

# **Modeling Of Dual Material Gate Junction less FinFET On Synopsis Sentaurus Tcad Tool**

**By Sanjeen Suman**

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# Structure Editor (SDE) Script

```
(define M1 @M1@)
```

```
(sdegeo:create-cuboid (position 0 0 0) (position 0.028 0.03 0.010) "SiO2" "BOX")
```

```
(sdegeo:create-cuboid (position 0 0.013 0.010) (position 0.028 0.018 0.015) "Silicon"  
"sourcedrain")
```

```
(sdegeo:set-default-boolean "BAB")
```

```
(sdegeo:create-cuboid (position (- M1 0.010) 0.010 0.010) (position M1 0.021 0.018) "HfO2"  
"TOX")
```

```
(sdegeo:create-cuboid (position (- M1 0.010) 0 0.010) (position 0.014 0.03 0.022) "@Metal2@"  
"M2")
```

```
(sdegeo:create-cuboid (position 0.014 0 0.010) (position M1 0.03 0.022) "@Metal1@" "M1")
```

```
(sdegeo:define-contact-set "source" 4 (color:rgb 1 0 0) "##")
```

```
(sdegeo:define-contact-set "drain" 4 (color:rgb 1 0 0) "##")
```

```
(sdegeo:define-contact-set "gate" 4 (color:rgb 1 0 0) "##")
```

```
(sdegeo:set-current-contact-set "source")
```

```
(sdegeo:set-contact (list (car (find-face-id (position 0.0235 0.0155 0.015)))) "source")
```

```
(sdegeo:set-current-contact-set "drain")
```

```
(sdegeo:set-contact (list (car (find-face-id (position 0.0045 0.0155 0.015)))) "drain")
```

```
(sdegeo:set-current-contact-set "gate")
```

```
(sdegeo:set-contact (list (car (find-face-id (position 0.0165 0.015 0.022)))) "gate")
```

```
(sdegeo:set-contact (list (car (find-face-id (position 0.0115 0.015 0.022)))) "gate")
```

```
(sdedr:define-constant-profile "ConstantProfileDefinition_1" "PhosphorusActiveConcentration"
@Con@)
```

```
(sdedr:define-constant-profile-material "ConstantProfilePlacement_1"
"ConstantProfileDefinition_1" "Silicon")
```

```
(sdedr:define-refeval-window "RefEvalWin_1" "Cuboid" (position -0.005 -0.005 -0.005)
(position 0.031 0.031 0.031))
```

```
(sdedr:define-refinement-size "RefinementDefinition_1" 0.002 0.005 0.001 0.002 0.005 0.001 )
```

```
(sdedr:define-refinement-placement "RefinementPlacement_1" "RefinementDefinition_1" (list
"window" "RefEvalWin_1" ) )
```

```
(sdedr:define-refinement-function "RefinementDefinition_1" "DopingConcentration"
"MaxTransDiff" 1)
```

```
(sdedr:define-refinement-function "RefinementDefinition_1" "MaxLenInt" "SiO2" "Silicon" 1
1.25 "DoubleSide")
```

```
(sde:build-mesh "n@node@")
```

# SDevice Script

File {

\* input files :

Grid= "@tdr@"

\* output files:

Plot = "@tdrdat@"

Current ="@plot@"

Output = "@log@"

\*Param = "Silicon.par"

}

Electrode {

{ Name = "source" Voltage=0}

{ Name = "drain" Voltage=0}

{ Name = "gate" Voltage=0 }

}

Physics (Material="Silicon"){

Mobility( DopingDependence Enormal)

Recombination (SRH(DopingDependence) Auger)

EffectiveIntrinsicDensity( OldSlotboom)

Recombination (

Band2Band (

Model = Schenk

DensityCorrection = Local

)  
)  
}

Physics (Material = "Aluminum") {  
MetalWorkfunction ( Workfunction= 4.28)  
}

Physics (Material = "Titanium") {  
MetalWorkfunction ( Workfunction= 4.66 )  
}

Plot {  
    eDensity hDensity eCurrent/Vector hCurrent/Vector  
    ElectrostaticPotential Potential SpaceCharge ElectricField  
    Doping DonorConcentration AcceptorConcentration  
    TotalCurrentDensity  
    ConductionBand ValenceBand  
    TotalCurrentDensity/Vector eCurrentDensity/Vector hCurrentDensity/Vector  
}

CurrentPlot {  
eDensity( Integrate(Semiconductor))  
}

Math {  
    Extrapolate

```

Avalderivatives
RelErrControl
Digits=5
ErRef(electron)=1.e10
ErRef(hole)=1.e10
Notdamped=50
Iterations=20
DirectCurrent
}

Solve {

NewCurrentPrefix="init"
Coupled(Iterations=100){ Poisson }
Coupled{ Poisson Electron Hole }

Quasistationary(
  InitialStep=1e-1 Increment=1.2
  Minstep=1e-5 MaxStep=0.05
  Goal{ Name="drain" Voltage= @Vd@ }
){ Coupled{ Poisson Electron Hole } }

NewCurrentPrefix=""
Quasistationary(
  DoZero
  InitialStep=0.02 Increment=1.5
  Minstep=0.02 MaxStep=0.02

```

```
Goal{ Name="gate" Voltage= @Vg@ }  
{ Coupled{ Poisson Electron Hole}  
  
}  
}
```

# TCL script for parameter extraction

```
set Vgo 1e-2
# Extract Vtgm for a p-MOSFET
set mydata [load_file "@plot@" -name DC]
set Vgs [get_variable_data "gate OuterVoltage" -dataset DC]
set Ids [get_variable_data "drain TotalCurrent" -dataset DC]
ext::AbsList -out absIds -x $Ids
ext::ExtractVtgm -out Vtgm -name "out" -v $Vgs -i $absIds
puts "Vt (Max gm method) is [format %.3f $Vtgm] V"
#-> Vt (Max gm method) is -0.234 V
ext::ExtractSS -out SS -name "out" -v $Vgs -i $Ids -vo $Vgo
puts "SS (subthreshold voltage swing) is [format %.3f $SS] mV/dec"
#-> SS (subthreshold voltage swing) is 89.555 mV/dec
ext::ExtractIoff -out Ioff -name "out" -v $Vgs -i $Ids -vo 1e-4 -log10 0
puts "Ioff is [format %.3e $Ioff] A/um"
```



# TCL script for Id vs Vg curve

```
set mydata [load_file "@plot@"]
set myplot [create_plot -1d]
set IdVgcurve [create_curve -plot $myplot -dataset $mydata \
    -axisX "gate InnerVoltage" -axisY "drain TotalCurrent"]

set_curve_prop $IdVgcurve -plot $myplot -show_markers -markers_size 7 \
    -markers_type circlef -label "DMGJLFinFET"

set_plot_prop -show_grid
set_grid_prop -show_minor_lines \
    -line1_style dash -line1_color #a0a0a4 \
    -line2_style dot -line2_color #c0c0c0

set_axis_prop -plot $myplot -axis x -title "V<sub>gate</sub> (V)"
set_axis_prop -plot $myplot -axis y -title "I<sub>drain</sub>\
    (A/<greek>m</greek>m)" -type log
set_axis_prop -plot $myplot -axis y -range {1e-08 0.001}

export_view "n@node@_curve.png" -plots $myplot -resolution 500x500 \
    -format PNG -overwrite
```

```

(define M1 @M1@)

(sdegeo:create-cuboid (position 0 0 0) (position 0.028 0.03 0.010) "SiO2" "BOX")
(sdegeo:create-cuboid (position 0 0.013 0.010) (position 0.028 0.018 0.015) "Silicon" "sourcedrain")
(sdegeo:set-default-boolean "BAB")
(sdegeo:create-cuboid (position (- M1 0.010) 0.010 0.010) (position M1 0.021 0.018) "HfO2" "TOX")

(sdegeo:create-cuboid (position (- M1 0.010) 0 0.010) (position 0.014 0.03 0.022) "@Metal2@" "M2")
(sdegeo:create-cuboid (position 0.014 0 0.010) (position M1 0.03 0.022) "@Metal1@" "M1")

(sdegeo:define-contact-set "source" 4 (color:rgb 1 0 0) "##")
(sdegeo:define-contact-set "drain" 4 (color:rgb 1 0 0) "##")
(sdegeo:define-contact-set "gate" 4 (color:rgb 1 0 0) "##")

(sdegeo:set-current-contact-set "source")
(sdegeo:set-contact (list (car (find-face-id (position 0.0235 0.0155 0.015)))) "source")
(sdegeo:set-current-contact-set "drain")
(sdegeo:set-contact (list (car (find-face-id (position 0.0045 0.0155 0.015)))) "drain")
(sdegeo:set-current-contact-set "gate")
(sdegeo:set-contact (list (car (find-face-id (position 0.0165 0.015 0.022)))) "gate")
(sdegeo:set-contact (list (car (find-face-id (position 0.0115 0.015 0.022)))) "gate")

(sedr:define-constant-profile "ConstantProfileDefinition_1" "PhosphorusActiveConcentration" @Con@)
(sedr:define-constant-profile-material "ConstantProfilePlacement_1" "ConstantProfileDefinition_1" "Silicon")

(sedr:define-refeval-window "RefEvalWin_1" "Cuboid" (position -0.005 -0.005 -0.005) (position 0.031 0.031 0.031))
(sedr:define-refinement-size "RefinementDefinition_1" 0.002 0.005 0.001 0.002 0.005 0.001)
(sedr:define-refinement-placement "RefinementPlacement_1" "RefinementDefinition_1" (list "window" "RefEvalWin_1" ) )
(sedr:define-refinement-function "RefinementDefinition_1" "DopingConcentration" "MaxTransDiff" 1)
(sedr:define-refinement-function "RefinementDefinition_1" "MaxLenInt" "SiO2" "Silicon" 1 1.25 "DoubleSide")

(sde:build-mesh "n@node@")

```

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Fig.1 SDE Script

```

set mydata [load file "@plot@"]
set myplot [create plot -ld]
set IdVgcurve [create_curve -plot $myplot -dataset $mydata \
-axisX "gate InnerVoltage" -axisY "drain TotalCurrent"]

set_curve_prop $IdVgcurve -plot $myplot -show_markers -markers_size 7 \
-markers_type circlef -label "DMGJLFInFET"

set_plot_prop -show_grid
set_grid_prop -show_minor_lines \
-line1_style dash -line1_color #a0a0a4 \
-line2_style dot -line2_color #c0c0c0

set_axis_prop -plot $myplot -axis x -title "V<sub>gate</sub> (V)"
set_axis_prop -plot $myplot -axis y -title "I<sub>drain</sub>\
(A/<greek>m</greek>m)" -type log
set_axis_prop -plot $myplot -axis y -range {1e-08 0.001}

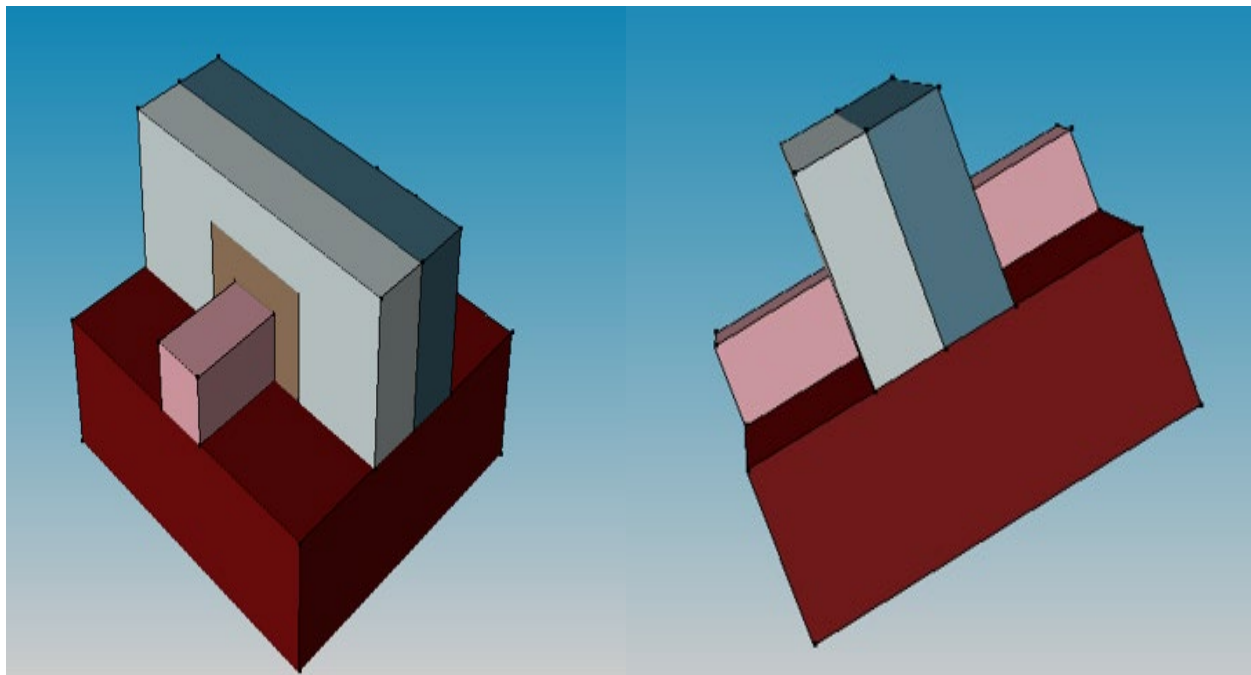
export_view "n@node@_curve.png" -plots $myplot -resolution 500x500 \
-format PNG -overwrite

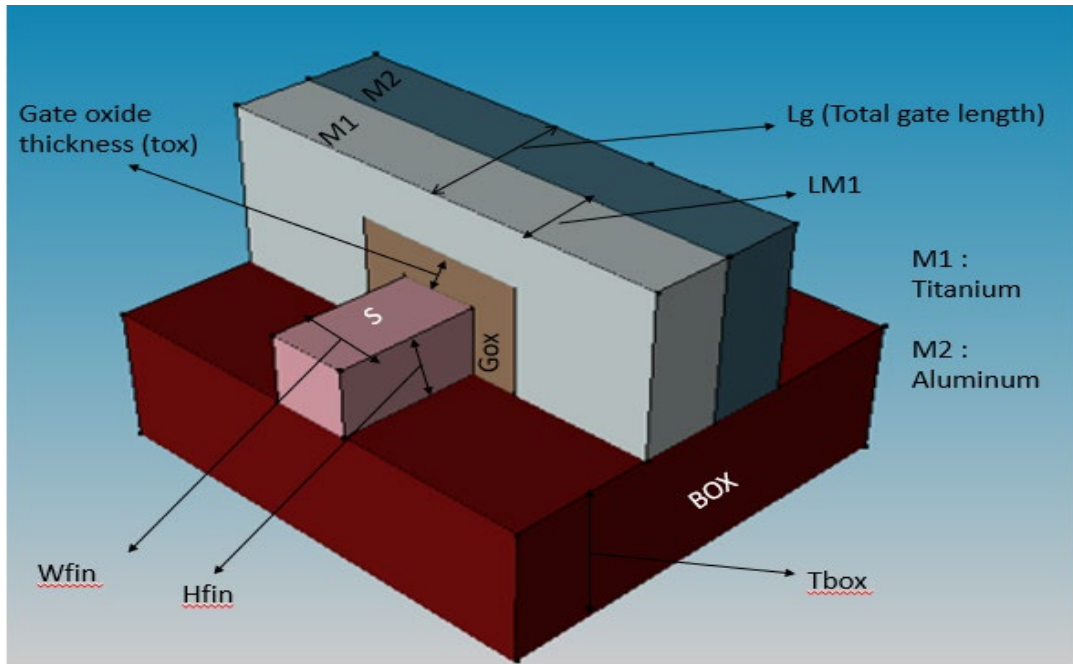
```

Fig.2 Id Vs Vg TCL Script

```
set Vgo 1e-2
# Extract Vtgm for a p-MOSFET
set mydata [load_file "@plot@" -name DC]
set Vgs [get_variable_data "gate OuterVoltage" -dataset DC]
set Ids [get_variable_data "drain TotalCurrent" -dataset DC]
ext::AbsList -out absIds -x $Ids
ext::ExtractVtgm -out Vtgm -name "out" -v $Vgs -i $absIds
puts "Vt (Max gm method) is [format %.3f $Vtgm] V"
#-> Vt (Max gm method) is -0.234 V
ext::ExtractSS -out SS -name "out" -v $Vgs -i $Ids -vo $Vgo
puts "SS (subthreshold voltage swing) is [format %.3f $SS] mV/dec"
#-> SS (subthreshold voltage swing) is 89.555 mV/dec
ext::ExtractIoff -out Ioff -name "out" -v $Vgs -i $Ids -vo 1e-4 -log10 0
puts "Ioff is [format %.3e $Ioff] A/um"
```

Fig.3 Parameter TCL Script





Project Edit Scheduler View Scenario Tool Parameter Experiments Nodes Variables PCM Studio Extensions Help

Scenario: all

Projects

- /home/tcad
  - Desktop
  - Documents
  - Downloads
  - FinFet\_VL027Sanjeen
  - tap
    - medici
    - Music
    - Pictures
    - project
    - Public
    - Rohit\_VL026
    - san1
    - san4
    - Sanjeen\_v1027
    - TCHD
    - Templates
    - tap
    - tsuprem
    - Videos
- /usr/tools/synopsys/sentaur
  - Analog
  - Backend
  - Bipolar
  - CMOS
  - FinFET
  - GettingStarted
  - Hetero
  - Memory
  - Nanowire
  - Opto
  - Power
  - Sensors
  - Solar
  - Templates
  - Variability

Project Scheduler

	M1	Metal1	Metal2	Con	Vg	Vd			Vtgn	SS	Ioff
1				[n1]: 1e+18	[n3]: 1.2	[n2]: 0.7	[n55]: --	[n133]: --	0.366	83.033	1.182e-10
2				[n6]: 1e+17	[n8]: 1.2	[n9]: 0.7	[n66]: --	[n134]: --	0.322	84.042	6.213e-11
3		[n26]: Titanium	[n5]: Aluminum	[n10]: 1e+16	[n12]: 1.2	[n13]: 0.7	[n67]: --	[n135]: --	0.260	86.039	3.692e-11
4				[n14]: 1e+15	[n16]: 1.2	[n17]: 0.7	[n68]: --	[n136]: --	0.198	88.397	1.785e-11
5				[n18]: 1e+19	[n20]: 1.2	[n21]: 0.7	[n69]: --	[n137]: --	0.376	85.182	1.610e-09
6				[n22]: 1e+20	[n24]: 1.2	[n25]: 0.7	[n60]: --	[n138]: --	0.082	755.220	2.219e-05
7	[n54]: 0.019			[n30]: 1e+18	[n32]: 1.2	[n33]: 0.7	[n61]: --	[n139]: --	0.295	72.712	1.394e-10
8				[n34]: 1e+17	[n36]: 1.2	[n37]: 0.7	[n62]: --	[n140]: --	0.248	72.251	8.850e-11
9		[n28]: Aluminum	[n29]: Titanium	[n38]: 1e+16	[n40]: 1.2	[n41]: 0.7	[n63]: --	[n141]: --	0.190	72.252	7.012e-11
10				[n42]: 1e+15	[n44]: 1.2	[n45]: 0.7	[n64]: --	[n142]: --	0.130	73.639	4.681e-11
11				[n46]: 1e+19	[n48]: 1.2	[n49]: 0.7	[n65]: --	[n143]: --	0.335	75.621	1.667e-09
12				[n50]: 1e+20	[n52]: 1.2	[n53]: 0.7	[n66]: --	[n144]: --	0.111	687.920	2.051e-05
13				[n71]: 1e+18	[n73]: 1.2	[n74]: 0.7	[n75]: --	[n145]: --	0.323	83.897	3.578e-10
14				[n76]: 1e+17	[n78]: 1.2	[n79]: 0.7	[n80]: --	[n146]: --	0.283	85.032	1.869e-10
15				[n81]: 1e+16	[n83]: 1.2	[n84]: 0.7	[n85]: --	[n147]: --	0.226	88.524	1.101e-10
16		[n69]: Titanium	[n70]: Aluminum	[n86]: 1e+15	[n88]: 1.2	[n89]: 0.7	[n89]: --	[n148]: --	0.177	91.909	5.146e-11
17				[n91]: 1e+19	[n93]: 1.2	[n94]: 0.7	[n95]: --	[n149]: --	0.329	86.935	4.715e-09
18				[n96]: 1e+20	[n98]: 1.2	[n99]: 0.7	[n100]: --	[n150]: --	0.049	766.193	2.442e-05
19	[n68]: 0.018			[n103]: 1e+18	[n105]: 1.2	[n106]: 0.7	[n107]: --	[n151]: --	0.345	71.426	2.323e-11
20				[n108]: 1e+17	[n110]: 1.2	[n111]: 0.7	[n112]: --	[n152]: --	0.299	71.064	1.503e-11
21				[n113]: 1e+16	[n115]: 1.2	[n116]: 0.7	[n117]: --	[n153]: --	0.240	71.054	1.227e-11
22		[n101]: Aluminum	[n102]: Titanium	[n118]: 1e+15	[n120]: 1.2	[n121]: 0.7	[n122]: --	[n154]: --	0.180	71.133	8.484e-12
23				[n123]: 1e+19	[n125]: 1.2	[n126]: 0.7	[n127]: --	[n155]: --	0.379	73.476	2.883e-10
24				[n128]: 1e+20	[n130]: 1.2	[n131]: 0.7	[n132]: --	[n156]: --	0.156	637.584	1.676e-05

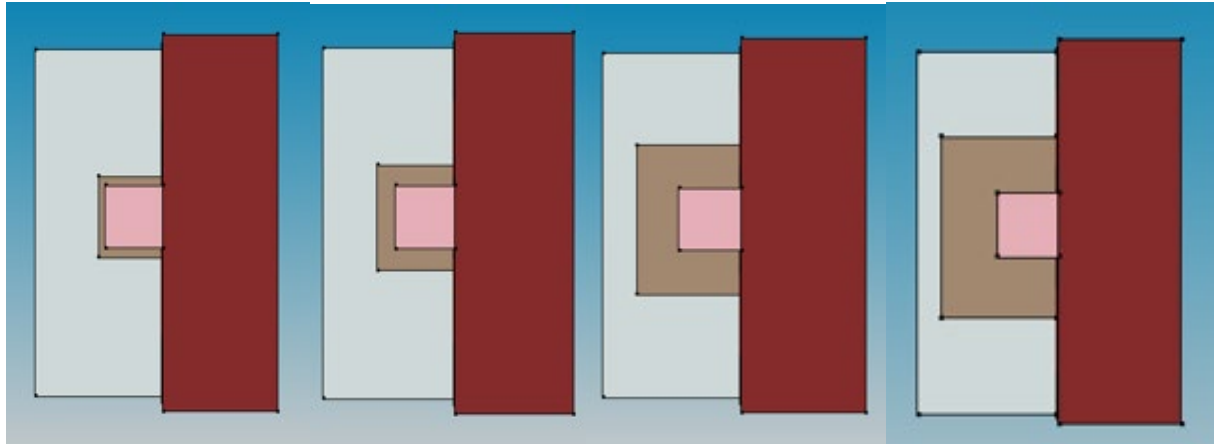
Edit mode

none queued ready pending running done failed aborted virtual pruned folded

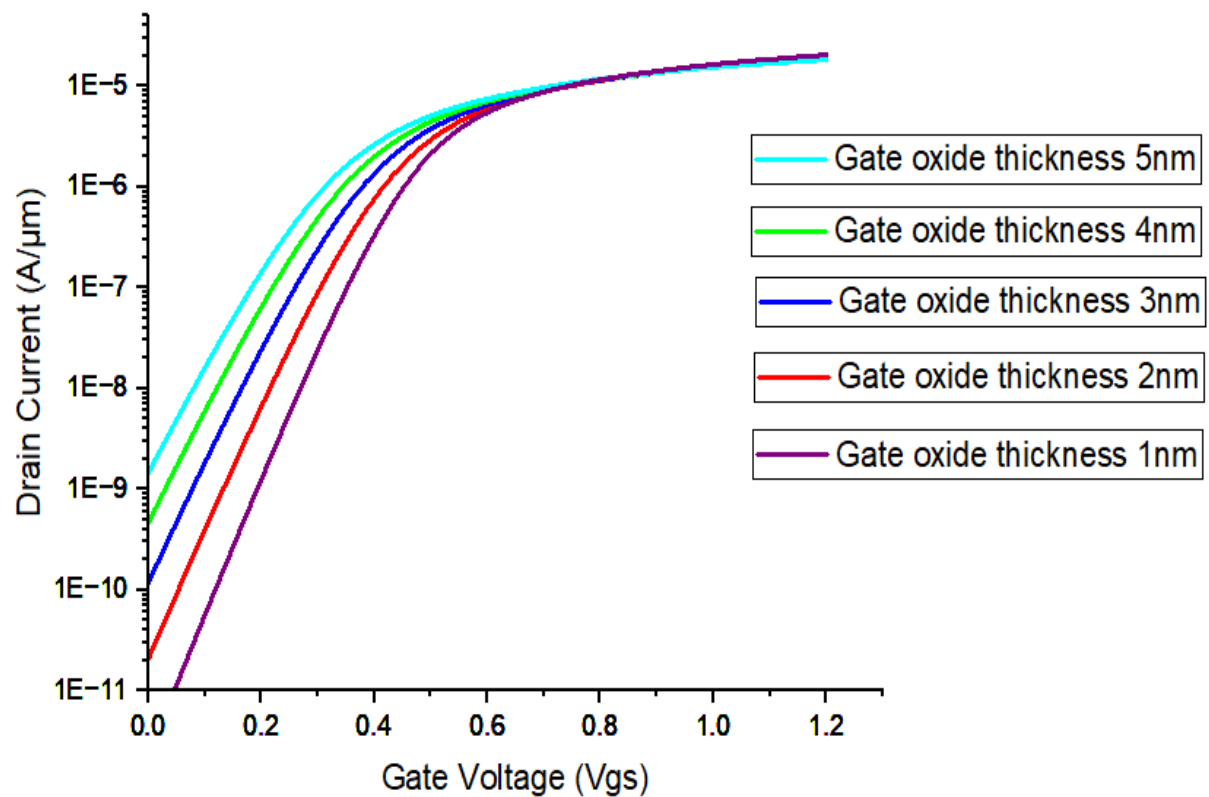
## Dual Material Gate Junctionless FinFET

All variations are for first metal Titanium and second metal Aluminum.

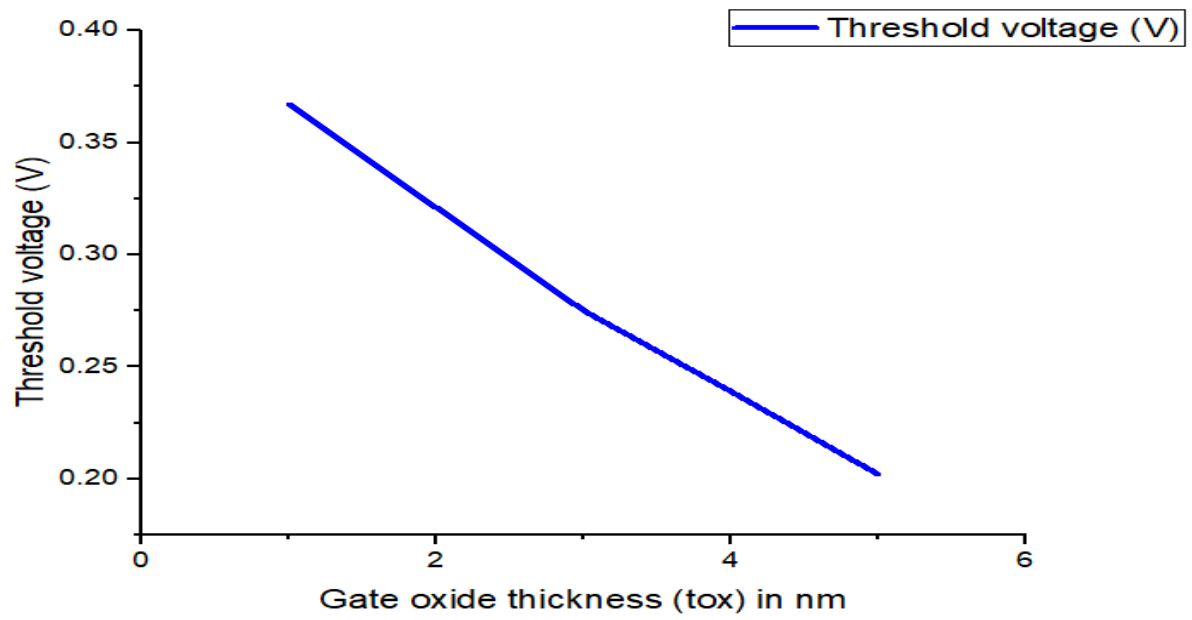
# Variations in Gate oxide Thickness-



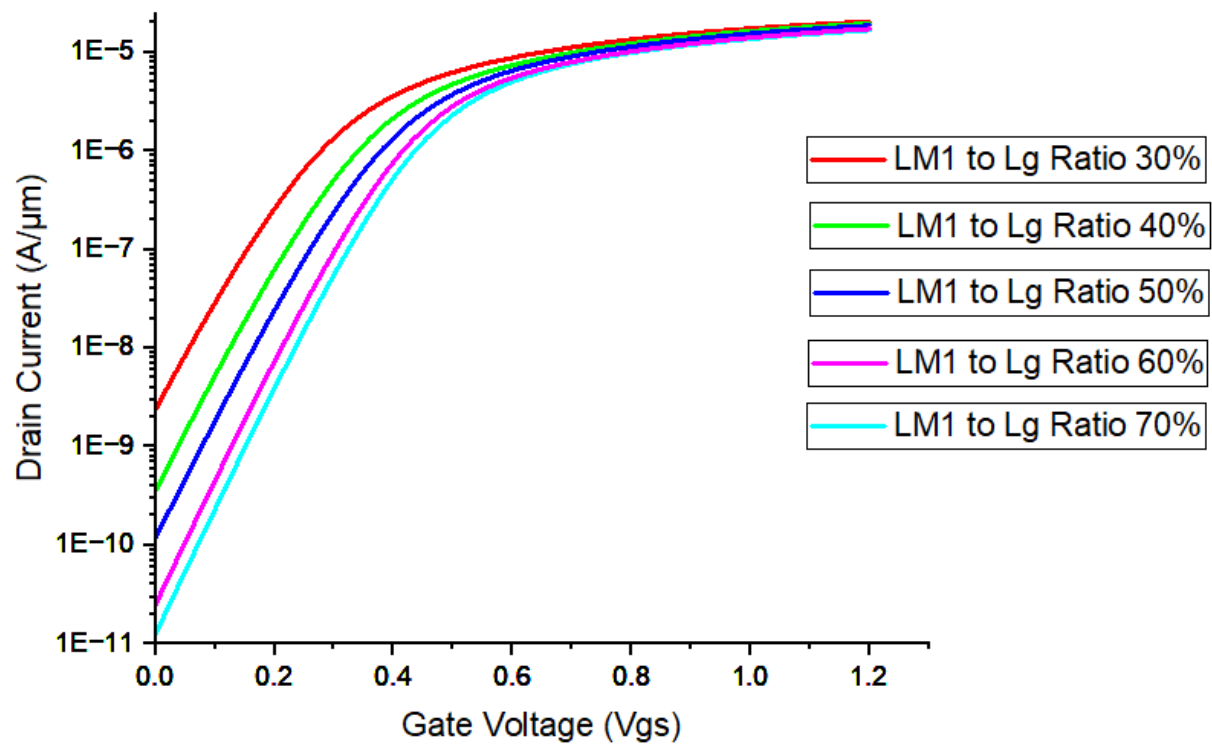
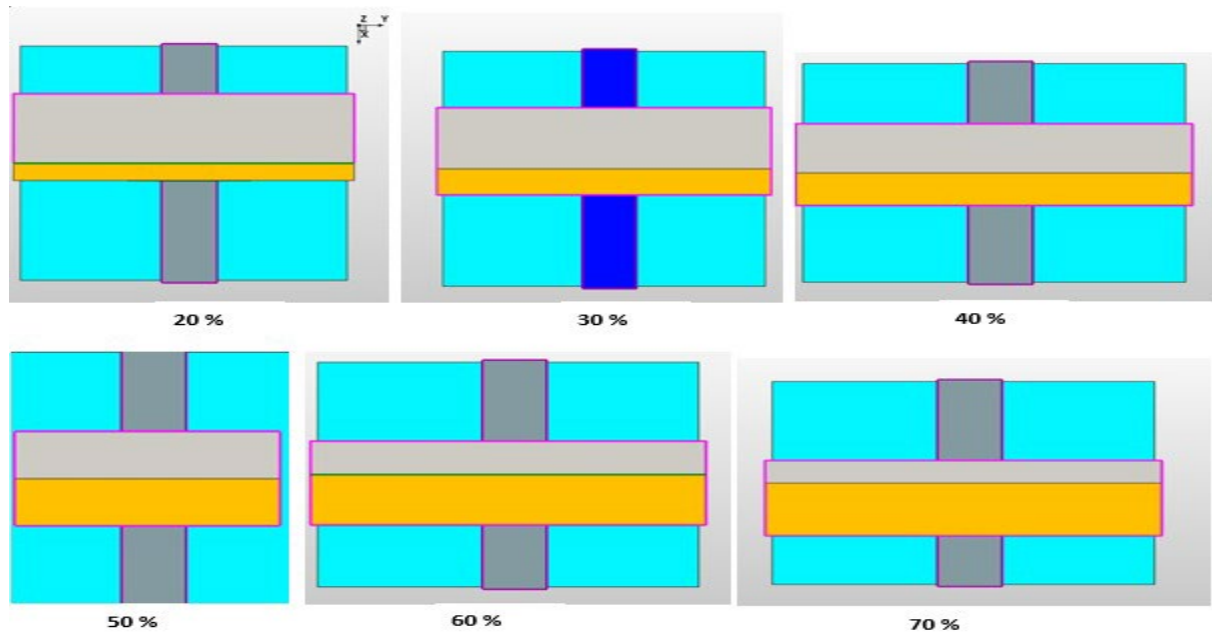
Plot-

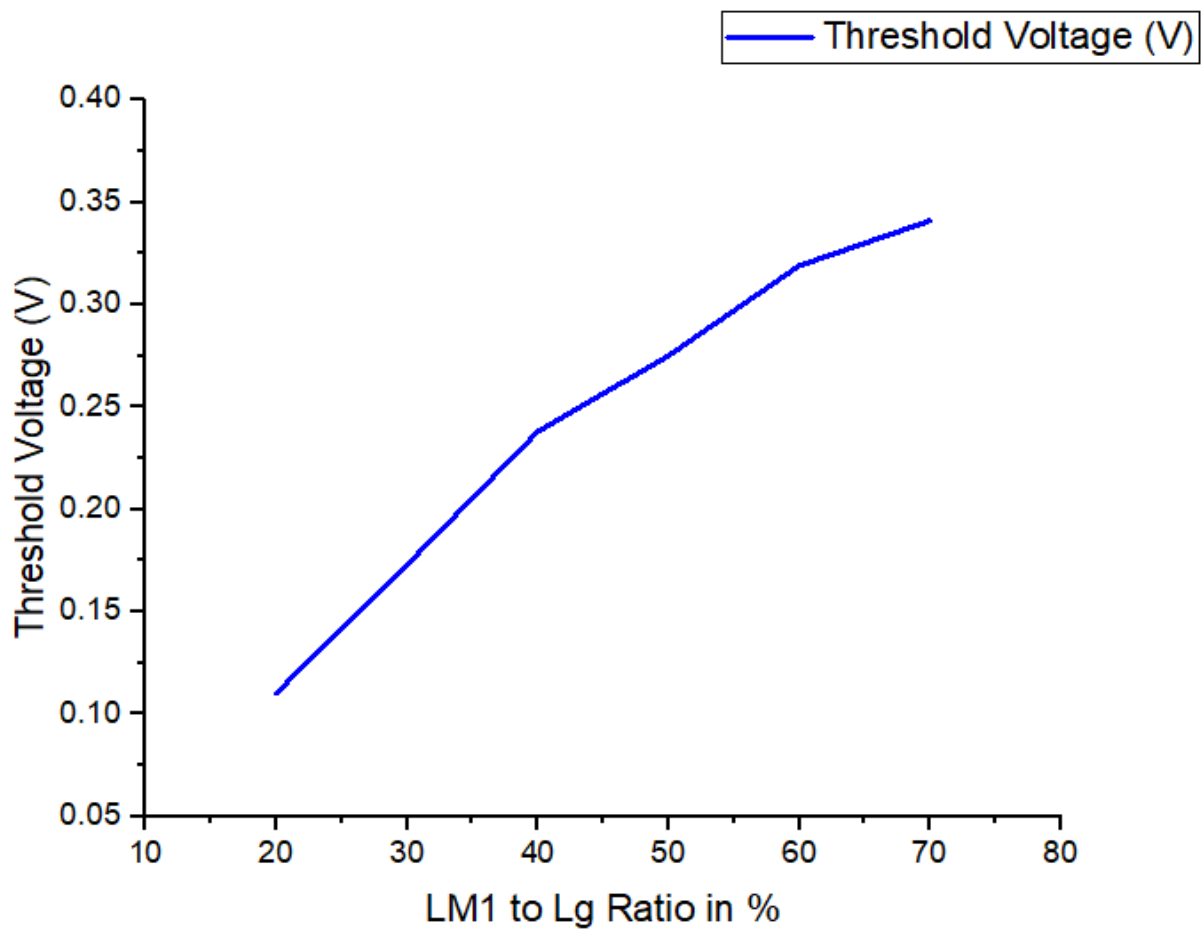


**Threshold voltage vs  $T_{ox}$ -**



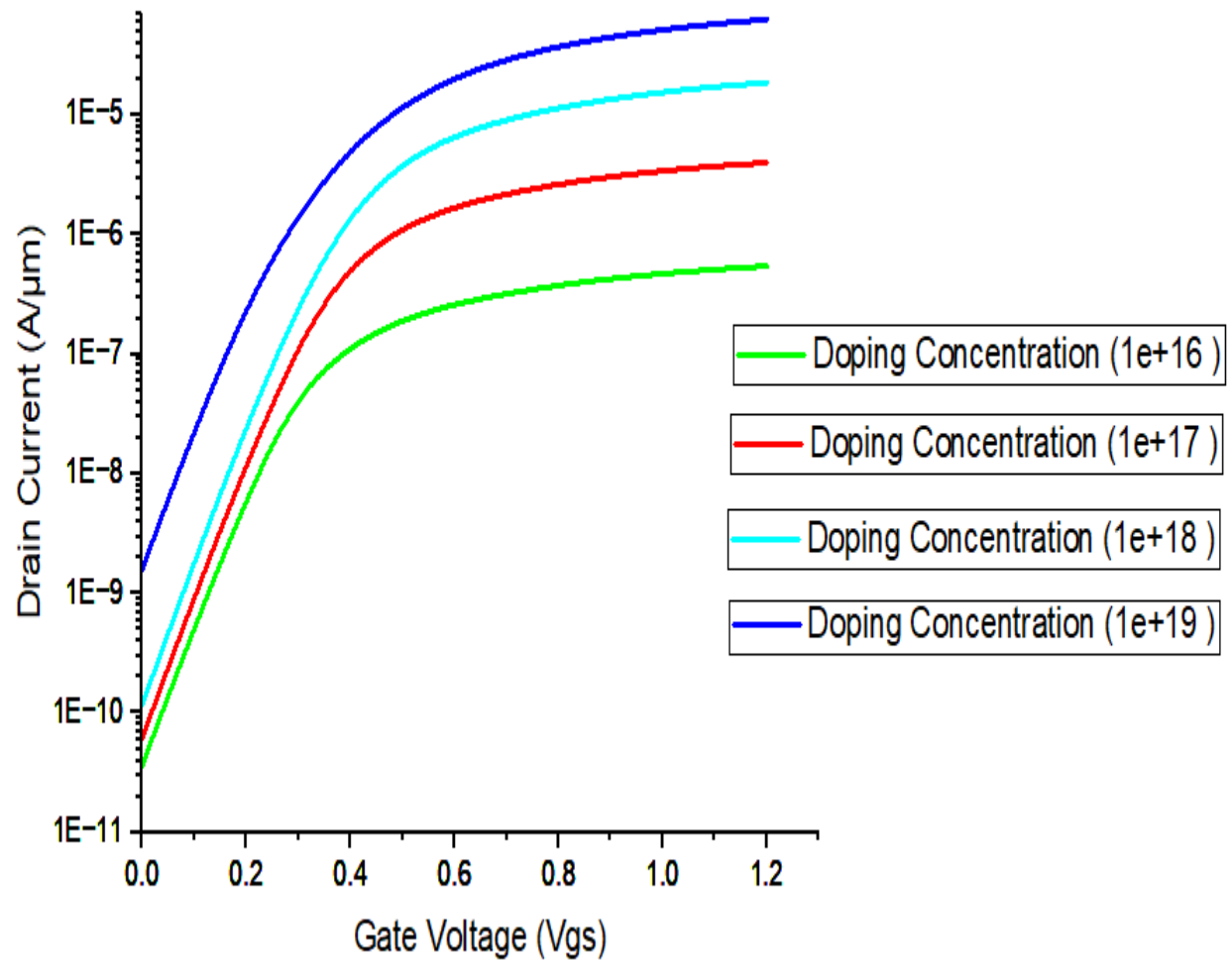
# Ratio of Gate 1 to total gate length







## Variation in concentration-



## DIBL-

