EE669: Simulation Exercise

Cleanroom Practice

Effect of minority carrier life time on a silicon pn junction diode reverse bias current – a simulation exercise

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Credits: First version of this exercise, Mr. Srinu Rowtu

Credits: Daniel Mejia, Gerhard Klimeck (2022), "PN Junction Lab (New Interactive Front End)," https://nanohub.org/resources/pnjunctionlab. (DOI: 10.21981/370V-EJ38).

Introduction

nanohub.org host several software tools for the simulation of a large variety of nano electronic materials, devices, etc. We will use the "**PN Junction Lab**" simulation tool in this exercise.

- Create an account in nanohub. (You can register with your gmail, or IIT Bombay email id)
 Link: https://nanohub.org
- Tool link: <u>https://nanohub.org/resources/pnjunctionlab/about</u>
- Read about the tool on web page. Tool name "PN Junction Lab (New Interactive Front End)"
- Demo video is available on the page.
- Introduction to the tool: <u>https://nanohub.org/resources/34222/download/PNJUNCTION_v1.pdf</u>
- We can simulate and view the following plots
 - Energy Band, I-V Characteristics, C-V Characteristics, Total Current, Total Density, Electric Filed, Electric Potential, Recombination, Carrier Density (shown in the left side in figure We can edit the structure, materials and Environment in settings.

Setting up the simulation

- We can edit the structure, materials and environment in settings.
- Doping concentrations, p-type, n-type lengths are edit in the **Structure** section
 - \circ Na: 2x10¹⁶ cm⁻³; Nd: 1x10¹⁵ /cm⁻³
 - P-type length 3 um, N-type length 6 um (default values)
- The minority carrier life time values can be edited in the **Materials** section. In this exercise, we would like to vary the minority carrier lifetime.
- The bias voltage can be given in the **Environment** section. To obtain the current voltage characteristics from -1 V to 0 V, set applied voltage to -1.0 V. To keep the simulation time low, you may choose the number of points as 10.
- To run the simulation, click on I-V characteristics or any of the boxes on the left other than the **Settings**.

Exercise

- 1. Simulate the reverse current density (leakage current density) at -1.0 V for minority carrier lifetimes of 10⁻⁹ sec, 10⁻⁷ sec, 10⁻⁵ sec.
- 2. Make a log log plot of the leakage current density versus minority carrier lifetime.

3. Write the conclusions of this experiment in one sentence.

<u>Appendix</u>

Steps for the simulation are given below with illustrations:

1. P+N junction is created with the following structure

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Energy Band	Structure Materials Environment		^			
I-V Characteristics	Structure					
	P-type length	3	μm			
C-v Characteristics	P-type Nodes	60				
Total Current	Intrinsic Region length	0	μm			
Total Density	Intrinsic Nodes	0				
Charge Density	N-type longth	6	μm			
Electric Potential	N-type Nodes	120				
Electric Field	Acceptor concentration (Na-)	2.00e+16	/cm3			
Recombination	Donor concentration (Nd+)	1.00e+15	/cm3			
Carrier Density						
Settings						
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2. Simulation started with Default carrier life time is 1e-10 s. You can edit the lifetime values.

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Energy Band	Structure Materials	Environment			^
I-V Characteristics			Materials		
C.V.Characteriation	Material				Si 🗸
C-V Characteristics		Mi	nority carrier lifetime		
Total Current	For electrons			1.00e-10	5
Total Density	For holes			1.00e-10) s
Charge Density			Impurities		
Electric Potential	Impurity doping in Intrinsic region.				no yes
Electric Field					
Recombination					
Carrier Density					
Settings					
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3. Set voltage is sweep from -1 V to 0.

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Energy Band	Structure Materials	Environment				*
				Ambient		
-V Characteristics	Ambient temperature				300	К
C-V Characteristics	Applied Voltage				-1	v
Total Current	Number of points				40	
Total Density						
Charge Density						
Electric Potential						
Electric Field						
Recombination						
Carrier Density						
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→ 30°C Haze			ନ୍ 🔳 💽 🚞	🗉 🚖 🧕 🖷		19:18 31-07-2022 2

4. Example, IV plot for the minority carrier life time of 1e-10 s

			8 N 8 -		PN-Junction Lab
Energy Band	I-V Characteristics				o Q+ II = X # II *
I-V Characteristics	0				
Total Current	-1e-4				
Total Density	-2e-4				
Charge Density	-3e-4				
Electric Field	-4e-4				
Recombination					
Settings	-56-4				
	-1	-0.8 -	0.6 Voltage [V]	-0.4 -	-0.2 0
Theme					