EECS 143
Microfabrication
Technology

SAMPLE TUTORIAL

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Introduction

SAMPLE is a simulation package that mimics a real processing laboratory. The machines SAMPLE simulates include an Exposure machine, a Developer machine, an E-beam machine, an Ion-beam machine, an X-ray machine, a Deposition machine and an Etching machine. SAMPLE is based on a model laboratory where the user performs each process step by describing the detailed actions to a technician in the laboratory.

There are three main categories of commands: parameter statements, action commands, and option statements. The parameter statements allow the user to enter the machine and material properties, as well as processing recipes. For instance, in a lithography step, the photoresist properties (e.g. refractive index, thickness), the machine properties (e.g. radiation source wavelength, lens numerical aperture), and the process recipe (e.g. exposure and develop time) would all be specified through parameter statements.

After specifying all the parameters, the process is initiated by an action command. For instance, in lithography simulation an EXPOSERUN would follow the parameter statements identifying the machine type and photoresist properties. Some action commands do allow parameter specification, although in general this is done through parameter statements.

SAMPLE also includes commands for setting various options. These statements allow the user to plot profiles, increase accuracy in numerical computation, address aspects of the program's physical or mathematical models, or utilize some additional program features. For example, the user requests a profile plot through option statements such as OPTIMEXP. Options statements usually have boolean arguments, i.e a 0 turns the option off, while a 1 turns the option on.

In summary, there are three command types: parameter, action, and option. The larger categories, parameter and action, cover most of the physically relevant information necessary for the simulation. Option statements generally address simulation and output issues. By properly specifying the processing environment, almost any recipe can be simulated.

Running Sample on UNIX systems

SAMPLE is generally run in batch mode. First, all the commands are collected in an input file. Then the SAMPLE binary file must be added to your path statement. The binary is located in ~cad/bin. To execute call SAMPLE with: **`sample <inputfile.name> outputfile.name`** This uses inputfile.name as the input, and re-directs the output diagnostics to outputfile.name.

Format of Input Statements

- SAMPLE takes only the first 80 characters of the input line.
- Comments start with the pound sign, "#".
- The numerical numbers can not be in exponential format.
- Each statement ends with a semicolon, ";".
- Input parameters can be separated by either commas, parentheses, or blanks. Tabs are NOT allowed.
- All blanks are skipped over, and should be used to make the input file more readable
- The command words can not be abbreviated.

SAMPLE OUTPUT

Executing SAMPLE results in three types of output: diagnostic information, ASCII line printer plot, and coordinates for high quality plots. The diagnostics and the line plot are sent to the output file, while the coordinate information is stored in a file named "f77punch7". To create the plot, type: **`drawplot f77punch7`** This displays a high quality plot of the profile. When finished viewing the graph, click on it, and the program will ask whether you would like to print the graph. If you type yes, the graph is sent to the ara cluster printer. If you type ‘n’, the graph is then stored in a postscript file "dataplot.ps" which can be printed later.

A complete list of the commands can be found in the on-line user guide, found on the ara cluster in the file ~cad/doc/sample. All the examples in the user guide can be found in the directory ~cad/examples/sample/Dexamp1.7.

Examples

Table 1: Optical Lithography Example

COMMAND	COMMENT
lambda 0.4358;	Set machine wavelength
proj 0.28;	Set numerical aperture of lens
linespace 1.25 1.25;	Specify mask as line/space pattern of 1.25 microns.
imagerun;	Action: Analyze machine and mask pattern
resmodel (0.4358) (0.5510, 0.58, 0.01) (1.68, -0.02) (0.7133);	Set resist parameters: radiation wavelength, sensitivity constants, real and imaginary refractive index, and thickness. The wavelength should be the same as lambda. We will always use the default resist constants.
layers (4.73, -0.14) (1.47,0.0, 0.0741);	Specifies layer thicknesses and refractive indices. The bottom layer (substrate) has a real and imaginary refractive index of 4.73 and -0.14. Since there is no third number, the layer is assumed infinitely thick. The next layer is 0.0741 microns thick. The photoresist thickness and refractive index is specified in the resmodel command.
dose 150;	Specifies exposure time such that a total energy density of 150 millijoules/cm^2 is incident on the mask.
exposerun;	Do exposure
devrate 1 (5.63, 7.43, -12.6);	Specifies development model (1) and the develop constants. We will always use the default constants.
devtime 15 75, 5;	Simulates 5 different develop times equally spaced from 15 to 75 seconds (15, 30, 45, 60, 75 sec.).
optdevelop 0 1 0;	Specifies output information. The first (0) turn off the line plot, the (1) prints a high quality plot, while the last 0 specifies normal computational accuracy
developrun;	Do development

The figure shows the extent of the developing for the 5 different times. The wave pattern is a result of standing waves during the exposure. A perfect opening would be sharp at exactly 0.625.

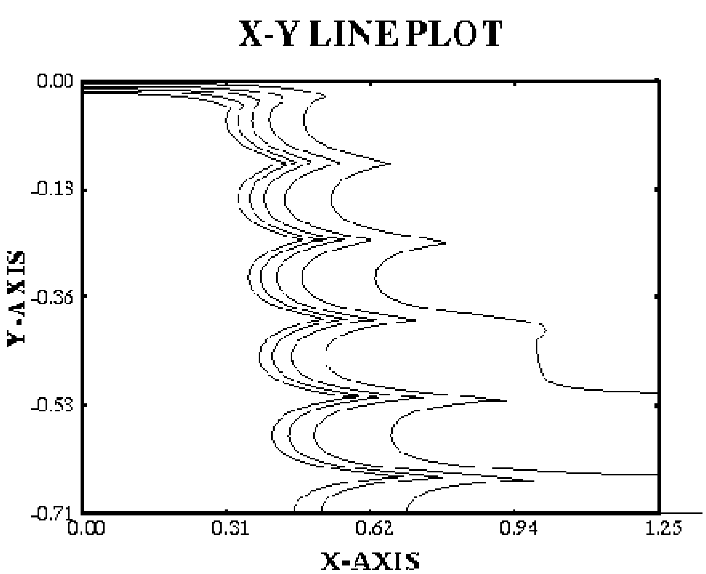

Table 2: Metal Deposition Example

COMMAND	COMMENT
metsrcparm 3 90.0 -90.0 -0.005;	Set deposition machine type. The choices are Unidirectional, Dual source, Hemispherical, Conical, Planetary. The (3) specifies hemispherical, the 90's are the source angles, and the -0.005 is the deposition rate in microns/s (positive means etching, negative means deposition).
metinprof (0.0,0.5) (1.0,0.5) (1.0,1.0) (2.0, 1.0) (2.0,0.5) (3.0,0.5);	Specifies initial profile by piecewise linear x, y coordinates. These coordinates describe a 0.5 micron step.
metgraphf 1;	Turns on plotting
metmaxxz 3.0 2.0;	Specifies width and height of plot.
mettimstep 0 60,3;	Specifies 3 different deposition times equally spaced from 0 to 60 (i.e. 20,40,60).
metrun;	Do deposition

This figure shows the deposition for the 3 time steps. Notice the shadowing of the corners, and the different depostion rates at different locations in the opening.

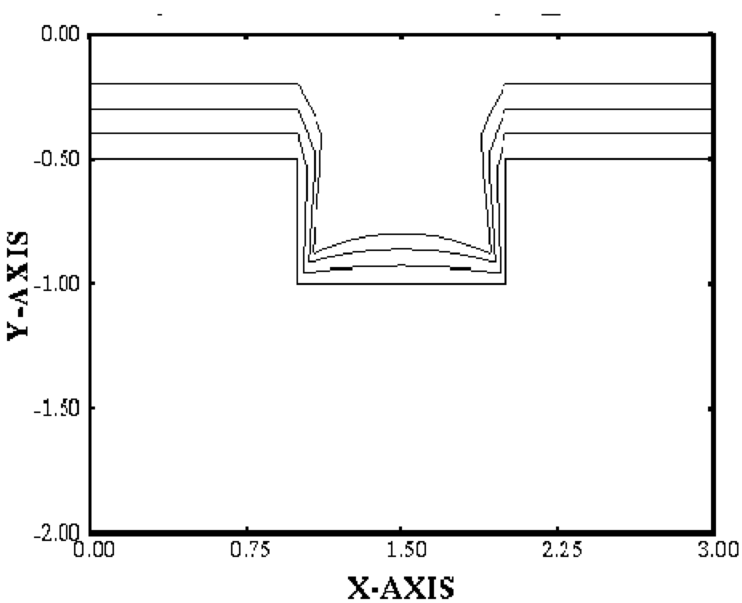

Table 3: Oxide Etching Example

COMMAND	COMMENT
etchnumlay 3;	Specifies 3 layers of material
etchlayers 2 1.0;	Top layer thickness in microns (e.g. photoresist)
etchlayers 1 1.0;	Second to top layer thickness (e.g. oxide)
etchlayers 0 2.0;	Silicon layer thickness. The layer should be as thin as possible to minimize computation.
etchprof (0.0,1.0) (4.0,1.0) (4.2,0.2) (4.5, 0.0) (8.0, 0.0);	Specifies top layer profile in piecewise linear x, y coordinates in microns.
etchrates 10 (0.00083, 0.0) (0.0, 0.00833) (0.0, 0.0);	Specifies etch rate for each layer. The 10 specifies etch model (10), which allows the user to specify both the isotropic and anisotropic etch rate. The top layer (photoresist) etches completely isotropically. The oxide layer etches completely anisotropically. The bottom layer (substrate) doesn't etch at all.
etchplot 1 1;	Turns on both line plot and high quality plotting.
etchwindow 8.0;	Sets plotting window width
etchtime 0,300,6;	Specifies 6 different etch times at equally spaced intervals from 0 to 300 seconds. (0, 60, 120, 180, 240, 300)
etchrun;	Do etching

This figure shows the etching for the five different etch times. The etching of the photoresist increases the final hole size.