MANIPAL
ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

MANIPAL SCHOOL OF INFORMATION SCIENCES
(A Constituent unit of MAHE, Manipal)

LAB RECORD

On

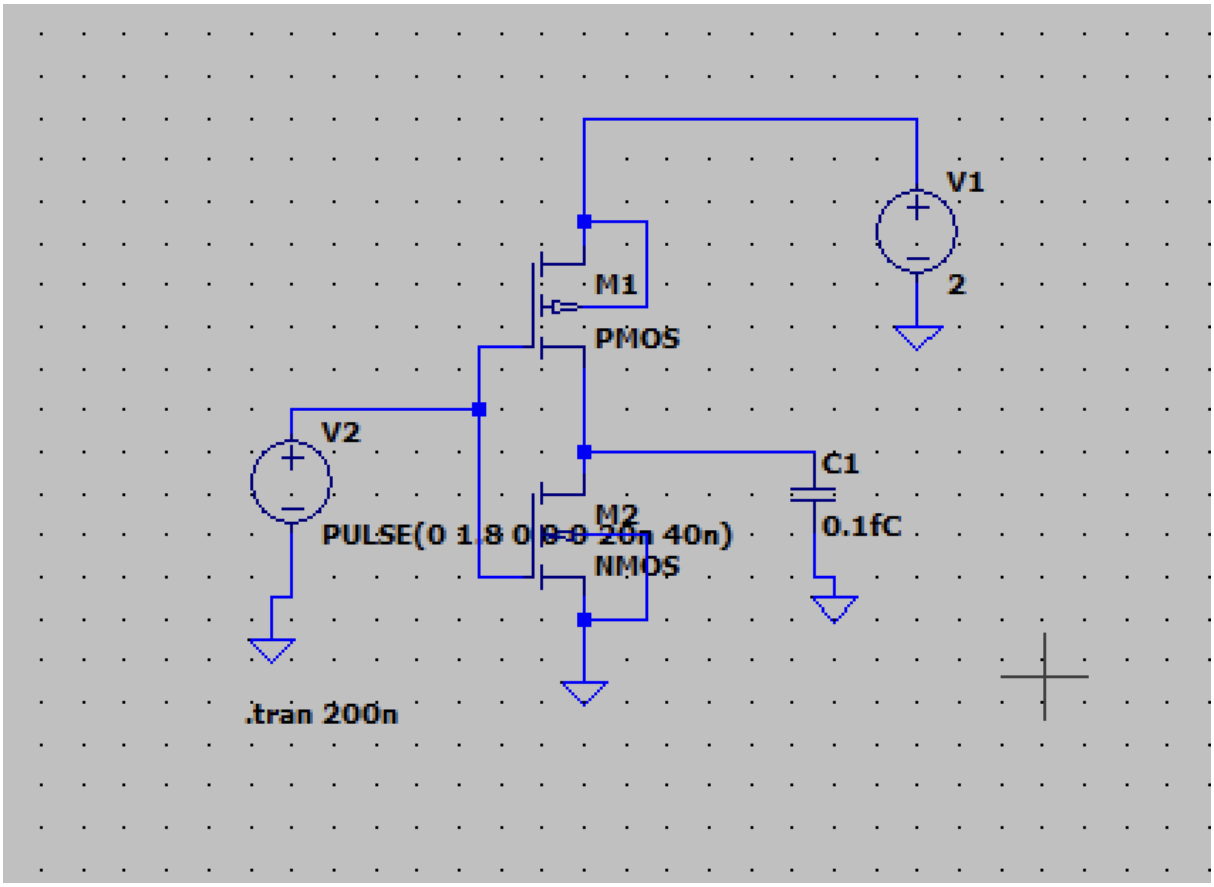
PDC

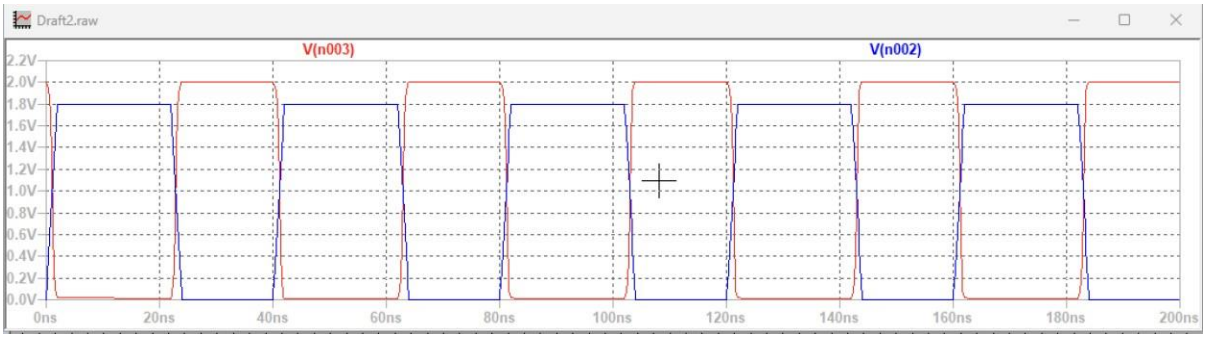
11/04/2024

MANIPAL SCHOOL OF INFORMATION SCIENCES
MANIPAL
(A constituent unit of MAHE, Manipal)

Experiment 1:

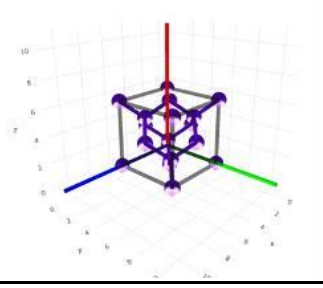
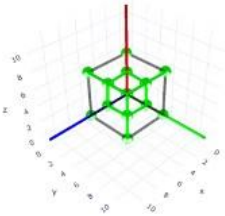
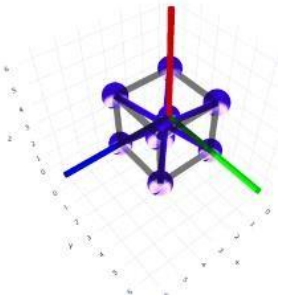
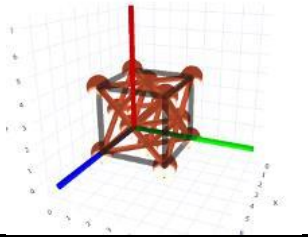
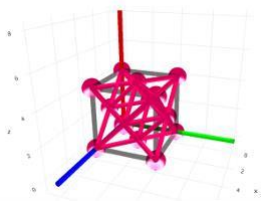
Investigation of CMOS inverter using Spice software

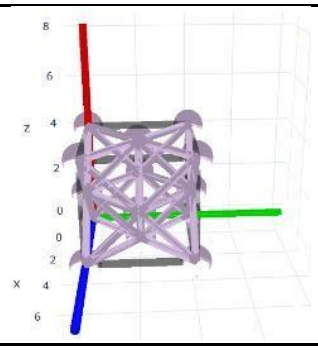
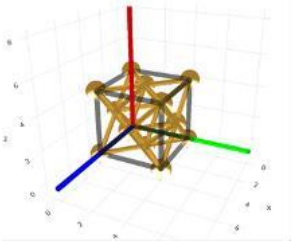
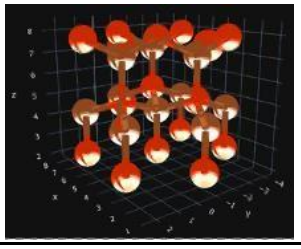
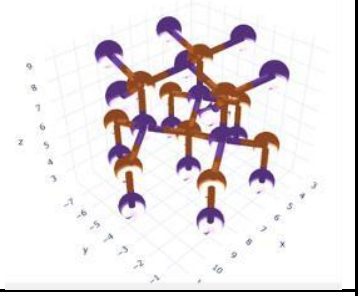
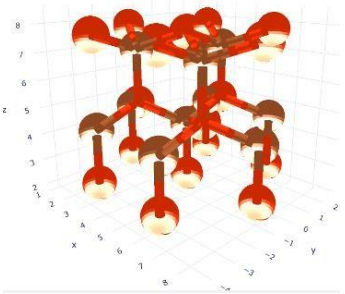


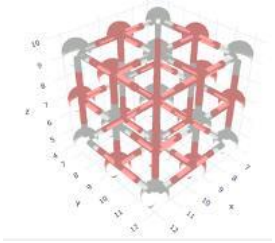
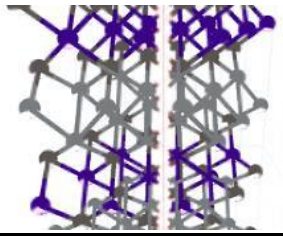
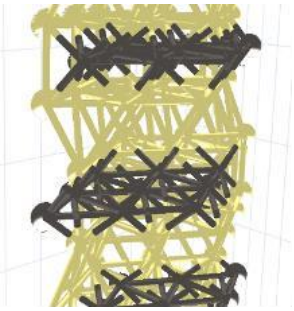
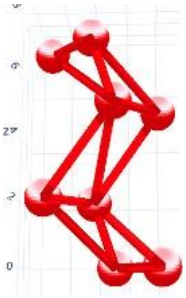
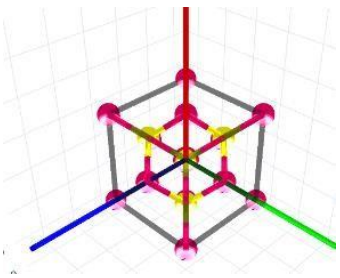


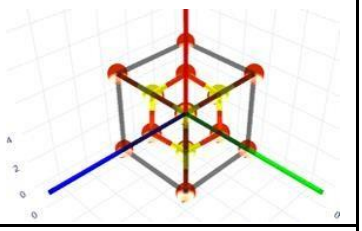
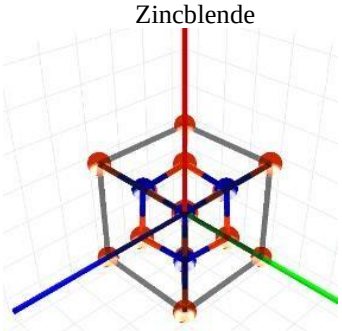
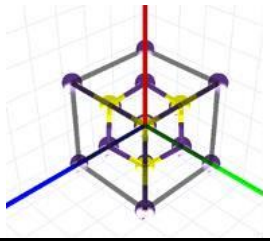
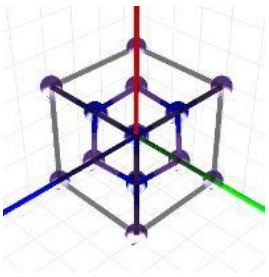
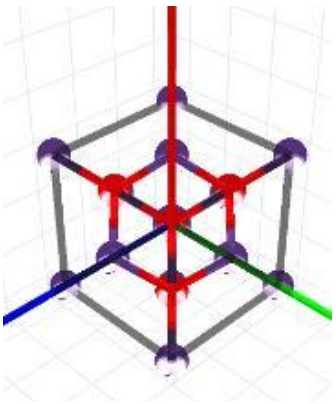
Experiment 2:

Investigation of crystal lattice using abacus crystal viewer

Sl. No.	Material	Application	Process	Crystal structure
1	Si (Silicon)	Device development	PVD, CZ, FZ	Diamond 
2	Ge (Germanium)	Device development	PVD,CVD	Diamond 
3	W (Tungsten)	Interconnects in electronic devices	CVD,PVD (likeSputtering, Evaporation), ALD(atomic layer deposition)	Body Centerd 
4	Cu (Copper)	Interconnects in electronic devices	Electroplating, CVD	Face Centered 
5	Al (Aluminium)	Interconnects in electronic devices	PVD (Sputtering)	Face Centered 
6	Ag (Silver)	Interconnects in electronic devices	PVD, CVD, Electroplating	Face Centered

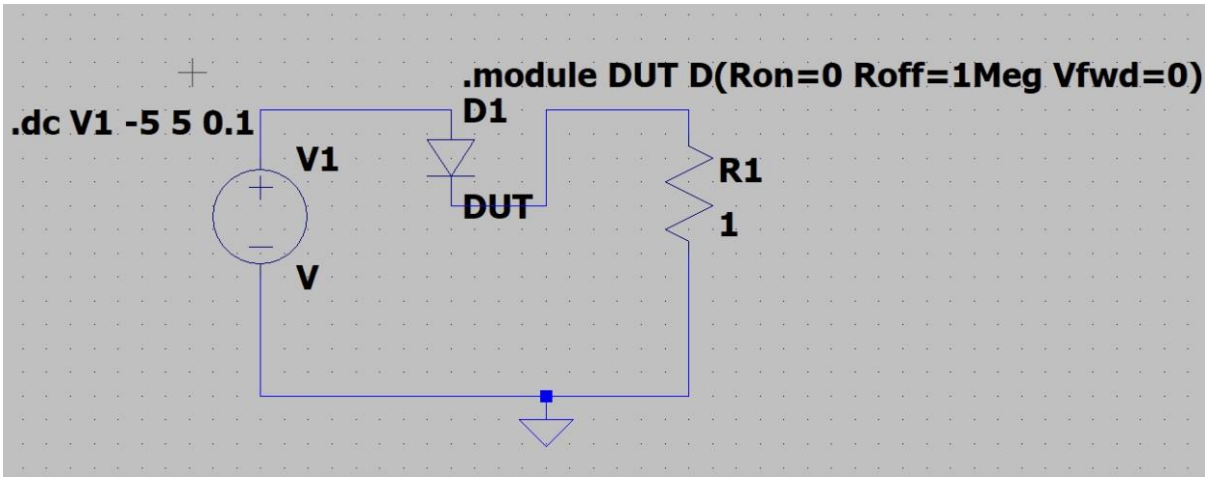
				
7	Au(Gold)	Interconnects and contacts	PVD via Thermal Vapour Deposition or Electron Beam Deposition	Face Centered 
8	AlN(Aluminium Nitride)	Dielectric layer, Passivation layer	PVD, CVD	Wurtzite 
9	InN(Indium Nitride)	Sensors,Nanoelectronics	PLD (Pulsed Laser Deposition), MBE (Moleculaar Beam Epitaxy)	Wurtzite 
10	GaN(GAlliu mNitride)	High power and High Frequency applications	PLD (Pulsed Laser Deposition), MBE (Moleculaar Beam Epitaxy)	Wurtzite 
11	NaCl(Sodium Chloride)	Lift-off lithography	Thermal Evaporation	Rock Salt

				
12	BismuthTelluride (Bi2Te3)	Thermoelectric Cooling	PVD(Sputtering), CVD(MBE)	Rhombohedral 
13	Molybdenum Disulfide(MoS2)	Transistors, FlexibleElectronics	PVD, CUD	TMD 
14	Black Phosphorus	Transistors, Memory devices, Photonic devices	CVD, Mechanical Exfoliation	
15	Aluminium Arsenide(AlAs)	Barrier material	Metalorganic chemical Vapour Deposition	Zincblende 
16	Gallium Arsenide (GaAs)	Sollar cells, Optoelectronic Devices	Metalorganic chemical Vapour Deposition, Molecular Beam Epitaxy	Zincblende

				
17	Gallium Antimonide(GaSb)	High speed Transistors, Infrared Detector	Molecular Beam Epitaxy, Metalorganic chemical Vapour Deposition	Zincblende 
18	Indium Arsenide(InAs)	High speed Transistors, Infrared Detector	Molecular Beam Epitaxy, Metalorganic chemical Vapour Deposition	
19	Indium Antimonade(InSb)	High speed Transistors, Solar Cells	Molecular Beam Epitaxy, Metalorganic chemical Vapour Deposition, Pulsed Laser Deposition(PLD)	Zincblende 
20	Indium Phosphide(InP)	High speed Transistors, Solar Cells	Molecular Beam Epitaxy, Metalorganic chemical Vapour Deposition, Pulsed Laser Deposition(PLD)	Zincblende 

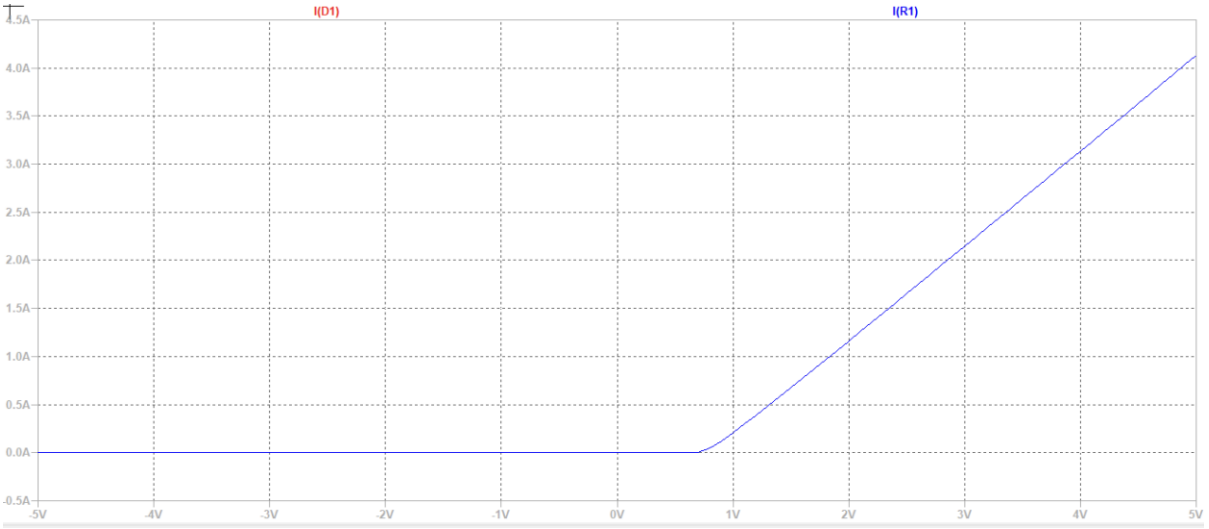
Experiment 3 :

Validation of Electrical Models of a PN junction diode using SPICE Software



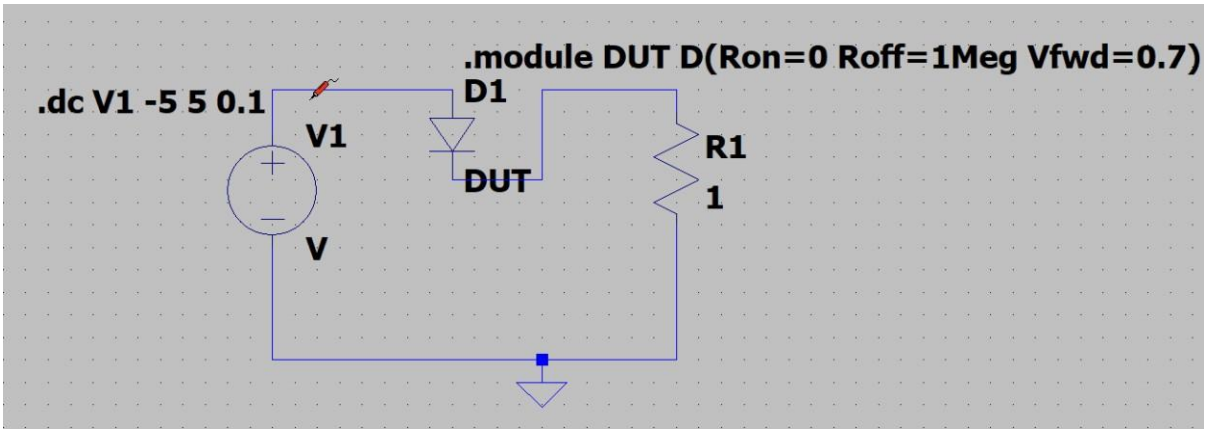
Ideal Model:

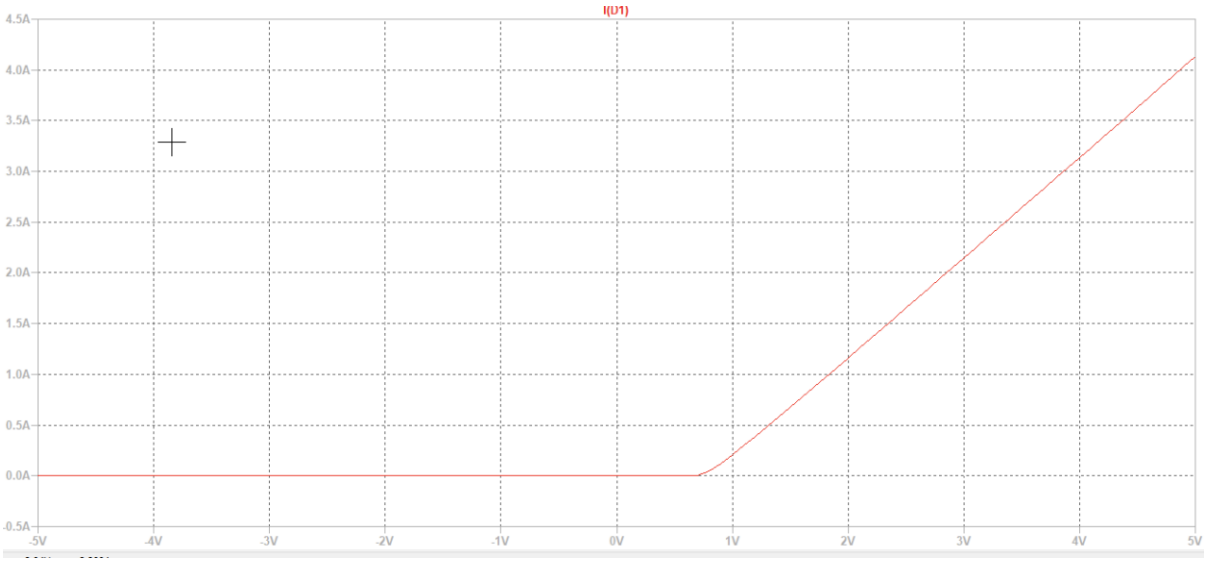
Parameters : Ron = 0Ω, Rout = ∞Ω, Vfwd = 0V.



Simplified model:

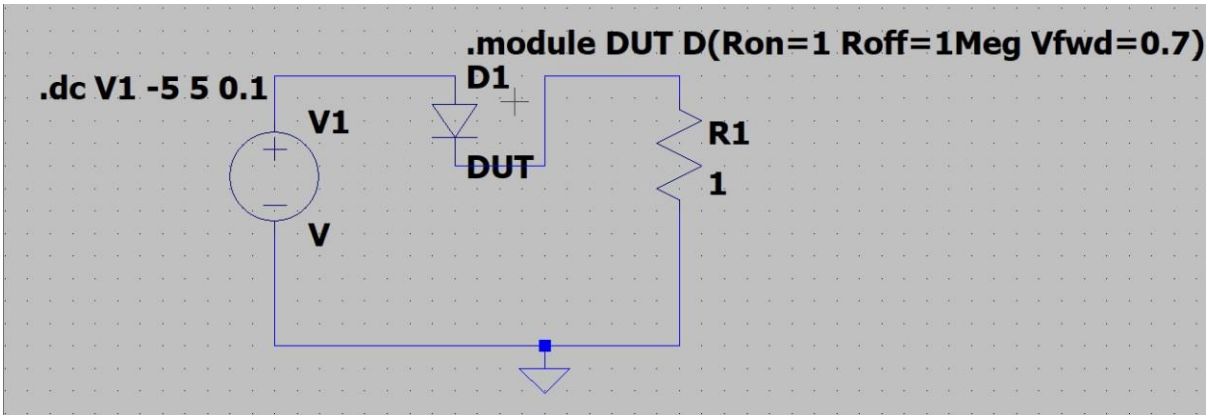
Parameters : Ron = 0Ω, Rout = 1GigaΩ, Vfwd = 0.7v

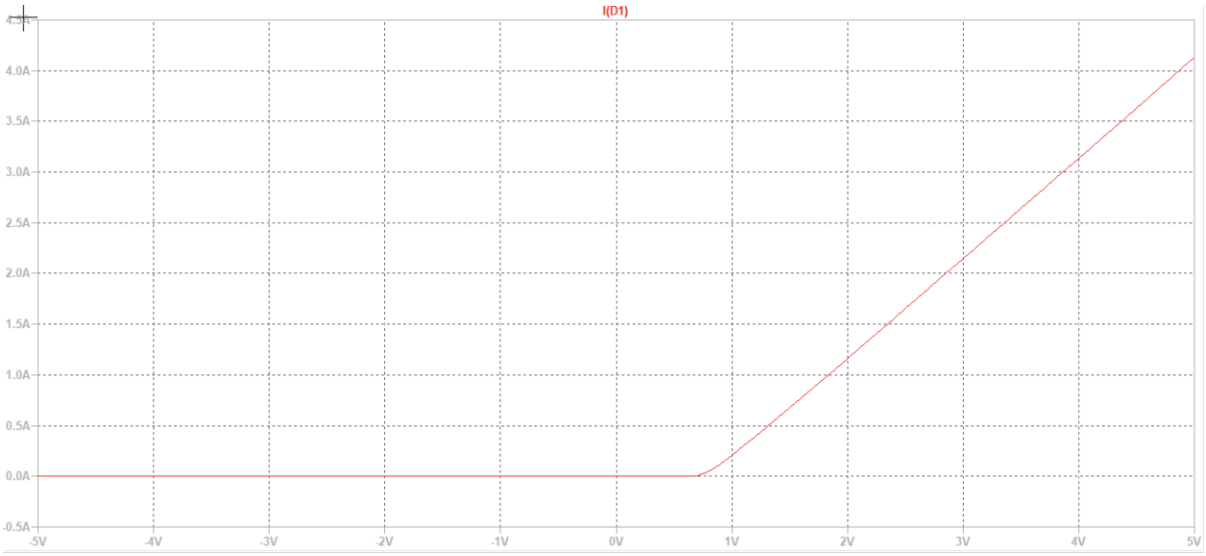




Linear-Piecewise model:

Parameters : Ron = 1Ω, Rout =1 Giga Ω, Vfwd = 0.7v



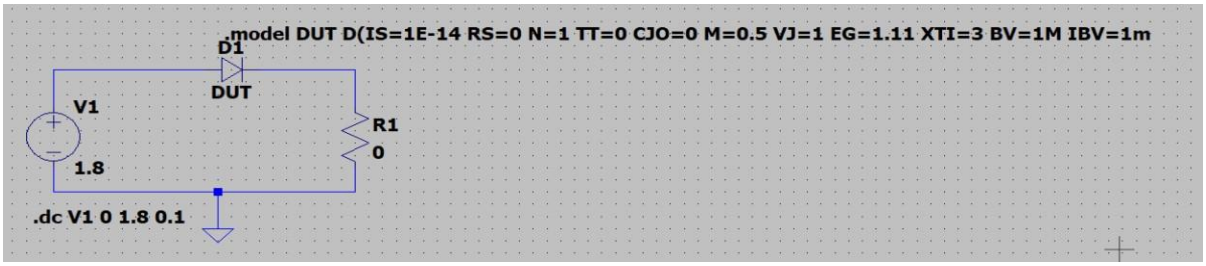


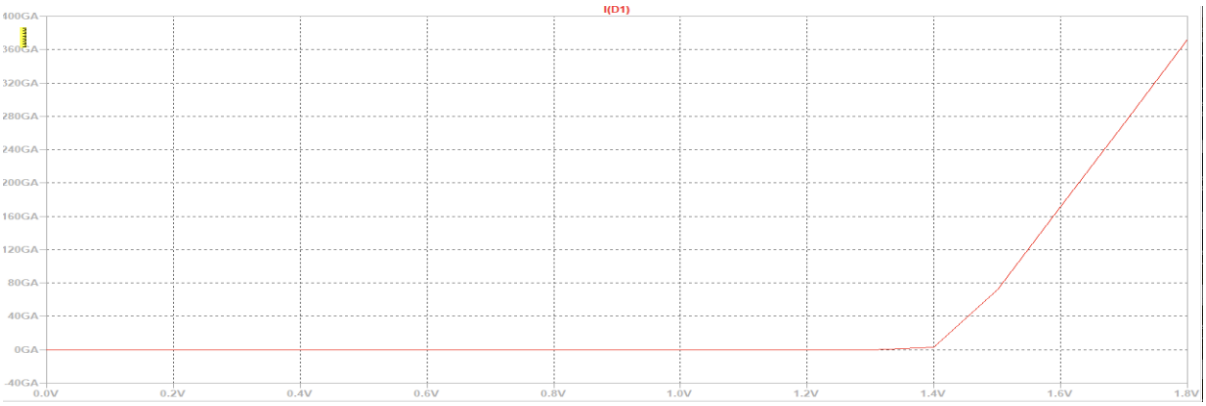
Experiment 4:

Investigation of Impact of the device parameters on PN junction diode using Spice

Case 1: Default

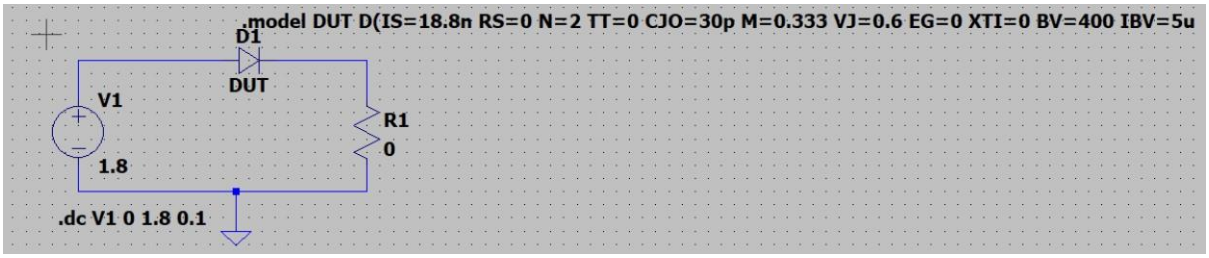
Parameters: IS=1E-14 RS=0 N=1 TT=0 CJO=0 M=0.5 VJ=1 EG=1.11 XTI=3 BV=∞ IBV=1m

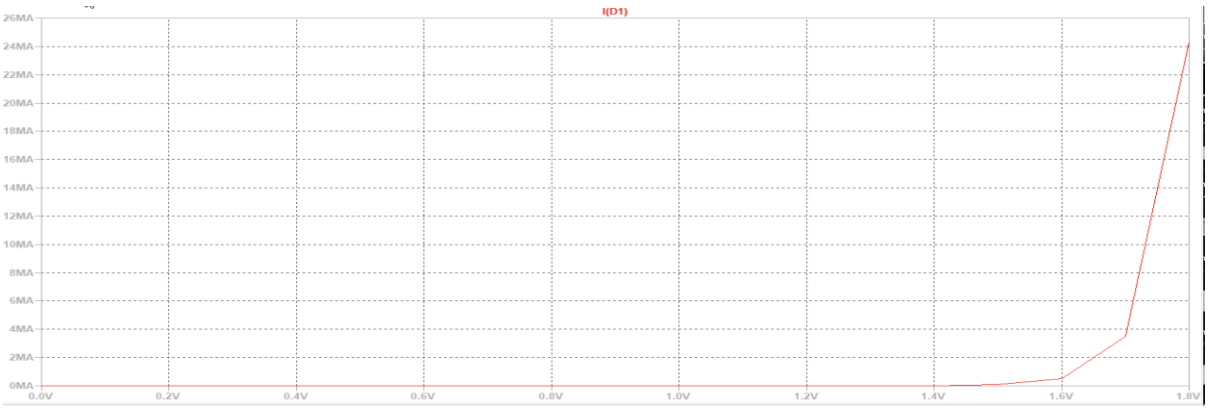




Case 2: 1N4004

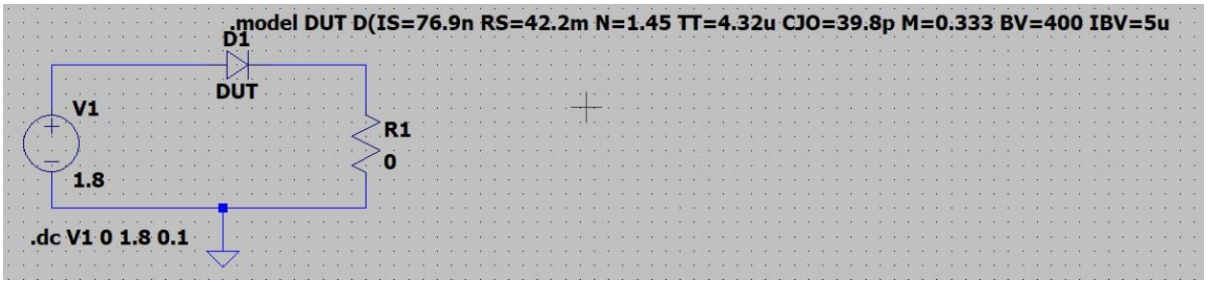
Parameters: IS=18.8n RS=0 N=2 TT=0 CJO=30p M=0.333 VJ=0.6 EG=0 XTI=0 BV=400 IBV=5u

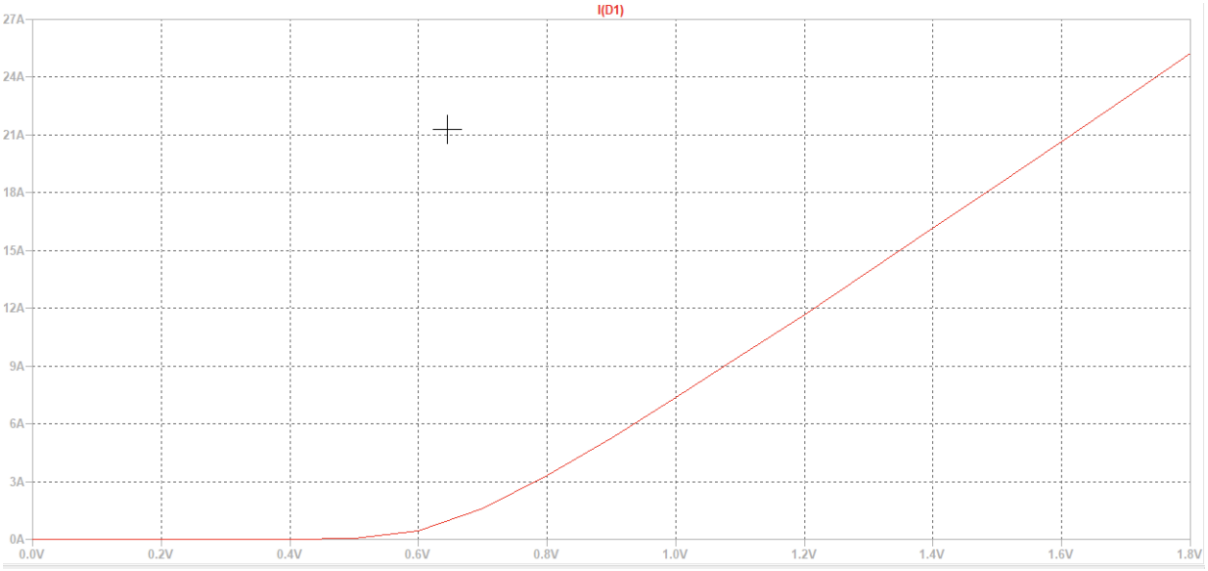




Case 3: 1N4004 1A

Parameters: IS=76.9n RS=42.2m N=1.45 TT=4.32u CJO=39.8p M=0.333 BV=400 IBV=5u

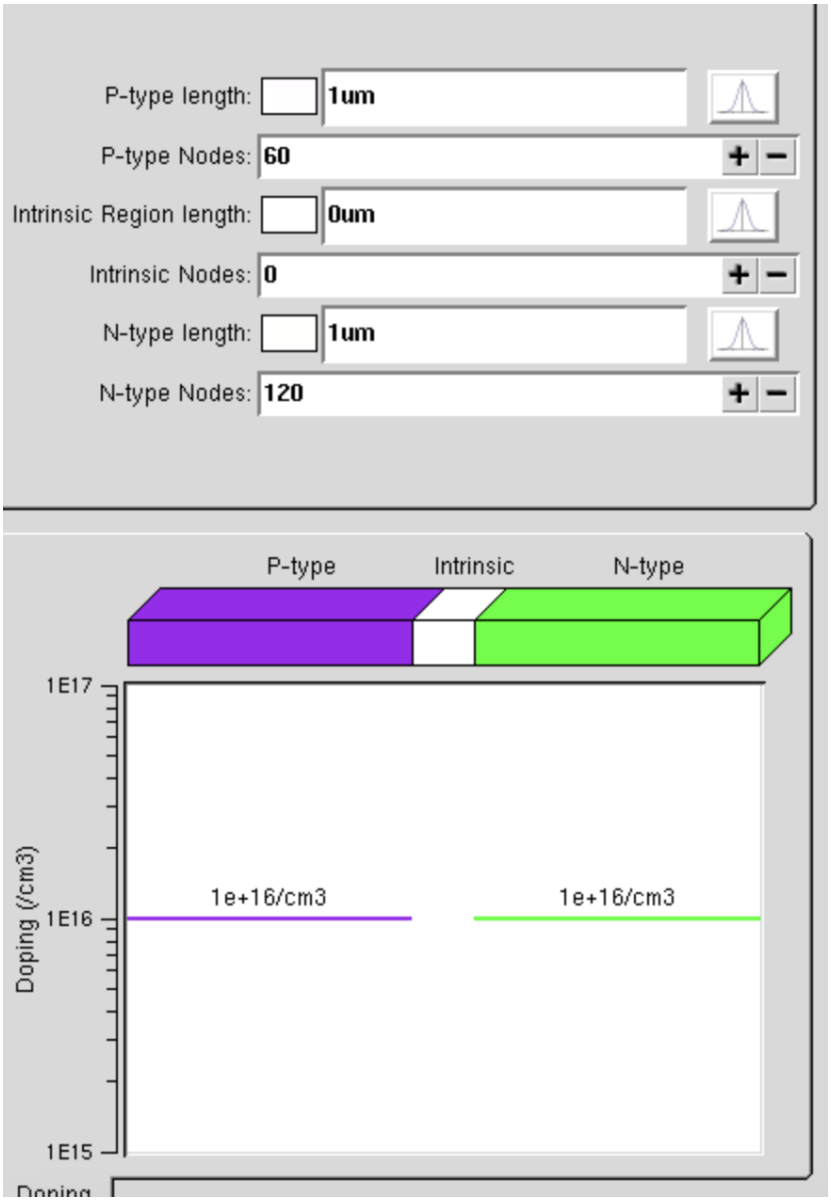

.model DUT D(IS=76.9n RS=42.2m N=1.45 TT=4.32u CJO=39.8p M=0.333 BV=400 IBV=5u
D1
DUT
V1
1.8
R1
0
.dc V1 0 1.8 0.1


I(D1)
27A
24A
21A
18A
15A
12A
9A
6A
3A
0A
0.0V
0.2V
0.4V
0.6V
0.8V
1.0V
1.2V
1.4V
1.6V
1.8V

Experiment 5:

Device Level simulation of PN junction using ABACUS

Parameters: Na = Nd = 1E+16 cm^{-3} Ln = Lp = 1μm. Vfb = 1VFor Si at 300K



At Equilibrium:

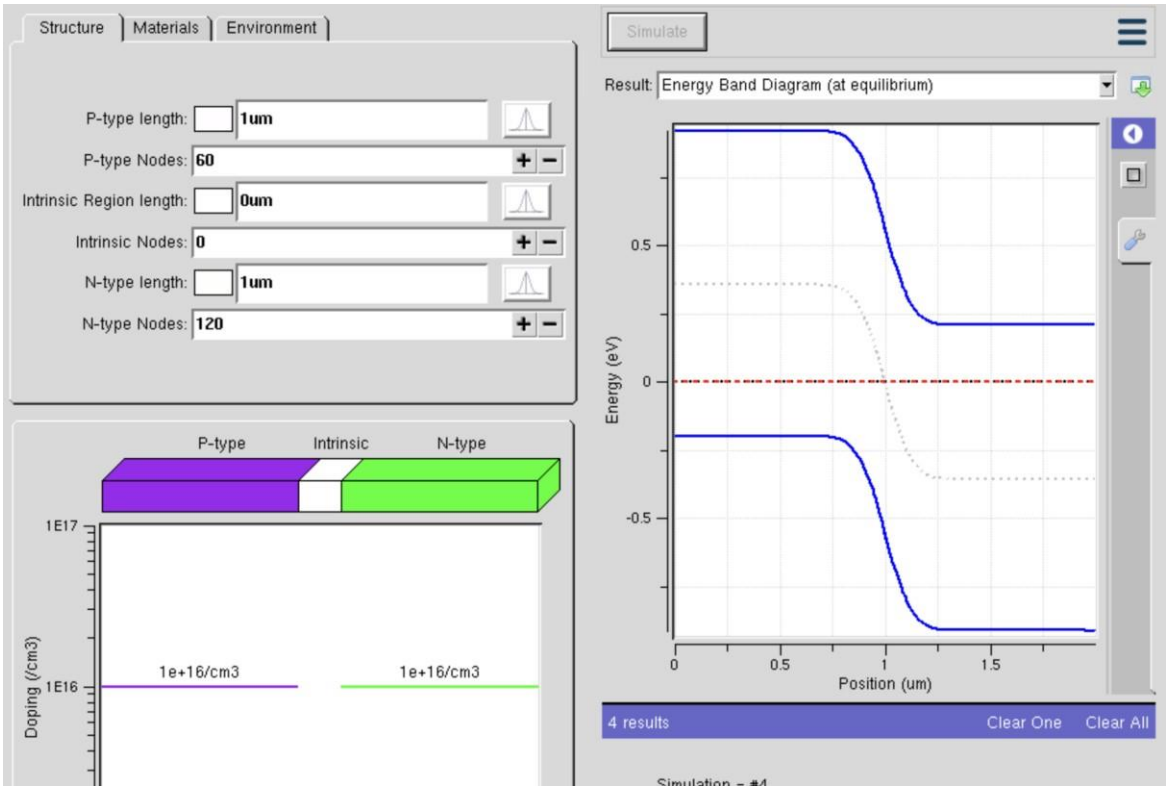


Fig: Energy Band Diagram at Equilibrium

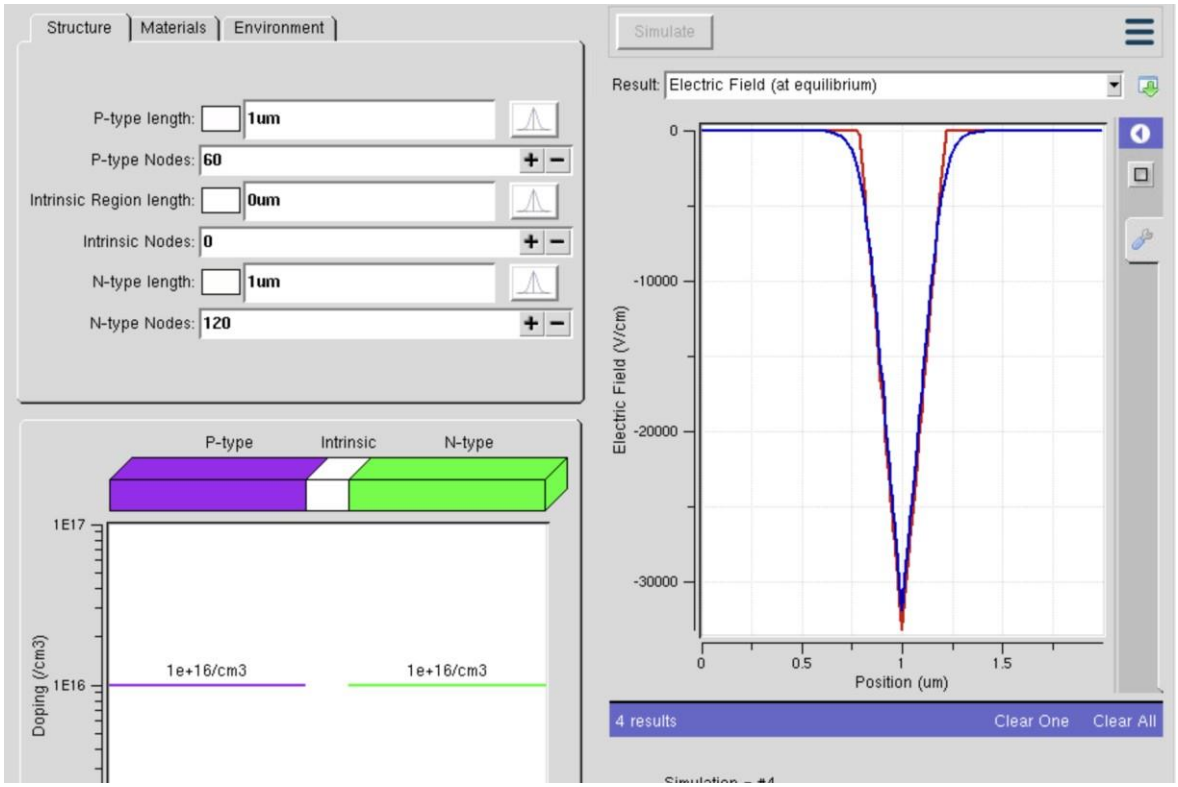


Fig: Electric field at Equilibrium

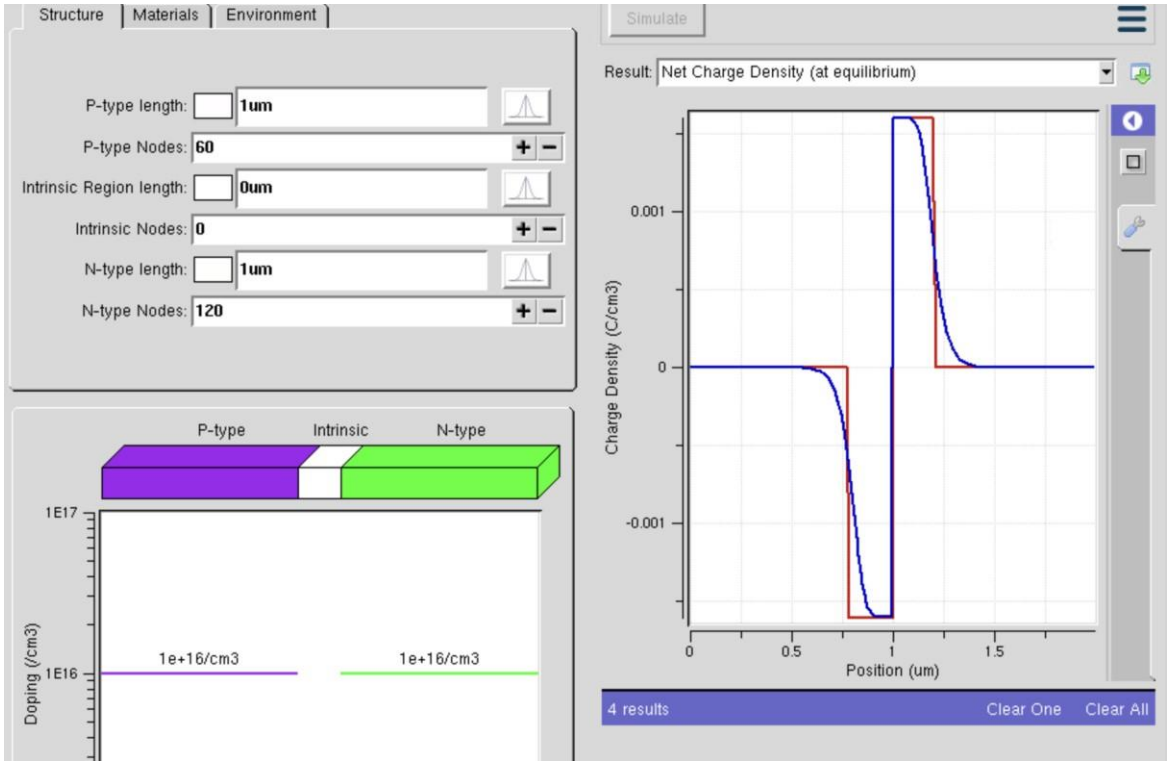


Fig: Net Charge Density at Equilibrium

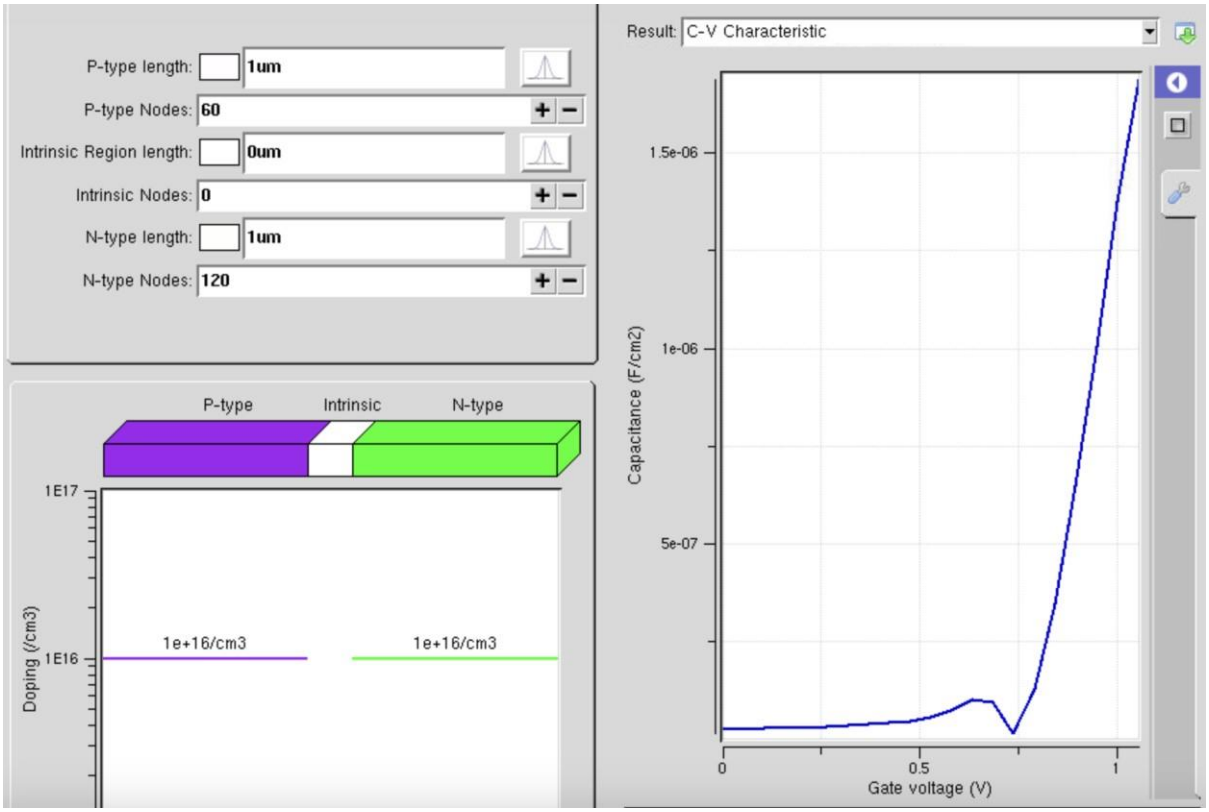


Fig: C-V Characteristics

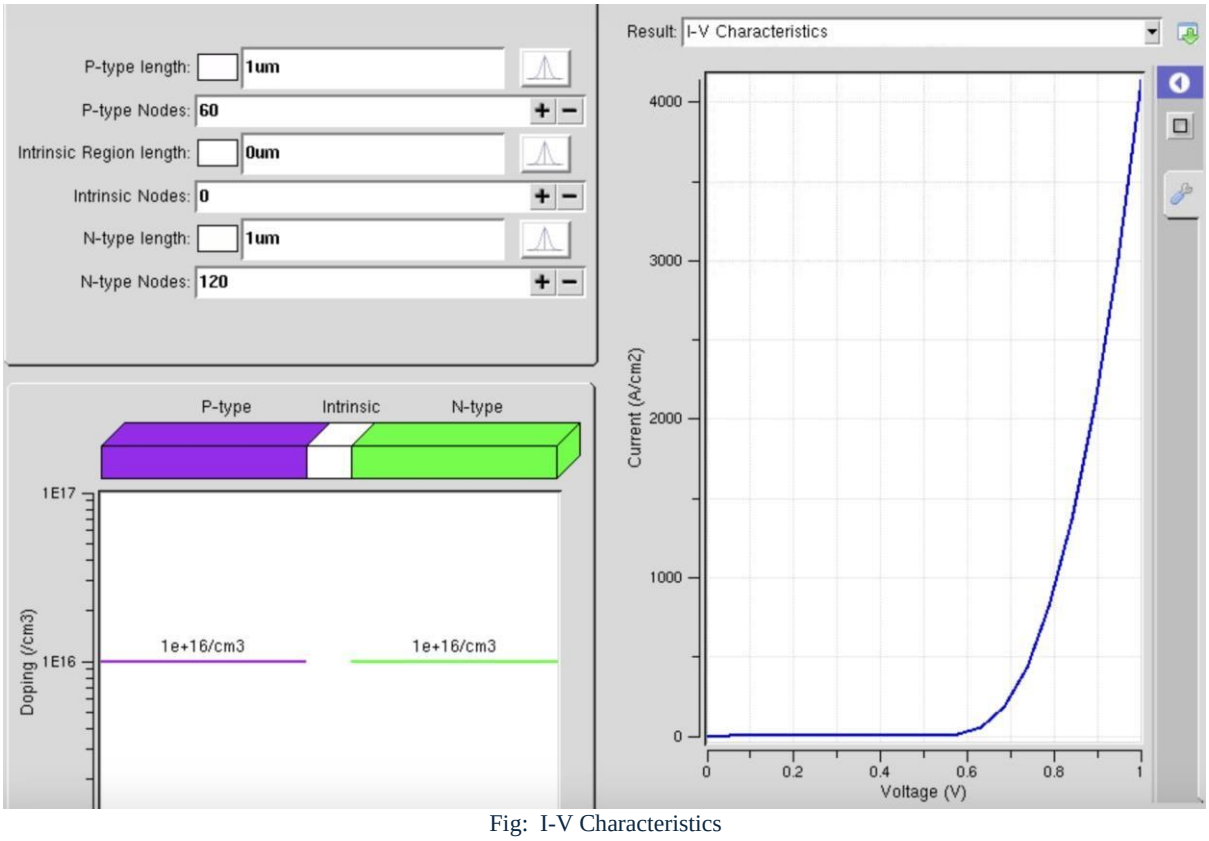


Fig: I-V Characteristics

At applied Bias:

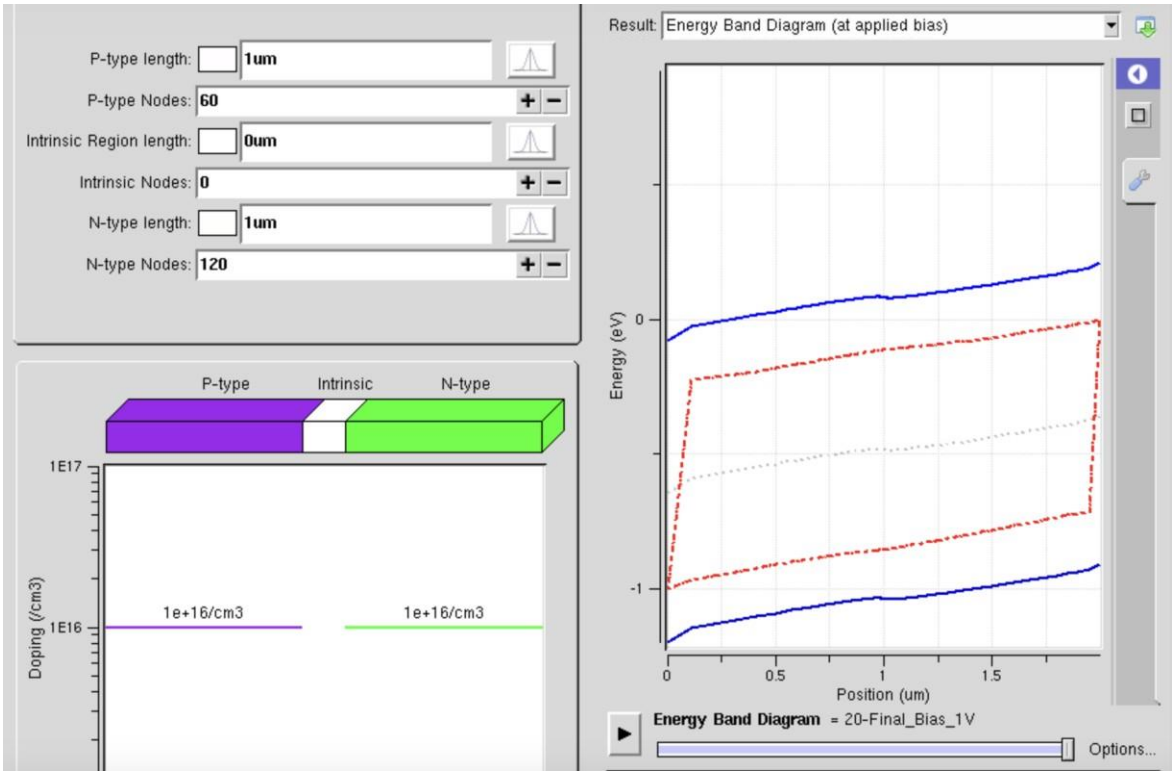


Fig: Energy Band Diagram at Applied Bias (20 final points at bias)

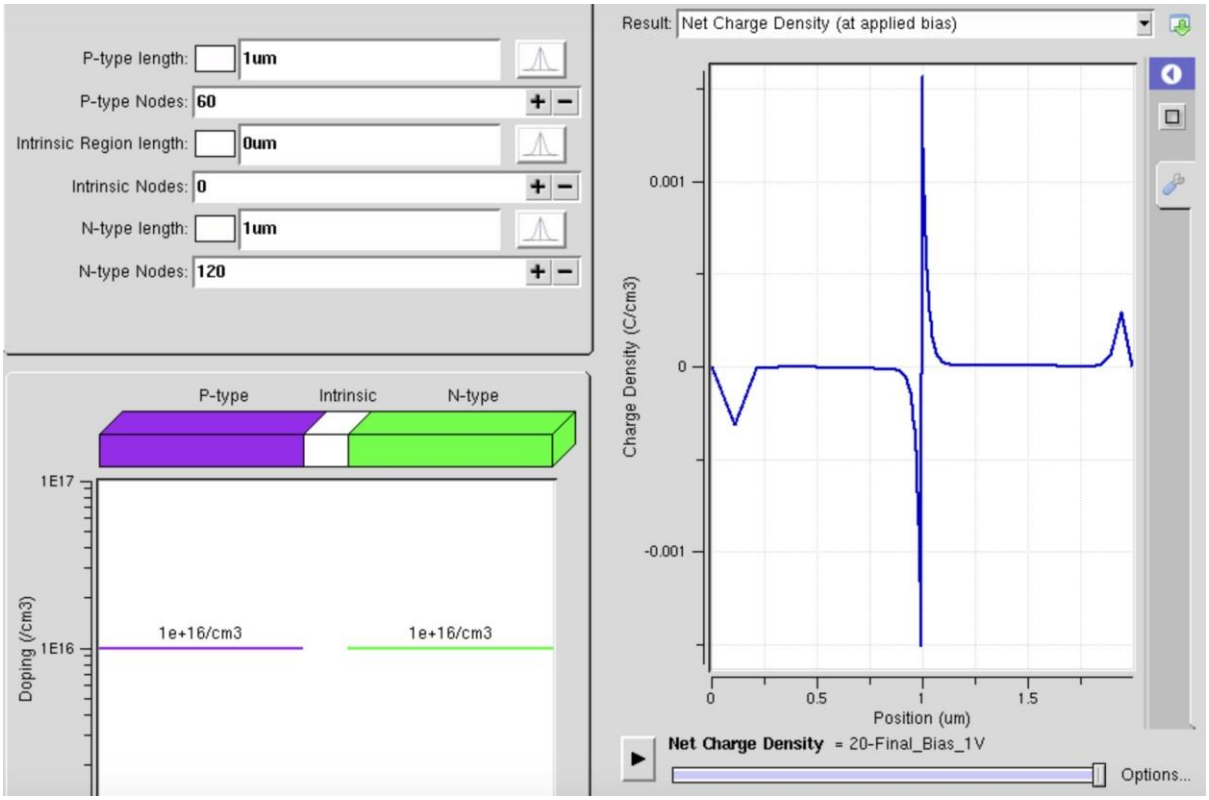


Fig: Net Charge Density at Applied Bias (20 final points at bias)

Reverse Biased:

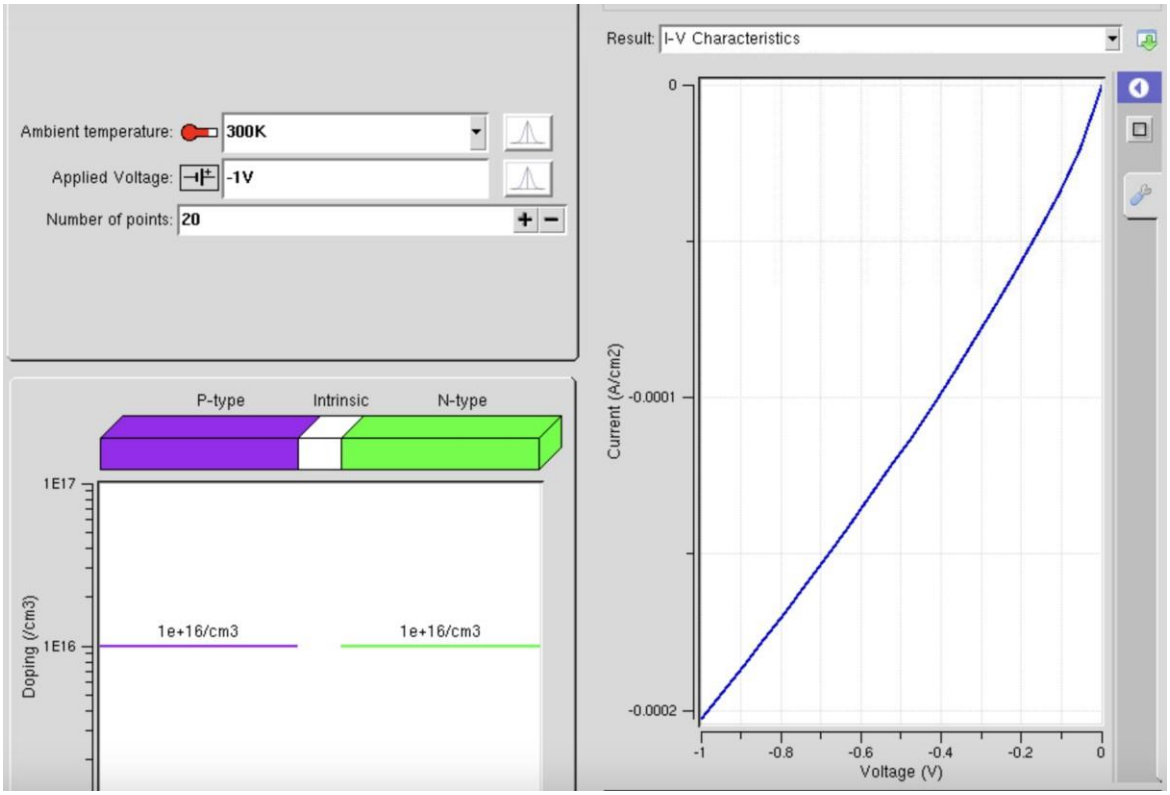


Fig: I-V Characteristics

Based on Temperature:For SI

at 400K:

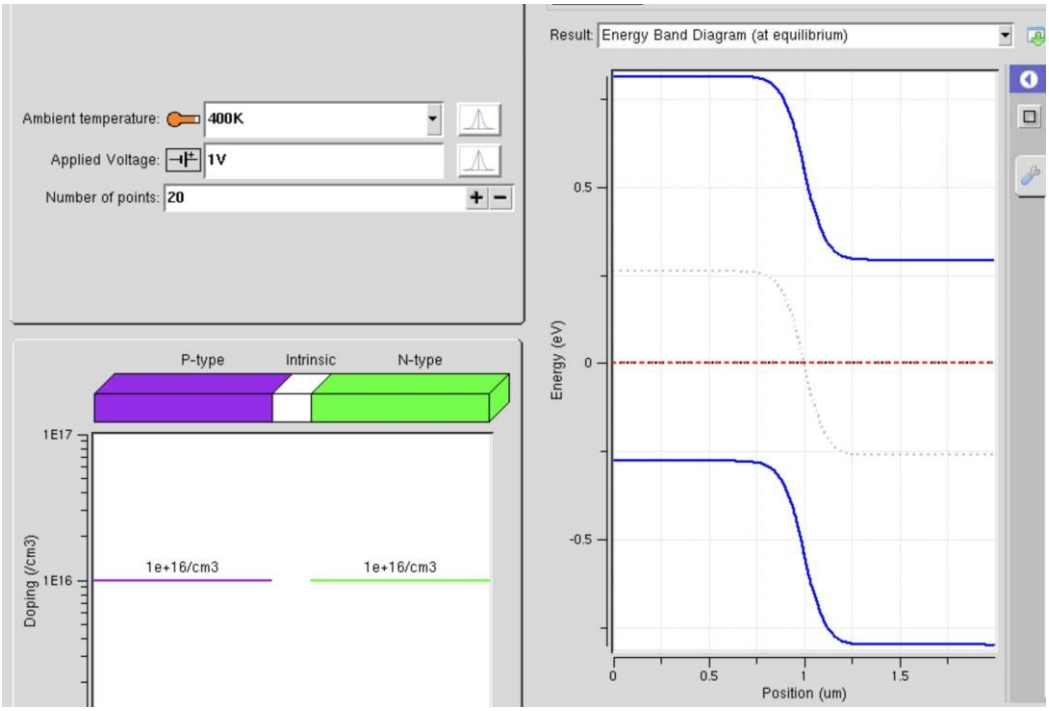


Fig: Energy Band Diagram at Equilibrium

For SI at 400K: Decrease in cut in voltage compared to 300K

For Si at 77K

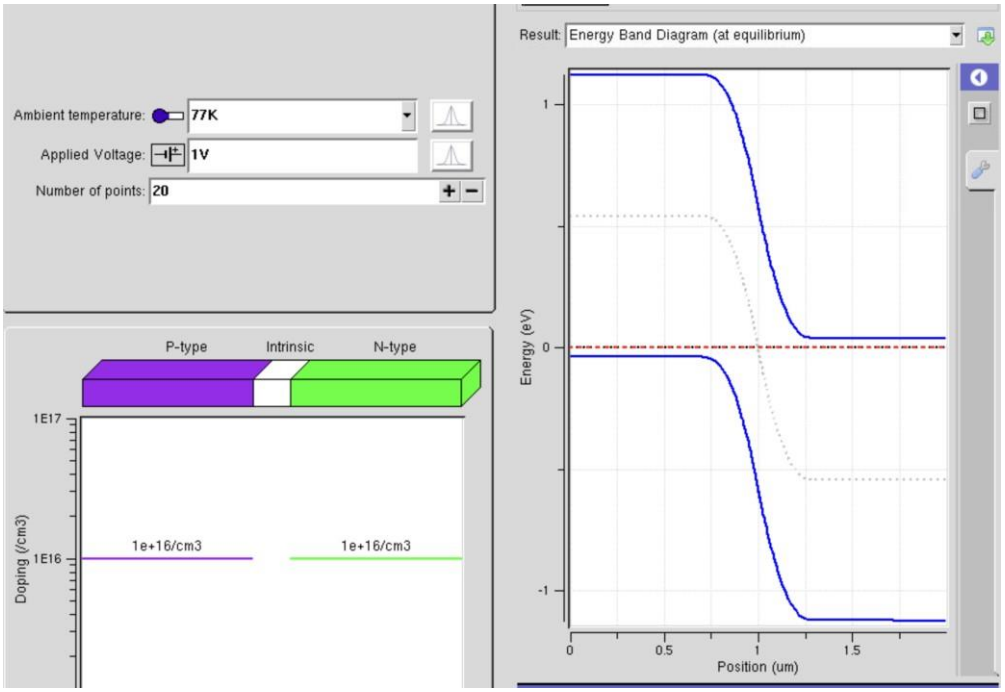


Fig: Energy Band Diagram at Equilibrium

For Si at 77K: Increase in cut in voltage compared to 300K

Based on Material:

Ge at 300K:

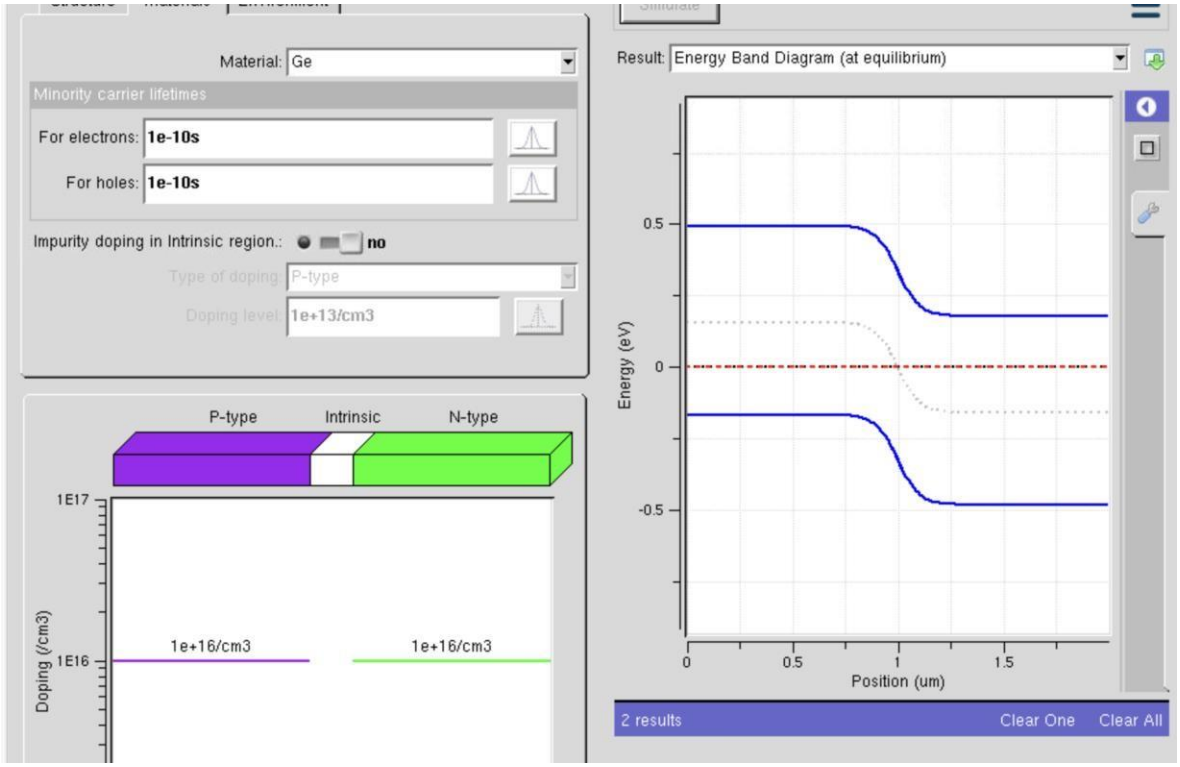


Fig: Energy Band Diagram at Equilibrium

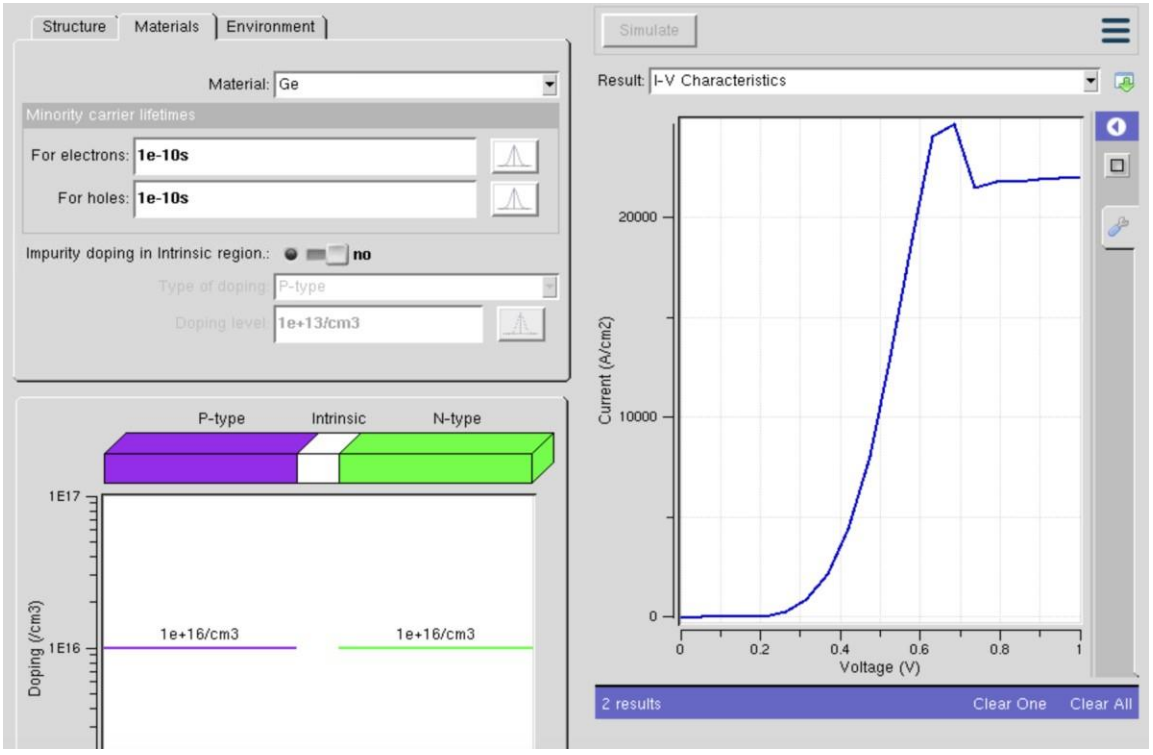


Fig: I-V Characteristics

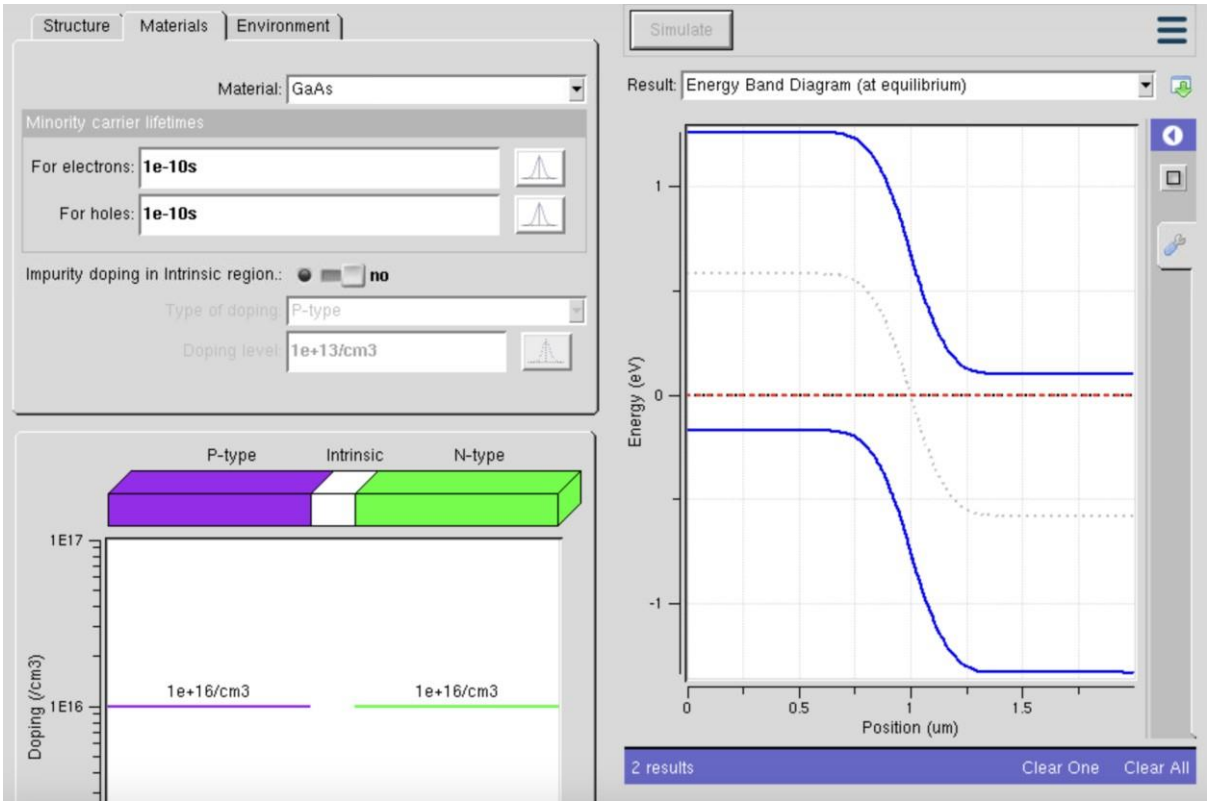


Fig: Energy Band Diagram at Equilibrium

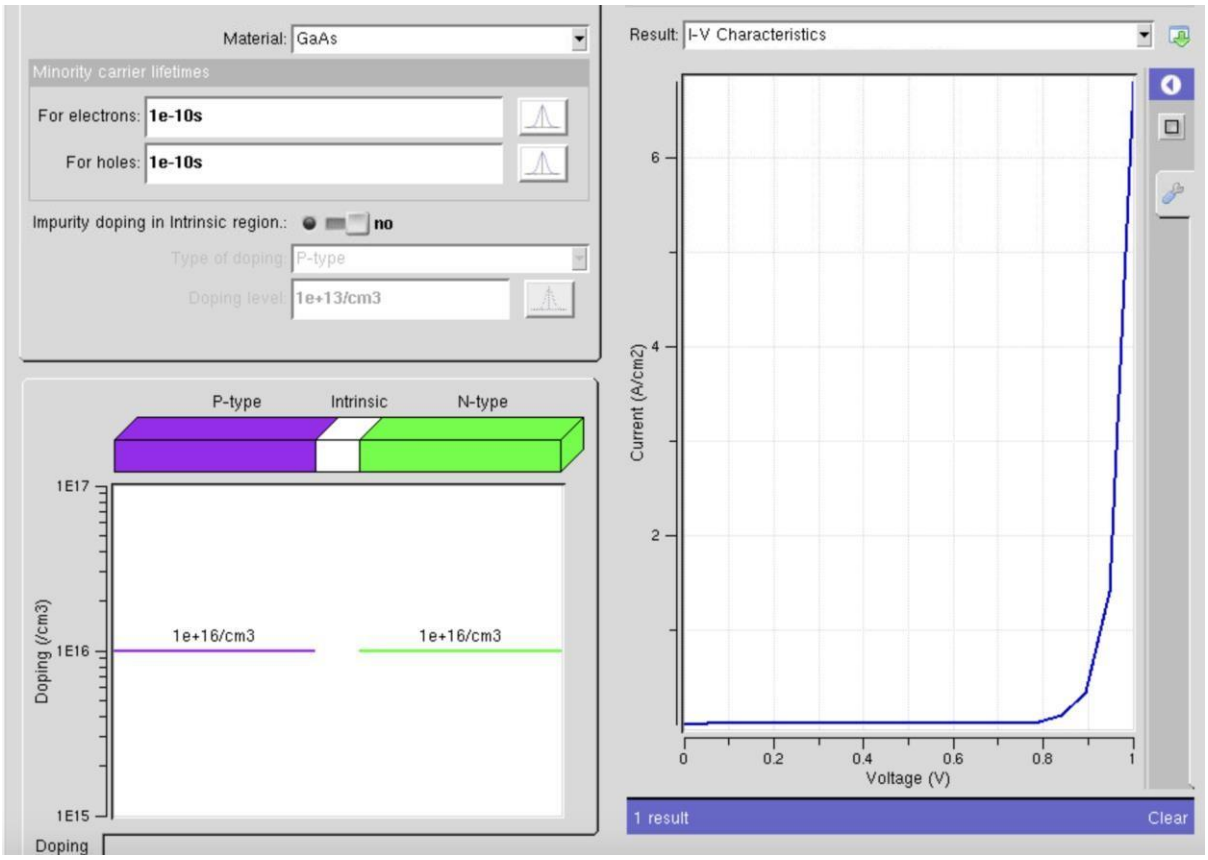


Fig: I-V Characteristics

InP at 300K:

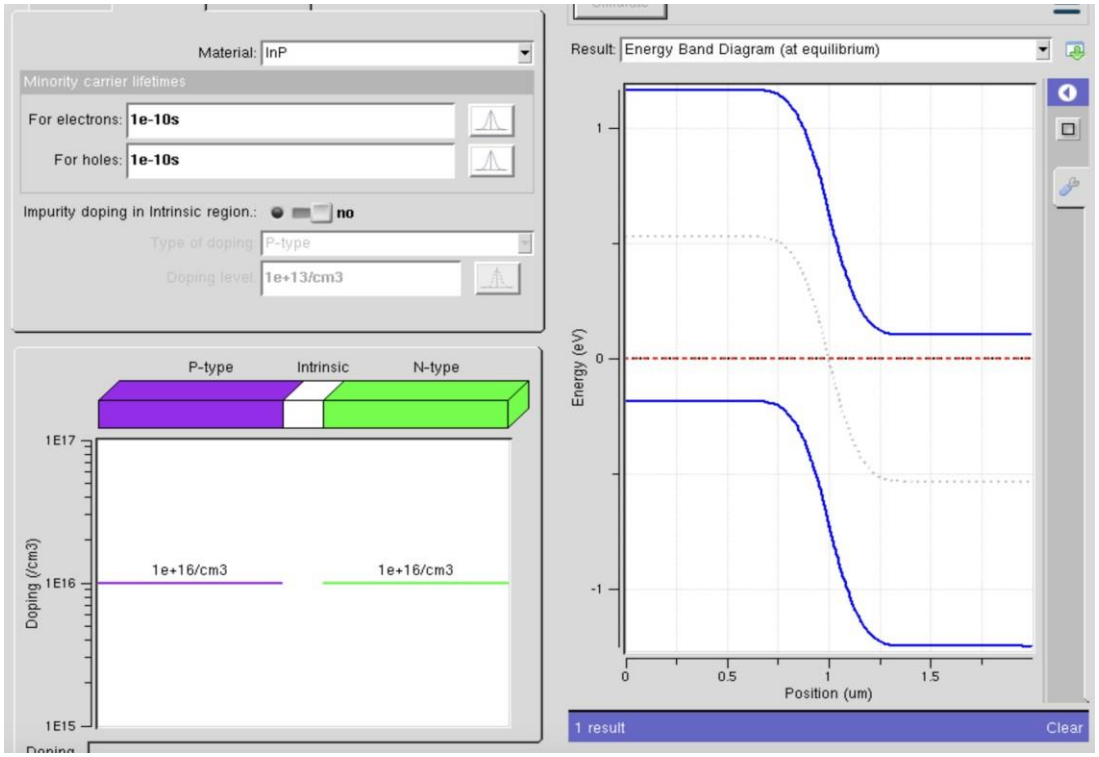


Fig: Energy Band Diagram at Equilibrium

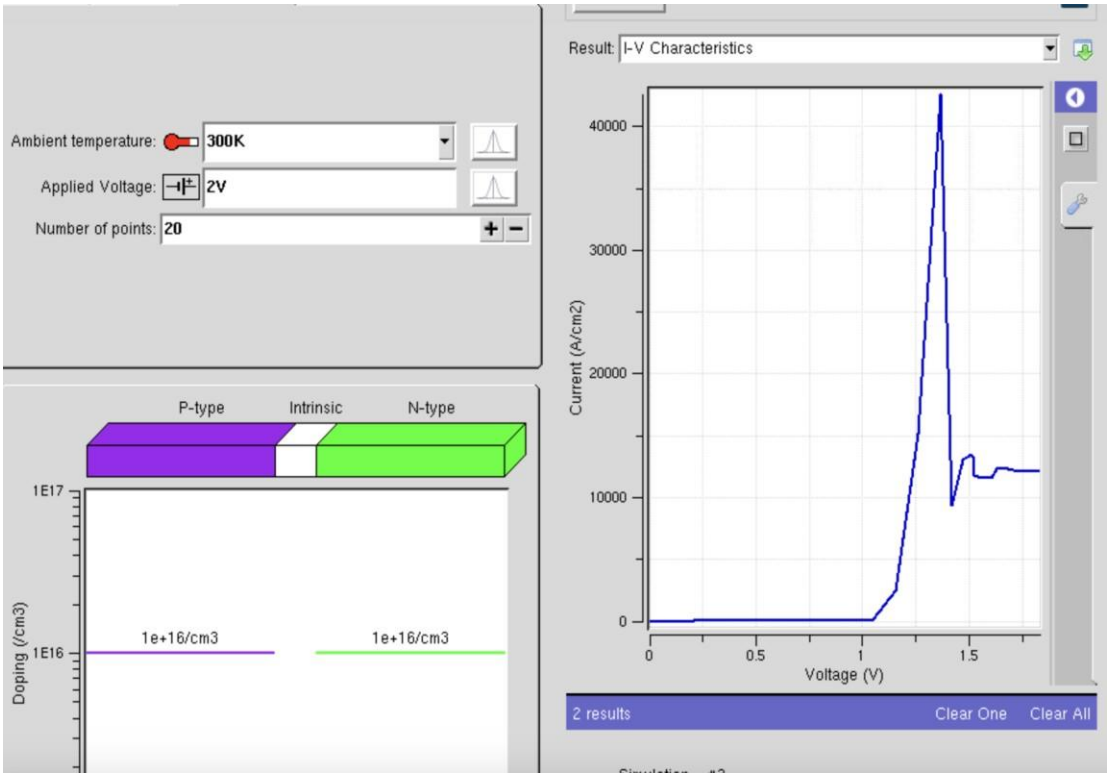


Fig: I-V Characteristics

Experiment 6:

Device level simulation of *p* n^+ junction using ABACUS

Parameters: Na=1E+15 cm^{-3} Nd = 1E+18 cm^{-3} Ln=Lp=3µmAt

Equilibrium:

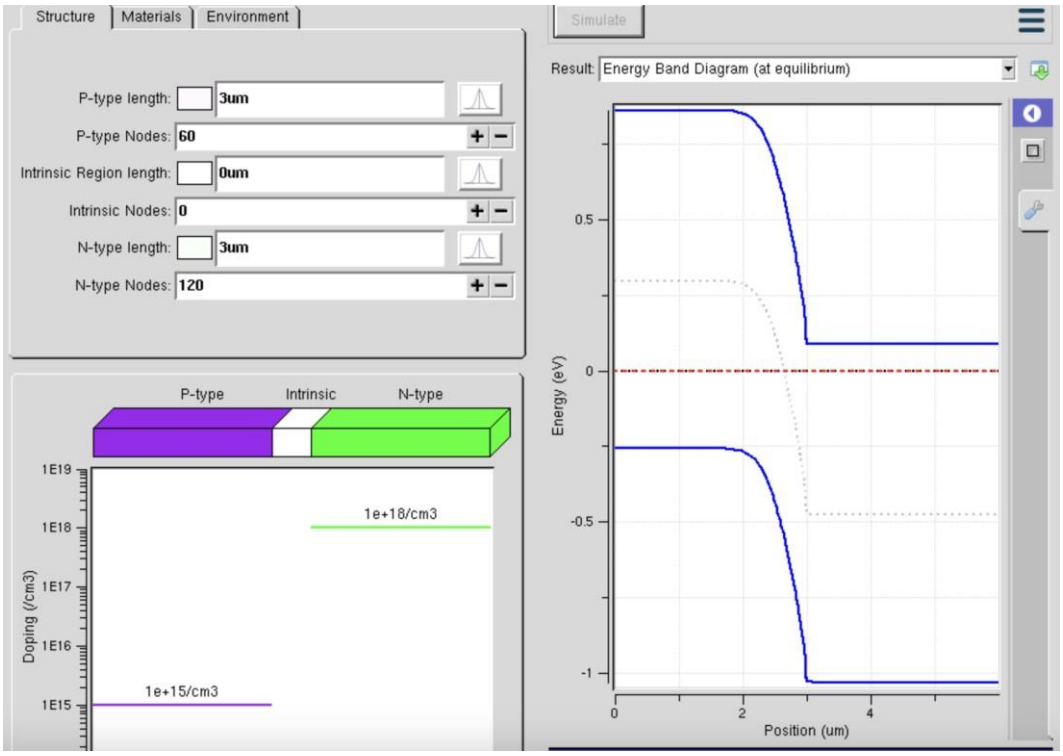


Fig: Energy Band Diagram at Equilibrium

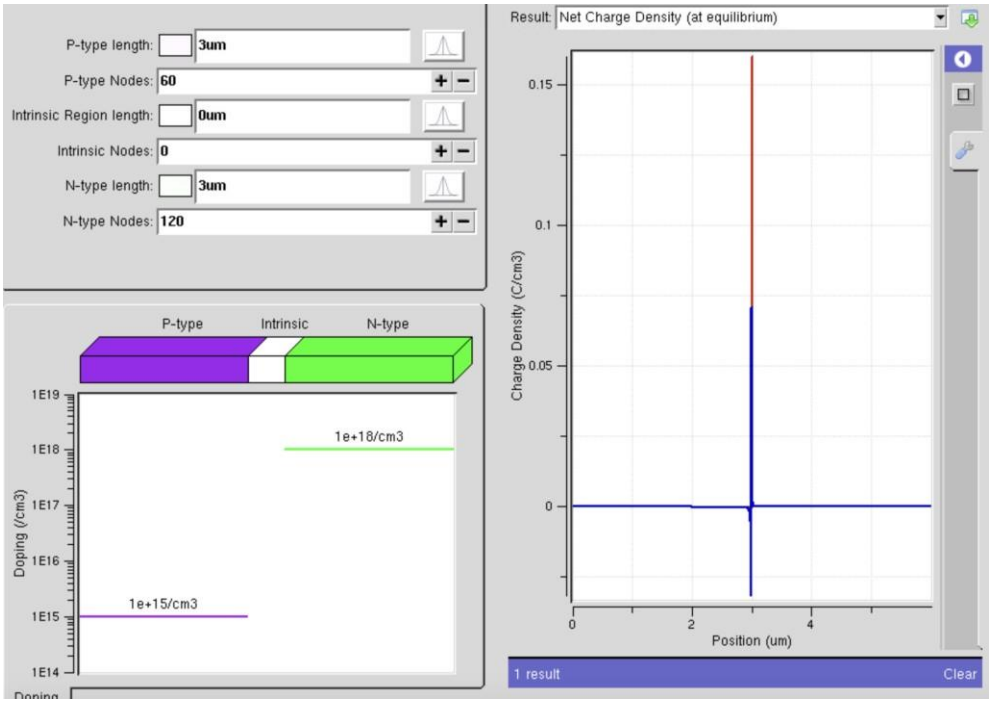


Fig: Net Charge Density at Equilibrium

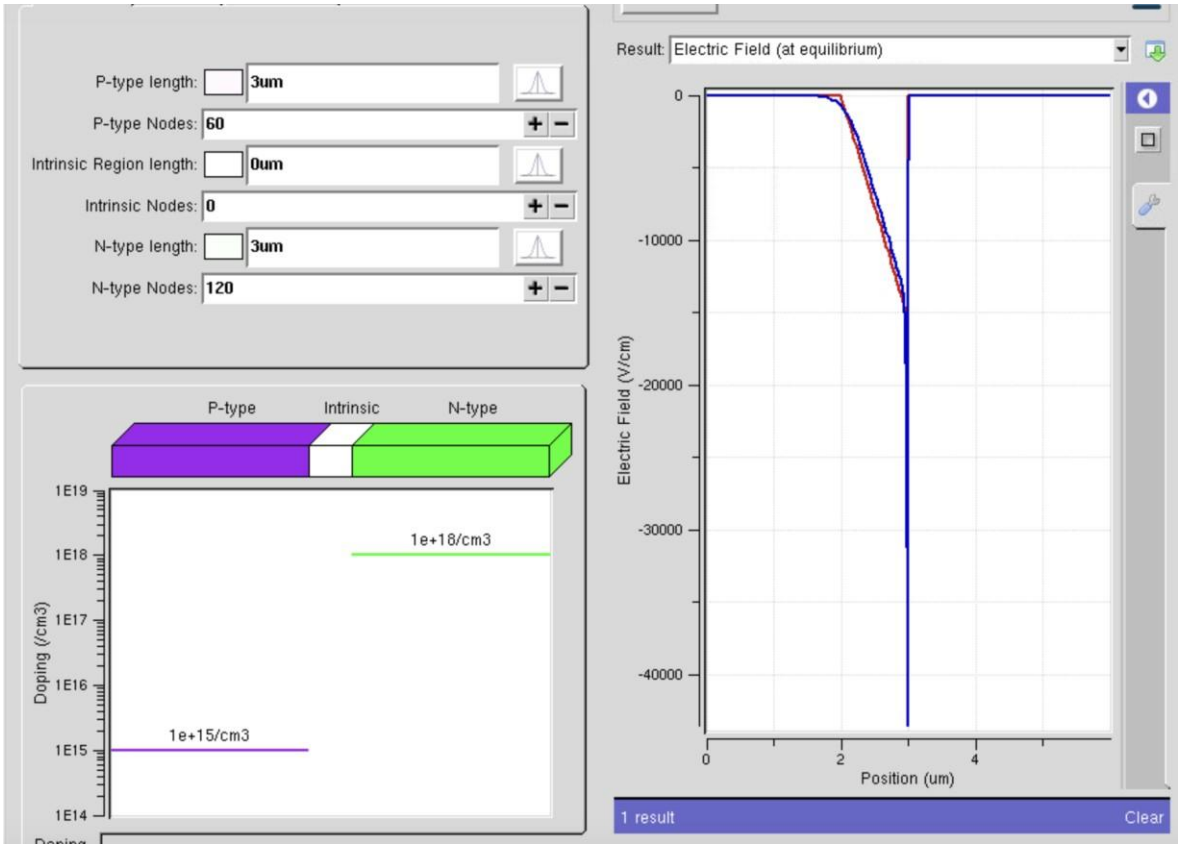


Fig: Electric Field at Equilibrium

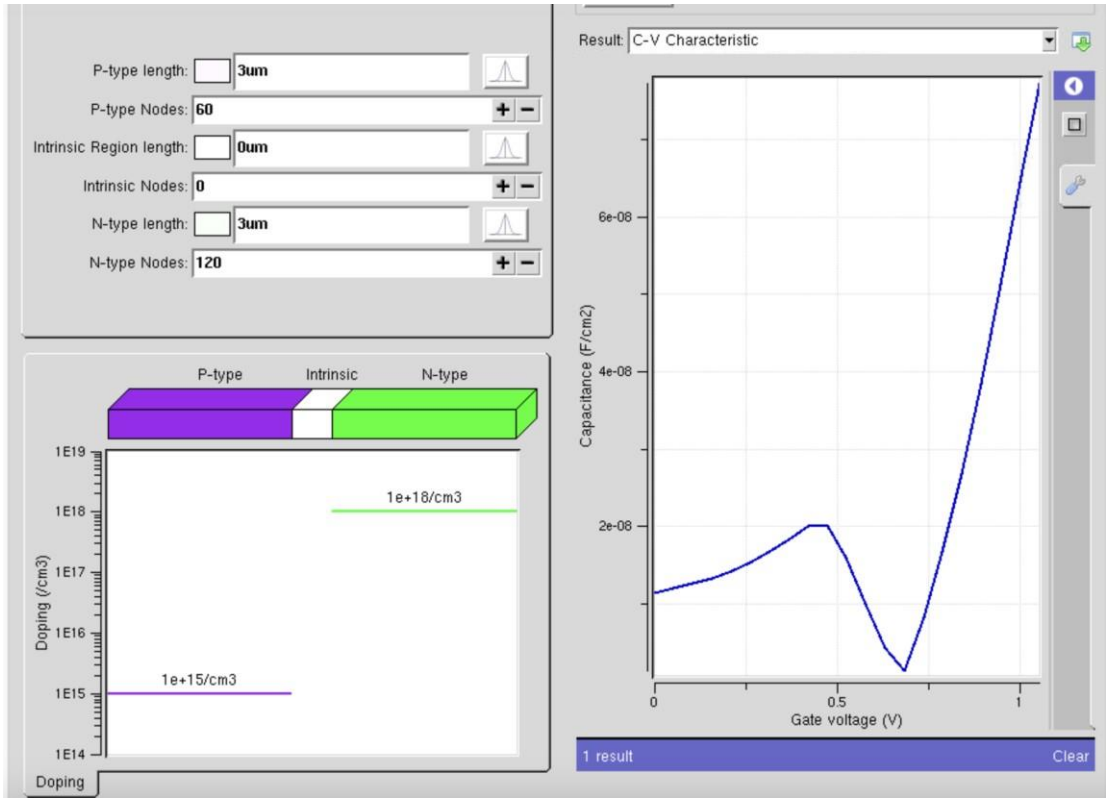


Fig: C-V Characteristics

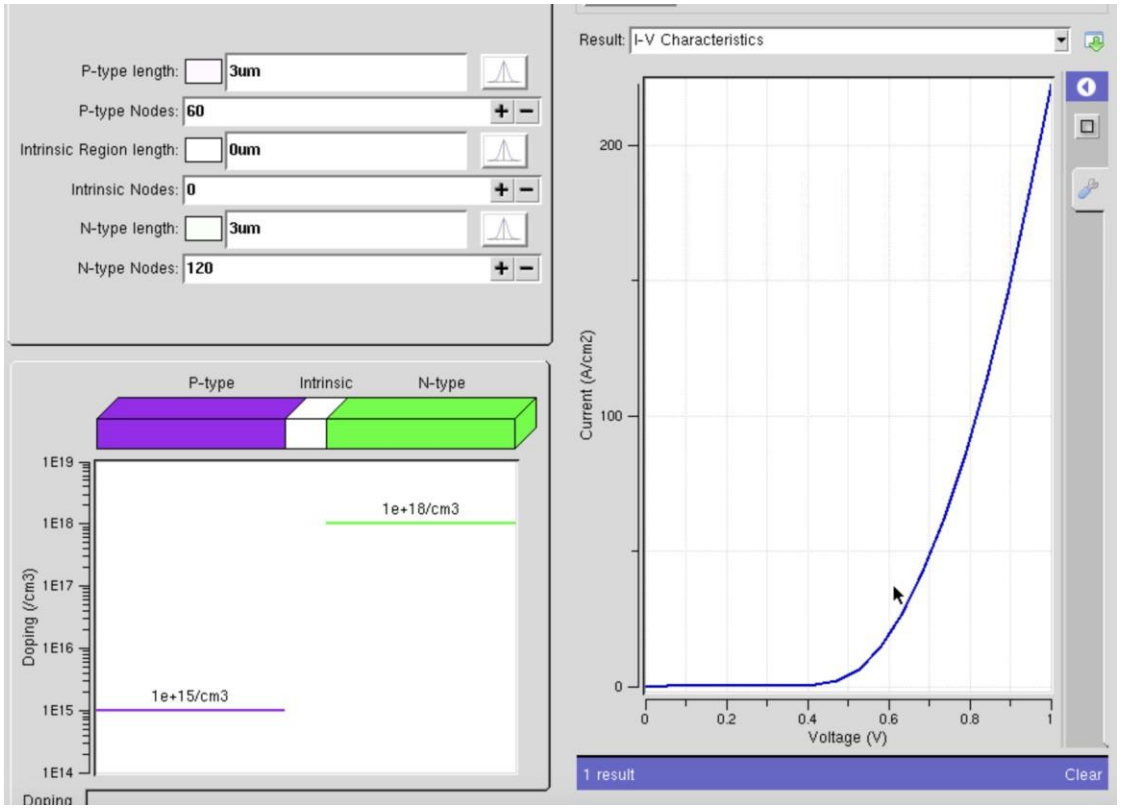


Fig: I-V Characteristics

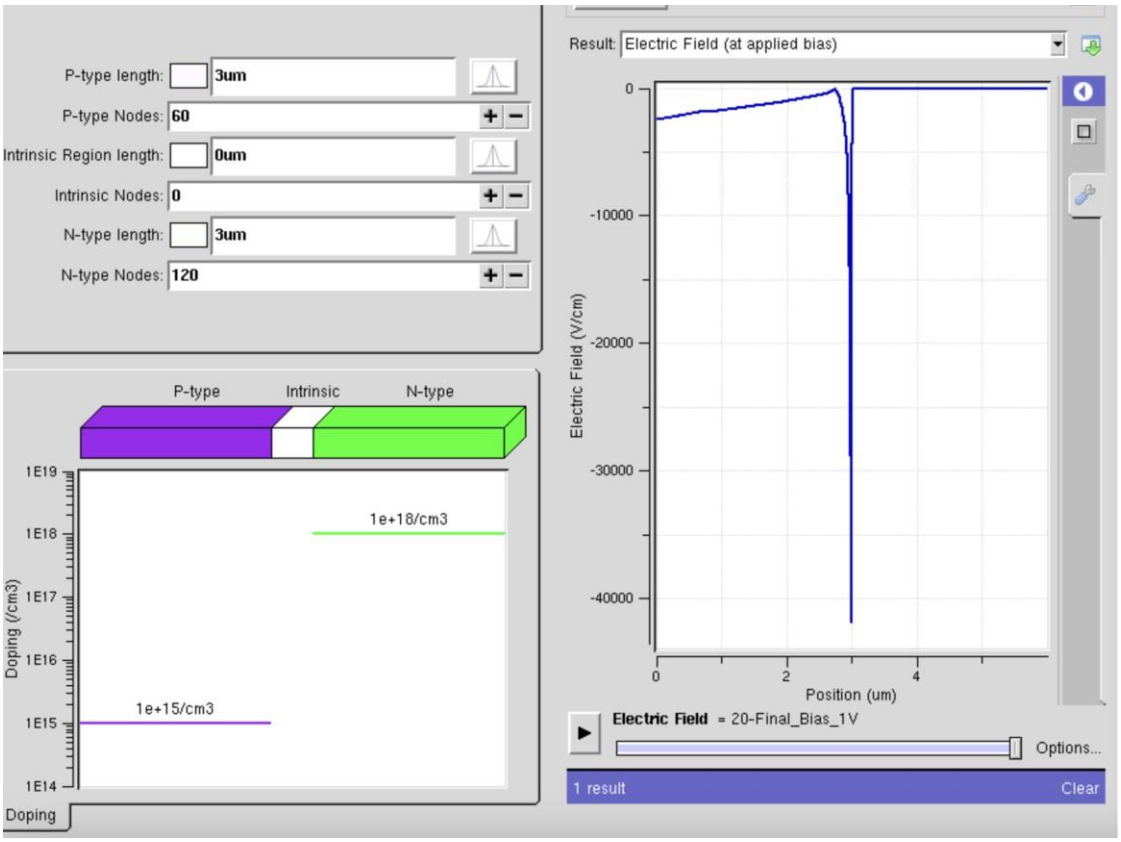


Fig: Electric Field at Applied Bias

At Applied Bias: 0.947 V

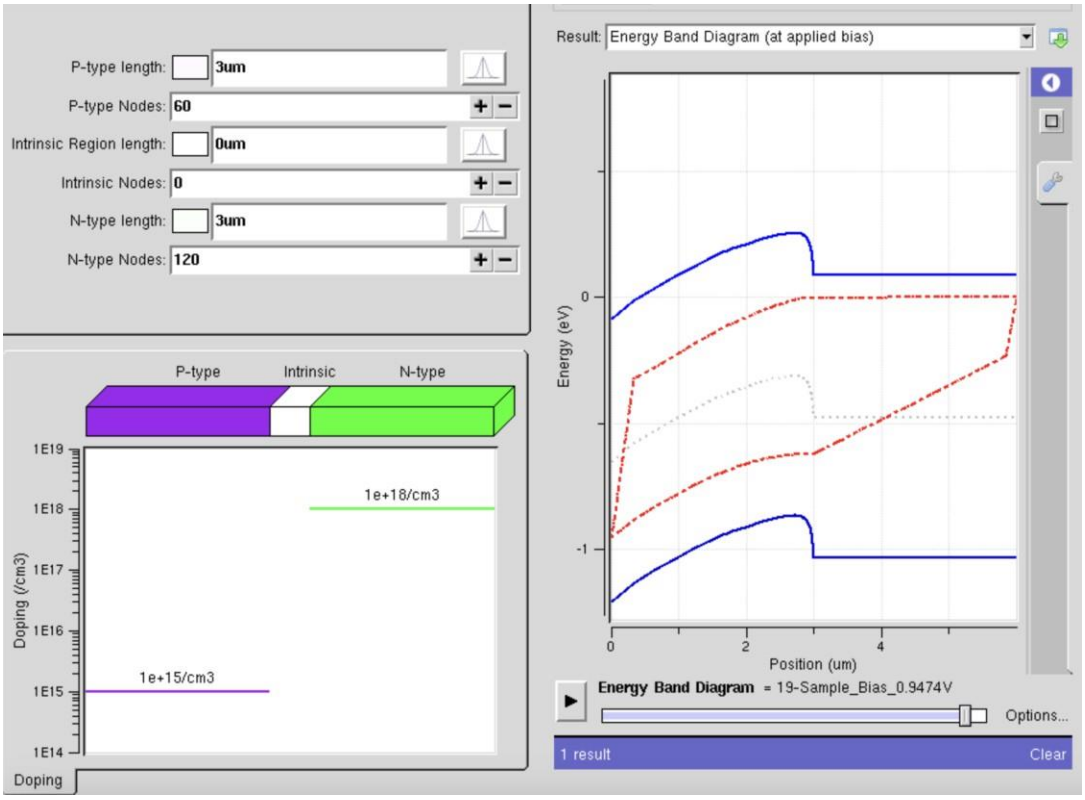


Fig: Energy Band Diagram at Applied Bias

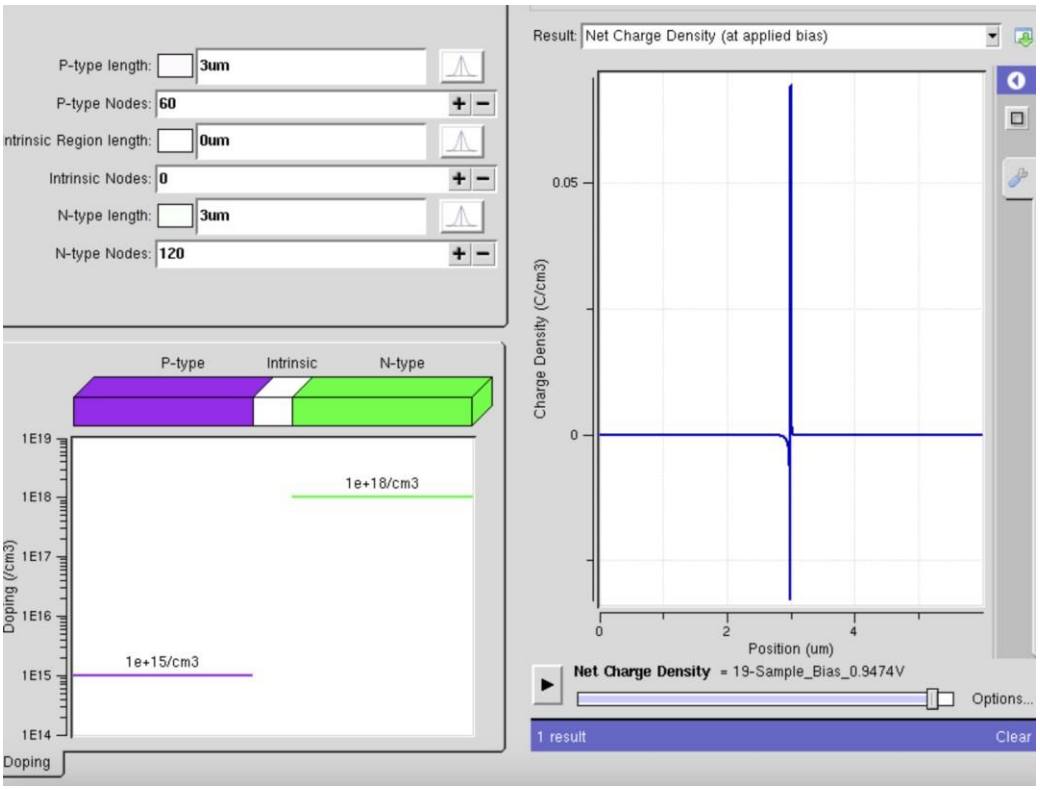


Fig: Net Charge Density at Applied Bias

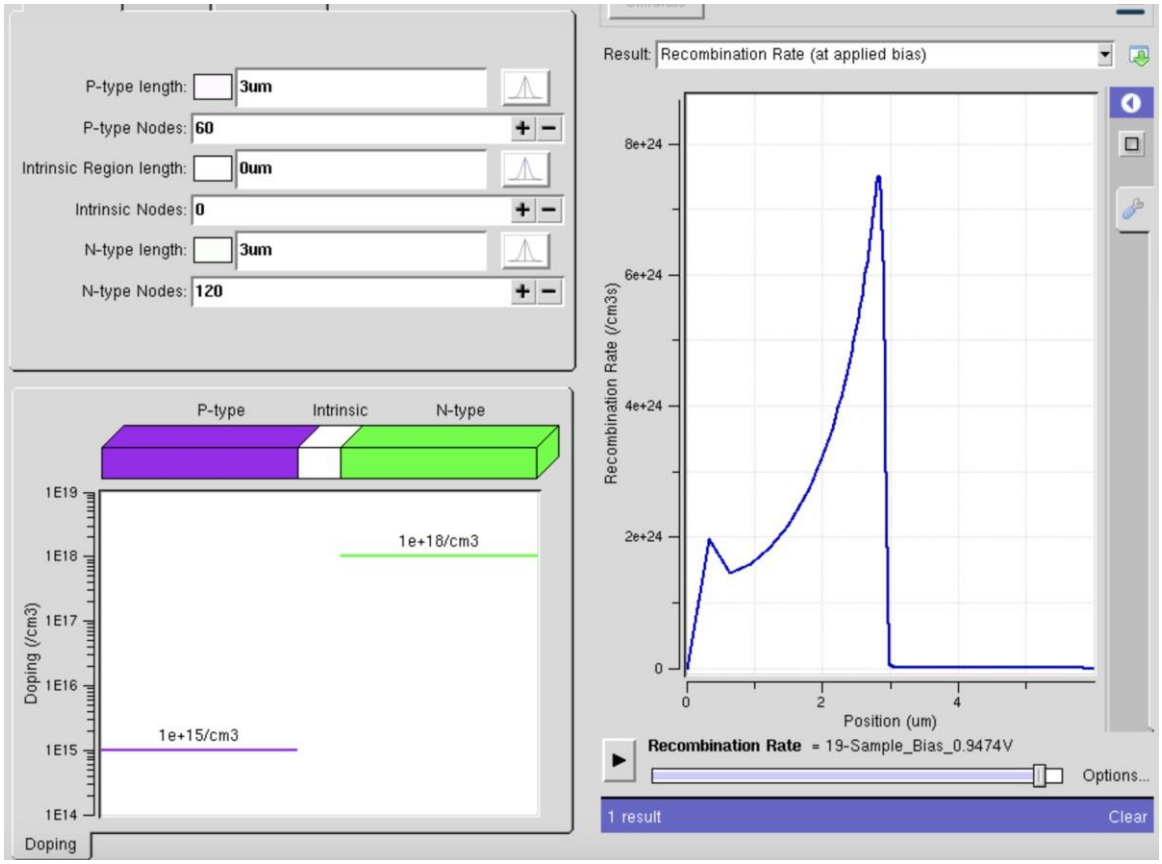


Fig: Recombination Rate at Applied Bias

Experiment 7 :

Extraction of pn junction diode device parameter using abacus

Parameter: Ln=Lp = 1µm Na = Nd = 1e+15 cm^{-3} Vapplied = 1.8 V

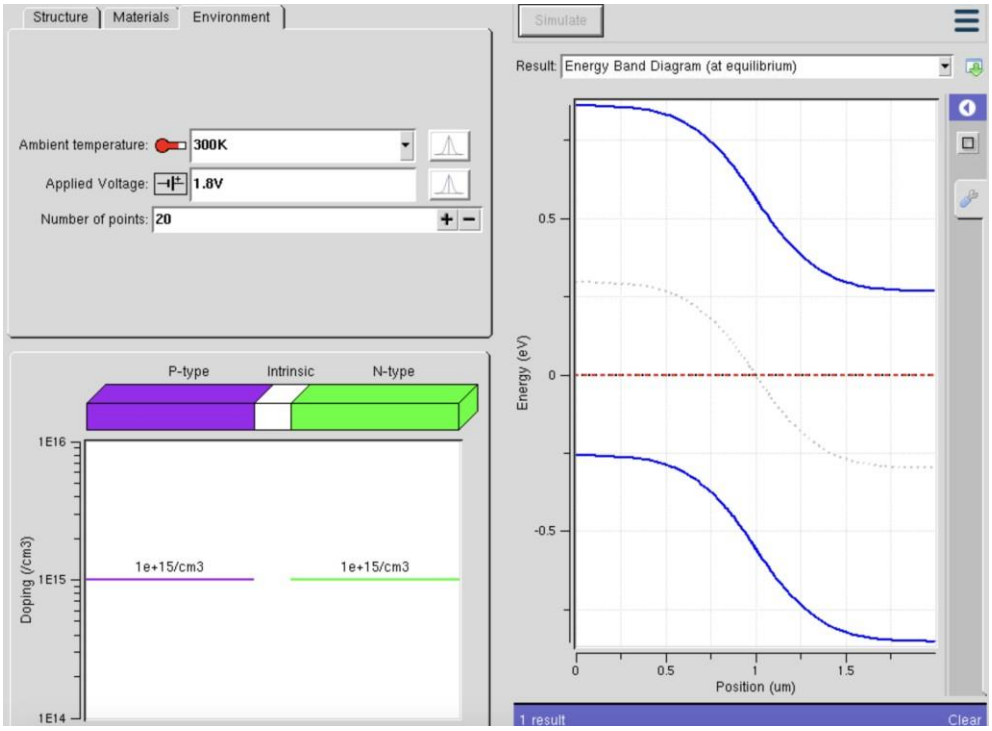


Fig: Energy Band Diagram at Equilibrium

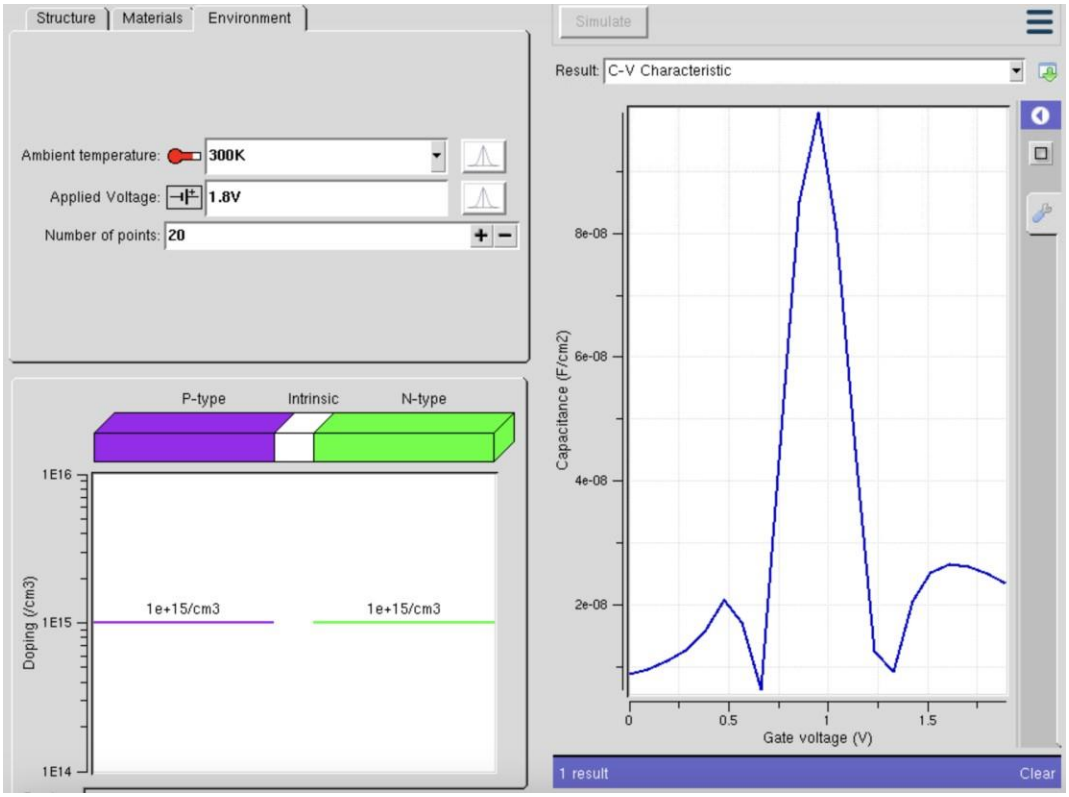


Fig: C-V Characteristics

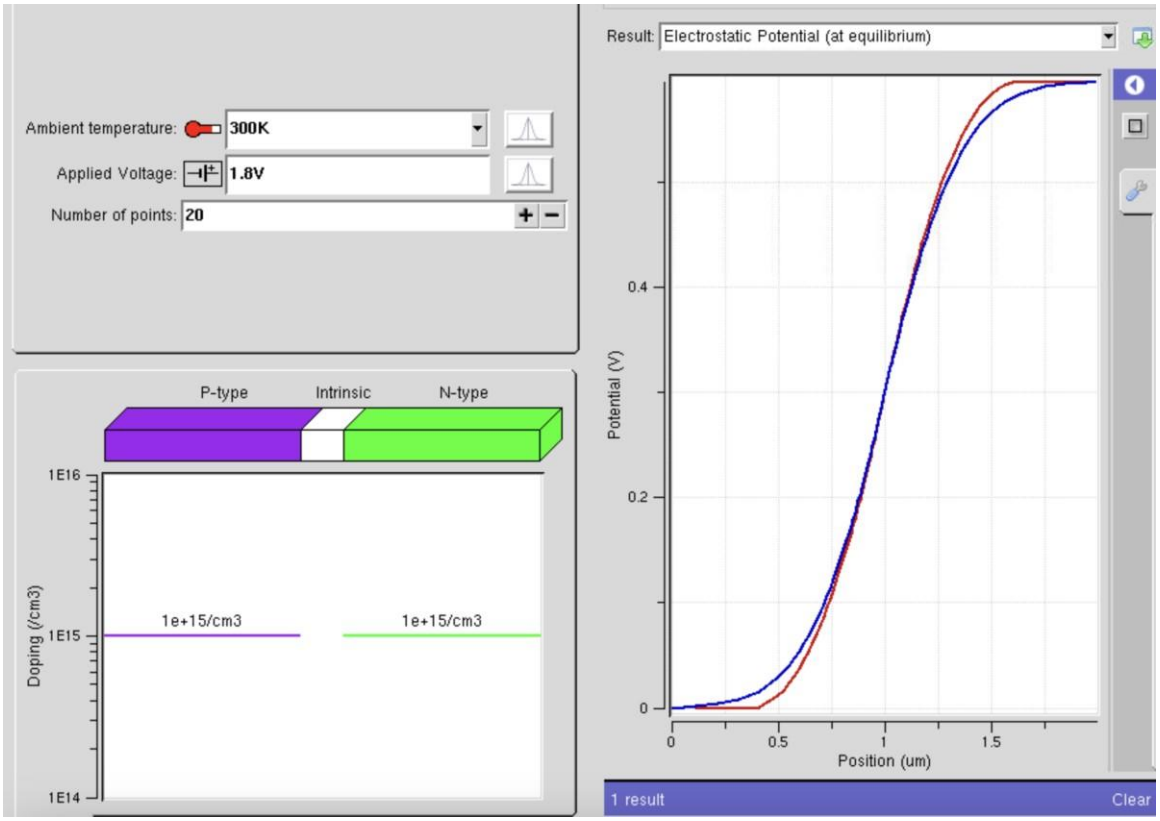


Fig:Electrostatic Potential at Equilibrium

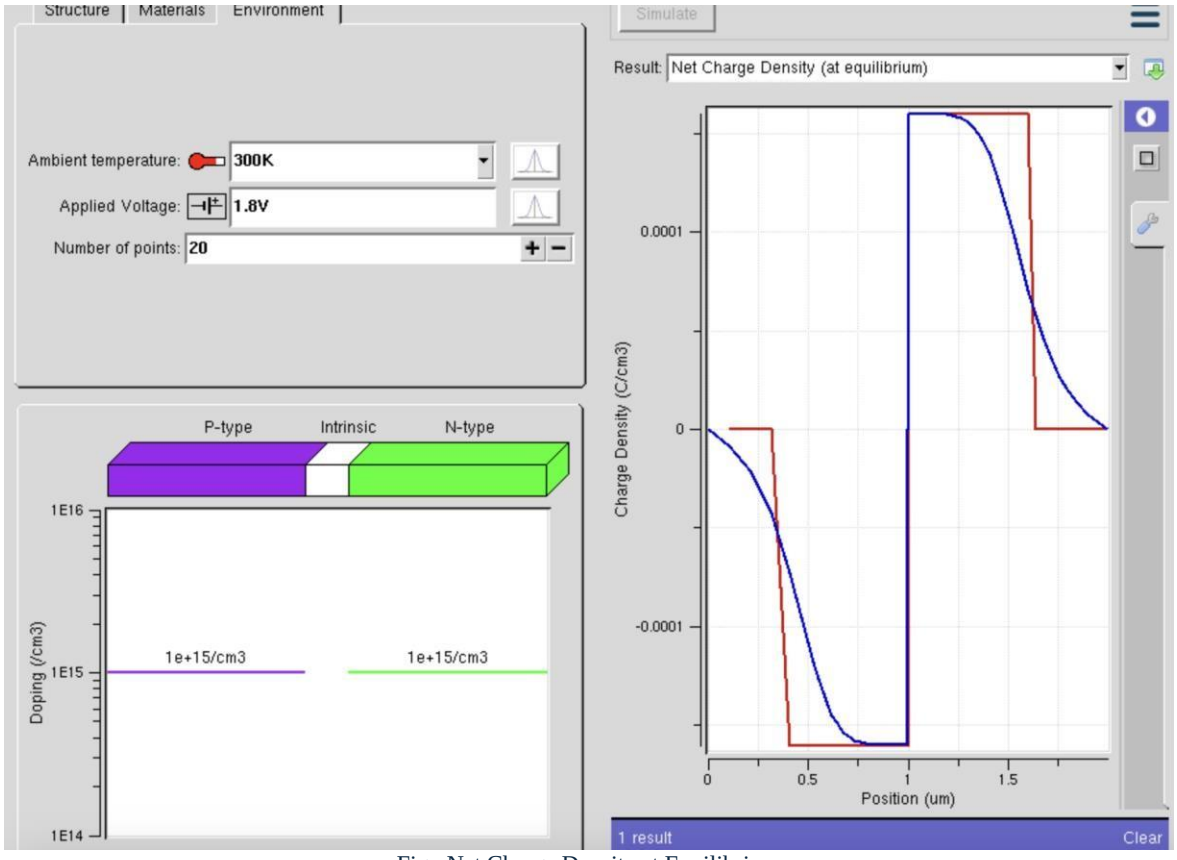
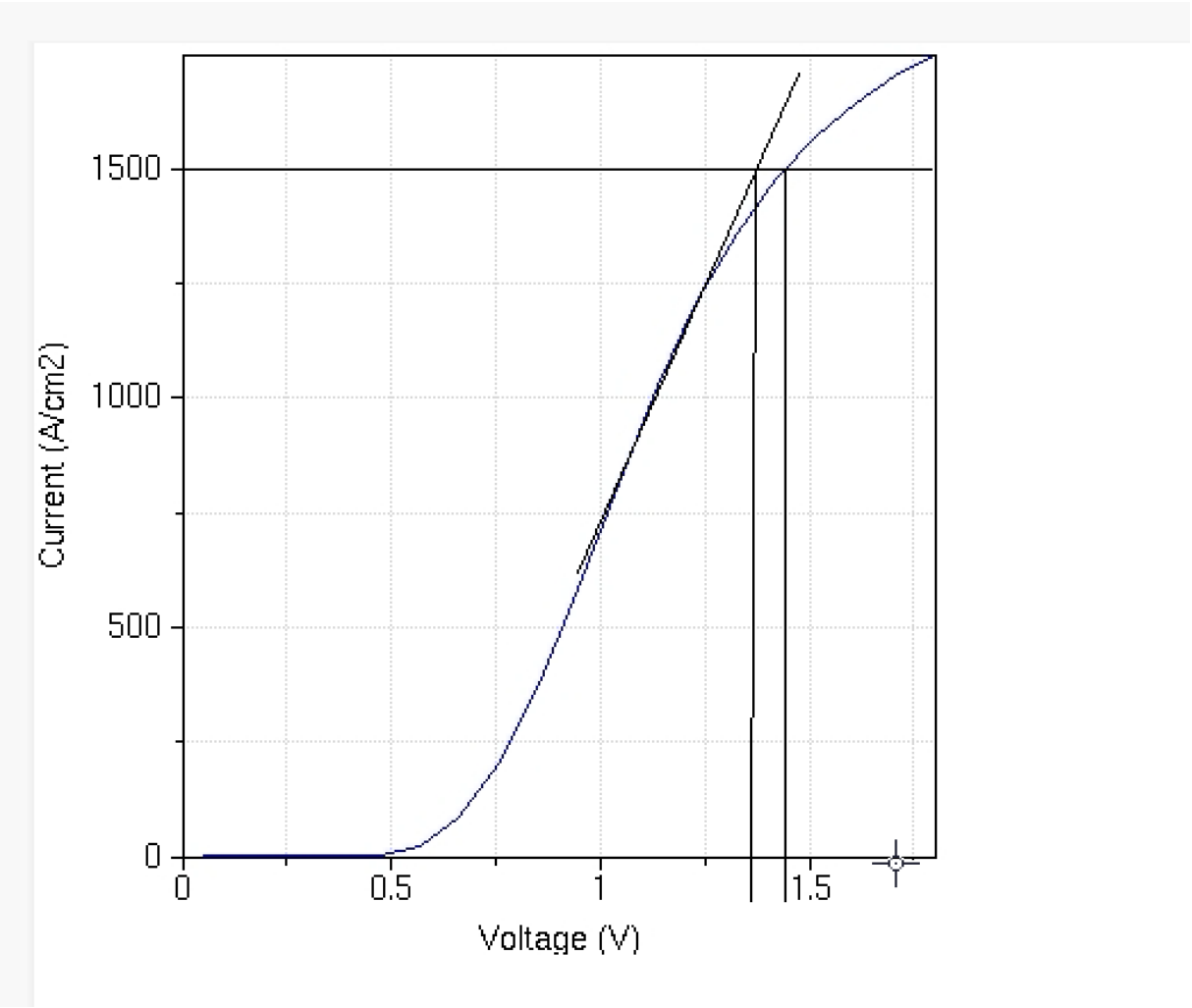


Fig: Net Charge Density at Equilibrium



W = 1.65-.315 = 1.335µm

Vbi = 0.524V

Ron = $\frac{V2-V1}{I}$ = $\frac{1.41-1.35}{1500}$ ≡ 42.12μcm^2

C = 2e-08 Fcm^{-2}

T = Ron C = 42.12u * 20n = 0.8424ps

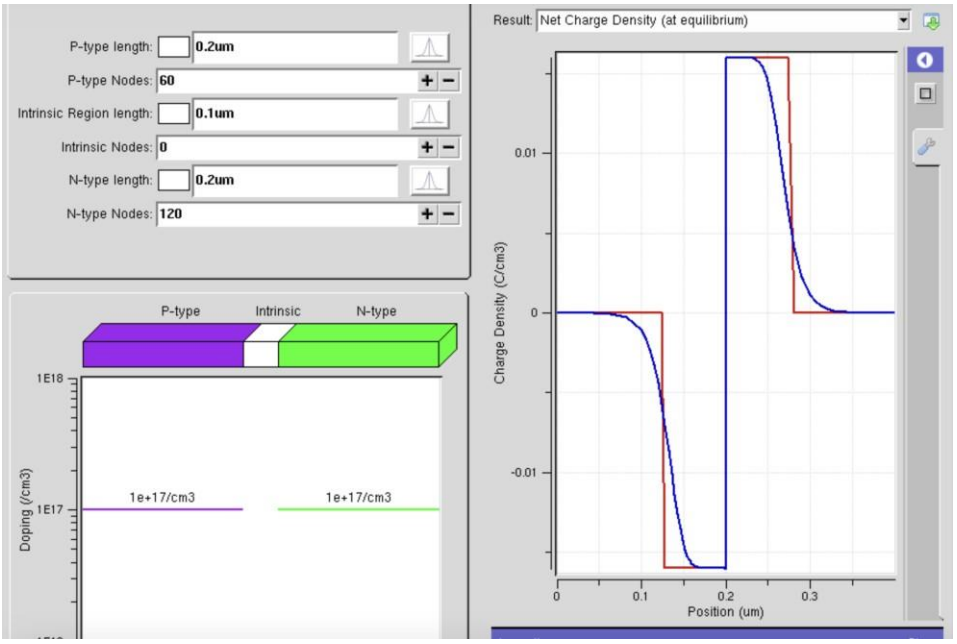
Experiment 8:

In this exercise we will examine the operation of a pin diode under forward andreverse bias conditions.

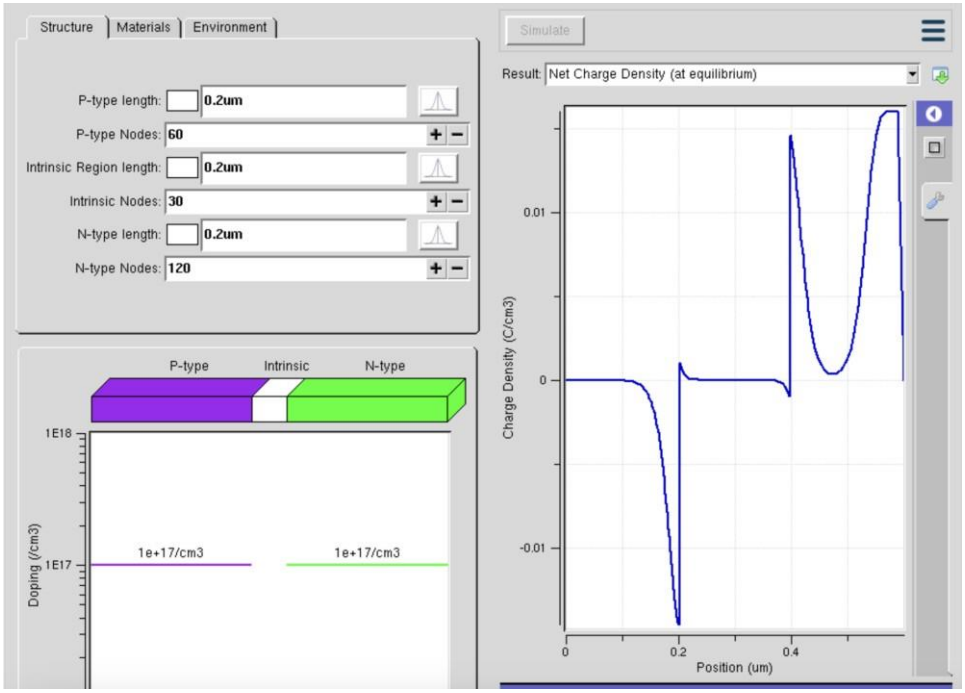
The p side doping is Na= 10 17 cm^{-3} and the n side doping is Nd= 10 17 cm^{-3}. The length of p sideand side region is 0.2um. the intrinsic region width is varying from 0.1um to 0.4um in an increment of 0.1um.

(A) Plot the total charge density under equilibrium conditions for all devices with differentintrinsic region width.

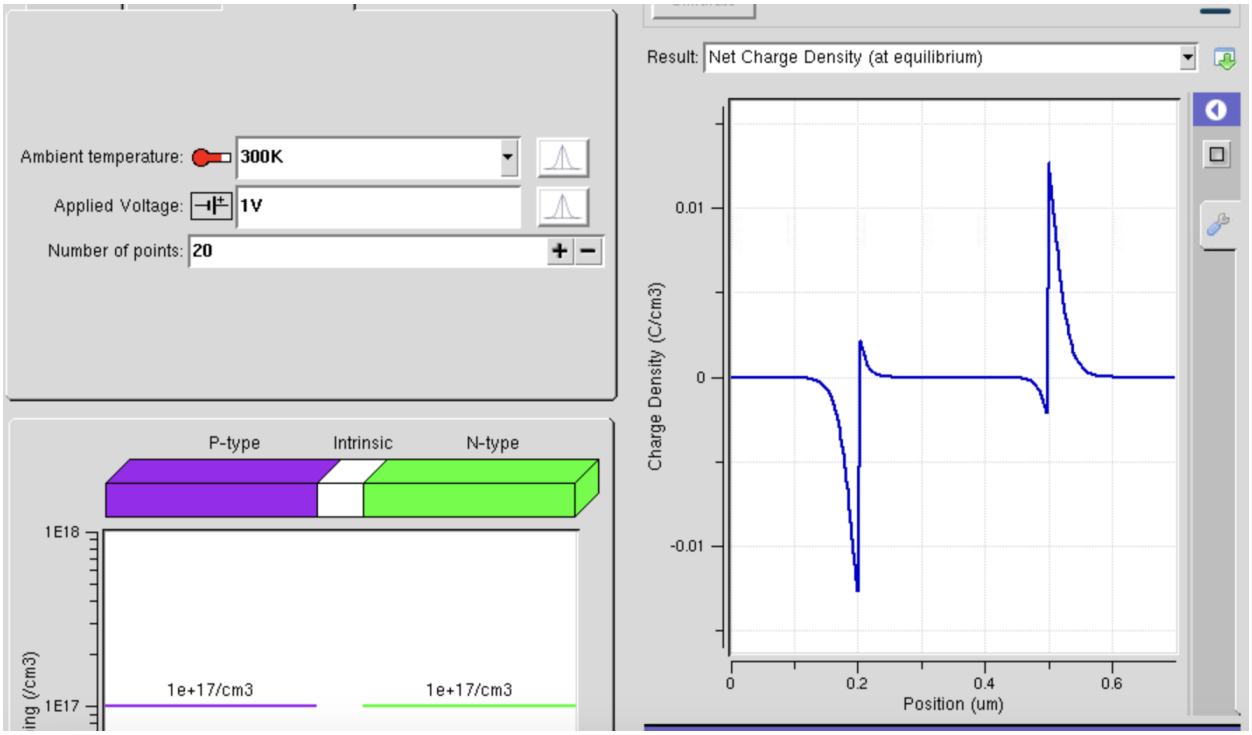
Case 1: intrinsic region width 0.1um



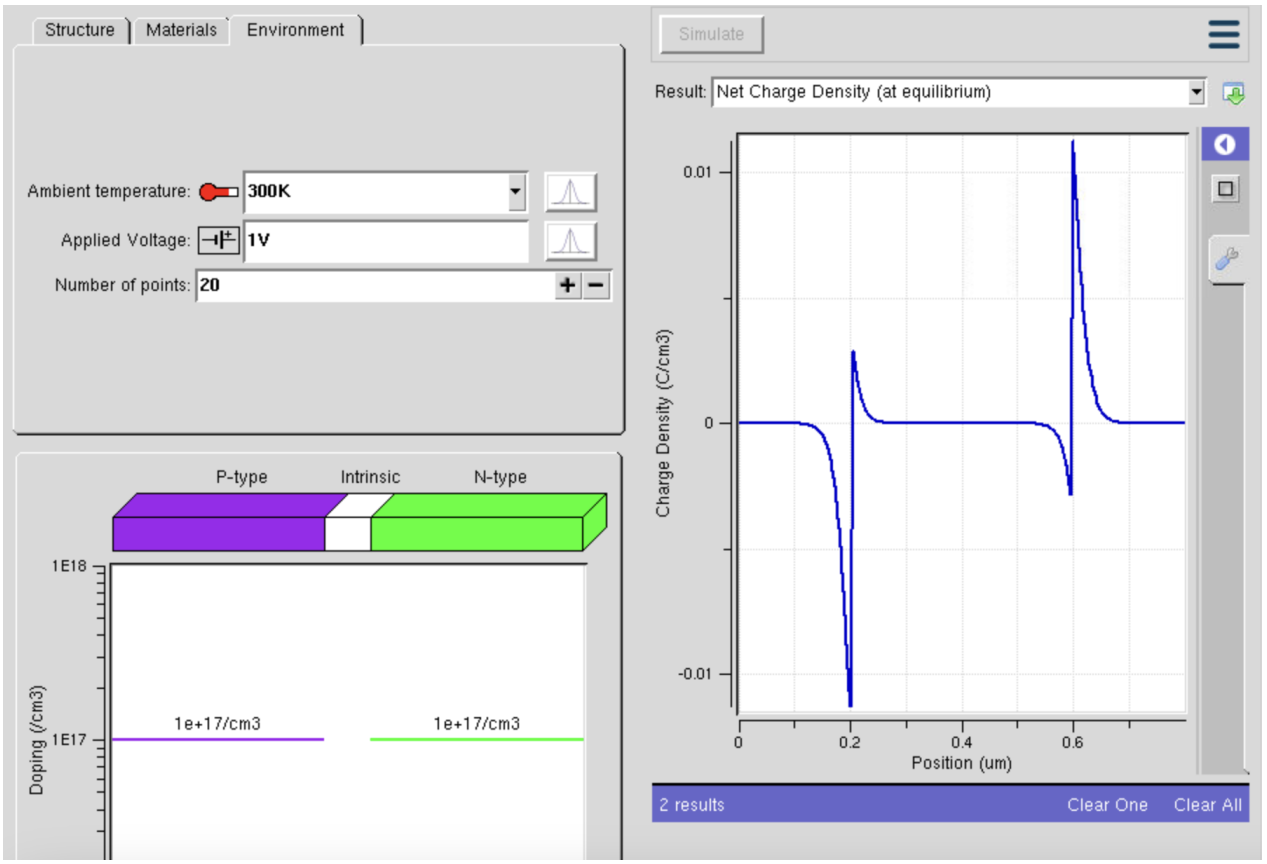
Case 2: intrinsic region width 0.2um



Case 3: intrinsic region width 0.3um

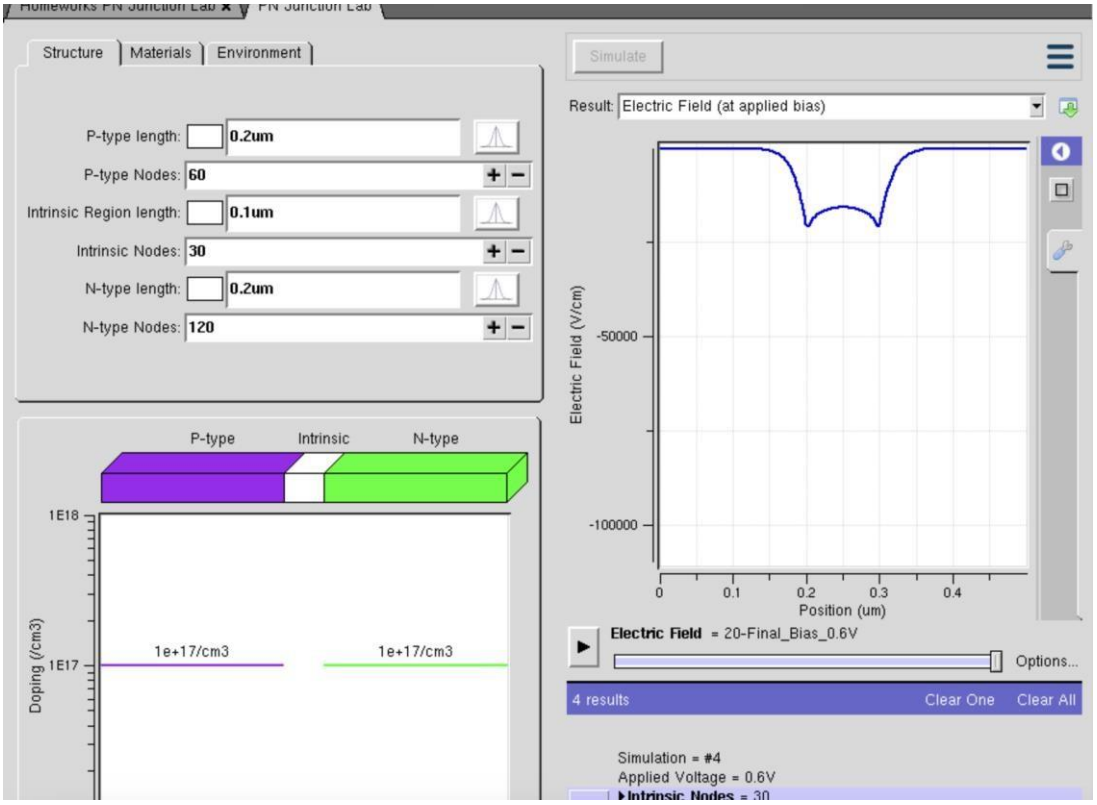


Case 4: intrinsic region width 0.4um

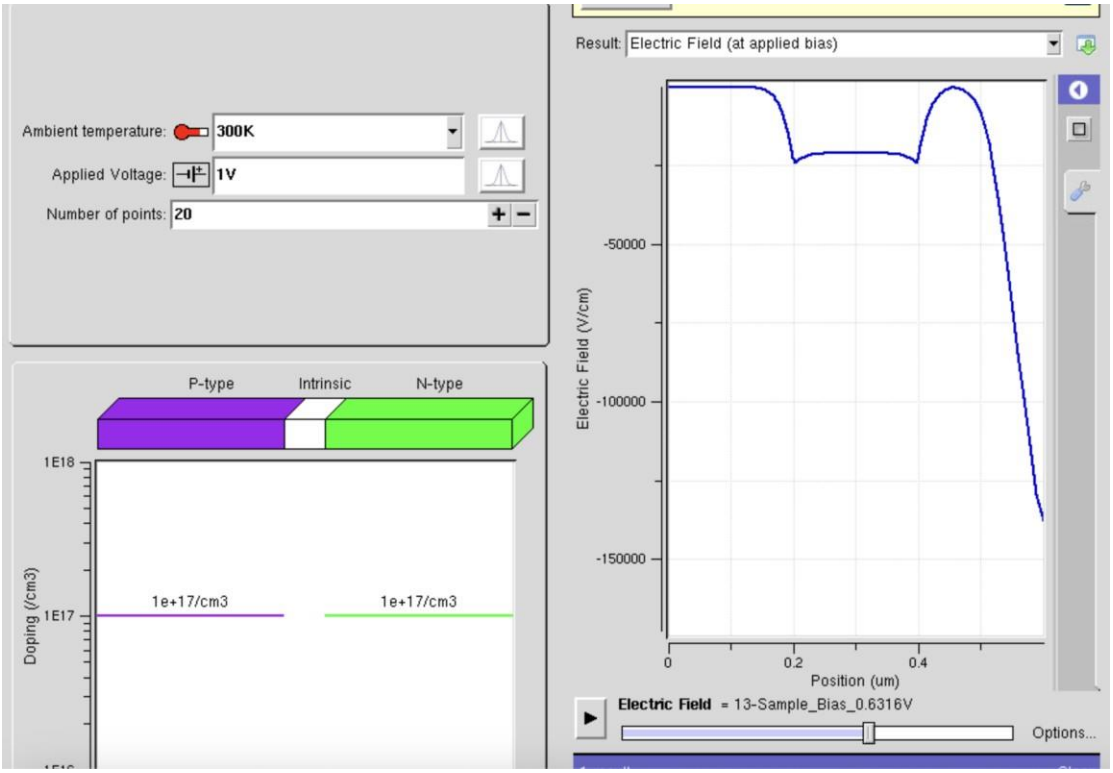


(B) Plot the electric field profile for applied bias on the anode of 0.6v for the three width ofthe intrinsic region width.

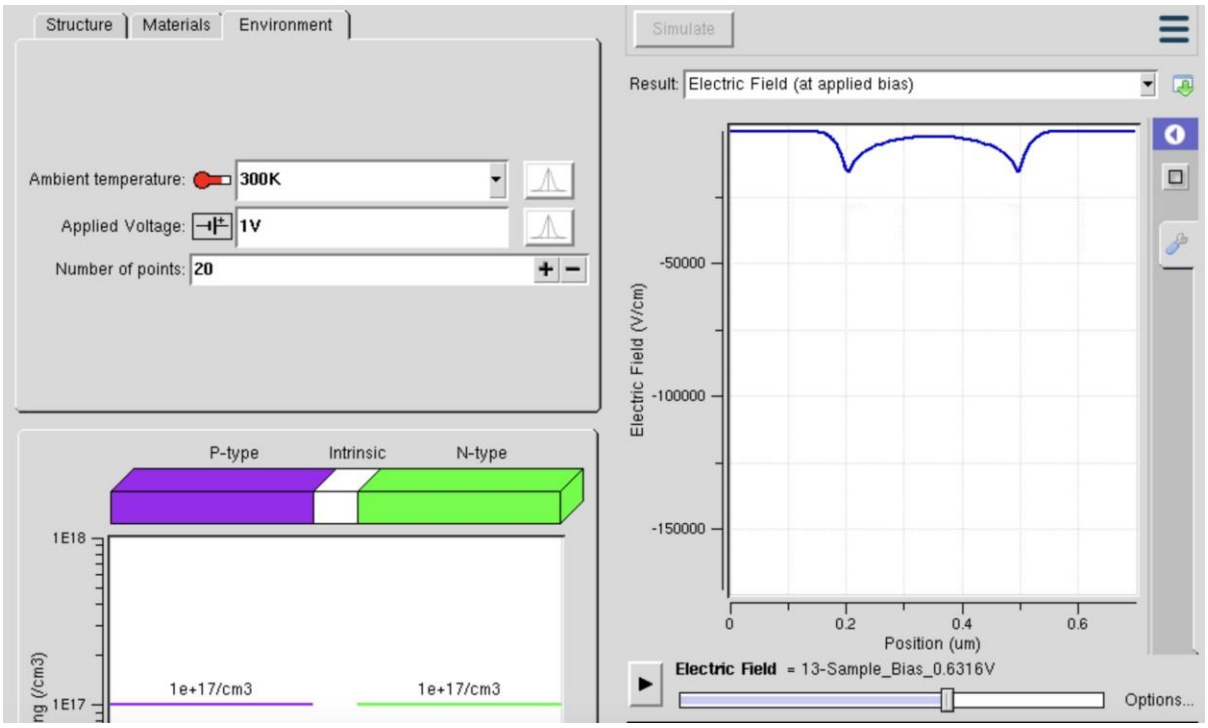
Case 1: intrinsic region width 0.1um



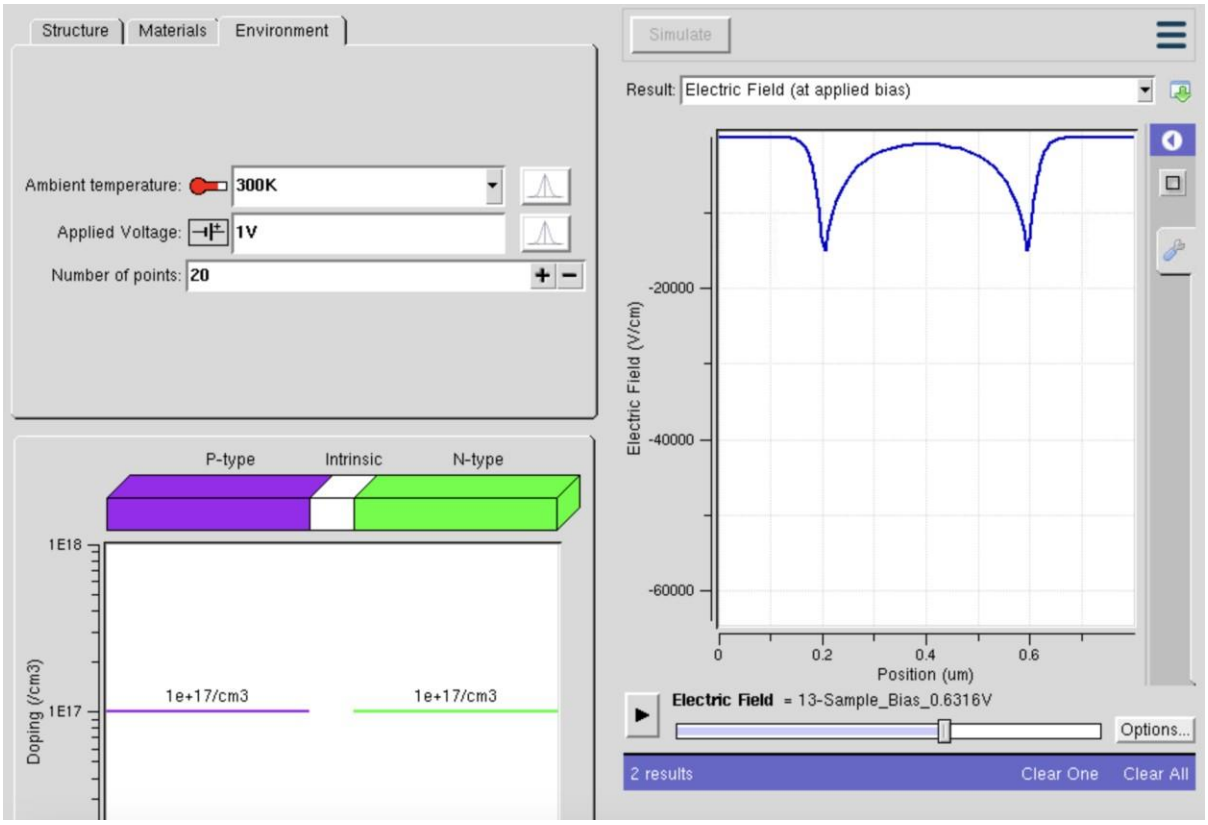
Case 2: intrinsic region width 0.2um



Case 3: intrinsic region width 0.3um

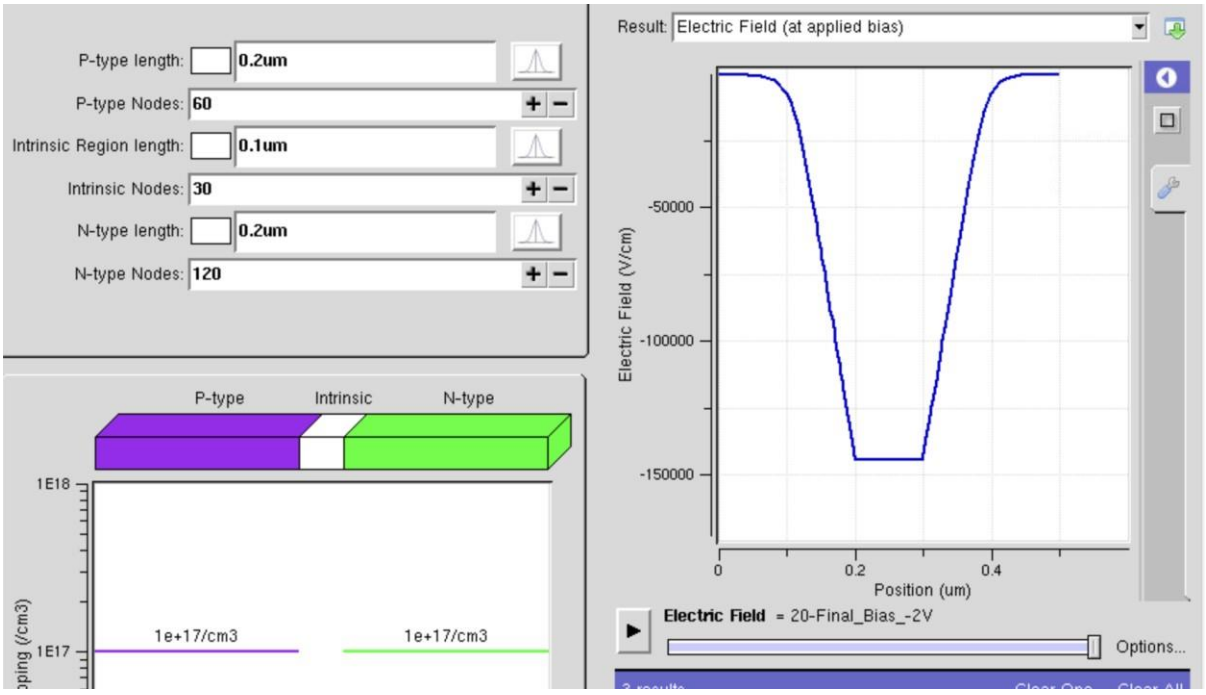


Case 4: intrinsic region width 0.4um

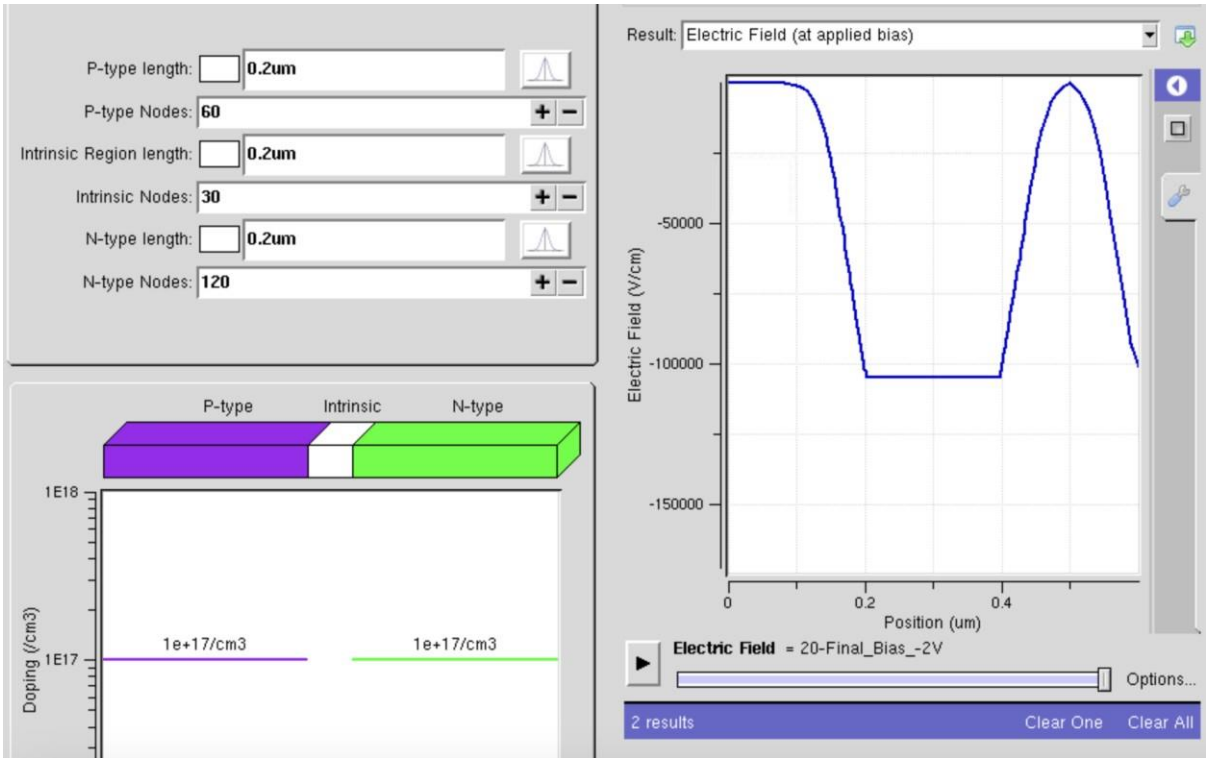


(C) Plot the electric field profile for applied bias on the anode of -2V for the three widths ofthe intrinsic region width.

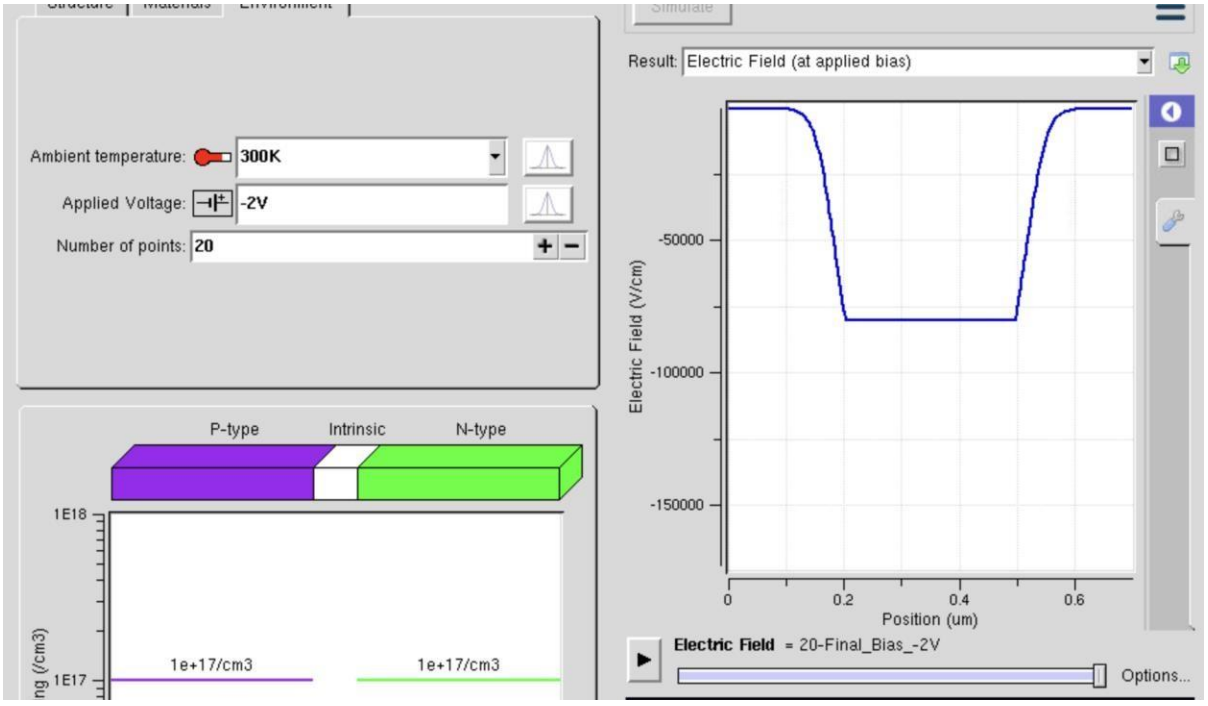
Case 1: intrinsic region width 0.1um



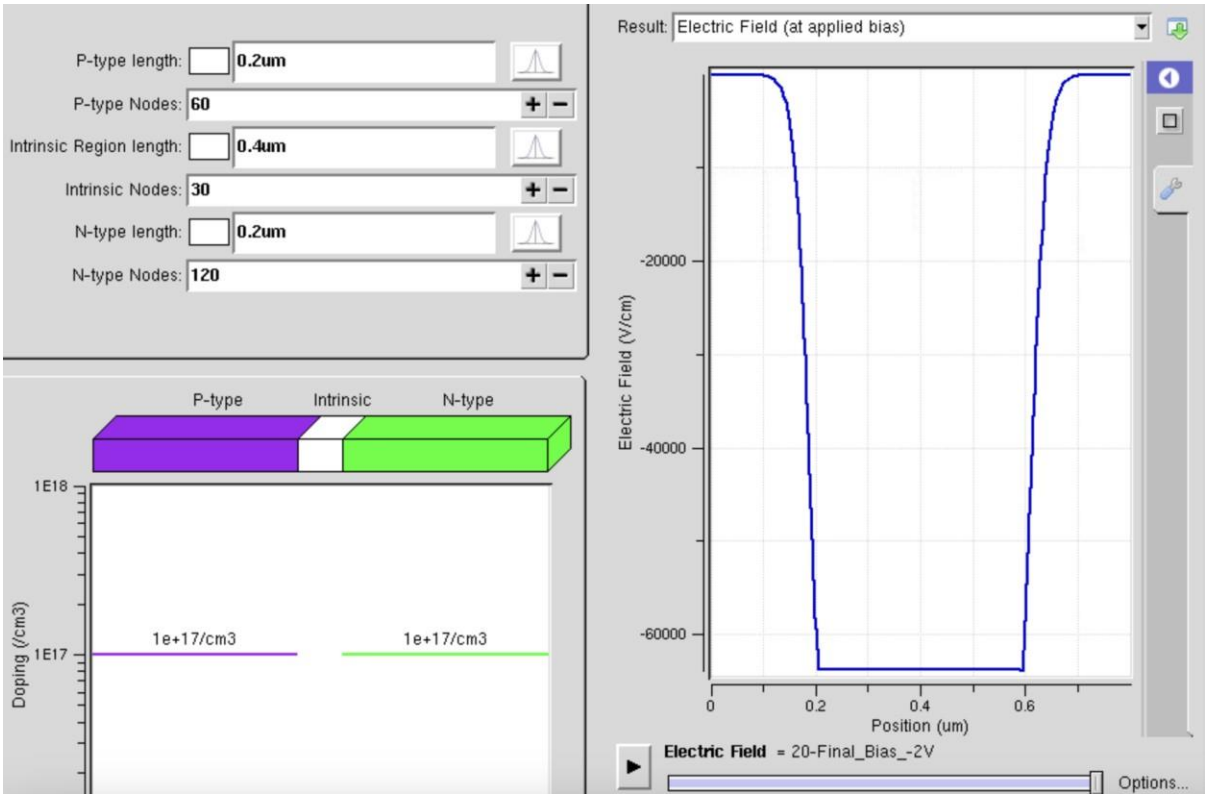
Case 2: intrinsic region width 0.2um



Case 3: intrinsic region width 0.3um



Case 4: intrinsic region width 0.4um



Experiment-9

Simulation of MOSFET characteristics as a function of doping process parameters using ABACUS

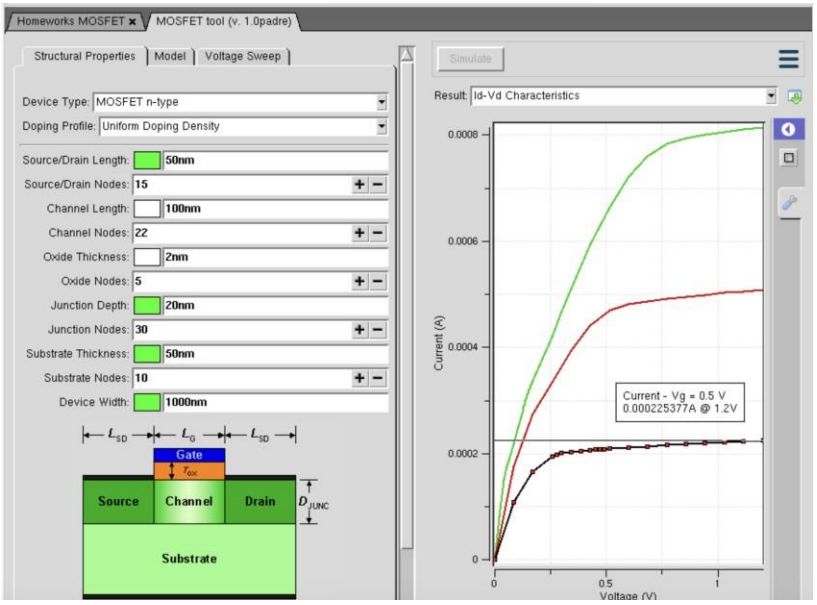
Doping profile

- 3 cases

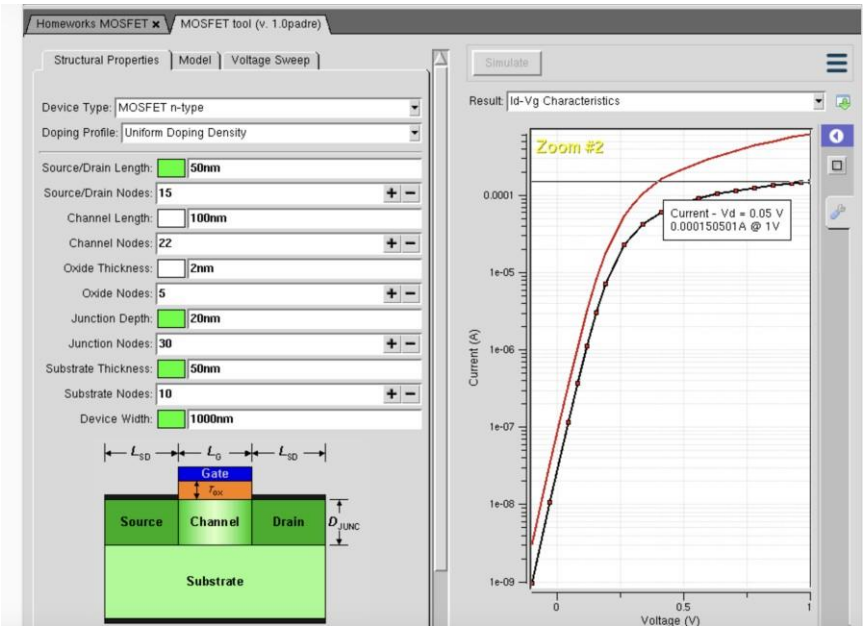
- check ID (for fixed VDS and VGS)Vds= 1.2 V Vgs= 1V

Case 1: Uniform Doping Density

Id vs Vd Characteristics: Id= 0.225mA

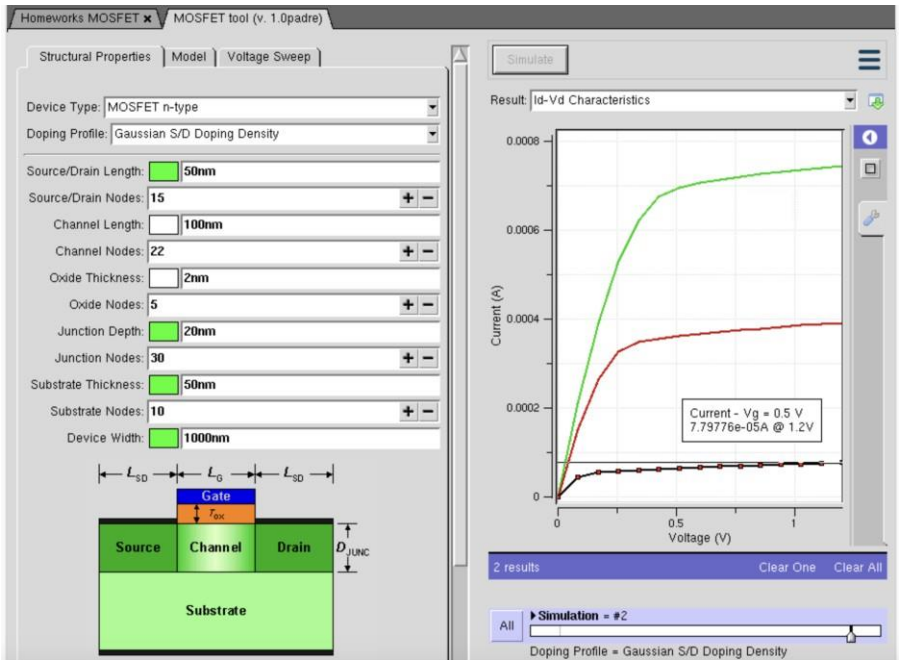


Id vs Vg Characteristics: Id= 0.150mA

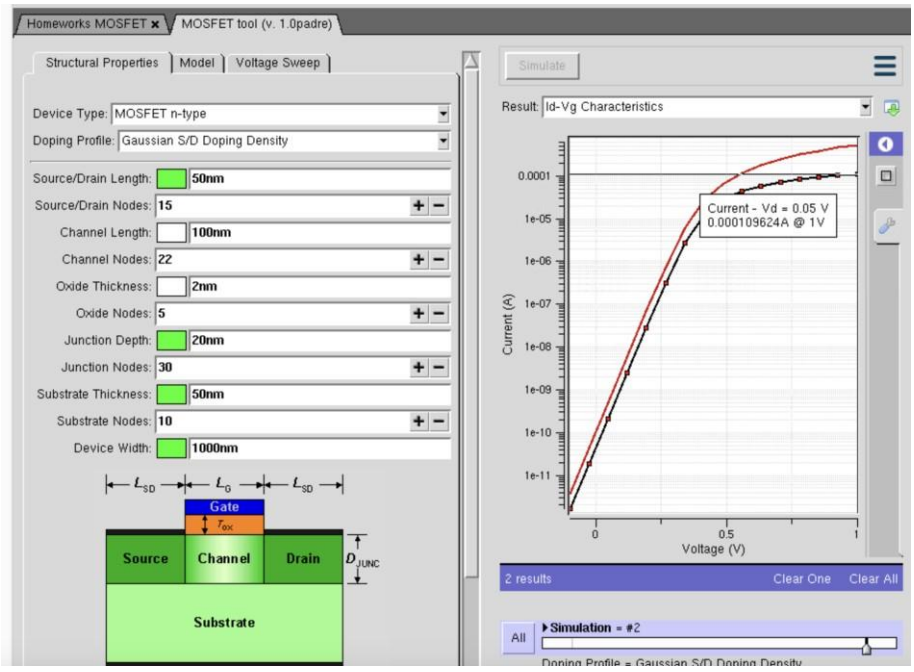


Case 2: Gaussian S/D Doping Density

Id vs Vd Characteristics: Id= 0.077977 mA

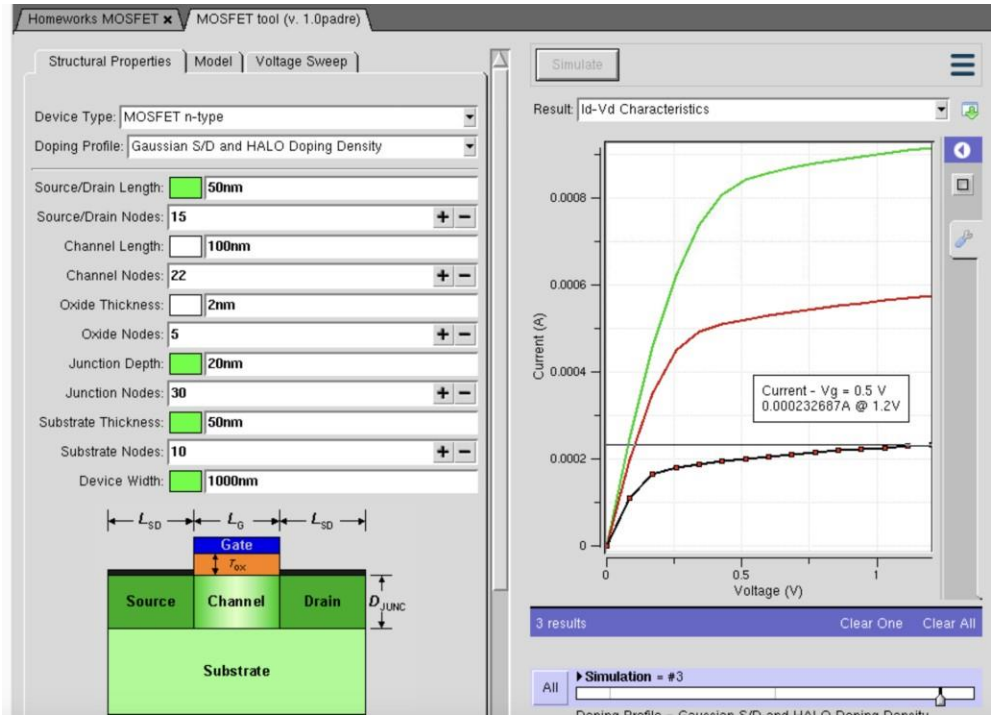


Id vs Vg Characteristics: Id= 0.109mA

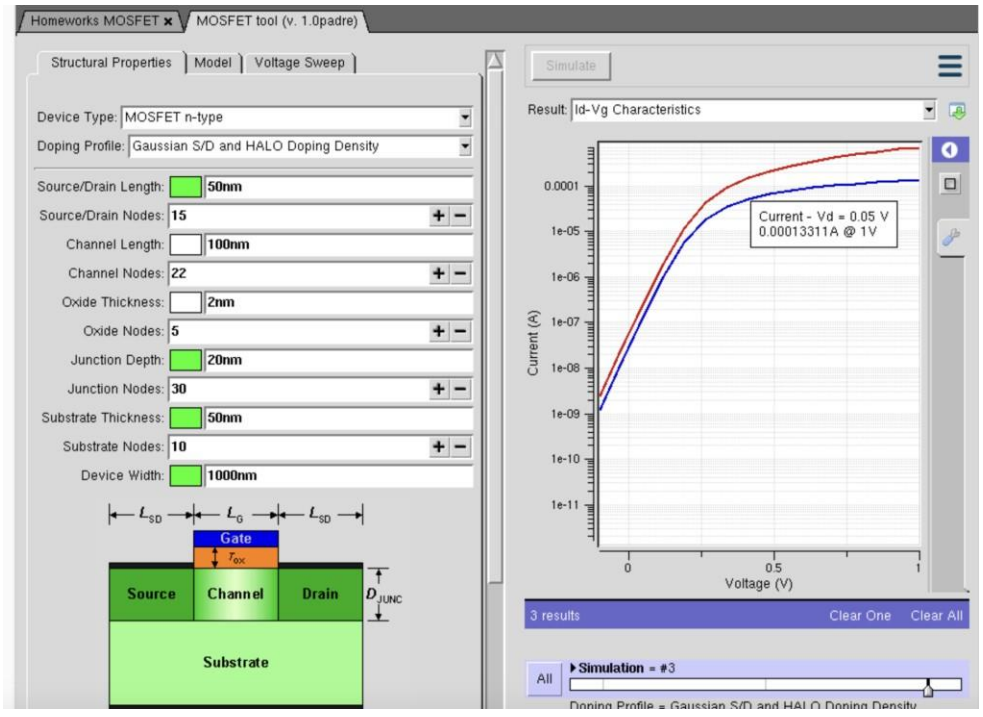


Case 3: Gaussian S/D and HALO Doping Density

Id vs Vd Characteristics: Id= 0.232687 mA



Id vs Vg Characteristics: Id= 0.13311mA



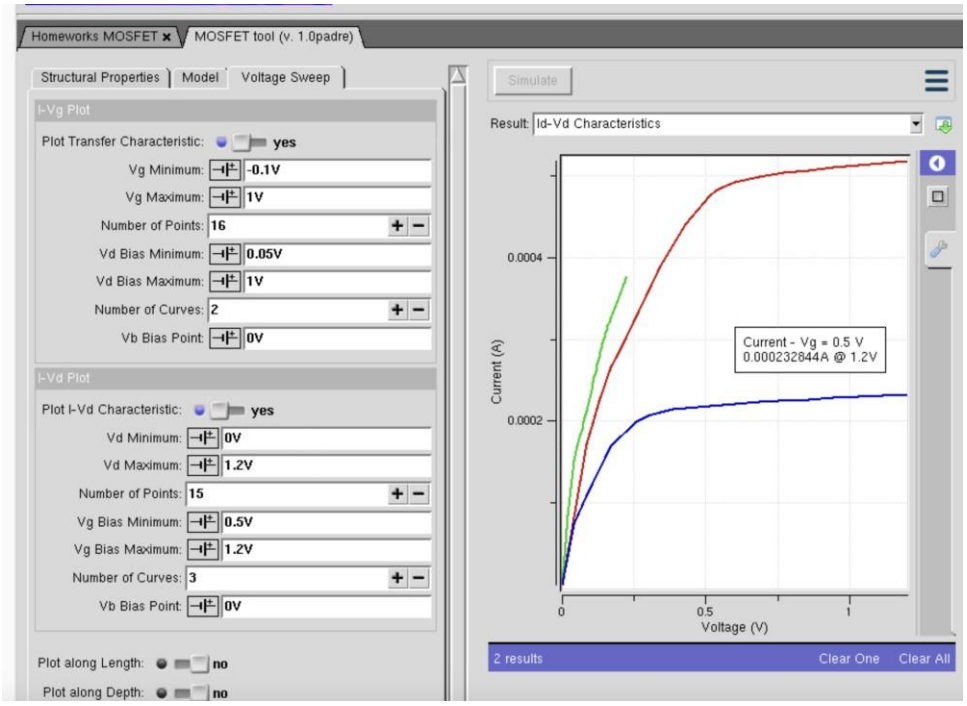
Junction depth

- 6 cases: 10nm,20nm, 40nm, 60nm,80 nm, 100 nm

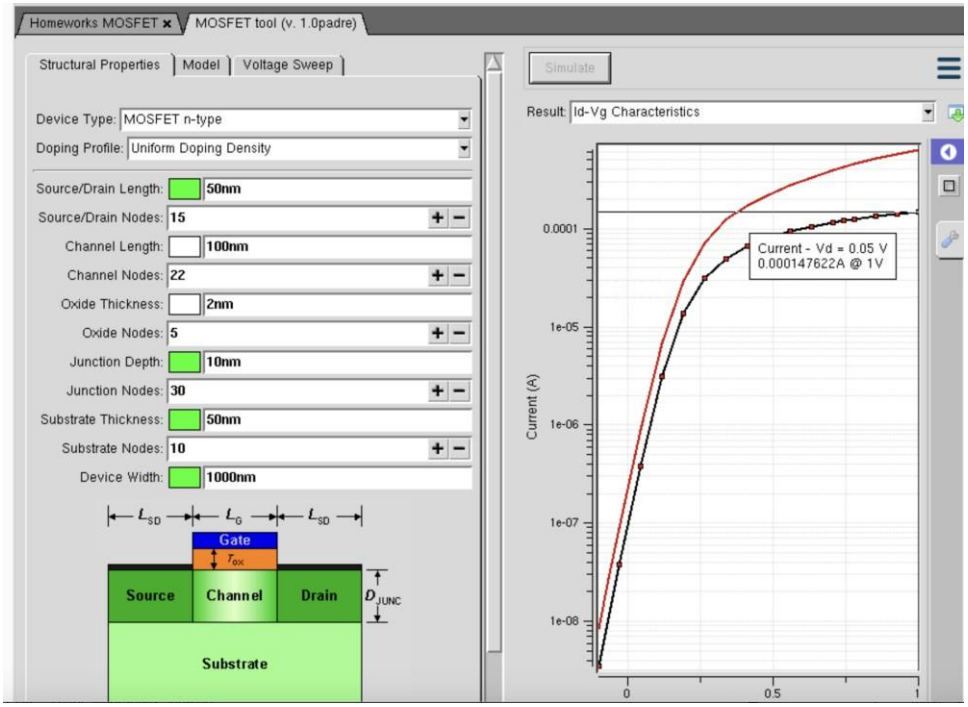
- check ID (for fixed VDS and VGS) Fixed VDS = 1.2V. VGS = 1V

Case 1: D_{jun} = 10nm

Id vs Vd Characteristics: Id= 0.232687 mA

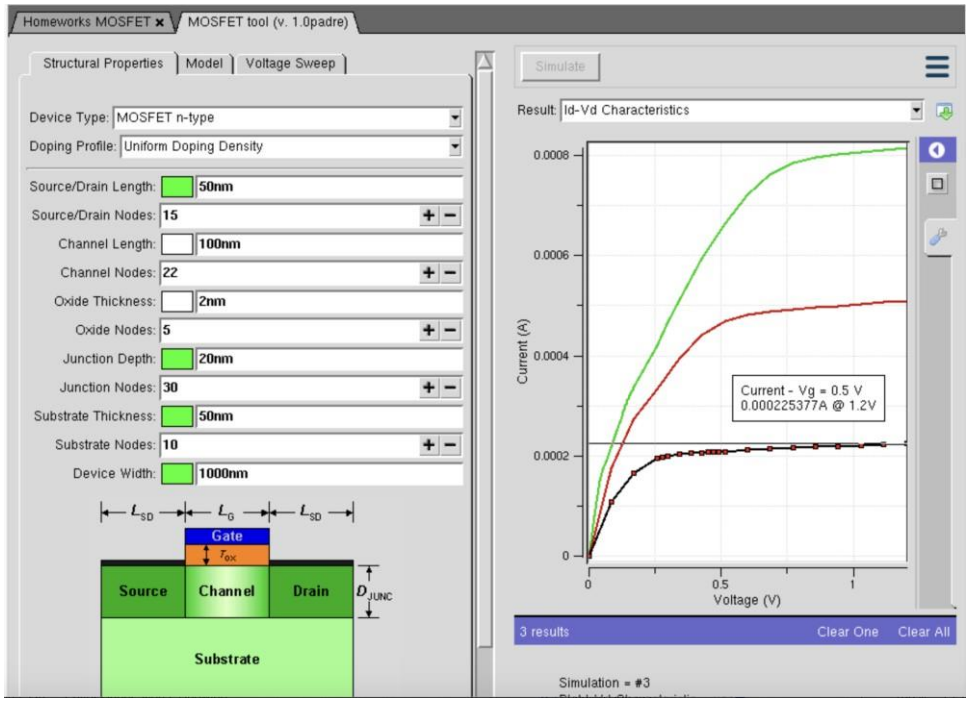


Id vs Vg Characteristics: Id= 0.147622mA

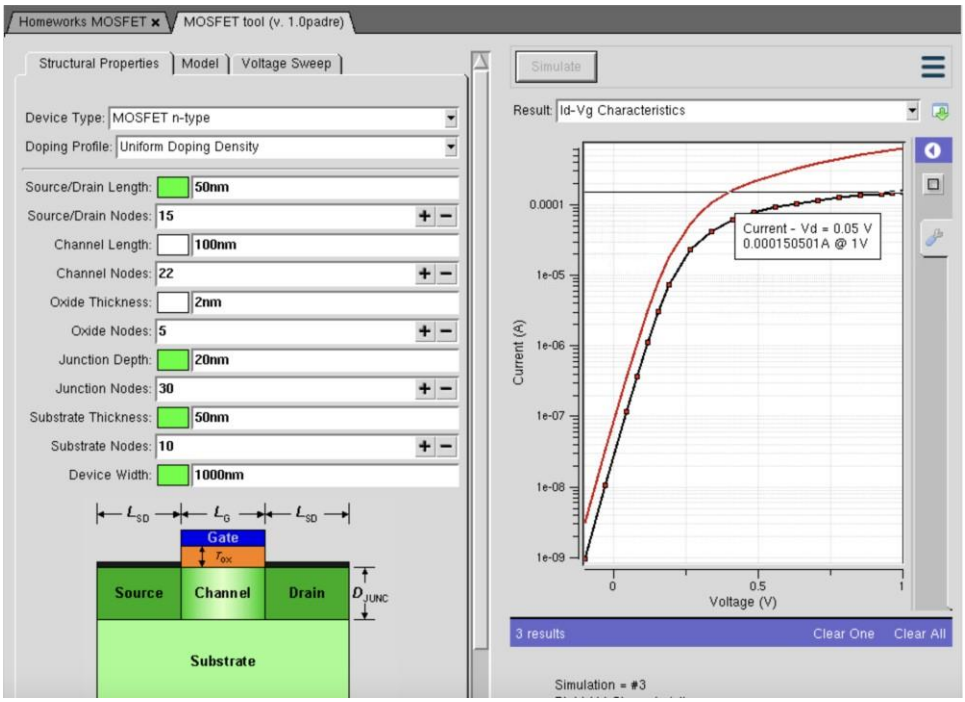


Case 2: D_{jun} = 20nm

Id vs Vd Characteristics: Id= 0.225377mA

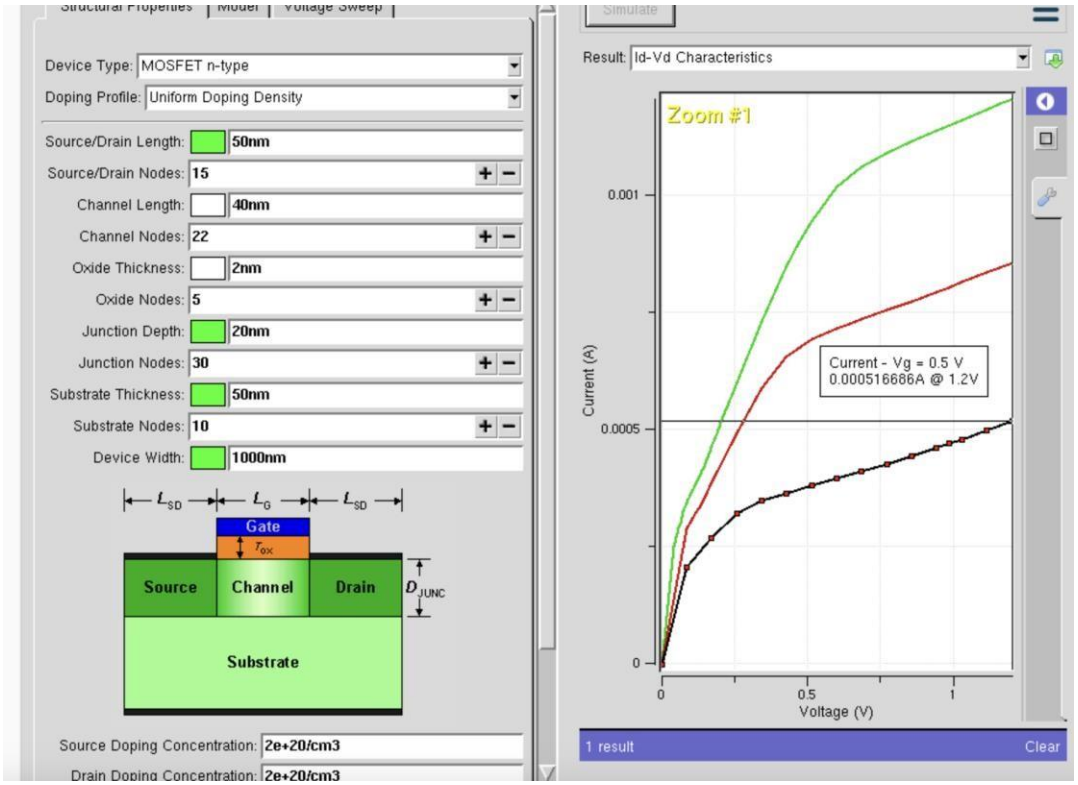


Id vs Vg Characteristics: Id= 0.150501mA

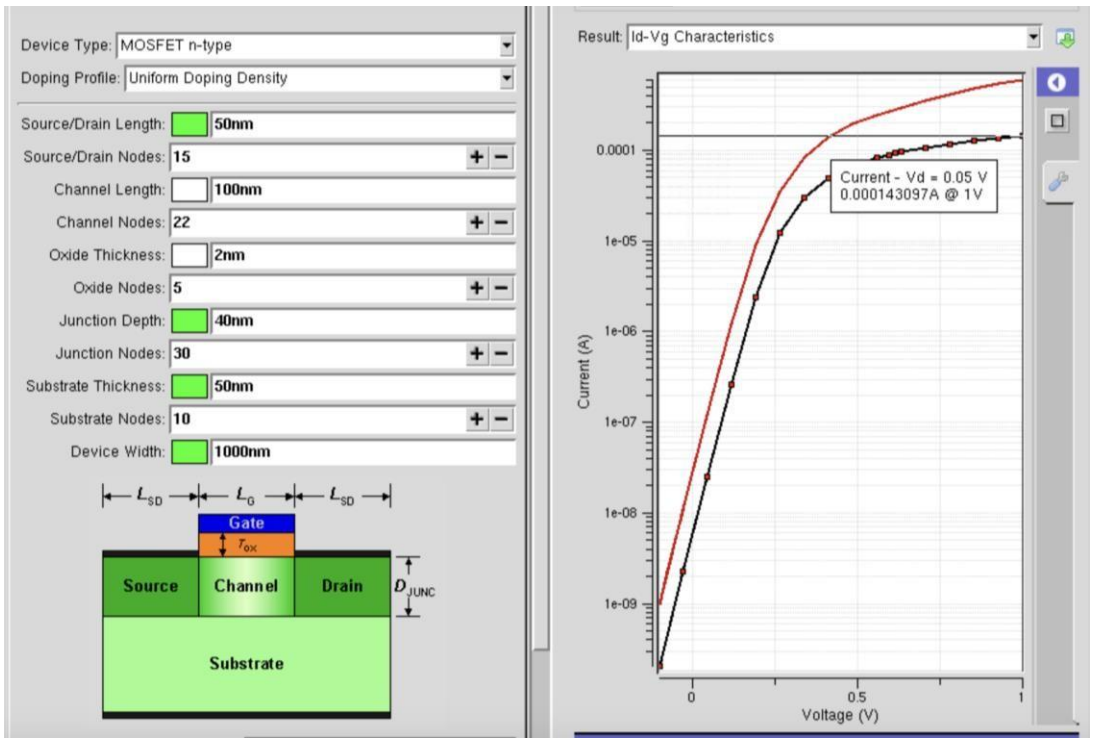


Case 3: D_{jun} = 40nm

Id vs Vd Characteristics: Id= 0.51667 mA

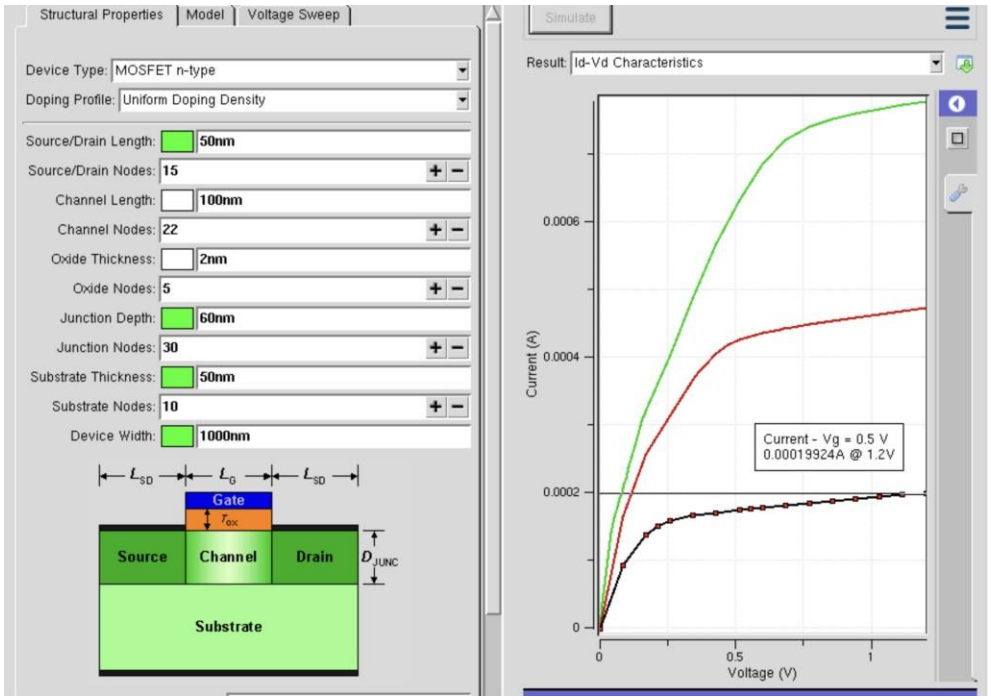


Id vs Vg Characteristics: Id= 0.143097mA

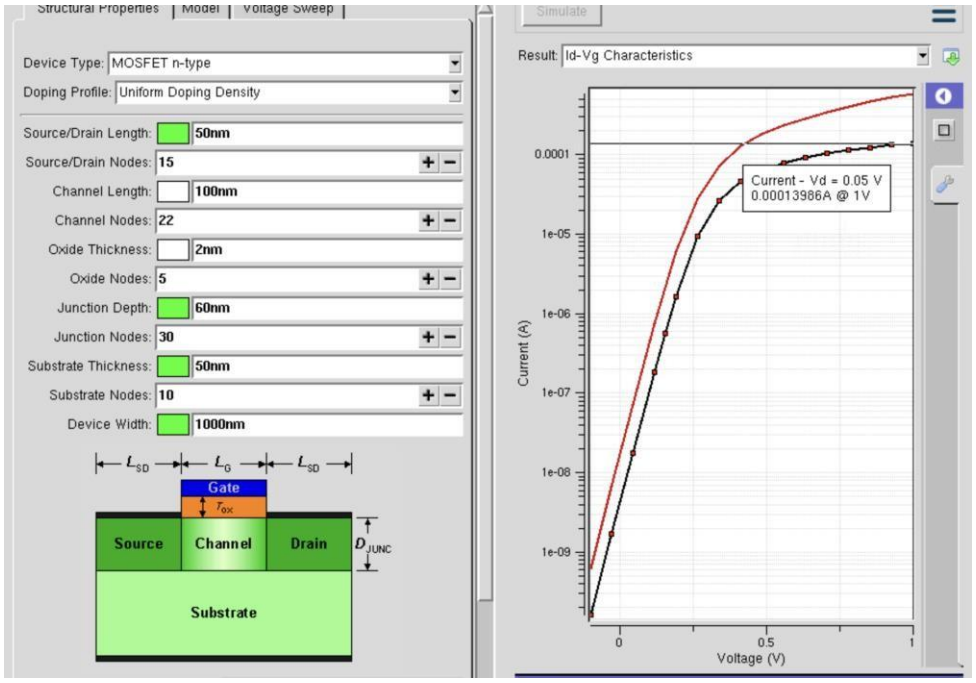


Case 4: D_{jun} = 60nm

Id vs Vd Characteristics: Id= 0.1992 mA

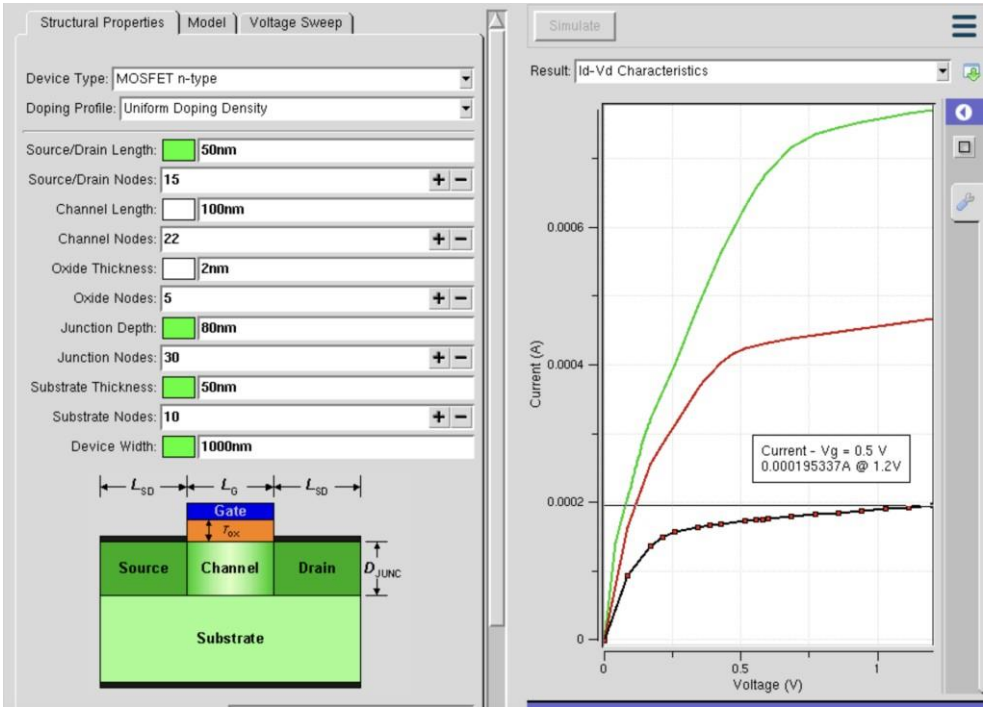


Id vs Vg Characteristics: Id= 0.13986mA

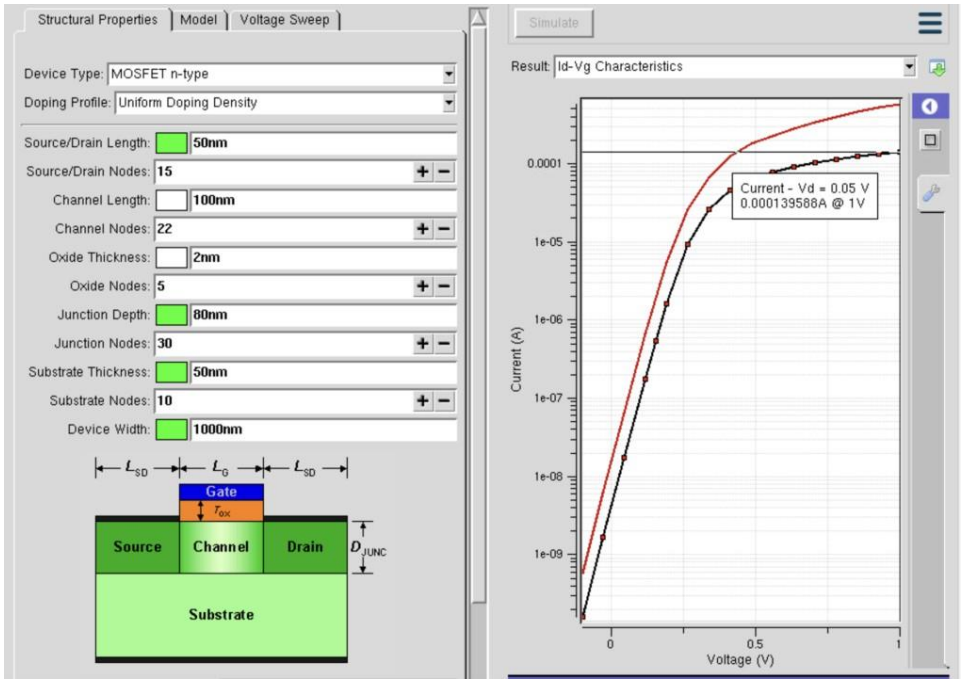


Case 5: D_{jun} = 80nm

Id vs Vd Characteristics: Id= 0.1953 mA

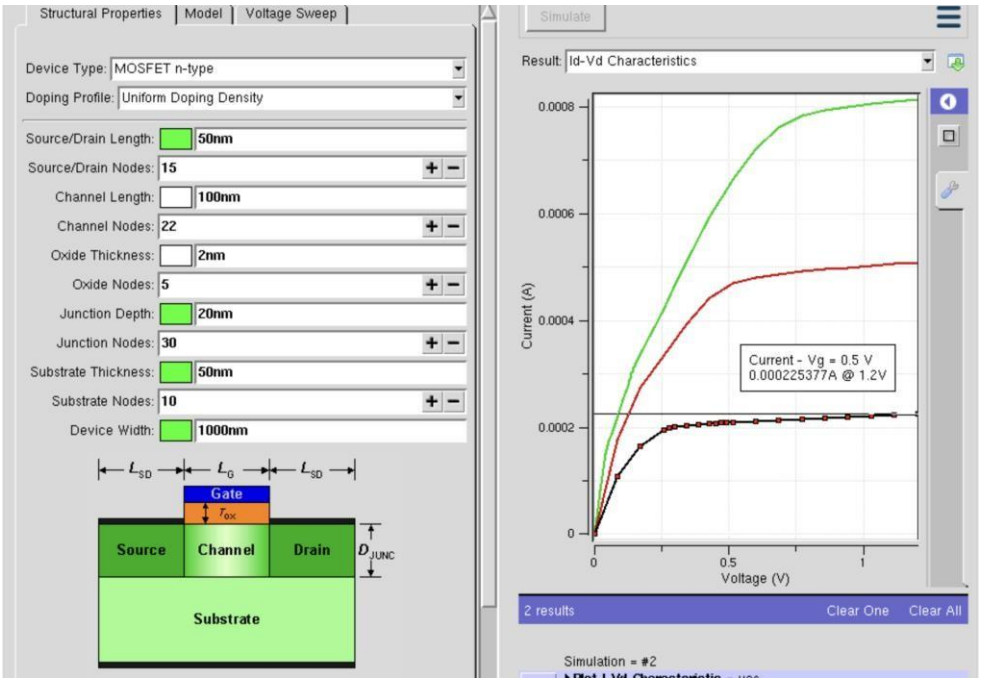


Id vs Vg Characteristics: Id= 0.139588mA

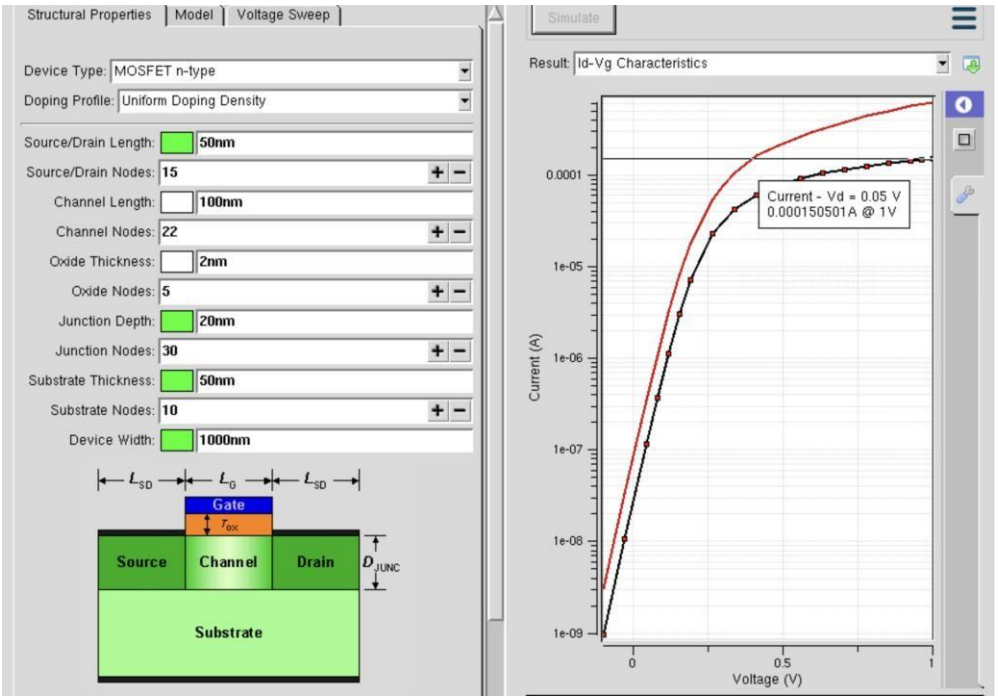


Case 6: D_{jun} = 100nm

Id vs Vd Characteristics: Id= 0.232687 mA



Id vs Vg Characteristics: Id= 0.150501mA



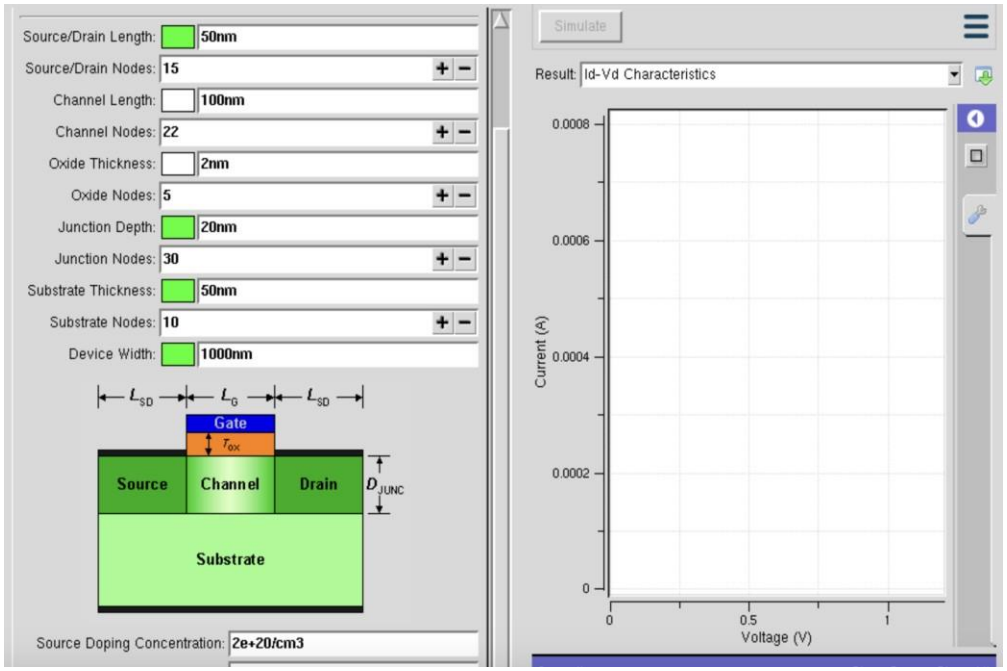
Channel concentration

- 4 cases: 1E17, 1E18, 1E19, 1E20

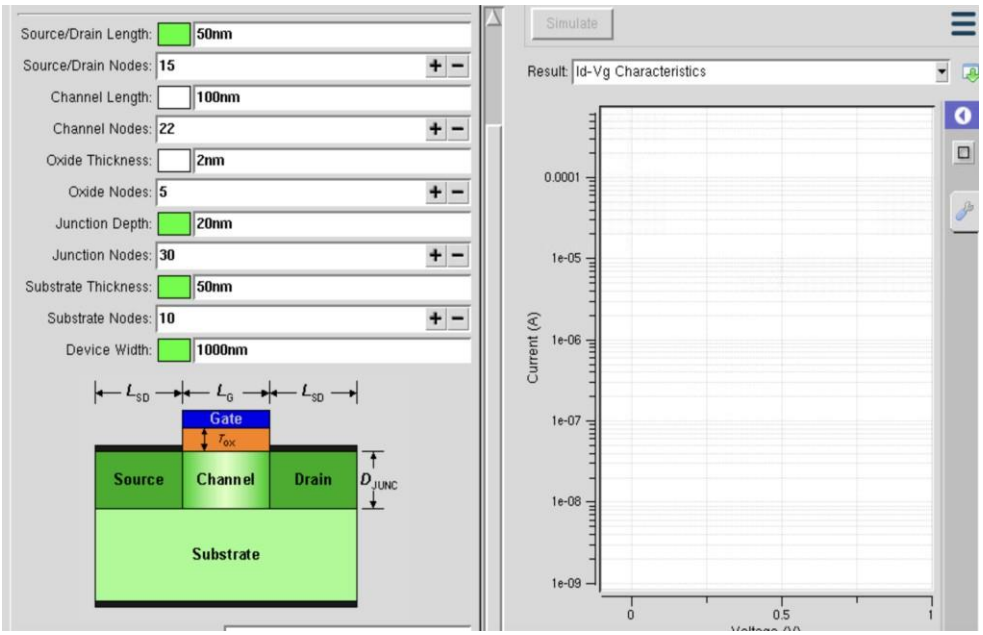
- check ID (for fixed VDS and VGS) Fixed VDS = 1.2V. VGS = 1V

Case 1: Channel concentration = 1E17

Id vs Vd Characteristics: Id=

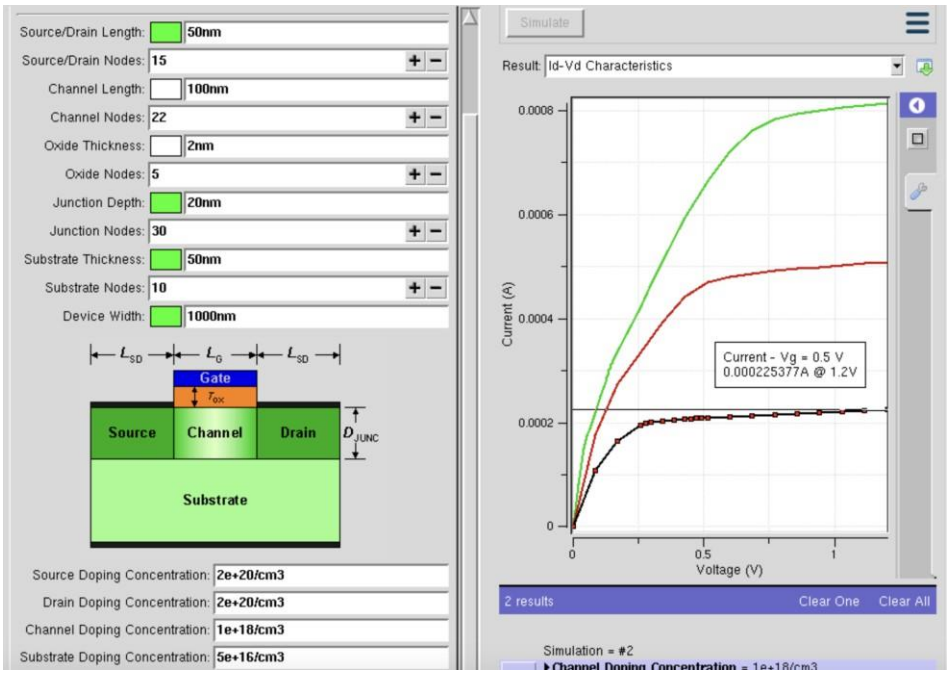


Id vs Vg Characteristics: Id=

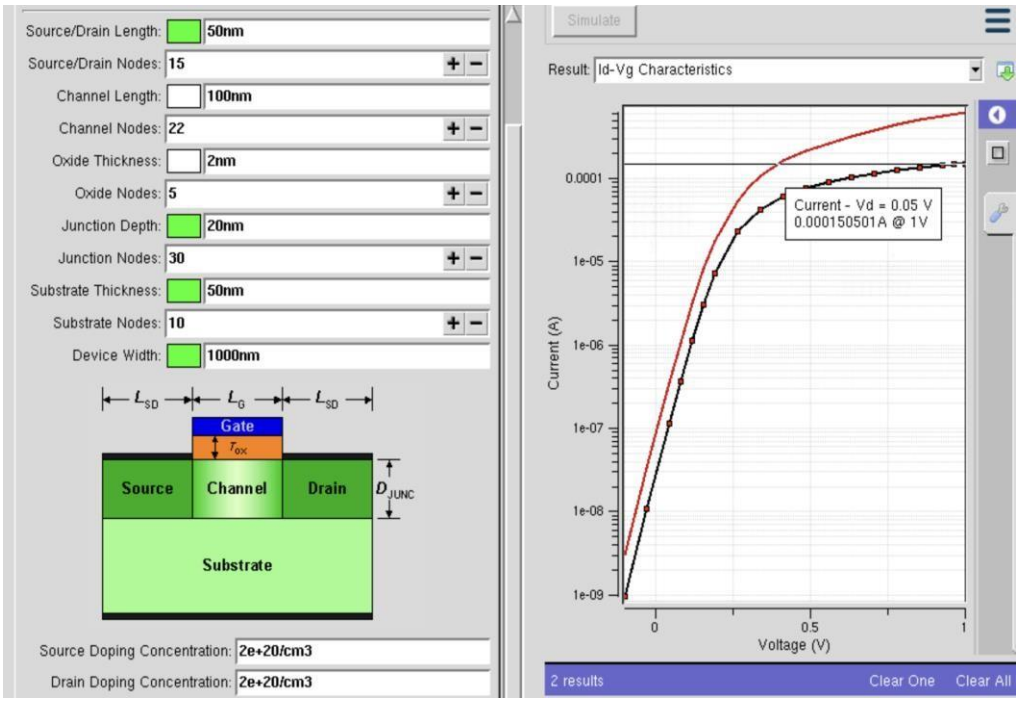


Case 2: Channel concentration = 1E18

Id vs Vd Characteristics: Id= 0.2253mA

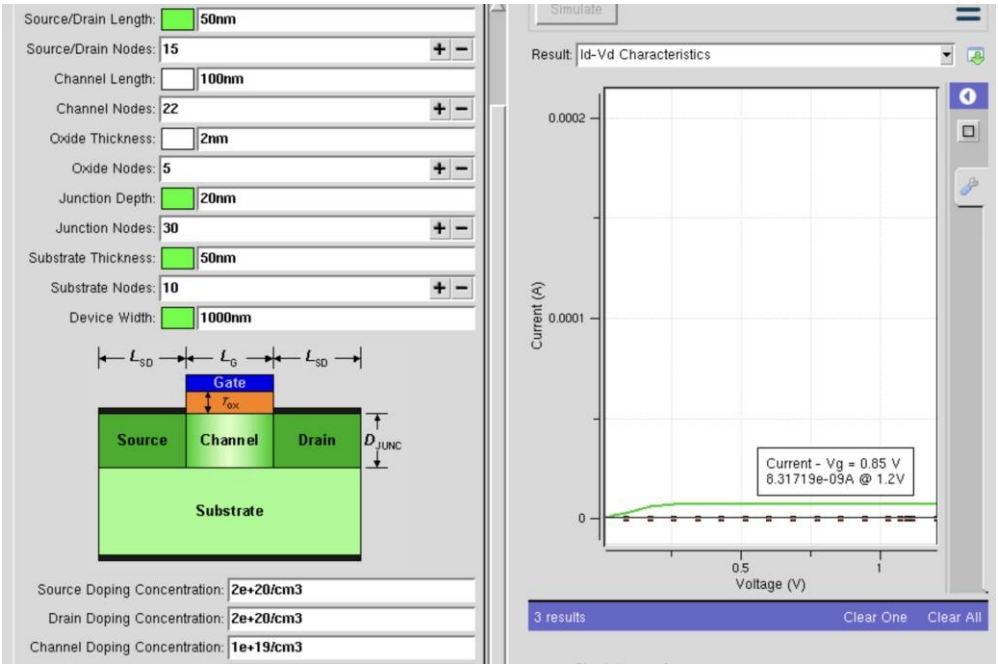


Id vs Vg Characteristics: Id= 0.150501mA

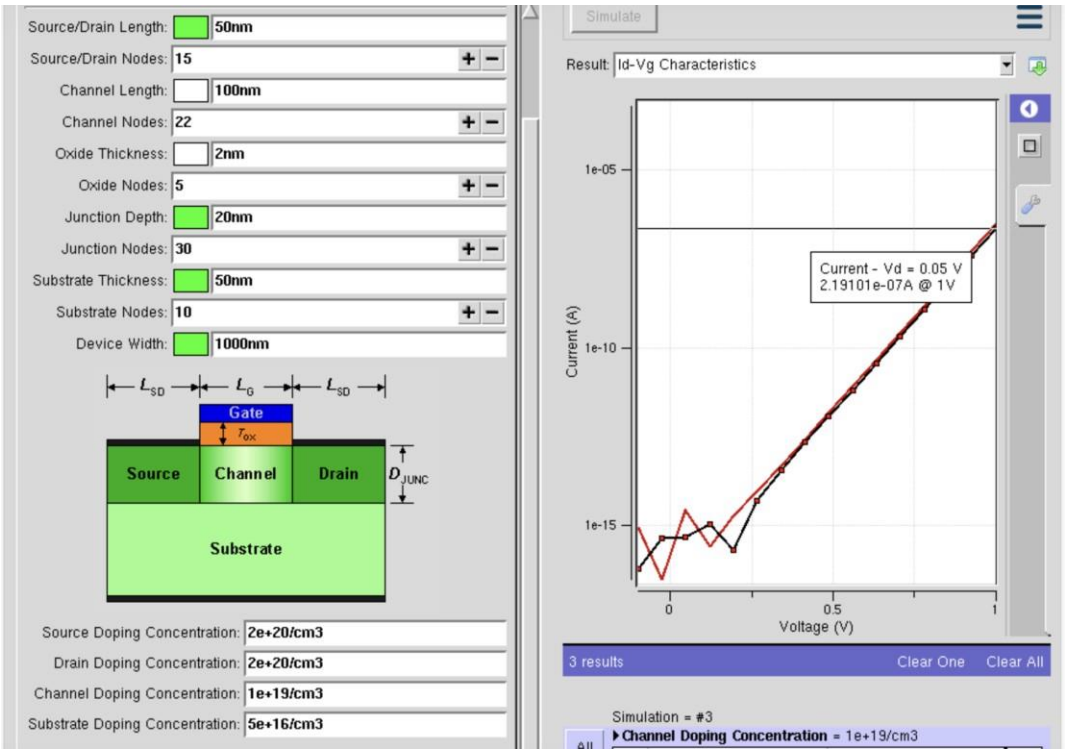


Case 3: Channel concentration = 1E19

Id vs Vd Characteristics: Id= 8.31718 nA

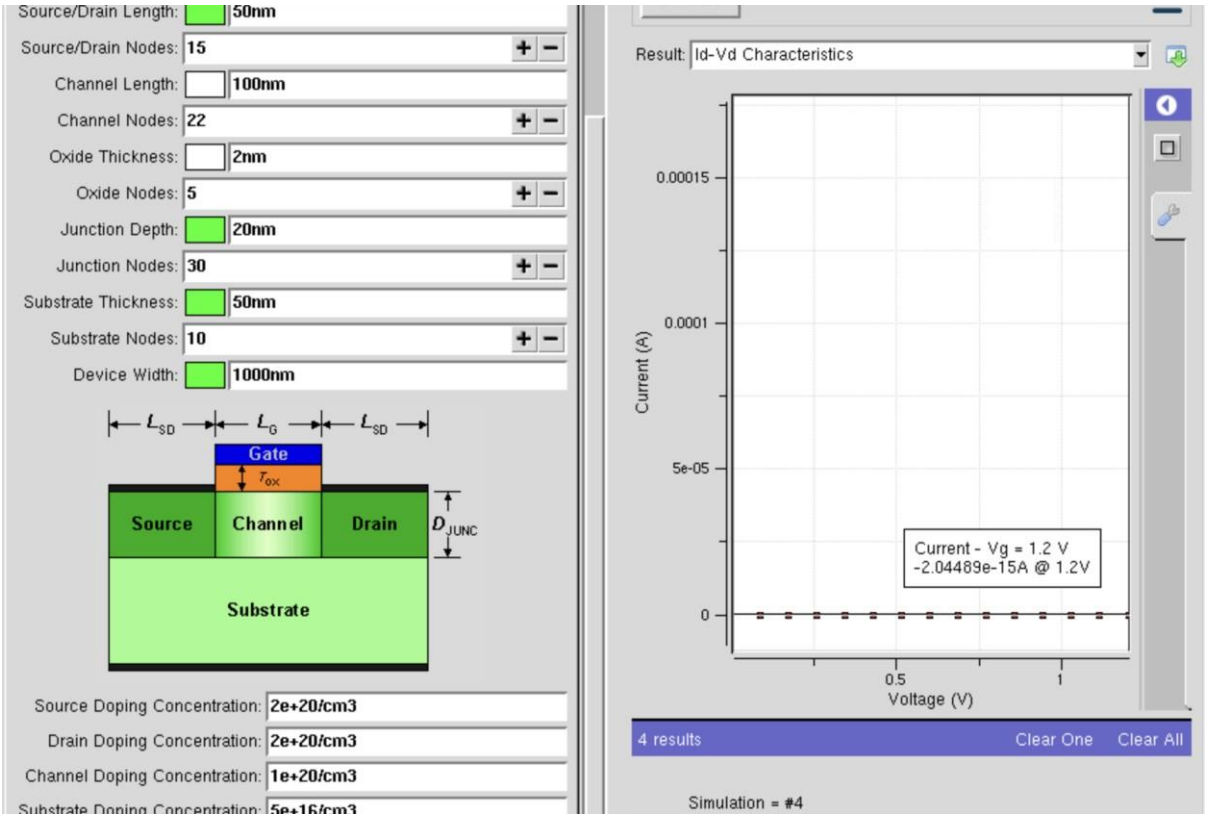


Id vs Vg Characteristics: Id= 0.219101 uA

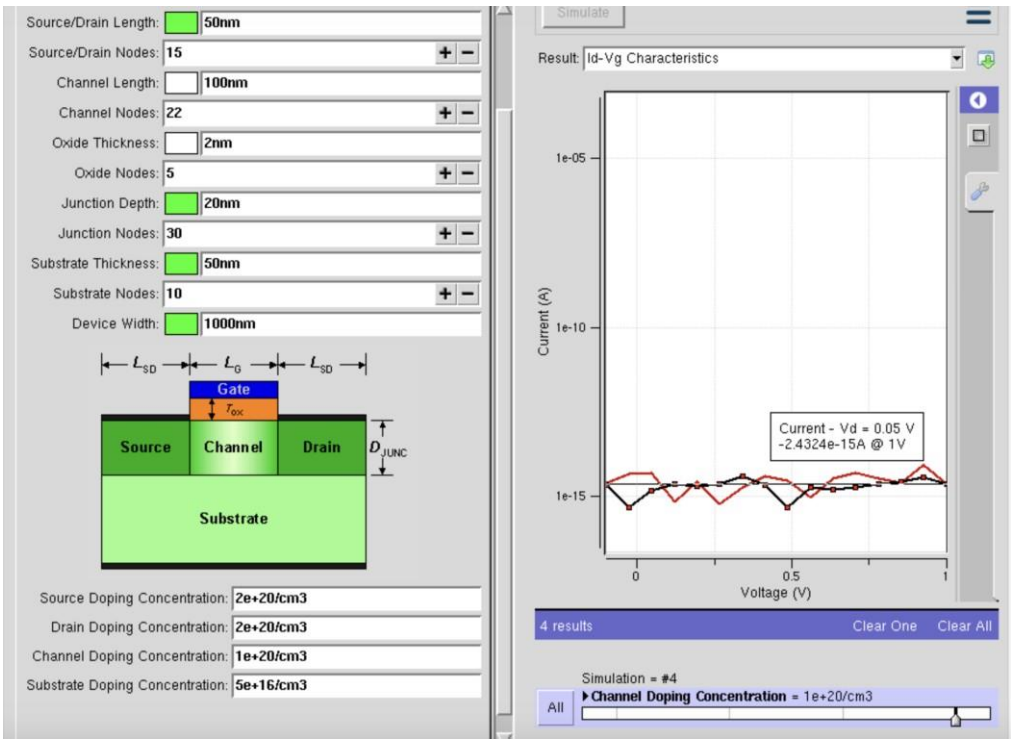


Case 4: Channel concentration = 1E20

Id vs Vd Characteristics: Id= -2.04489 pA



Id vs Vg Characteristics: Id= -2.4324 pA



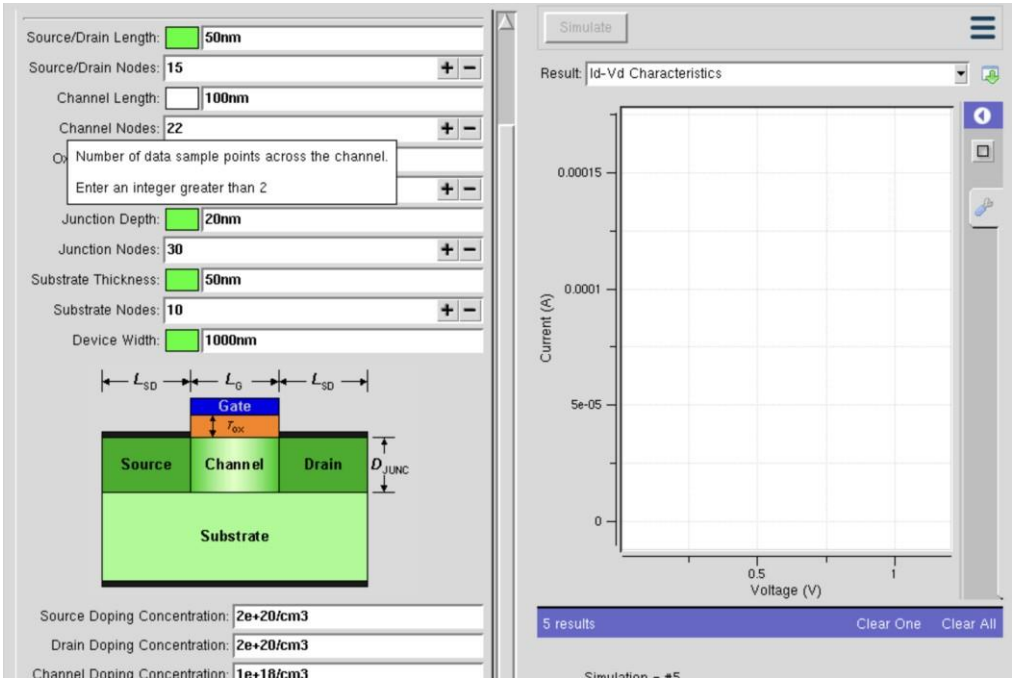
Substrate doping con:

- 4 cases: 5E15, 1E16, 5E16, 1E17,

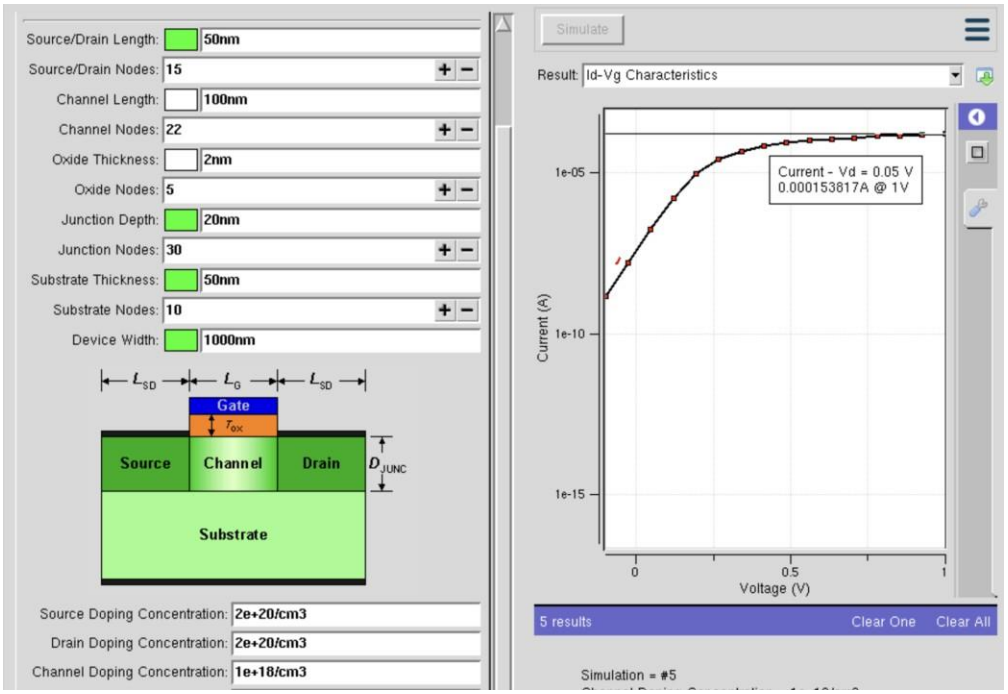
- check ID (for fixed VDS and VGS)

Case 1: Substrate Doping concentration = 5E15

Id vs Vd Characteristics: Id=

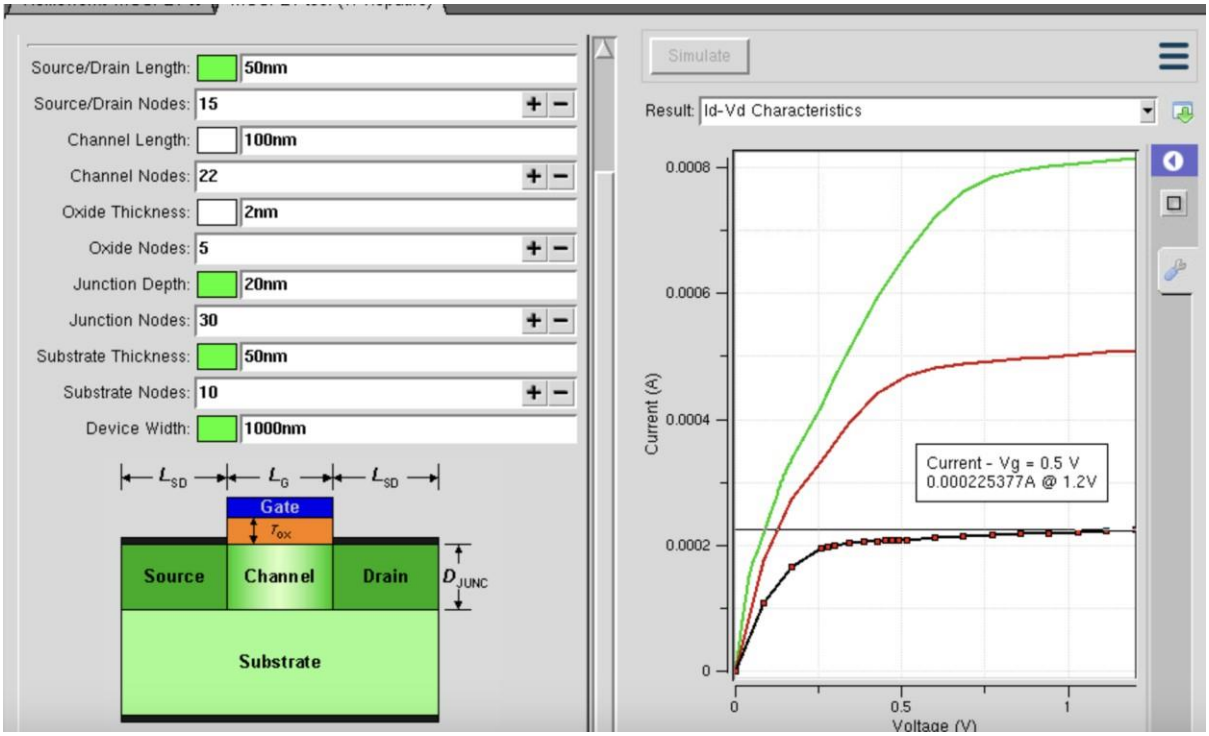


Id vs Vg Characteristics: Id= 0.153817 mA

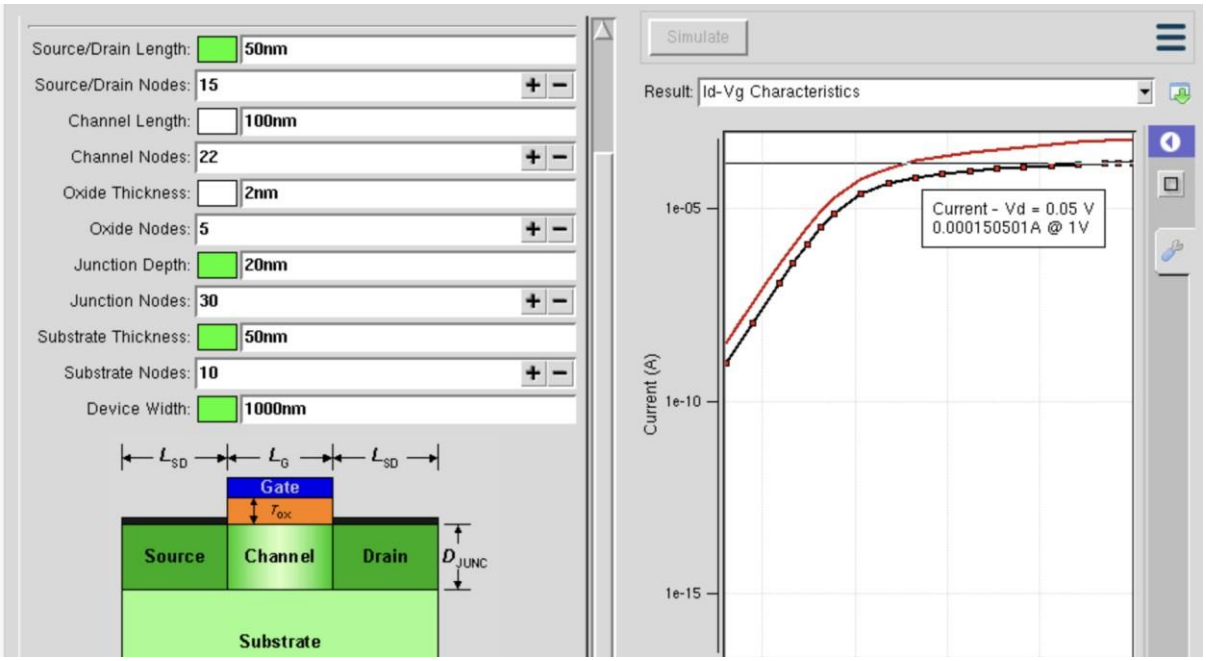


Case 2: Substrate Doping concentration = 5E16

Id vs Vd Characteristics: Id= 0.225377 mA

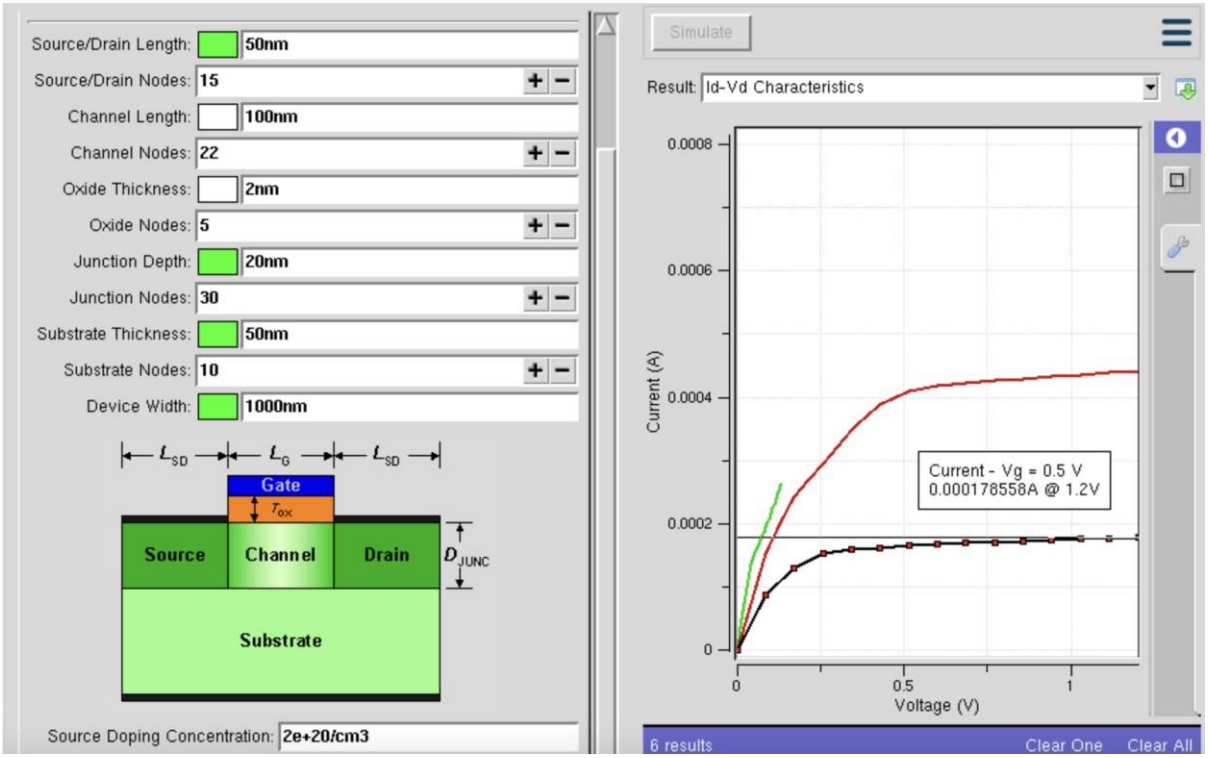


Id vs Vg Characteristics: Id= 0.150501 mA

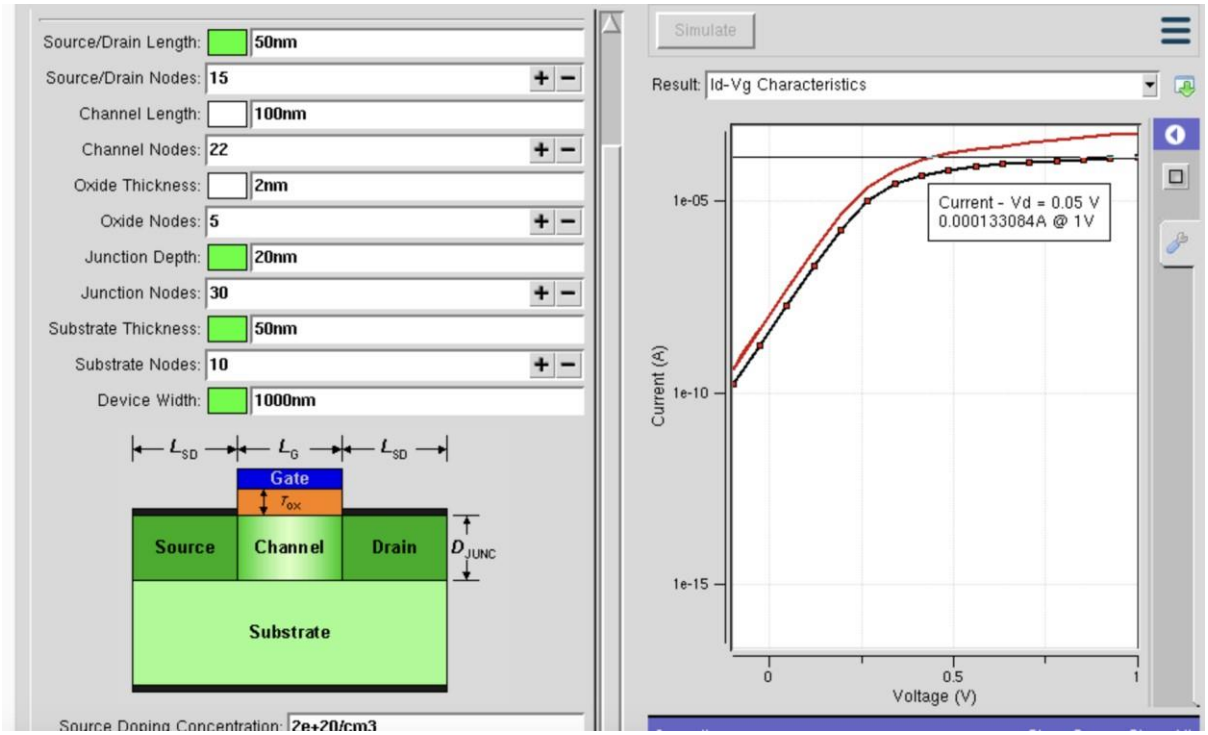


Case 3: Substrate Doping concentration = 5E17

Id vs Vd Characteristics: Id= 0.178558 mA

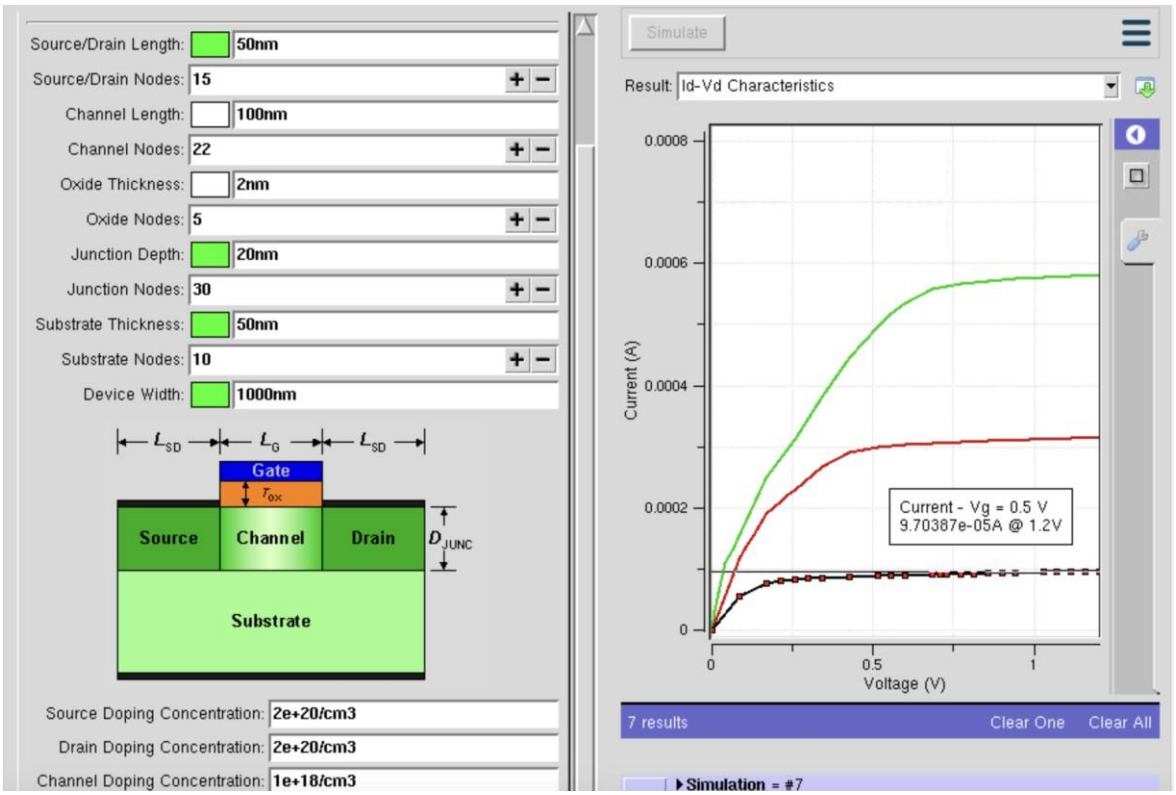


Id vs Vg Characteristics: Id= 0.133084 mA

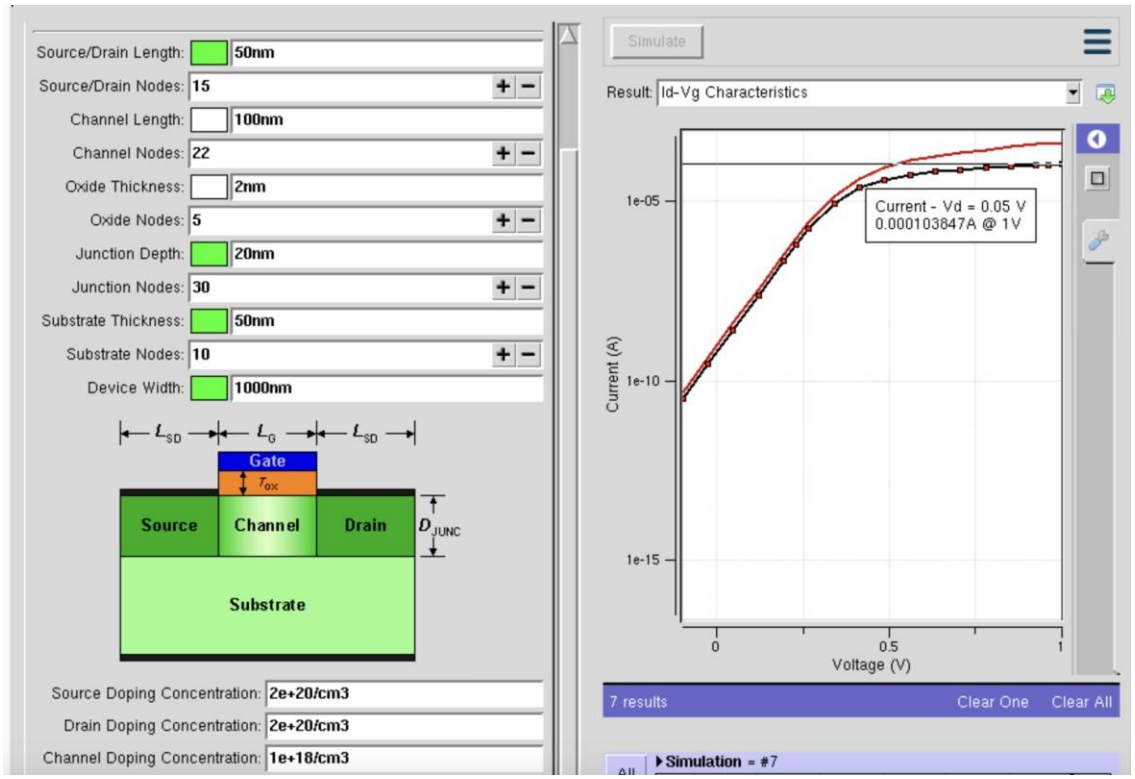


Case 4: Substrate Doping concentration = 5E18

Id vs Vd Characteristics: Id= 0.097038 mA



Id vs Vg Characteristics: Id=0.103847 mA



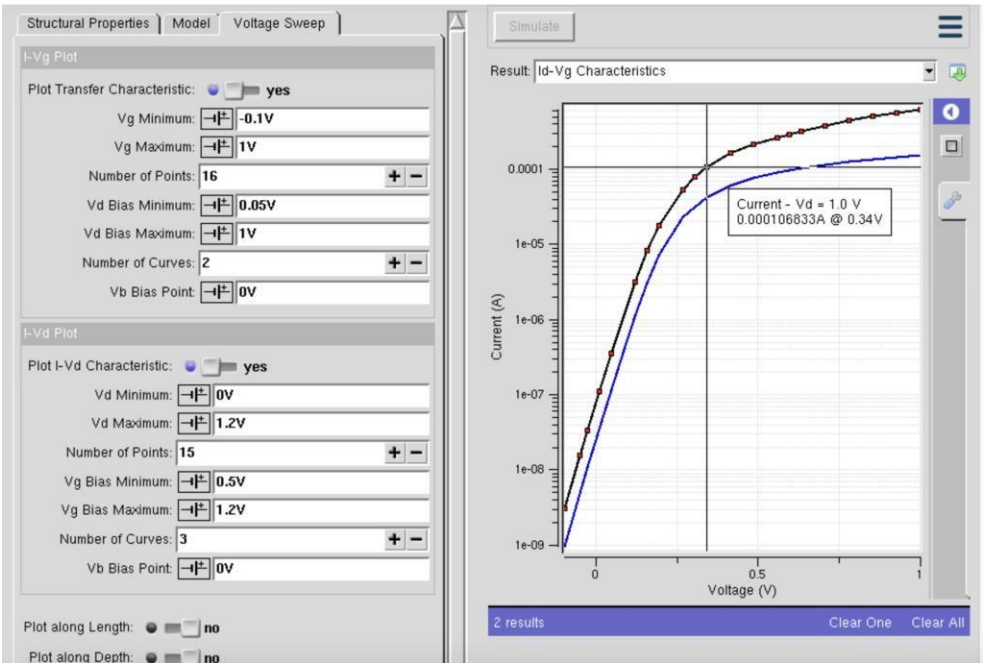
Experiment 10:

Aim: Investigation of transconductance of n-MOS using ABACUS

DoE:

- For a fixed doping concentration and device dimensions

- Observe: IDS Vs VGS plot

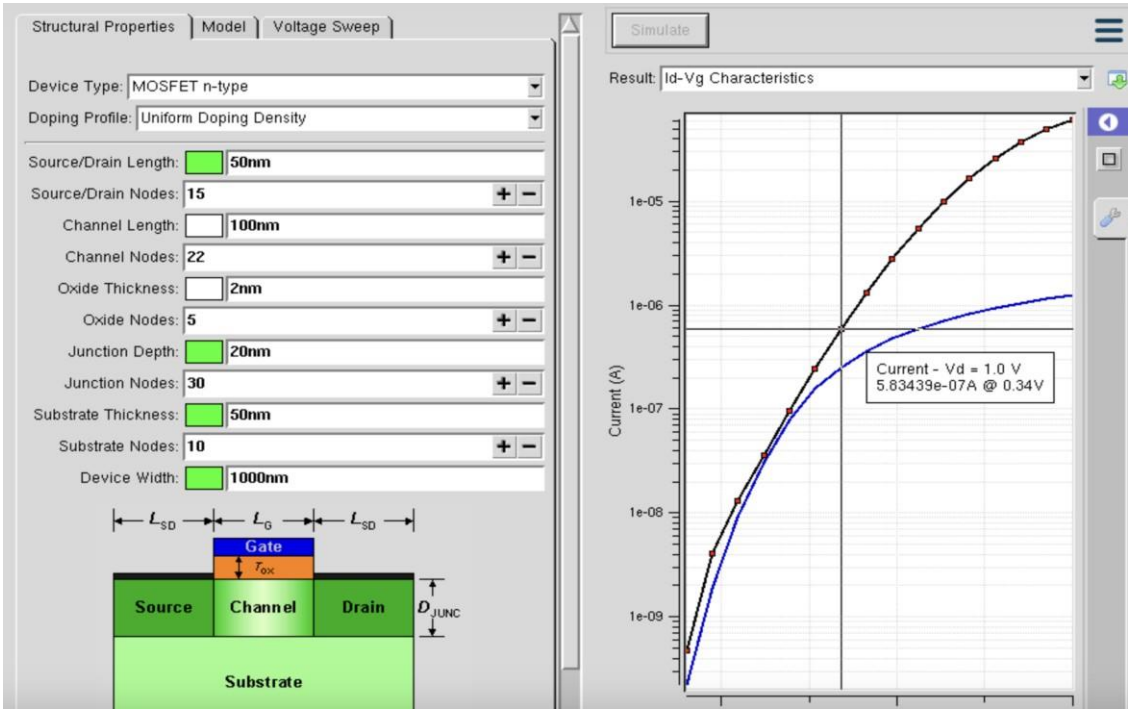


Calculate transconductance. Gm= 0.0003141

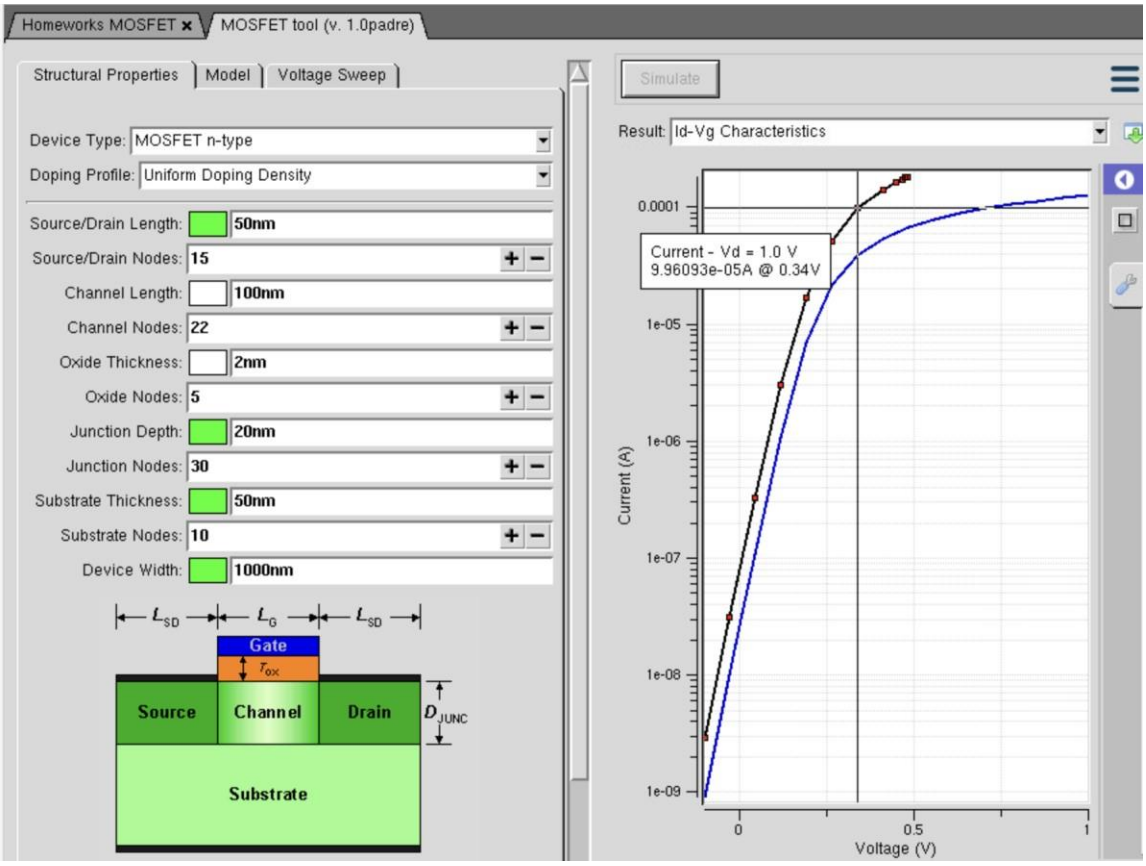
Exercise:

1. Choose 2 values of doping concentration

Case-I Ns=Nd= 1*10^18 --- gm= 1.71599 x 10^{-6}

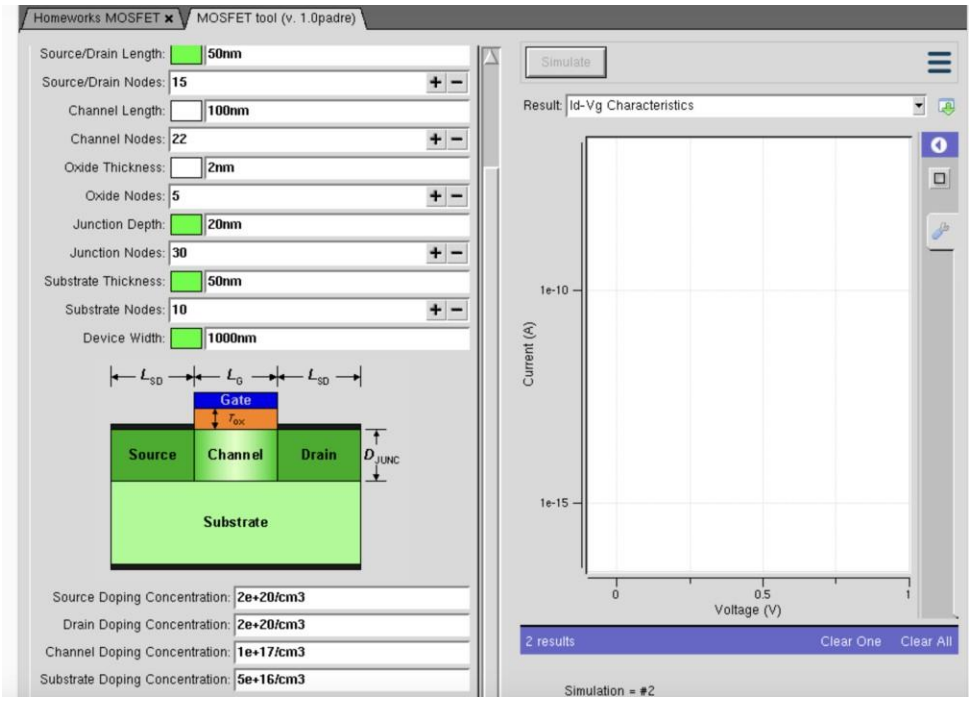


Ns=Nd= 1*10^20 --- gm= 2.929 x 10^{-4}

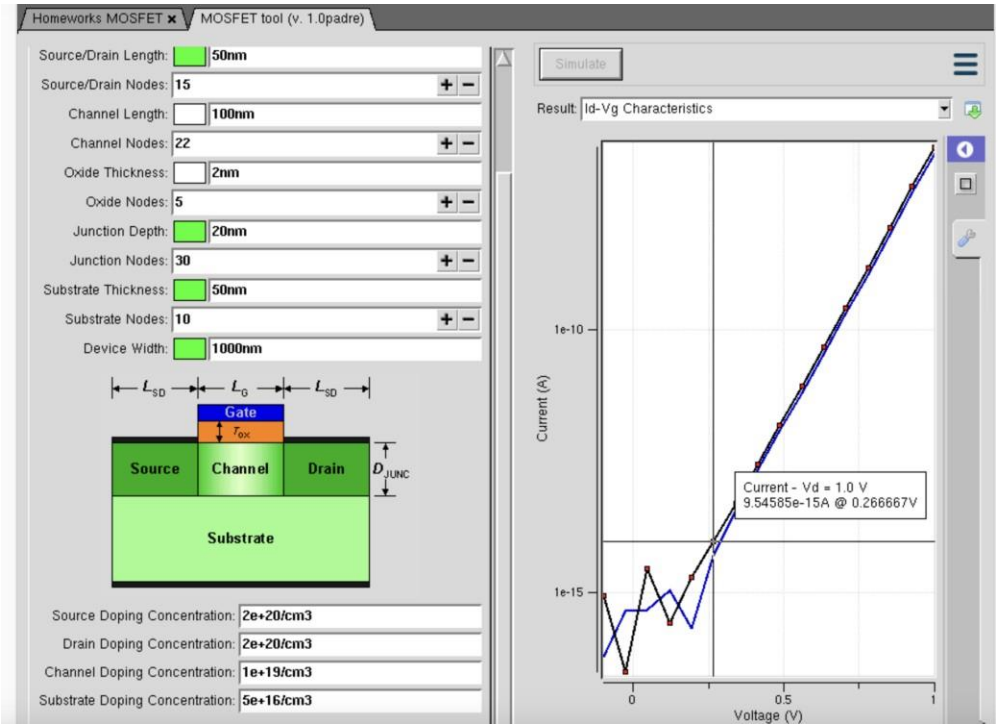


Case-II

Nchannel= 10^{17} --- gm=

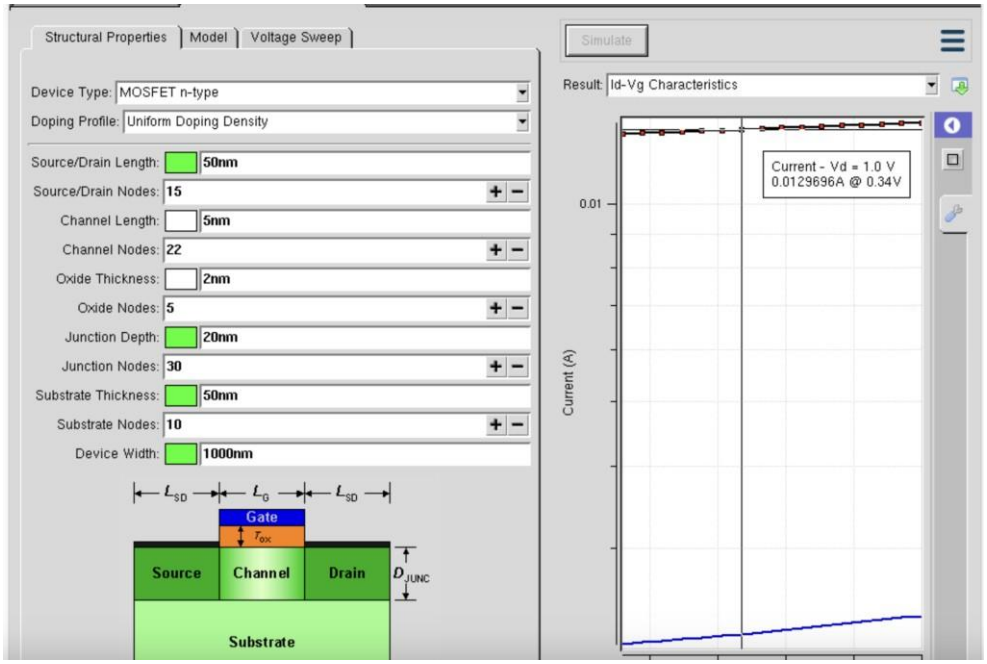


Nchannel= $10^{\wedge 19}$ --- gm= 3.5796 x 10^{-14}



2. Choose 2 values of W and L dimensions

Case-I W= 100nm, L= 5nm--- gm= 0.038145



W= 1000nm, L= 5nm --- gm= 0.031454