacuum, try cleaning the backside of the wafer or the chuck with methanol or IPA on a wipe.

Appendix

A. Tight tolerance adjustments on the MA6 and MABA6 contact aligners

Before you start:

1) Verify that your mask is clean

a) Photoresist on the mask will interfere with good contact between the mask and your wafer

2) Choose the right photoresist

a) Use the thinnest photoresist possible. For example, do not use S1818 (coats approximately 1.8μ at 3,000 rpm for 30 seconds) to mask an etch of 500Å of silicon dioxide if S1805 (coats approximately 0.6μ at 3,000 rpm for 30 seconds) is sufficient. The thickness of your photoresist affects your ability to focus the aligner and achieve high resolution. It is practical to work initially with a practice wafer to determine how much resist thickness you actually need.

3) Alignment marks

a) Have the right type of alignment marks or fiducials on your mask. If you need 1μm tolerance, have fiducials that show a 0.5μm shift.

Aligning your wafer

1) Choose the right program

a) For 1μm alignment, you will need to use the Low Vacuum or Vacuum programs. For 2μm alignment, hard contact may be sufficient.

b) Use the right exposure and development time. If you do not use the right exposure and develop times, your features may be larger or smaller than the design calls for. If development is inappropriate then the features may not fully develop or they may be distorted or gone after development. Improper development or exposure time might have no effect on you current layer but future layers may be off the mark (say you seek to align a line on one layer to a space in the succeeding layer. If the line ends up being too wide, it may exceed the tolerance allowed by the space in the proceeding layer.)

c) Use minimum alignment gap. You do not need a 30μm alignment gap when using S1805 on a flat wafer. 10 -12 μm is a good place to start. If you wafer does not seem to be move when adjusting the micrometers, the alignment gap is too small. You want the smallest alignment gap possible while allowing your wafer to move freely while adjusting the micrometers.

2) Load your wafer

a) Verify the chuck is clean. Put some methanol on a clean room towel and gently clean the chuck.

b) Verify the chuck is level (it should sit correctly on the aligner and not be titled)

c) When loading your wafer, check the pins/screws for flat alignment. Make sure they are lower than your wafer. If they are higher than your wafer, it will not be parallel to your mask. The alignment will be off. This can also trigger the OVERCURRENT error.

3) Align your wafer

a) Use the highest objective possible when aligning your wafer. Do not use the 5x objective if you need an alignment tolerance of 1µm. Use at minimum the 10X objectives when aligning, after you have obtained your alignment marks using the 5X objectives.
b) Starting at a 10 – 12 µm alignment gap, focus on your mask alignment marks. Use the coarse focus knob, to get a clear image. With the top/bottom button lit, use the top substrate focus knobs to get the best possible image.
c) Turn the top/bottom button off. Using the bottom substrate focus knobs, focus on your wafer alignment marks.
d) Gradually lower the separation using the SEP keys. You should be able to get to an 8-10 µm gap and align your wafer. If your wafer does not move when adjusting the micrometer your alignment gap is too close. You may want to test this on a practice wafer first.
e) Once your wafer is aligned with at least 10X objective, check the alignment. You can do this by slowly adjusting the separation to zero. Do not move the micrometers while doing this; doing so will cause your wafer to adhere to the mask. If your alignment marks are still aligned while in contact, increase the gap to 8-10 µm. Press Alignment Check key to verify alignment again. Press Expose. You can also go from zero contact directly to expose. The alignment check button runs the program first (like vacuum contact) which may give a slight focus improvement.

Achieving tight alignments on the contact aligners takes practice. It may be best to try this on a practice wafer first before running your actual device. If you have trouble with focusing the aligners on fine features, do not proceed with the alignment. Contact a staff member for assistance and place a problem report in CORAL. If no staff member is available you can try the other contact aligner.

B. System Specifications

MA6 and MABA6 Contact Aligner Specifications

Exposure optics:	UV400 Lamp	350 watts
Spectral lines (nm)	436	g-line
	405	h-line
	365	i-line
Intensity	$12 \pm 0.1 \; {mWatt}/{cm^2}$	
	The aligners are set a constant intensity	
Mask sizes:	4-inch, 5-inch and 7-inch plates	
Wafer sizes:	Pieces $> 1cm^2$, 4 inch and 6 inch.	

TECHNICAL DATA: SUSS MA6 MASK ALIGNER

Wafer Size — 2" - 150 mm; 200 mm (option)

Substrate Size — 2"x 2" - 6"x 6", pieces; 8"x 8" (option)

Mask Size — up to 7"x 7" standard; 10"x 10" (option)

Exposure Modes

Large gap and proximity	
Exposure gap	1 - 100 µm
Gap adjustment resolution	1 µm
Contact pressure, adjustable	0.02 - 1.0 N/cm²
Contact vacuum, adjustable	to 200 mbar abs

Exposure Optics

Wavelength	Range	Exposure Source
UV400	350 - 450 nm	350W or 1000 W Hg
UV300	280 - 350 nm	350W or 1000 W Hg
UV250	240 - 260 nm	500 W HgXe
UV248	248 nm	KrF Excimer Laser
UV193	193 nm	ArF Excimer Laser
Exposure uniformity		better ± 5 %

Alignment

Types	BSA, TSA, ISA
Electronic alignment system	SUSS AL300
Mode	Image storage
Accuracy (see page 8)	down to 0.5 µm (3σ)
Alignment Gap	0 - 300 µm

Alignment Stage

Alignment range in X	± 10 mm
Alignment range in Y	± 5 mm
Alignment range in Θ	± 5 deg
Mechanical resolution in XYΘ	0.1 µm
Adapter/transport slide	manual, motorized (option)

Manipulator

Manipulator type	motorized, for BSA, TSA, ISA; manual for TSA only (option)
Microscope lift	pneumatic, for TSA only

Microscopes

Topside microscope TSA	
Movement range in X	50 mm (+25, -25 mm)
Option	100 mm (+50, -50 mm)
Movement range in Y	60 mm (+10, -50 mm)
Option	75 mm (+10, -65 mm)
Rotational range	± 4 deg manual
Bottomside microscope	
Objective separation	25 -100 mm
Movement range in Y	70 mm (+50, -20 mm)
Overall magnification	80 x (240 x screen)
Field of view	0.83 x 1.1 mm

Programming

Exposure modes	Large gap, proximity, soft contact, hard contact, adjustable vacuum contact, vacuum contact
Exposure time	0-999 sec, 0.1 sec steps
Alignment gap	1-300 µm, 1µm steps
Exposure gap	1-100 µm, 1µm steps
Resist type	Positive, negative
Alignment side	Top/Bottom/Inter Substrate
Program storage	20 different programs
Substrate parameters	Round, square, flat, notch

Utilities

Vacuum	<-0.8 bar, 200 mbar abs
Compressed air	5 bar (75 psi)
Nitrogen	≥1 bar (15 psi),
with 350 W lamp	0.4 m³/h
with 1000 W lamp	0.6 m³/h

Power Requirements

Voltage	AC 115 V, AC 230 V
Frequency	50 - 60 Hz
Consumption with 350/500/1000 W lamp	1500/2000/2600 W

Dimensions

Width/Depth/Height	
Standard	930/1140/860 mm
With mask holder deposit	1230/1140/860 mm

Weight — 360 - 396 kg