ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

2D Process Modeling with Silvaco ATHENA

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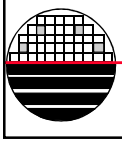

4-30-2014 TCAD-SILVACO.ppt

OUTLINE

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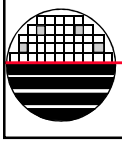
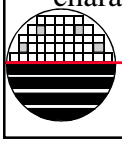


INTRODUCTION

SUPREM – **S**tanford **U**niversity **PR**ocess **E**ngineering **M**odule, 1977

ATHENA is Silvaco, Inc's. version of SUPREM. ATHENA is normally used in conjunction with VWF Interactive tools. These include DECKBUILD, TONYPLOT,DEVEDIT, MASKVIEWS and OPTIMIZER. DECKBUILD provides an interactive run time environment. TONYPLOT supplies scientific visualization capabilities. DEVEDIT is an interactive tool for structure and mesh specification and refinement, and MASKLVIEWS is an IC Layout Editor. The OPTIMIZER supports black box optimizations across multiple simulators. ATHENA is frequently used in conjunction with ATLAS device simulator. ATHENA predicts the physical structure that result from processing. These physical structures are used as input by ATLAS, which then predicts the electrical characteristics associated with specified bias conditions.

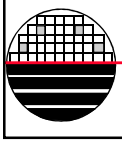


TIPS AND PRINTING TONYPLOT

Tips: The software runs on a UNIX computer. The commands are case sensitive. The pull down menus are often enabled with a right mouse click (RMC) and then the desired selection is made with a left mouse click (LMC).

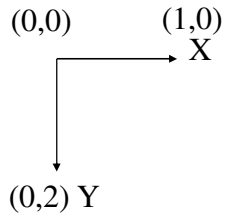
Example: once you run ATHENA you most often generate a graph of the results using the software TONYPLOT. To print the plot you need to do the following:

Pull down Print on the top banner (right mouse click, RMC)
Select Printers (left mouse click, LMC)
Pull down Queue (right mouse click, RMC)
Select prec2 (left mouse click, LMC)
Update
Save Set Up (click on icon at bottom right)
Pull down Print on top banner (RMC)
Select Print view (LMC)

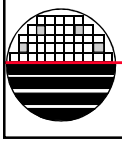


GETTING STARTED

To get started you need to invoke the DECKBUILD application. DECKBUILD will allow you to specify the process steps you want to analyze.

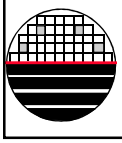


Open terminal window (shell)
Type deckbuild
commands (RMC) select mesh define
commands select mesh initialize (LMC)
commands select process (RMC) deposit (LMC)
select parameters for nitride layer
commands select process (RMC) select implant (LMC)
select parameters for ion implant
tonyplot
quit



DECKBUILD EXAMPLE

```
go athena
#comment lines start with #
#near location 0µm on the x line set grid approximately 0.1 µm
#near location 1µm on the x line set grid approximately 0.1 µm
line x loc=0.00 space=0.1
line x loc=1.00 space=0.1
#near location 0µm on the y line set grid approximately 0.01 µm
#near location 2µm on the y line set grid approximately 0.01 µm
line y loc=0.00 space=0.01
line y loc=2.00 space=0.01
#
init silicon phosphorous resistivity=15 orientation=100
#change nitride thickness to investigate implant penetration
deposit nitride thick=0.30
# dual Pearson model is SIMS verified empirical model
implant boron dose=8.0e12 energy=100 tilt=0 \
        rotation=0 crystal lat.ratio1=1.0 lat.ratio2=1.0
#
tonyplot
quit
```



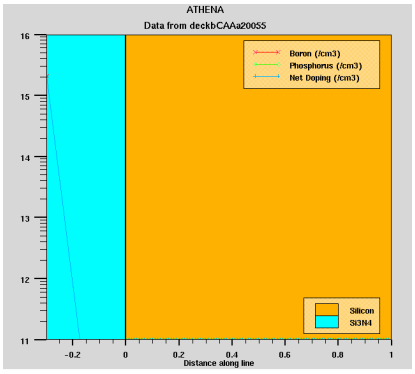
TIPS AND PRINTING DECKBUILD FILE

To print the DECKBUILD file select file on the top banner (right mouse click) and Select Save As (left mouse click) and enter a filename. Then open another HP Term window and at the command prompt type lpr filename <RET>

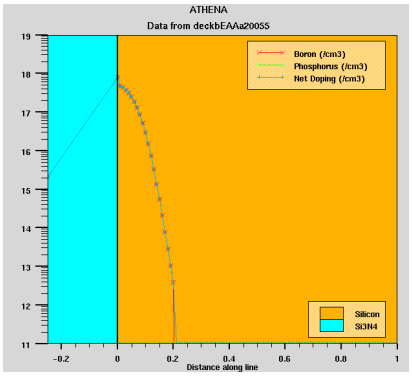
Or

Open terminal window and type nedit then open saved file. Save the file as filename.in and print it or ftp to another account.

TONY PLOT FOR EXAMPLE



3000 Å Nitride



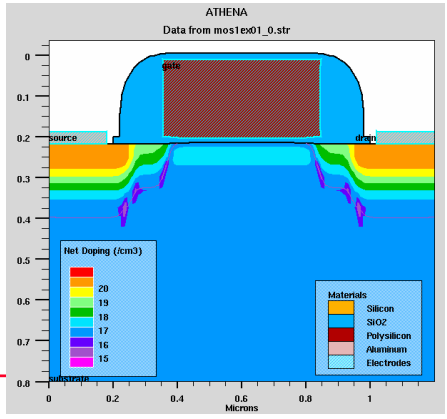
2500 Å Nitride

TIPS ON CAPTURE OF IMAGE

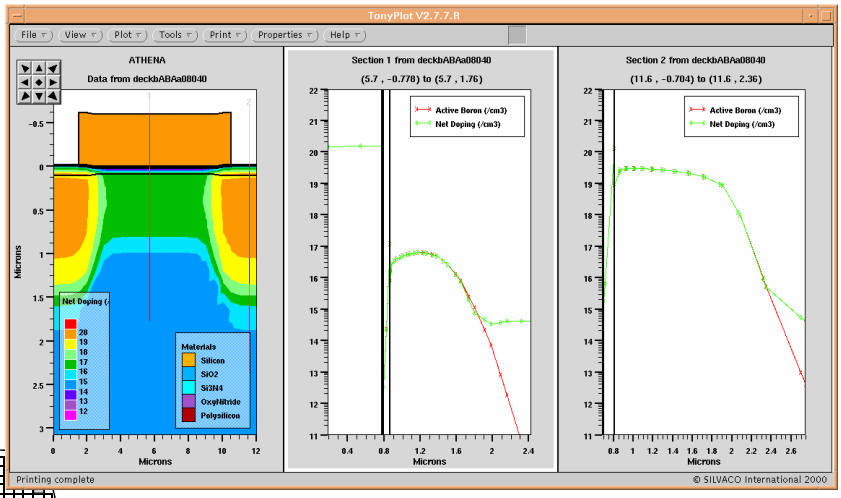
Open a terminal window and type xv
right click on xv software start up page
grab, 5 seconds delay, autograb, move mouse to desired window
wait for xv save window to pop up
select save give a filename.gif
ok
Open another terminal window and type ftp grace.rit.edu
enter (DCE) username and password
put local_filename remote_filename
ftp>quit
Go to PC and invoke Internet explorer
type ftp://username@grace.rit.edu
username and password
open My Computer
click and drag from grace to file location on PC

SUMMARY

Silvaco ATHENA (SUPREM) analysis allows for the calculation of resultant impurity concentrations, layer thickness, and much more for processes such as oxidation, diffusion, implantation and deposition for temperatures above 800 C.



SILVACO ATHENA SIMULATIONS OF D/S IMPLANT



SILVACO ATHENA (SUPREM)

```
go athena
# set grid
line x loc=0.0 spac=0.1
line x loc=1.0 spac=0.05
line x loc=10.0 spac=0.05
line x loc=12.0 spac=0.1

line y loc=0.0 spac=0.01
line y loc=2.2 spac=0.01
line y loc=3.5 spac=0.3
line y loc=6.0 spac=0.5
```

Starting wafer resistivity = 11.3 ohm-cm

```
init silicon phosphor resistivity=11.3 orientation=1.00 space.mult=5.0

# ramp up from 800 to 900°c soak 50 min dry o2, ramp down to 800 n2
diff time=10 temp=800 t.final=900 dryo2 press=1.0 hcl.pc=0
diff time=50 temp=900 dryo2 press=1.0 hcl.pc=0
diff time=20 temp=900 t.final=800 nitro press=1.0 hcl.pc=0
```

Grow Kooi oxide 1000 Å

```
deposit photoresist thickness=1.0
etch phtotoresist left ;1.x=2.0
etch photoresist right p1.x=10.00
```

Ion Implant P-type D/S at Dose = 1E15

```
# ion implant drain and source
implant boron dose=1e15 energy=70 tilt=0 rotation=0 crysatal lat.ratio1=1.0 lat.ratio2=1.0

Etch photoresist all
```

Strip photoresist

```
# ramp up from 800 to 1000°c soak 90 min, ramp down to 800 n2
diff time=20 temp=800 t.final=1000 nitro press=1.0 hcl.pc=0
diff time=90 temp=1000 nitro press=1.0 hcl.pc=0
diff time=40 temp=1000 t.final=800 nitro press=1.0 hcl.pc=0
```

Anneal D/S implant

SILVACO ATHENA (SUPREM)

Ion Implant P-type channel at Dose = 0, 4E12, 4e11, 1e12

```
# ion implant channel
implant boron dose=4e12 energy=100 tilt=0 rotation=0 crysatal lat.ratio1=1.0 lat.ratio2=1.0

etch oxide all

# ramp up from 800 to 1000°c soak 90 min dry o2, ramp down to 800 n2
diff time=20 temp=800 t.final=1000 dryo2 press=1.0 hcl.pc=0
diff time=90 temp=1000 dryo2 press=1.0 hcl.pc=0
diff time=40 temp=1000 t.final=800 nitro press=1.0 hcl.pc=0
```

Grow 700 Å gate oxide

```
deposit nitride thick=0.010
```

Deposit 100 Å nitride

```
# ramp up from 800 to 1000°c soak 50 min dry o2, ramp down to 800 n2
diff time=10 temp=800 t.final=1000 dryo2 press=1.0 hcl.pc=0
diff time=50 temp=1000 dryo2 press=1.0 hcl.pc=0
diff time=20 temp=1000 t.final=800 nitro press=1.0 hcl.pc=0
```

Temp cycle for growth of oxynitride

```
deposit oxynitride thick=0.01
```

Deposit 100 Å oxynitride

```
deposit poly thick=0.60 c.phosphor=4e20
```

Deposit 6000 Å poly

```
# ramp up from 800 to 1000°c soak 30 min, ramp down to 800 n2
diff time=20 temp=800 t.final=1000 nitro press=1.0 hcl.pc=0
diff time=30 temp=1000 nitro press=1.0 hcl.pc=0
diff time=40 temp=1000 t.final=800 nitro press=1.0 hcl.pc=0
```

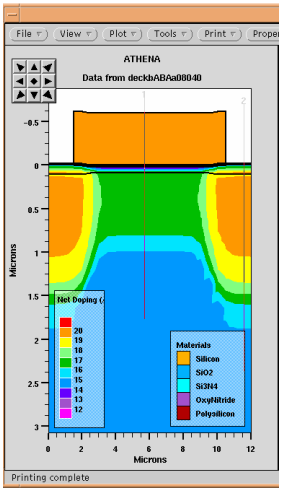
Temp cycle for poly dope

SILVACO ATHENA (SUPREM)

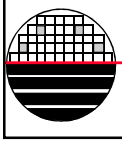
```
etch poly left p1.x=1.5
etch poly right p1.x=10.5

etch oxynitride left p1.x=1.5
etch oxynitride right p1.x=10.5

etch nitride left p1.x=1.5
etch nitride right p1.x=10.5

etch oxide left p1.x=1.5
etch oxide right p1.x=10.5

deposit alumin thick=0.5
```

Deposit 5000 Å aluminum

```
etch alum start x=1.0 y= -2.0
etch cont x=1.0 y= 2.0
etch x=11.0 y= 2.0
etch done x=11.0 y= -2.0

struct outfile=UofH.str

tonyplot UofH.str

quit
```

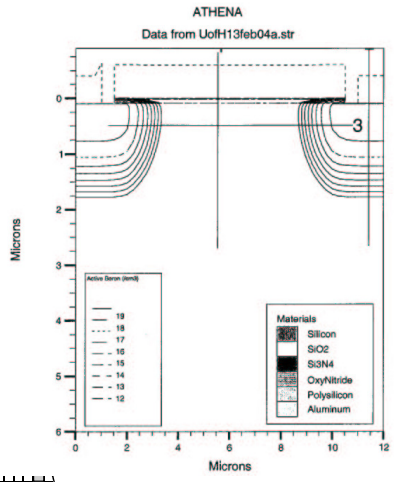


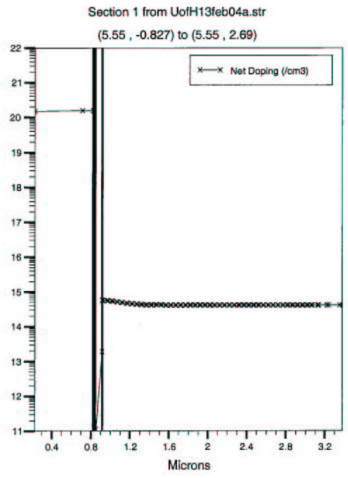
Tonyplot example Only



Process Modeling - TCAD

SILVACO ATHENA (SUPREM)





Process Modeling - TCAD

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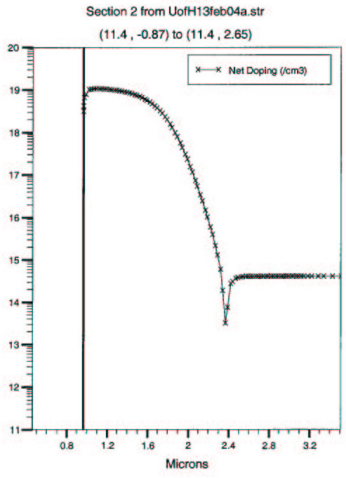

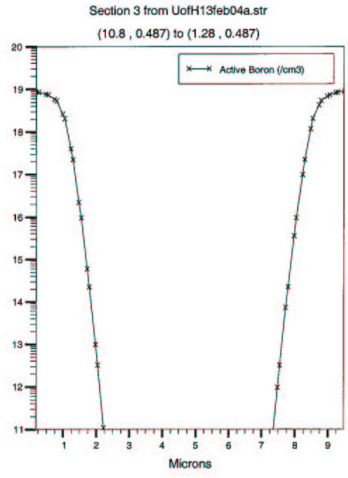

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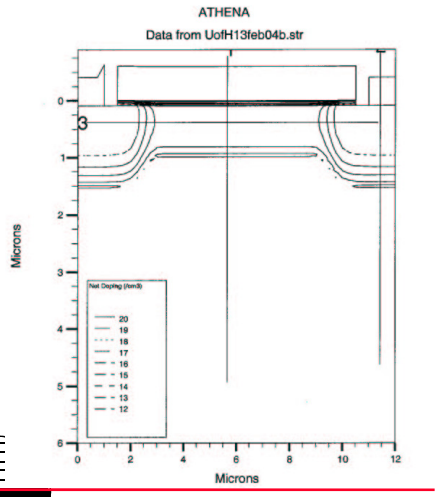

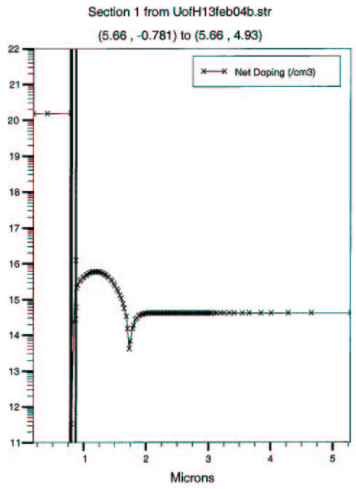

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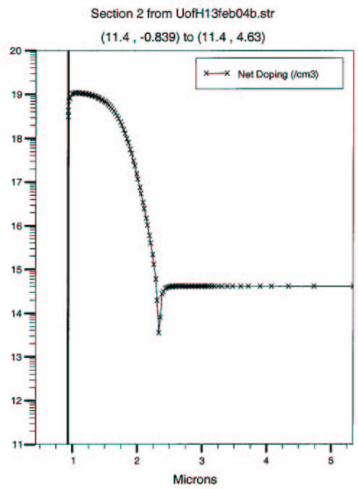

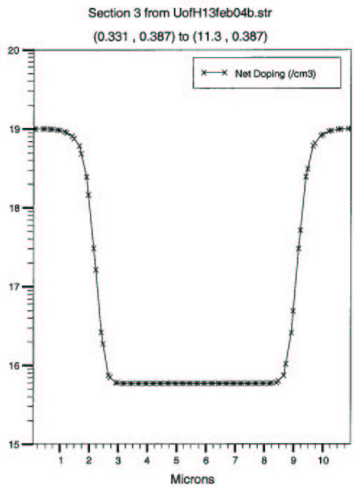

Process Modeling - TCAD

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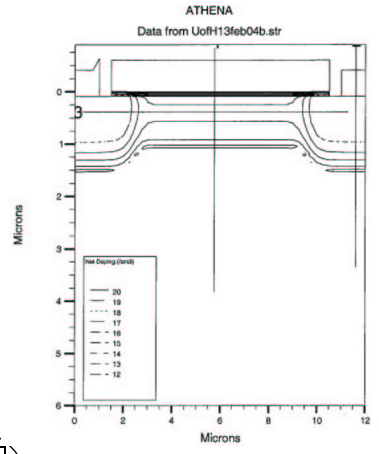
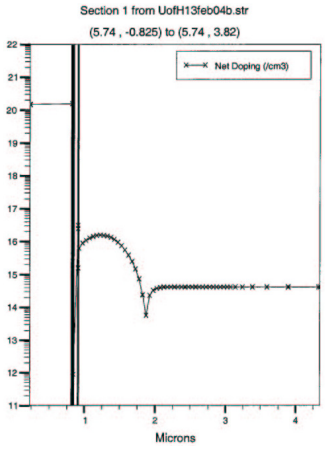
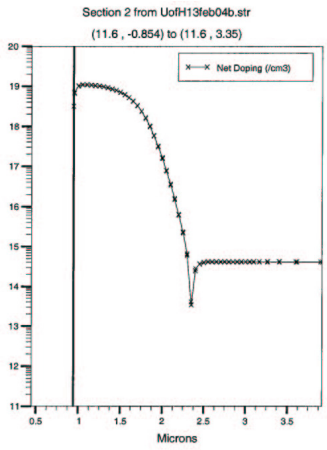
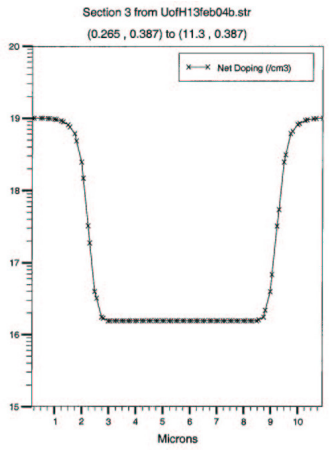




Process Modeling - TCAD

SILVACO ATHENA (SUPREM)





SILVACO ATLAS (DEVICE SIMULATOR)

```
Go athena
Init infile=UofH.str
```

Read in structure file created by Athena

```
#name the electrodes…
Electrode name=gate x=6
Electrode name=source x=0
Electrode name=drain x=12
Electrode name=substrate backside
```

Define location of gate, source and drain

```
Extract name="vt" 1dvt ptype qss=1e11 workfunc=4.11 x.val=6

Go atlas

# define the gate workfunction
Contact name=gate n.poly
# define the Gate Qss
Interface qf=1e11

# use the cvt mobility model for MOS
Models cvt srh

# set gate biases with Vds=0.0
Solve init
Solve vgate=0 outf=solve_temp0
Solve vgate=-1 outf=solve_temp1
Solve vgate=-1 outf=solve_temp2
Solve vgate=-3 outf=solve_temp3
Solve vgate=-4 outf=solve_temp4
Solve vgate=-5 outf=solve_temp5
```

Step gate voltage from 0 to –5 volts in 1 volt steps

```
# load in temporary file and ramp Vds
Load infile=solve_temp0
Log outf=Vg_0.log
Solve name=drain vdrain=0 vfinal=-5 vstep=-0.5
```

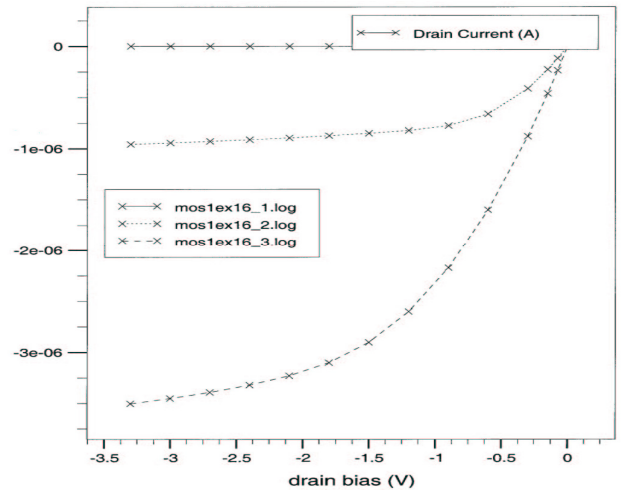

SILVACO ATLAS (DEVICE SIMULATOR

```
# load in temporary file and ramp vds
load infile=solve_temp1
log outf=vg_1.log
solve name=drain vdrain=0 vfinal=-5 vstep=-0.5

# load in temporary file and ramp vds
load infile=solve_temp2
log outf=vg_2.log
solve name=drain vdrain=0 vfinal=-5 vstep=-0.5

# load in temporary file and ramp vds
load infile=solve_temp3
log outf=vg_3.log
solve name=drain vdrain=0 vfinal=-5 vstep=-0.5

# load in temporary file and ramp vds
load infile=solve_temp4
log outf=vg_4.log
solve name=drain vdrain=0 vfinal=-5 vstep=-0.5

# load in temporary file and ramp vds
load infile=solve_temp5
log outf=vg_5.log
solve name=drain vdrain=0 vfinal=-5 vstep=-0.5
```

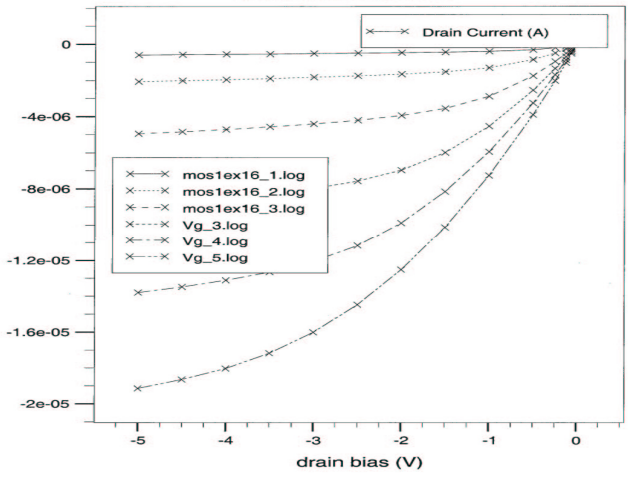
Sweep drain voltage from 0 to –5 volts in 0.5 volt steps

```
# extract max current and saturation slope
extract name="pidsmax" max(abs(i."drain"))
extract name="p_sat_slope" slope(minslope(curve(abs(v."drain"), abs(i."drain"))))

tonyplot –overlay vg_0.log vg_1.log vg_2.log vg_3.log vg_4.log vg_5.log –set mos1ex09_1
quit
```

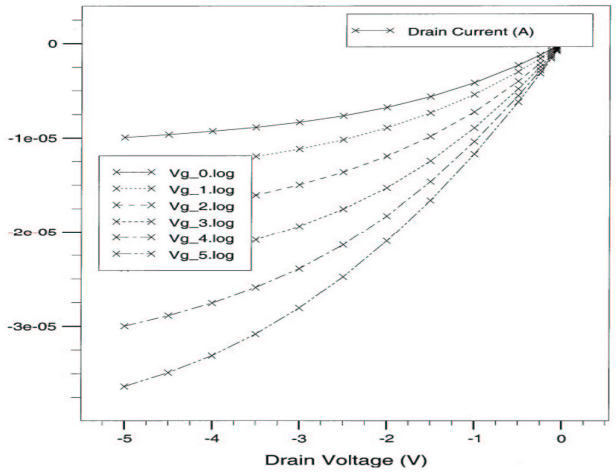
ATLAS SIMULATED FAMILY OF CURVES



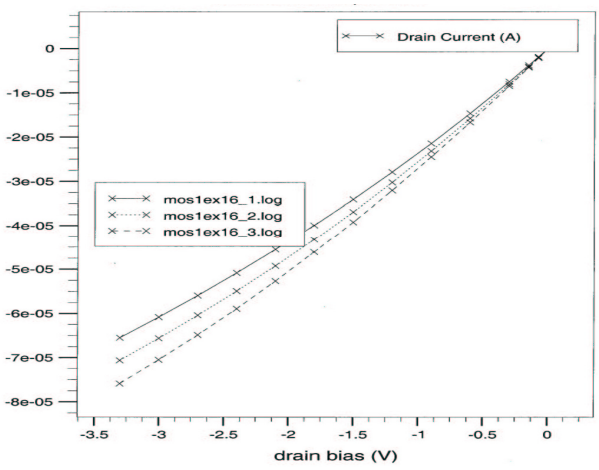
ATLAS SIMULATED FAMILY OF CURVES



ATLAS SIMULATED FAMILY OF CURVES



ATLAS SIMULATED FAMILY OF CURVES



REFERENCES

1. Silicon Processing for the VLSI Era, Vol.2., Stanley Wolf
2. The Science and Engineering of Microelectronic Processing, Stephen Campbell
3. Technology Modeling Associates, TMA-SUPREM-4, Instruction Manual.
4. Silvaco Modeling, Inc.
5. MicroTec-3.03 release note of March 27, 1998 floppy-disk contains a complete set of MicroTec-3.03 programs for 2D semiconductor process and device simulation and the Manual in Adobe Acrobat format. http://www.siborg.ca