



## Photolithography Procedures for the Argon Laser Writer System

### **SAFETY FIRST**

- The Florod Laser Beam Writer uses a 500mW Argon Ion laser. When operating the laser, use basic laser safety precautions. Laser safety goggles are available next to the system.
- Do not attempt to bypass the safety interlocks on the system. These interlocks are designed to turn the laser off when the stage doors are opened. This will prevent exposure to harmful laser light.
- A cooler fan keeps the laser at an operable temperature, and it should be left on 15 minutes after the laser itself is turned off. In the event that the cooler motor power supply fails, an accessory cord has been adapted to plug the cooler fan into the 220V power supply. IF THE POWER TO THE FAN FAILS, IMMEDIATELY DISCONNECT THE FAN CABLE AND PLUG THE FAN INTO THE 200V POWER SUPPLY WITH THE ACCESSORY CORD. FAILURE TO DO SO WILL RESULT IN PERMANENT DAMAGE TO THE LASER!!
- Photoresist and most of the etchants can be very harmful to your body. Make sure the room is well ventilated. Use proper gloves and ALWAYS use goggles. Check the Materials Safety Data Sheets of the chemicals you use.
- Make sure that you do not mix solvents, acids, and bases.

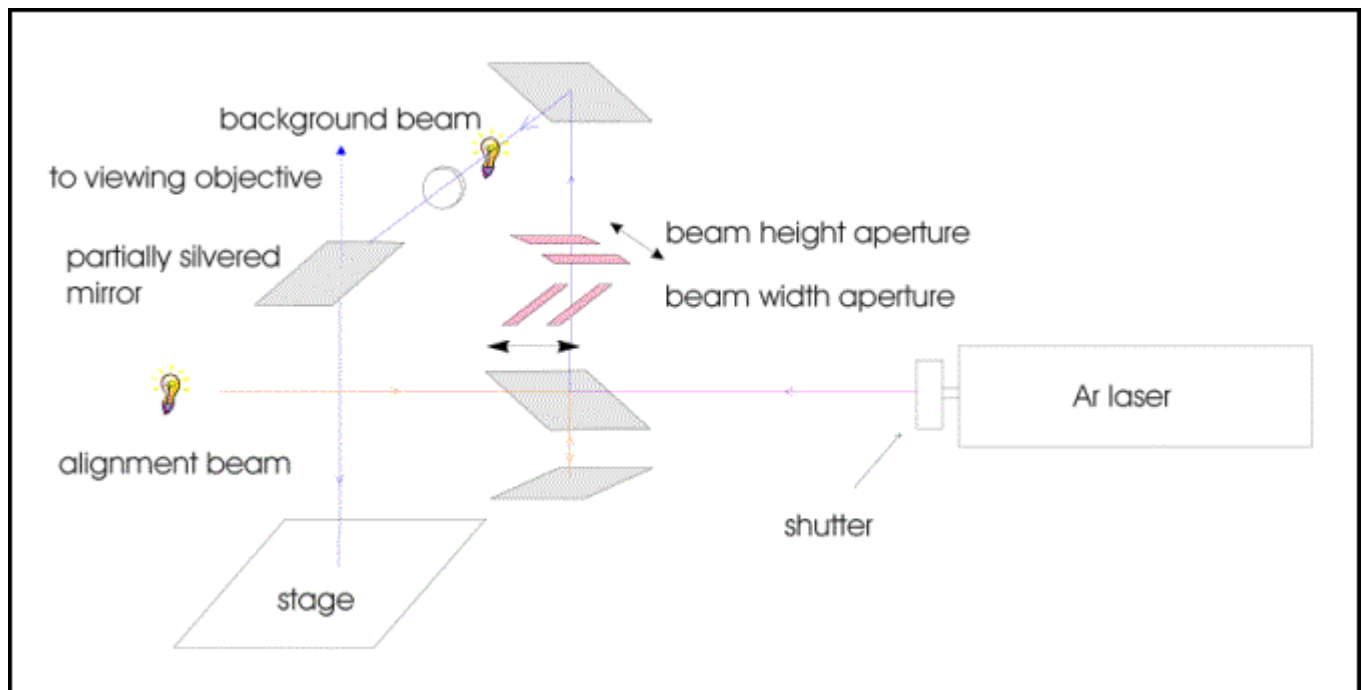
## THEORY OF OPERATION

### Introduction

The physics department at Southwest Texas State University has recently acquired a laser deposition system donated by [Advanced Micro Devices](#). The system works at atmospheric pressure and room temperature. It was originally designed to fix defects in masks and circuits by lasing an organo-metallic substance onto selected areas. The physics department currently uses this laser system to create patterns in PR for photolithography.

The system, designed by Florod™ Corporation, is equipped with an argon laser with nine wavelengths from 454nm to 514nm. A [spectral filter](#) has been put in place so that the exposing wavelength can be chosen. The laser beam is directed by partially silvered mirrors to pass through a variable aperture, collimating lens, then a focusing objective. After passing through the objective, the beam strikes a motorized stage on which the sample is placed. The beam size when using a 50X objective is from 1.7μm to 10μm, from 3μm to 25μm when using a 20X objective, and from 17μm to 100μm using the 5X objective.

The beam power ranges from 100-500mW, and can be controlled in optical or current mode. The sample stage can be controlled by a computer.



## General Operation Procedure

### General Photolithography Procedure

The sample to be patterned is first cleaned in an ultrasonic bath and then spin coated with Shipley S1805 Microposit® 351 PR (abbreviated PR). For spin on of PR, the sample is adhered to a spin on motor with double-sided tape. The spin on motor power supply switch is labeled “Power to Motor”. The power supply has various dials on its face which control the voltage supplied to the motor. This voltage, in turn, controls the spin speed and therefore the thickness of the PR. The voltage must be adjusted for different substrates.

Once the PR is spun on, the sample must be soft baked. This serves to drive out any remaining solvents and helps the PR adhere to the surface. Soft bake is done at 115° C for 60 seconds.

Once the sample is spin coated and soft baked, it is ready for use. For optimal results, the sample should be used within 30 minutes of soft bake.

A laminar flow hood is available for use with the PR spin on motor. It is equipped with a HEPA filter that makes the area under the hood a class 1000 clean area. If possible, all preparation procedures (except for cleaning) should be done under the hood.

### Starting up the Laser Writer System

The laser system is equipped with safety interlocks which prevent unwanted exposure to laser light. On the front of the laser housing is a shutter which opens and closes to allow light to pass through to the stage. When a door or panel to the stage housing is open, the shutter will remain closed. Once the doors and panels are closed, the shutter will be allowed to open.

On the front panel are two power switches – System Power and Laser Power. The System Power should be turned on first, then the Laser Power. Once the Laser Power is on, the cooler fan will be turned on. This cooler fan operates to keep the laser at an operable temperature, and it should be left on 15 minutes after the laser itself is turned off. In the event that the cooler motor power supply fails, an accessory cord has been adapted to plug the cooler fan into the 220V power supply. [IF THE POWER TO THE FAN FAILS, IMMEDIATELY DISCONNECT THE FAN CABLE AND PLUG THE FAN INTO THE 200V POWER SUPPLY WITH THE ACCESSORY CORD. FAILURE TO DO SO WILL RESULT IN PERMANENT DAMAGE TO THE LASER!!](#)

Before turning on the laser, open one of the doors to the stage housing. This will prevent the laser shutter from automatically opening once the laser turns on.

The stage motion is controlled by a program on the computer next to the system. To start the stage control software, double-click the "Laser\_Writer" program icon on the desktop. A library of command files is also available.

[Click here for information on Running the Laser Writer program.](#)

## **Step-by-step Operation Procedures**

### **Application of PR to sample**

A sample size of 3-4cm is optimal. If the sample is too small, the PR will not coat evenly at the edges. Samples bigger than 5cm across tend to fly off during spinning. For the application of PR to the sample, you will need

Shipley S1805 Microposit® PR. Located in RM 181 in the drawer labeled "B Photoresist". Brown bottle with PR is in a cardboard box labeled "PHOTORESIST DO NOT EXPOSE TO LIGHT"

Plastic pipettes, also located in RM 181

Thermolyne 2200 hotplate

Stopwatch

Spin on motor and power supply

Double sided tape

Tweezers

Disposable cloth mask

Method of transferring sample with PR without exposing to light

1. Switch on the Thermolyne 2200 hotplate. Put the knob of the hotplate on 250. This should correspond with approximately 115 Celsius.
2. Clean your sample in an ultrasonic bath.
3. After cleaning, lay your sample directly on the hotplate. Dehydrate your sample on the hotplate for one minute.
4. Attach the sample with double-sided tape on the spinner. Do not use too much tape as than it will be impossible to remove the sample in one piece.
5. Place the plastic cover around the spinner.
6. Switch power supply labeled with an "A" on. If the spinner does not start: switch off the power supply and rotate the spinner by hand over a short distance ( less than one revolution). Switch on the power supply again, and make sure the sample stays attached to the chuck of the spinner. Switch off the spinner.
7. Switch on the yellow light. Open the drawer labeled with a "B". The photo-resist is in a brown bottle. Use the plastic disposable pipettes.
8. Adjust the power supply voltage for your sample. For tungsten, use 4.04V. For aluminum and permalloy (NiFe), use 4.8V. Other substrates must be tested for spin speed. A higher spin speed also results in a thinner PR coat.
9. Apply 3-4 drops of PR to the sample, let the pool of PR spread out for 2 seconds, and

immediately switch on the spinner. While spinning watch the color changes of the sample and close the brown PR bottle. If desired, wear a mask to prevent the inhalation of photoresist fumes. Depending on the kind of sample, color oscillations (red-green-red-green-red-green) can be observed. When the color does not change any more, wait another 20 seconds before switching off the power supply A.

10. Remove the sample carefully from the chuck of the spinner.

11. Place the sample on the hotplate for 60 seconds (soft-bake). After soft bake, allow the sample to cool to room temperature before exposing. (A 3-4cm wide silicon sample takes around 2 or 3 minutes to cool to room temperature.)

## **Exposure of photoresist**

The Laser Beam Writer has three light sources. The laser power can be regulated on the [remote control box](#) (brown panel with laser enable key). The system also has two halogen lamps. Their intensity can be regulated by [two potentiometers](#) on the right side of the microscope. Potentiometer A will regulate the background illumination of the sample so that the sample can be observed through the optical microscope. Potentiometer B regulates the intensity of the light-beam that runs parallel with the laser-beam (alignment beam). Both the laser beam and this halogen beam B are projected on a variable aperture in the back of the LBW. The microscope images this aperture on the sample. Two knobs that are situated just behind the oculars can be used to modify the width and height of the slit and thus the spot size on the sample.

Command files have been provided for basic movements of the laser beam across the sample. Command files are text files with macro commands in them. If you are interested in writing your own command files please refer to the Origin Micro Systems manual.

The positive x direction is defined as movement of the laser beam from right to left across the sample. Through the viewing objective, this will *appear* as movement of the beam from left to right with respect to the sample.

The positive y direction is defined as movement of the laser beam from the front of the sample to the back. The back is defined as the back of the stage housing, farthest from the operator. Through the viewing objective, this will *appear* as movement of the beam from back to front with respect to the sample.

The movement commands provided are named according to the direction the beam will travel across the sample.

An “m” in front of the file name indicates travel in the negative direction.

The last letter of the file name will be either an “m” or a “u”. An “m” indicates the measurement is in millimeters. A “u” indicates the measurement is in microns.

Movement files are available for increments of 1,5,10,50,100, and 500 microns, and

for 1 and 5 millimeters.

For example, "x1u.txt" moves the beam across the sample in the x direction 1micron.

For this procedure, you will need

1. Laser Goggles
2. Tweezers

1. Switch on the computer, switch on the system power, then switch on the laser power. Put the laser in stand-by mode. Push the decrease switch on the remote control panel for 30 seconds, and leave at least one door to the stage housing open.
2. Put on the argon laser goggles. Switch on the laser by rotating the laser-enable key clockwise (past ON). After approximately 40 seconds several clicks can be heard. The argon laser should start. If the argon laser does not start within 2 minutes turn the laser-enable key counter clockwise and inform Dr. Geerts.
3. Set the [filter](#) to approximately 450nm, i.e. the purple line of the argon laser. Make sure that the filter is centered around the purple line by checking the intensity of the transmitted beam.
4. Set the [remote control box](#) of the laser to optical control mode.
5. Set the remote control box to "OPERATE".
6. Increase the laser intensity to 200mW.
7. Place the sample on the XY-stage. Choose an objective:

20X objective		50X objective	
Height setting	Line width( $\mu\text{m}$ )	Height setting	Line width( $\mu\text{m}$ )
		10	1.2
		11	1
10	3	12	1.8
12	4.5	13	1.8
15	8		
		18	2.5
20	8	20	3.2
25	6	25	2.4
30	11	30	4.4
35	11	35	4.4
40	12.5	40	5
45	14	45	5.6
50	17	50	6.8
55	17	55	6.8
60	19.5	60	7.8
65	22	65	8.8
70	23	70	9.2
Development was done for approximately 3min in 1:20 developer.			

20x: for line width of 3-23 micron; 50x: for line width of 2-10 micron

8. Start the LBW software by double clicking the Laser\_Writer icon on the desktop. With this software it is possible to send command files to the electronics of the XY-stage. To

begin, press F5 and enter "laseroff.txt" at the command prompt to close the shutter. then type the macro-file name of the structure you want to write.

NOTE: A speed of more than 20,000 will cause [vibrations in the system and wavy lines](#). As a rule of thumb, stay below 15,000 pulses/sec (0.374 mm/sec) when using a beam height of 15 or lower. Stay below 20,000 pulses/sec (0.5mm/sec) when using a beam height of 30 or lower.

9. Close all the doors. Turn potentiometer A counterclockwise and potentiometer B clockwise. Make sure that the slit width and height are larger than 20 and smaller than 100. Focus the slit on to the sample. The image should be a rectangle or square. If the image is a filament turn the microscope knob counterclockwise until the image becomes a sharp rectangle in the middle of your field of view.

10. Select the beam size by setting the slit height and width. Values over 120 will not result in a larger beam size.

11. Before switching off the system execute the gotozero.txt command.

12. To switch off the laser system, decrease the power to 50 mW, switch to stand-by mode, and turn the laser-enable key on the remote control counter-clockwise to OFF. WAIT for at least 15 minutes before switching off the laser power and the system power switches on the LBW. If you switch off the laser (from the remote control panel), it will not be possible to switch it on again during the same day.

### **Development of Mask**

For the development of the PR we use concentrated NaOH developer that is diluted with boiled, deionized water (does not have to be 18M-ohm) in a ratio of 1:5. A brown bottle is available in the base storage cabinet in RM 181. For the following procedures, you will need:

- Two Pyrex petri dishes
- Tweezers
- One 300mL beaker
- Deionized water
- Diluted developer
- Stopwatch

1. Pour 40mL of diluted developer into a Pyrex petri dish. If a petri dish is not available, use a 100mL beaker instead. Close the bottle as the developer will react with the carbon dioxide in the air and lose its development power.
2. Depending on the size of the features to be developed, development will take from 2 to 4 minutes. *For NiFe features, development time is 1 minute.* The smaller the feature, the longer the development time. However, the remaining PR will not be affected if the sample is left in the developer longer. Eventually, the PR will be eaten away by the developer, but this may take hours. If you are unsure how long to develop your sample,

start by developing for 3 minutes. You can always develop longer if needed.  
3. Dip the sample in the beaker of deionized water. Check the pattern under an optical microscope. Make sure you use yellow illumination.

### **Etching of metallic thin films**

For the etching of your thin film, you will need:

One Pyrex petri dish or one 100mL beaker  
Tweezers  
Stopwatch  
Etchant. See instructions below.  
One 300mL beaker  
Deionized water

1. Begin by choosing which etchant to use. The etchants are located in the acids cabinet in RM 181. Etchants for copper, aluminum, and NiFe are available.
2. Pour 50mL of etchant into Pyrex petri dish.
3. Place sample into etchant and begin stopwatch.
4. For copper etching, leave sample in dish for 2 minutes.
5. For aluminum and NiFe etching, leave sample in dish for 5 minutes.
6. Rinse sample in beaker of deionized water. Examine under optical microscope.

### **Removal of remaining photoresist**

This step is done when the photoresist mask is no longer needed for patterning your thin film.

For this procedure you will need:

Acetone squirt bottle  
Tweezers  
100mL beaker

With the tweezers, hold your sample over the beaker and squirt the acetone onto the sample surface until all remaining photoresist is gone. If the photoresist has been severely baked (115° C for 2 or more minutes), it may be hard or impossible to remove all of the photoresist.

### **Disposal of acids, bases, and solvents**

Plastic pipettes should be discarded into the trash can.



There are three disposal containers in the fume hood in RM 181. They are labeled ACID, BASE, and SOLVENT. Dispose of all left over materials in the proper containers. If you are unsure of the pH of a chemical, use a piece of litmus paper to test the pH level before disposing.

When washing glassware in the sink, leave the faucet running for 20 minutes to wash remaining chemicals down the drain.