NanoFab’s General Overview of Making a Mask on the Pattern Generator

Creating a mask on the DWL 200 Pattern Generator is typically the first step to start fabricating at the NanoFab. A mask is a physical 5” X 5” piece of glass that has a chrome pattern on it. This mask then transfers the pattern onto other substrates like a negative is used to transfers an image on a photograph. The following general overview will discuss designing and fabricating a mask.

- **Determining the Process**
- **Wafer Layout**
- **Wafer Design**
- **Requirements**
- **Heidelberg Compiling**
- **Printing**
- **Developing**
- **Cleaning**
Designing a Mask

Determining the Process

The first step in making a mask is determining what you are going to do. This may sound straightforward, but there are many things to take into consideration. You need to know what machines, substrates and chemicals will be needed, the geometry and layout of your device, and the limitations. The limitations can be whether or not the NanoFab has the machines, materials, recipes, or protocols that you need. These limitations can be very important or they can be insignificant. It is a good idea to show our Director, Ken Westra, or our Training Coordinator, Stephanie Bozic, your overall process flow so that some of the obvious limitations can be discussed before you start your project when it may be easier to fix.

Wafer Layout

When creating your CAD design, the layout of your devices on the mask is important.

- Know what type and size of substrate you are planning to use and design your pattern for that substrate size.
- Also, know if your substrate (i.e. Si) has a crystal structure that can only be diced or scribed in certain directions. This limitation will make substrate layout much more important.
- Make sure that your design is centered and that the outer 2 – 4 mm of your substrate is avoided.
- If you have devices under 1 cm across, arrange your mask with a grid of cells, where each cell contains your devices as shown in Fig. 1.
- For other important design considerations, please read the Pattern Generator Considerations document that follows.

Figure 1. Arranging your devices into a grid of cells can make designing, testing, and dicing much easier.
**Wafer Design**

The NanoFab uses and supports the L-EDIT CAD program by MEMSPro. Other CAD programs may work, however, we will only support problems that occur within L-EDIT.

- In L-EDIT, simple shapes such as squares and circles are combined to create more complex shapes such as the final device design.
- L-EDIT also allows hierarchal design. This allows you to create a simple design in a Cell1, and Cell 1 can be “Instanced” or placed in Cell2 and/or Cell 100, as long as the cell is higher on the design ladder. This is beneficial because if you change that initial design in Cell1, those changes will be made to all the cells that Cell1 was “Instanced” or placed in.
- Please read the Pattern Generator Considerations document before designing a mask for some important tips.

**Requirements**

Before you will be placed on the queue for the pattern generator you must have two things:

- The Optical Mask Information Form
  - This form will document all the parameters that should be known before writing a mask such as:
    - The minimum feature size.
    - The final cell title and the GDSii Layer number.
    - Whether the design is to be inverted (positive) or noninverted (negative).
    - Whether the design is to be RRCU or RRCD.
    - If this form is not completely filled out, you will not be placed in the queue.
    - Your design must be converted on the Linux computer before it will be placed on the queue.
      - Exception: The NanoFab will convert designs for out-of-town users.
  
- Authorization
  - Authorization must be given by your supervisor before the mask is placed on the queue to be written.
    - One time authorization is given when your supervisor signs the Optical Mask Information Form in the appropriate place.
    - If your supervisor fills out the Full Authorization form, you can check the full authorization box on the Mask Information Form, instead of getting your supervisors signature every time. Full Authorization Form available at [www.nanofab.ualberta.ca/forms.htm](http://www.nanofab.ualberta.ca/forms.htm)
- There is a different Authorization form for Academic and Industrial users.

**Feature Size**

It is important to remember that while you may design a feature to be 10 um, it is almost never going to end up to be 10 um on the final mask (usually around +/- 0.7 um). This is because of the isotropic chemistry that occurs during developing and etching. These means that a chrome line that was patterned to be 4 um wide will most likely be 3.3 um wide. You can increase/decrease the width to get close to the feature sizes you are looking for.
Fabricating a Mask

Heidelberg Compiling

With the design complete, the GDSii file can be converted and compiled into LIC files that enable the DWL 200 to control laser movement. The conversion is done on a Linux computer on an interface that allows you to recheck your design and choose whether you want a positive/negative mask, or whether you want a RRCU/RRCD mask. The LIC files are then transferred from the Linux computer onto the DWL 200 computer.

Printing

A NanoFab staff member will write your masks for you. This enables a more efficient use of the system and laser and is useful if users are from out-of-town and they wish to ensure that their masks are ready before coming down.

The Heidelberg DWL 200 Direct Write Laser System:

- Is a highly precise, accurate, and resolved instrument.
- Uses a Krypton-Ion laser to expose at a wavelength of 413nm.
- Writes patterns by raster scanning the blank mask plate.
- Uses acoustic-optic deflectors to sweep 4 laser beams over the surface of the mask blank, decreasing the write time significantly.
- Optimizes the design, which enables the DWL 200 to skip over areas that do not need to be written to save additional time.
- Can attain a minimum feature size of 0.7 – 0.8\(\mu\)m, depending on the geometry of the feature. The NanoFab calibrates the DWL 200 to 1\(\mu\)m lines.

Developing

Once the mask blank has been exposed by the Krypton-Ion laser, the exposed photoresist will be chemically altered so that when it is agitated in a developer, that photoresist will be washed away as shown in Fig 2 b). This will reveal the pattern that was designed in the CAD program. It is very important to pay attention when developing features under 5 um because the developer is isotropic and will undercut these features. If the mask is overdeveloped, the small features may be washed away or their critical dimension may be significantly altered. To prevent this, the small features are developed for 20 seconds, and then inspected. If they are not fully developed, they are develop for another 5 - 10 seconds, inspected, and this is repeat until the user is satisfied.
**Etching**

After developing, the mask blank will have both exposed chrome and photoresist on it. The photoresist acts like a protective layer so that when the mask is placed in some chrome etch, only the exposed chrome is removed as shown in Fig. 2 c). Again, it is important to pay attention while etching features under 5 um because the etchant is isotropic and may undercut these features. If the mask is overetched the features may be washed away or the critical dimension may be altered significantly. Remember a mask can always be etched some more if it is underetched, but overetching cannot be undone. Inspection is critical to ensure that all the chrome has been removed.

**Cleaning**

Once the developing and etching is finished, the mask must be properly cleaned before it is used in traditional lithography. The mask should be inspected properly and then the photoresist is stripped using acetone and IPA. A great deal of photoresist residue will remain on the mask so it must be properly cleaned in a cold piranha bath, as shown in Fig. 2 c).

![Diagram showing the stages of mask processing](image)

Figure 2. a) A mask blank that has been exposed. b) After developing the exposed regions are washed away. c) After etching, the exposed chrome is removed. D) After cleaning all the photoresist is removed.

- Photoresist
- Chrome
- Glass