Surface MEMS Project

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9-12-2014 SurfaceMEMsProject.ppt

OUTLINE

Introduction
List of Possible MEMS Devices
Key Equations
Device Cross Section
MEMS Switch Example
MEMS Mirror Example
Design Rules
Packaging
Mentor Graphics Instructions
Maskmaking
Stepper Jobs
Fabrication Details
Signal Processing
Testing
Summary
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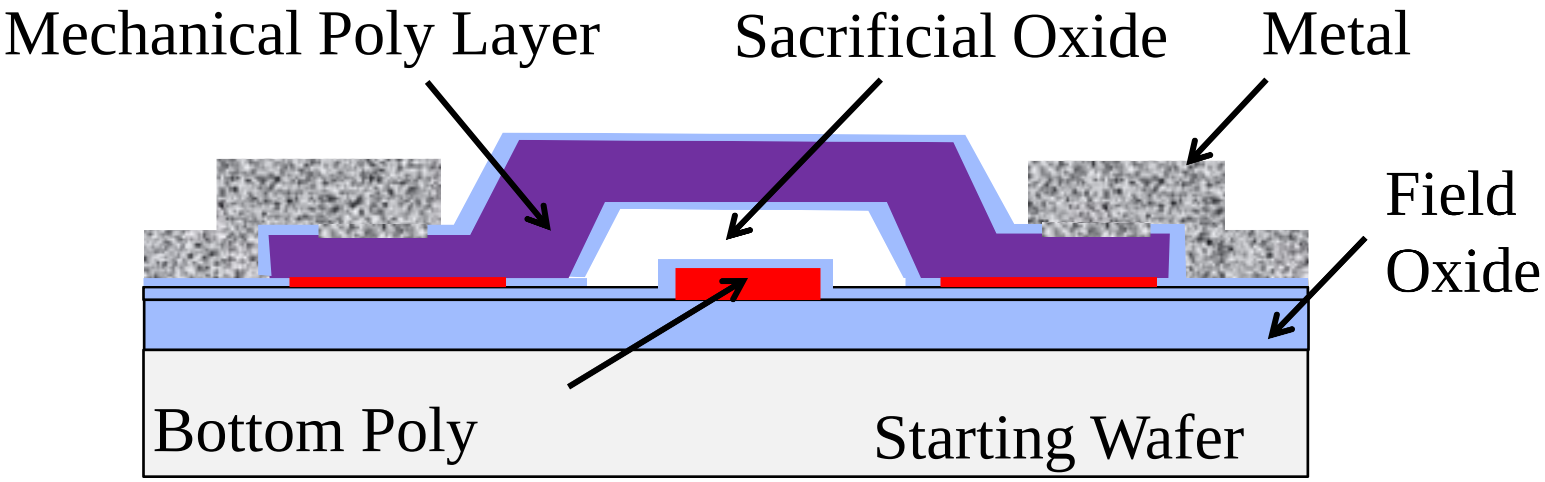
INTRODUCTION

This document provides detailed information on RIT's surface micromachine process. This process is capable of making many different types of MEMS devices. This MEMS fabrication process is CMOS compatible (with some modifications) back end module that can be added to realize compact microsystems (CMOS plus MEMS).

LIST OF MEMS DEVICES MADE WITH THIS PROCESS

Resistors – Micro Bolometer
Heaters – Chemical Sensors
Micro Mirror - Two Axis Mirror
Thermally Actuated Two Arm Cantilever
Chevron Actuators
Electrostatic Comb Drive
MEMS Switch
Accelerometer
Gas Flow Sensor, Anemometer, Thermionic
Light Modulator
Bio Probes
Speaker
Humidity Sensors
Pressure Sensors - Microphone
Temperature Sensors – Thermopile, Resistor
Inductors, Capacitors – Humidity Sensor
Hall Effect Sensors – other Magnetic Field Sensors

DEVICE CROSS SECTION



- Bottom Poly 1 (Red) Layer 1 🟥
- Sacrificial Oxide (Blue Outline) Layer 2 ▨
- Anchor (Green) Layer 3 🟩
- Mechanical Poly 2 (Purple) Layer 4 🟪
- Contact Cut (White) Layer 6 ⬜
- Metal (Blue) Layer 7 🟦
- Outline (Yellow Outline) Layer 9 □
- No Implant Yellow Layer 15 🟨
- Holes Layer 16 (combined with Poly 2)

KEY EQUATIONS

Cantilever Deflection - Ymax

E = Youngs Modulus
b = beam width
L = beam Length
h = beam thickness

$$F = \frac{Ymax\ 3\ E\ bh^3}{12L^3}$$

Stress for Cantilever

$$\sigma_{x=0} = \frac{12\ F\ L}{2b\ h^2}$$

Electrostatic Force

eo = 8.85e-14 V/cm
er = relative permitivitty
d = distance between plates
V = volts
A = area of plates

$$F = \frac{\varepsilon o\ \varepsilon r\ AV^2}{2d^2}$$

Capacitance

$$C = \frac{\varepsilon o\ \varepsilon r\ A}{d}$$

KEY EQUATIONS

Force due to Acceleration

m = mass
a = acceleration
d = density
V = volume

F = m a = d V a

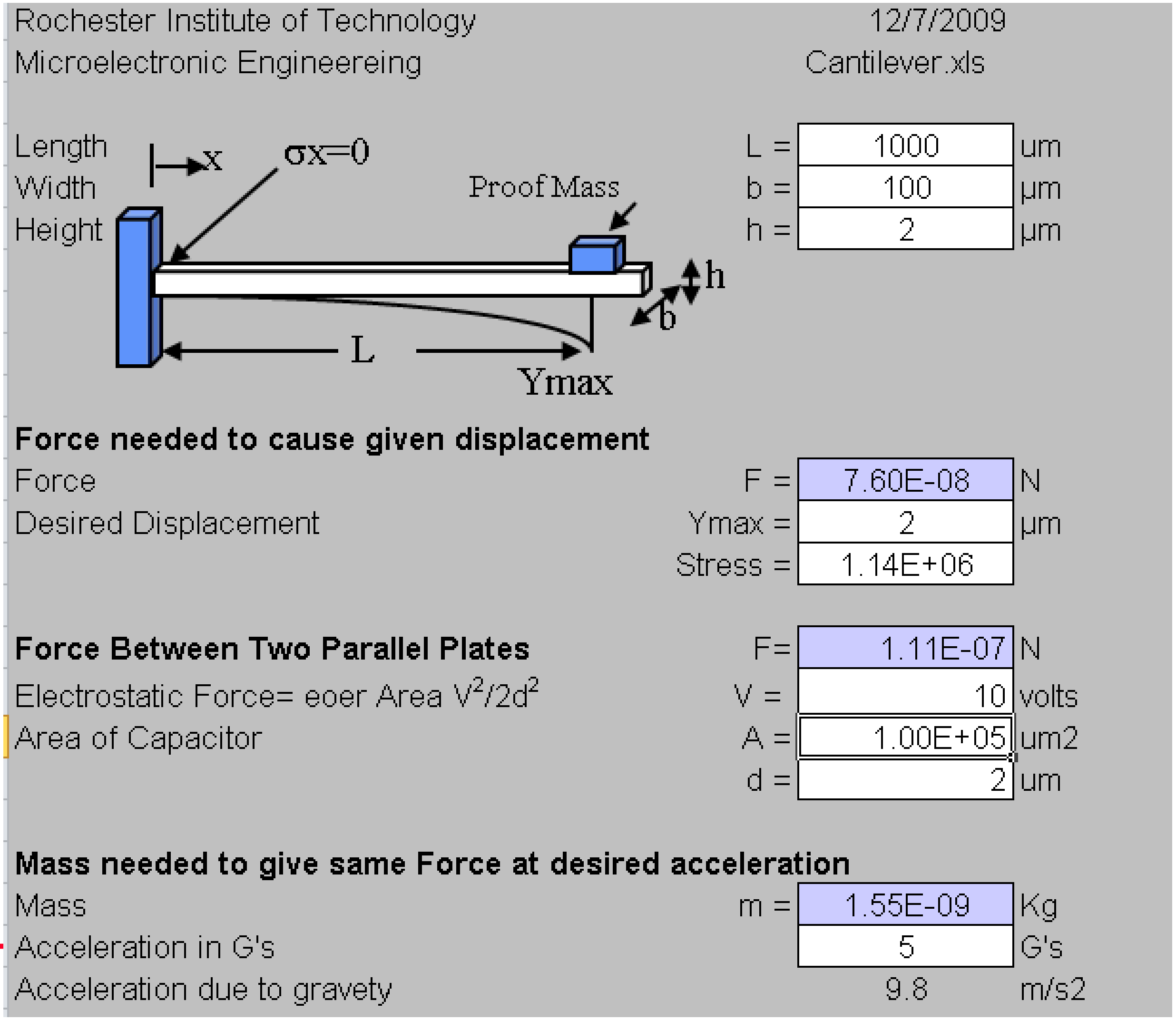
Resistance

Rhos = Sheet Resistance
L = Length
W = Width
q = 1.6E-19
u = mobility

F = Rhos L/W
Rhos=1/(qu Dose)

For single crystal silicon

CALCULATIONS



Rochester Institute of Technology		12/7/2009	
Microelectronic Engineereing		Cantilever.xls	
Length	L =	1000	um
Width	b =	100	µm
Height	h =	2	µm

Force needed to cause given displacement

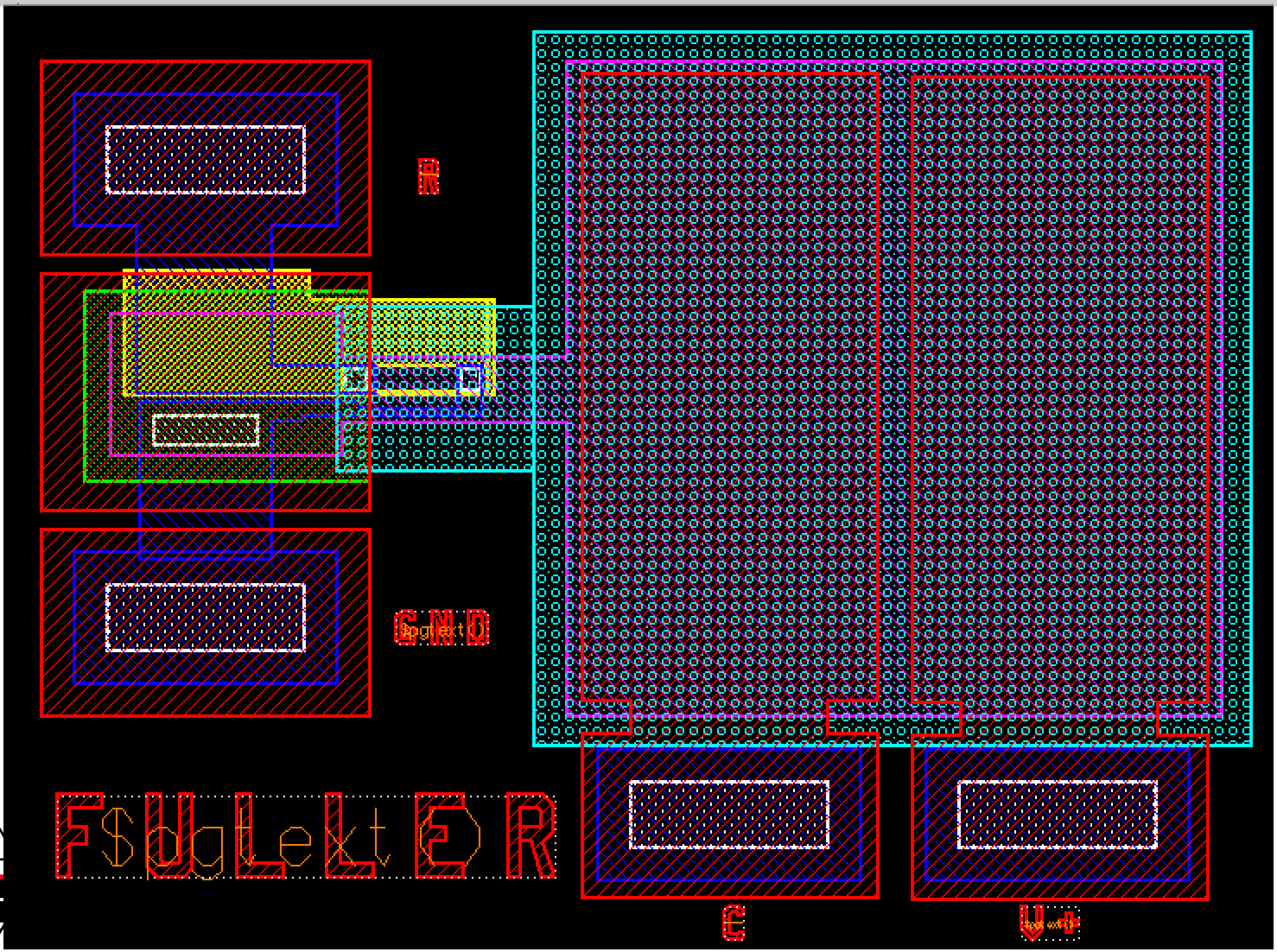
Force	F =	7.60E-08	N
Desired Displacement	Ymax =	2	µm
	Stress =	1.14E+06	

Force Between Two Parallel Plates	F=	1.11E-07	N
Electrostatic Force= eoer Area $V^2/2d^2$	V =	10	volts
Area of Capacitor	A =	1.00E+05	um2
	d =	2	um

Mass needed to give same Force at desired acceleration

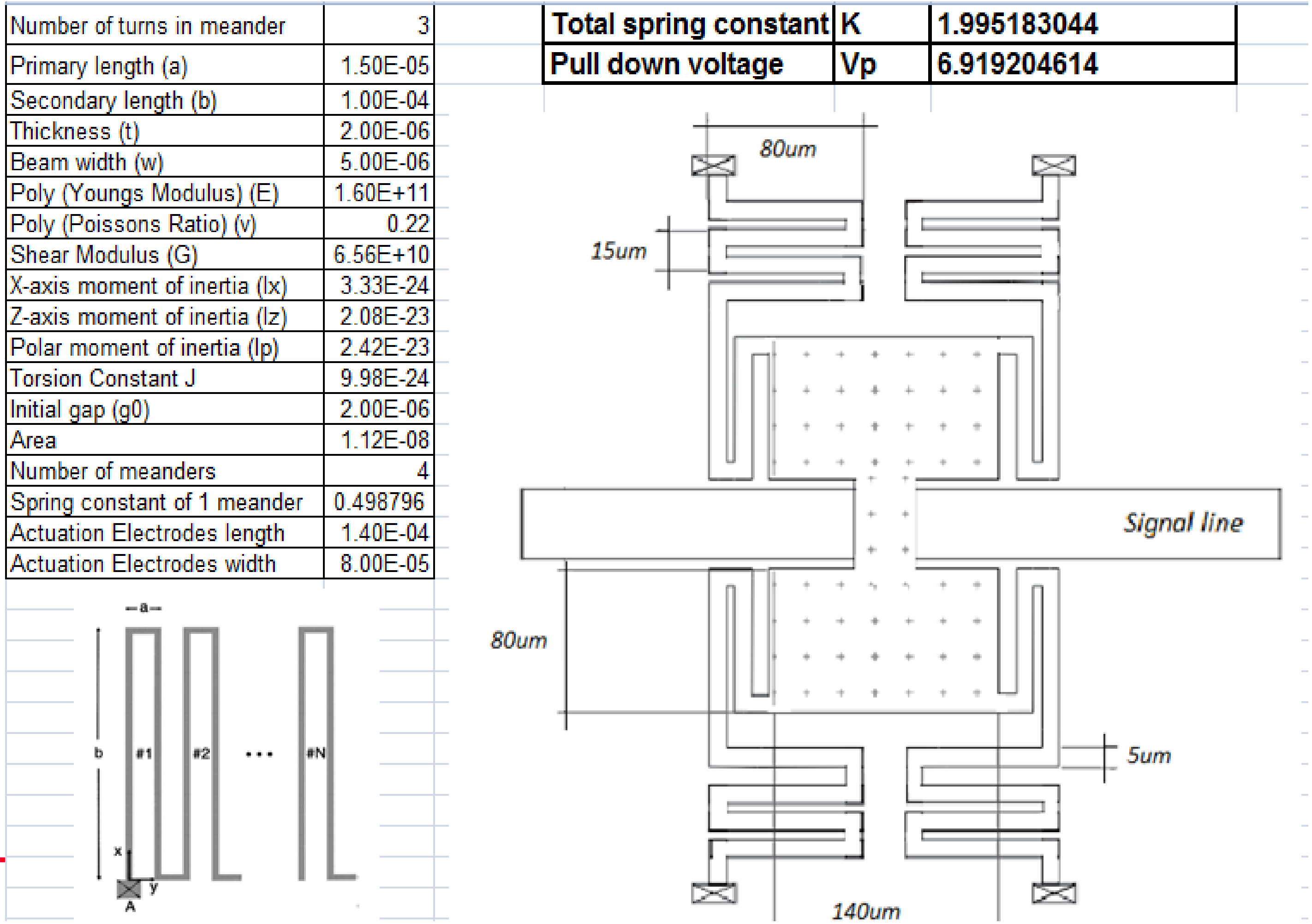
Mass	m =	1.55E-09	Kg
Acceleration in G's		5	G's
Acceleration due to gravety		9.8	m/s2

MENTOR GRAPHICS LAYOUT OF CANTILEVER



SWITCH CALCULATIONS PLUS DIMENSIONS

Each project has 5mm x 5mm layout space



Number of turns in meander	3
Primary length (a)	1.50E-05
Secondary length (b)	1.00E-04
Thickness (t)	2.00E-06
Beam width (w)	5.00E-06
Poly (Youngs Modulus) (E)	1.60E+11
Poly (Poissons Ratio) (v)	0.22
Shear Modulus (G)	6.56E+10
X-axis moment of inertia (Ix)	3.33E-24
Z-axis moment of inertia (Iz)	2.08E-23
Polar moment of inertia (Ip)	2.42E-23
Torsion Constant J	9.98E-24
Initial gap (g0)	2.00E-06
Area	1.12E-08
Number of meanders	4
Spring constant of 1 meander	0.498796
Actuation Electrodes length	1.40E-04
Actuation Electrodes width	8.00E-05

Total spring constant	**K**	**1.995183044**
Pull down voltage	**Vp**	**6.919204614**

SWITCH LAYOUT

🟥 Bottom Poly

▒ Sacrificial Oxide

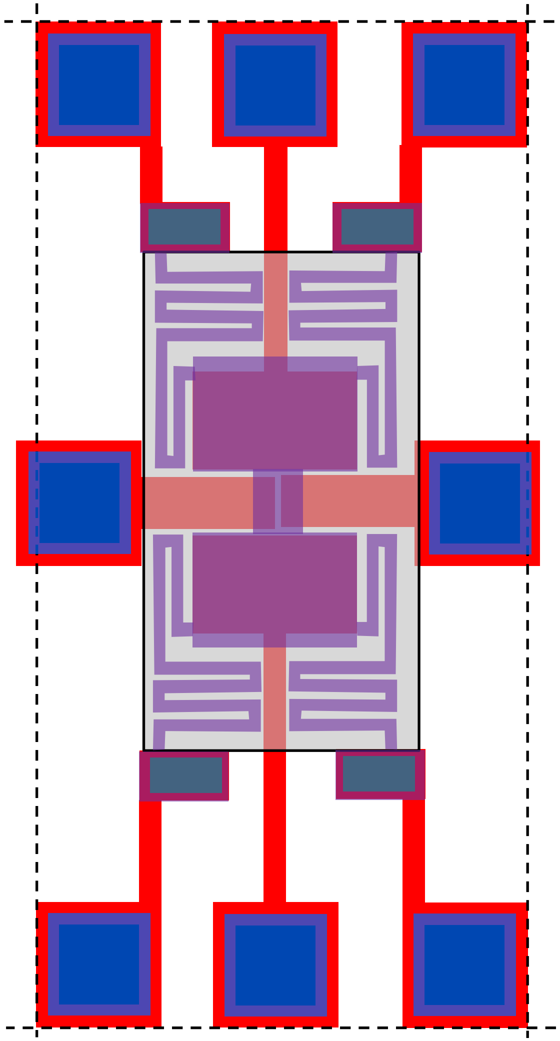
🟨 Anchor Cuts

⬛ Silicide (switch contacts)

🟪 Mechanical Poly

⬜ CC

🟦 Metal

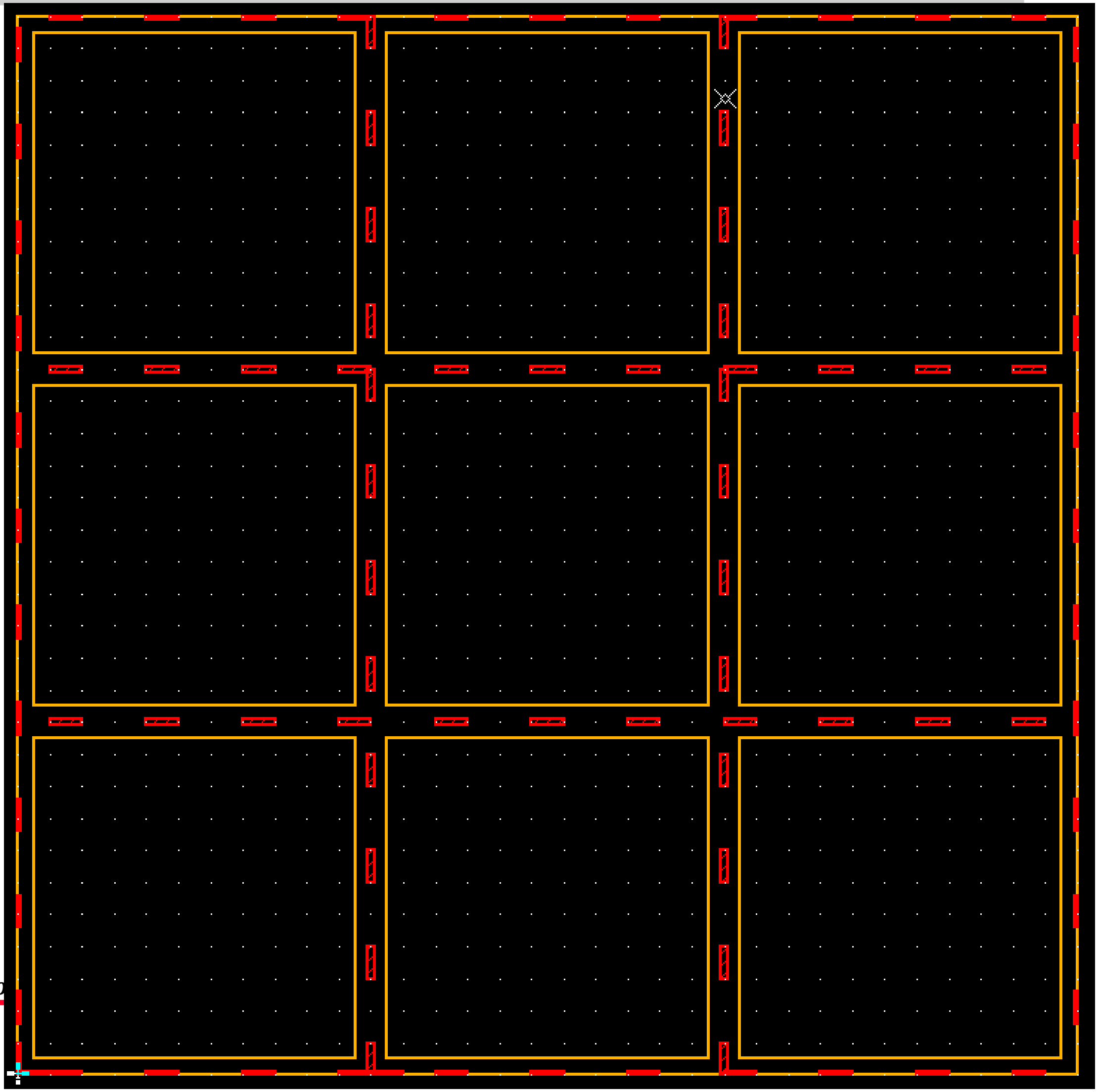


MEMS MULTICHIP PROJECT TEMPLATE

Total 15 mm by
15 mm plus 500 um for
sawing into 9 chips for
overall 16.5mm by
16.5mm size.

Wafer sawing is easier if
all chips are the same size

5mm by 5mm
design space
for each project

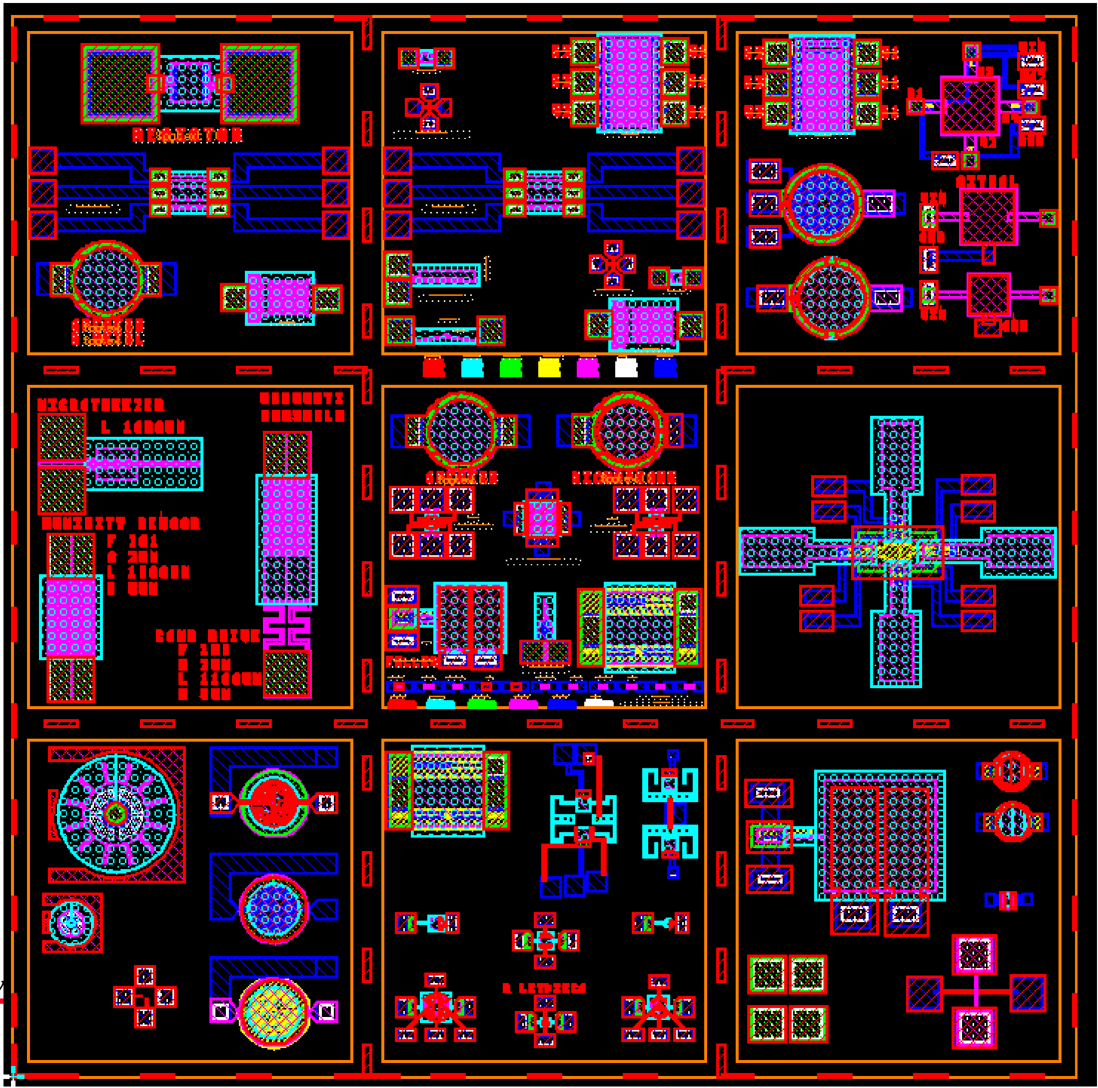


2014 MEMS MULTICHIP PROJECT DESIGN

Total 15 mm by 15 mm plus 500 um for sawing into 9 chips for overall 16.5mm by 16.5mm size.

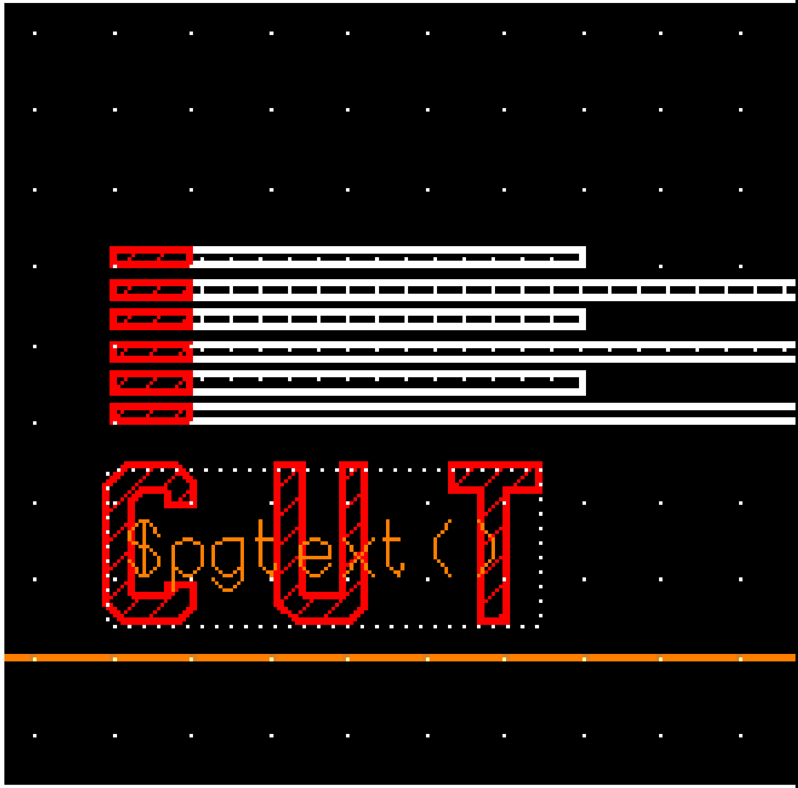
Wafer sawing is easier if all chips are the same size

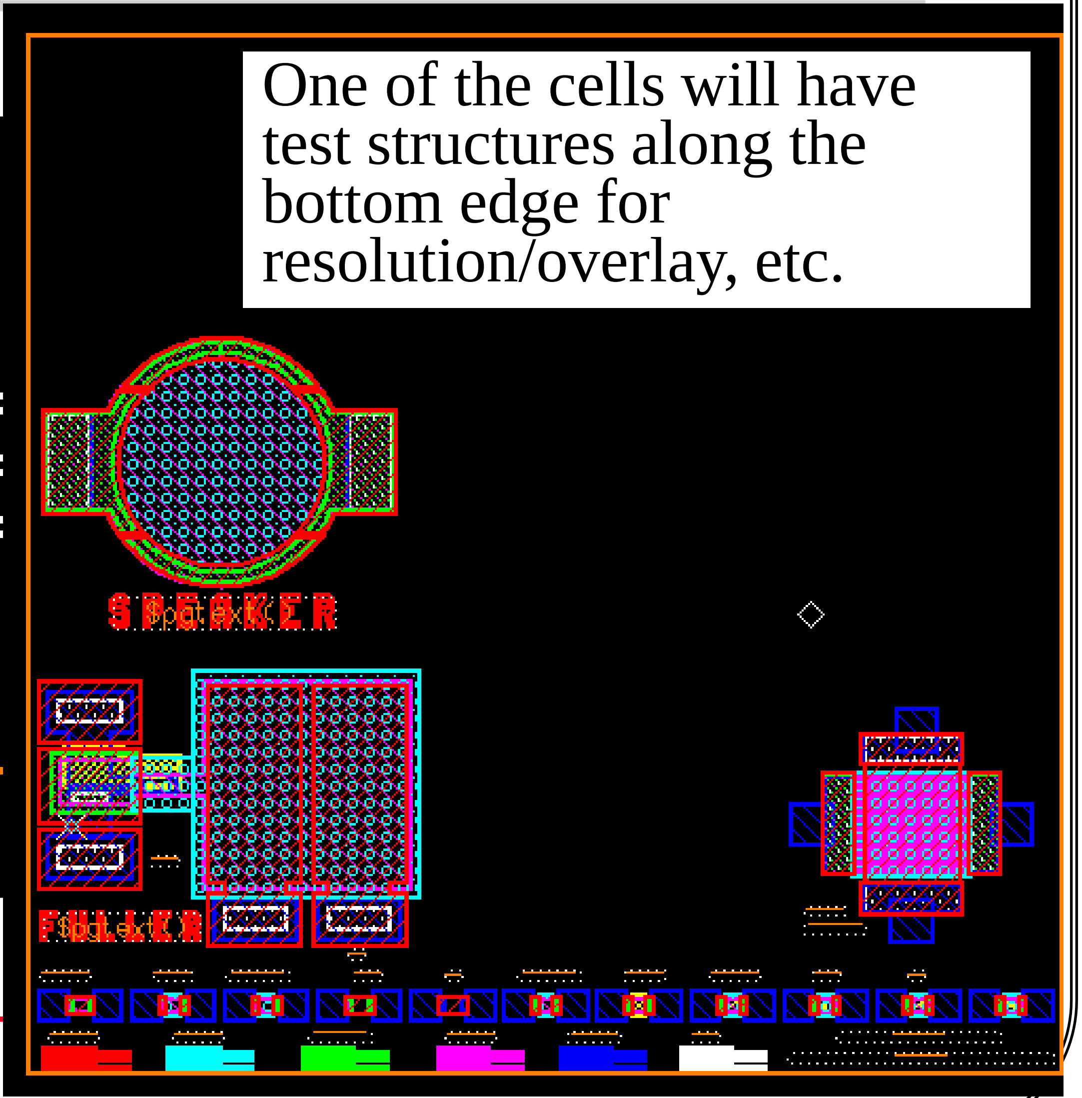
5mm by 5mm design space for each project



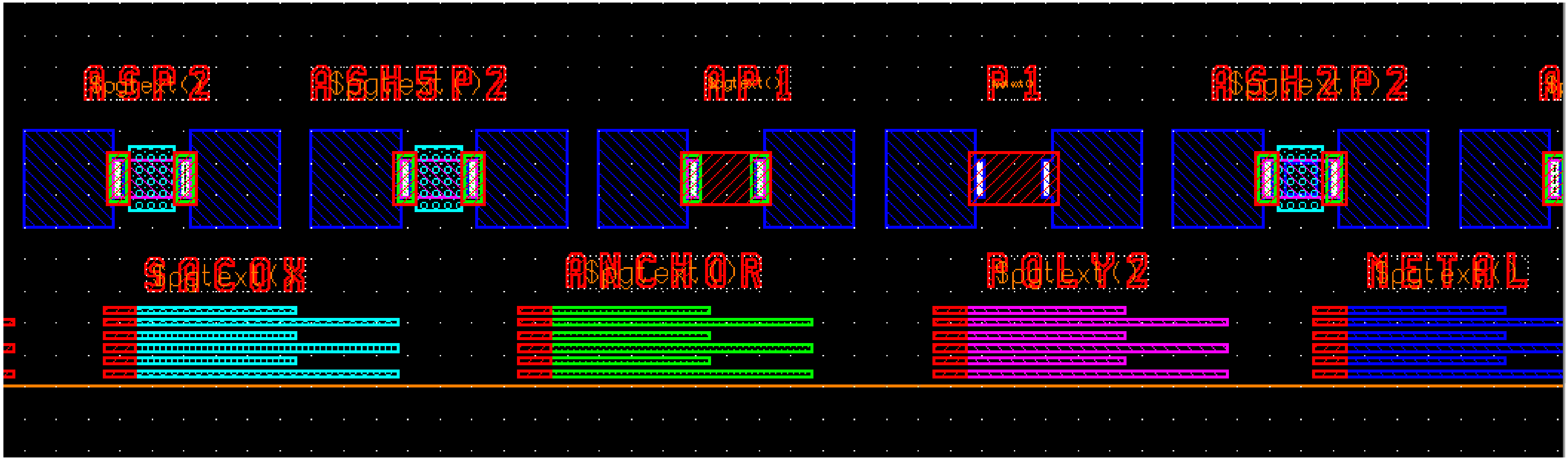
TEST STRUCTURES

One of the cells will have test structures along the bottom edge for resolution/overlay, etc.





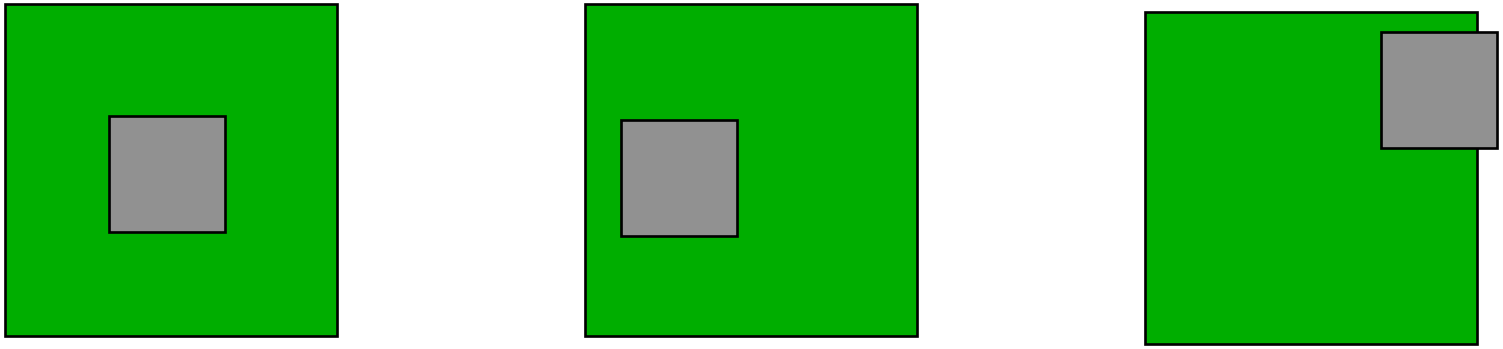
TEST STRUCTURES



1. Poly1 in Parallel with Poly2
2. No Etch Holes Poly 2
3. 5um Etch Holes Poly2
4. Metal contact to Poly2 to Poly1
5. Metal contact to Poly1
6. 2um Etch Holes Poly2
7. Poly2 No Implant, No SacOx
8. Poly2 No Implant
9. Poly2 No Implant 5um Gap
10. Poly2 No Implant 5um Resistor
11. Poly 2 No Implant 10um Resistor

Starting from Left Resistors
L = ~100µm W = ~50µm

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)

DESIGN RULES (GUIDELINES)

Outline is used to define the 5mm x 5mm work space.

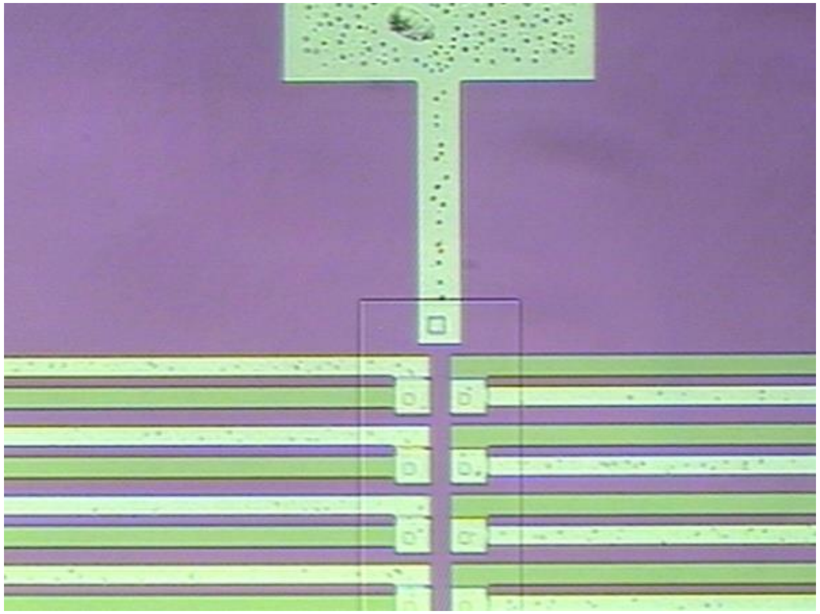
Minimum metal pad size for probing and wirebond connections is 150 µm by 150 µm, bigger may be better except for capacitor connections. Should be placed around the perimeter of the 5mm x 5mm workspace.

Suggest using Bottom Poly1 Layer for PG Text lettering.

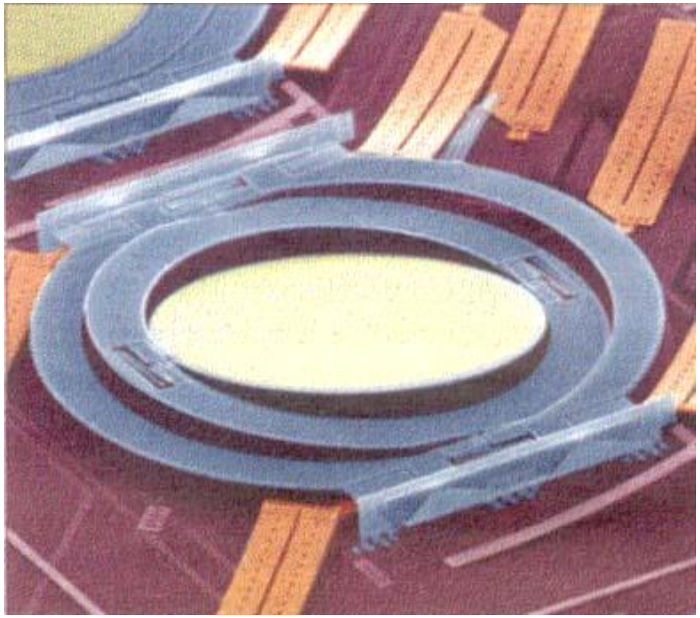
If mechanical Poly2 has sacrifical oxide under it then 5um by 5um etch holes on a 25um grid need to be included. Draw the holes on separate layer. We will combine with Mechanical Poly2 at maskmaking.

Metal should extend beyond via by 10um, Poly2 should extend beyond Anchor Holes by 10 um.

SOME EXAMPLES OF DEVICES



Thermocouples
and Heater

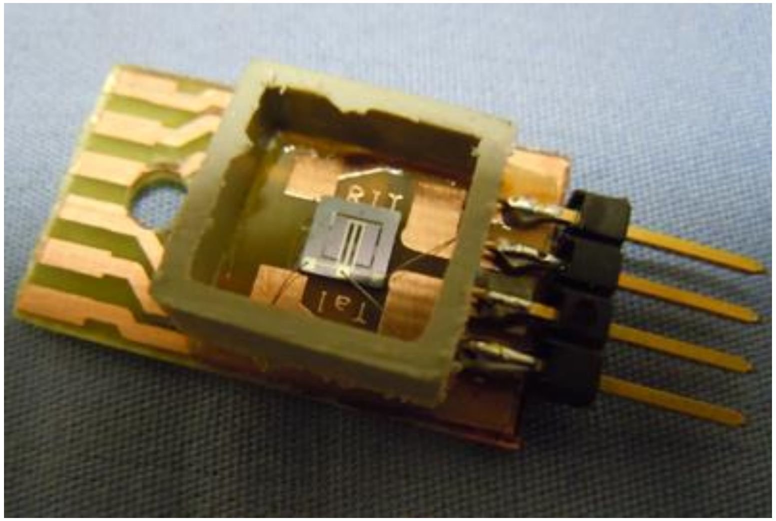


3-axis Mirror

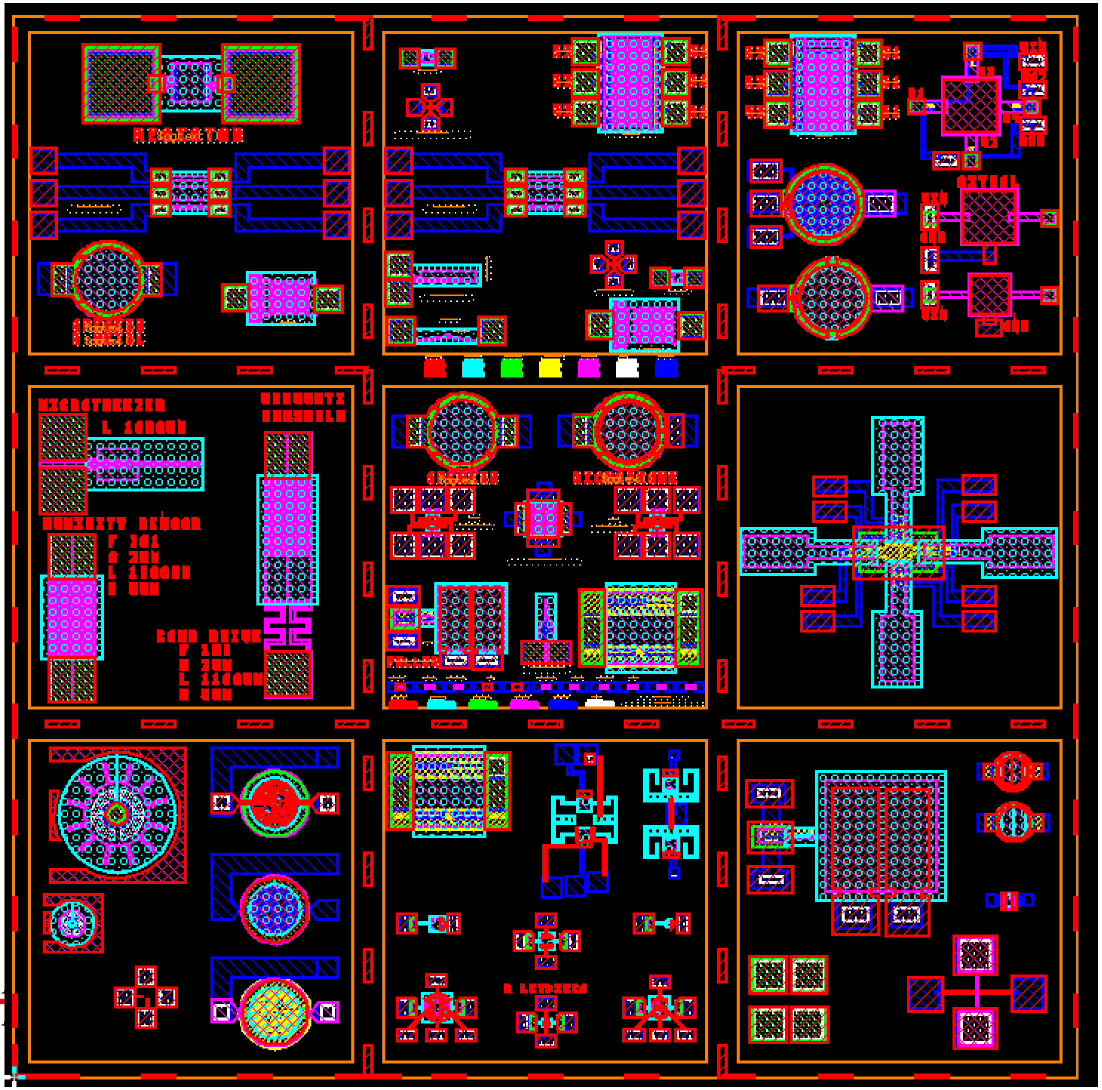
SOME EXAMPLES OF PACKAGED DEVICES

Magnetic Proximity Sensor

Packaged Accelerometer



2014 MEMS MULTICHIP PROJECT DESIGN



VLSI DESIGN LAB

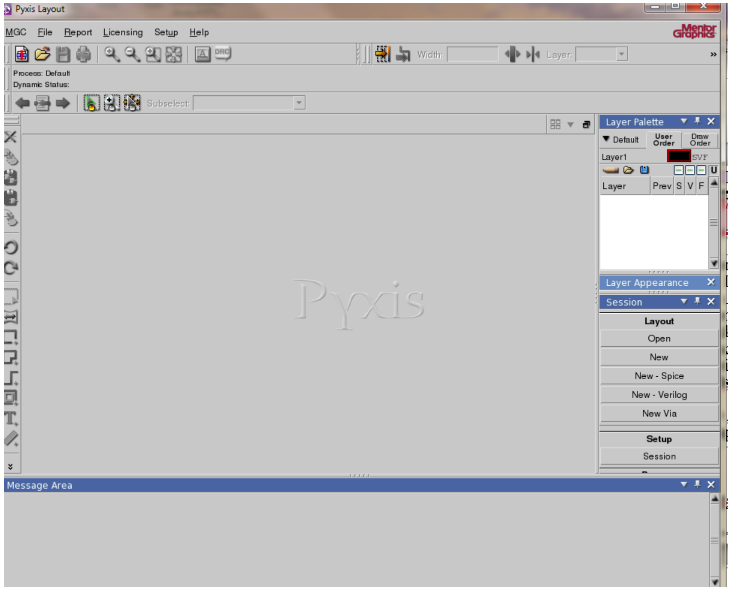
USING THE VLSI LAB WORKSTATIONS AND MENTOR GRAPHICS CAD TOOLS

Usually the workstation screen will be blank, press any key to view a login window. Login or switch user and then login.

Login: username (RIT computer account)
Password: *********

The screen background will change and your desktop will appear. On the top of the screen click on **Applications** then **System Tools** then **Terminal**. A window will appear that has a Unix prompt inside. Type the command **ls** at the prompt to see a list of your directories and files.

Type **ic** <RET>, it will take a few seconds, then the Pyxis Layout user interface will appear.
Maximize the Pyxis Layout window.



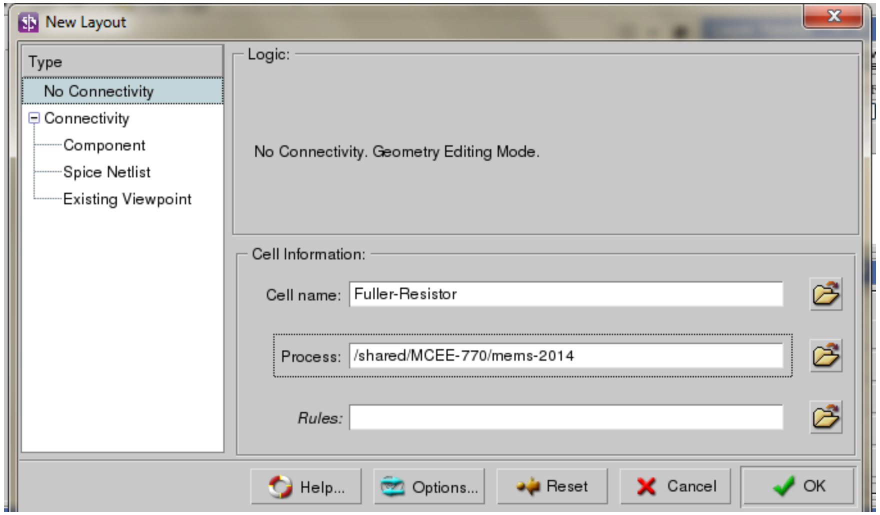
USING THE HP WORKSTATIONS AND MENTOR GRAPHICS CAD TOOLS - PROCESS AND GRID

In the session menu palette on the right hand side of the screen, under Layout, select **New**, using the left mouse button. For cell name type **name-device**. Set the process by typing **/tools/ritpub/process/mems-2014** in the process field. Leave the Rules field blank. Click **OK**

At the top left of the window check that the process is **mems-2014** not Default. If not correct go to top banner click on **Context>Process>Set Process**

The Layer Palette should show the layers you expect to used for your device layout.

On top banner select **Setup>Preferences>Display>Rulers/Grid** Set Snap to **10** and **10** as shown. (or other values as necessary)

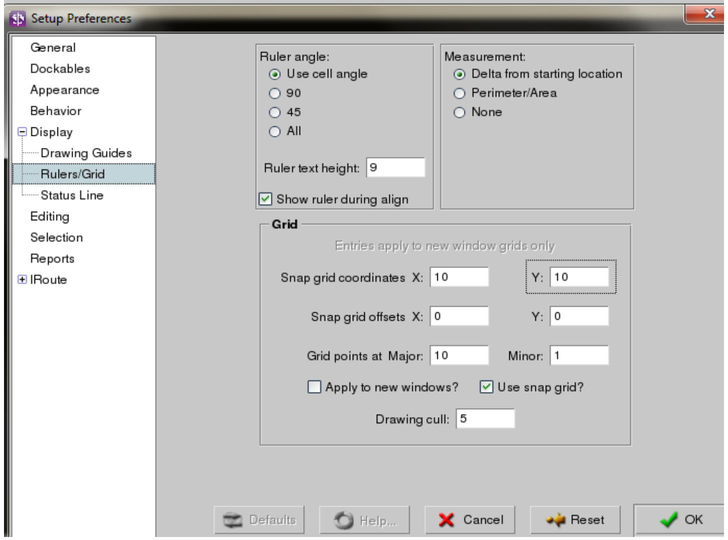


No Connectivity. Geometry Editing Mode.

Cell name: Fuller-Resistor

Process: /shared/MCEE-770/mems-2014

Rules:



Ruler angle:
● Use cell angle
○ 90
○ 45
○ All

Ruler text height: 9

☑ Show ruler during align

Measurement:
● Delta from starting location
○ Perimeter/Area
○ None

Grid

Entries apply to new window grids only

Snap grid coordinates X: 10 Y: 10

Snap grid offsets X: 0 Y: 0

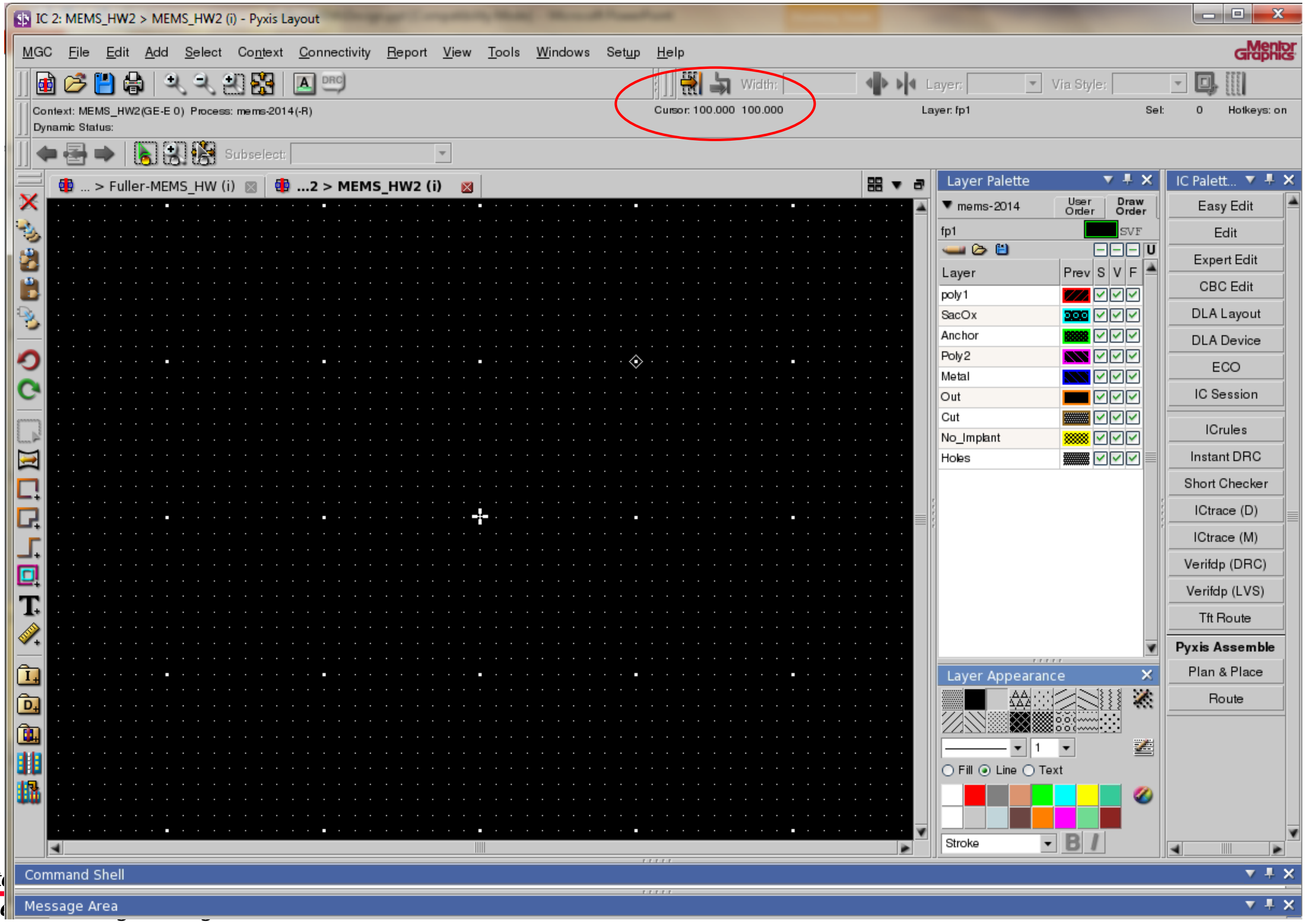
Grid points at Major: 10 Minor: 1

☐ Apply to new windows? ☑ Use snap grid?

Drawing cull: 5

USING THE HP WORKSTATIONS AND MENTOR GRAPHICS CAD TOOLS – WORKSPACE, LOCATION

The plus mark + is (0,0) the small dots are the 10 um grid the large dots are the 100um grid. The mouse curser is shown by the diamond and is at (100um,100um) as indicated by the cursor position at the top of the workspace.



Context: MEMS_HW2(GE-E 0) Process: mems-2014(-R)

Dynamic Status:

Cursor: 100.000 100.000

Layer: fp1

Sel: 0

Hotkeys: on

fp1 SVF

Layer	Prev	S	V	F
poly1	▨	☑	☑	☑
SacOx	▨	☑	☑	☑
Anchor	▨	☑	☑	☑
Poly2	▨	☑	☑	☑
Metal	▨	☑	☑	☑
Out	■	☑	☑	☑
Cut	▨	☑	☑	☑
No_Implant	▨	☑	☑	☑
Holes	▨	☑	☑	☑

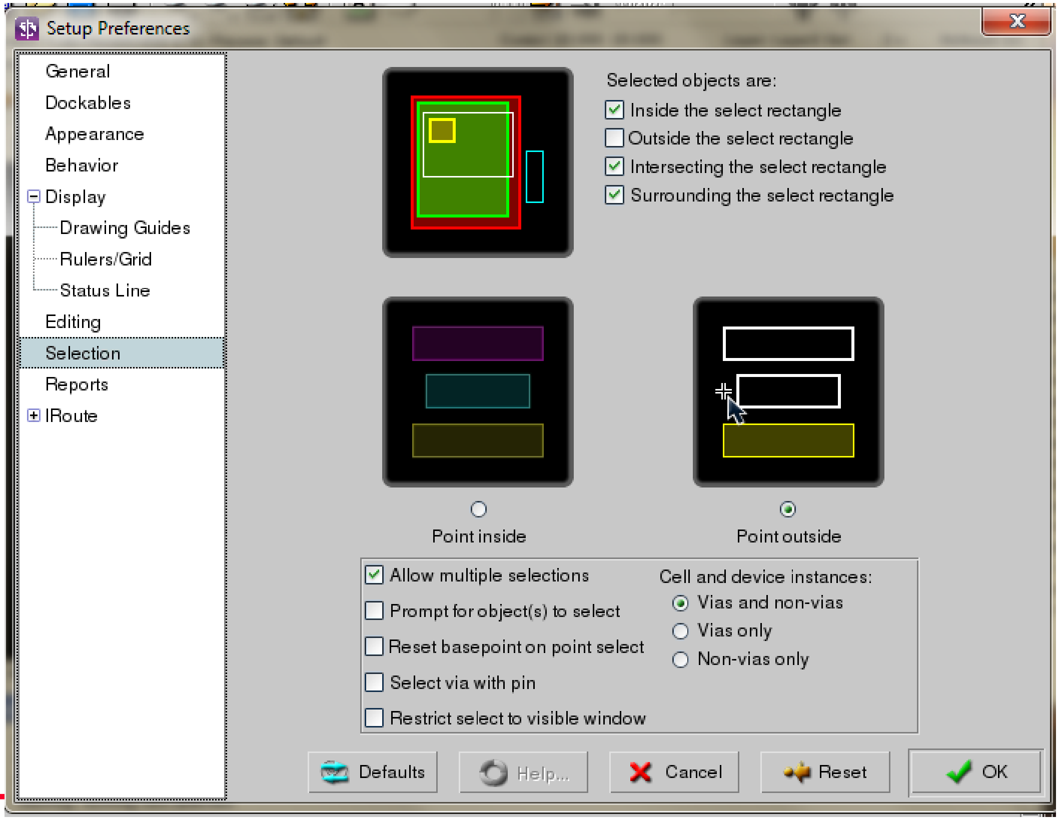
○ Fill ● Line ○ Text

USING THE HP WORKSTATIONS AND MENTOR GRAPHICS CAD TOOLS – SELECTING OBJECTS

Select easy edit, Select Shape. Draw boxes by click and drag of mouse. Unselect by pressing **F2** function key. The highlighted layer in the layer palette is selected prior to drawing. Unselect by pressing **F2**. Exit drawing by pressing **ESC**.

Selecting multiple objects is defined in **Setup>Selection**

Unclick **Surrounding the select rectangle** to not select the cell outline



Selected objects are:

☑ Inside the select rectangle
☐ Outside the select rectangle
☑ Intersecting the select rectangle
☑ Surrounding the select rectangle

○ Point inside
● Point outside

☑ Allow multiple selections
☐ Prompt for object(s) to select
☐ Reset basepoint on point select
☐ Select via with pin
☐ Restrict select to visible window

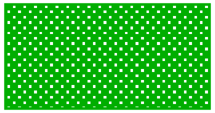
Cell and device instances:

● Vias and non-vias
○ Vias only
○ Non-vias only

DRAWING BOXES AND OTHER SHAPES

Select easy edit, right click and select Show Scroll Bars, scroll through the various edit commands.

DRAW BOXES by click and drag of mouse. Unselect by pressing F2 function key. The following command will draw a 3000 µm by 3000 µm box with layer 4 color/shading. Put the curser in the workspace and start typing. A text line window will pop up. If the command has a typo just start typing again and use the up arrow to recall previous text.



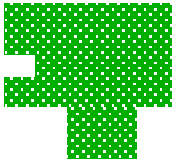
$add_shape([[0,0],[3000,3000]],4)

Location of lower left corner

Location of upper right corner

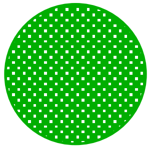
Box Color

The Notch command is useful to change the size of a selected box or alter rectangular shapes into more complex shapes.

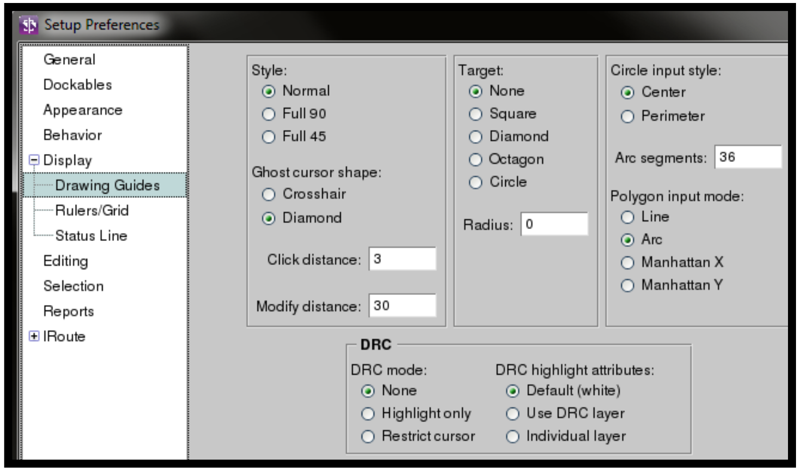


DRAWING CIRCLES

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.
$add_shape($get_circle([0,0],[100,0],300),3)
To reset to rectangles type $set_location_mode(@line) return.



MOVE, COPY, DELETE, NOTCH, etc: Selected objects will appear to have a bright outline. Selected objects can be moved (**Move**), copied (**Copy**), deleted (**Del**), notched (**Notc**). When done **unselect** objects, press F2.



Style:
● Normal
○ Full 90
○ Full 45

Ghost cursor shape:
○ Crosshair
● Diamond

Click distance: 3

Modify distance: 30

Target:
● None
○ Square
○ Diamond
○ Octagon
○ Circle

Radius: 0

Circle input style:
● Center
○ Perimeter

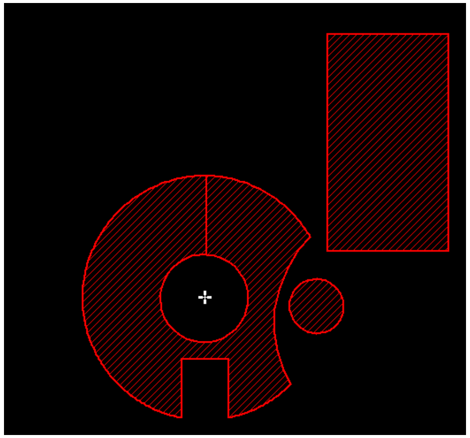
Arc segments: 36

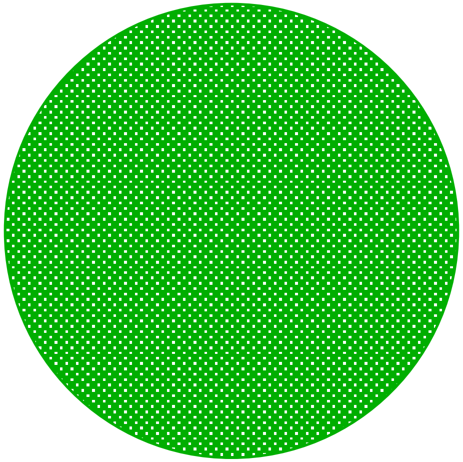
Polygon input mode:
○ Line
● Arc
○ Manhattan X
○ Manhattan Y

DRC

DRC mode:
● None
○ Highlight only
○ Restrict cursor

DRC highlight attributes:
● Default (white)
○ Use DRC layer
○ Individual layer





Change an Object to another layer: Selected object(s) click on **Edit** on the top banner, select **Change Attributes**, change **layer name** to the name you want. When done press **F2** to unselect

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** then **Area** and 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.\

ADDING TEXT: Add > Polygon Text click on layout where you want it located. Select the text box and **Edit > Change > Attributes**, change pgtext, change scale to 3.0

SCREEN PRINT: Click on **MGC** and select **Capture Screen.** Enter file name and location such as **Lynn.png** and **Desktop.** After saving you can use a flash drive and transfer the file to another computer.

LOG OUT: upper right of screen click on name and select **LOG OUT**

BASIC UNIX COMMANDS

Command	**Description**
ls	list the files and directories in the current directory
cd	change directory
cd ..	go up one directory
mv	move a file (rename a file)
rm	remove a file (delete a file)
pwd	display path of current directory
mkdir	create a new directory
rmdir	remove a directory
yppasswd	change your password

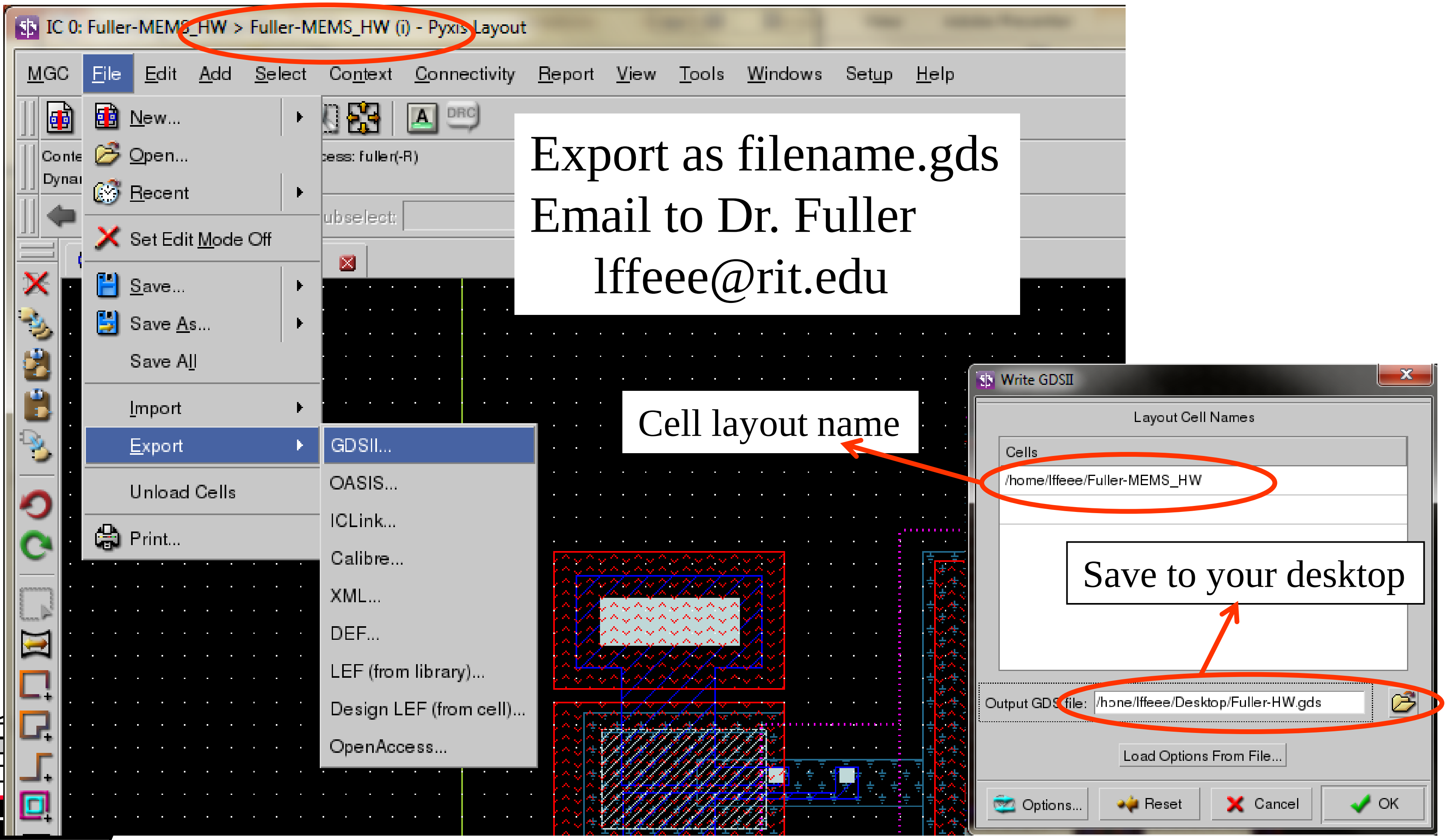
It is important to remember that since this is a UNIX operating system, the commands are case sensitive.

DRAWING SPIRALS

From MGC pull down menu select userware>load… and select file “spiral”. Once this file has been successfully loaded and an active sheet is open, type spiral() in the dialog box. Enter values for radius_incr and angle_incr (try 1 and 0.3). To change the width of your spiral line change the number 10 from the line in the file ($add_path(points,”1”,@internal,10,@center,@extended,@nokeep). Source Path: /home/rgm3104/spiral

```
//In IC Station. From MGG pull donw menu select userware>load... and
select file "spiral". Once this file has been succefuly loaded and an
active sheet is open, type spiral() in the dialog box. Enter values for
radius_incr and angle_incr, I'm not sure what these do, but 1 and 0.3
worked for me. To change the width of your spiral line - which is set to
10um in this case - change the number 10 from this line in the program
below $add_path(points,"1", @internal,10,@center,@extended,@nokeep);
//  Source path: /home/rgm3104/spiral

function spiral(radius_incr : number,
                angle_incr : number,
                init_rad : ic_line)
{
      local radius;
      local MAX_VERT=2040;

      local deltx, delty;

      local initx=init_rad[0][0], inity=init_rad[0][1];

   deltx=init_rad[1][0]-init_rad[0][0];
   delty=init_rad[1][1]-init_rad[0][1];

      radius=sqrt((deltx*deltx)+(delty*delty));

      local rad=0;
      local ang=0;
      local points=[[initx,inity]];
      local i;
      for (i=0;i<MAX_VERT-1;i=i+1) {
            if (rad>=radius) break;
            local cart=cartesian(rad,ang);
            cart[0]=initx+cart[0];
            cart[1]=inity+cart[1];
            points=$create_vector(length(points)+1,points);
            points[length(points)-1]=cart;
            rad=rad+radius_incr;
            ang=ang+angle_incr;
      }
      $writes_file(1,"num vert is: ",length(points),"\n");
      $add_path(points,"1", @internal,10,@center,@extended,@nokeep);
}

function spiral_prompt()
{
      $create_prompt("user_ic", @spiral,"Spiral",
            $prompt_arg(@radius_incr,"Radius Increments: "),
            $prompt_arg(@angle_incr, "Angle Increments: "),
            $prompt_arg(@init_rad,"Enter a line for initial point and
radius"),
            $prompt_dynamic(@init_rad, "($prompt_for_ic_line())")
      );
}

function cartesian(rad : number, angle : number)
{
      local ret_val=[0,0];
      ret_val[0]=cos(angle)*rad;
      ret_val[1]=sin(angle)*rad;
      return ret_val;
}
```

EXPORT CELL DESIGN AS GDS II FILE



Cells: /home/lffeee/Fuller-MEMS_HW

Output GDS file: /hone/lffeee/Desktop/Fuller-HW.gds

Export as filename.gds
Email to Dr. Fuller
lffeee@rit.edu

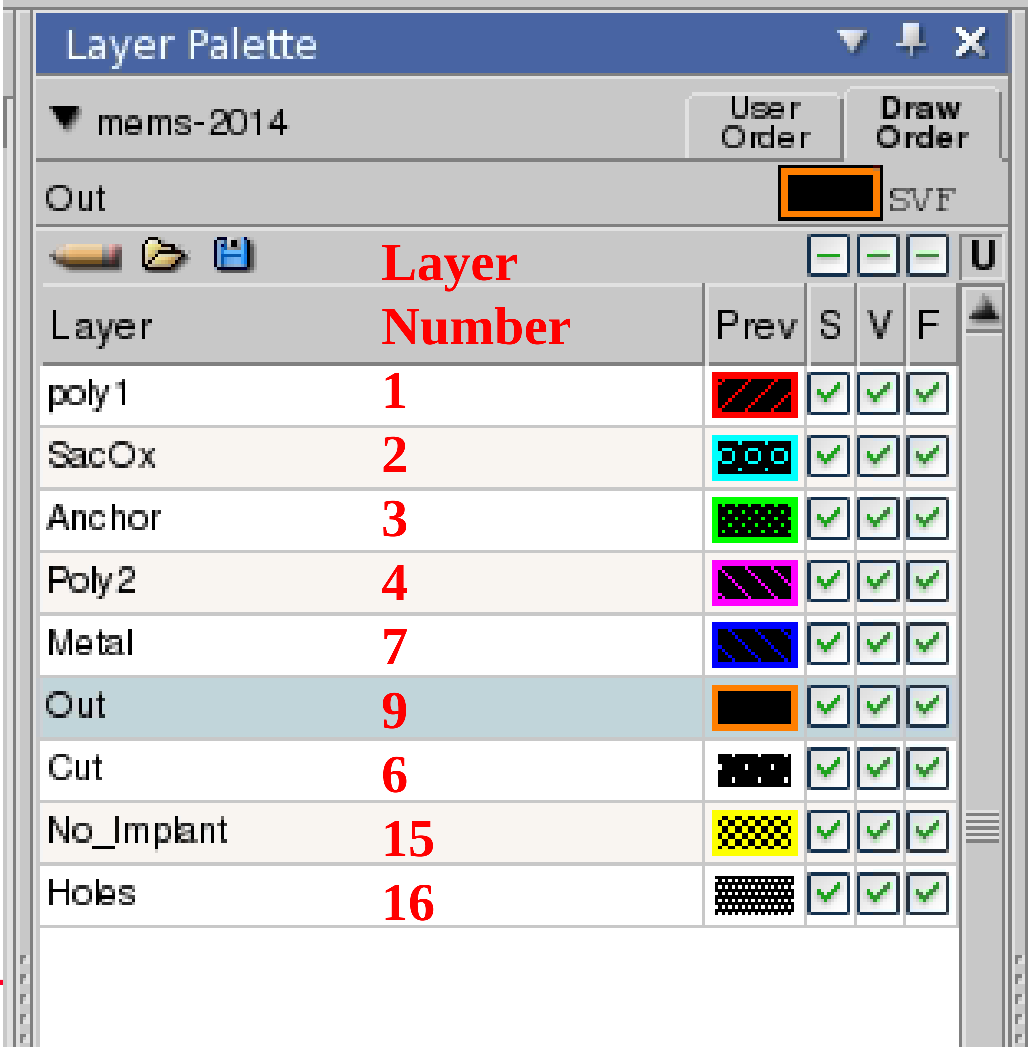
Cell layout name

Save to your desktop

GDS II LAYER NUMBERS

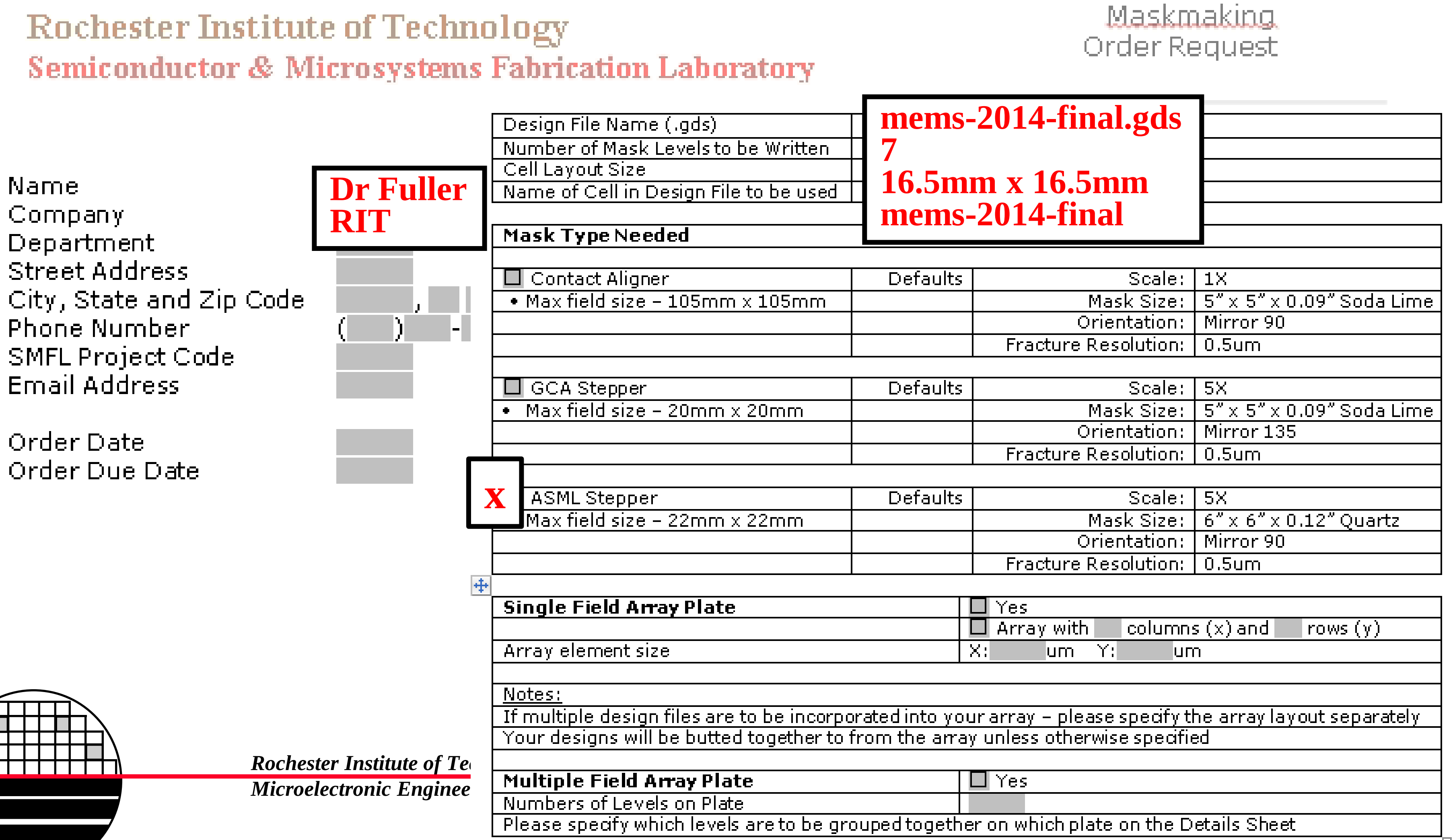
The design layer names and colors are lost when converting to GDS II. Only the layer number is kept.

Individual Student Designs are converted to GDS-II files and emailed to course instructor.



Layer	Layer Number	Prev	S	V	F
poly1	1	🟥	☑	☑	☑
SacOx	2	🟦	☑	☑	☑
Anchor	3	🟩	☑	☑	☑
Poly2	4	🟪	☑	☑	☑
Metal	7	🟦	☑	☑	☑
Out	9	⬛	☑	☑	☑
Cut	6	▩	☑	☑	☑
No_Implant	15	🟨	☑	☑	☑
Holes	16	▩	☑	☑	☑

MASK ORDER FORM



Rochester Institute of Technology
Semiconductor & Microsystems Fabrication Laboratory

Maskmaking
Order Request

Name	Dr Fuller
Company	RIT
Department	
Street Address	
City, State and Zip Code	,
Phone Number	( ) -
SMFL Project Code	
Email Address	
Order Date	
Order Due Date	

Design File Name (.gds)	mems-2014-final.gds
Number of Mask Levels to be Written	7
Cell Layout Size	16.5mm x 16.5mm
Name of Cell in Design File to be used	mems-2014-final

Mask Type Needed			
☐ Contact Aligner	Defaults	Scale:	1X
• Max field size – 105mm x 105mm		Mask Size:	5" x 5" x 0.09" Soda Lime
		Orientation:	Mirror 90
		Fracture Resolution:	0.5um
☐ GCA Stepper	Defaults	Scale:	5X
• Max field size – 20mm x 20mm		Mask Size:	5" x 5" x 0.09" Soda Lime
		Orientation:	Mirror 135
		Fracture Resolution:	0.5um
☒ ASML Stepper	Defaults	Scale:	5X
Max field size – 22mm x 22mm		Mask Size:	6" x 6" x 0.12" Quartz
		Orientation:	Mirror 90
		Fracture Resolution:	0.5um

Single Field Array Plate	☐ Yes
	☐ Array with columns (x) and rows (y)
Array element size	X: um Y: um

Notes:
If multiple design files are to be incorporated into your array – please specify the array layout separately
Your designs will be butted together to from the array unless otherwise specified

Multiple Field Array Plate	☐ Yes
Numbers of Levels on Plate	

Please specify which levels are to be grouped together on which plate on the Details Sheet

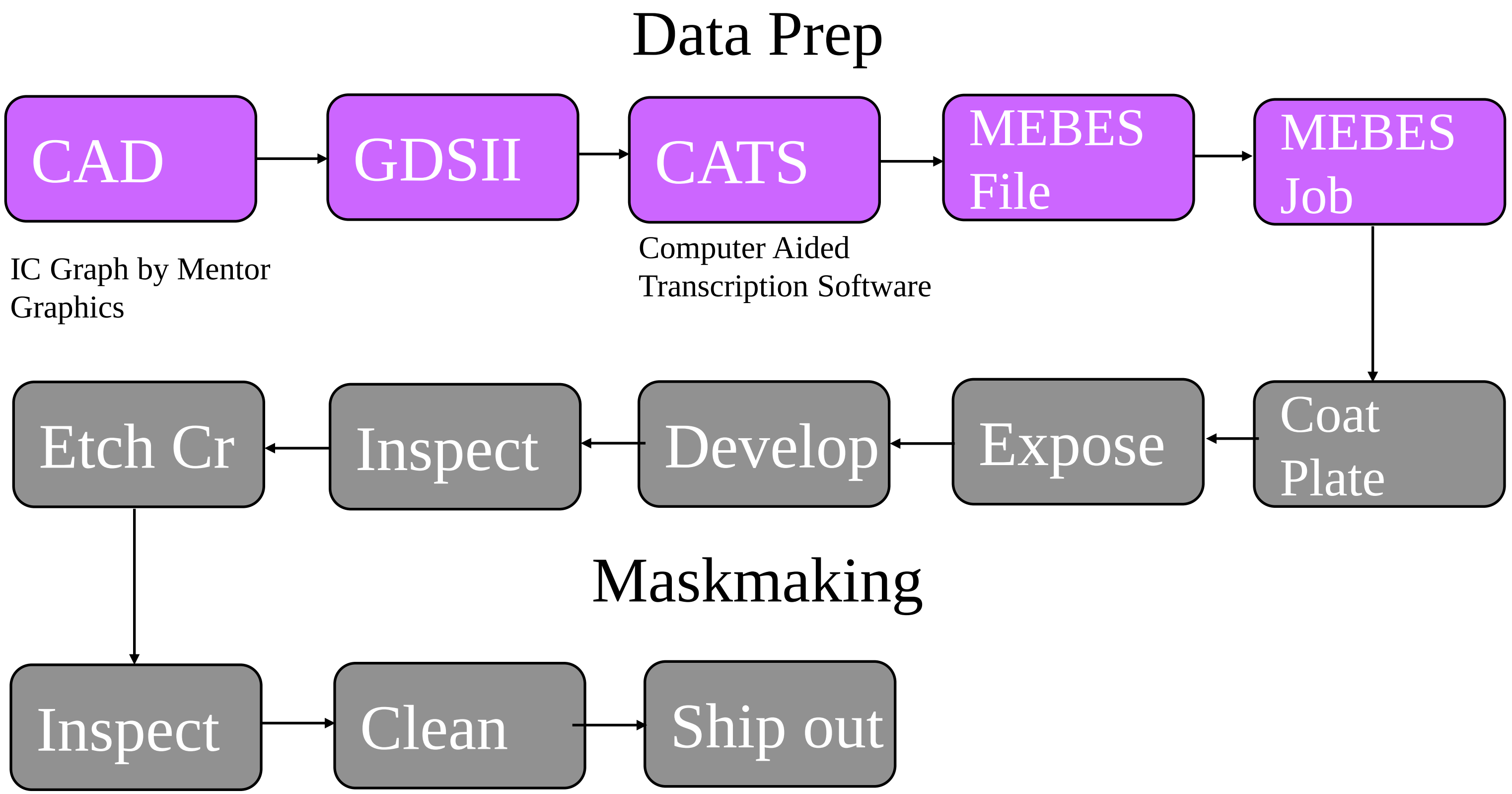
MASK ORDER FORM DETAILS

Reticle Number	Reticle Name	Design Layer #'s	Boolean Function	Dark/ Clear	Comment
1	Poly1	1	None	Clear	
2	SacOx	2	None	Clear	
3	Anchor	3	3 Inverted	Dark	
4	No Implant	15	None	Clear	
5	Poly2	4,16	4 AND (16 Inverted)	Clear	
6	Cut	6	6 Inverted	Dark	
7	Metal	7	None	Clear	

Design Layer 9 Out (outline) is not used. It is only for placement of projects on the multi-project reticle template.

`cp <filename>.gds /dropbox/masks`

MASK PROCESS FLOW



Data Prep

CAD

IC Graph by Mentor Graphics

GDSII

CATS

Computer Aided Transcription Software

MEBES File

MEBES Job

Coat Plate

Expose

Develop

Inspect

Etch Cr

Maskmaking

Inspect

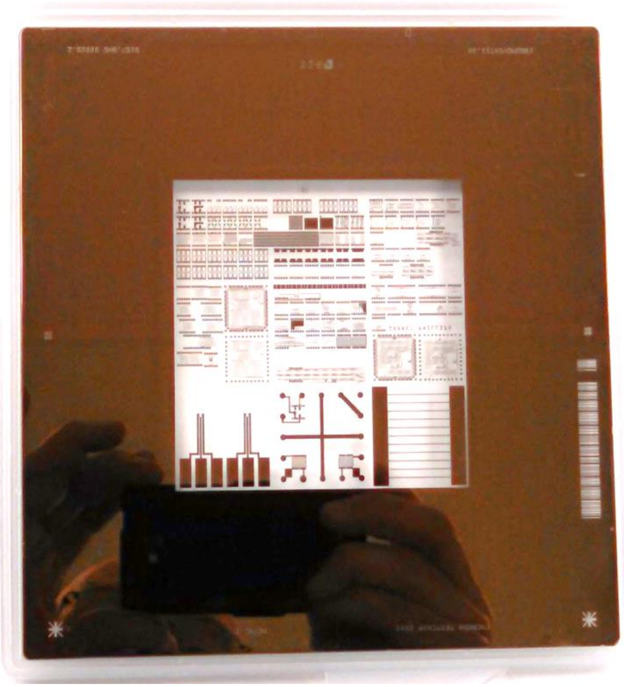
Clean

Ship out

This process can take weeks and cost between $1000 and $20,000 for each mask depending on the design complexity.

MEBES - Manufacturing Electron Beam Exposure System

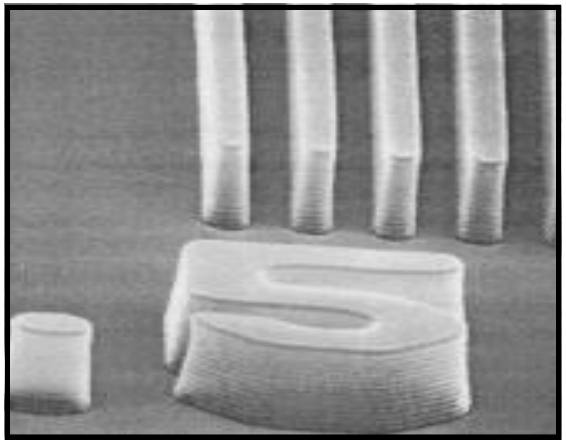
ASML RETICLE



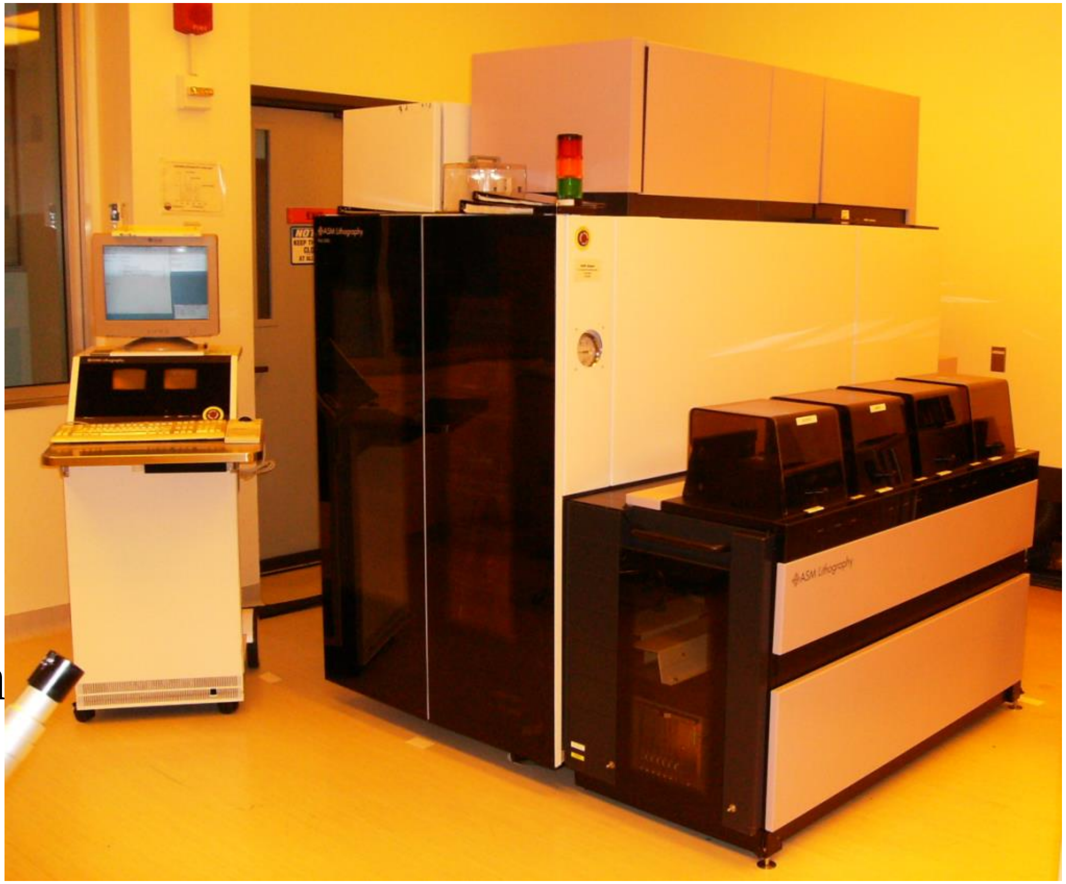
Chrome Side
Mirrored 90°
Chip Bottom at Bottom

Non Chrome Side
As loaded into Reticle Pod, Chrome Down, Reticle Pre-Alignment Stars Sticking out of Pod

ASML 5500/200

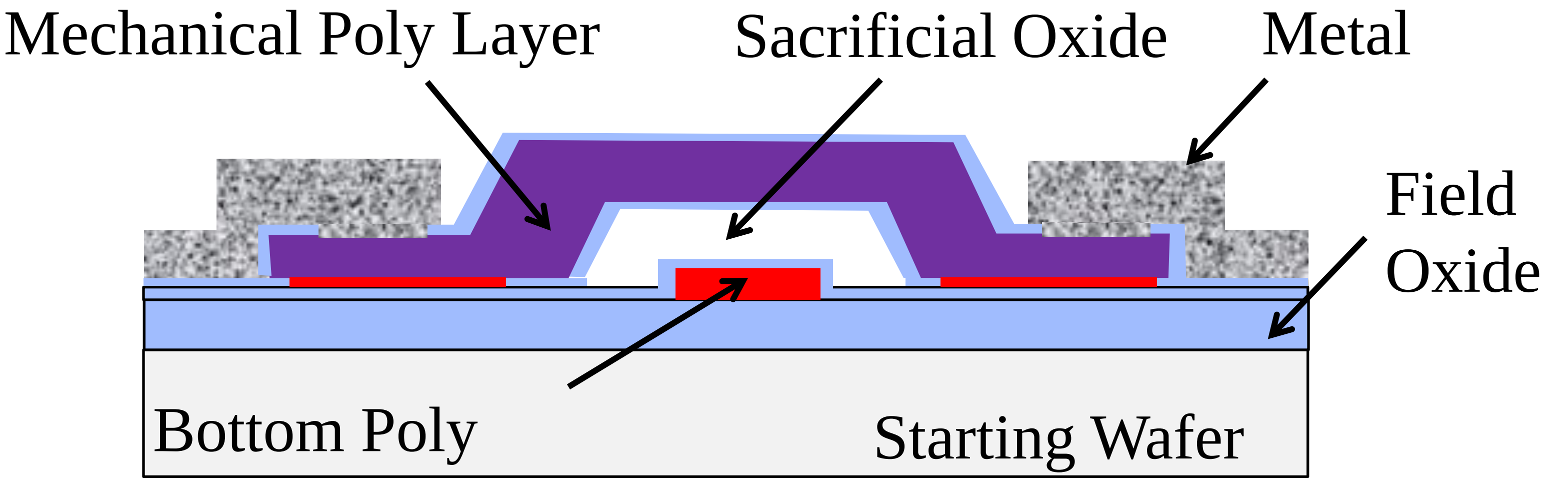


NA = 0.48 to 0.60 variable
σ= 0.35 to 0.85 variable
With Variable Kohler, or
Variable Annular illumination
Resolution = K1 λ/NA
= ~ 0.35µm
for NA=0.6, σ =0.85
Depth of Focus = $k_2\ \lambda/(NA)^2$
= > 1.0 µm for NA = 0.6



i-Line Stepper λ = 365 nm
22 x 27 mm Field Size

DEVICE CROSS SECTION



Bottom Poly 1 (Red) Layer 1 🟥
Sacrificial Oxide (Blue Outline) Layer 2 ▨
Anchor (Green) Layer 3 🟩
Mechanical Poly 2 (Purple) Layer 4 🟪
Contact Cut (White) Layer 6 ⬜
Metal (Blue) Layer 7 🟦
Outline (Yellow Outline) Layer 9 ☐
No Implant Yellow Layer 15 🟨
Holes Layer 16 (combined with Poly 2)

STEPPER JOB

Mask Barcode:

Stepper Jobname: MCEE770-MEMS
- Level 0 (combi reticle)
- Level Clearout (combi reticle)
- Level SacOx
- Level Poly 1
- Level Anchor
- Level Poly 2
- Level CC
- Level Metal
- Level No Implant

RECIPES FOR RESIST COAT AND DEVELOP

Level	Level Name	Resist	Coat Recipe	Develop Recipe	Resist Thickness
0	Zero	OIR-620	Coat	Develop	1.0um
1	Poly 1	OIR-620	Coat	Develop	1.0um
2	Sac Ox	OIR-620	Coat	Develop	1.0um
3	Anchor	S1827	MEMS-COAT	MEMS-DEV	4.5um
4	Poly 2	S1827	MEMS-COAT	MEMS-DEV	4.5um
5	CC	S1827	MEMS-COAT	MEMS-DEV	4.5um
6	Metal 1	S1827	MEMS-COAT	MEMS-DEV	4.5um

MEMS-COAT.rcp 2500rpm, 1min Hand Dispense
Exposure for S1827, 375mj/cm2, NA=0.46, σ=0.45
MEMS-DEV.rcp has 200 second develop time, no hardbake

POSSIBLE NEW PROCESSES (NEED VERIFICATION)

Can we make isolated poly resistors by ion implant?
Sacrificial Oxide Etch Holes, Size, Spacing,

Sacrificial Poly Etch Stop and Oxidation
Mechanical Poly Layer Deposition
Mechanical Poly Layer Etch Recipe (STS Tool)
CC Thick Resist Coat, Develop, Expose Recipe
Metal Lift-Off
Sawing Recipes….
Release Sequence, Details,

FABRICATION PROCESS

Zero Level Lithography
Drytek Quad Etch of ASML marks
Grow 6500Å Oxide
Deposit 5000Å Poly
Photo Level 1 Bottom Electrode
RIE-DryTek Quad, Etch Poly
Ash Resist
Clean (Two HF Dips)
Deposit 1000Å Poly
Dope Poly – Spin-on
Deposit 15000Å TEOS Sac Oxide
Photo Level 2 Sacrificial Oxide
Wet Etch Sacrificial Oxide
Deposit TEOS Oxide Etch Stop 2000Å
Photo Level 3 Anchor Cuts
Wet Etch TEOS Oxide Anchor Cuts
Ash Resist

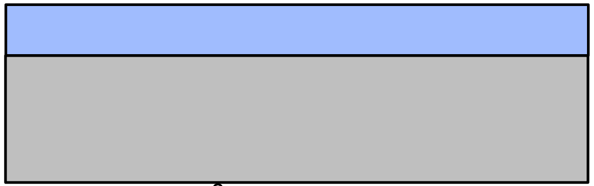
Deposit Mechanical Poly 1.5um
Dope Poly & Anneal
Photo Alignment Marks Clear Out
Etch Poly Clear Out
Ash Resist
Photo Level 4 Mechanical Poly
RIE-STS Poly Etch
Ash Resist
Etch Sacrificial Oxide
Oxidize Poly
Photo Level 5 CC
Wet Etch CC
Ash Resist
Clean (Two HF Dips)
Photo 6 Metal Lift-Off
Deposit Metal
Lift-Off
Coat Resist and Saw

FABRICATION PROCESS

1.

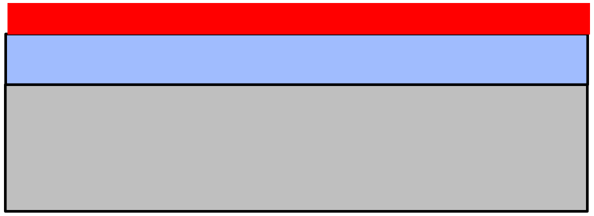
Starting Wafer with Electronics

2.



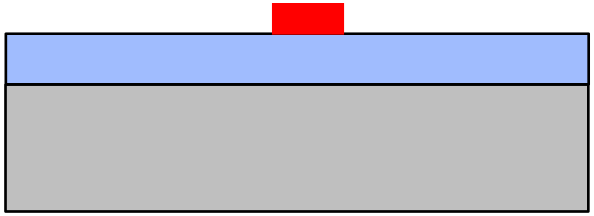
6500Å Field Oxide

3.



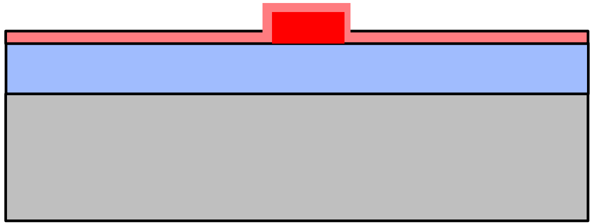
5000Å Poly n-Type

4.



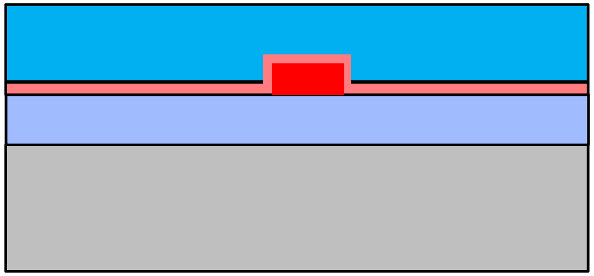
Etched Poly Bottom Electrode

5.



Undoped Poly Etch Stop

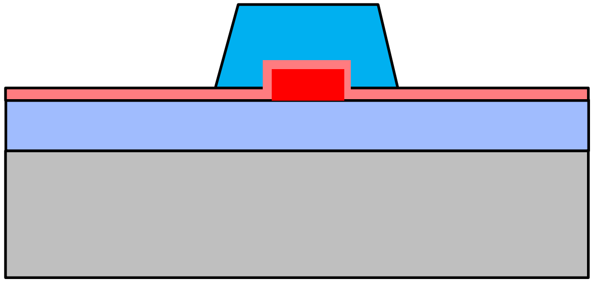
6.



Oxide from TEOS 1.5µm

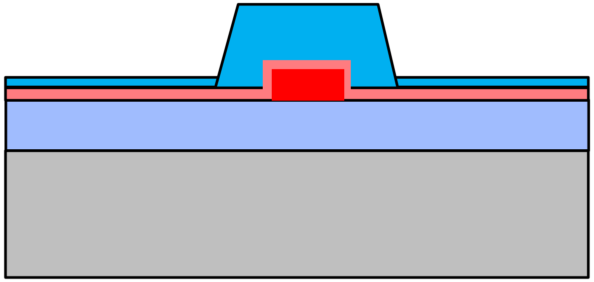
FABRICATION PROCESS

7.



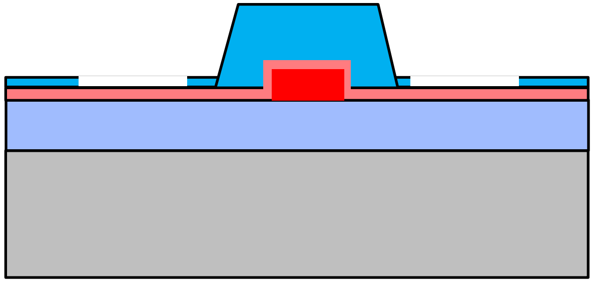
Wet Etch TEOS Sacrificial Oxide

8.



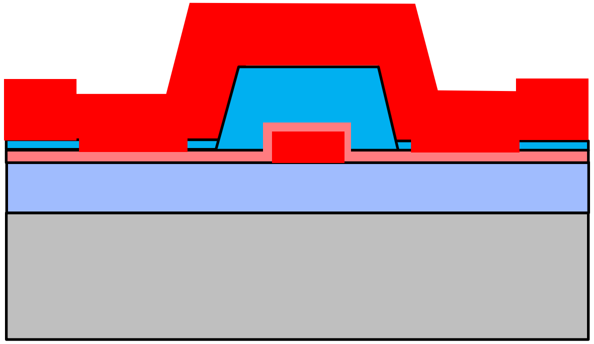
TEOS Etch Stop

9.



Anchor Holes

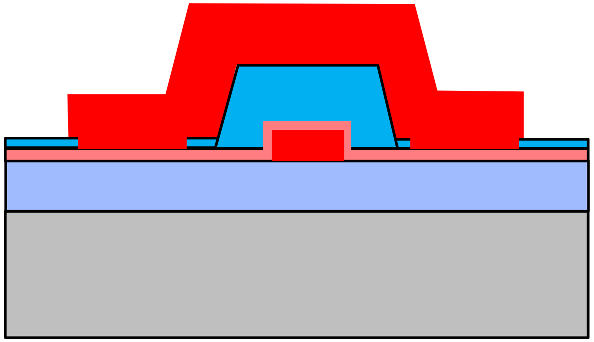
10.



1.5µm Mechanical n+ Poly

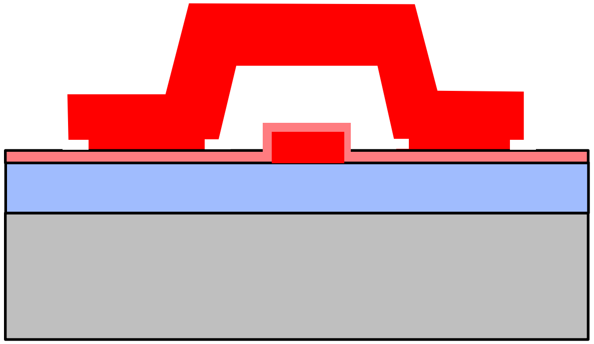
FABRICATION PROCESS

11.



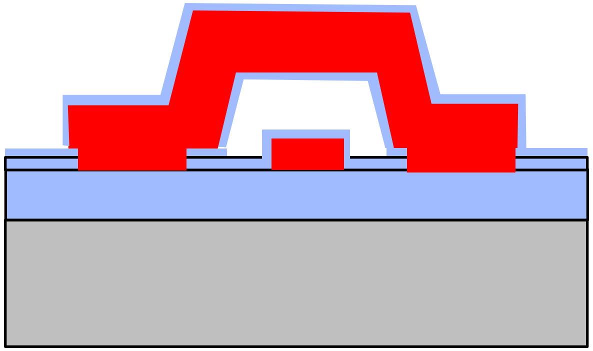
Etch Poly STS Etcher

12.



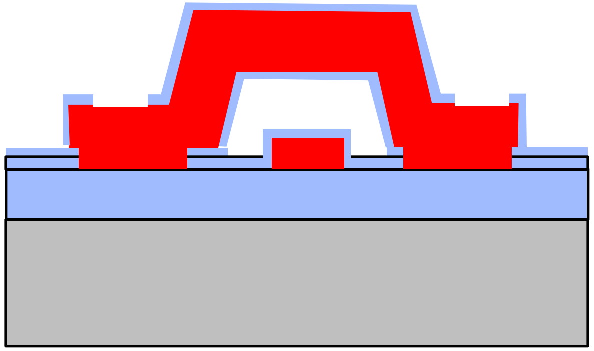
Wet Etch Sacrificial Oxide

13.



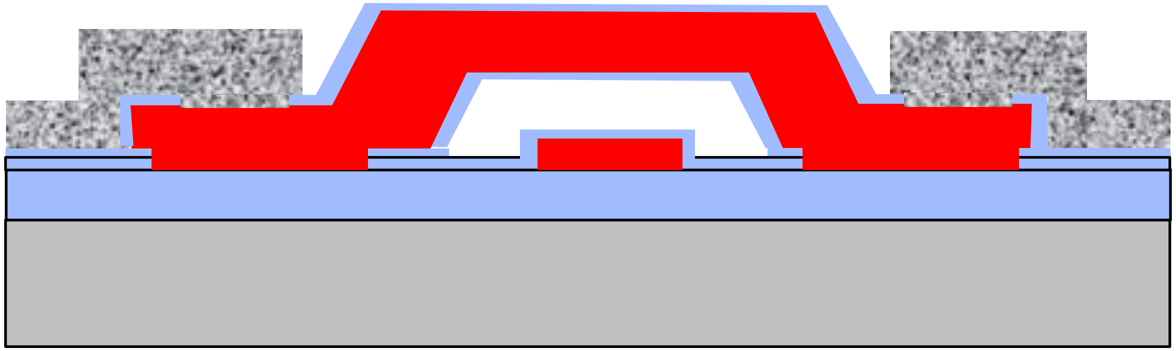
Oxidize Poly

14.



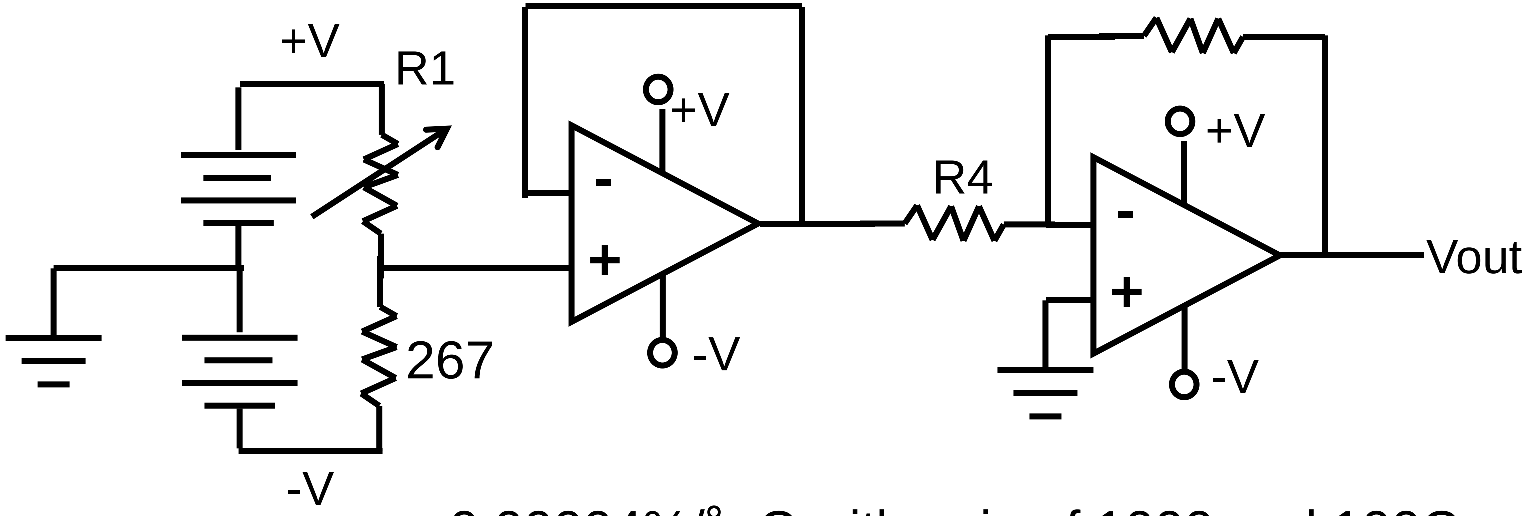
Etch Contact Cuts

FABRICATION PROCESS



Final Cross Section

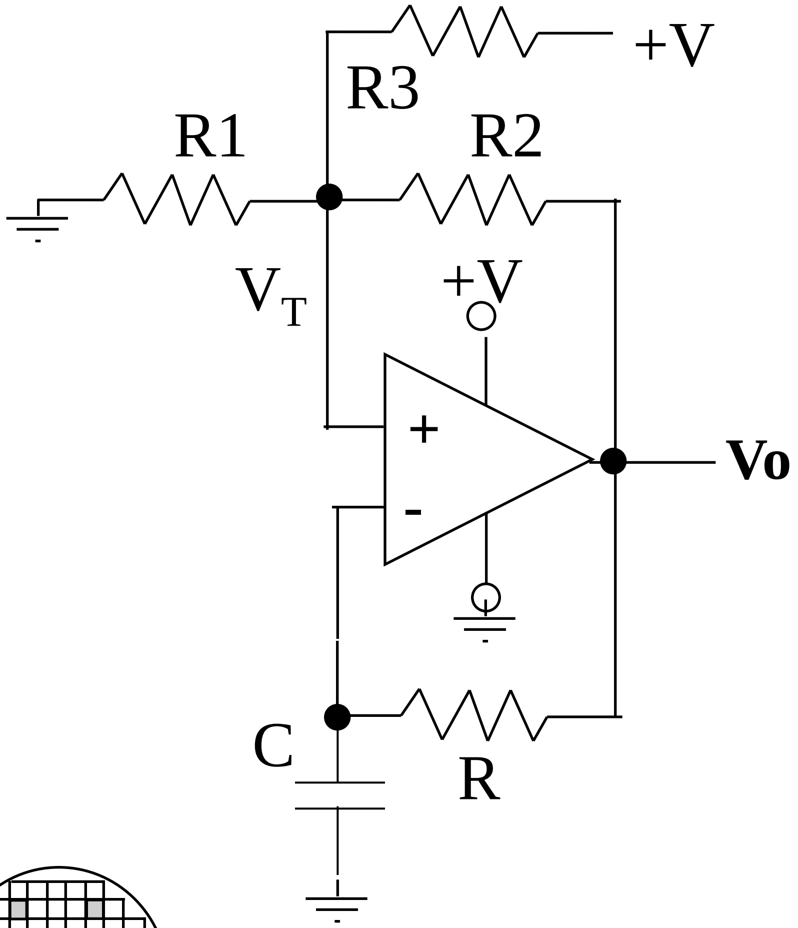
SINGLE RESISTOR SENSOR AMPLIFIER DESIGN

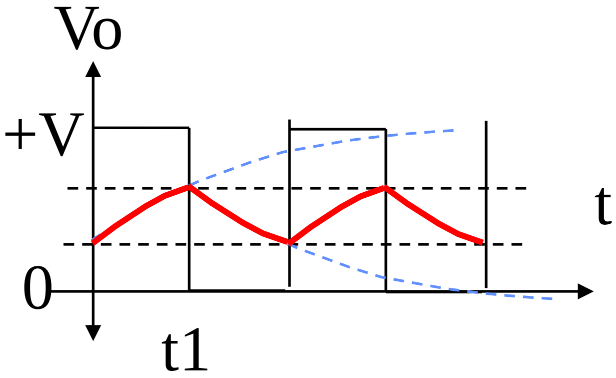


0.00004%/° C with gain of 1000 and 100C

$$Vout = \frac{V(1.004)}{(2.004 - {}^{1}/_{2})} = 3mV$$

SINGLE SUPPLY OSCILLATOR (MULTIVIBRATOR)





Let R1 = 100K, R2=R3=100K
and +V = 3.3
Then V_T = 2.2 when Vo = 3.3
V_T = 1.1 when Vo = 0

PACKAGING AND TESTING

SUMMARY

CMOS Compatible?

REFERENCES

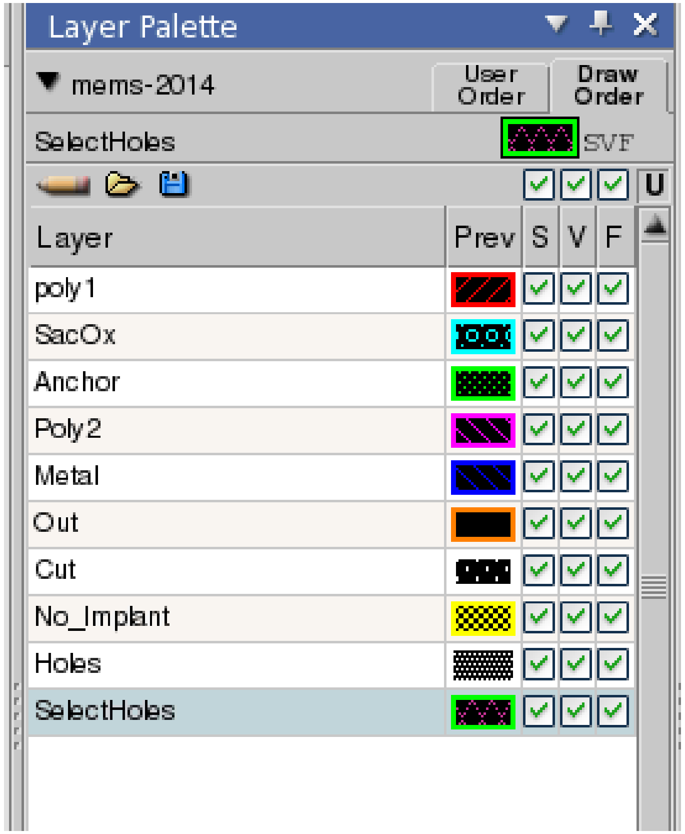
1. Dr. Lynn Fuller’s webpage
2. more

HOMEWORK – PROJECT OVERVIEW

1. Where do design rules come from? What are they for?
2. Why do all individual student designs have to use the same layout layer number for multichip project designs.
3. What are reticles, what are they used for, and how are they made?
4. What does clear field and dark field mask mean? What determines if the reticle should be clear field or dark field?
5. How much does a reticle cost?

HOMEWORK – DESIGN AND LAYOUT

1. Design And Layout a simple cantilever as shown on the following pages.
2. Use the process /tools/ritpub/process/mems-2014
3. Start by drawing an5000um x 5000um outline with lower left corner at (0,0)
4. Setup>Preferences>Selection only check boxes inside the selection rectangle and Intersecting the selection rectangle.



Layer Palette

mems-2014

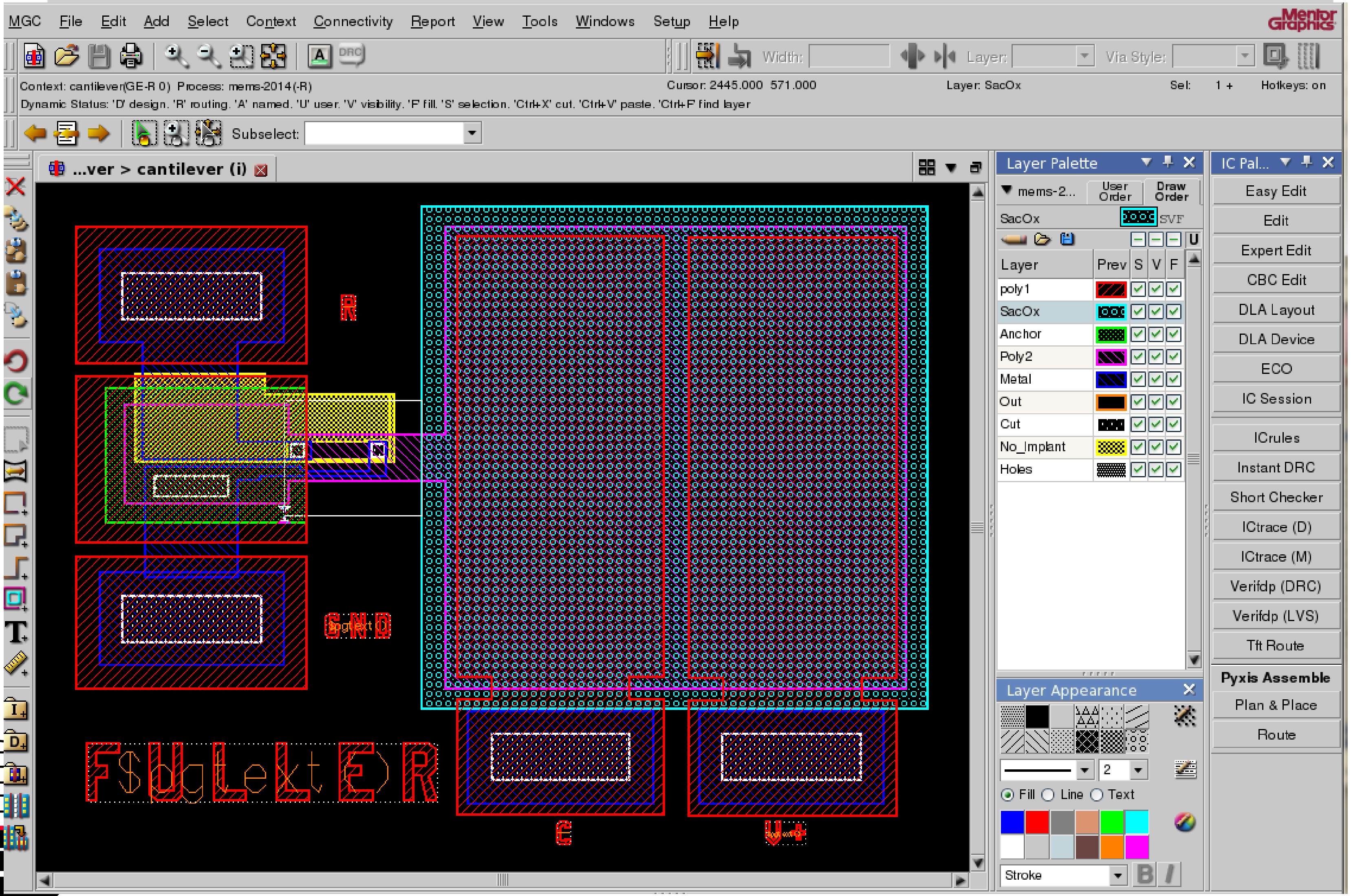
SelectHoles SVF

Layer	Prev	S	V	F
poly1	▨	☑	☑	☑
SacOx	▨	☑	☑	☑
Anchor	▨	☑	☑	☑
Poly2	▨	☑	☑	☑
Metal	▨	☑	☑	☑
Out	■	☑	☑	☑
Cut	▨	☑	☑	☑
No_Implant	▨	☑	☑	☑
Holes	▨	☑	☑	☑
SelectHoles	▨	☑	☑	☑

HOMEWORK – DESIGN AND LAYOUT

5. Draw the simple cantilever similar to that shown in the pictures below.
6. Calculate the force needed to bend the cantilever down by 2um
7. Calculate the electrostatic force created by 10 volts
8. Describe how the resistor sensor works
9. Describe how the capacitor sensor works
10. Print out your final layout.
11. Export the GDS-II file and email to your instructor. Name your files with yourname_cantilever.gds if you send screen captures name it yourname_assignment.png (or .jpg, etc.)

MENTOR GRAPHICS LAYOUT OF CANTILEVER



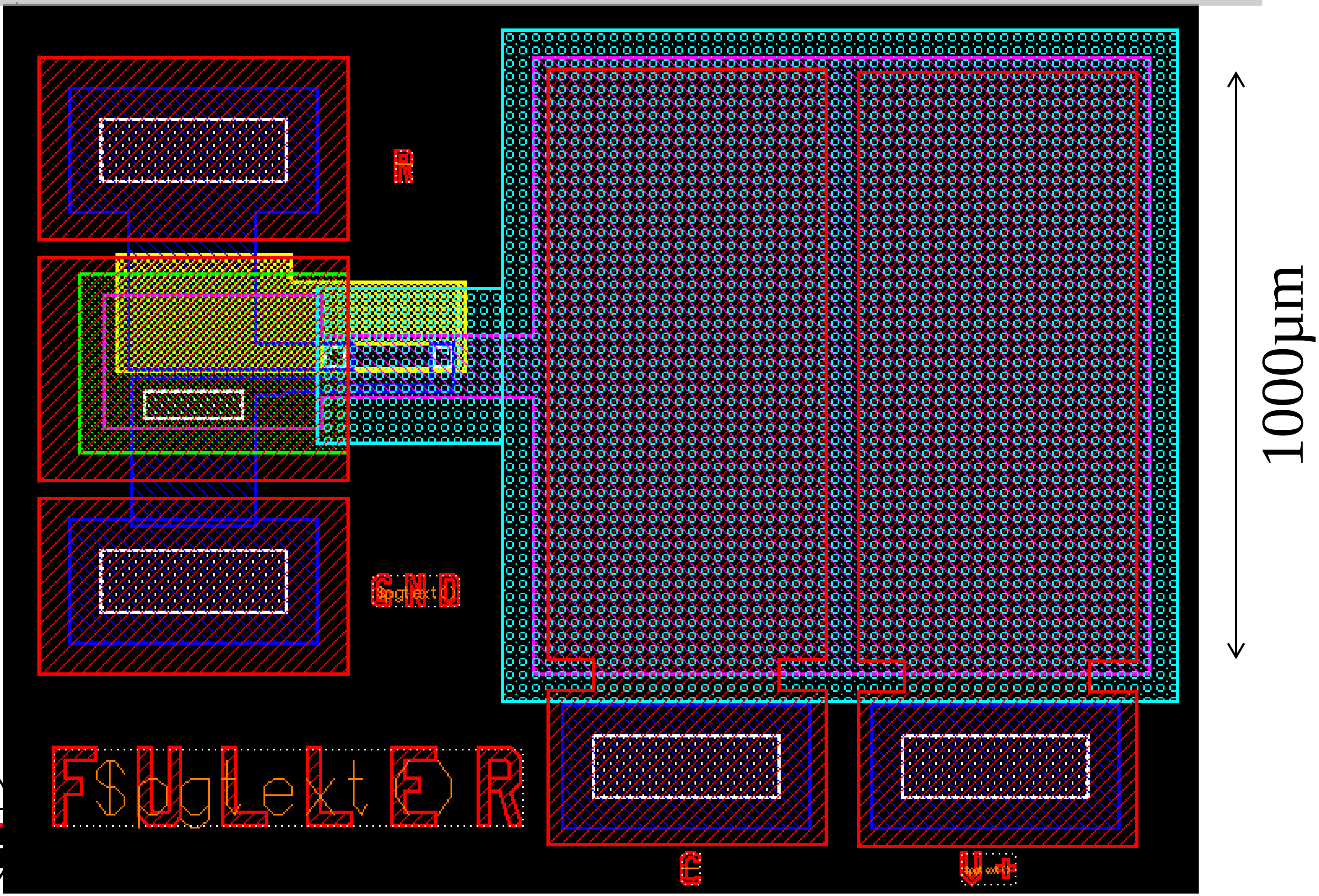
Context: cantilever(GE-R 0) Process: mems-2014(-R) Cursor: 2445.000 571.000 Layer: SacOx Sel: 1 + Hotkeys: on

Dynamic Status: 'D' design. 'R' routing. 'A' named. 'U' user. 'V' visibility. 'F' fill. 'S' selection. 'Ctrl+X' cut. 'Ctrl+V' paste. 'Ctrl+F' find layer

Layer	Prev	S	V	F
poly1	▨	☑	☑	☑
SacOx	▨	☑	☑	☑
Anchor	▨	☑	☑	☑
Poly2	▨	☑	☑	☑
Metal	▨	☑	☑	☑
Out	▨	☑	☑	☑
Cut	▨	☑	☑	☑
No_Implant	▨	☑	☑	☑
Holes	▨	☑	☑	☑

● Fill ○ Line ○ Text

MENTOR GRAPHICS LAYOUT OF CANTILEVER



MENTOR GRAPHICS LAYOUT OF CANTILEVER