The George Washington University
WASHINGTON DC

SEAS
School of Engineering and Applied Science

DESIGN & ANALYSIS OF A CANTILEVER BY USING INTELLISUITE

by ONUR TIGLI

Basic Design Steps:

I-DESIGN PROCEDURE

- Draw the masks using the *Mask Editor*
- Using *IntelliFab* to define the fabrication steps and the technology to be used for fabricating the device.
- Simulate and visualize the structure that is being designed.

II-ANALYSIS PROCEDURE

- Realize the structure and mesh by using *3D Builder*.
- Refine the mesh according to the analysis purposes and run the analysis in any of the analysis modules. (ESAnalysis, EMAnalysis, MEAnalysis)

I-DESIGN PROCEDURE

The Mask Editor of Intellisuite, is designed to be used for drawing the masks of MEMS structures. This Editor is mainly composed of tools that can be used for drawing and editing structures such as rectangles, polygons, arcs etc. Most of the Intellisuite's subprograms are usually used by other subprograms. For instance Intellifab supports access to the Mask Editor while editing the layouts for definition layers. There is no rigid procedure that you have to obey. For the time being we leave the Mask Editor aside and skip to IntelliFab.

IntelliFab:

IntelliFab allows you to construct 3D models directly from the process steps and then export them to the analysis modules. In the IntelliFab window there are two main sections. The one on the left is the selection area. This area displays all available process steps. The blue dashed area on the right of the window is the process area, where you build your process flow (MUMPS in our case)from the selection area.

First of all we have to define all fabrication steps so as to satisfy our requirements. From *File* choose *Open Database*. The standard database is matfab, located in the IntelliDB directory. After opening the database you will see four main bodies under which you can find (by double clicking on them) the main MEMS fabrication steps and structures. These bodies are namely, Deposition, Etch, Bonding, Definition.

Deposition: Contains all the operations to deposit thin films on a substrate.
Etch: Contains all operations that remove films from the substrate.
Bonding: Contains the processes, which are used to join independently fabricated components.
Definition: Contains all the operations that define the device. We will be using the interaction of this module with Mask Editor to define our structure.!! IntelliFab uses only *.msk files to define the structure. So make sure that your mask files are in this form.!!

First of all we have to define our wafer on which we will build the cantilever structure.

Click *Definition...Si...Czochralski.*

Double Click on *100* to open *Process Dialog Window.*

Click Apply Changes to add this step to our process table.

Since we defined our wafer we are now ready to deposit the layers. (i.e. describe the remaining steps of the MUMPS process). If you look at the MUMPS process table you can see that there are 7 layers being used in general. However we will only need 4 of those layers for our basic cantilever structure. Our cantilever is composed of two polysilicon layers and a nitride layer which is deposited for electrical isolation purposes. According to the MUMPS steps, we now have to deposit the nitride layer.

Click *Deposition...Si3N4...LPCVD*

Double Click on *Generic*

Now change the film thickness to 600nm, as it is specified by MUMPS.

Click *Apply changes* .

After the nitride layer is defined, the next step is to deposit the poly 0. We want our cantilever to be composed of the poly0 and poly1 for presenting both of these steps. Basically our structure will look something like the one in Figure 1.

Click *Deposition...PolySi...LPCVD*

Double Click on *Standard*

Now change the film thickness to 500nm, as it is specified by MUMPS.

Click *Apply changes* .

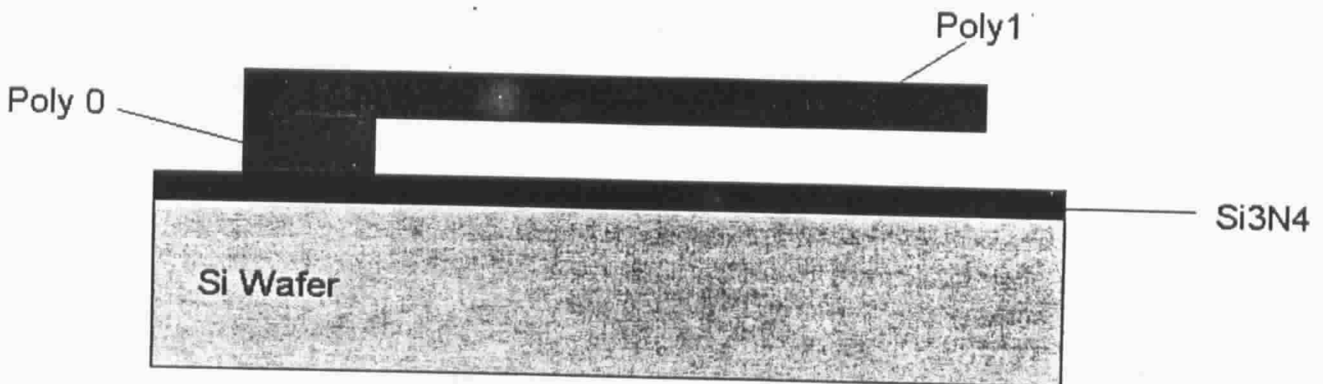

Figure 1. The basic cantilever structure designed in MUMPS technology.

After depositing the poly0 layer we have to define the structure.

Click *Definition…UV…Contact*

Double Click on *Suss*

This will bring us to a window where we will draw the layout. Now

Double Click on *Layout*

This will open the *Mask Editor*. Now we will draw the poly0 mask. It is basically a rectangle lying within the dimensions of our wafer. After drawing this mask save it as Mask1.msk. Then close the Mask Editor window. Now change the mask number to 1 by double clicking on the mask number option. Double Click on Apply changes and close the dialog window. Now we have to etch the poly0 layer and obtain the basement post that the cantilever beam will be grown over.

Click *Etch…PolySi…RIE*

Double Click on *RIE*

Click *Apply changes*

Now that we had defined our poly0 structure, we can go on with the deposition of the 1st oxide layer, which is the next step in the MUMPS process.

Click *Deposition...PSGSacr...Generic*

Double Click on *Generic*

Click *Apply changes* .

Note that we are using this oxide layer as a sacrificial layer (i.e. it will be etched out later in the process according to our structure's masks. That is why we had chosen PSGSacr as our oxide layer instead of Si02. Besides, this is the oxide layer defined by the MUMPS process.

Click *Definition...UV...Contact*

Double Click on *Suss*

This will again bring a window for drawing the mask. Since we want a contact between the poly0 and the poly1 layers, we need to remove the oxide and make an opening at the top of the poly0 layer. To achieve this, we use the same mask, namely Mask1. But there is a difference in the orientation of the mask used. For photolithographic processes we use photoresists to define our structures. So the masks that we are drawing can either leave the photoresist outside the mask or inside the mask. See Figure 2,3 & 4 for the visualization of the photolithographic process.

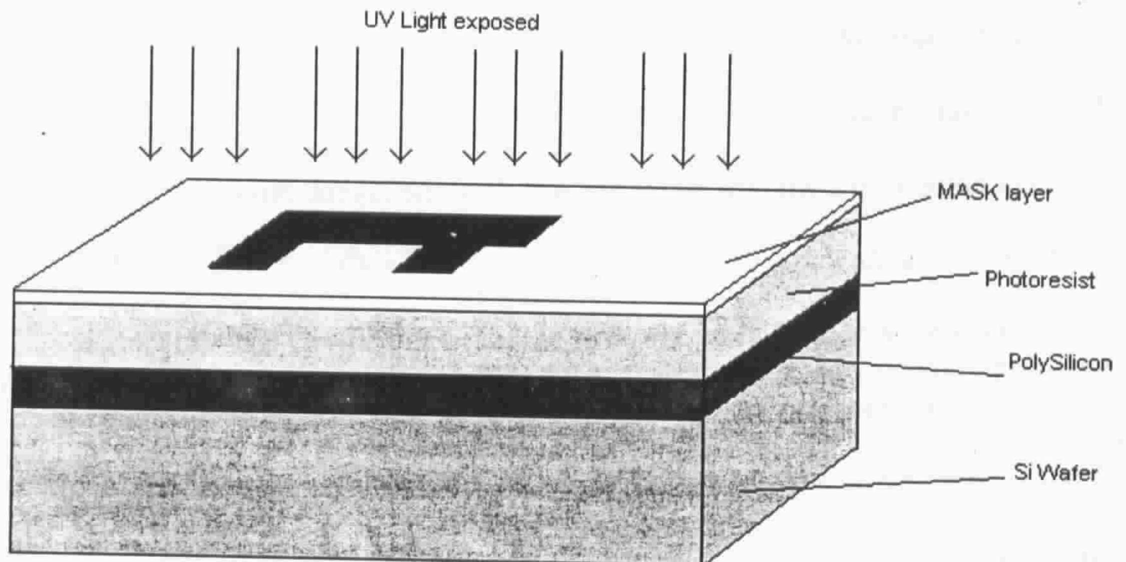

Figure 2: The photolithography used to shape the photoresist. Note that we can either leave the photoresist inside the black region or outside the black region depending on the application.

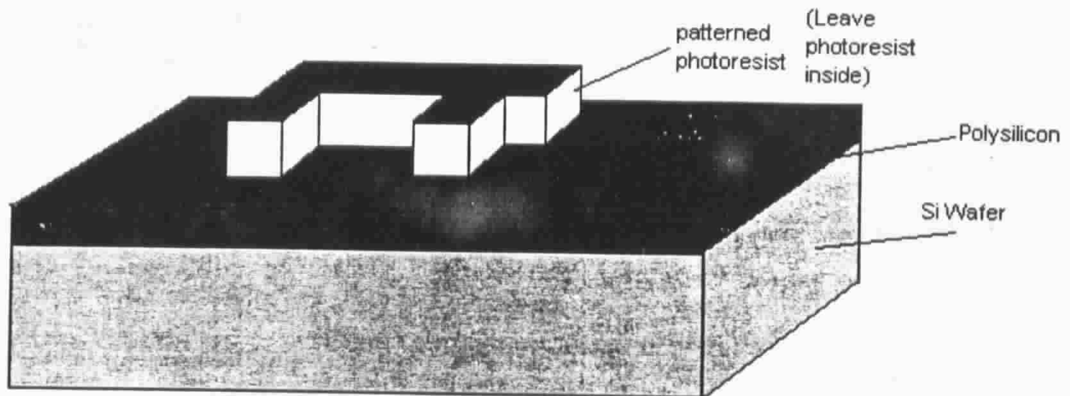

Figure 3: The patterned photoresist with the leave photoresist inside the mask option selected.

Click on the photoresist orientation pull down menu and change it from the default inside to outside. Now that we have defined our oxide layer, next step is to etch the oxide and make the opening for poly0-poly1 contact.

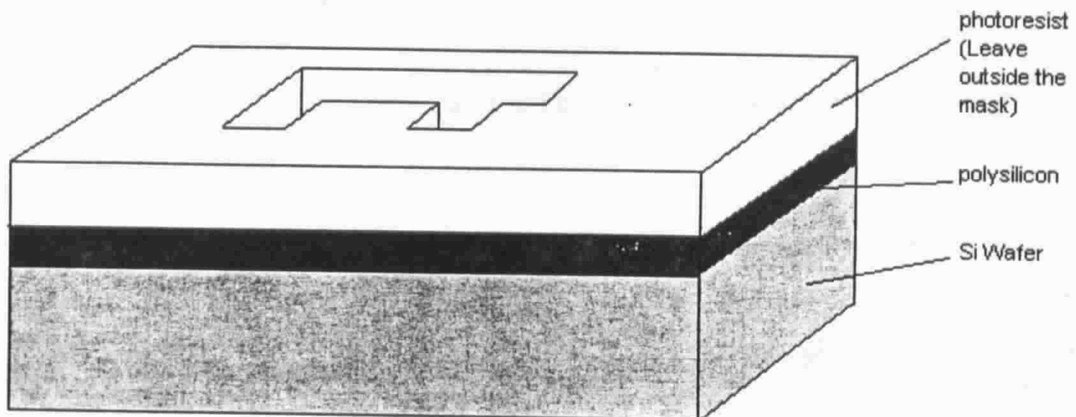

Figure 4: The patterned photoresist with the leave photoresist outside the mask option selected.

Click *Etch…PSGSacr…Generic*

Double Click on *Generic*

Click *Apply changes* .

So far, we have defined four layers in the same manner. While you are working with IntelliFab, there are three basic operations you frequently use. The idea holds for every layer with some slight differences in defining the photoresist and sacrificial layers. The common steps to be carried out for every layer is as follows;

1. Deposition of the material (Si02, Poly, Al..)
2. Definition by UV Contact Suss –mask definition.
3. Etch the material.

Use the same steps we had used for poly0 and add the fabrication steps for poly1 to your fabrication file. After you are finished with this, the only thing remains is to remove the sacrificial oxide layer so as to have the beam suspended in the air. For this step,

Click *Etch…PSGSacr…Generic*

Double Click on *Generic*

Note that we have to change the setting for the etching process at this point. By default it is set to be partial etching, which in fact is the one we had been using so far to etch the last structure deposited according to the mask input. This time we want to sacrifice the oxide layer, so change it to sacrificial etching and click on apply changes.

After all these steps the final fabrication steps window should look like the one in Figure 5.

Now, we can see how the structure we had built looks like.

Click on *Construct…Visualize*

The computer will ask you to save your file with an extension of *.fab.

After that it will run the process for you and will pop up a dialog window in which you will see the structure you had built. Note that on the right side of this dialog window there are various view options. (Start, Last…etc) You can use these to simulate each step and visualize your cantilever. You can rotate the structure by dragging the mouse in the window. The dialog window with the final picture of the cantilever will look like the one in Figure 6.

Figure 5: The snapshot of the IntelliFab screen with the completed fabrication steps of the cantilever using MUMPS technology.