MEM’s Computer Aided Design

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Microelectromechanical Systems
The basic unit of distance in a scalable set of design rules is called Lambda, $\lambda$
For the current MEMS process $\lambda$ is ten microns (10 $\mu$m)
The process has eight mask layers, they are:

- P+ Diffusion (Green)(layer 1)
- N+ Diffusion (Yellow)(layer 6)
- Poly Resistor (Red)(layer 2)
- Contact (Gray)(layer 3)
- Metal (Blue)(layer 4)
- Diaphragm (Purple) (layer 5)
- Top Via (White)(layer 7)
DESIGN RULES

Construction Line and module layers are not mask layers but aid in layout. The module layer should be used to define the 4mm x 4mm work space. The construction line layer might be used to show the size of the diaphragm which is smaller than the diaphragm opening on the back of the wafer.

Minimum pad size for probing 100 µm by 100 µm
Minimum pad size for wire connections 1000 µm by 1000 µm
All probe pads have metal top layer.

10 µm by 10 µm box needed in four corners of 4000 µm by 4000 µm work space. (for maskmaking accuracy)

Put lettering in Poly Layer
LAYOUT RULES

Perfect Overlay
Slight Overlay
Not Fatal
Misalignment
Fatal

Layout rules prevent slight misalignment from being fatal. Also, rules help make device performance consistent (minimum width for resistor will make values more consistent)
RULES FOR DIFFUSION LAYER

Level 1 – Design Layer 1 - Diffusion 1 (green)

Rule 1.1 Minimum Width
\[ W_d = 2\lambda \]

Rule 1.2 Minimum Spacing
\[ S_{dd} = 2\lambda \]

Rule 1.3 Extension beyond Contact cut
\[ E_{dc} = 2\lambda \]
RULES FOR DIFFUSION LAYER

Level 6 – Design Layer 6 – N+ Diffusion (Yellow)

Rule 1.1 Minimum Width
\[ W_d = 2\lambda \]

Rule 1.2 Minimum Spacing
\[ S_{dd} = 2\lambda \]

Rule 1.3 Extension beyond Contact cut
\[ E_{dc} = 2\lambda \]

\[ W_d = 2\lambda \quad (20 \, \mu m) \]
\[ S_{dd} = 2\lambda \quad (20 \, \mu m) \]

10 by 10 µm
Level 2 – Design Layer 2 - Poly (Red)

Rule 2.1 Minimum Width
\[ W_p = 2 \lambda \]

Rule 2.2 Minimum Spacing
\[ S_{pp} = 2 \lambda \]

Rule 2.3 Extension beyond Contact Cut
\[ E_{pc} = 2 \lambda \]

\[ W_p = 2 \lambda \quad (20 \, \mu m) \]

\[ S_{pp} = 2 \lambda \quad (20 \, \mu m) \]
RULES FOR CONTACT CUT

Level 3 – Design Layer 3 – Contact Cut (Gray)

Rule 3.1 Minimum Width
\[ W_c = 2 \lambda \]

Rule 3.2 Minimum Spacing
\[ S_{cc} = 2 \lambda \]

10 by 10 µm
RULES FOR METAL

Level 4 – Design Layer 4 - Metal (Blue)

Rule 4.1 Minimum Width
\[ W_m = 2 \lambda \]

Rule 4.2 Minimum Spacing
\[ S_{mm} = 2 \lambda \]

Rule 4.3 Extension of Metal Beyond Contact Cut
\[ E_{mc} = 2 \lambda \]

- \[ W_m = 2 \lambda \quad (20 \mu m) \]
- \[ S_{mm} = 2 \lambda \quad (20 \mu m) \]

10 by 10 \( \mu \)m
RULES FOR DIAPHRAGM

Level 6 – Design Layer 6 – Diaphragm (purple)

Rule 6.1 Minimum Width
\[ Wh = 100 \lambda \]

Rule 6.2 Minimum Spacing
\[ Shh = 10 \lambda \]

10 by 10 µm
RULES FOR TOP VIA

Level 7 – Design Layer 7 – Top Via (White)

Rule 7.1 Minimum Width
\[ W_v = 2 \lambda \]

Rule 7.2 Minimum Spacing
\[ S_{vv} = 2 \lambda \]

Rule 7.3 Minimum Extension of Metal beyond Top Via
\[ E_{mv} = 2 \lambda \]

\[ W_v = 2 \lambda \quad (20 \mu m) \]
\[ S_{vv} = 2 \lambda \quad (20 \mu m) \]

10 by 10 \( \mu m \)
RULES FOR THE POLY, METAL AND CONTACT CUT

Overlay (Extension)

Rule 2.3 Minimum Extension of poly beyond contact cut
   \( E_{pc} = 2 \lambda \)

Rule 4.3 Minimum Extension of Metal beyond contact cut
   \( E_{mc} = 2 \lambda \)

Rule 7.3 Minimum Extension of Metal beyond Top Via
   \( E_{mv} = 2 \lambda \)
Total 20 mm by 20 mm for 20 student projects

4mm by 4mm Design Space for Each Project
POSSIBLE DEVICES

Thermally actuated bimetallic micro-pump
Thermally actuated bimetallic micro-pump with resistors for sensing and feedback
Pressure Sensor, diffused resistors or poly resistors
Thermocouples on diaphragm with built-in heater
Heater on diaphragm either poly or diffused resistor heater
Heater plus temperature sensor (diffused heater, poly resistor sensor)
Heater plus interdigitated chemical sensor
Gas flow sensor single resistor anemometer
Gas flow sensor with heater and two resistors
PN junction temperature sensors
Transistors and logic
RF Inductors
1 P+ Diffused Layer (110 Ohm/sq)
1 N+ Layer (50 Ohm/sq)
1 N-Poly layer (40 Ohm/sq)
1 metal layer (Al 1µm thick)
Top Passivation and Via
20-30 µm Si diaphragm
20082 TEMPTATIVE BULK MEMS PROCESS FLOW

1. Obtain qty 10, 4” n-type wafers
2. Wafer grind to 300um
3. Polish back side
4. CMP Clean
5. RCA Clean
6. Grow masking oxide 5000 Å, Recipe 350
7. Photo 1: P+ diffusion
8. Etch Oxide, 12 min, Rinse, SRD
9. Strip Resist
10. Spin-on Glass, Borofilm 100, include dummy
11. Dopant Diffusion Recipe 110
12. Etch SOG and Masking Oxide, 20min BOE
13. Four Point Probe Dummy Wafer
14. RCA Clean
15. 500Å Pad Ox - recipe 250
16. Deposit 1500Å Nitride
17. Coat back of wafer and protect edge
18. Plasma Etch Nitride on front of wafer, Lam-490
19. Strip backside resist
20. Remove pad oxide - 1min BOE
21. RCA Clean
22. Grow 5,000Å of oxide - recipe 350
23. Photo 6: N+ diffusion
24. Etch oxide
25. N+ SOG
26. Strip resist, RCA clean
27. N+ drive -in
28. Photo 2: Backside Diaphragm
29. Coat front of wafer and protect edge
30. Etch oxynitride, 1 min 10:1HF
31. Plasma Etch Nitride on back of wafer, Lam-490
32. 1.5min 10:1 HF to remove Pad ox
33. Remove resist - solvent strip 5min + 5min rinse
34. RCA Clean
35. Deposit 6000Å Poly LPCVD
36. Spin on Glass, N-250
37. Poly Diffusion, Recipe 120
38. Etch SOG
39. 4 pt Probe
40. Photo 3, Poly
41. Etch poly, LAM490
42. Strip resist
43. RCA Clean
44. Oxidize Poly Recipe 250
45. Deposit 8,000Å TEOS or LTO Oxide
46. Photo 4, Contact Cut
47. Etch Oxide in BOE, Rinse, SRD
48. Strip Resist
49. RCA Clean, include extra HF step
50. Deposit Aluminum, 10,000Å
51. Photo 5, Metal
52. Etch Aluminum, Wet Etch
53. Strip Resist
54. Deposit 10,000Å LTO Oxide Passivation-Protek Adhesion
55. Photo 6, Via
56. Via etch - pad etch 8 min
57. Ash resist
58. Spin coat PROTEK on front of wafer
59. Etch Diaphragm in KOH, ~4 hours
60. Strip PROTEK
61. Test
Individual Student Designs are sent to a dropbox to be combined with other designs.

Click:
File/Cell/Save/as:
/shared/0305-870/your_name_design

Example:
/shared/0305-870/lynn_fuller_mirror
Usually the workstation screen will be blank, press any key to view a login window.
   Login: -------
   Password: -------
The screen background will change and the control panel will appear. Click the left mouse button on the terminal icon. A window will appear that says hp term on the top and has a unix prompt inside. Type the command `ls` at the prompt to see a list of directories and files, the account should be empty. Typing `yppasswd` will allow you to change your password if you want to.

Type `ic <RET>`, it will take 20-30 seconds, then maximize the IC Station window by clicking the left mouse button on the large square in the upper right corner of the IC Station window.
In the session menu palette on the right hand side of the screen, under Cell, select Create, using the lift mouse button. For cell name type device# (the # assigned to you, no space). Also set the process to the mems_bulk process by typing /tools/ritpub/process/mems_bulk_073 in the process field and click on return OK. In the gray area under the banner at the top of the screen, the process should now read mems_bulk. Select other>show layer palette, click/drag on layers 1 to 6 then press select. Layers colors and shading should appear in upper right corner.

A large window with a black background and white dots should appear. We can now check the grid settings. In the top banner choose Other > Window > Set Grid. Set the Snap to 10 for both x and y, minor=1, major=10, then click on OK.

The cursor position is given at the top center of the window. The layer being used and the number of items selected is shown at the top right. The 12 gray buttons which correspond to the F1-F8 and 4 white buttons allow multiple functions. For example push F2 to (Unselect All). To get the next function listed below that (Unselect Area) push shift and F2. To get the function listed on the bottom for the F2 key (Move) press the CTRL key and the F2 key.
Select easy edit, Select Shape, Select Options and see the layer names, colors and shading pattern. Draw boxes by click and drag of mouse. Unselect by pressing F2 function key. The Notch command is useful to change the size of a selected box or merge rectangular shapes into more complex objects. The following command will draw a 3000 µm by 3000 µm box with level 5 color/shading. $add_shape([[0,0],[3000,3000]],5)

Draw circles by typing $set_location_mode(@arc) return. The following command will draw a 100µm radius circle centered at (0,0) using 300 straight line segments. To reset to rectangles type $set_location_mode(@line) return.

Select objects by clicking or by click and drag. Selected objects will appear to have a bright outline. Selected objects can be moved (Move), copied (Copy), deleted (Del) or notched (Notc). To unselect objects press F2.
USING THE HP WORKSTATIONS AND MENTOR GRAPHICS CAD Tools - Other

**ZOOM IN OUT:** pressing the + or - sign on right key pad will zoom in or out. Also pressing shift + F8 will zoom so that all objects are in the view area. Select View and Area on top banner then click and drag a rectangle will zoom so that the objects in the rectangle are in the view area.

**MOVING VIEW CENTER:** pressing the middle mouse button will center the view around the pointer.

**LASER PRINT OUTPUT:** Select File and Print, OK. This gives a laser printer output of entire cell. Select printer mgcprec2, clear width, len, pages, scale by using backspace so nothing is in those boxes. Say OK.

**PRINT PART OF LAYOUT:** first create a panel. Under objects, select add a panel, name it and click on rectangle symbol. Then use the left mouse button to drag a rectangle around the objects you want in the panel to be printed. Then select File and Print and enter panel name, click on print set up, printer is mgcprec2, clear width, len, pages, scale by using backspace so nothing is in those boxes. Say OK.
ADDING TEXT: Type $add_device(“$pgtext”) after entering text and placing the object on the layout it can be scaled by selecting objects>scale…

CHANGING SIZE OF TEXT: Bring in the ritpmos_12_pads as indicated above. Scale can be set to some number before the cell is flattened. Try 3 to make letters 100 um high.

SETTING CELL ORIGIN: under CONTEXT
COPY A CELL FROM A STUDENTS ACCOUNT TO COURSE DROPBOX:
Individual Student Designs are sent to a dropbox to be combined with other designs. Click: File/Cell/Save/as: /shared/0305-870/your_name_design

Example: /shared/0305-870/lynn_fuller_mirror

GRAB A PLOT IN TIFF FORMAT TO PUT IN POWERPOINT, ETC.: Open a second unix window while viewing the chip layout (or any other display) in another window. Type xv, select option to grab and set pause to ~5 seconds, save to hp account as .tiff file. You will have ~5 seconds to bring up what you want to grab. Log on to hp account from your pc and use FTP software to copy the file to your pc.
REFERENCES

1. Sketch the layout of a torsional mirror that can tip in two directions.
2. Sketch the layout of a metal inductor.