

NAME: SATYAM PANDEY

ROLL NO: BTECH/10452/20

BRANCH: ELECTRONICS AND COMMUNICATION (B)

SUBJECT: ELECTRONIC DEVICES LAB EC-202

## EXPERIMENT #1

**Aim of the Experiment:** To construct a silicon (Si) pn junction diode and evaluate I-V characteristics of it using T-CAD tool.

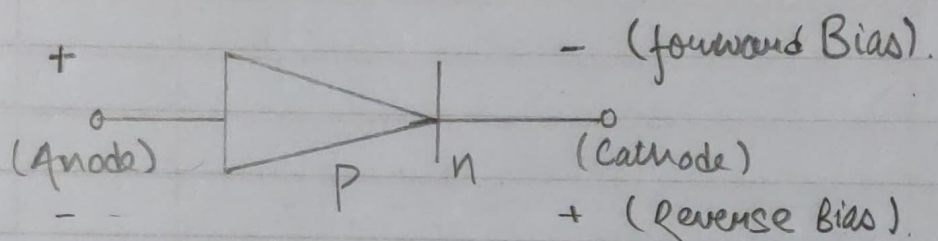
### Objective:

- (i) Construct a silicon pn junction diode having n-type and p-type doping concentration of  $1 \times 10^{18}/\text{cc}$ .
- (ii) finding the I-V characteristics of the diode by varying voltage across diode from -1V to 1V.

**Software used:** Logendra Visual TCAD tool.

**Theory:** Diode is a 2-terminal device also known as p-n junction diode and depending on its doping level can work in both forward bias and reverse bias mode. When the positive voltage terminal is connected to p type junction, the diode is forward biased. In forward biased mode, after a certain voltage known as knee voltage, current flows infinitely i.e. the diode provides zero resistance. This knee voltage is 0.3V for Germanium and 0.7V for Silicon. When the negative voltage terminal is connected to p type junction, it is reverse biased. In reverse bias mode, diode ideally provides infinite resistance and hence no

Teacher's Signature.....



pn junction diode symbol.

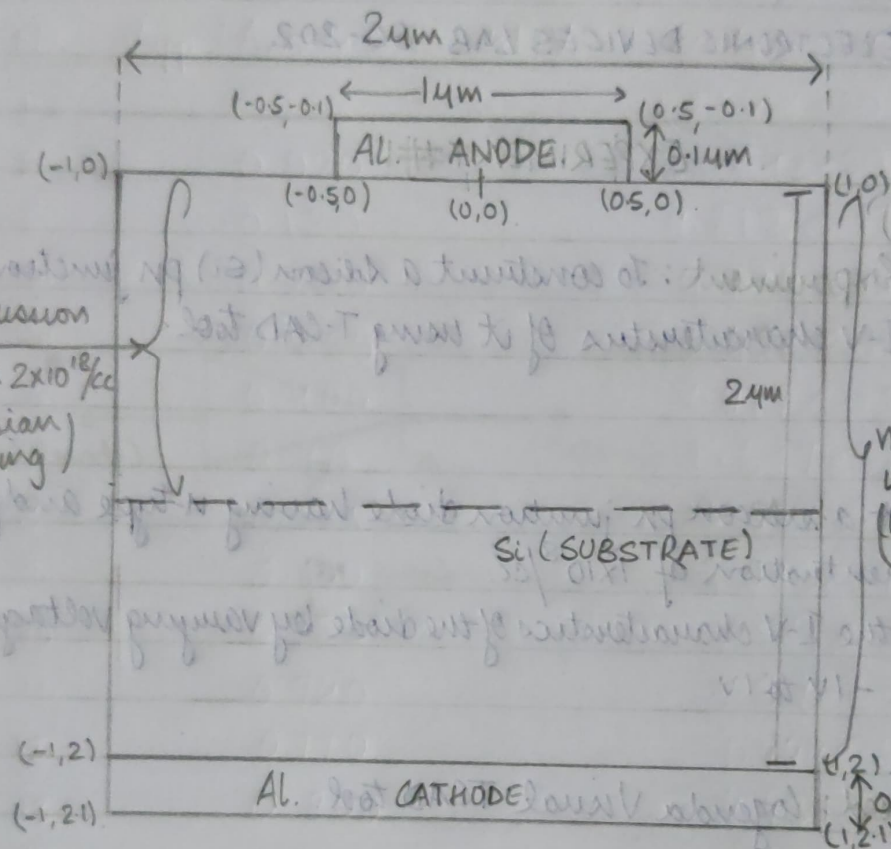


current flows through it. The various places where the diode finds its usage is rectifier circuit to convert AC to DC, it can be used as a switch, voltage regulator.

### Procedure:

- ① We will open the Visual TCAD tool by opening the terminal and goto the new file and choose device drawing option. A window with black background will open up. with default grid spacing width of  $0.01 \mu\text{m}$ .
- ② We have to prepare a diode of ( $L=2 \mu\text{m}$  &  $H=2 \mu\text{m}$ ) with anode of ( $L=1 \mu\text{m}$  &  $H=0.1 \mu\text{m}$ ) and cathode of ( $L=2 \mu\text{m}$  &  $H=0.1 \mu\text{m}$ ).
- ③ With the help of shapes given on left top we will use rectangular shape to design the device.
- ④ Add the region label substrate ( $2 \mu\text{m} \times 2 \mu\text{m}$ ) from the silicon material with the mesh size as  $1/10^{\text{th}}$  of the block size & add anode & cathode with Aluminium.
- ⑤ Now ~~adding~~ using Add Doping profile, we will make doping of the substrate. We dope the whole substrate with n-type/donor with the concentration of  $1 \times 10^{18} / \text{cc}$ . This doping is uniform doping. Then we do p-type doping in the upper half of the substrate. P-type/acceptor with the concentration of  $2 \times 10^{16} / \text{cc}$ . And this type of doping is gaussian doping.
- ⑥ Now with the option Do mesh we can mesh the device and refine the mesh with the option Refine existing mesh and make the area of junction denser after refining 2 to 3 times.





### DEVICE STRUCTURE of pn junction diode

Substrate doping: n type (donor): uniform doping:  $1 \times 10^{16}/cc$

n-diffusion: n type (donor): uniform doping:  $1 \times 10^{18}/cc$

p-diffusion: p type (acceptor): Gaussian doping:  $2 \times 10^{18}/cc$

⑦ After the meshing being done, we will save this file to .tif file using derive option in menu bar and save mesh to file option to be selected.

⑧ Now we go to derive simulation, from the folder below setup with the location open the .tif file and it would take a little while to load.

⑨ We will apply biasing as contact name "Anode", source type "Voltage Sweep" start Voltage = -1V to stop Voltage = 1V in step of 0.05.

⑩ Now we simulate with the help of run button, we firstly save it and then create a folder and choose this folder for simulation. Our simulation result ".dat" from the folder we have selected to simulate it.

⑪ We plot the graph between  $I_{anode}$  &  $V_{app(anode)}$ .

Result: The graph of  $I_{anode}$  Vs  $V_{app(anode)}$  is drawn and it can be seen that knee voltage of the diode is approximately 0.7V.



Observation Table: at JA tunnel at tunneling region is present

S. NO.	$V_{app}$ (Anode to Si Subst.) V.	$I$ (Anode to Si Subst.) A.
1.	0.005	$1.214e-20$
2.	0.020	$2.684e-20$
3.	0.120	$4.812e-17$
4.	0.200	$4.794e-16$
5.	0.330	$6.458e-14$
6.	0.400	$9.417e-13$
7.	0.475	$1.697e-11$
8.	0.555	$3.677e-10$
9.	0.600	$2.085e-9$
10.	0.725	$2.581e-7$
11.	0.740	$4.398e-7$
12.	0.770	$1.444e-6$
13.	0.800	$4.431e-6$
14.	0.815	$7.607e-6$
15.	0.820	$9.607e-6$
16.	0.835	$1.507e-5$
17.	0.855	$2.818e-5$
18.	0.900	$8.906e-5$
19.	0.915	$0.00013$
20.	0.935	$0.00017$



Current

KNEE VOLTAGE



0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Voltage

Activities

VisualTCAD.LINUX

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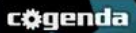

Visual TCAD

File Edit View Drawing Device Window Help

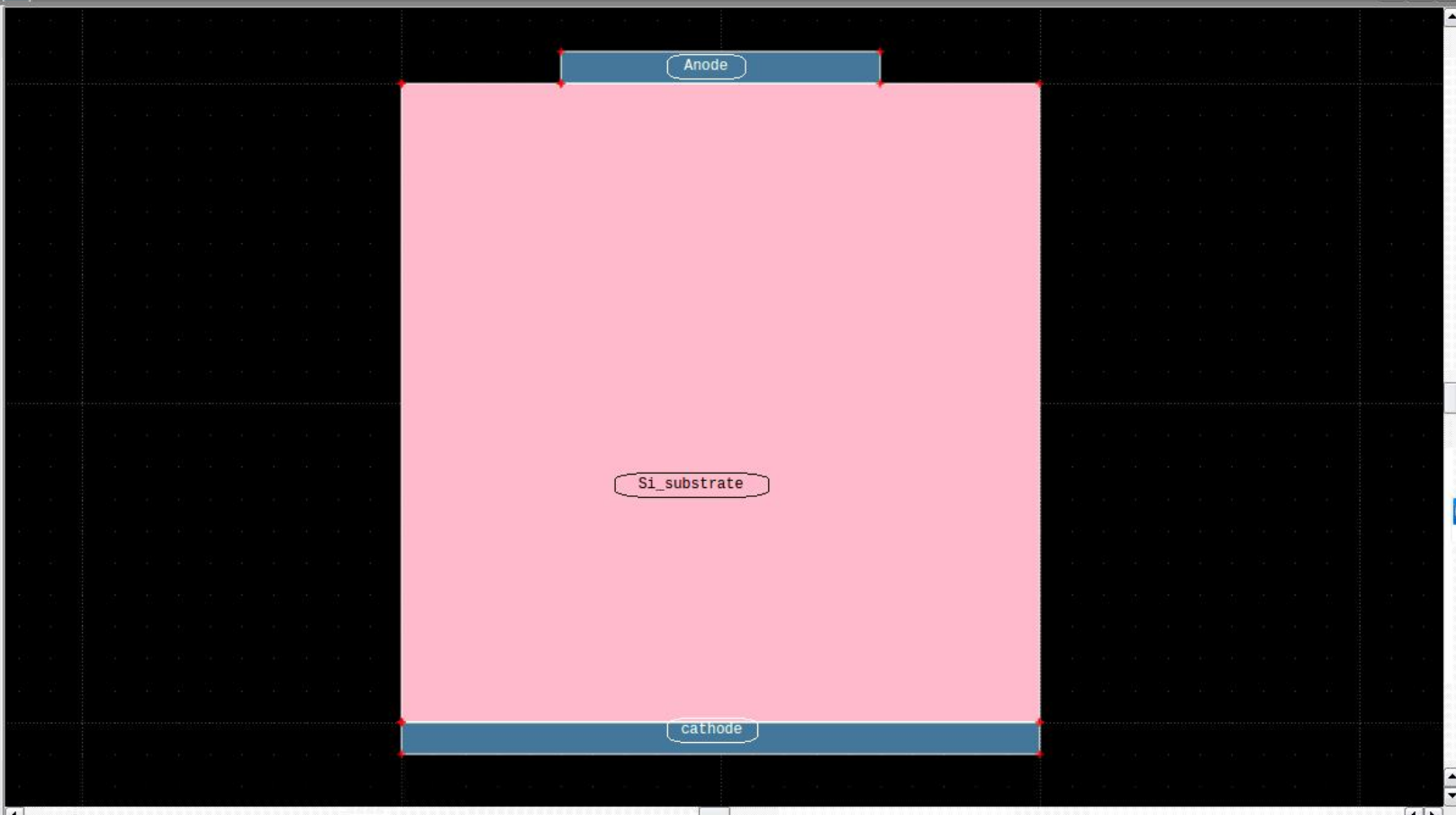
1 Untitled 2 Untitled 3 diode group10.drw

Explorer Start Device Drawing

Start

  
  
Recently used files:  
[/home...de/Diode\\_data/result.dat](#)

Device 2D: diode group10.drw\*



Plot: Untitled\* Device 2D: Un

Input Coord. : ( 0.0 , 0.0 ) enter Mouse: (1.5676,-0.3432) um Snap: (1.6000,-0.3000) um



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Activities VisualTCAD.LINUX

File Edit View Drawing Device Window Help

1 Diode.drw 2 diode.sim 3 Untitled 4 result.dat 5 Untitled

Explorer Start Device Drawing

Device Drawing

Layer List

Object List

- Name
- Drawing items
  - PolylineItem (#157)
  - PolylineItem (#161)
  - PolylineItem (#164)
- Region items
  - Region item (#191)
  - Region item (#192)
  - Region item (#193)
- Label items
  - Region label item 'Anode' (#170)
  - Region label item 'Cathode' (#174)
  - Region label item 'Si\_substrate' (#178)
- Profile items
  - Doping profile item 'N\_type\_Substrate'...
  - Doping profile item 'N\_type' (#186)
  - Doping profile item 'P\_type' (#190)
- Mesh-control items
- Annotation items

Si\_substrate

Input Coord.: ( 0.5 , 0 ) enter Mouse: (0.9107,2.0423) um Snap: (0.9107,2.0423) um

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File Edit Simulation Window Help

1 Diode.drw 2 diode.sim 3 Untitled 4 result.dat 5 Untitled

Explorer Start Simulation Control

Simulation Control

Setup

Simulation Mode: Steady-state

Switches: Resistive Metal

Device Structure Item

- Regions
- Boundaries

Results

Electrodes

Contact Name: AnodeSource Type: Voltage SweepStart Voltage: -1 VStop Voltage: 1 VStep Voltage: 0.05 V

Contact Name: CathodeSource Type: Const VoltageVoltage: 0 V

Structure Viewer

Region

- Cathode
- Si\_substrate
- Anode

Progress: Overall 100% Step 100%

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ActivitiesVisualTCAD.LINUX

FileEditSpreadsheetWindowHelp

1 Diode.drw2 diode.sim3 result.dat4 Untitled

ExplorerStartSpreadsheet Tools

Column Name	Properties
1 Anode[Anode_to_...	...
2 de[Anode_to_Si...	...
3 le[Anode_to_Si...	...
4 Anode[Anode_to_...	...
5 de[Anode_to_Si...	...
6 de[Anode_to_Si...	...
7 Cathode[Cathode...	...
8 node[Cathode_to_...	...
9 de[Cathode_to_...	...
10 Cathode[Cathode...	...
11 node[Cathode_to...	...
12 node[Cathode_to...	...
13 [W]	...

	lnode_to_Si_si	node_to_Si_sub	ode_to_Si_sub	Anode_to_Si_si	node_to_Si_sub	node_to_Si_sub	Cathode_to_Si	athode_to_Si_si	thode_to_Si_si	Cathode_to_Si	athode_to_Si_si	athode_to_Si...
18	-0.15	-0.15	-4.7220526194...	0	-5.6985630178...	-4.6650669892...	0	0	3.97719245114...	0	-9.1618901598...	3.977192451...
19	-0.0999999999...	-0.0999999999...	-3.2067497254...	0	-5.5863710354...	2.37962131000...	0	0	3.90265592819...	0	-9.1618901598...	3.90265592...
20	-0.0499999999...	-0.0499999999...	-2.4927999507...	0	-4.8724212607...	2.37962131000...	0	0	3.40673207858...	0	-9.1618901598...	3.40673207...
21	3.19189119579...	3.19189119579...	5.17350208646...	0	5.17386580091...	-3.6371445603...	0	0	-4.8552803929...	0	-9.1618901598...	-4.855188774
22	0.05000000000...	0.05000000000...	2.44267570144...	0	3.35971264181...	2.40907857502...	0	0	-2.3520294840...	0	-9.1618901598...	-2.352029484
23	0.1	0.1	2.09193056404...	0	2.65604470748...	1.82632609329...	0	0	1.34671178957...	0	3.20690000802...	-1.860188218
24	0.15	0.15	8.53610180553...	0	1.86810759212...	6.66799421341...	0	0	-1.2105261217...	0	-1.0796563360...	-1.308697857
25	0.2	0.2	5.02016437512...	0	1.29369943779...	3.72646493732...	0	0	-5.5457275303...	0	-4.6393153449...	-9.064121853
26	0.25	0.25	3.10499185364...	0	8.93882698193...	2.21110915545...	0	0	-3.0361020340...	0	-2.4097966166...	-6.263054174
27	0.3	0.3	2.05014834637...	0	6.17372674454...	1.43277567192...	0	0	-2.0457378367...	0	-1.6131627353...	-4.325751013
28	0.35	0.35	1.38326117353...	0	4.26331246788...	9.56929926742...	0	0	-1.3833495600...	0	-1.0846048833...	-2.987446766
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31	0.5	0.5	4.41625930945...	0	1.40331545822...	3.01294385123...	0	0	-4.4162580353...	0	-3.4320860808...	-9.841719545
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