1.0 Karl Suss MA6 Mask Aligner

Figure 1: MA6 Mask Aligner

1.1 Introduction

The Karl Suss MA6 is a top and bottom side contact lithography printer used for fine line lithography down to 1 micron or better. It is capable of processing 4-inch substrate. After reading this manual, the User should be able to describe a typical MA6 process for both top and backside alignment, explain the theory of operation, and state all hazards associated with the system. After successfully completing the qualification procedures for this tool, the User should be able to perform a full photolithography process for both TSA and BSA using this system. Only trained and approved (qualified) Users may use this tool.

1.2 Features

The system includes a number of unique features including:

a)   350 W mercury arc lamp with "smart power supply" capable of operating in constant power mode, or constant intensity mode. The default is constant intensity mode. In the constant intensity mode, as the lamp deteriorates, the power is automatically adjusted to keep the intensity of the wavelength. Also the Intensity of the lamp may be read from the power supply during exposure or during a lamp test.
b)   Top side wafer alignment using a conventional microscope, wafer and mask stage assemblies.
c)   Bottom side alignment using bottom viewing optics, CCD imaging with image frame grabber and TV monitor. This allows registration of features on the backside of a wafer to the topside of the same wafer (e.g. through wafer etching, backside window etching for membrane formation, back side masks for wafer-wafer bond alignment, etc.).
d)   Automatic computer control with LCD status for User prompting and keypad entry. Up to 100 programs may be stored with five on line at any one time. Each program may be edited for key parameters pertinent to the lithography mode.
e)   1 of 4 lithography modes may be used for exposure. These include: soft contact, hard contact, vacuum contact, and low vacuum contact. Each mode is easily selected by keypad.
f)   Fast or slow scanning of mask/substrate with a memory toggle to quickly view between two locations is also available. This makes alignment using one objective easier.

1.3   Applicable Documents

    a)   Karl Suss MA6 Operating manual - hardcopy located at machine.

1.4 Safety

1.4.1 Moving Components – The User should be aware at all times of the moving components associated with this tool. For instance, the topside microscope assembly moves up and down, and does present a potential hazard. The User must exert caution at all times such that a limb, finger, or article of clothing does not become trapped or entangled (or worse, violently detached) when components of the machine are in motion.

1.4.2 Ultra Violet Light – The MA6 uses an Hg bulb that operates at a 365 nm wavelength. The lamp intensity for exposure is set to 18 mW/cm2 by default, although the indirect light that escapes the lamphouse during exposure is much weaker. Nonetheless, the User should be aware that excessive ultraviolet radiation can be harmful to the eyes and skin. Do not open any panels.

1.4.3 High Voltage: This machine is connected to HIGH VOLTAGE. Be very careful and aware of electrical hazards. DO NOT operate this machine with any component enclosures/panels open.

1.4.4 EMO: Emergency off button is available on the left side of the machine. The EMO switch should be pressed only in an emergency. An emergency would be fire, smoke, electrocution hazards, and an injury to anyone using this particular piece of equipment. If the EMO is pressed notify staff immediately.

1.5 Startup/Shut Down Procedure

Figure 2: Front panel on MA6

1.5.1 Startup
   a) Activate the equipment in FOM
   b) Ensure CDA, nitrogen, and vacuum is on.
   c) If UV lamp is off, on UV power supply press ON, then CP, and then Start button. Press Ch1 (365nm) or Ch2 (405nm) for CI (constant intensity mode). Intensity for 365 nm is 18 mW/cm^2 and for 405 nm is 30 mW/cm^2.
   d) On MA6 panel turn ON/OFF momentary switch to ON and release.

1.5.2 Shut-down
Skip steps b and c below if next user has arrived. UV lamp should not be off for less than ½ hour before turning it on again.

a) Turn ON/OFF momentary off.
b) On UV power supply, press OFF.
c) Turn CDA, nitrogen, and vacuum off.
d) Deactivate the equipment in FOM.

1.5.3   Default Idle State: The correct default idle state of the MA6 should be as follows,

a) System power ON - machine in MA6 mode.
b) Power to the TV monitor is OFF.
c) Lamp power is ON with the LED power supply readout at 350 W in constant intensity mode (Sometimes the display is set to intensity. It can be toggled back to power mode by pressing the DS button.)
d) CDA = 5-7 bar, Nitrogen = 2-3 bar, Vacuum < -0.8 bar.

1.6   UV Power Supply

Figure 3: UV power supply.

 1.7   Basic Exposure Programs

1.7.1 Soft Contact – The substrate is brought into contact with the mask by a preset force during exposure.

1.7.2 Hard Contact - This is virtually the same as soft contact mode save for a pillow pressure of Nitrogen that gives an additional upward force to the wafer.

1.7.3 Vacuum Contact - The vacuum seal inflates to form a chamber, which is then evacuated. The parameter "PreVac time" in this mode serves to allow the vacuum to proceed slowly. This aids in preventing alignment shift.

1.7.4 Low Vacuum Contact - This is the same as vacuum mode except that a small amount of Nitrogen is bled into the chamber to reduce contact force.

1.8   Equipment Operation

The MA6 allows 5 different program recipes (one for each contact mode) to be in online memory at one time: a low vacuum contact program, a vacuum contact program, a hard contact program, a soft contact program, and a proximity program. One of these 5 programs may be immediately chosen by simply pushing the Select Program key until the appropriate program appears in the display. 50 programs (numbered 0-49) may be stored in archived memory. These programs must be loaded before they can be executed. Only one program per contact mode may be loaded into online memory at a time.
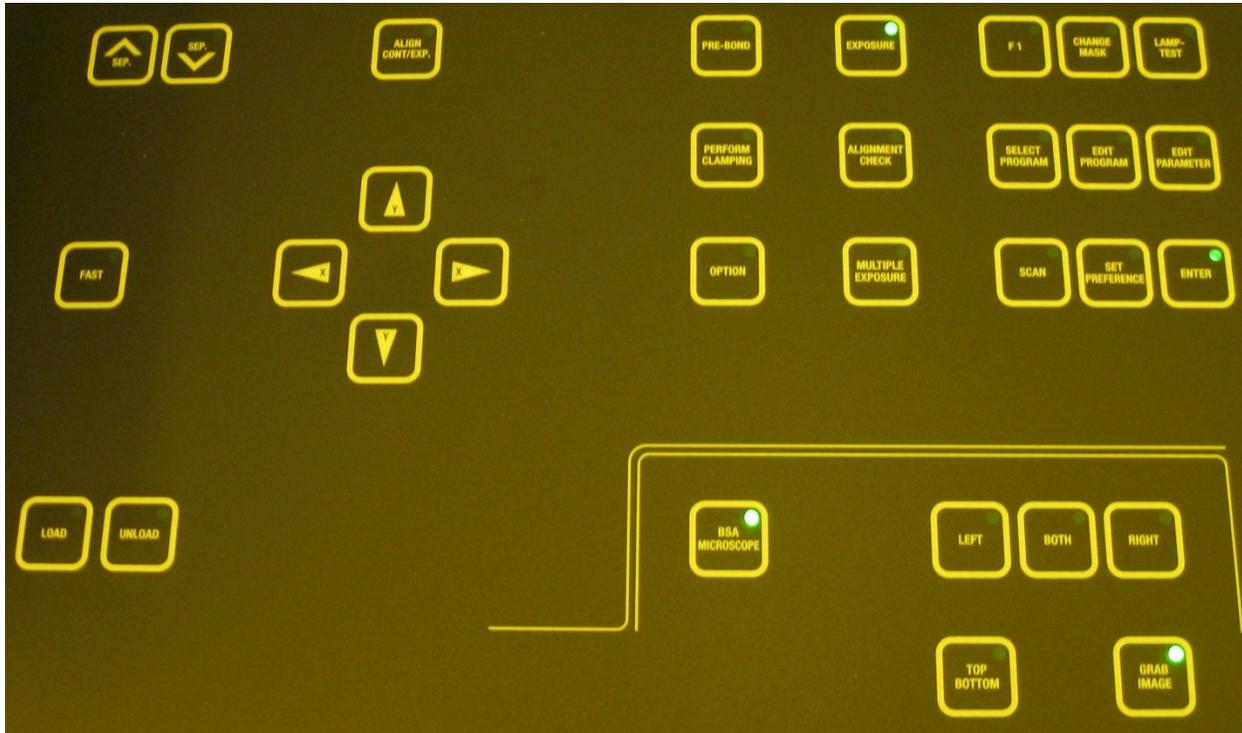

Figure 4: Keypad on MA6.

1.8.1 Viewing a program

   a)   Press the Edit Program key. The keypad will flash.
   b)   Press the Y (up/down arrow) keys. Each program #, contact mode, alignment gap and exposure time will be displayed as you scroll through each program. You can scroll up or down through the list by pressing the Y-up or Y-down key.
   c)   To exit viewing a program, press the flashing Edit Program key.

1.8.2 Loading an already stored program

   a)   Press the Edit Program key. The keypad will flash.
   b)   Press the X-lateral key to scroll among: 1; save prgm to, 2; load prgm from, 3; delete prgm #, and 4; exit prgm editor without change. Scroll to 2; load prgm from.
   c)   Press the Y –up/down key until the desired program number appears in the LCD display
   d)   Press the flashing Edit Program key to load the stored program into online memory.

EXAMPLE: Loading program 9:

Press the Edit Program key. The keypad will flash.
Press the X-lateral key once to scroll to load prgm from.
Press the Y-up/down key 9 times to scroll to recipe 9.
Press the Edit Program key again to both load the recipe and exit the editor.

1.8.3 Changing parameters in a program

a) Load the desired program as described previously.
b) Press the Edit Parameter key. The keypad will flash.
c) Press the X-lateral key to scroll through the parameters. For soft or hard contact modes the parameters are: Expose Time, Alignment Gap, and Wedge Error Compensation (WEC) type. NOTE: For vacuum mode there are additional parameters. Select the parameter(s) to be changed.
d) Press the Y-up/down key to change a parameter to the desired value.
e) Press the Edit Parameter key again. The change should appear on the display (pad stops flashing). Note that this program must still be saved for future use.

1.8.4   Saving the current program to a different memory slot

a) Press the Edit Program key. The pad will flash, and save prgm to should be displayed.
b) Press the Y-up/down key to select the program # to save to. When you save a program the position of the objectives is also saved. NOTE: DO NOT save programs to memory slot #'s 1-10.
c) Press the Edit Program key again to execute the save.

 1.8.5   Deleting a program

a) Press the Edit Program key. The pad should flash.
b) Press the X-lateral key twice to scroll to option 3; delete prgm #.
c) Press the Y-up/down key until the program you wish to delete appears.
d) Press the flashing Edit Program key again. The flashing should stop, and the program should now be deleted.

1.8.6   Exiting Edit Program mode without making a change

a) Press the Edit Program key. The pad will flash.
b) Press the X-lateral key until option 4, exit prgm editor is displayed.
c) Press the Edit Program key again to exit.

1.8.7 Changing a parameter without loading a new program

EXAMPLE 1: Changing the exposure time for the next substrate only.
Press the Edit Parameter key. Exp time should be displayed.
Press the Y-up/down key to increase/decrease the exposure time.
Press the flashing Edit Parameter key once more. The new exposure time should now be displayed.

EXAMPLE 2: Changing the alignment gap for the next substrate only:
Press the Edit Parameter key.
Press the X-lateral key until Al Gap is displayed.
Press the Y-up/down key to set the desired value of Al Gap.
Press the flashing Edit Parameter key again to save this new value. NOTE: The separation key pads (^) also serve to adjust the parameter Al Gap without having to enter the program editor.

1.8.8   Mask Loading

a) Press the Change Mask key. This key and the Enter key will flash.

b) Verify on the LCD display that the vacuum holding the mask is ON before pulling out the tray. If the vacuum is OFF, press the Enter key to toggle the vacuum ON. Pull the mask tray out, gently flip it over, and place it on the special shelf at the left of the machine.
c) Release the spring-loaded clip to the mask and toggle the vacuum OFF by pressing the Enter key. The mask may then be carefully removed.
d) Place the mask to be used onto the tray, emulsion/chrome side up. Use the three alignment pins to center the mask over the tray aperture.
e) Press the flashing Enter key to turn the vacuum ON. Verify that the vacuum is ON by reading the vacuum gauge. It should read less than –0.7.
f) Push the silver tab down on the spring loaded clip to engage it against the mask. CAUTION: This clip may not be strong enough to hold the mask in place when the tray is inverted. The vacuum should always be ON before the tray is inverted or the mask will drop and possibly break.
g) Turn the tray over such that the mask is on the bottom facing up. Carefully slide the tray back into the mask frame's dovetail grooves. Then pull close to the right edge.
h) Press the Change Mask key again. The flashing light will extinguish, and the mask tray will be locked into place. A Ready for Load message should then appear on the LCD display.

1.8.9   Substrate Loading

The vacuum grooves on the chuck must be completely covered by your substrate.
CAUTION: The chucks are made by precision machining and should be handled with extreme care. Do not drop, scratch or otherwise damage them.

a) Adjust the stage rotation knob to 0 (zero) (such that the rotation indicator is centered) and set the X and Y stage micrometers to 10 (ten).
b) Press the Load key and pull the substrate slide straight out. The Enter and Unload lights should flash.
c) Verify that the chuck and red vacuum seal are clean from stains or particles. Use IPA (Isopropyl Alcohol) and a clean wipe to remove any stains. DO NOT allow IPA to get on the seal. DO NOT use acetone to clean the chuck. If the chuck is dirty enough to require an acetone clean, inform staff. Furthermore, leaving resist or particles on the chuck can be grounds for disqualification. Ensure that the chuck and tool in general is left in a clean state when finished.
d) Place the substrate on the center of the chuck with the major flat facing the User. Ensure that all the vacuum grooves are covered. When placed properly, the substrate should touch up against the three small steel alignment pins on the chuck.
e) Press the Enter key to toggle the substrate vacuum ON.
f) Slowly push the slide all the way back into the machine.
g) Push the Enter key again. WEC will then be performed. After WEC, the substrate is ready to be aligned to the mask.

1.8.10   TSA Setup

a) Position both objectives over the mask using the X-Y arrow keys. A swifter movement of the objectives may be obtained by toggling the Fast key. The key will illuminate when in "fast" mode.
b) The distance between the left and right objectives may be adjusted by means of the lateral separation knobs. Each separation knob is located on the left and right side of the objectives. In general, it is best to find an alignment mark at the extreme left and right side of the mask. The rotation knob located at the front of the microscope allows the "theta", or rotational angle of both objectives to be adjusted.
c) Rotate the field select knob to the center position to obtain a split-field view on the monitor. A split-field view denotes when the left and right objective images may be seen simultaneously. It is also possible to view a full-screen image of the left or right objective by adjusting the field select knob accordingly.
d) The intensity of illumination from the objectives may be adjusted by means of the illumination control knobs. First ensure that TSA is selected, then adjust to the desired intensity using the illumination knob for TSA.

e) The large coarse focus knob is located at the top of the TSA microscope. Naturally, this is used for bringing the objective's depth of focus into the fine focus range. Fine focusing may be adjusted by means of the focus control knobs. The fine focus knobs labeled Top Substrate should be used to focus on the mask. The fine focus knobs labeled Bottom Substrate should be used to focus on the wafer. The Top/Bottom key may be toggled to switch focus control between the two sets of fine focus knobs. When illuminated, the Top/Bottom key will provide focus control to the Top Substrate knobs. When the Top/Bottom key is not lit, focus control is allotted to the Bottom Substrate knobs. Note: This logic applies to both TSA and BSA processes.

f) MA6 has the ability to remember microscope position via the Set Reference key. To use this option, position the microscope to the first reference location using the X-Y arrow keys. Then press the Set Reference key (key becomes illuminated). Next, reposition the microscope to the 2nd desired location using the X-Y arrow keys. Finally, press the Scan key. The microscope will automatically move back to the first reference location. Pressing the Scan key once more will move the microscope to the 2nd location. Note: This feature is also available for use with the bottom side microscope.

1.8.11   Wafer Alignment

CAUTION: Before any attempt to align, ensure that the machine is in alignment mode. The Alignment/Cont key will be illuminated when the machine is in alignment mode. If the system is in contact mode (orange contact LED illuminated), any attempt to align will scratch/ruin the mask and wafer, and possibly damage the machine.

a) Locate the three micro-manipulators near the bottom left and right sides of the stage. These allow the chuck (upon which the wafer rests) to be moved (X, Y, and R-rotation) relative to the mask.

b) If resistance is felt during wafer movement, press the separation key labeled "v" to increase the distance between the wafer and mask (z value becomes more negative). The other separation key labeled "^" will decrease the distance between the wafer and mask (z value on LCD display becomes less negative).

c) Alignment shift between the mask and substrate may sometimes occur during the contact exposure process. To ensure proper alignment before exposure, press the Alignment Check key. When this is done, the machine will undergo all the steps in the contact program up to the actual exposure (i.e. vacuum pump down, N2 boost, etc.). Any shift may then be observed through microscope. If unacceptable shift is observed, the substrate or mask may need to be re-cleaned, WEC may need to be redone, or a pressure adjustment may need to be made (inform staff). DO NOT attempt to re-align the substrate in "contact" Mode. Ensure the wafer and mask are separated before re-aligning the wafer (toggle with Alignment Check key). If the alignment is acceptable, the wafer may be subsequently exposed. Note: The Alignment Check key is not available for proximity or soft contact modes. Use the Alignment/Cont key instead.

1.8.12   Wafer Exposure

The lamp power supply should be set to CI (constant Intensity at 365 nm) mode with a 350 W LED readout prior to exposure. The system's intensity is set at18 mW/cm2 under normal conditions. NOTE: If a steady beep is heard during exposure, the lamp needs to be replaced, and staff should be informed.

a) If the exposure time must be changed, press the Edit Parameter key. Use the Y-arrow keys to change the exposure time. Then press the Edit Parameter key again. The LCD readout in the program should reflect the changed exposure time.

b) Press the Exposure key. The top side microscope assembly will lift, and the exposure assembly will slide out over the mask.

c) After exposure, the microscope will drop back down over the mask. The exposed wafer is then ready to be unloaded.

d) Pull the wafer tray out and press the Enter key to toggle the vacuum OFF. Remove the exposed substrate, and slide the wafer tray back into the machine.

1.8.13   Bottom Microscope (BSA) Setup

The bottom microscope is used to print a pattern on the backside of a substrate that is aligned to a pattern on the front side of the substrate. It accomplishes this by using a stored image of the mask prior to loading the substrate. The mask and microscope then lock into place while the substrate is loaded patterned side down (resist side up). The patterned wafer may then be viewed by the bottom microscope, and alignment may be accomplished by moving the wafer. Both the mask's stored image and the real time wafer image are viewed on the TV monitor during this procedure. NOTE: The top microscope may NOT be used during the following procedure.

a)   Verify that MA6 is in the default idle mode.
b)   Select the desired program and parameter settings as described previously.
c)   Load the desired mask as previously described.
d)   Select BSA/IR on the front panel's illumination switch.
e)   Activate the bottom microscope movement controls by pressing the BSA Microscope key (key should illuminate). The X-Y and Fast keys may now be used to move the bottom microscope objectives.
f)   Three keypads, Left, Both, and Right determine the bottom objectives' mode of movement. When the Left key is selected (key illuminated), the left objective movement only is controlled by the X-Y keys. The Right key controls the right objective movement only. The Both key controls movement of both objectives at the same time.
g)   Press the Top/Bottom key to activate mask focus (key should be illuminated).
h)   Adjust the Top Substrate (mask) left and right focus knobs to obtain a sharp image on the monitor.
i)   The bottom microscope position may be read from the LCD. Xl = left objective x position; Xr = right objective x position, Yl = left objective Y position etc. Effective rotation may be accomplished by moving one objective relative to the other. The Set Reference key may be used as described previously.
j)   Find the alignment marks on the mask (use split field mode). Adjust the left and right illumination knobs if necessary to obtain a clear image on the monitor.
k)   After ensuring that the alignment marks are in focus, press the Grab Image key to capture a mask image. NOTE: This must be done each time a new substrate is loaded. The bottom microscope objectives will consequently lock and may not be moved. To cancel the stored image, press the Grab Image key again.
l)   Press the Load key. Pull the wafer tray out and load the substrate patterned-side down (resist side up). Press the Enter key to toggle the vacuum to the wafer on.
m)   Slide the tray back into machine and press the Enter key. WEC will be performed and a fuzzy image may appear on the monitor.
n)   Ensure the Top/Bottom key is toggled to the bottom mode (key NOT illuminated).
o)   Adjust the Bottom Substrate focus and illumination knobs to obtain a clear image of the wafer.
p)   Alignment of the wafer to the mask may now be done by moving the chuck's X, Y, and R knobs. Once the alignment is complete, the wafer may be exposed.