TNL

# Particle DeviceSimulator (TNL-PD Simulator) Tutorial

Particle based device simulationSoftware



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10<sup>th</sup> Feb,2021

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# **1.1 Getting Started**

To use the TNL Particle Device (TNL-PDS) simulator user needs to get the official license. Once they get the license for the same, they can verify it by opening the TNL-Framework. At framework user will see a tick mark on the side of the name Particle Device Simulator (2D Poisson Solver) in green color which confirms the license for same as represented in Fig. 1. But if a cross mark in red color is seen then user might not using valid license (in this case user needs to contact Tech Next Lab Pvt. Ltd.). For more information user needs to go through the License Manual.



Fig. 1 : TNL-Framework

There are two ways to open the TNL-PD Simulator from the Framework shown in Fig.1. Those ways are shown in red rectangular boxes (box1 and box2).

- 1. This box1 contains PD Simulator's icon and name. By a single click on icon or name user gets access to use the simulator
- This box2 contains sub menu named as MC Particle Device Simulator 2D and 3D. By clicking on the menu Command user will get several sub-menus containing the names of all simulators of TNL family. By a single click on name user gets access to use the simulator.

Using any of the above two methods user will be directed to the TNL-PD Simulator window frame PDSimulator as shown in Fig. 2.



Particle Device Simulator (TNL-PI	DS)						-	
File Edit Simulate Examples	Help							
		Run Unload	Refresh Reset	Exit				
Tachnology Add P	agion Mash	Dhyrice Bine		Structure	Pup Output Script	Innut Scrint		
Add K	legion wesh	Physics blas			Kun Output Script	input script	 	
Select Tech 💌	Wor	kspace Setting						
	X Scale	300	nm					
	Y Scale	300	GO					
	2502			=				
TNL-PD Sim	ulator	A product by	Tech Next Lab Pvt Ltd.					
		Ĩ	N L ramework					
© Copyright Tech Next Lab. All Rig	ghts Reserved	C						

# 1.2 TNL-PD SIMULATOR window frame

Fig. 2: ParticleDevice Simulator window frame.

TNL-PD Simulator window frame in Fig. 2 divided in two boxes located in left and right of the frame. Each of them consists of several tabs used for dedicated function for different operations.

- i. Technology
- ii. Add Region
- iii. Mesh
- iv. Physics
- v. Biasing
- vi. Structure
- vii. Run Output Script
- viii. Input Script

The TNL-PD simulator utilizes the essential information needed to define a device structure which flows from selection of technology and work space, designing device structure, choosing appropriate physical models, applied external voltages and running the simulations. Following sections will elaborate about these things.Before starting the simulation, users need to take note of their device type andit's dimensions



## 1.2.1 Technology tab

This version of the TNL-PD Simulator is structured with the five types of device technology and their related physical models. As shown in Fig. 3 this tab consists of:

- i. Select Technology
- ii. Workspace Setting
- iii. Text field.

Technology	Add Region	Mesh	Physics	Biasing	
Select Tech		Wor	kspace Setti	ng	
		X Scale	300		nm
		Y Scale	300		GO

Fig. 3: Technology tab.

# **1.2.1.1 Select Technology**

In current version the device technologies included are given below;

- i. FDSOI (Fully Depleted Silicon on Insulator)
- ii. MOFET (Metal Oxide Field Effect Transistor)
- iii. TFET (Tunnel Field Effect Transistor)
- iv. MESFET (Metal Semiconductor Field Effect Transistor)
- v. HEMT (High Electron Mobility Transistor)

Depending on the user's requirement to select any of the above technologies specified.

# **1.2.2.1** Workspace Setting

After selecting the specific device technology, workspace needs to be defined by users for generation of device structure. Workspace is the area within which device dimensions in 'Add Region' tab will be given.

Workspace setting contains X Scale and Y Scale fields, unit of dimension and GO button. X Scale is for setting working Area in towards X Axis & Y Scale is for setting working Area in towards Y Axis. "GO" button is used for set maximum working area as per device structure requirements.

As 'GO' button is clicked the information of the device technology selected and workspace dimensions will get written in the blank text-field present below workspaces setting. TNL-PD simulator allots the selected workspace and device structure environment. Now users can define their required device structure by defining its different regions with suitable materials inbuilt in the simulator or they can accommodate their user define materials. With the addition of



regions one by one, simulator generates that graphics in right hand of the TNL-PDS frame named under Structure.

# 1.2.2 Add Region tab

This feature is most useful to select device structure. The structure is created by a set of regions with different coordinates, material and doping. As shown below:

Technology	Add Regio	n M	lesh	Physics	Biasing	,	
Choose Mate	rial 🔽	Dop	ing 🔻	)	Region/C	Contact	•
Concentration		×	min		Xmax		
1	]						
Oxide dielectric			Ymin	-	Yma	ж	
3.9 Width		-					
1e-6		Add			Delete	1	
Mater Xmir	n Xmax	Ymin	Ymax	Doping	Dose	Name	Regio

Fig. 4: Add Region

This tab provides different material, regions and contact to define the device structure. The semiconducting materials Si, GaAs, AlGaAs, GaN, AlGaN are added to current version of simulator, an oxide region whose dielectric constant can be separately applied, Al and Al-Au alloy can be used as a metal contacts (Ohmic & Schottky), SiO<sub>2</sub> Si<sub>3</sub>N<sub>4</sub> as insulator.



Fig. 5: Feasibility to choose (a) material (b) type of doping and (c) region or contact of device from various options.



- (a) Any one from the given options of semiconductor material can be selected for a specific region of the device structure.
- (b) From this option acceptor or donor type of doping can be implanted by selecting "P-type" or "N-type" respectively.
- (c) The name of the region need to be identified by selecting one of the option like Source, Drain, Gate etc. and Ohmic or Shcottky type contact etc.





- (d) The concentration field shown in Fig. 6 is for the doping density of selected type of the current region you need to define.
- (e) The four fields named Xmin, Xmax, Ymin, Ymax are present to give the boundaries in all four directions for a 2D structure.
- (f) Oxide dielectric field requires the dielectric constant of the oxide, users need to define it as per device structure requirements. Eg. dielectric constant of SiO<sub>2</sub>is 3.9.
- (g) Width field is for defining the width of the device. By-default it 1um, you can edit and can give some other value as per material used, but user need to be careful in choosing the value of dielectric constant, doping concentrations and the mesh sizes (will talk about this later on).



Fig. 7: Add and Delete button. Table for complete data of every single region

(h) Users may choose different regions dimensions with setting minimum and maximum x and y coordinates values after clicking on add button. After adding every region, users need to click refresh button. Every time you click on add button the information of material, xmin, xmax, ymin, ymax, doping type, dose, name of region and region will get print on a new row of the table shown in Fig. 7.



- (i) If user finds some wrong information about any region has been chosen, then they can eliminate that particular row by clicking on the Delete button and then click on Refresh button
- (j) Every time user have flexibilities to click Add or Delete buttons, the pane in Structure tab present in right column of the simulator main frame to add or delete that respective region.

#### 1.2.3 Mesh tab

Technology	Add Region	Mesh	Physics	Biasing
Select Region 🔻				
Step Size X		Step Size	Y	
	Ge	enerare Mesh	]	
Message>> Chose	Step-sizes wisely and	d comparable t	to your doping p	rofile.
	Fig. 8: Mesh	tab		

Next tab on main frame is Mesh. Users may choose uniform meshing on the created device geometry. In case of two dimensional (2D) structures, the intersection point of mesh in x and y dimension will be used for charge distribution in form of super particle or charge in cloud (CIC) and calculation of potential by Poisson's equation. Step Size X is for distance between two consecutive mesh lines in X direction and Step Size Y is for distance between two consecutive mesh lines in Y direction. The Step Size X and Y are in the nanometer by default. After inserting suitable values in both of the above fields, click on Generate Mesh button. It will automatically generate mesh on Device Structure pane and also create number of node points in x and y directions which are very important quantity for the simulation.

For more accurate simulation user need to take notice of the following;

- i. Try to take square mesh.
- ii. Smaller the mesh size, the simulation complexity will be more and thus simulation time will be longer.
- iii. There is trade of between doping concentrations and the cell volume in the device.Cell Volume = step size x \* step size y \* device depth.



Doping concentrations of the regions where it should be extrinsically doped needs to be comparable with the cell volume.

Doping concentration \* cell volume >= 1.

This version of TNL-PD Simulator, the uniform rectangular meshing can be chosen, in next version of the simulator will be loaded with the capability of non-uniform and triangular meshes.

#### 1.2.4 Physics tab

Technology	Add Region	Mesh	Physics	Biasing	
Material Used	>>				
🔲 Si					
Compound					
Scattering Mecha	nisms>>				
Acoustic	Acoustic_L	Intervalle	ey_gamma_L	Polar_gan	nma
Coulomb	Acoustic_X	Intervalle	ey_L_gamma	Polar_X	
Intervalley_g	Acoustic_gamma	Intervalle	ey_gamma_X	Polar_L	
Intervalley_f		Intervalle	ey_X_gamma		
Polar		Intervalle	ey_X_L		
		Intervalle	ey_L_X		
		Intervalle	ey_X_X		
		Intervalle	ey_L_L		
Charge Assi	Select C	harge Assign	ment		
SOR	Method				
Default	Quatum	Confinement	Effect Co	onfinement in X I	Direction
				onfinement in Y I	Direction

Fig. 9: Physics tab

Under Physics tab users have facility to select scattering mechanism as per their requirements, can choose one of the Charge Assignment Technique i.e. (CIC, NEC, NGP), Numerical Method (SOR) and Quantum Confinement Effect direction.

#### i. Scattering Mechanism

At least one of the scattering mechanisms is essential requirement to take in consideration for running device simulation. All types of scattering mechanism are given for both single element and compound materials.

There are two ways to select the scattering mechanism. First, if you select Si or Compound semiconductors placed under material used name, all the respective mechanisms will automatically get selected. Second, users can select one by one many of the available mechanism per your requirement.

#### ii. Select Charge Assignment

Next option is for selection type of charge assignment techniques on the node points of the meshes. Three types of charge assignment techniques have been implemented in the TNL-PD Simulator. All three charge assignment techniques produce similar results.



## (a) Charge in Cloud (CIC)

In the CIC scheme a better approximation can be obtained assigning the charge of a super particle to the two nearest neighbor cell points.

# (b) Nearest Element Center (NEC)

The NEC charge assignment force interpolation scheme attempts to reduce the selfforces and increase the spatial accuracy in the presence of non-uniformly spaced tensor-product meshes and/or spatially-dependent permittivity.

#### (c) Nearest Grid Point (NGP)

In the NGP scheme all the charge from a given particle is assigned to the nearest grid point. The force on the particle is also taken as the one calculated on the nearest grid point.

#### iii. Method

Next tab is method use for solution of Poisson equation on node points for super particles. The Succession Over Relaxation (SOR) method has been implemented to improve the rate of convergence for solution of Poisson equation. SOR method uses a weighted average of the results of the two most recent estimates to obtain the next best guess of the solution. If the solution is converging, this might help extrapolate to the real solution more quickly.

#### iv. Quantum Confinement Effect

We have developed a different approach, which introduces an effective potential for consideration of quantum confinement effects in x-, y-, and z- directions separately. Here, the natural non-zero size of an electron wave packet, in the quantized system, is used to introduce a smoothing of the local potential (found from Poisson's equation). This approach naturally incorporates the quantum potentials, which are approximations to the effective potential. The effective potential is related to the self-consistent potential through an integral smoothing relation.

By-default this effect is disabled, if user want to include this effect to their device simulation, they may chose Enable option and also select one check box between confinement in x or confinement in y direction.

#### 1.2.5 Biasing

- i. The biasing tab in main frame is use to provide input voltages at different electrode terminals through "Solve" tab. Four type of terminals are given Source, Drain, Gate and Substrate. Click on insert button number of times as per the electrodes created in the device structure for providing the voltage ramping information.
- ii. User may choose constant or ramping voltage conditions on a particular electrode.



- iii. Give the initial, step and final biasing point. Suppose user gives initial value 0, step value 0.1 and final value 1. Then the simulation will first start at the 0 then it will proceed to 0.1, 0.2, 0.3, ..., up to final value 1.
- iv. During the simulation all respective results will be saved at these voltages (we will talk about it later in this tutorial).
- v. Then click on load button on the main frame under solve tab. The given voltage will be added to particular electrode.
- vi. A field named 'Barrier voltage for Schottky contact', if you have added any contact terminal of Schottky type then you need to give the barrier voltage here. Barrier voltage is the difference between the work function of metal and the electron affinity of semiconductor. Unit is in Volt.

$$\phi_{\rm B}=\phi_{\rm M}-\chi$$

Once all the information has been provided by user, the structure is ready for starting simulation for which there are three ways:

- i. Click on 'RUN' button present above.
- ii. Go to Simulate menu, then click on Run submenu.
- iii. Go with the key combination of Shift+F6.

# 1.2.6 Structure Tab



Fig. 10: Structure tab showing graphics of device

This tab shows the graphics of the device structure with all the regions added in the Add Region section. Users may select X-Scale and Y-Scale values in work space setting, the blank space in Structure tab shown in Fig 10. Initializing the working device geometry ranges in it and becomes ready to draw the 2D or 3D structure graphics of the desired structure. When users give dimensions and other data of a region and click on ADD button, then that area will be shown with particular material's convetional color in the workspace. If users found that there is some wrong information has been entered, then you can delete that easily. Users need to select that



row from the table present in Add Region tab and then click on 'Delete' button. To see that change in graphics users need to click on the 'Refresh' button.

TNL-PD simulator's GUI capabilities provide feasibility to view and verify device structure from table which contains the database of the designed structure or through the structure graphics. Through this it can be easily checked that at the time of input whether there is some unnecessary void or overlapping have been made or not and can be removed easily.

# **1.2.7 Run Output Script**

This column will show the simulation points and few parameters value at each bias point. It will show simulation date and time. When simulation starts it will show the directory where all the simulation results will be saved with the line named working directory. After this some value of each bias point will be shown with the line named Calculation starts at Drain voltage = x and Gate voltage = y. At the end of last bias point it will write a line Simulation Completed which will notify user the successful completion of whole simulation after that he can see the results going to the working directory of respective simulation.

Structure Run Output Script Input Script	Structure Run Output Script Input Script
H H H H	
# # # ########	
TECH NEXT LAB FAMILY OF SIMULATORS     ALL SIMULATORS ARE PROPERTARY PRODUCTS OF TECHNEXT LAB PVT LTD.     ALL SIMULATORS ARE TRADEMARK OF TECHNEXT LAB PVT LTD     USER AGREE TO ALL TERM SE CONDITIONS TO RUN ANY TNL SIMULATORS.     TILL FRAMEWORK LLC INFO     NO OF USERS     FULL BAND     HALL MOBILITY     MC PARTICLE DEVICE     STRVLEVER	11/26/2020 11:21:37 ########### 11_26_guant1 ######### rowXcol 8 9 Material X min x max y min y max doping type conc Region Si 50 75 5 15 NType 1e25 Source 1 Si 100 125 5 15 NType 1e25 Drain 2 Si 75 100 5 15 PType 2e24 Gate 3 Ovide 75 100 5 15 PType 2e24 Gate 3
- INEPLOT	
Simulation Starts 02/09/2021 12:32:32	Oxide         50         125         15         55         0         0         Bulk-Oxide         5           Al-Au_alloy         50         75         5         0         0         Ohmic         6           Al-Au_alloy         100         125         5         5         0         Ohmic         7           Al-Au_alloy         75         100         2         2         0         Ohmic         7
Working Directory C-UlserstJanisDocuments\device1\device1\Gate_vtg.3.0\drain_vtd0.0 Mechanisms in the gamma valley = 6 Mechanisms in the Xalley = 8 Mechanisms in the Xalley = 8 Mechanisms in the Xalley = 8 Mechanisms in the L valley = 8 Mechanisms in the L valley = 8 Mechanisms in the gamma valley = 6 Mechanisms in the gamma valley = 6 Mechanisms in the Xalley = 8 Mechanisms in the Xalley = 4 Mechanisms in the Xalley	FD SOI mesh_sizeX 1.0E-9 mesh_sizeY 1.0E-9 mult_factor 1.0E-9 acoustic ON intervalley_g ON intervalley_f ON coulomb ON charge_Assignment CIC Parallet_Processing OFF rowXcol2 2 6 Contact Biasing-Type Volt/Current Int Step Final
Calculation starts at Drain voltage = 0.0 and Gate voltage = -3.0 Number of time steps for averaging =1000 Teach number of literation = 01000	Gate Step Voltage -0.3 0.1 0.4 1 Drain Constant Voltage 0.6 0.6 0.6 2

Fig. 11: (a) Output script tab

(b) Input Script tab

# 1.2.8Input Script

This tab consists of information about all the input information provided to initiate simulation from all tabs on the left column of the main frame in script form. Users have flexibility to load an example (.txt) file, then that whole script will get printed here.

# 1.2.9 Menu

i. File

When users click on File menu option, Open sub-menu will open. Click on Open, a pop-up window will float on user's screen. From this users will go to specific directory and then to that folder in which your script for the device input is present. Select that .txt file and click on open button below of the pop-up window. (See Section 1.3)



#### ii. Simulate

This menu contains Run option, click on this users may click to start the simulation after giving the path to save your simulation.

#### iii. Example

Here five device technology names have been given. Simulator is loaded with an example script of each device technology. User can select any of this and try for simulation. (See Section 1.3)

## iv. Help

Here three options named About, TNL-PDS Manual and TNL-PDS Tutorial are provided.

Clicking on about or by giving shortcut-key combination of Ctrl+H will transfer you the <u>TechNext Lab Pvt. Ltd.</u> official website <u>https://www.technextlab.com</u>. Clicking on above options TNL-PDS Manual and TNL-PDS Tutorial manual and tutorial file will get open.

#### 1.2.10 Other

- i. Run Button: This button use to start the simulation.
- ii. Unload Button: This button use to unload or delete all the input information given previously. This button is necessary when you need to input your data from the script file.
- iii. Refresh Button: This button is to refresh the graphics of device when there is some edit needed to be performed.
- iv. Reset Button: This button delete each and every thing and brings it to null value.
- v. Exit Button: This button closes the simulator GUI window.

# **1.3 Simulation of Examples (Script)**

Simulator provides flexibility to do device simulation through the script file as by using the ways told in section 1.2.9. To start using Example simulation, go through following steps:

- 1) Click on Unload button
- 2) Click on the Example menu and then select any of on technology name.
- 3) Now go to the Technology tab. Select technology name same as user have selected in step2.
- 4) Give the workspace (X and Y scale) comparable to the device dimension written in the Example script file. User can see this in the Input Script tab.
- 5) Click on Refresh button. User's device structure in script file will be loaded on GUI frame.
- 6) Click on Run button and select any directory or folder or path and give the name of your simulation file, then click on save button, thus simulation will be started of examples.
- 7) After some time scroll the Run Output Script pane and see the progress of your simulation. At the time of completion 'Simulation Completed Successfully' message will be shown in Run Output Window.



8) See your results by going to the directory as selected in Step6.

Same steps will be taken if you select a script file from Open option of File menu.



# 2.Hands-On Tutorial

For new user to get familiar with MC Particle device simulator, user may follow step by step the given tutorial. In current tutorial the Simulation of 20 nm channel length SOI MOSFET is described exploiting the Monte Carlo Particle Device Simulator.

## 2.1 Technology and Workspace setting

- Set Technology to FDSOI.
- Set workspace as per requirement.
- In present case our device dimension is in nanometer (nm)
- Set X Scale 100nm.
- Set Y Scale 100nm.
- By-default all scale in nm
- Click "GO" button.
- Information about all the above things will get displayed on below blank text area.

## 2.2 Add Region

#### **Adding Source Region:**

Technology Add Regio	m Mesh Physics	Biasing	Structure Run Ou	tput Script Input Scr	ript
Si  Concentration Le25 Oxide dielectric	NType  Xmin V	Source Xmax 20 Ymax			
3.9 Width 1e-6 Mater Xmin Xmax	0 Add Ymin Ymax Doping 0 10 NType	10 Delete Dose Name Regio 1e25 Source 1	Si  Concentration Le25 Oxide dielectric 3.9	NType  Xmin Vmin Vmin 0	Source  Xmax 20 Ymax 10
			Width 1e-6 Mater Xmin Xmax Si 0 20	Add Ymin Ymax Doping 0 10 NType	Delete Dose Name Regio 1e25 Source 1

- Choose Source as a First region.For source region choose material Si (Silicon) using mouse orup/down key in keyboard.
- Doping type, N Type, Dose 1E25.
- Select region Source.
- Set X and Y Dimensions as

Works	space Setting	
X Scale	300	nm
Y Scale	300	GO



- X Min: 0, X Max: 20nm.Y Min: 0, Y Max: 10nm.
- Click Add Button.

# **Adding Drain Region:**

Technology	Add Region	Mesh	Physics	Biasing		Structure	Run Output Script	Input Script	
Si	•	NType	•	Drain	•				
Concentration		Xmin		Xmax					
1e25	]	40		60					
Oxide dielectric		Ymin		Ymax					
3.9		0		10					
Width 1e-6		Add		Delete					
Mater Xmi	n Xmax	Ymin Ymax	Doping	Dose	Name Regio				
Si	0 20	0 1	0 NType	1e25 5	ource 1				
51	40 60	0 1	0 NType	1e25 D	rain 2				

- For Drain Region choose material Si (Silicon) using.
- Doping type N Type, Dose 1E25.
- Select region Drain.
- Set X and Y Dimensions as

X Min: 40, X Max: 60nm.Y Min: 0, Y Max: 10nm.

• Click Add Button.

# **Adding Gate Region:**

Technology	Add Regio	n Mesh	Physics	Biasing			Stru	icture	Run Out	put Script	Input Script	
Si		РТуре	•	Gate		•						
Concentration	L.	Xmin		Xmax								
1e24		20		40								
Oxide dielectric		Ymin		Yma	х							
3.9		0		10								
Width 1e-6		Add		Delete	)							
Mater Xm	n Xmax	Ymin Ym	ax Doping	Dose	Name	Regio						
Si	0 20	0	10 NType	1e25	Source	1						
Si	40 60	0	10 NType	1e25	Drain	2						
51	20 40	0	10 Plype	1e24 (	ate	3						

- For Gate Region choose material Si (Silicon).
- Doping type P Type, Dose 1E24.
- Select region Gate.



• Set X and Y Dimensions as

X Min: 20, X Max: 40nm.Y Min: 0, Y Max: 10nm.

• Click Add Button.

# Adding Gate Oxide Region:

Technolog	ay A	dd Region	Mes	h P	hysics	Biasing	9		Structure	Run Output	Script	Input Script
<u></u>												
Oxide		•	Dopin	g 🔻		Gate-Ox	ide	•				
Concen	tration		Xmi	n		Xmax						
			20			40						
Oxide diel	lectric		Yr	min		Ym	ах					
3.9			-2		ſ	0						
Width												
1e-6			Add			Delete						
-							_					
Mater	Xmin	Xmax	Ymin	Ymax	Doping	Dose	Name	Regio				
Si	0	20	0	10 M	NType	1e25	Source	1				
	40	60	0	10 M	NType	1e25	Drain	2				
Si			0	10 0	DType	1e24	Gate	3				
Si Si	20	40	U	10 1	TYPE		uute	5				

- For Gate Oxide Region choose material Oxide.
- Set Doping type as Doping type, Dose 0.
- Select region Gate-Oxide.
- Set X and Y Dimensions as

X Min: 20, X Max: 40nm.Y Min: -2, Y Max: 0nm.

• Click Add Button.

# Adding Bulk Oxide Region:

Oxide         Doping         Bulk-Oxide           Concentration         Xmin         Xmax           0         60           Oxide dielectric         Ymin         Ymax           3.9         10         60           Width         Ie-6         Add         Delete           Mater         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         MType         1e25         Source         1           Si         0         20         0         10         MType         1e25         Source         1           Si         20         40         0         10         PType         1e24         Source         1           Si         20         40         -2         0         0         Gate-0         4	egion Mesh Physics Biasing Structure Run Output Script I	Input Script
Concentration         Xmin         Xmax           0         60           Oxide dielectric         Ymin         Ymax           3.9         10         60           Width         1e-6         Add         Delete           Mater         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           5i         0         20         0         10         NType         1e25         Source         1           5i         0         20         0         10         NType         1e25         Dorain         2           5i         20         40         0         10         PType         1e24         Gate         3           Oxide         20         40         -2         0         0         Gate-O         4	Doping V Bulk-Oxide V	
O         60           Oxide dielectric         Ymin         Ymax           3.9         10         60           Width         Add         Delete           Mater         Xmin         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         Mitype         1e25         Source         1           Si         40         60         10         Mitype         1e25         Dorin         2           Si         20         40         10         Pitype         1e24         Gate         3           Oxide         20         40         -2         0         0         Gate-O         4	Xmin Xmax	
Oxide dielectric         Ymin         Ymax           3.9         10         60           Width	0 60	
3.9       10       60         Width           1e-6       Add       Delete         Mater       Xmin       Xmax       Ymin         Ymax       Doping       Dose       Name       Regio         Si       0       20       0       10       NType       1e25       Source       1         Si       40       60       0       10       NType       1e25       Drain       2         Si       20       40       -2       0       0       Gate-O       4         Oxide       20       40       -2       0       0       Gate-O       4	Ymin Ymax	
Width         Add         Delete           Mater         Xmin         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         NType         1e25         Source         1           Si         40         60         0         10         NType         1e25         Drain         2           Si         20         40         0         10         PType         1e24         Gate         3           Oxide         20         40         -2         0         0         Gate-O         4	10 60	
Ie-6         Add         Delete           Mater         Xmin         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         NType         1e25         Source         1           Si         40         60         0         10         NType         1e25         Drain         2           Si         20         40         0         10         PType         1e25         Drain         2           Si         20         40         -2         0         0         Gate-0         4           Oxide         20         40         -2         0         0         Gate-0         4		
Mater         Xmin         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         NType         1e25         Source         1           Si         40         60         0         10         NType         1e25         Drain         2           Si         20         40         0         10         PType         1e25         Drain         2           Si         20         40         -2         0         0         Gate         3           Oxide         20         40         -2         0         0         Bate-O         4	Add Delete	
Mater         Xmin         Xmax         Ymin         Ymax         Doping         Dose         Name         Regio           Si         0         20         0         10         MType         1e25         Source         1           Si         40         60         0         10         MType         1e25         Drain         2           Si         20         40         0         10         PType         1e25         Drain         2           Si         20         40         0         10         PType         1e24         Gate         3           Oxide         20         40         -2         0         0         Gate-O         4		
Si       0       20       0       10       NType       1e25       Source       1         Si       40       60       0       10       NType       1e25       Drain       2         Si       20       40       0       10       PType       1e25       Drain       2         Si       20       40       -2       0       0       Gate       3         Oxide       20       40       -2       0       0       Gate       4         Oxide       20       40       -2       0       0       Bate       4	ax Ymin Ymax Doping Dose Name Regio	
Si         20         40         0         10         Prype         1223         Drain         2           Si         20         40         0         10         Prype         1224         Gate         3           Oxide         20         40         -2         0         0         Gate         3           Oxide         20         40         -2         0         0         Gate         3	20 0 10 NType 1e25 Source 1	
Oxide 20 40 -2 0 0 0 Gate-0 4	40 0 10 PTvpe 1e24 Gate 3	
	40 -2 0 0 0 Gate-0 4	
UXIde U 6U 1U 6U U UBUIK-UX 5	60 10 60 0 0 Bulk-Ox 5	

• For Bulk Oxide Region choose material Oxide.



- Set Doping type as Doping type, Dose 0.
- Select region Bulk-Oxide.
- Set X and Y Dimensions as
  - X Min: 0, X Max: 60nm.Y Min: 10, Y Max: 60nm.
- Click Add Button.

#### Adding Contact1 (Ohmic):

- Ohmic contact over Gate region.
- For Contacts choose material Al (Aluminium).
- Set Doping type as Doping type, Dose 0.
- Select region Ohmic.
- Set X and Y Dimensions as

X Min: 20, X Max: 40nm. Y Min: -2, Y Max: -2nm.

• Click Add Button.

## Adding Contact2 (Ohmic):

- Ohmic contact under **Source** region.
- For Contacts choose material Al (Aluminium).
- Set Doping type as Doping type, Dose 0.
- Select region Ohmic.
- Set X and Y Dimensions as
   X Min: 0, X Max: 20nm.Y Min: 0, Y Max: 0nm.
- Click Add Button.

#### Adding Contact3 (Ohmic):

- Ohmic contact under **Drain** region.
- For Contacts choose material Al (Aluminium).
- Set Doping type as Doping type, Dose 0.
- Select region Ohmic.
- Set X and Y Dimensions as
  - X Min: 40, X Max: 60nm. Y Min: 0, Y Max: 0nm.
- Click Add Button.



# Adding Contact4(Ohmic):

- Ohmic contact under Substrate region.
- For Contacts choose material Al (Aluminium).
- Set Doping type as Doping type, Dose 0.
- Select region Ohmic.
- Set X and Y Dimensions as

X Min: 0, X Max: 60nm.Y Min: 60, Y Max: 60nm.

• Click Add Button.



#### 2.3 Mesh

Technology	Add Region	Mesh	Physics	Biasing	$\int$	Structure	Run Output Script	Input Script	
Region 1 🔻				_					
Step Size X 1	Ge	Step Size ) nerare Mesh	( <u>1</u>						
Message>> Chose	Step-sizes wisely and	l comparable tr	your doping (	profile.					

- Select Mesh tab
- In Step-size X write 1.
- In Step-size Y write 1. It means you are working on 1nm X 1nm mesh.



- Click on Generate Mesh
- Mesh graphics will be seen in Structure tab.

#### 2.4 Physics

Technology Ad	d Region	Mesh	Physics	Biasing	5	structure	Run Output Script	Input Script	
Material Used>>									
🗹 Si									
Compound									
Scattering Mechanisms	>>								
Acoustic									
Coulomb									
✓ Intervalley_g									
✓ Intervalley_f									
V Polar									
CIC	Select Ch	narge Assign	ment						
SOR	Method								
Disable	Quatum (	Confinement	Effect						

- Select Si check-box in Material Used options
- In Scattering Mechanism all five mechanism are auto-selected
- In Select Charge Assignment select option CIC.
- In Quantum Confinement Effect choose Disable option.

#### 2.5 Biasing

rechnology	Add Re	gion	Mesh	Physics	Biasing	
C	Parallel Proces	sing		Ba	arrier Voltage for .8	Schottky cont
Contact	Biasing Type	V	int		Step	Final
Gate	Constant	Voltage	(	0.1	0.	.1 0.1
Drain	Step	voltage		U	0.	.1 0.0
	Insert				Load	

- For biasing click below Contact in the table,
- Choose Gate, chose Constant bias, Voltage in next field.
- Gate initial voltage 0.1, step size 0.1, final 0.1 V.
- Click insert choose Drain as contact,
- Chose step bias, provide initial voltage 0.0, step size 0.1, final 0.6 V.



• Click Load Button.

# 2.6 Start Simulation

Physics	Biasing		Structure	Run Output Script	Input Script
B	arrier Voltage for S	chottky cont	*****	*****	*****
	0.8 🍒 Save			×	# # #
	Lookin:	Documents			# # # #
int		Documents			# # ########
0.1				÷	ODUCTS OF TECHNEYT I
					ECHNEXT LAB PVT LTD
					F USERS
			17796		
				7.6	
	File <u>N</u> ame:	FDSOI-demo			
	Files of Type:	Text		•	********

- Click on Run button, a Save pop-up window opened as shown in above figure.
- In save window default directory is 'Documents'. Go to field named File name and write name of your file name (FDSOI-demo for this example) to create a folder in the 'Documents' path of your system.
- Now click Save button. With this step your FDSOI device simulation starts and you can see the information about this in Run Output Script.
- Output script column shows the working directory "C:\Users\...\Documents\FDSOIdemo\FDSOI-demo\...". It also shows calculation points, no. of particle initialized at a bias point and no. of particles used in every steps.
- When simulation gets completed 'Simulation Successful message will be displayed

# 2.7 Output Files

• After the completion of simulation, go to the directory you selected there is a folder named FDSOI-demo.

, and the second s	> FDSOI-demo > Gate_vtgu.I >			
Name	Date modified	Туре		
🧧 drain_vtd0.0	2/9/2021 5:15 PM	File folder	Name	Date modified
drain_vtd0.1	2/9/2021 5:15 PM	File folder	Warne	Date mounted
drain_vtd0.2	2/9/2021 5:16 PM	File folder	Carrier_Energy	2/9/2021 5:18 PM
drain_vtd0.3	2/9/2021 5:16 PM	File folder	📓 ld Vd	2/9/2021 5:18 PM
drain_vtd0.4	2/9/2021 5:16 PM	File folder	ld Va	2/9/2021 5:18 PM
drain_vtd0.5	2/9/2021 5:16 PM	File folder		2/0/2021 5:10 PM
drain_vtd0.6	2/9/2021 5:16 PM	File folder	welocity_x	2/9/2021 5:18 PM
			Velocity_y	2/9/2021 5:18 PM



- Open this folder, you get several folder and text file like FDSOI-demo, plot and FDSOI-demo.txt
- FDSOI-demo folder will contain data folder for drain voltage steps at every gate voltage steps. (drain\_vtd\_y within Gate\_vtg\_x ). Open these folders which contains various file related to the simulation.
- Plot folder contains i-v curves data, velocity-energy-average and carrier energy data files.
- The text file contains all the input information of the device given to simulator.
- User can plot this data on TNL-PLOT by importing the data file.

