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")

(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@")
```

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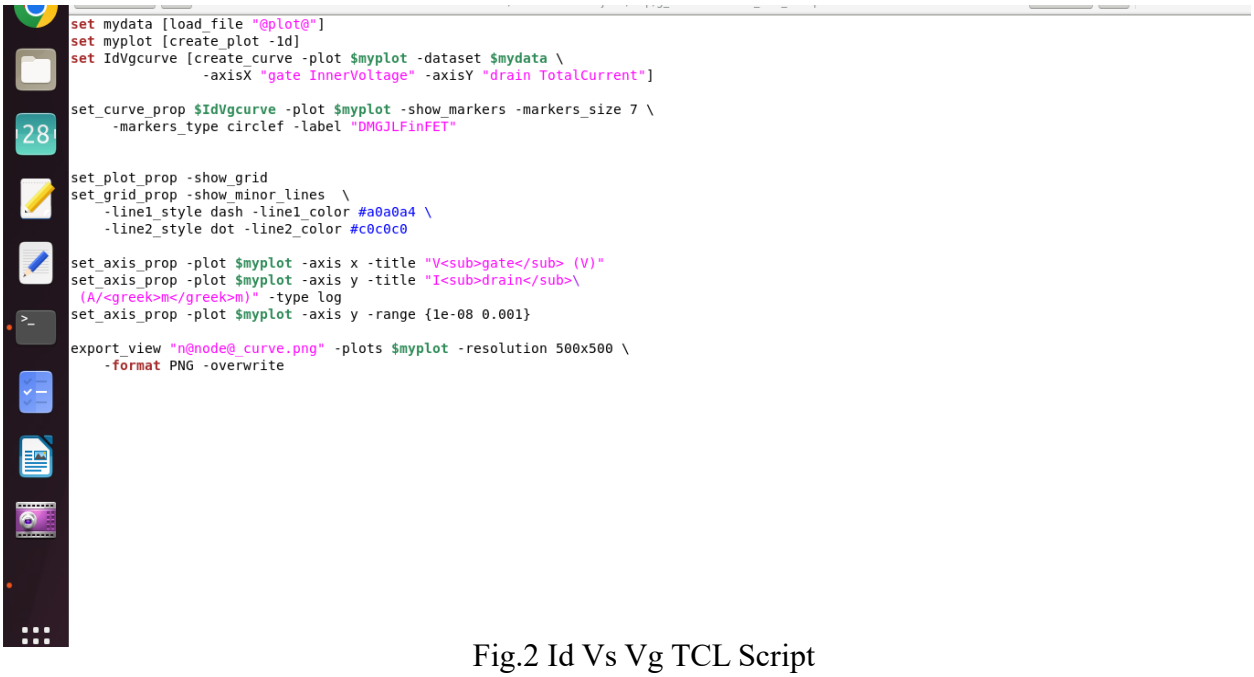
Fig.1 SDE Script

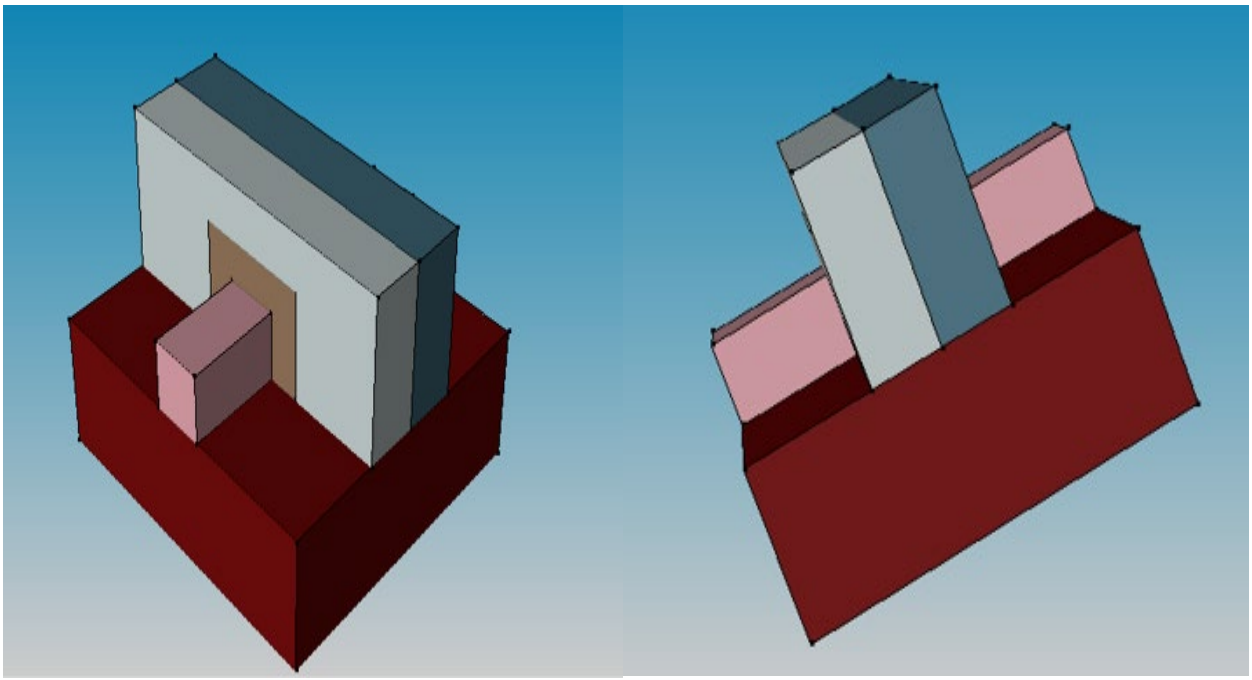


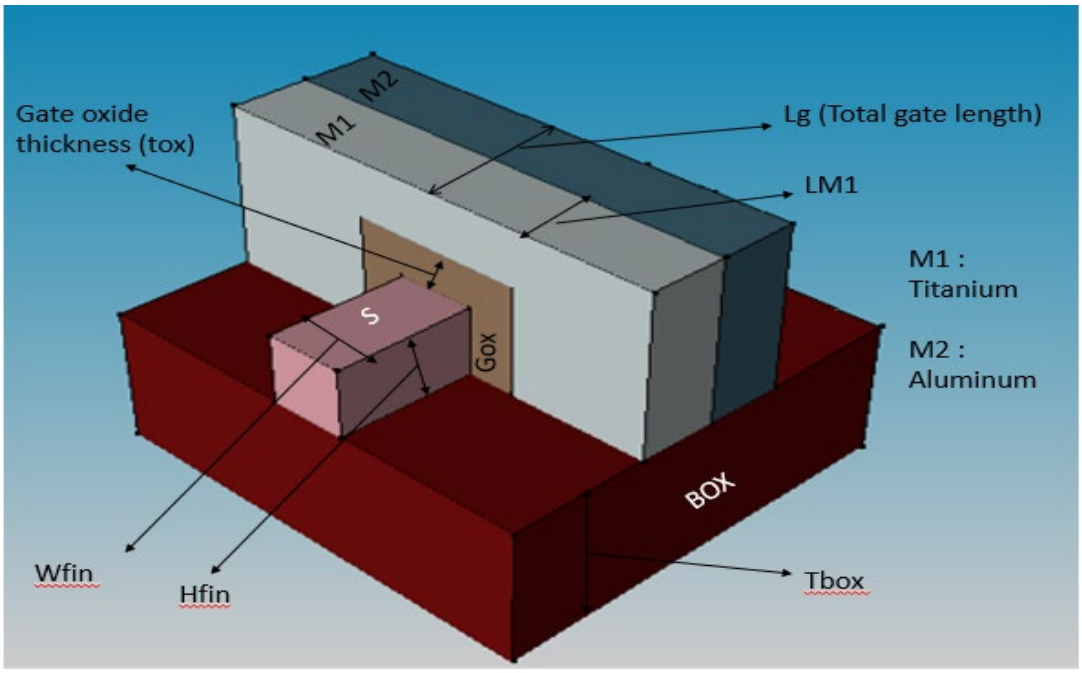
```
set mydata [load_file "@plot@"]
set myplot [create_plot -1d]
set IdVgcurve [create_curve -plot $myplot -dataset $mydata \
                -axisX "gate InnerVoltage" -axisY "drain TotalCurrent"]

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
```

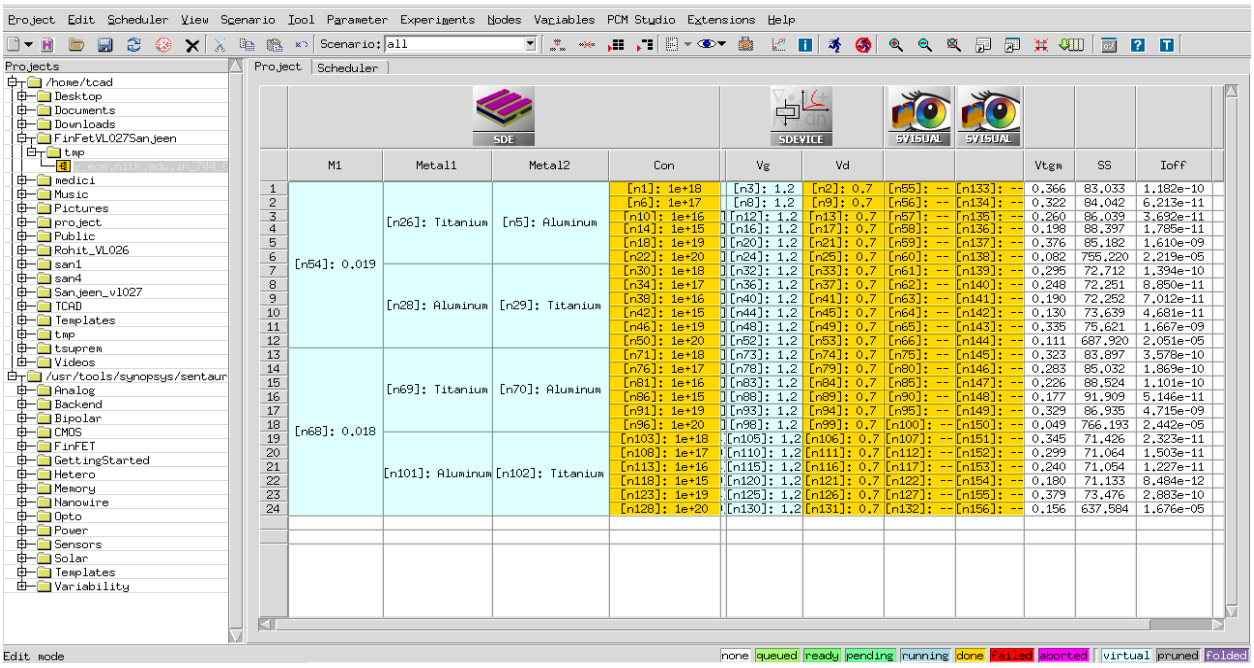
Fig.2 Id Vs Vg TCL Script

```
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



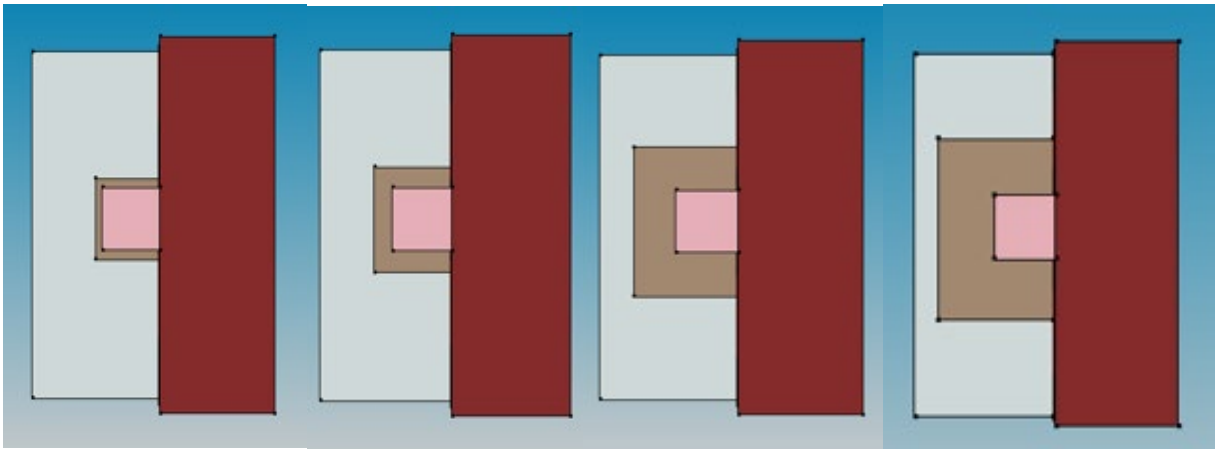




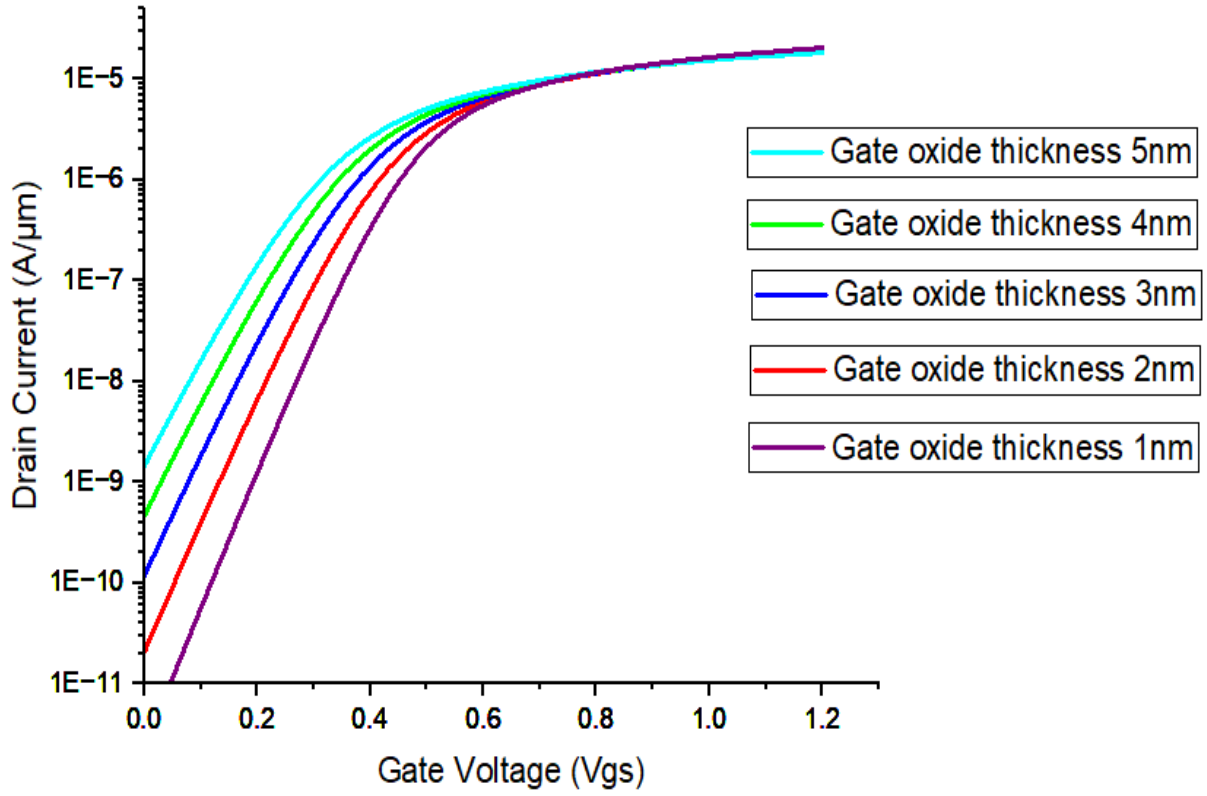
Dual Material Gate Junctionless FinFet

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

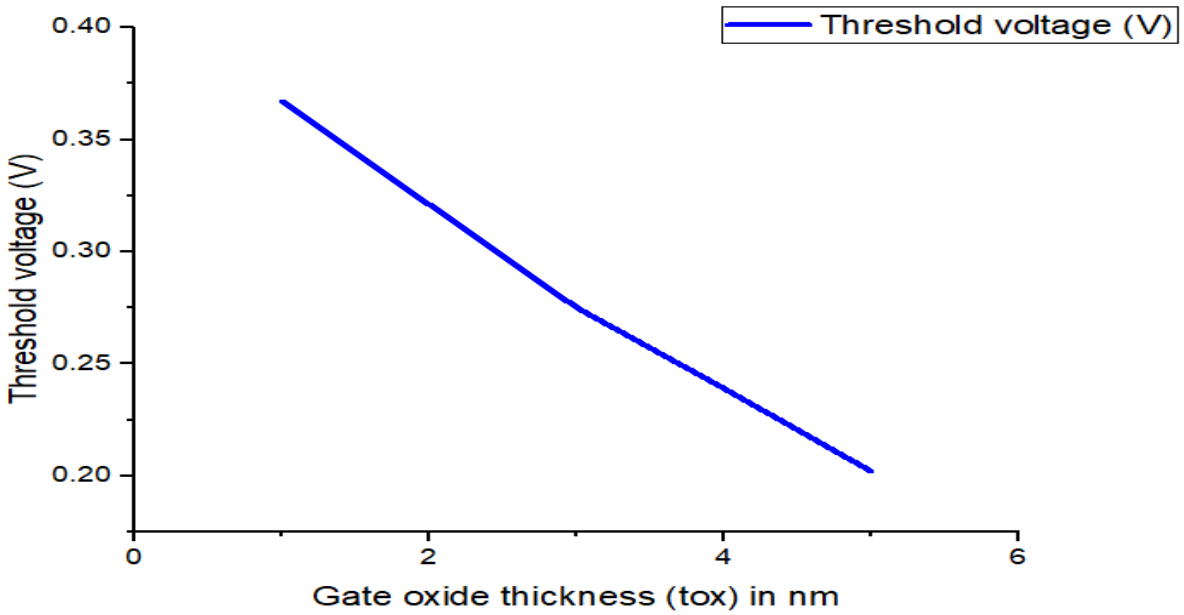
Variations in Gate oxide Thickness-



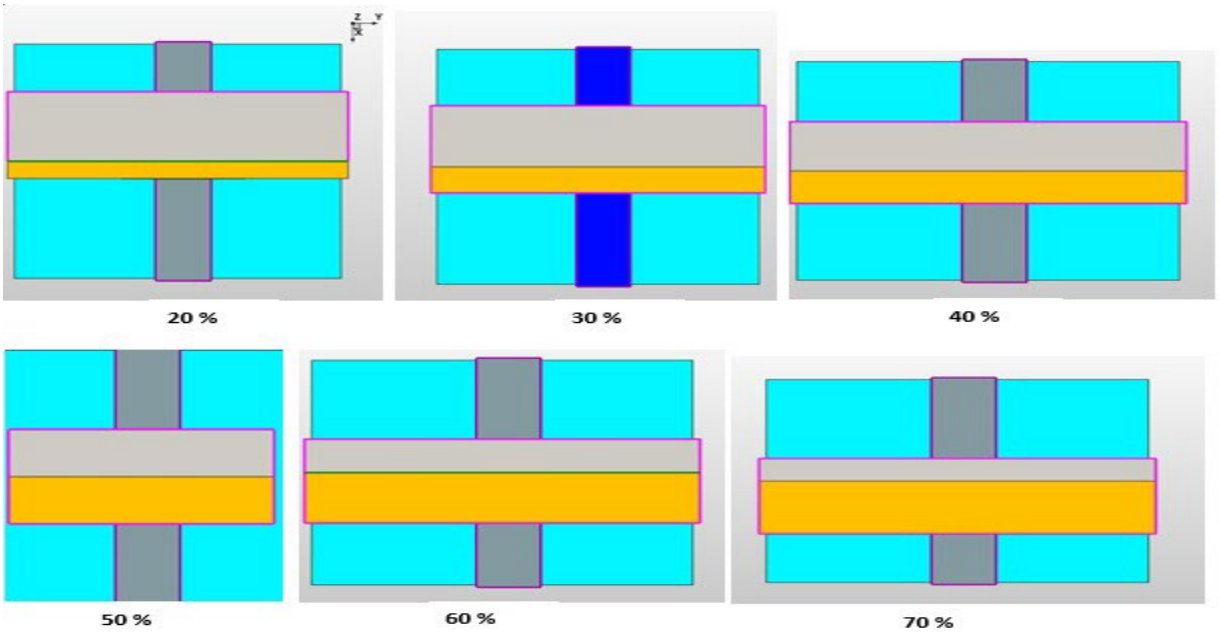
Plot-

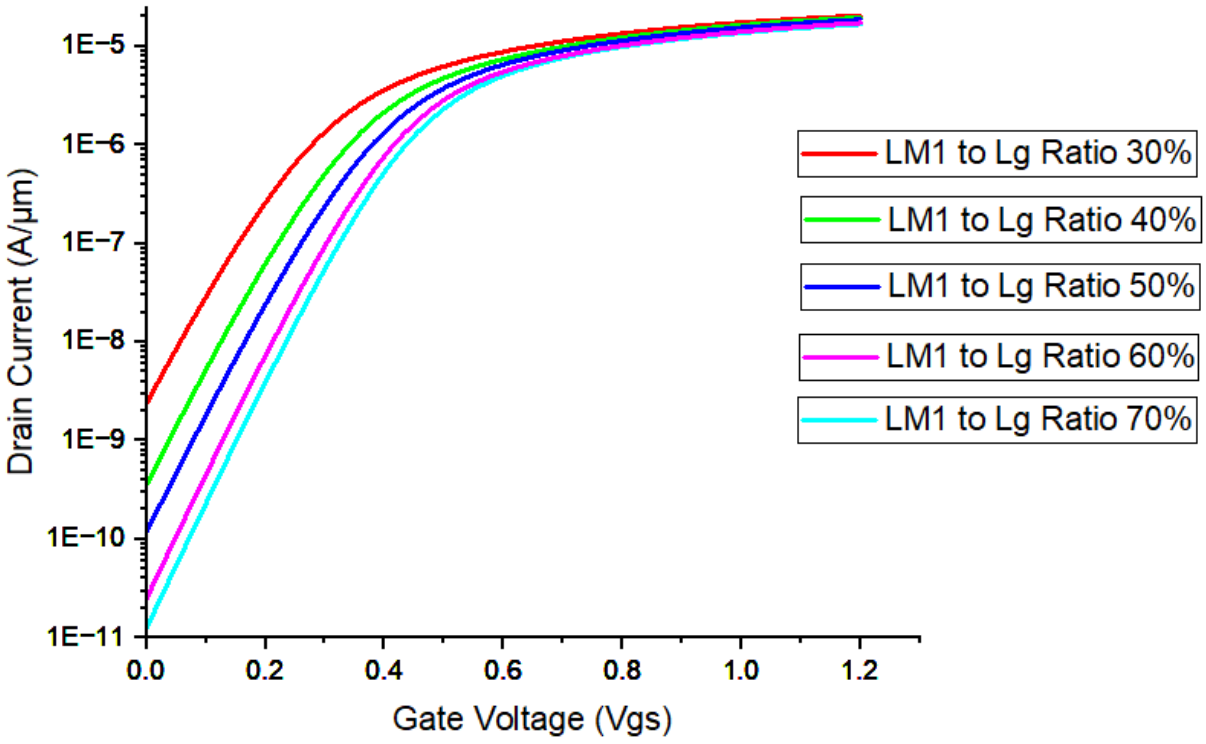


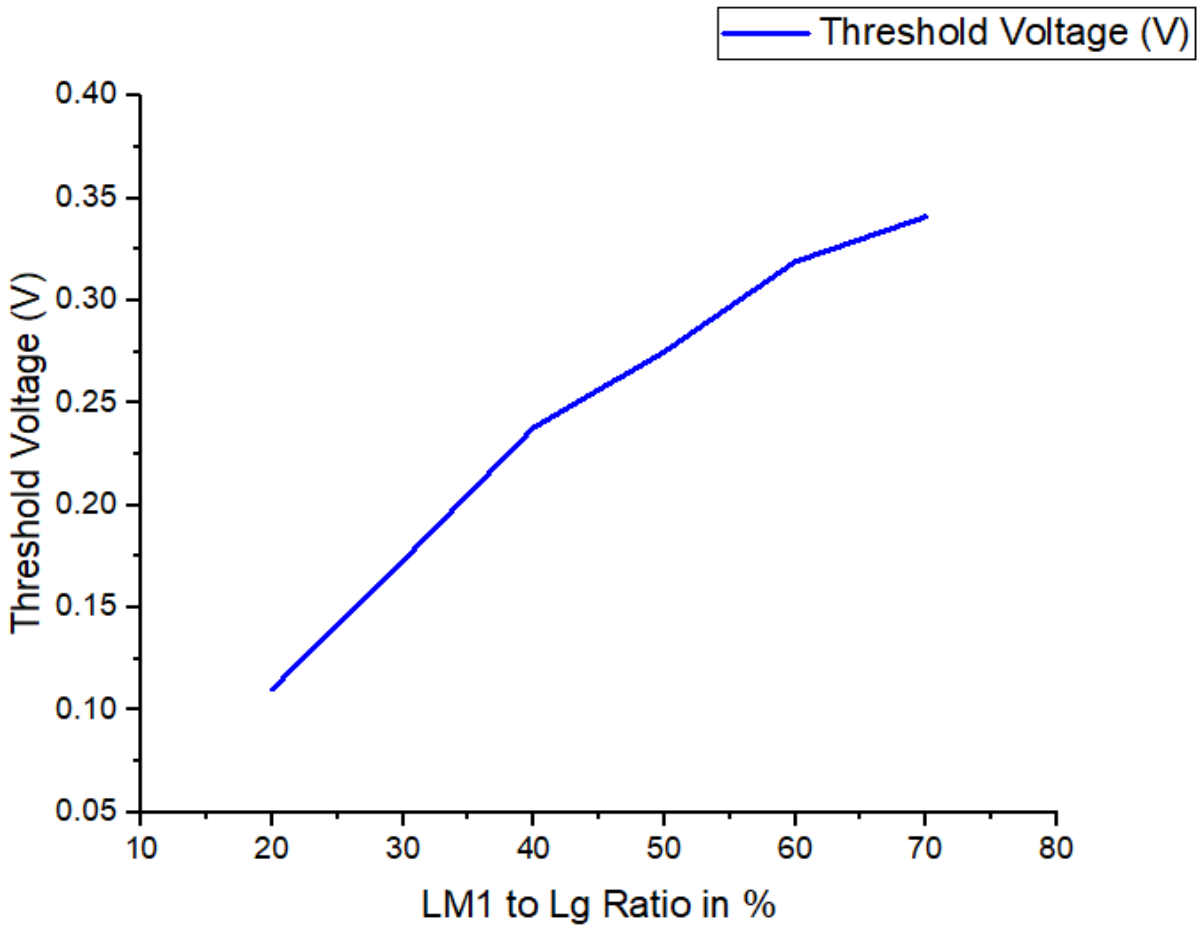
Threshold voltage vs Tox-



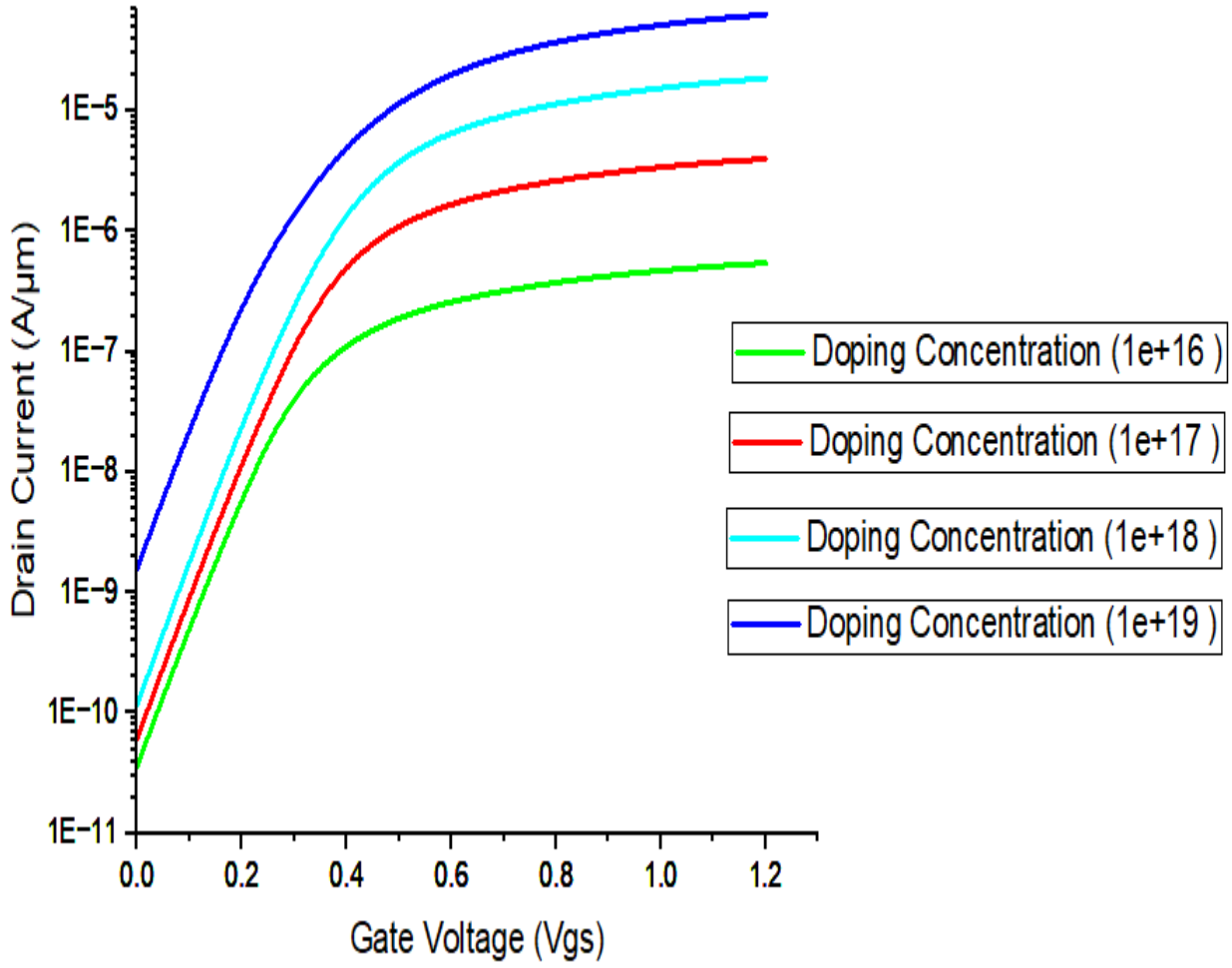
Ratio of Gate 1 to total gate length



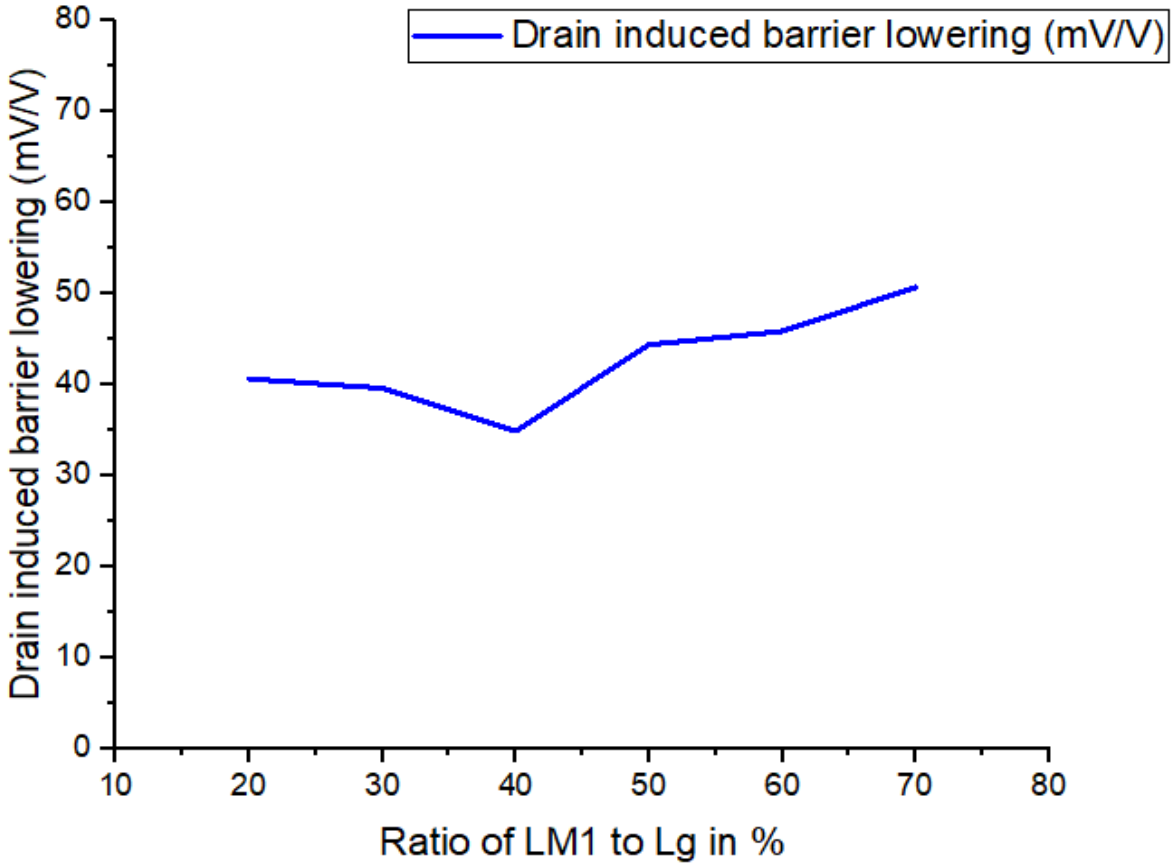



Threshold Voltage (V)
Threshold Voltage (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
10
20
30
40
50
60
70
80
LM1 to Lg Ratio in %

Variation in concentration-



DIBL-


Drain induced barrier lowering (mV/V)
Drain induced barrier lowering (mV/V)
Ratio of LM1 to Lg in %
0
10
20
30
40
50
60
70
80
10
20
30
40
50
60
70
80