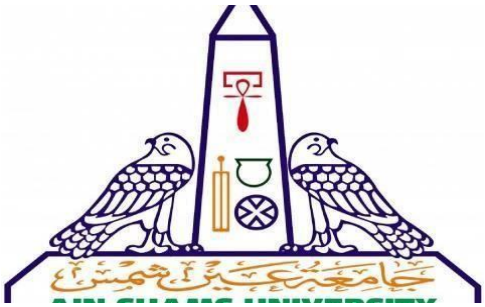

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTRONICS & COMMUNICATION ENG. DEPT.

**4TH year**

FIRST SEMESTER

2019-2020

# IC Technolog

# CMOS fabrication using silvaco tool

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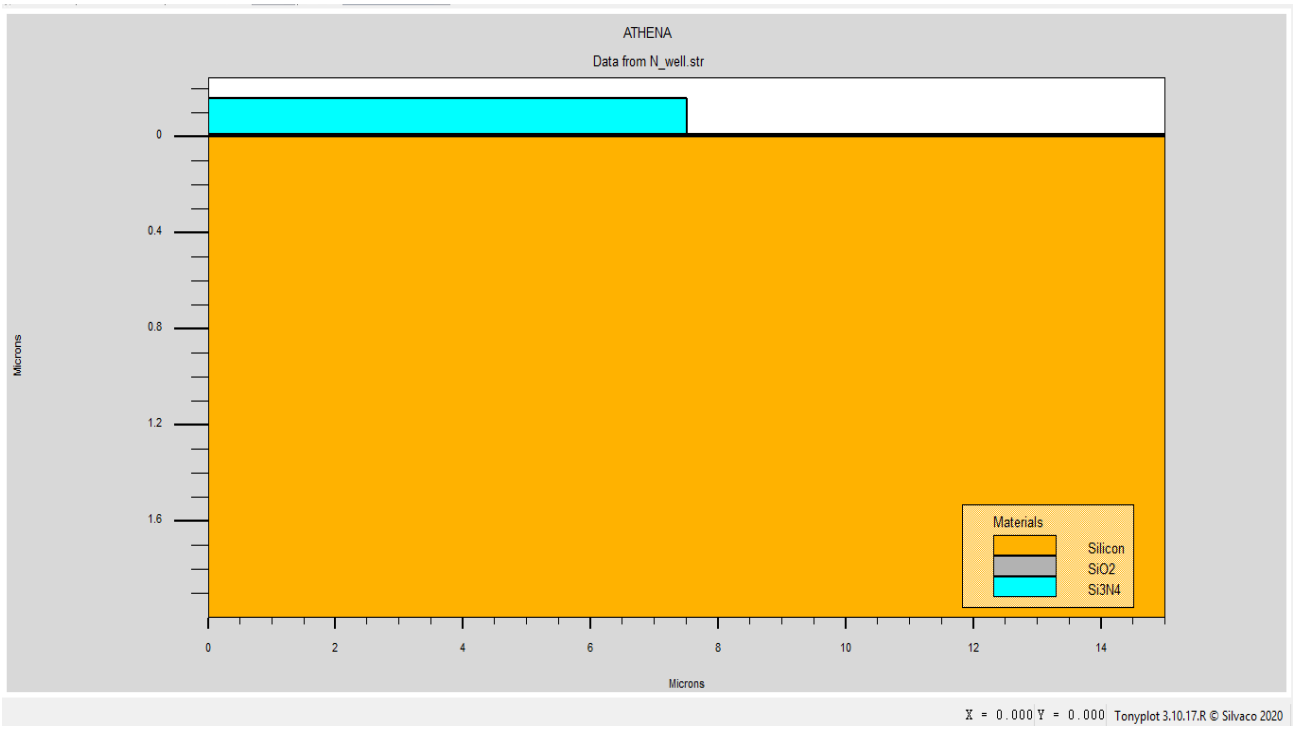
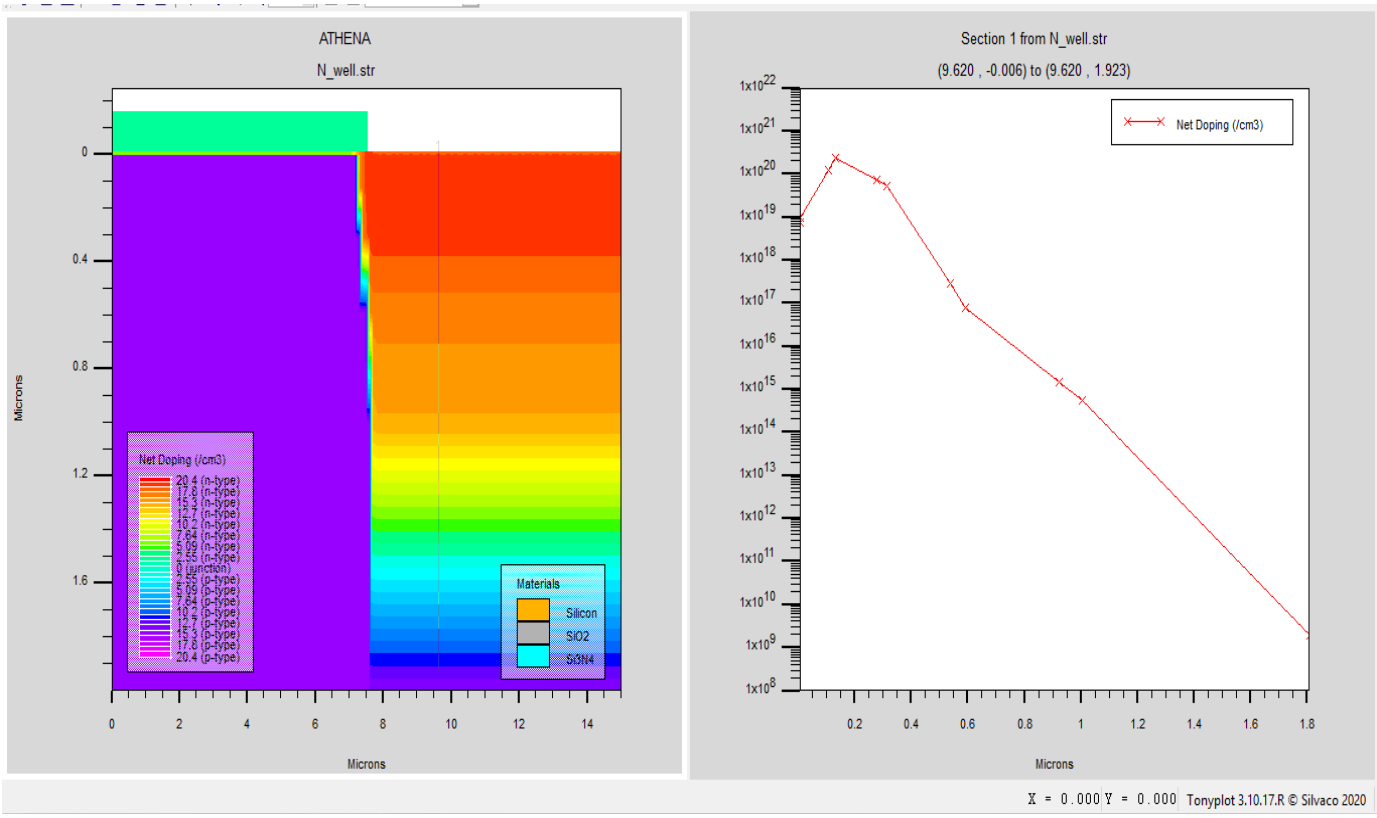
Submitted to : prof / Hany Fakry

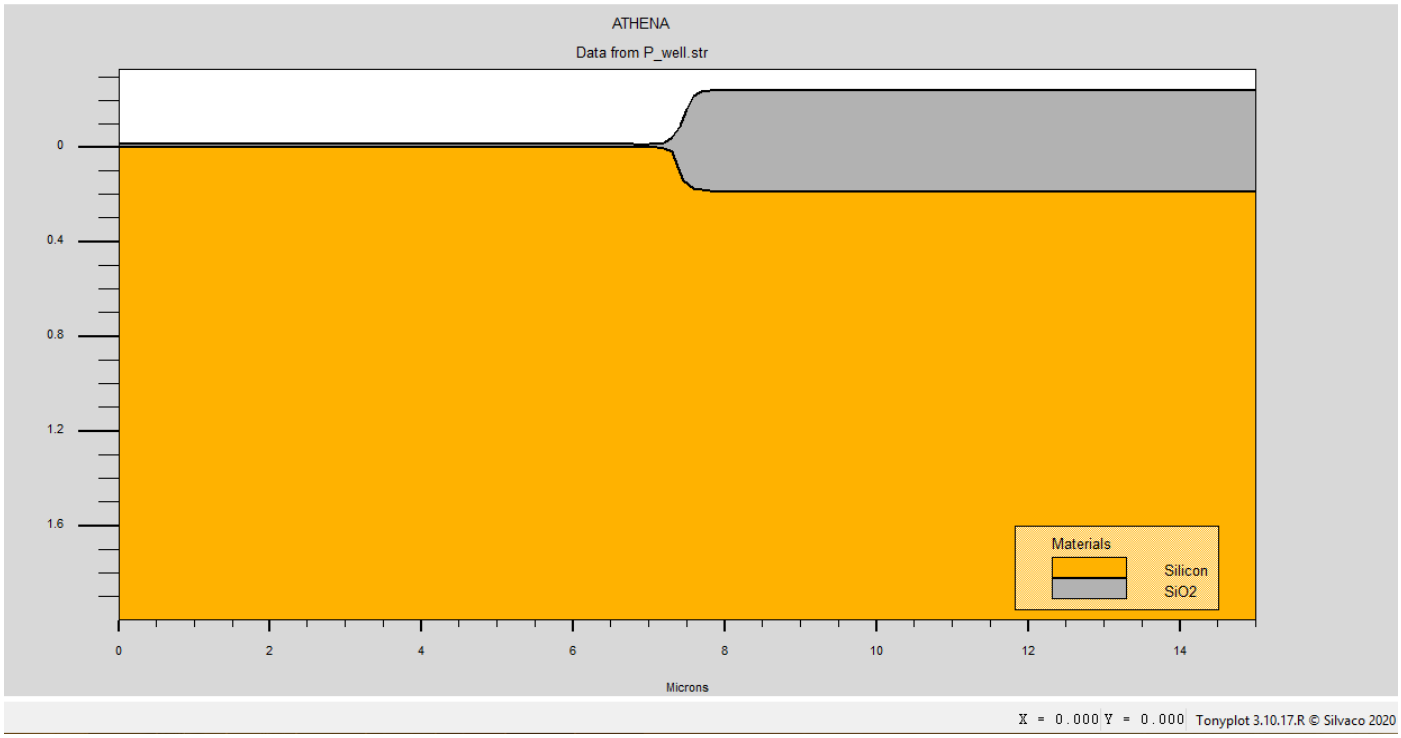
2/2/2020

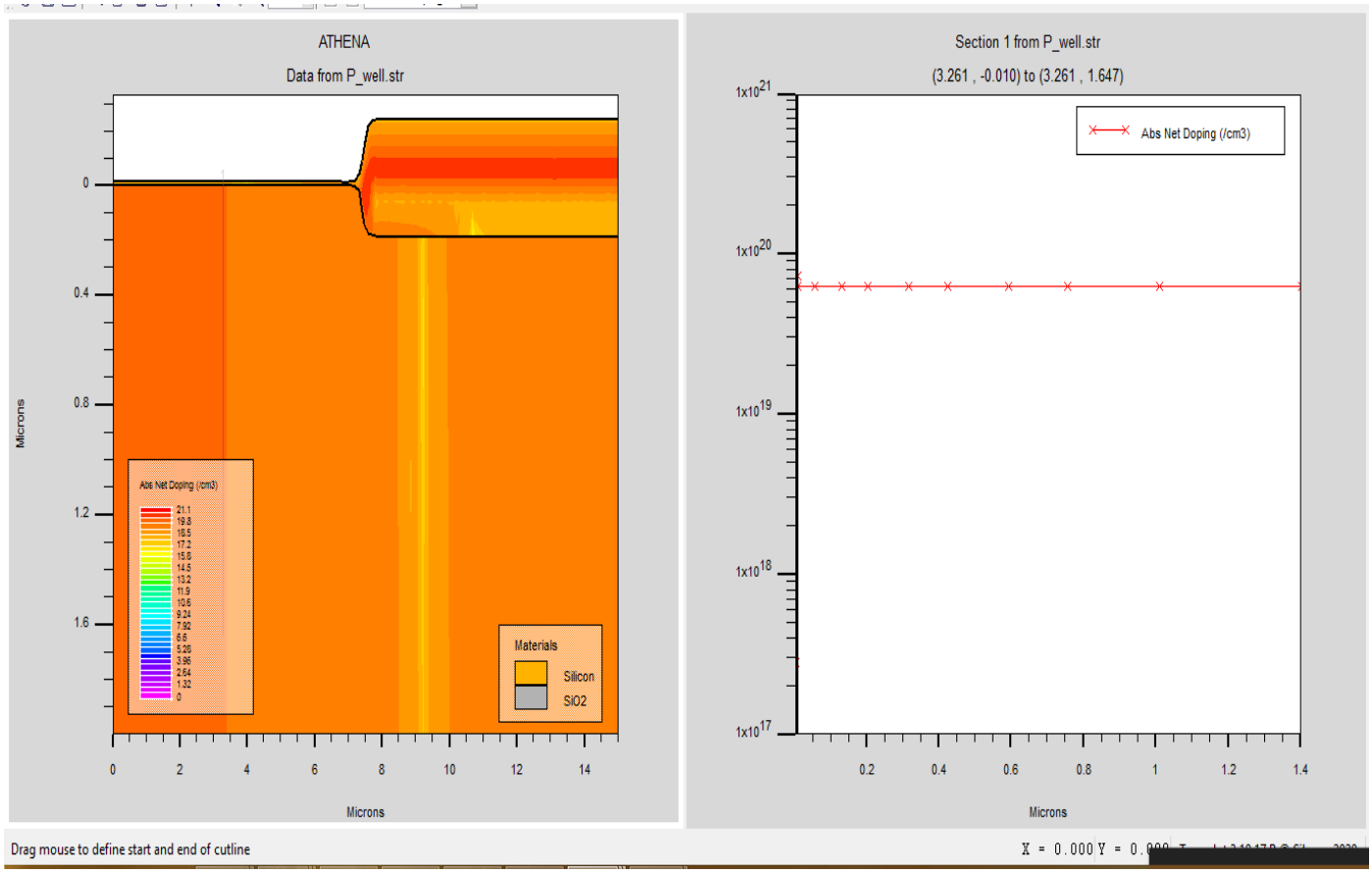
## N-well : make N-well in p-substrate:



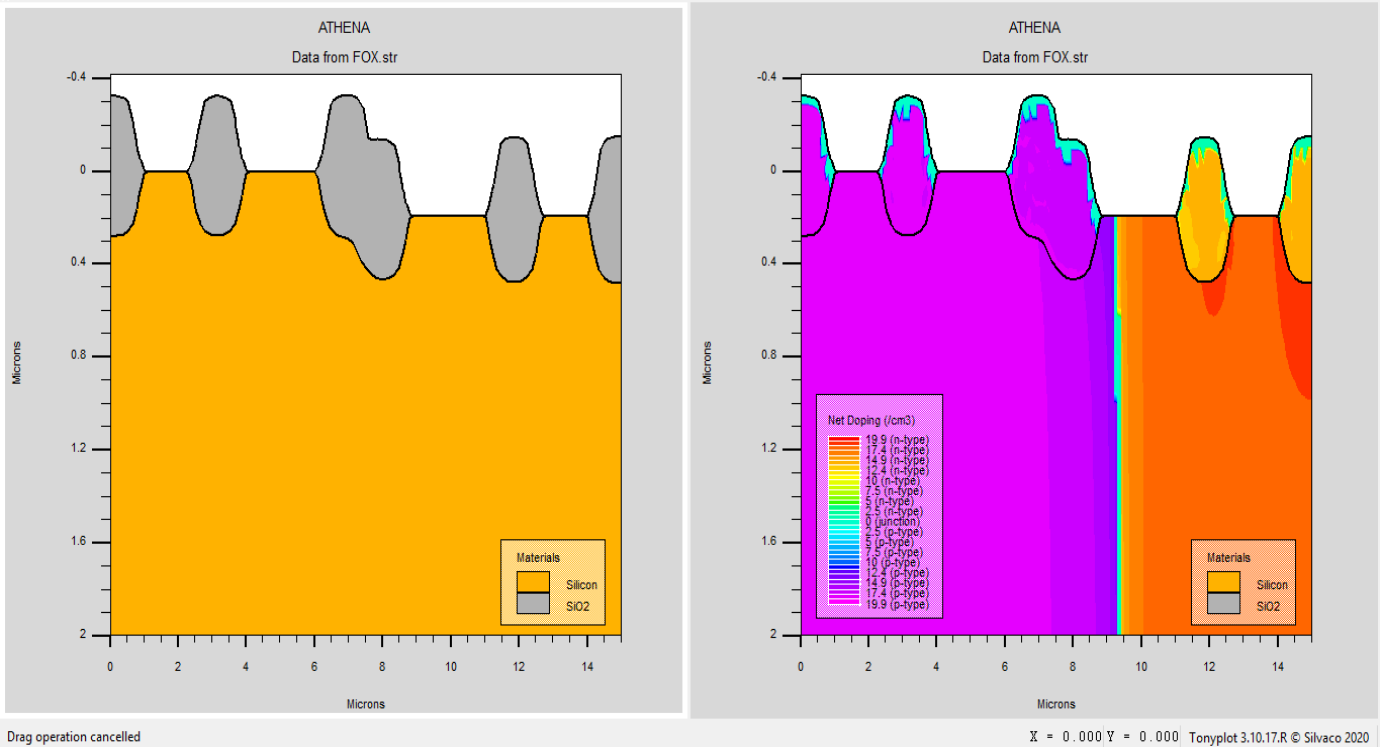



## P-well : make p-well in p-substrate:

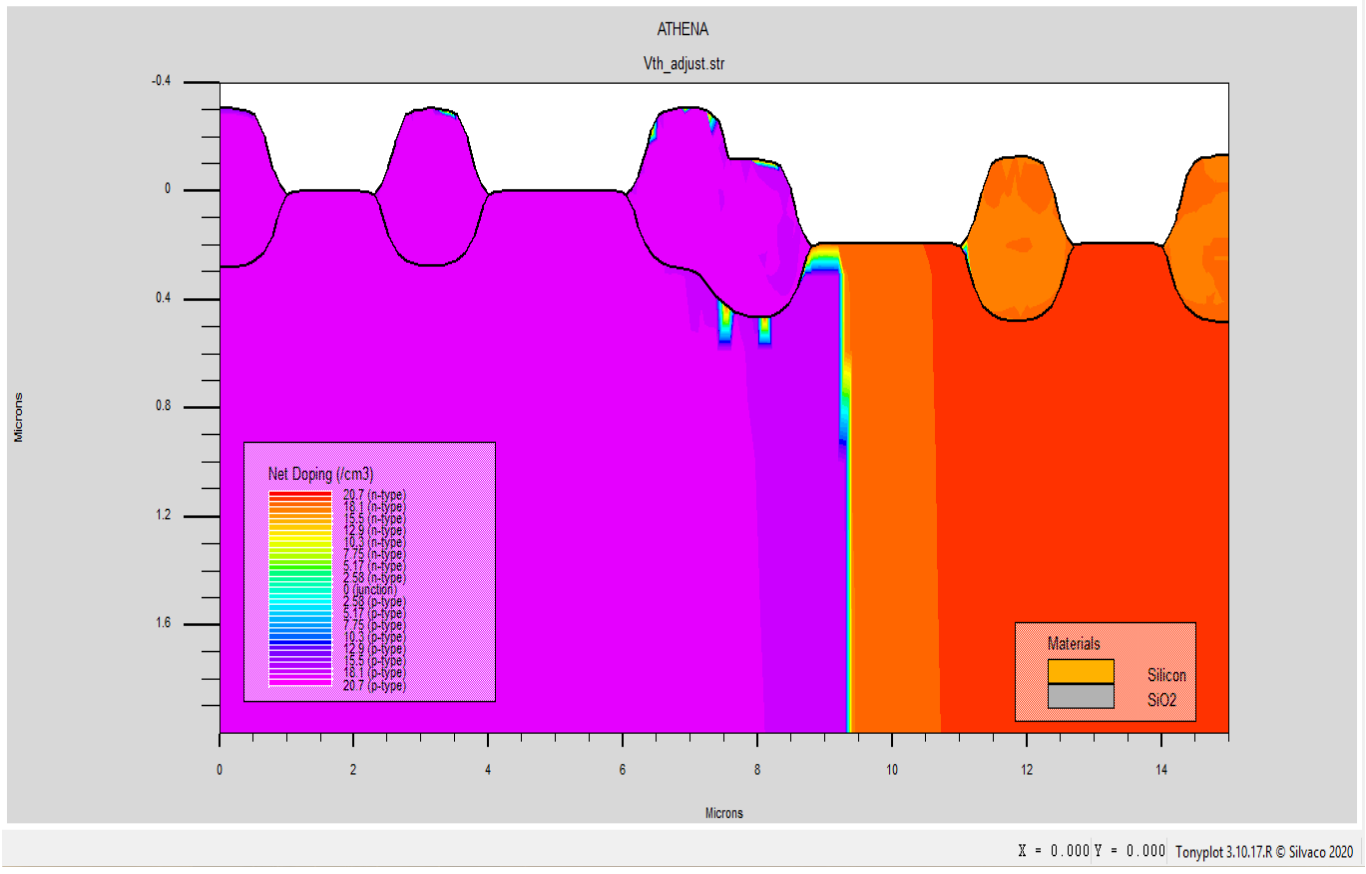


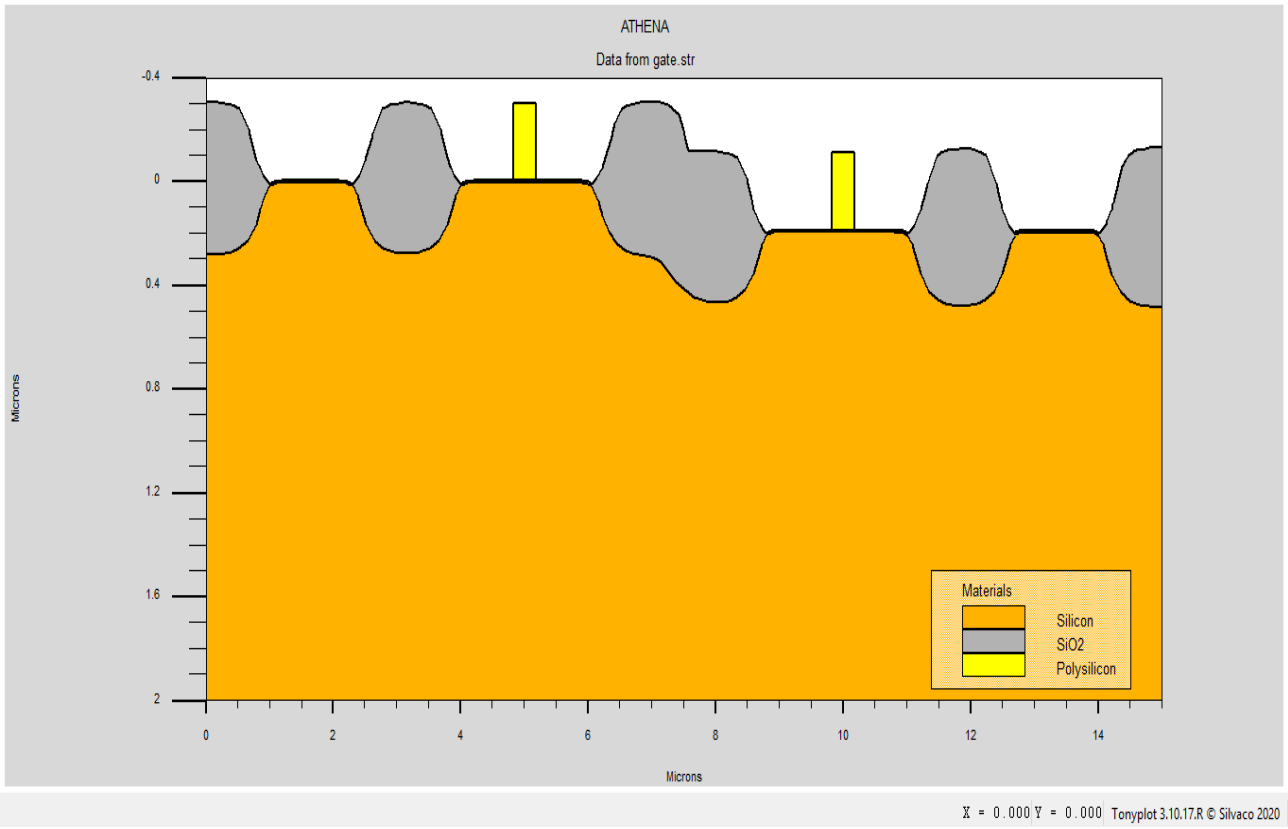
## FOX :



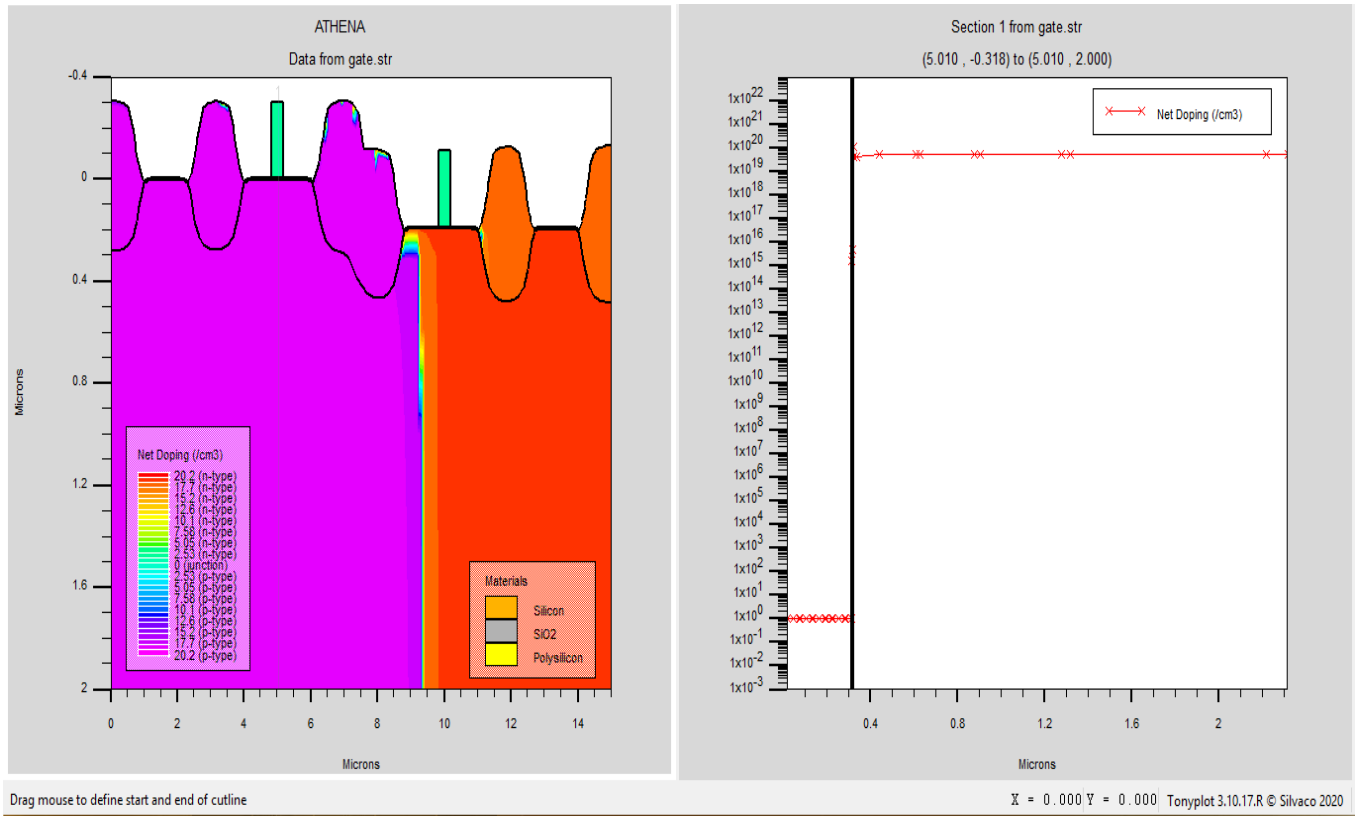

## PMOS Vth adjust:



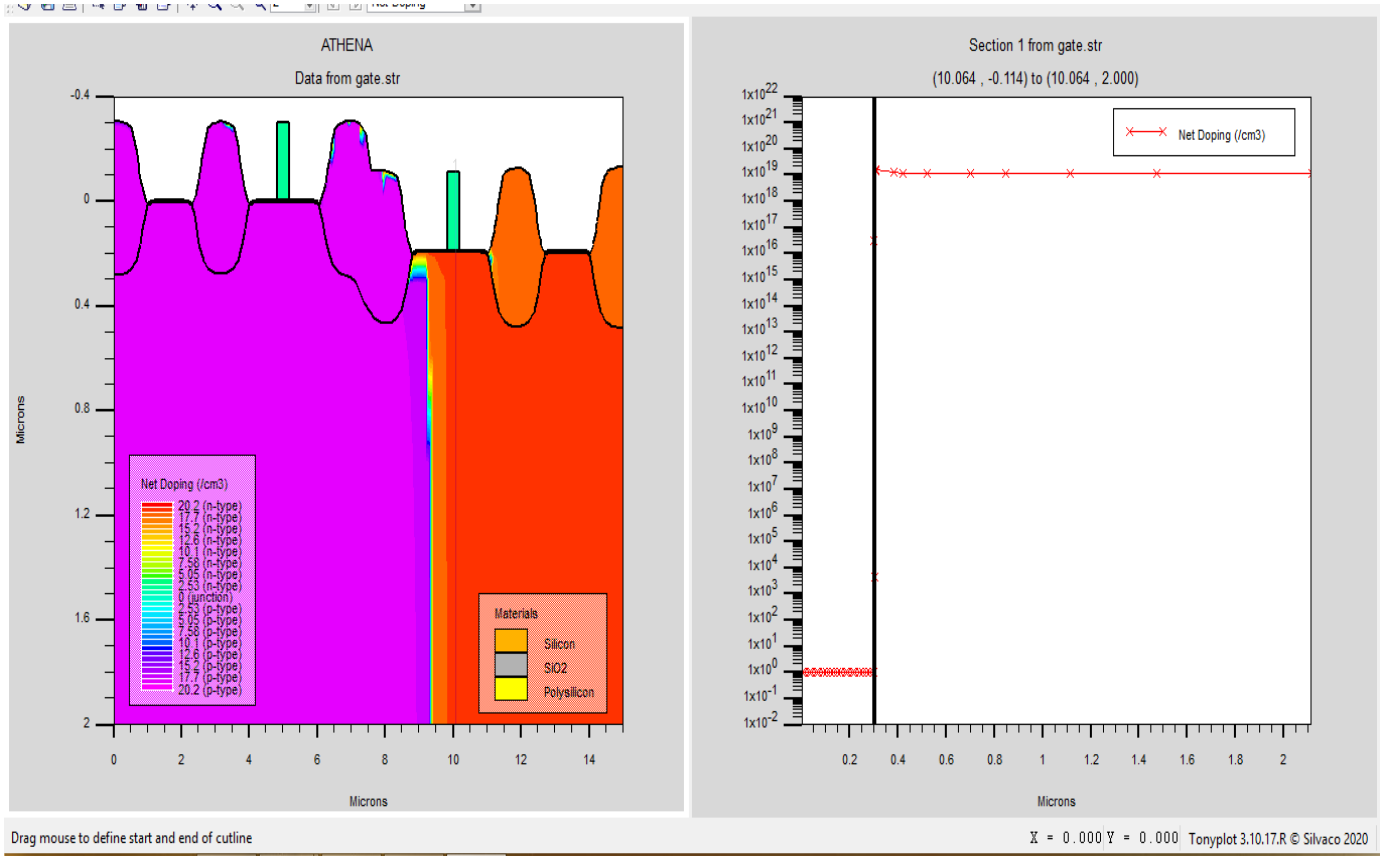
## Gate creation:




## For N-gate:

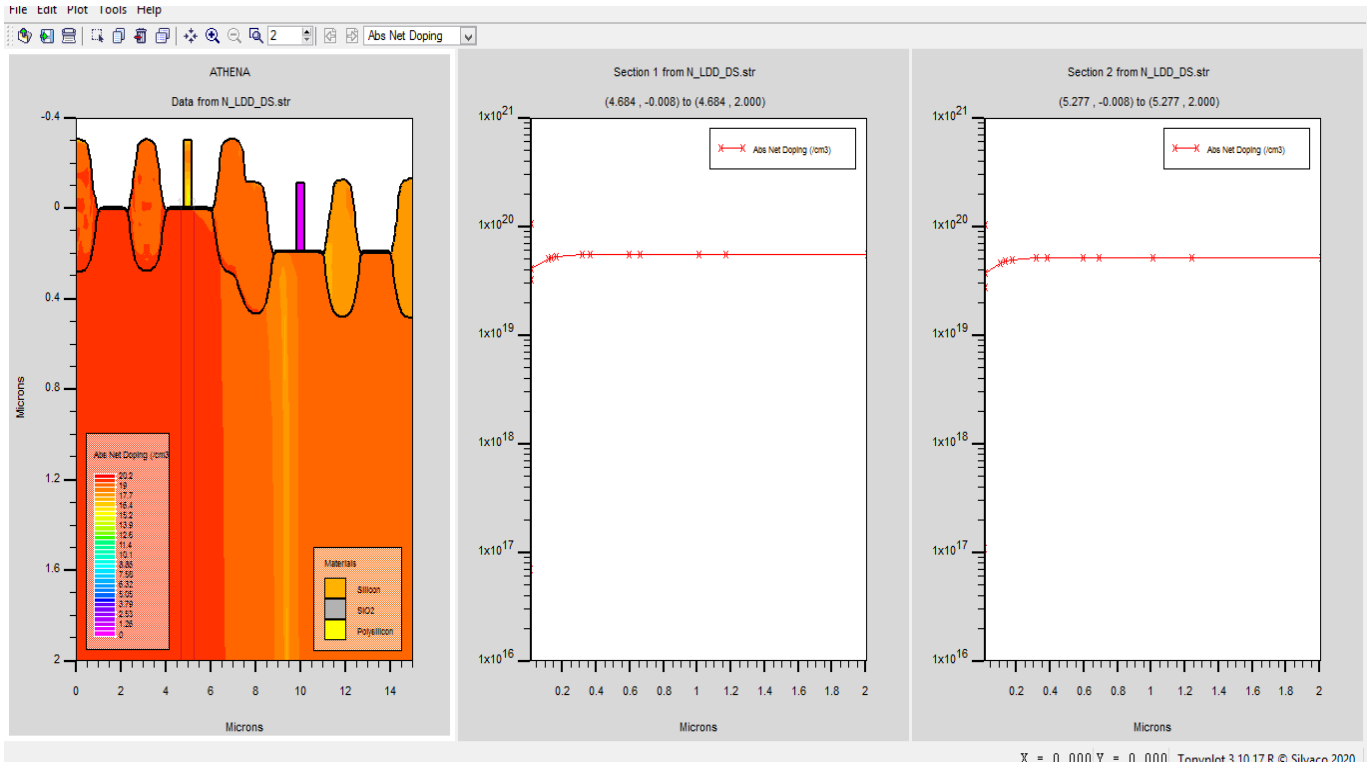


## P-gate:



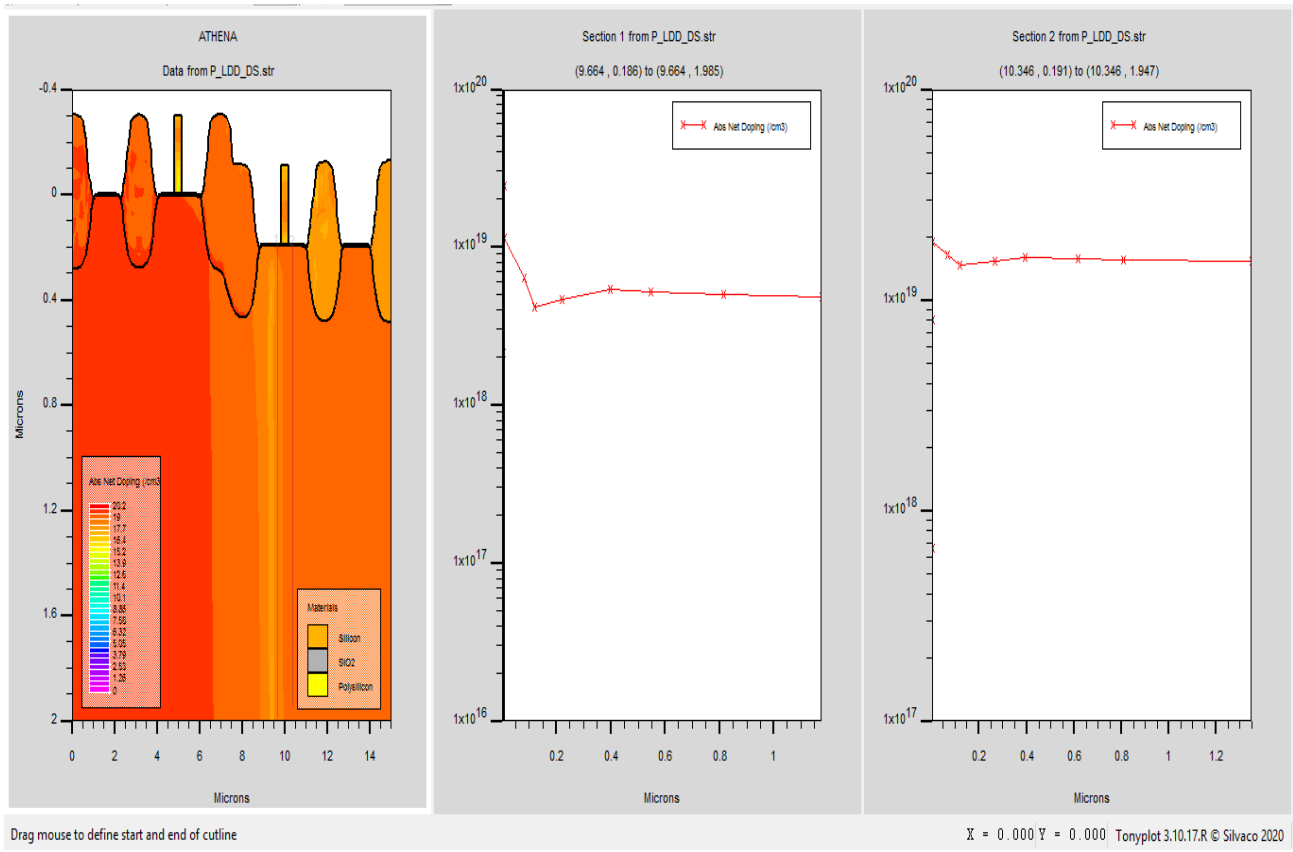

## N_LDD D/S:

-The middle curve for source conc while the RHS one for drain conc.

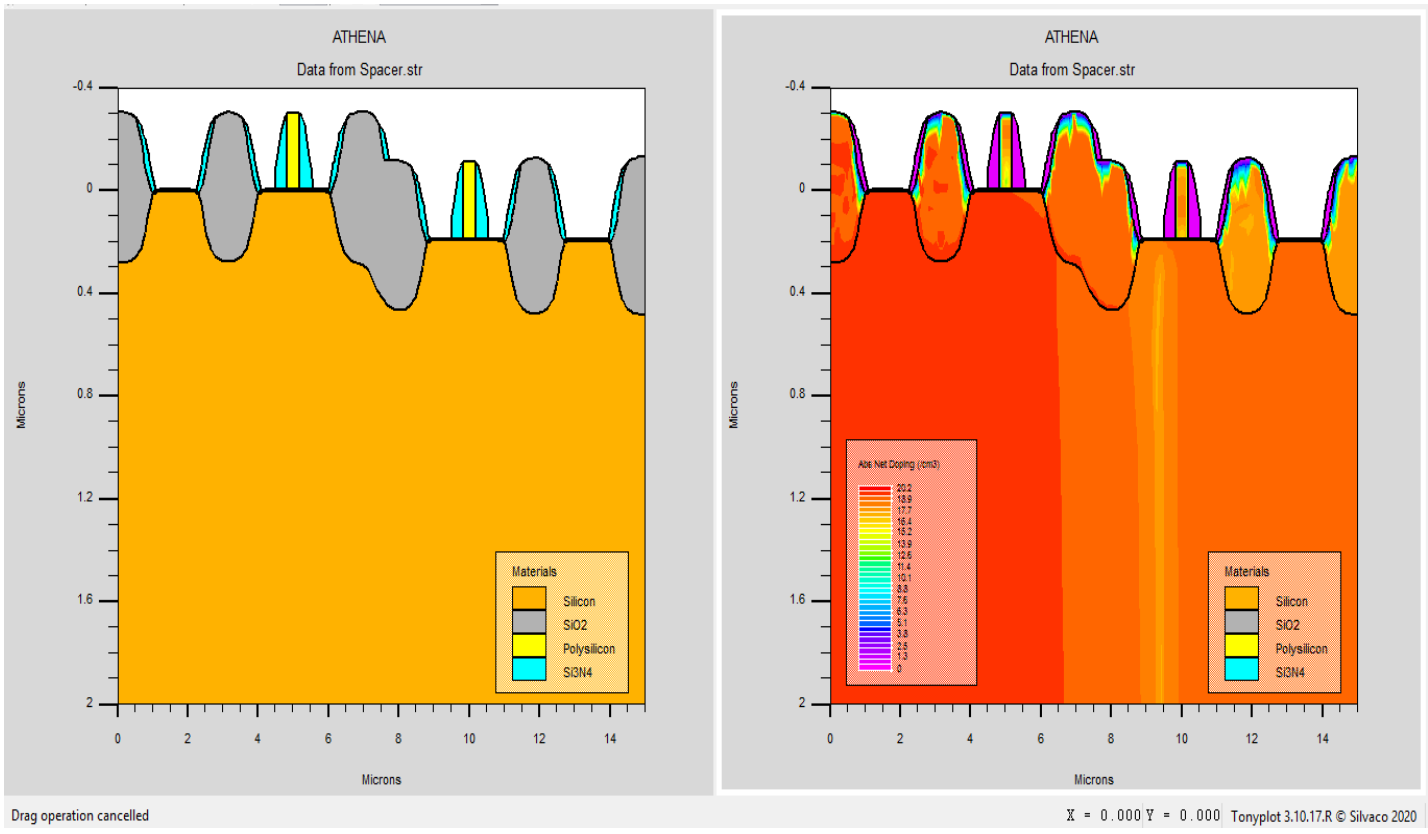


## P-LDD-D/S:

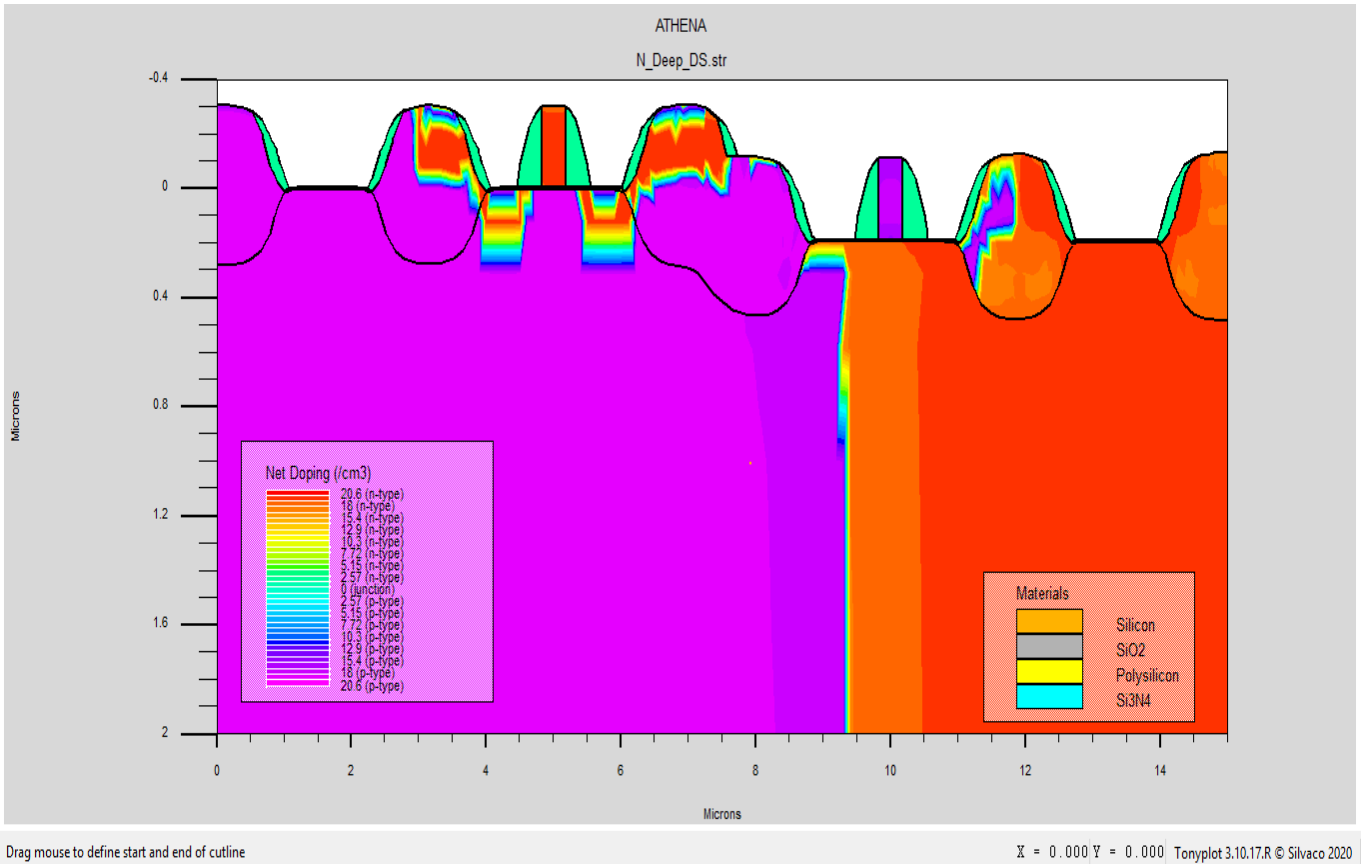
-The middle curve for Drain conc while the RHS one for Source conc.

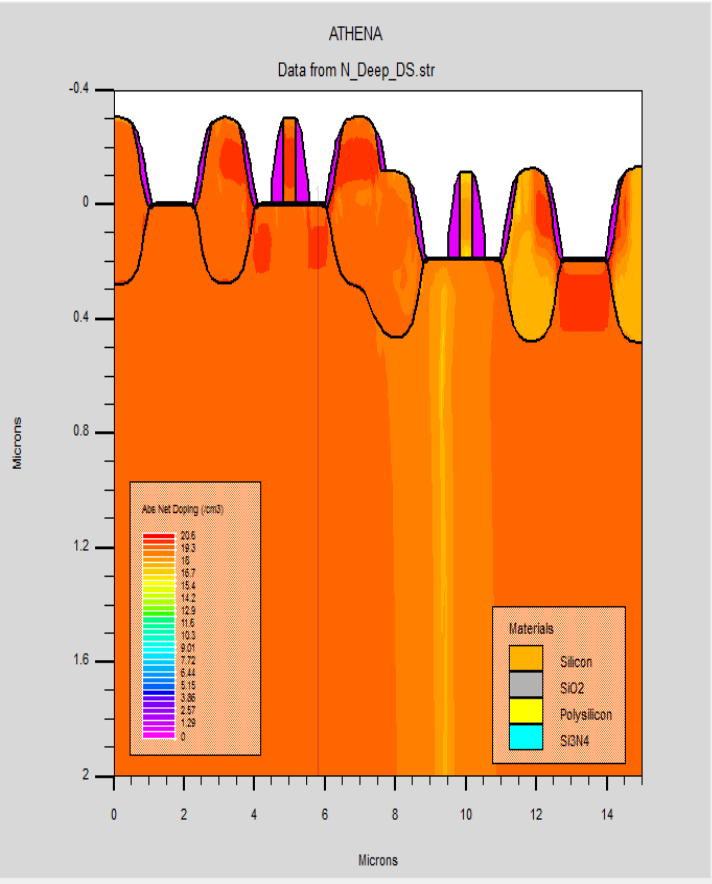


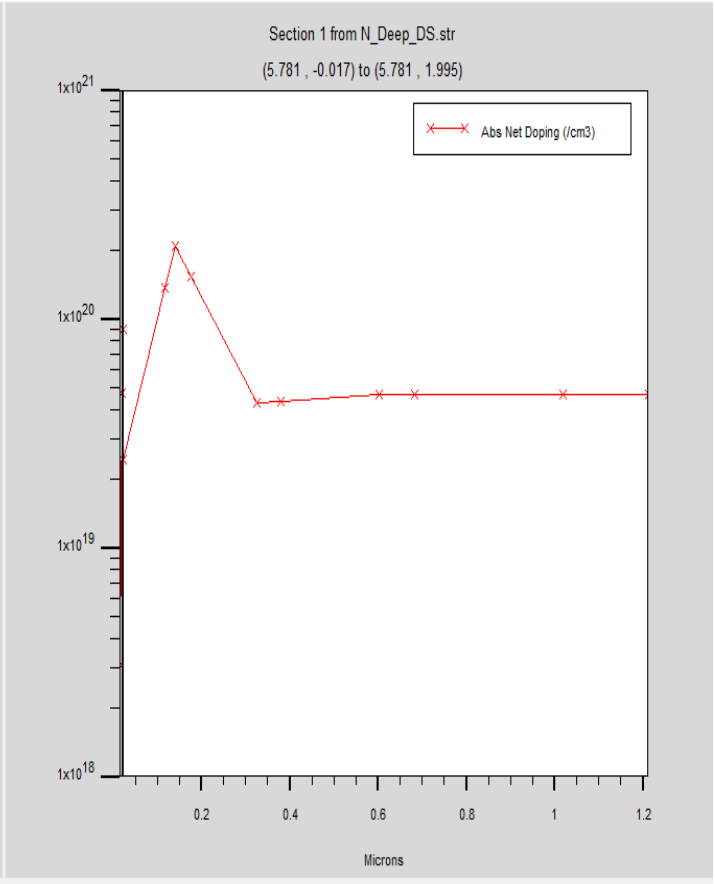

## Spacer:



## N-Deep-D/S:



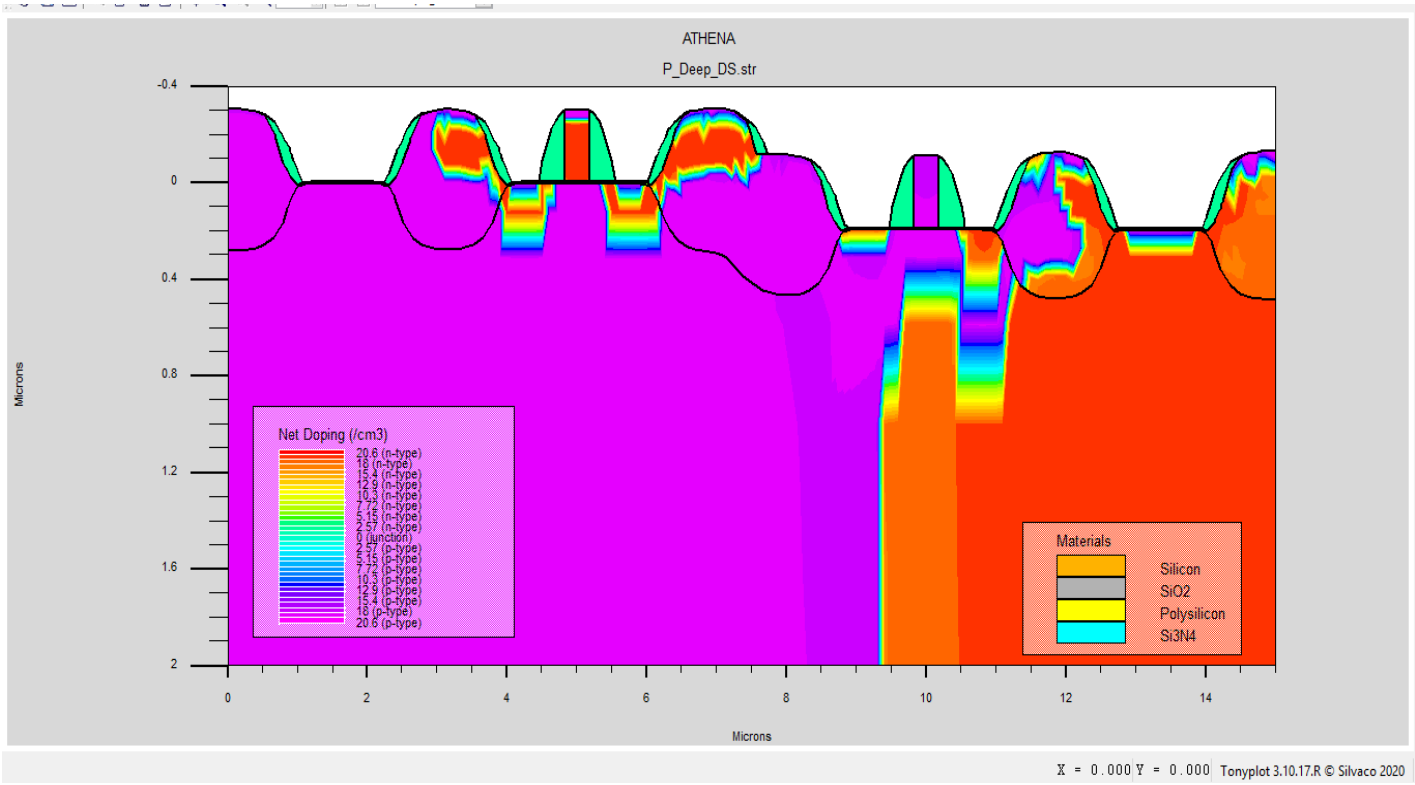



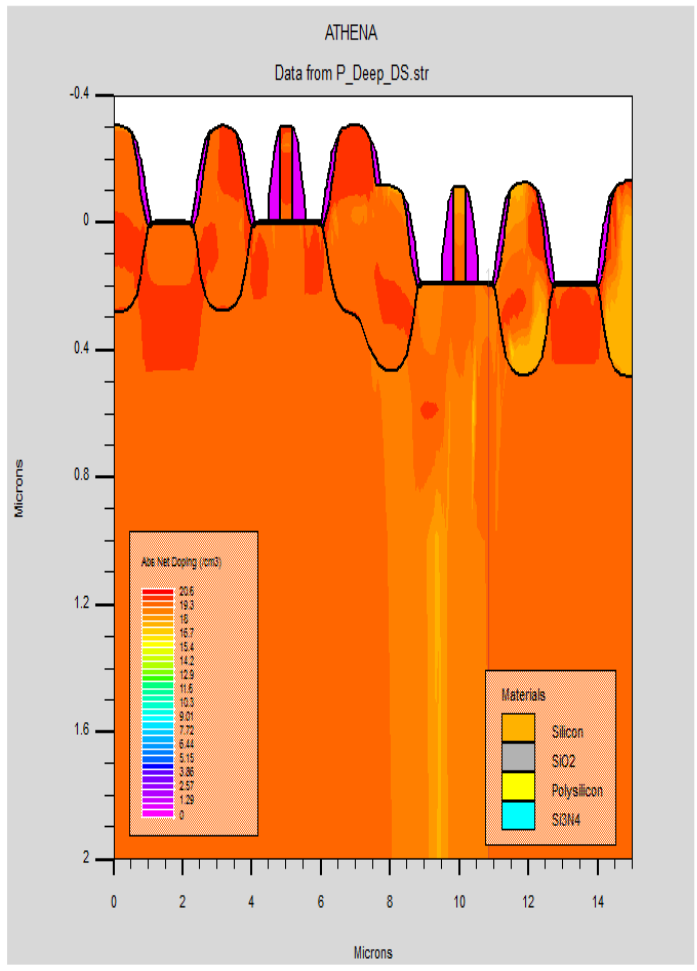



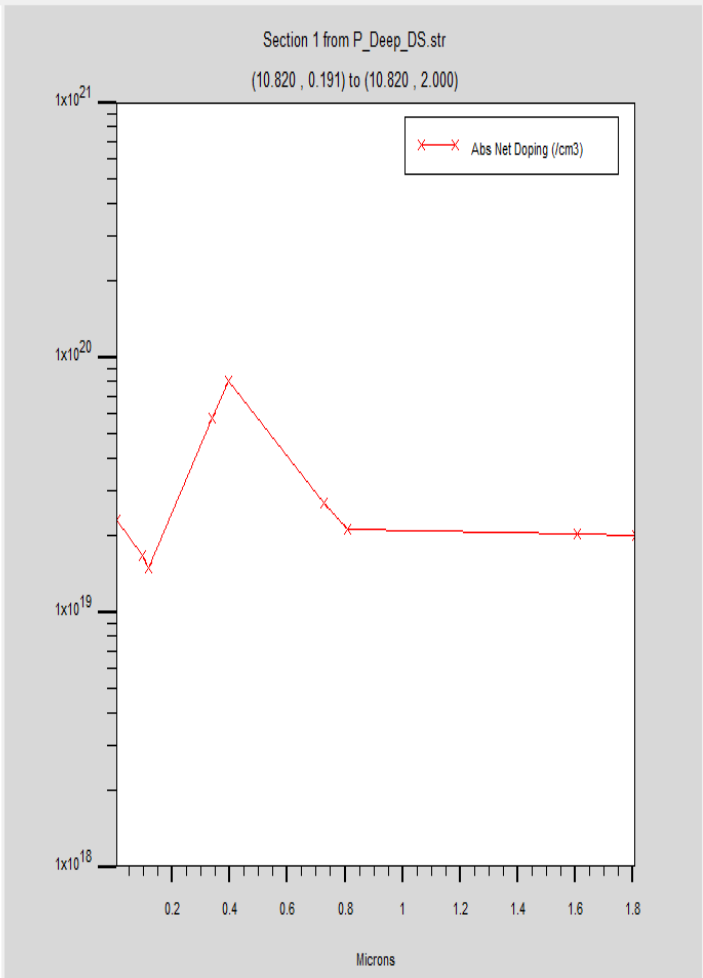

Drag operation cancelled

X = 0.000 Y = 0.000 Tonyplot 3.10.17.R © Silvaco 2020

## P-Deep-D/S:



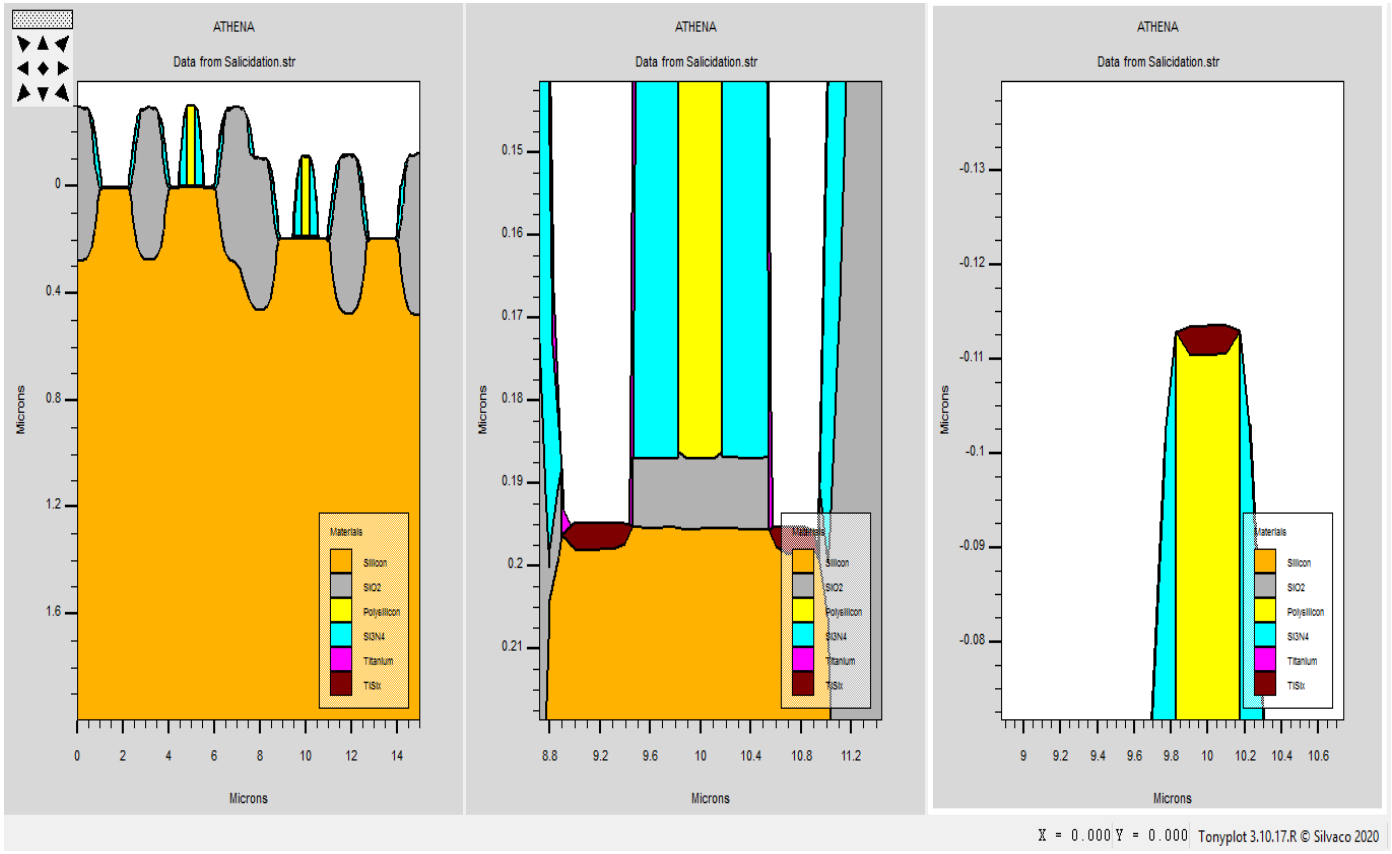



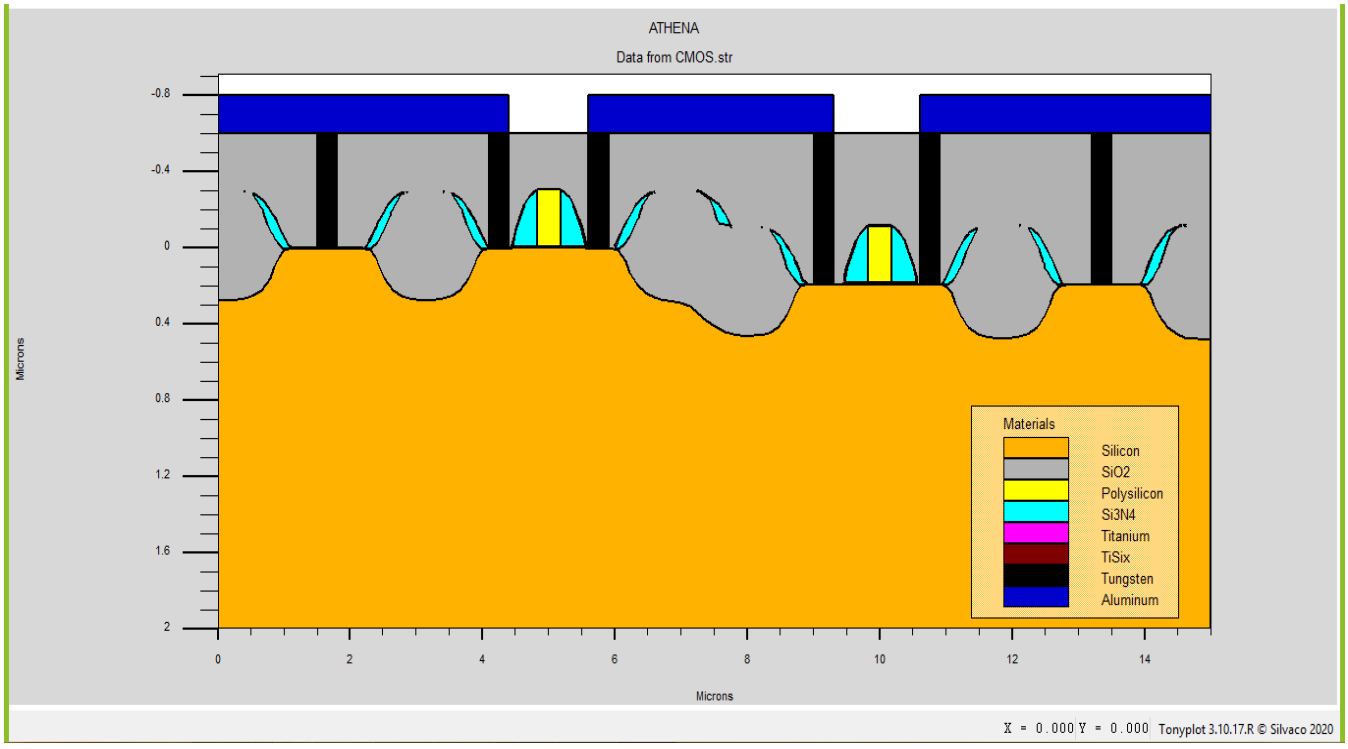

Drag mouse to define start and end of cutline

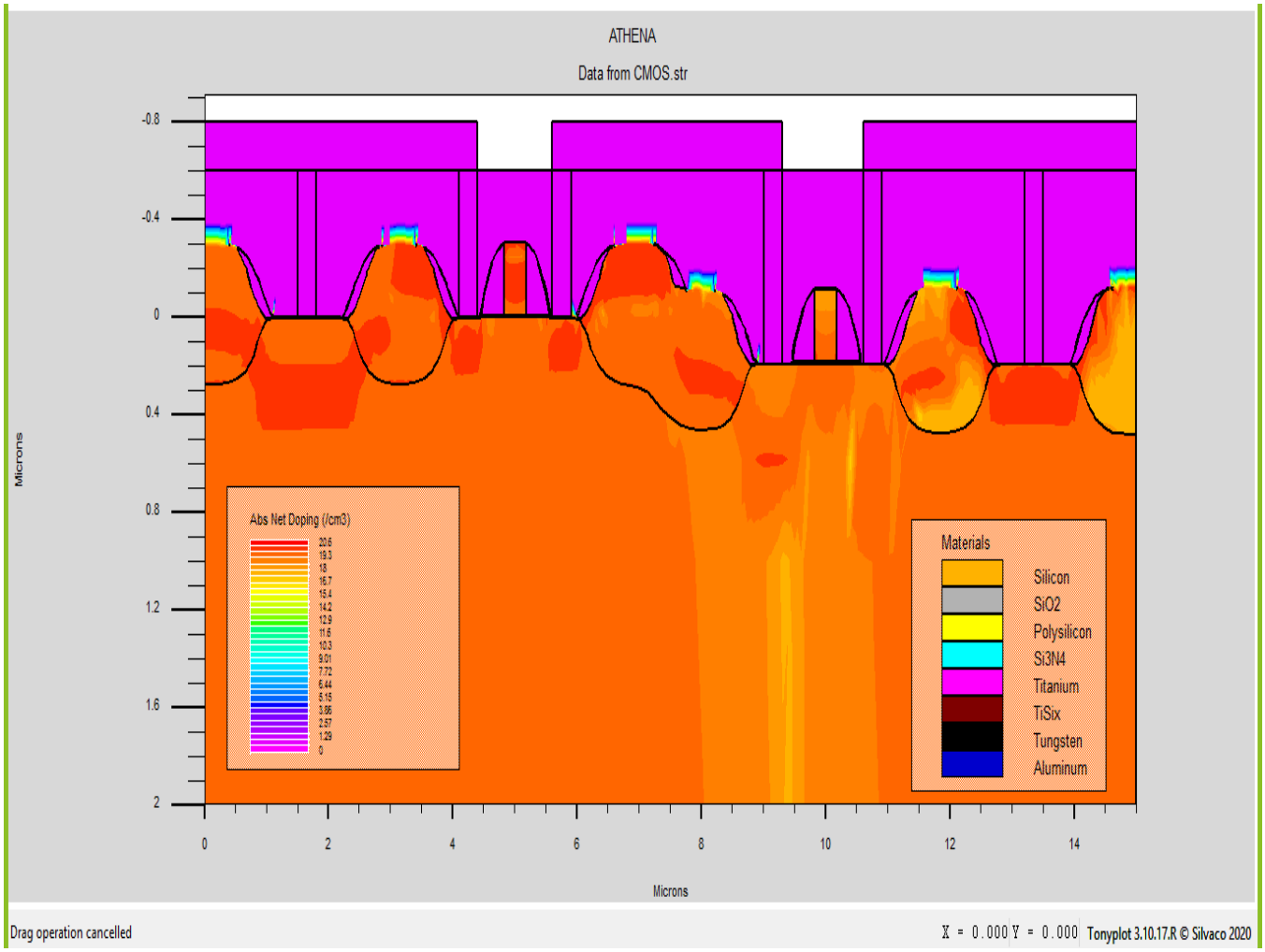
X = 0.000 Y = 0.000 Tonyplot 3.10.17.R © Silvaco 2020

## Salicidation:




## Contacts Creation & Metalization:






## Code explanation (Athena part):

### -Defining Initial Rectangular Grid:

go athena

#define and use a global shrnk variable...
set scalling=3
line x loc=0*$scalling spac=0.1
line x loc=2.5*$scalling spac=0.1
line x loc=5*$scalling spac=0.1

line y loc=0 spac=0.1
line y loc=1 spac=1
line y loc=2 spac=2

---

### -Defining the Initial Substrate:

init silicon boron resistivity=10 orientation=100

---

**-N-well creation:**

```
# step 2 make thin buffer
deposit oxide thick=0.01 divisions= 1
# step 3 nitride deposition
deposit nitride thick=0.15 divisions= 5
# step 4 photo resist
deposit photoresist thick=0.5 divisions=2
#step 5 develop PR
etch photoresist right p1.x=2.5*$scalling
# step 5 etch nitride
etch nitride right p1.x=2.5*$scalling
# step 6 n-well implant
implant phosphor dose=6.8e15 energy=150 pear
strip
```

---

**-P-well creation:**

```
# step 7 locos mask
diffus time=30 minutes temp=1000 weto2
#step 8 etch nitride
etch nitride left p1.x=2.5*$scalling
# step 9 p-well implant
implant boron dose=1.6e16 energy=50 pear
# step 10 wells drive-in
diffus time=120 minutes temp=1200 nitro press=1
```

---

**-FOX creation:**

```
#step 11 etch oxide
etch oxide all
#step 12 pad thermal oxide
deposit oxide thick=0.01 divisions=1
# step 13 nitride deposition
deposit nitride thick=0.15 divisions= 2
# mask 2
deposit photoresist thick=0.5 divisions=2
#step 14 & step 15 locos fox & etch nitride
#window of mask 2

etch photoresist left p1.x=0.2*$scalling
etch photoresist right p1.x=4.8*$scalling

etch nitride left p1.x=0.2*$scalling
etch nitride right p1.x=4.8*$scalling

#for tie window
etch photoresist start x=0.9*$scalling y=-2
etch cont x=0.9*$scalling y=2
etch cont x=1.2*$scalling y=2
etch done x=1.2*$scalling y=-2
```

```
etch nitride  start x=0.9*$scalling   y=-2
etch cont x=0.9*$scalling   y=2
etch cont x=1.2*$scalling   y=2
etch done x=1.2*$scalling   y=-2

#for fox inbtn  2 devicies
etch photoresist  start x=2.3*$scalling   y=-2
etch cont x=2*$scalling   y=2
etch cont x=2.8*$scalling   y=2
etch done x=2.8*$scalling   y=-2

etch nitride  start x=2.3*$scalling   y=-2
etch cont x=2*$scalling   y=2
etch cont x=2.8*$scalling   y=2
etch done x=2.8*$scalling   y=-2
#for tie window
etch photoresist  start x=3.8*$scalling   y=-2
etch cont x=3.8*$scalling   y=2
etch cont x=4.1*$scalling   y=2
etch done x=4.1*$scalling   y=-2

etch nitride  start x=3.8*$scalling   y=-2
etch cont x=3.8*$scalling   y=2
etch cont x=4.1*$scalling   y=2
etch done x=4.1*$scalling   y=-2
etch photoresist  all

## make channel stopper (to prevent parasitic  channel may be formed  due to invertion)
#step16 mask 3
deposit photoresist  thick=0.5  divisions=2
# develope  PR
etch photoresist  left  p1.x=2.5*$scalling
# step 17 channel  stopper
implant  boron dose=8.0e13 energy=100  pear
strip

# step 18 & 19 locos (fox )
method  grid.oxide=0.05
diffuse  temp=1200  time=30  wet
strip  nitride
etch oxide  dry thick=0.02
```

---

**-Pmos Vth adjust  ( modified doping to cancel shifting in Vth):**

```
#step 20 sacrifical  oxide  growth
diffuse  temp=900  time=10  dry
# step 21 threthold  adjust
implant  boron dose=7e11 energy=60  pear
# step 22 photo resist  (mask4)
deposit photoresist  thick=0.5  divisions=2
```

```
#step 22 develop PR
etch photoresist right p1.x=2.5*$scalling
# step 23 pmos vth threthold adjust
implant boron dose=2.6e12 energy=60 pear

# step 24 strip pR & etch sacrificial oxide
strip
etch oxide dry thick=0.02
```

---

**-Gate creation:**

```
#step 25 gate oxide
diffus time=1 minutes temp=1052 dryo2 press=1 hcl.pc=3

#
extract name="P_tox" thickness material="SiO~2" mat.occno=1 x.val=1.5*$scalling
extract name="N_tox" thickness material="SiO~2" mat.occno=1 x.val=2.967*$scalling

# step 26 poly dep
deposit polysilicon thick=0.3 divisions=10
#Mask 4
deposit photoresist thick=0.5 divisions=2
# P-gate
etch photoresist left p1.x=4.825
etch polysilicon left p1.x=4.825

#structure outf=P_gate.str
#tonyplot P_gate.str

# N-gate
etch photoresist right p1.x=10.175
etch polysilicon right p1.x=10.175
# in btn P&N-gate mask
etch photoresist start x=5.175 y=-2
etch cont x=9.825 y=-2
etch cont x=9.825 y=2
etch done x=5.175 y=2

etch polysilicon start x=5.175 y=-2
etch cont x=9.825 y=-2
etch cont x=9.825 y=2
etch done x=5.175 y=2

strip
```

---

**N_LDD D/S creation:**

```
#step 32 mask 6 n-select
deposit photoresist thick=0.5 divisions=2

# N-select mask
etch photoresist start x=1*$scalling y=-2
etch cont x=2.5*$scalling y=-2
etch cont x=2.5*$scalling y= 2
etch done x=1*$scalling y= 2
```

```
etch photoresist start x=12 y=-2
etch cont x=14.5 y=-2
etch cont x=14.5 y= 2
etch done x=12 y= 2

# step 33 N D/S LDD
implant phosphor dose=2.5e13 energy=60 tilt=10 fullrot crystal
# step 34
strip
```

---

**P_LDD D/S creation:**

```
#step 35 mask#7 p-select
deposit photoresist thick=0.5 divisions=2
# P-select mask
etch photoresist left p1.x=1*$scalling

etch photoresist start x=2.5*$scalling y=-2
etch cont x=12 y=-2
etch cont x=12 y= 2
etch done x=2.5*$scalling y= 2
# step 36&37 P D/S LDD
implant boron dose=4e13 energy=50 tilt=10 fullrot crystal

strip
```

---

**Spacer (to cover LDD to create deep D/S):**

```
deposit nitride thick=0.4 divisions=3

# Spacer nitride Etch
etch nitride dry thick=0.4
```

---

**N Deep D/S creation:**

```
deposit photoresist thick=0.5 divisions=2

# N-select mask again
etch photoresist start x=1*$scalling y=-2
etch cont x=2.5*$scalling y=-2
etch cont x=2.5*$scalling y= 2
etch done x=1*$scalling y= 2

etch photoresist start x=12 y=-2
etch cont x=14.5 y=-2
etch cont x=14.5 y= 2
etch done x=12 y= 2

# N Deep D/S
implant phosphor dose=4e15 energy=120 tilt=10 fullrot crystal

strip
```

---

**P Deep D/S creation:**

```
deposit photoresist thick=0.5 divisions=2
# P-select mask again
etch photoresist left p1.x=1*$scalling

etch photoresist start x=2.5*$scalling  y=-2
etch cont x=12 y=-2
etch cont x=12 y= 2
etch done x=2.5*$scalling  y= 2

#P Deep D/S
implant boron dose=2e15 energy=110 tilt=10 fullrot crystal

strip
```

---

**Salcidation: (to prevent the penetration of AL into the surface of active area):**

```
# step 46 etch damage oxide
etch oxide dry thick=0.01
# step 47salcidation
deposit titanium thick=0.03 divisions=2
# step 48 RTA ( to avoid affecting the previous junction depths)
method fermi
diffus time=1 sec temp=600 nitro press=1
etch titanium dry thick=0.03
```

---

**1St isolation:**

```
deposit oxide thick=0.8 divisions=10

#planarization
etch oxide above p1.y=-0.6
```

---

**contact cuts creation:**

```
#mask of CC
deposit photoresist thick=0.5 divisions=2

etch photoresist start x=0.5*$scalling   y=-2
etch cont x=0.5*$scalling   y=2
etch cont x=0.6*$scalling   y=2
etch done x=0.6*$scalling   y=-2

etch photoresist start x=4.1  y=-2
etch cont x=4.1  y=2
etch cont x=4.4  y=2
etch done x=4.4  y=-2

etch photoresist start x=5.6  y=-2
etch cont x=5.6  y=2
etch cont x=5.9  y=2
etch done x=5.9  y=-2

etch photoresist start x=3*$scalling   y=-2
etch cont x=3*$scalling   y=2
etch cont x=3.1*$scalling   y=2
```

```
etch done x=3.1*$scalling   y=-2

etch photoresist  start x=10.6  y=-2
etch cont x=10.6  y=2
etch cont x=10.9  y=2
etch done x=10.9  y=-2

etch photoresist  start x=4.4*$scalling   y=-2
etch cont x=4.4*$scalling   y=2
etch cont x=4.5*$scalling   y=2
etch done x=4.5*$scalling   y=-2

etch oxide start x=0.5*$scalling   y=-2
etch cont x=0.5*$scalling   y=2
etch cont x=0.6*$scalling   y=2
etch done x=0.6*$scalling   y=-2

etch oxide start x=4.1  y=-2
etch cont x=4.1  y=2
etch cont x=4.4 y=2
etch done x=4.4  y=-2

etch oxide start x=5.6  y=-2
etch cont x=5.6  y=2
etch cont x=5.9  y=2
etch done x=5.9  y=-2

etch oxide start x=3*$scalling   y=-2
etch cont x=3*$scalling   y=2
etch cont x=3.1*$scalling   y=2
etch done x=3.1*$scalling   y=-2

etch oxide start x=10.6  y=-2
etch cont x=10.6  y=2
etch cont x=10.9  y=2
etch done x=10.9  y=-2

etch oxide start x=4.4*$scalling   y=-2
etch cont x=4.4*$scalling   y=2
etch cont x=4.5*$scalling   y=2
etch done x=4.5*$scalling   y=-2

strip
# step 54 contacts
deposit tungsten  thick=0.7  divisions=2
etch tungsten  above p1.y=-0.6
```

---

**M1 creation:**

```
deposit aluminum  thick=0.2  divisions=2

etch aluminum  start x=4.4  y=-2
etch cont x=4.4  y=2
etch cont x=5.6 y=2
```

```
etch done x=5.6  y=-2

etch aluminum  start x=3.1*$scalling   y=-2
etch cont x=3.1*$scalling   y=2
etch cont x=10.6  y=2
etch done x=10.6  y=-2
```

---

**Extraction (to control on the thickness of gate oxide and the junction depth):**

```
extract name="P_tox" thickness material="SiO~2" mat.occno=1 x.val=1.5*$scalling
extract name="N_tox" thickness material="SiO~2" mat.occno=1 x.val=2.967*$scalling
extract name="n++ xj"xj silicon mat.occno=1 x.val=3.658*$scalling junc.occno=1
extract name="P++ xj"xj silicon mat.occno=1 x.val=1.3315*$scalling junc.occno=1
```

---

**Biasing: (To enable biasing in the device simulator ATLAS):**

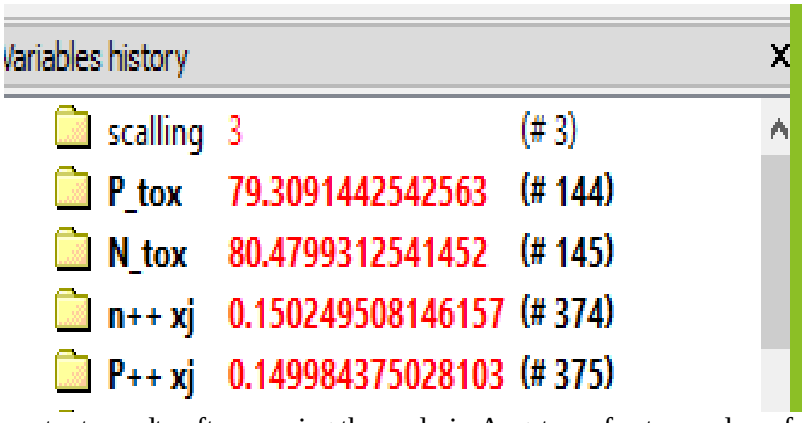
```
electrode name=gate x=5 y=-0.2
electrode name=gate x=10 y=-0.2
electrode name=drain x=5.7 y=-0.7
electrode name=drain x=9.1 y=-0.7
electrode name=source x=4.2 y=-0.7
electrode name=source x=10.7 y=-0.7
electrode name=bulk x=1.5 y=-0.7
electrode name=bulk x=13.3 y=-0.7
```

**For the required specs:**

Table 1: CMOS process parameters

| | | | |
|---|---|---|---|
| L | $0.35\mu m$ | $T_{ox}$ | 7.9 nm |
| $X_J$ | 150 nm | $L_D$ | $0.8\mu m$ |
| $N_{subNMOS}$ | $6.8 \times 10^{15} cm^{-3}$ | $N_{subPMOS}$ | $1.6 \times 10^{16} cm^{-3}$ |

We had almost achieved them as shown below:




The output results after running the code in Angstrom for tox and um for xj

**Atlas code:**

```
go atlas
contact name=polysi  workfunction=4.2
#select models
MODELS fermi bgn srh consrh conmob fldmob  mosfet
#
solve init
output val.band  con.band charge e.lines  band.param PERMITTIVITY
#
save outf=fil1.str
#tonyplot  fil1.str
#
# do IDVG characteristic
#
#method  newton  gummel
solve  vdrain=0
solve  vdrain=0.005
solve  vdrain=0.01
solve  vdrain=0.015
solve  vdrain=0.02
solve  vdrain=0.025
solve  vdrain=0.03
solve  vdrain=0.035
solve  vdrain=0.05
solve  vdrain=0.10
solve  vdrain=0.25
solve  vdrain=0.50
solve  vdrain=1
output val.band  con.band charge e.lines  band.param PERMITTIVITY
save outf=fil2.str
#tonyplot  fil2.str
#
# ramp  gate  voltage
log outf=metalization.log  master
solve name=gate  vstep=0.05 vfinal=1  ac direct frequency=1e06
output val.band  con.band u.bbt charge  e.lines  band.param
save outf=fil3.str
#tonyplot  fil3.str

#and this  for vt
extract  name="vt"  (xintercept(maxslope(curve(v."gate",abs(i."drain"))))  \
- abs(ave(v."drain"))/2.0)
#
extract  name="Ioff"  min(curve(v."gate",  i."drain"))
extract  name="Ion"  y.val from curve(v."gate",  i."drain")  where x.val=1
extract  name="Ion/Ioff"  (y.val from curve(v."gate",  i."drain")  where  x.val=1)  / min(curve(v."gate",
i."drain"))
# SS:
extract  name="subvt"  1.0/slope(maxslope(curve(abs(  v."gate"),log10(abs(i."drain")  ))))
### P-channel  DIBL  Test : Returns  Vt with  0.1 and 3 volts  Vd ## and a DIBL Parameter  ####
# extract  the next device parameter  wuth the drain now at 3 volts....
extract  init  inf="metalization.log"
```

```
# put ur file name here
extract name="metalization" x.val from curve(abs(v."gate"),abs(i."drain")) where y.val=0.1e-6
# Calculate a DIBL parameter....in V/V
extract name="pdibl" ($"pvt1"-$"metalization")/(3.0-0.1)
#### Nmos DIBL Test : Returns Vt with 0.1 and 3 volts Vd ####
# extract the next device parameter with the drain now at 3 volts....
extract init inf="metalization.log"
# put ur file name here
extract name="metalization" x.val from curve(abs(v."gate"),abs(i."drain")) where y.val=0.1e-6
# Calculate a DIBL parameter....in V/V
extract name="ndibl" ($"nvt1"-$"metalization")/(3.0-0.1)
```

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**Results:**

Unfortunately,the CMOS device doesn't work well (that's so obivous from output results)
this maybe because many factors:
-inaccurate doping levels
-FOX wasn't effective enough
-Biasing process isn't correct.