A tutorial for the CAD program LayoutEditor

LayoutEditor is available from

www.layouteditor.net

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Common terminology

Layers designate processing steps

Cells are parts, or parts of parts

Top-level cell contains the whole enchilada
Typical example

Side view

Top view

CELL “TRANSISTOR”

Fill/isolation oxide  LAYER 2
Gate oxide  LAYER 3
Gate polysilicon  LAYER 4
Implant dopants  LAYER 5
Metal wiring  LAYER 6
Your design should be a hierarchy of cells

Each cell may contain shapes on many layers, describing how to build separate devices.

To produce one mask plate for one processing step, we pull out one LAYER.

Get it? Cells = devices or parts
Layers = processing steps
A lot of people don’t understand this, so pay attention:

CAD cells are parts of the final device

The cells are contained inside higher level cells.

Inside each cell are found layers which represent steps in the manufacturing process.
To build the device, the cells are “flattened” to remove hierarchy, then the layers are extracted into separate files.

But not until later, and not with the CAD program.

There is a separate program for flattening and extracting layers, and then fracturing the shapes into simple forms that can be printed with the e-beam system.
Remember this:

The top-level cell should look just like the final device.

e.g., alignment marks do not go into a separate FILE they go on a separate LAYER. Do not make this typical, stupid mistake.
Now let’s get started with the CAD program Layout.
Log into the Linux server and open a terminal window (try the right-click menu).

Use “mkdir” to create a directory for your project, then use “cd” to make this the default directory.

Type “layout” to fire up the CAD program.
Create a new cell by clicking on the “new cell” icon, and then give this cell a name by clicking on the “cell name” icon.
Click on a layer to make it the default
Grid → Set Grid
Click on the measurement icon to display coordinates in lower-left of screen.
Polygon mode
Start clicking to draw a polygon

Use the mouse wheel to zoom in & out.
Use the right mouse button (and drag) to pan.
Close the polygon with middle-click. That is, push down on the wheel.
Add a few more shapes on a few more layers, just for fun.

Suppose we need to assign a different dose to one of these shapes. The traditional way is to assign a different “datatype” to the shape. Later, we can map that datatype onto a dose.
Select → Form Select (or Home key)
Click on a shape, then right-click to choose Properties
Datatype is hidden until you click on +
Now change the datatype from the default value of 0 to some other value, such as 1.

Datatypes can be displayed in color using Cview or Beamer.
To set the datatype of a selected group of polygons, use Utilities → Macros → Datatype.

Keep in mind that doses can also be assigned by LAYER. That works fine if you are not using layers to designate processing steps.
Use the Backspace key to clear all selections.
File → Save the file in GDS format.

DXF format is bad. Do not use it.

CIF is not so hot either, but is sometimes useful for algorithmically-generated shapes.
Let's create a new cell called “bar”, and then place the cell “foo” inside it, at a few different locations.
Cell
The cursor now looks like the cell “foo”.

Click

Click

Click
Now let's create an ARRAY of the cell “foo”.

First click on New Cell and then Cell Name, as before.
Click on “cell array” at the upper-left. A dialog box pops up, asking you to choose a cell and to choose the number of rows and columns.
Click to place the lower-left corner, then move the cursor by $\Delta X, \Delta Y$. The shape of the array is displayed as you move the cursor. Click again to create the array.
You’ll probably want to display everything using Zoom Fit All.
If the array does not come out right, do not despair. Use Select → Cell Select (or Page Up) to select the array, and then right click to select Properties.
Here you can change the origin, pitch, and number of rows/columns.
Let's make a circle. Start with the usual “New Cell”, “Cell Name” sequence, then select Utilities → Circular Utilities → Circle
The grid (G) is set to 10 nm. Zoom in with the wheel until you see the grid, then click to set the circle’s center. Move the mouse and click to set a radius of 30 nm.

The number of verticies is too large for such a small circle. More verticies means more shapes, which leads to a lot of wasted settling time during exposure.
Press HOME for “form select”, click on the circle, then right-click to select Properties. Here we can change the number of vertices to 8.
But this is not exactly what we want. Let's rotate the octagon by 22.5° so that it looks like a “stop” sign. The shape is still selected, so just right-click, select Rotate, and enter 22.5°.
That doesn’t look right either. The verticies have snapped off the grid. We can move the verticies manually to put them back on the desired grid. You could press G to switch to a 5 nm grid.
The shape is still selected, so we can use Draw → Move Point (or ^M)
Click on a vertex to pick it up, then move the mouse and click again to put it down. Once the octogon is on the grid, the later shape fracturing for e-beam exposure will result in only three trapezoids.
It’s most likely that you will want to create an array of this cell. That way, when you change the “circle” cell, the entire array changes. But just for the sake of illustration, suppose we want a copy of the polygon. Maybe you’d like to copy it and then change the shape. Start by selecting the polygon and then right-click to choose “copy”. Click, click and you’re done. Note that this is new polygon is separate from the original.
Now measure the area of the shapes. This will be very important for estimating exposure time. Start by selecting all the shapes, using Select → Select All.
Utilities → Measurement Tools → Area
Overlap removal

Use the “merge” function to eliminate overlaps, thereby avoiding double exposures.

(Alternatively, you could use Beamer to remove all overlaps; but then you would lose all dose assignments.)
Select two shapes with [home] and [click], or use “select all”. Use Draw → Merge or type ‘V’ to remove the overlap.
**Boolean operations**

Logical operations such as “and”, “or”, and “not”, as well as +/-, are very useful for designing complex designs.

Layout will let you perform Boolean operations on individual shapes, but this example shows you how to do these operations on entire layers.

First we will assign the label “A” to one layer, and the label “B” to another layer. We will select a third layer to hold the results, and then we will perform an operation such as $A - B$. 
First draw a rectangle on layer 1, and some other shape (such as a circle) on layer 2.
Make layer 1 active (click) then choose Utilities → Boolean → Set active layer to A

Or, use Ctrl-8
Make layer 2 active (click) then choose Utilities → Boolean → Set active layer to B

Or, use Ctrl-9
Click on layer 3 to make it the active layer. Now the result of the Boolean operation will go to layer 3.

Choose Utilities \( \rightarrow \) Boolean \( \rightarrow \) A - B

Or, use 7
Middle-click (with the mouse wheel) on layers 1 and 2, to hide them. Now we can see the results on layer 3.

Naturally, you’ll want to delete the shapes left on layers 1 and 2.

More recent versions of Layout can do the deletion automatically.
**Homework:** Design a simple transistor:

Put square alignment marks on layer 0.

Draw the mesa (silicon island) on layer 1.

Source and drain go on layer 2.

Metal pads go on layer 3.

Alignment marks should be 20 um squares, in the corners. The center of each mark should fall on a 10 um grid; that is, the coordinate of each mark should be a multiple of 10 um.
Sometimes it is handy to mock up the full wafer by creating a higher-level cell.

But you would not print this version with the e-beam writer.

Instead, the e-beam writer will step out the unit cell.

Do not start thinking that you can simplify the job by creating one gigantic “chip” that covers the wafer. There are several reasons why this is not a good strategy.
Optional subjects:

Algorithmic pattern generation

Using photos in CAD

(you can stop here if you are not interested)
Algorithmic CAD

You will find an example C program on sizzlorr, in /public

The program

    write_gds_examples.c

can be compiled by copying this along with /public/makefile, then

    make write_gds_examples
Copy the example to your directory (folder)
Copy the makefile to ‘.’ meaning “here”

We can delete these 5 lines
and replace “make_gds_examples” with “barf”
Make whatever changes you like to the C program
Compile `barf.c` with the command "make barf"

Run it by typing "barf"

Look at the result with Layout or any other CAD program
To combine this GDS file with another GDS file, use “attach” in Layout’s File menu.
Using microscope images in CAD

Start by adding an image to the background. Look in /public for an image.

At this step X and Y can be scaled independently. But rotation does not work right – so do this later as part of cell placement.
The image can be moved around in the background, but it is not part of the design and it is not inside any particular cell. If you need the image in a cell then use “vectorize”.
In the “vectorize” tab, choose “preview” and adjust the parameters. The chosen threshold will be used to turn the image into polygons. The “pixel” method seems to work better than the “threshold” method. Click on the Vectorize button and wait.
Go back to the Setup tab and delete the background image.
The resulting polygons are in the currently active layer.
Now the image is in a cell which can be scaled, rotated, or even exposed.
Create a new cell, then place the image cell inside. Select the cell (Page Up key) then right-click to change its properties. This is the best way to do rotation.
Converting images to exposable shapes

Simple thresholding, as shown above, is not a good way to prepare images for printing with e-beam or photo-lithography.

Since you are using a binary tone printing process, the image should be converted to grey-scale, and then the grey scales should be represented by different densities of dots. This dot representation is called “half tone” or “newsprint”.

Start by opening an image in gimp. (You could instead use Photoshop, but this tutorial uses gimp, which is free and runs on any operating system.)
Convert the image to grayscale, using Image → Mode → Grayscale
Adjust the brightness and contrast, keeping in mind that the bright parts will be exposed as shapes.

If necessary, invert the tone with colors → invert
Convert the image to half-tone using GIMP’s function “Newsprint”
Use a small cell size and oversampling of ~6.
Play with the angle to get the best antialiasing.
Save the image in TIFF format (filename.tif) then convert the bright pixels to polygons in CIF format.

From a terminal window, use

```
tif2gds filename
```

to convert filename.tif to filename.gds

Start the CAD program with the command

```
layout
```

then open the file filename.gds
You can merge this file to another GDS file using File → Attach