OPTICAL LITHOGRAPHY USING LASERWRITER LW405

Tool identifier: LaserWriter LW405

SYSTEM OWNER/OPERATOR	CONTACT DETAILS
AKHIL KUMAR	akhilatnik@ee.iitb.ac.in
ARATHY MENON	arathymenoniit@gmail.com arathy_menon@iitb.ac.in

Synopsis:

The LaserWriter System is designed for patterning planar structures on a mask or directly on the substrate. It can also be used for surface diagnostics, in applications where maximum resolutions down to 0.7µm are required. The system transforms a laser beam into a controlled writing tool for photolithographic mask fabrication or for direct *in situ* processing on planar substrates. Besides microlithographic applications, its optical apparatus and substrate motion management are also well suited for surface inspection or diagnostics. The patterns are generated by accurately moving the target (mask or substrate) underneath a focused and scanning laser beam with proper wavelength.

Specifications of LaserWriter LW405

Maximum working area can range from 100 mm × 100mm to 400 × 400. The substrate size can be equal to the working area or larger. Currently, we use 3” x 3” and 5” x 5” mask plates.

Position Accuracy(µm): This parameter indicates the absolute positioning error on the whole working area and is about 0.1 micron.

Minimum line width: The minimum linewidth can be selected by the operator among 1, 2 or 4 micron. Currently, the smallest linewidth that can be written is 2 um.

Exposure Wavelength: The standard wavelength of the writing beam is 405 nm (from a GaN solid state laser). Optional 325 nm wavelength is available (from a He-Cd gas laser) for biochemistry applications.

Exposure on resist: All standard resist-coated masks (chrome or iron oxide). We use iron oxide mask plates.

Besides mask writing, the system is also specially suited for maskless direct patterning on the final substrate (Si, GaAs, InP, microwave/cryogenic/biological substrates, etc.). The system is currently used only for mask writing.

Exposure energy stabilizer: The exposure level is continuously monitored in order to keep it constant during the whole writing process. For grey-level exposure, a reference level is kept constant.

Variable resolution: Some processes can take advantage of a reduced planar resolution during a microlithographic step. One typical example is the use of rough surfaces as a substrate (alumina, for instance). In the LaserWriter system, the resolution is changed by replacing the beam focusing optics, which takes only a few seconds.

Use as substrate inspection station: Each system includes a CCD camera and related illumination system. This allows the operator to use the LaserWriter as a surface inspection and metrology system.

Laser focusing: The LaserWriter includes a full automatic focus track system. This is capable to dynamically keep the laser beam focused on the substrate even if this is slightly concave, convex or tilted.

Writing on non-planar samples: This option allows microlithographic operations to be performed on samples with poor planarity or slightly concave

or convex substrate.

Writing on tilted samples: Patterning can be made also on slightly tilted samples(up to 2°). This is useful in a R&D environment, if small samples are used after being glued to a larger holder. Although the samples are still planar, the uneven glue layer can affect their orthogonality with the laser beam. In such case the operator can easily instruct the machine to follow the substrate plane during the writing process.

Alignment on marks: If a maskless process has been selected, all different microlithographic processes are performed on the same work sample. In order to properly align to each other the patterns of different layers, a specific procedure is included in the Laser Draw software package. Each new patterning level is drawn aligned with the reference patterns already on the sample.

Selectable full manual control: Full manual control mode is useful when the system is used as an inspection and metrology station, and for manual trimming or photo processing.

CIF, DXF, GDSII data formats: The LaserWriter is driven by a MICROTECH proprietary data format - LDF, Laser Draw Format - obtained by automatic translation from a number of industry standard languages accepted by the LaserWriter, such as CIF, DXF, GDSII.

Different writing modes: Apart from beam scan mode, raster writing mode or vector patterning mode can be selected for different applications.

START-UP

1. Before entering the yellow room for lithography;

Ensure that AC plant is ON

2. After entering the yellow room;

Check the amount of photoresist, DI water in bottles.

3. Preparation of samples for lithography

Turn on the laminar bench switch.

Put on the switch for baking iron. Wrap aluminium foil on the hot plate. Set the temperature to 90°C.

Take a new PPR coated mask plate from the black mask box. Each mask plate has a corner cut on one face. The other (flip side) face contains the PPR layer. Bake the mask plate on the hot plate at 90°C for 3 minutes. Ensure that the PPR layer is facing up. After baking, wait for about 5 minutes to allow the mask plate to cool down to lab temperature. Blow nitrogen on the mask plate using the nitrogen gun.

Step by step operator's guide for patterning using LaserWriter LW405

Note: Wear the nylon gloves meant for LaserWriter before operating the LaserWriter. Power Supply and XY-Z Initialization:

1) Switch ON the power supply to the LW405 and the supply to the vacuum pump. (Two switches are on the wall behind LW405).

2) Start the whole system by pushing the <1> button in the UPS front panel.

3) Wait until Windows starts completely and the mouse indicator is a stable arrow.

4) Double-click on the "LW0" shortcut. (interferometer will take about 4 mins to warm up from the time of start-up. Note that the interferometer is currently disabled).

5) Initialise the XYZ microtranslation stages. XYZ initialisation is done automatically. (Just press "ok" button whenever the window appears)

Data Management:

6) From the "Data management" menu, click <Import>. The "Import" procedure will assign automatically a number to the new project.

7) Go to Data-Management if a new mask-pattern is required. If a new pattern is required, you can select it from the database, create it using layout editor, edit it or import it from a CD.

Refer to the CleWin section for details on using the layout-editor.

8) Select the archive to use for saving the new project (arch_1 to arch_10), click<Save> and exit the
"Import" procedure.

9) From the "Data management" menu, click <Select> Select the archive where your job file is, and the file, by clicking on the corresponding field (first column of the table). Click "Select" and exit the job selection procedure. Now the selected file appears in the field at the bottom of the "Data management" page.

10) Exit "Data management" and return to the main menu page by clicking on Exit button.

11) If the selected job number is not properly indicated, enter "Data management"and exit again.

Instructions on layout editor CleWin

For editing a new pattern with CleWin:

1) From the LaserWriter main menu, click <Data management>.

2) The name of the current "active job" is shown in the field at the bottom of the screen.

3) From the "Data management" menu, click <Layout editor>. This opens the CleWin layout editor. If the current active job is "binary" type, this will be automatically shown in the CleWin window. Otherwise, an empty layout is shown.

4) You can edit and modify the current job, or create a new one, according to CleWin menus. For bright field patterns, one must insert horizontal lines (typically 10 um thick) above and below the pattern to limit the writing area.

5) Save the project by clicking on "Save" button in Clewin if you are making any changes in your design. This will save changes in the active job (xxx.cif) in the database.

6) Exit CleWin

Make LDF (Laser Descriptor File):

1) We use lens 4 for writing features greater than 10 um and lens 5 for writing features smaller than 10 um. The current focusing lens is the one that is pointing at the outer edge of the XYZ stage in the unloaded position. For changing the lens, move the black flap to your left and simultaneously gently push/pull the lens holder depending on current lens. As soon as the holder begins to move, release the black flap and continue to move the holder until you hear a clicking sound and the holder stops moving.

2) Click the <Make LDF> button, in order to covert the CIF file into the LDF format. The current focusing lens is displayed. Click on the GO button.

3)Note that each time a change is made on the original CIF file, a new LDF file must be created.

4) From the main menu page, click the <START> button. The left side of the “Start”window is automatically enabled, that is the side devoted to manual operation.

5) Measure the thickness of the substrate (in micron) and enter it in the <substr.>field, in the “lens” frame, followed by <enter>. For mask(glass) plate, thickness is around 2000 Microns. For substrate it is around 300 microns. For glass+substrate, it is around 2300 microns. These are approximate values.

6) Click <set z> in the “lens” frame. The Z axis will move in order to bring the vacuum chuck in a position close to the focus position for the substrate, when this will be placed on the chuck. (Do not use SetZ when you are using mask/glassplate but try and get focus by manually adjusting the z position.)

Loading of the Substrate:

1) Before loading, ensure that sufficient distance is maintained between the lens and the stage. Before unloading, Z is kept at -900 um. In case the stage is in loaded position, click on “UNLOAD” button and wait for the chuck to move towards the operator. The stage will move away from the lens by 500 um after unloading.

2) Place the substrate on the chuck, against the mechanical stops. The PPR layer should be facing up (towards the lens). As a convention, one can load the mask plate in such a way that the corner cut is at the bottom right hand side of the plate. This will be useful during inspection after development.

3) Turn on the vacuum pump. After a few seconds, the “vacuum ok” indication should appear, against a green background. (if your substrate is 2” diameter then the“vacuum ok” indication may not appear against a green background).

4) Click on “LOAD” for loading the substrate. The stage will move towards the lens by 500 um after loading.

Focusing System:

1) Move the <focus rings> slider, until the rings appear. If they are outside the green frame, or if they are very small, move the Z axis until they fit sharply inside the left and right side of the green frame. (Approximate diameters of the focus-rings for each lens can be found in the laserdraw manual. One can also use knife edge focusing. In this case, move the Z axis until you notice a sharp edge at the screen that can be contrasted from the background.

2) If the outer ring is sharply white against a dark background, click the <auto>button in the “focus (rings)” frame. The system will automatically move the Zaxis to the best focus position. If the rings are not sharp, move the Z axis in orderto get the new best focus conditions for the new substrate and then store it usingthe <Store> button.

Beam Control:

1) Select the beam attenuator, by clicking a transmission value in the “filter” frame.Typically, for 0.5-2 micron thick resist, the 1% or 3% filters should be used.For lens 4, we use 3% filter and for lens 5, we use 1% filter.

2) Select the beam gain and bias (Not required for binary level patterning)

3) Click the <reset> button close to the Y position display. After reset, the display should indicate random values around 0,0. Also, the 2+2 small indicators in the interferometer position displays should become green. If this is not the case, the interferometer is not ready yet. Wait a bit longer and occasionally click the<reset> button, until the interferometer actually resets. The interferometer is currently disabled. This step may be skipped.

Instructions on M1, M2 and M3 points to set up the focus plane

The focus plane group which includes M1, M2, M3 points sets the coordinates of three points that define the focusing plane (substrate plane) for the writing process, according to the following procedure:

1) Enclose the pattern with guidelines thereby forming a rectangular boundary. Currently, as per our convention, M1 is the top left hand corner of the rectangle, M3 is the bottom left hand corner of the rectangle and M2 is the mid-point of the right hand side of the rectangle.

2) After substrate loading, this is positioned on the first of the three points, properly chosen on its surface.

3) For lens 4, Z should be increased from -900 um to 900 um in steps of 100 um. Enter 100 in Z step field. For lens 5, Z should be increased from -900 um to 1100 um in steps of 100 um. Enter 1 in Zstep field.

Enter the Clewin co-ordinates of M1 as per the stated convention by entering the values in xset and yset and pressing Enter after each entry. Click on "SET". This will move the stage towards the stated point.

Focus the point by moving the stage along Z axis. Care should be taken to ensure that the mask plate does not hit the lens. One may use knife edge focusing or focus rings. Once the stated co-ordinate is focused, the XY position and the Z height of the focusing point are memorized by pushing the M1 key;

4) The procedure is repeated for other two points, respectively using the M2 and the M3 keys keeping Z height constant. These other two points should be millimeters or centimeters apart from M1, in order to achieve a precise plane definition.

Automatic patterning:

1) At this point the system is ready for the automatic patterning process. Click the >button. This disables part of the commands in the left part of the <START>window, and enables the right part, devoted to patterning. The pattern is shown in the upper window.

2) Select the patterning options (mirror, reverse for bright field) and the exposure level (*gain* only for binary patterns and *gain+bias* for multilevel patterns). Currently, the gain is 24 for lens 4 and 37 for lens 5.

3) Enter a proper D-step and positional speed value (refer to the manual for details). Currently, the D-step used is 4 and the positioning speed is 4 mm/s.

4) Select the autofocus mode (*none, plane, rings*). Currently, we use plane mode.

5) Press <GO> for starting the pattern. Ensure that the correct layer is selected before clicking on ok.

6) While patterning, the "line #" display in the lower part of the screen shows the current scan line of the current strip, and switches to light blue to blue when the beam is on.

7) If you want to make some test exposures, use the "pause" option. This stops the system after each strip, waiting for the "space bar" to be pressed. While the system is in stand-by, the operator can modify the exposure settings.

8) When the pattern is completed, press < to return to the manual section. Decrease Z to -900 um in steps of 100 um and unload the substrate by clicking on the "unload" button. This moves the holder away from lens. Wait for it to stop and then turn off the vacuum pump. Remove the mask plate.

For switching the system off:

i. Close Windows;

ii. Wait until a message appears on the computer display, indicating to turn off the system;

iii. Push the red "emergency stop" button on the system cabinet or the small "0"button in the UPS front panel.

iv. Switch OFF the two supply switches.

Instructions on Alignment (We currently do not use the system for direct wafer writing. This feature is not used)

For Alignment one uses the A and B buttons.

1) After substrate focusing, the substrate is moved to the first of the two *marks* and it is focused with precision.

2) The laser beam is sent on the substrate. The beam intensity level must

be set to the minimum possible to produce some substrate (photoresist) luminescence. To this purpose, maximum video contrast and reduced sample illumination should be used.

3) With small substrate movements, the *laser spot* is precisely positioned on the mark (A) and soon switched off.

4) After clicking the **A** button, related to the x co-ordinate, the operator enters the x position that was assigned to the first mark at design time.

5) After clicking the **A** button related to the y co-ordinate, the operator enters the y position as well.

6) Steps 1) to 5) are repeated for the second mark.

7) At this point the design coordinates and the real ones are memorized, and can be used during the writing process, if the operator decides to use the marks.

After writing, the mask plate should be developed and then etched. Please refer to the following link for development and etching:

(link to be provided)

Refer to the LW405 manual for details. Manuals are available at the following link:

http://www.cen.iitb.ac.in/slotbooking/GLIMPSE/92_GLIMPSE.pdf

The usage of Clewin software is explained in YouTube very well and the links are given below.

https://www.youtube.com/watch?v=2EzB3RS0W80
https://www.youtube.com/watch?v=b0s-1qsFdoM
https://www.youtube.com/watch?v=AHw2vaSnZrc

DEVELOPMENT AND INSPECTION OF THE WRITTEN MASK PLATES

After the writing of mask plates, unload the mask plates from the laser writer. (The humidity should be less than 60% and temperature should be between 19 and 22 degree Celsius for safe operation.)

Develop the mask plate by moving the mask plate in horizontal motion inside the solution tank (MF319) for a minimum of 20 seconds. (Development time will vary as per the mask plate features and concentration of solution).

After development, rinse the mask plate in DI water for 1 minute to ensure that no development solution is remaining.

Development of the mask plate will be always carried out in the yellow room itself as the photoresist on the mask plate is sensitive to light.

Dry the mask plate completely using nitrogen gun and load it again in Laser writer for inspection to check whether the mask plate is completely developed or not. A mask plate is completely developed when there are no resist traces at the exposed areas of the mask plate.

The mask plate can now be inspected. Lens 4 should always be used for inspection. Follow the steps listed in the section “Loading of the Substrate” to load the mask plate. Increase Z from - 900 um to 900 um in steps of 100 um. Move the stage to the CleWin co-ordinates of the pattern to be inspected. Move the Z axis in steps of 1 um until the lens is focused and you can clearly see the pattern. You can measure the pattern size by clicking on “ruler”. If the pattern features are clearly visible with no resist traces, then the mask plate can be etched.

ETCHING OF THE DEVELOPED MASK PLATES

After development, photoresist will be removed from the exposed part and the next layer is iron oxide layer. Etching is used to remove the iron oxide layer to make the exposed region transparent.

We are using iron oxide etchant (Ferrous Chloride aqueous solution with conc. HCL) to etch the mask plate.

Shake the bottle slightly which contains the mask etchant before use and pour it in a petridish. Wash the bottle with hand shower before keeping it back to avoid chemical stains. Rinse the mask plate in the etchant with mask plate tweezer until the iron oxide in the exposed region is completely removed (by observing the color change in the exposed region). Wash the mask plate with DI water and keep it in a petridish filled with DI water (separate petridishes for each mask plate). We can etch a maximum of 6 to 7 mask plates in the same etchant solution.

After removing the iron oxide from the exposed region, rinse the mask plate in acetone to remove the remaining photoresist in the unexposed region for 5 minutes. After that wash the mask plate with IPA for another 1 minute (separate petridishes for each mask plate) to remove acetone traces and to ensure that all the resist traces are removed properly in the unexposed region. Dry the mask plate using a nitrogen gun. The mask plate is ready for lithography.

Preparation of iron oxide etchant

Iron Oxide Mask Etchants are used for etching the exposed iron oxide layer in laser written masks thereby making the exposed area transparent.

To prepare Iron oxide etchant, the basic constituents are

6) Ferrous Chloride in powder form
7) Conc. Hydrochloric acid
8) DI Water

Steps to follow

8) Keep the temperature of heater as 70°C with one beaker of DI water.
9) Powder the Ferrous Chloride chemical from its solid form and filter it to remove all the grains from it.
10) Remove the beaker with DI water from the heater and add Ferrous Chloride powder into it and stir it for 10 minutes.
11) Add conc. Hydrochloric acid in the solution and stir it for another 5 minutes.
12) Transfer the mixture into a bottle.

(For 160g of Ferrous chloride powder, use 350 ml of DI water and 700ml of Conc. Hydrochloric acid)

References

http://www.townetech.com/feo_proc.htm

ONLY FOR SYSTEM OWNER AND OPERATOR

Laser writer baseline test

The baseline test is carried out to determine the variation of resolution of the LW with time. It can also be used to determine whether stitching error correction needs to be conducted. In this case, please refer to the stitching error correction document. It is conducted on lens 4 and lens 5. The baseline test requires preparing a spin coated mask plate detailed below.

Preparation of spin coated mask plate

1) Ensure that you have iron oxide coated mask plate. Positive photoresist will be spun on this plate.
2) Dehydrate the plate by keeping it on a hot plate at 50°C for few minutes.
3) Switch on the 2” spinner in Micro 1 yellow room. Make sure that the vacuum system is working properly.
4) Cover the spinner with aluminium foil from the inside.
5) Remove the wafer chuck and place the mask plate on the flat chuck such that the corner cut is facing down.
6) Please refer to the 2” spinner SOP for details on operating the spinner.
7) The recipe containing the spin speed, acceleration and time is stored in program G of the spinner.
8) Ensure that a test spin is conducted before pouring resist on the mask plate.
9) If the test run is successful, pour S1813 PPR on the mask plate, close the lid and run the spinner.
10) Once the spinning is over, open the lid, remove the mask plate and bake it at 90°C for 3 minutes.
11) Remove the aluminium foil and clean the spinner with acetone to remove resist residues.
12) Put the wafer chuck back on the spinner and close the lid.
13) Turn off the vacuum and the spinner.

Resolution test

The resolution is the smallest feature that can be reliably and reproducibly written on the mask plate. The resolution test is conducted by loading a .cif Clewin file that contains a pattern of squares, circles and lines. The pattern is written on the spin coated mask plate, developed using fresh MF319 developer for 1 minute and then inspected. The resolution is estimated by determining the smallest square that remains a square on the mask plate. The squares that are smaller than this square would appear as circles on the mask plate. The baseline patterns are stored in the following file IDs:

File ID#418: For lens 5
File ID#419: For lens 4

Both files can be written on the same mask plate and then developed. Four copies of the square patterns have been made in the design. The spatial reproducibility can be verified by noting the respective resolutions at all 4 copies of the square patterns. Report the estimated resolution to the process committee.

Stitching error correction

The stitching error causes waviness along the horizontal direction in the pattern. This error is periodic and the period is of the order of the strip width of the lens. This error can be minimized by adjusting the strip width of the lens. The design file contains 45° slanted lines. The error is minimized when the slanted line contains minimum distortion/offset corresponding to a particular strip width. The correction should be performed only when the stitching error is beyond acceptable tolerance limit. The steps required to perform this correction are listed below:

1) Prepare a spin coated mask plate. For more details, please refer to the laser writer baseline test document.
2) Select the Clewin design files used for stitching error correction. The file IDs are: File ID#200: For lens 4
   File ID#305: For lens 5
3) Click on “Setup” in the laser writer menu in LW0.

4) Enter the password 444.
5) Note the field value corresponding to the current strip width. Then vary the field value and note the change in strip width.
6) Prepare a table containing the strip width and corresponding field value. Five sets of readings can be taken.
7) The Clewin design file contains 10 sets of slanted lines. We can utilize 5 sets corresponding to 5 strip width values.
8) For every set to be written, the start strip no. and stop strip no. should be calculated on the basis of the corresponding strip width and set no. Focusing (setting up M1, M2 and M3) should be repeated for every set.
9) Write, develop and inspect the written mask plate and determine the strip width corresponding to minimum stitching error.
10) Update the process committee with your results.