NOTES FOR TROUBLESHOOTING ALIGNMENTS

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FACTORS THAT AFFECT PATTERNING

1) Feature size
2) Sample size
3) Substrate type
4) Bare or coated substrate. If coated, with what?
5) Optically flat, rough, textured, or curved surface
6) Thickness of photoresist
7) Brand of photoresist
8) Negative or positive resist
9) Single layer or multiple layer
10) Type of subsequent pattern definition (wet etch, dry etch, liftoff, electroplating, etc.)
11) Equipment needed to perform the subsequent pattern definition
12) Any combination of the above factors

SAMPLE, PHOTORESIST AND PHOTOMASK CLEANLINESS

1) **Pre-clean steps**
   a) Sonicate samples in solvent bath.
   b) Remove organic contaminants from sample using a Piranha Solution.
2) **Photoresist bubbles**
   a) Remove bubbles and particles in dispensed photoresist as they will affect the alignment of samples.
   b) Please consider the following:
      i) Expired resist or improperly stored resists form particles.
      ii) Improperly diluted resist forms bubbles.
      iii) Moving resist bottles, storing resist bottles for long time periods, and manual dispensing will all form bubbles. In these cases, give the resist sufficient time for bubbles to rise and dissipate.
3) **Edge bead removal**
   a) Design mask regions with consideration to edge bead zones (**Figure 1**).
   b) Edge beads can cause sample to stick to mask (**Figure 2**)
   c) It may also reduce your feature size due to the inability of your sample to make intimate contact to the photomask (**Figure 2** & **Figure 3**). The gap between the mask and the sample extends the diffraction pattern and therefore deteriorates resolution.

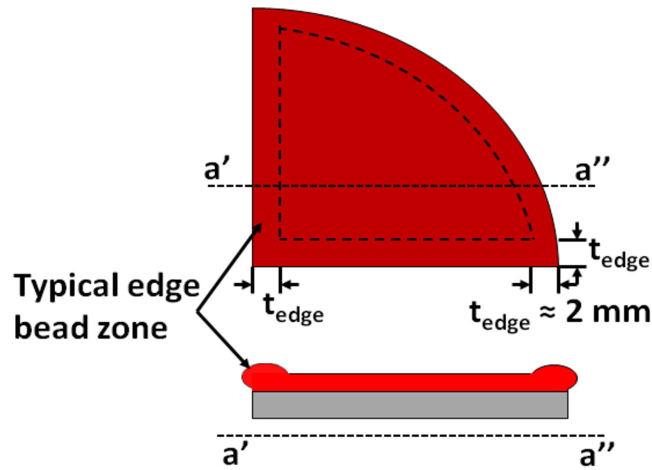

Figure 1 Edge bead zone after photoresist spin coating.

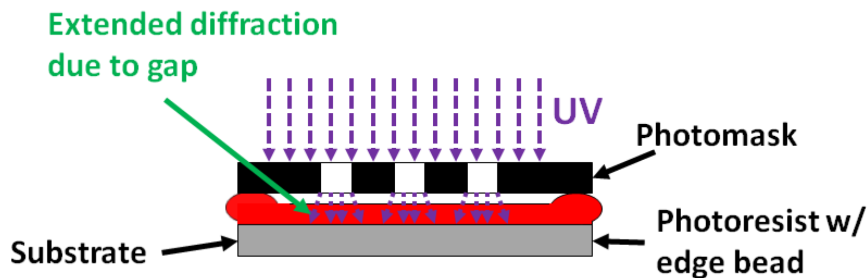

Figure 2 Undesired diffraction effect due to gap created by the edge bead.

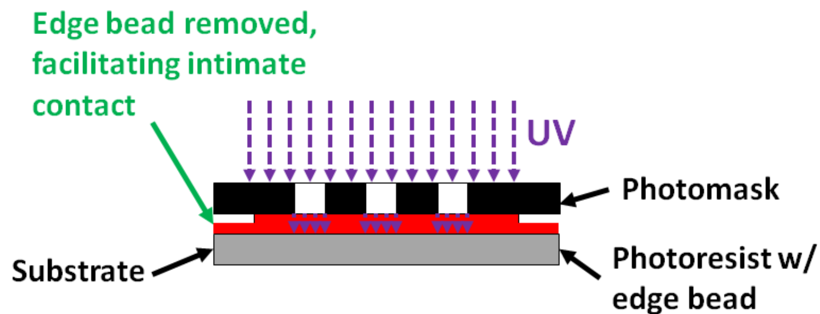

Figure 3 Desired intimate contact with photomask is achieved when the edge bead is removed.

4) **Clean backside of wafer of excess photoresist**
   a) Photoresist may prevent the sample from being planar, which may cause part of the sample to stick to the photomask even if the separation lever is engaged (**Figure 4**).
   b) <u>Before soft-bake</u>, use a cotton swab dipped in acetone to clean the backside.

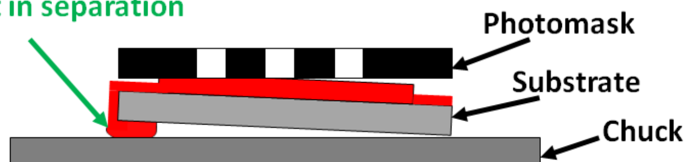

Figure 4 Proper alignment is inhibited due to non parallel surfaces from backside resist which sticks to the mask in separation mode.

5) **Mask cleaning.**
  a) Depending on the feature size, mask cleaning can be performed between each alignment for improved repeatability.
  b) Solvent clean (**both chrome and iron oxide mask**).
    i) Always keep masks wet during the cleaning process. When a mask is dry during the cleaning step, it can easily be scratched.
    ii) Pour enough acetone to cover a mask in a large glass baking dish at the lithography bay.
    iii) Soak mask for 5 minutes in the solution.
    iv) Scrub the front and back of the mask with texwipe.
    v) Pour enough methanol to cover the mask in a large glass baking dish at the lithography bay.
    vi) Soak the mask for 5 minutes in methanol to eliminate possibility of unwanted film left behind by the acetone
    vii) Rinse the front and back of the mask with deionized water for 60 seconds.
    viii) Use nitrogen gun to blow dry the mask. Do not allow the water to evaporate from the surface.
    ix) Inspect the mask either visually or with the Carl Zeiss Optical microscope.
    x) Repeat above steps if necessary.
  c) Heated PRS-3000 clean (**chrome only**).
    i) Submerge mask completely in a large baking dish with PRS-3000, place dish on a hotplate heated to 110 Celsius for more than 3 hours.
    ii) Carefully remove the mask from the solution and rinse the mask thoroughly with deionized water over a sink.
    iii) Use nitrogen gun to blow dry the mask (Do not allow the water to evaporate from the surface).
  d) Acid clean with piranha (**CHROME MASK ONLY!!!**).
    i) Pour enough sulfuric acid: hydrogen peroxide (30%/wt) 1:1 in a large glass baking dish to be able to completely submerge your mask.
    ii) Gently and safely place your mask in the piranha solution using Teflon lab equipment.
    iii) Leave the mask in the solution completely submerged for 10 minutes.
    iv) Remove the mask from piranha, rinse well with deionized water to ensure all acid is washed away from the sample.
    v) Use the nitrogen gun at the station to dry the mask (Do not allow the water to evaporate from the surface).
    vi) Inspect the mask either visually or with the Carl Zeiss Optical Microscope.
    vii) Repeat this sequence with fresh piranha solution if necessary.

<u>**PHOTOMASK AND ALIGNMENT CONSIDERATIONS**</u>

1) Rubber piece with silicon wafer pieces for WEC.

a) When the contact lever is raised, the Karl Suss MA-4 performs a wedge error compensation (WEC). This step ensures that the sample is parallel to the photomask.

b) The MA-4 is designed for aligning 4 inch wafers. However, since we are interested in aligning pieces, we must provide additional support surfaces in order for the WEC to be performed properly.

c) To accomplish this, we can permanently attach 3 quarters of a dummy wafer to a 4" diameter rubber piece (**Figure 5a**).

d) This piece is made by cleaning both the silicon and rubber pieces thoroughly with acetone and deionized water. Then, simply press the parts together. The mask aligner can be used to press the pieces together.

e) Make sure the wafer pieces are close to the thickness of your actual sample you wish to align (**Figure 5b**).

f) The rubber piece also ensures that the wafer chuck vacuum is satisfied.

g) The surface tension between the rubber and your substrate will be sufficient in preventing the sample from sliding.

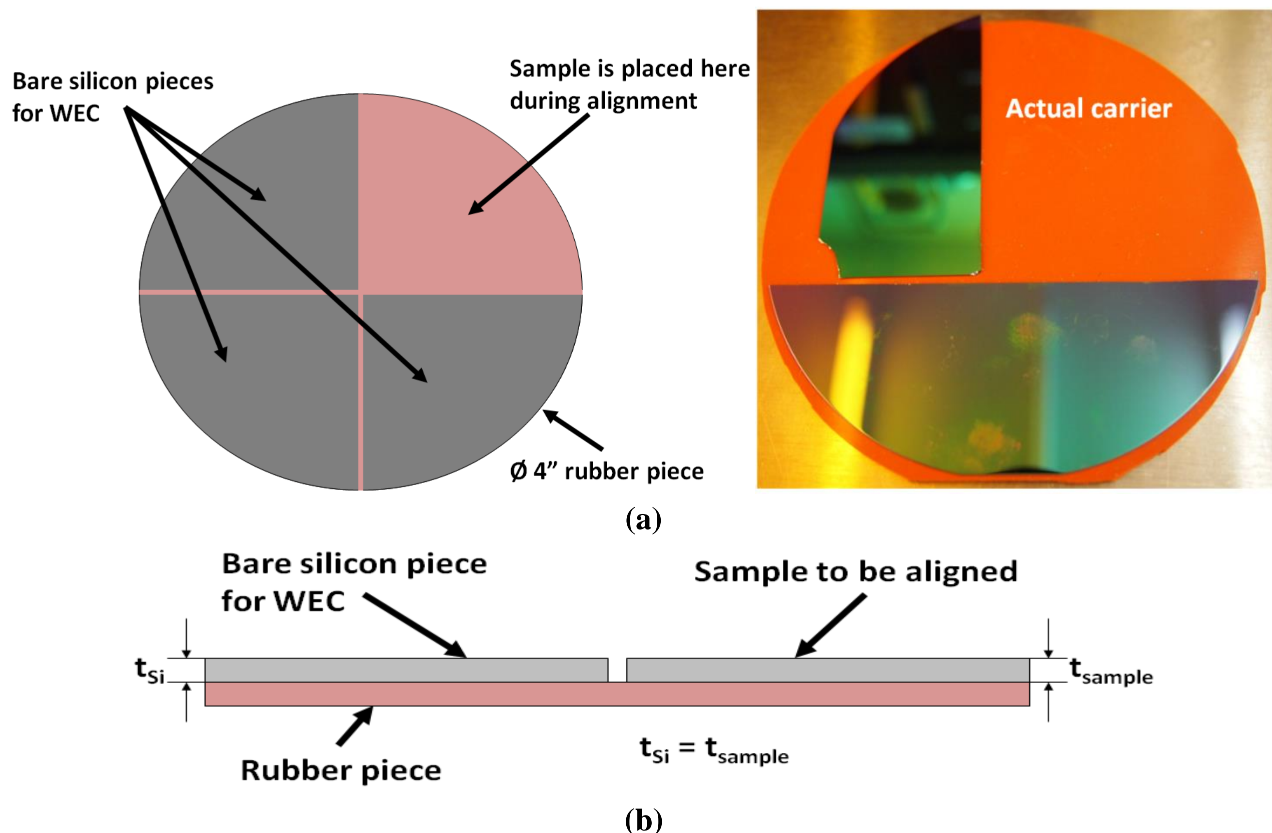

Figure 5 Chuck modification when working with samples much smaller than a 4" wafer. (a) Top side view (b) profile view.

2) Performing a coarse alignment.

a) Home (center) the x, y, and θ micrometers using the reticule. This is found on the right side of the alignment stage (**Figure 6**).

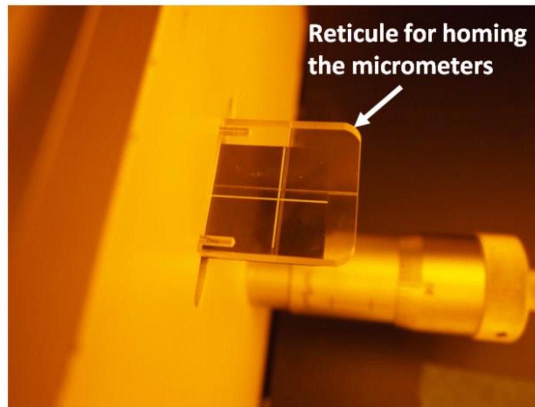

Figure 6 Reticule used for homing the positioning micrometers.

b) Before starting the alignment with the x, y, and θ micrometers, it is best to perform a coarse alignment with your eyes.
c) Incorporate large alignment marks like a large "L" (**Figure 7**) on to your photomask to help with this process.
d) Minimize the necessary movement of the positioning micrometers. They have a limited range of motion. Once the end limit is reached, the micrometers will literally "pop" out of the socket. This may cause permanent damage to the tool.

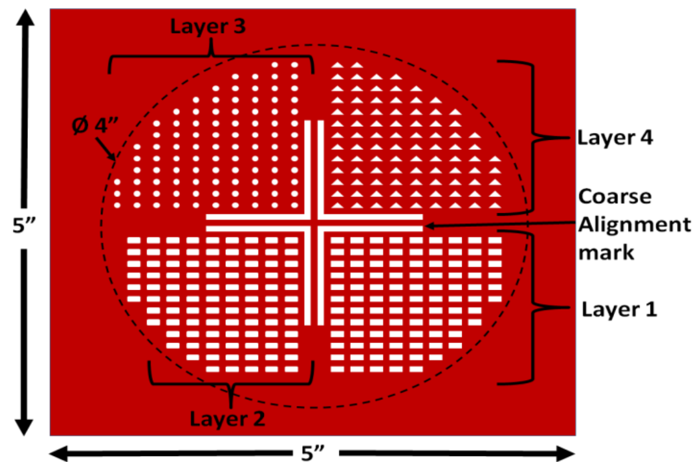

Figure 7 Mask layout with coarse alignment marks.

3) Mask Layout

a) To maximize repeatability, the wafer should be placed in the same location on the chuck for each alignment and exposure.
b) To accomplish this, when laying out the mask, layer 2 is positioned in the lower left quadrant of the mask with a 90 degree clockwise rotation with respect to layer 1 (**Figure 8**).
c) To align layer 2, we place the sample in the lower right quadrant of the wafer chuck. The mask is rotated 90 degrees counterclockwise such that layer two is now over the sample, as opposed to layer 1.
d) The same mask layout design for layer 3 and 4 are shown below in **Figure 8**.

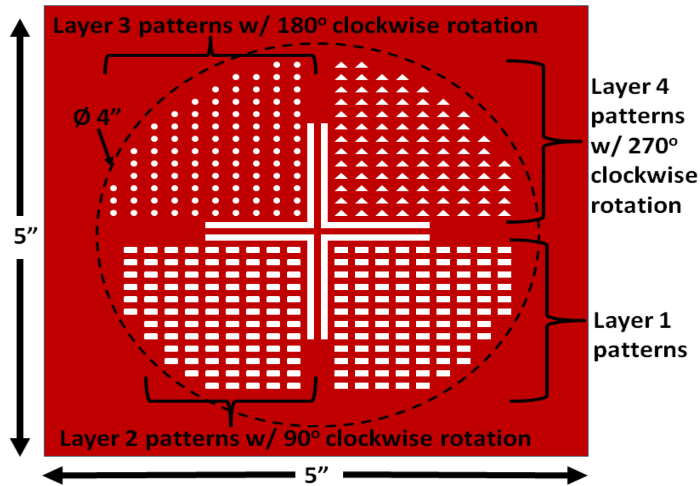

Figure 8 Mask layout illustrating rotation of the layers.

4) Alignment Marks

a) Have alignment marks that provide coarse and fine alignment. (For ex, see: **Figure 8**)

b) Place alignment marks throughout your sample. Especially at the boundaries of the layout.

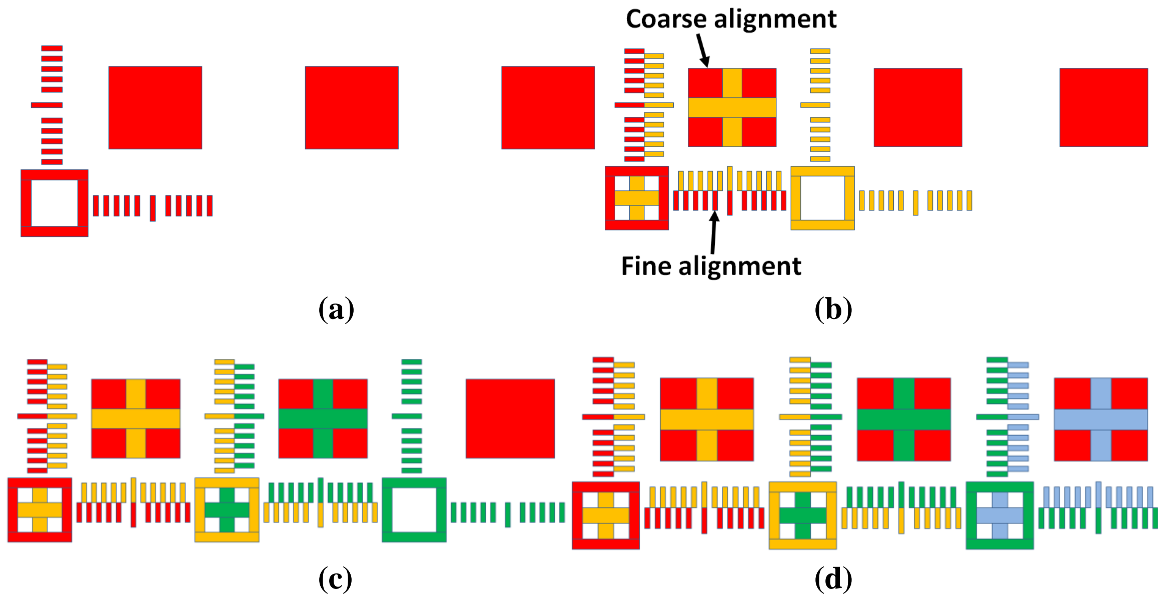

Figure 9 Alignment marks. (a) First layer in red, (b) second layer in yellow, (c) third layer in green, and (d) fourth layer in blue.

5) How to align

By exploiting the dynamics of the wafer chuck positioning, we can systematically align our sample to the mask.

a) Alignment is accomplished by manipulating the x, y and θ position of the sample with respect to the stationary mask.

   i) The x and y micrometers impact the positioning of the chuck across the entire area. (**Figure 10**).

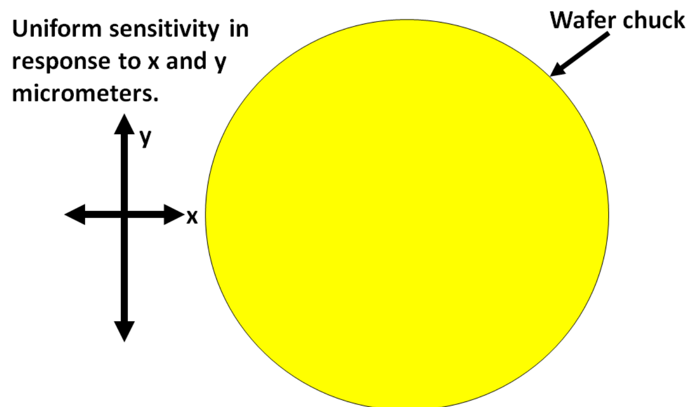

Figure 10 Impact of x and y micrometers on the positioning of the wafer chuck.

ii) The θ micrometer has a range of sensitivity (**Figure 11**). If we were to observe <u>the center</u> of the wafer chuck while turning the θ micrometer, we would observe little movement of the chuck.

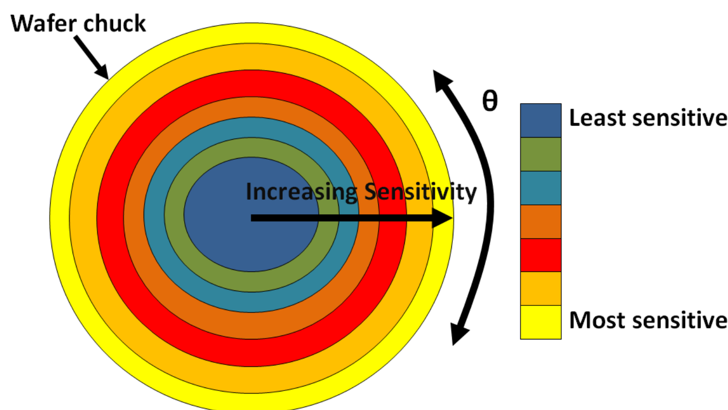

Figure 11 Impact of θ micrometer on the positioning of the wafer chuck.

iii) However, if we were to observe <u>the edge</u> of the chuck while turning the θ micrometer, we would observe that this region is far more sensitive and has much larger displacement.

iv) Consequently, we can isolate the impact the θ micrometer has on certain regions of our sample as we perform the alignment procedure.

v) Perform all x and y positioning with alignment marks that are as close to the center of the chuck as possible (**Figure 12**).

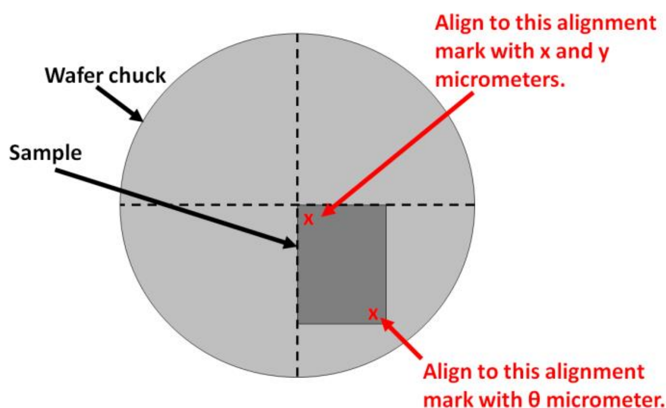

Figure 12 Aligning the sample when placed in the lower right quadrant.

vi) More likely than not the alignment marks will be offset by a θ component (**Figure 13**). **Resist the urge to use θ micrometers to correct this misalignment.**

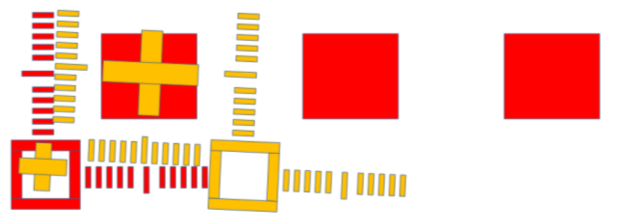

Figure 13 Typical misalignment when initially aligning the center patterns.

vii) All θ positioning will be performed with alignment marks that are as close to the edge of the chuck as possible (Please see **Figure 12**).

viii) More likely than not, the alignment marks will be offset by an x and y components (**Figure 14**). **Resist the urge to use the x and y micrometers to correct this misalignment.**

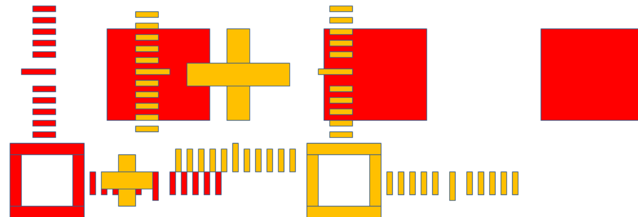

Figure 14 Typical misalignment when initially aligning the edge patterns.

ix) Return to the center alignment marks. Perform alignment with the x and y micrometers only. The θ misalignment should be improved.

x) Return to the edge alignment marks. Perform alignment with the θ micrometer only. The x and y misalignment should be improved.

xi) Continue to go back and forth until the alignment between the sample and the mask is satisfied.

xii) Check the actual devices to make sure they are aligned as desired.

b) Center alignment

i) Certain circumstances may prevent you from using the quadrant approach as described above. Leaving you to use the center of the wafer chuck to perform alignment. In this case, the appropriate set of alignment marks must be chosen for successful alignment and this must be carefully considered in the mask layout.

ii) If we place our sample in the center of the chuck and perform alignment, then it is best to use the marks that are in the center of the sample as well as marks at one edge of the sample (**Figure 15**).

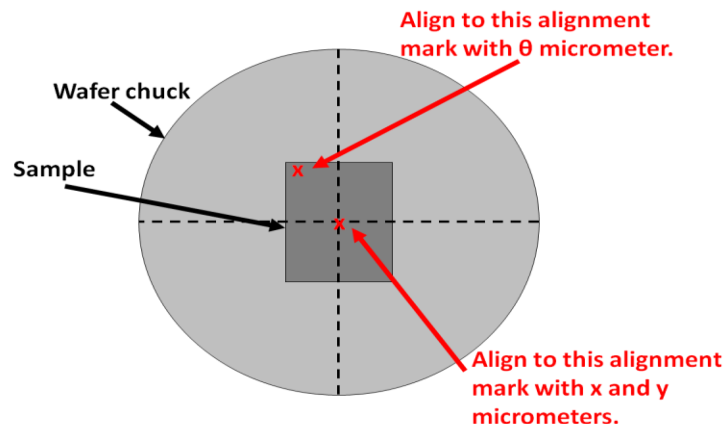

Figure 15 Alignment when placing the sample in the center of the chuck.

iii) The center marks have relatively less sensitivity to the θ knob, giving us the isolation we need.

iv) If we choose alignment marks that are at the edges of the sample, both sets are equally sensitive to the θ knob rotation. When we align one set, we will be misaligning the previous set.

c) Splitfield/Dual objective alignment

i) The MA4-2 has the option of two objectives. This can substantially expedite the alignment process by allowing the user to view both alignment marks simultaneously (**Figure 16**).

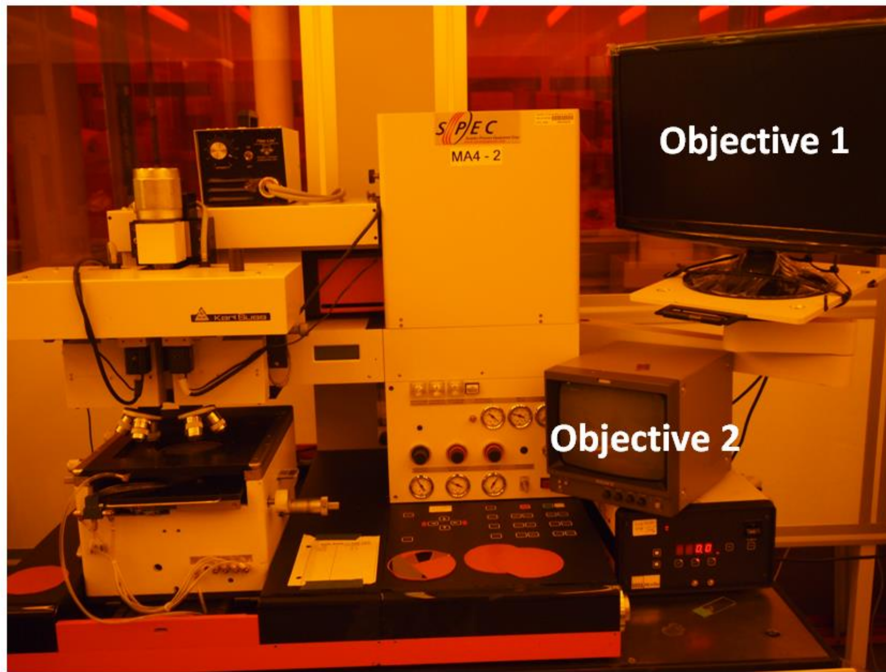

Figure 16 MA4-2 two separate monitors for splitfield alignment.

ii) Please allow a distance of at least 4 cm between the alignment marks due to the minimum distance that can be achieved between the objectives.

iii) This may also require a larger sample size.

d) Image resolution for aligning

i) Typically, the alignment marks on the mask will be in focus, while the patterns on the sample will be out of focus. This is due to the separation gap between the mask and the sample (**Figure 17**).

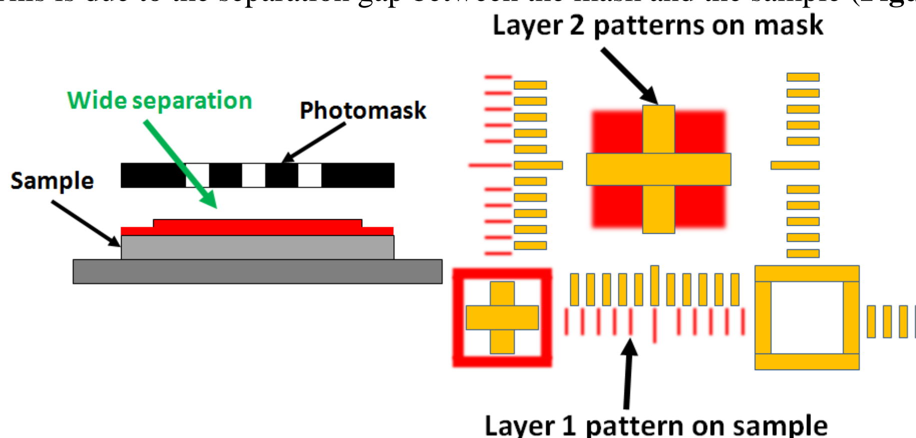

Figure 17 Wide separation between the mask and sample. The patterns on the sample are fuzzy due to the large difference in the depth of focus.

ii) To improve the resolution, we can use the separation lever to slightly raise the sample towards the mask. Thereby allowing the depth of focus of the patterns on the sample to approach the depth of focus of the patterns on the mask.

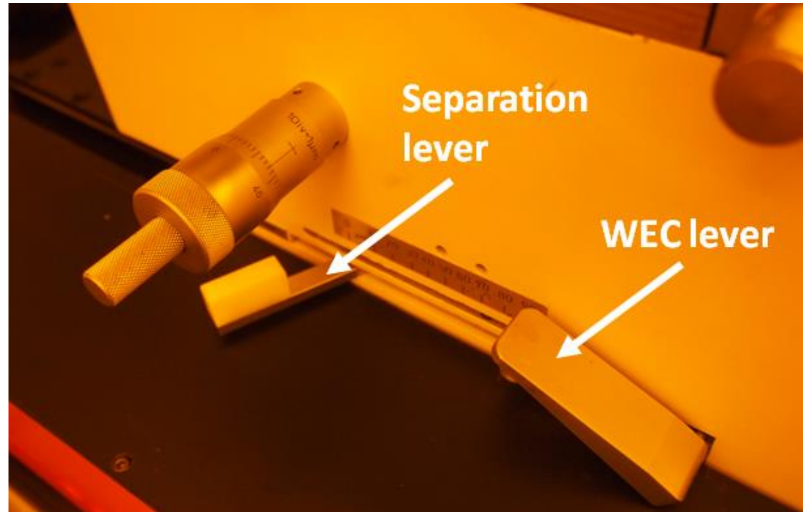

Figure 18 Chuck height manipulation levers.

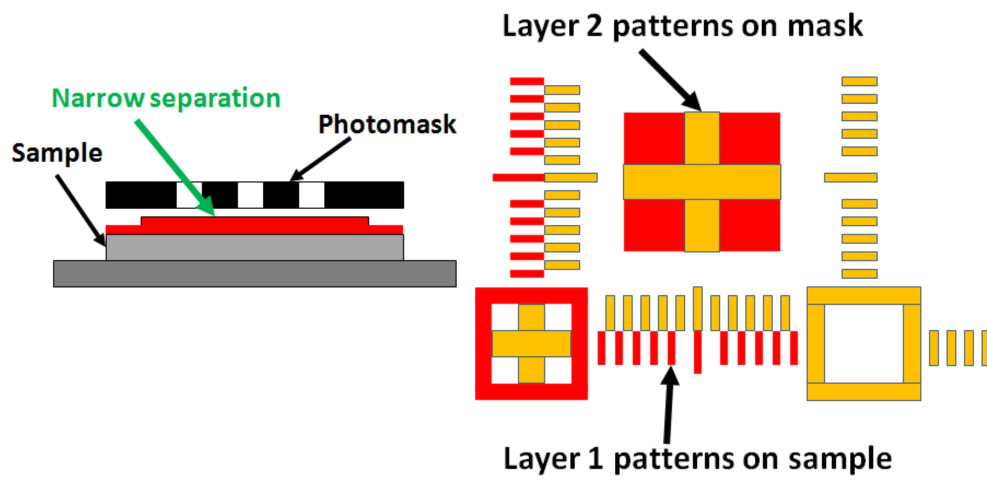

Figure 19 Improved resolution of the mask patterns when the separation gap is narrow.

OTHER CONSIDERATIONS

1) **WEC pressure values.**
   a) The value of the wedge error pressure determines the force between mask and substrate during Wedge Error Compensation (WEC).
   b) The pressure should be 0.4 - 1.0 bar (**Figure 20**).

Figure 20 Image of pressure meters and regulators.

2) **Over current Error.**
   a) This error is removed by shutting down the machine.
   b) It occurs when excess current is drawn from the motor.
   c) A common source of the over current error is when the vacuum and gas lines get caught under the alignment stage while it is moving (**Figure 21**).

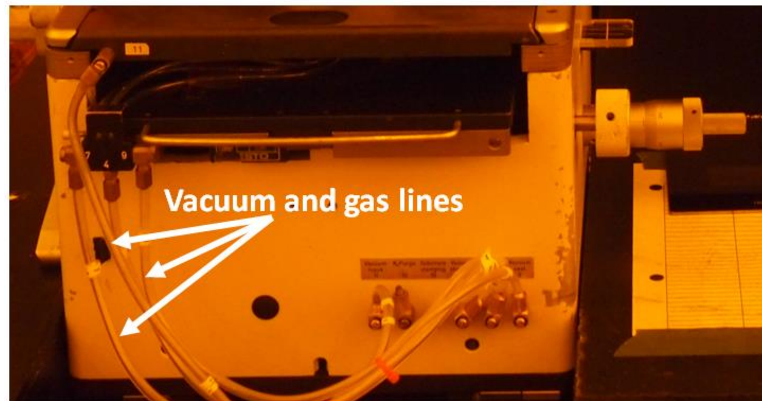

Figure 21 Mask vacuum and pressure lines.

3) **Cannot drop chuck error (for MA4-1).**
   a) From time to time MA4-1 will give the error it cannot lower the chuck.
   b) To alleviate this issue, very gently tap the WEC lever (Please see **Figure 18**).
   c) If you tap it with too much force, the tool may be permanently damaged.