Electronic Devices and Circuits Lab

Experiment 2- Group 4

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Aim-

Using Diode in ABACUS tool on nanohub.org perform the following analysis-

1) Electron and Hole concentration on the p-side and n-side.

2) Energy Band Structure across the diode.

3) Electric Field inside the diode.

4) The Current-Voltage characteristics of the diode.

Theory-

A diode is made up of two types of semiconductors, one is p-type which is doped with acceptor atoms having lack of electrons and the other is n-type which is doped with donor atoms having excess of electrons. These two types of semiconductors are joined together and their joining point is called junction.

At the junction, there is a huge concentration gradient of oppositely charged carriers(i.e. Electrons and Holes) which causes the electrons to diffuse to the p-side and holes to diffuse to the n-side. Due to this movement, oppositely charged ions are formed which creates an electric field in the direction of the moving electrons. This electric field builds up in strength which opposes the motion of electrons and there comes a point when the electric field is strong enough to stop the electrons. The potential difference caused due to this field is called barrier potential.

Biasing voltage is the external voltage applied across the semiconductor wherein a positive biasing voltage means that the p-type side is connected to the positive terminal and n-type is connected to the negative side of the voltage source. Positive biasing voltage essentially opposes the barrier potential.

Procedure-

Parameters for the ABACUS tool-

Length of p-type and n-type = 6μm

Concentration of Acceptor atoms = N_A = 5e15 cm^{-3}

Concentration of Donor atoms = N_D = 5e18 cm^{-3}

Bias Voltages are 0V, 0.1V, 0.3V

All the simulations were done on nanohub.org using the ABACUS tool and the graphs were plotted using python' s matplotlib library.

Understandings from the plots-

1) At places away from the junction, the hole concentration will be 5e15 cm^{-3} and electron concentration will be 5e18 cm^{-3} as each donor or acceptor atom will contribute towards one electron or hole. But the concentration near the junction will depend on the applied bias voltage-

At 0V, the movement of charge carriers was restricted by the electric field created by the ions left behind. So, there is a sharp change in the concentrations of holes and electrons at the junction. When we apply a bias voltage, the barrier potential reduces which allows more movement of electrons and holes across the barrier which is reflected as a gradual change in the concentration graph.

2) The energy level of the conduction band and the valence band of p-type semiconductor is higher than that of n-type semiconductor. The higher energy level of the conduction band acts as an energy barrier for electrons to move from n-side to p-side. When a bias is applied, it reduces the diffusion potential, thereby lowering the energy of the conduction band of p-type which allows for electrons to cross the junction. At equilibrium the Quasi-Fermi level of electrons and holes is the same since there is no flow of charge carriers. When we apply a bias voltage, the Fermi-Level gets split into quasi fermi levels due to the movement of electrons and also the conduction band and valence band of p-type get lowered. As we increase the biasing the fermi level splits more.

3) Due to the movement of charge carriers, ions were created on the p-side and n-side which created an electric field which opposed the movement of charge carriers. But the electric field away from the junction will be 0. So as seen in the graph, the electric field is 0 away from the 6μm point and there is a sudden dip at 6μm. When bias voltage is applied, it acts against the direction of the electric field and hence it's magnitude decreases but does not change for the rest of the semiconductor.

4) The Current-Voltage characteristic graph shows us the variation of charge density with applied bias for a diode at the junction. At equilibrium, there is no current flowing through the diode. As we keep increasing the bias, the barrier potential reduces as the direction of bias is opposite to the barrier potential. So for a bias voltage higher than the barrier potential, the electrons start flowing across the barrier which is shown as a sharp increase in the IV characteristics graph.

Conclusions-

1) At equilibrium the charge carrier density remains constant except at the junction where there is an abrupt change due to different types of semiconductors. When a bias is applied, this abrupt change in concentration at the junction is smoothened out.

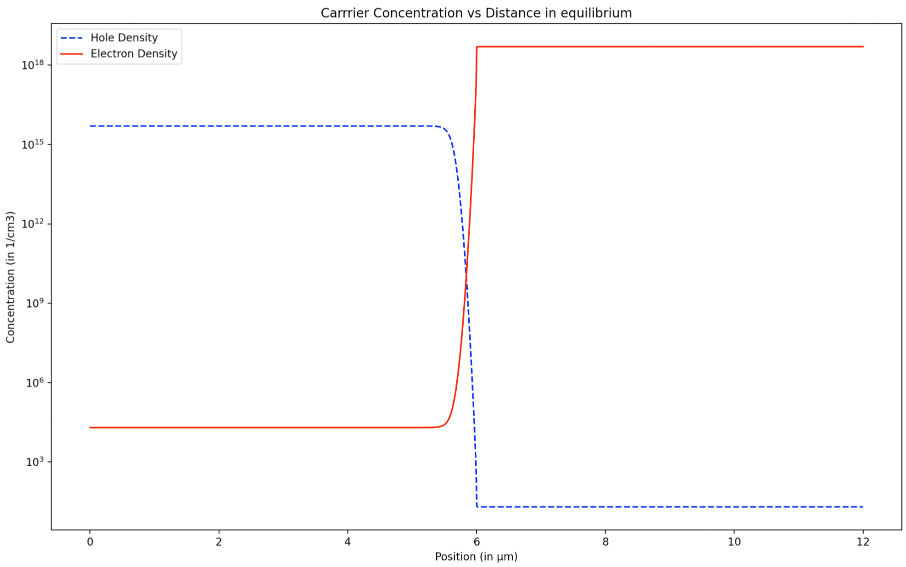
2) At equilibrium, the Quasi Fermi Levels of p-type and n-type coincide due to lack of movement of electrons. However when a bias is applied, the Fermi Levels split up and the more the bias the more is the splitting of the levels.

3) There is an electric field at the junction restricting the motion of electrons. As the biasing increases, the magnitude of the electric field decreases.

4) Due to the barrier potential and diffusion current, the net current inside a diode is 0. But as the biasing crosses the barrier potential there is a current flowing in the diode.

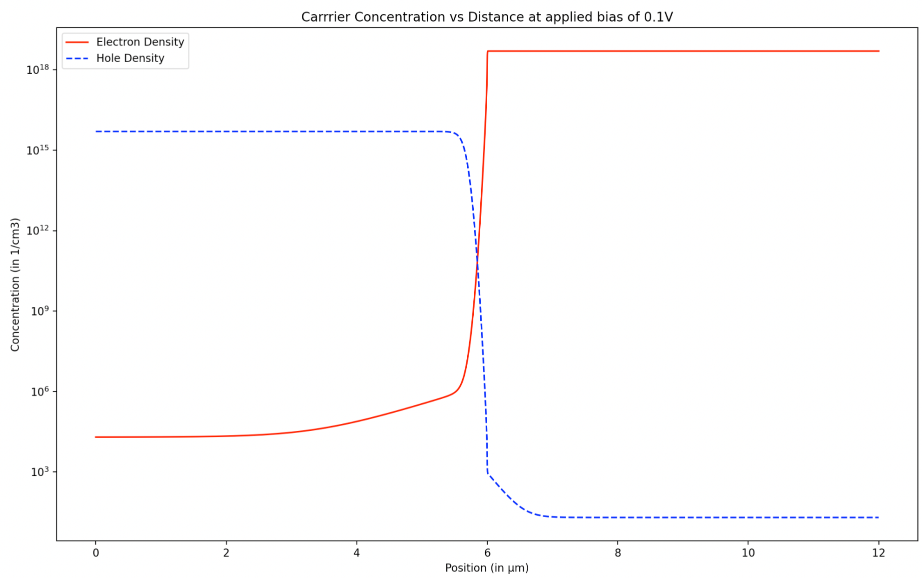
Plots-

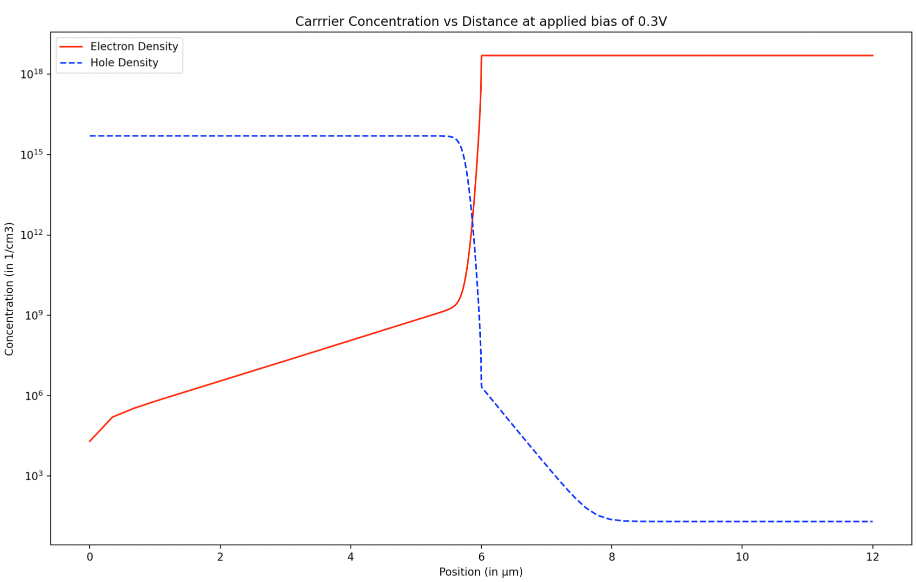
1) Electron and Hole Concentrations-



At equilibrium

At V_A=0.1V

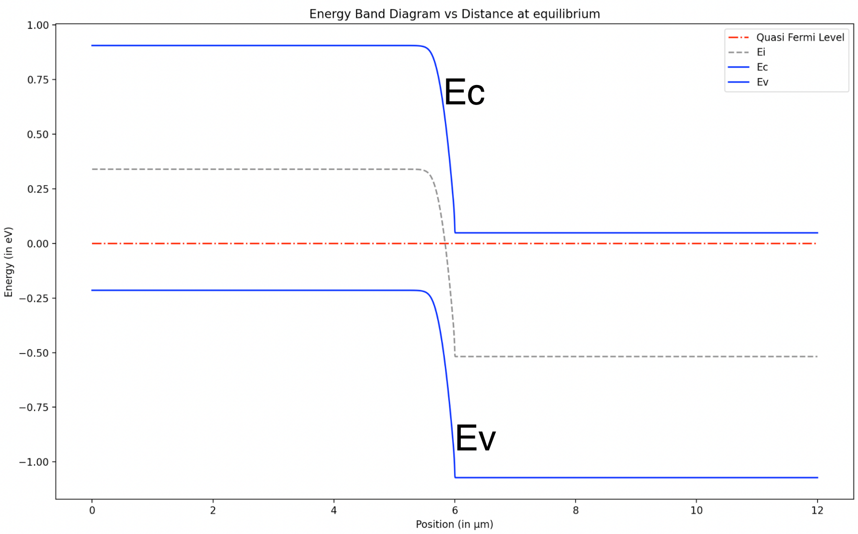




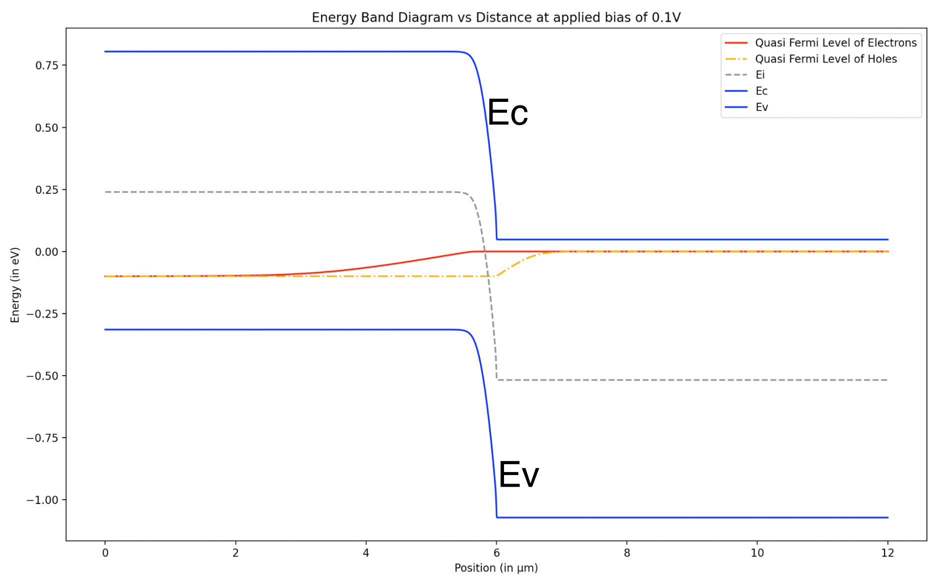
At V_A=0.3V

2) Energy Band Diagrams-

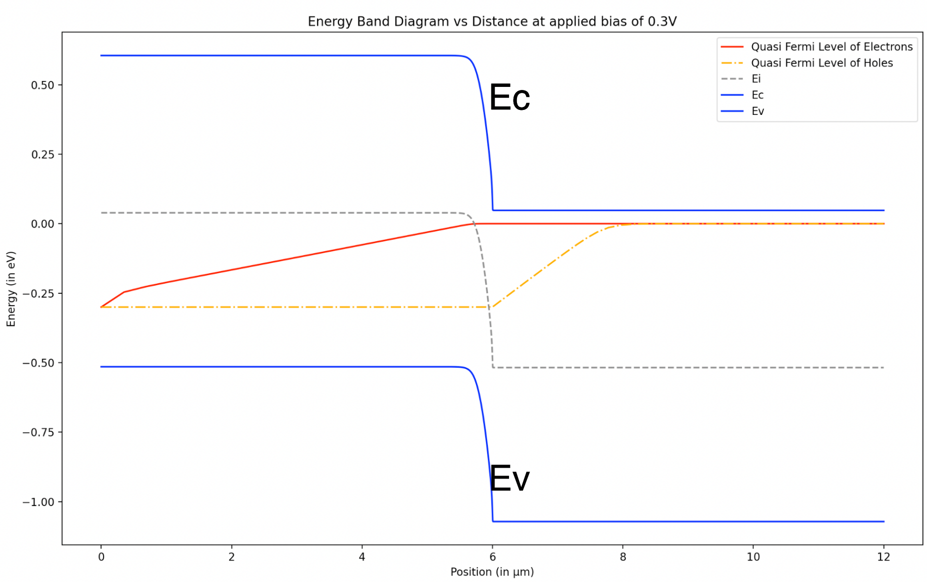
At equilibrium



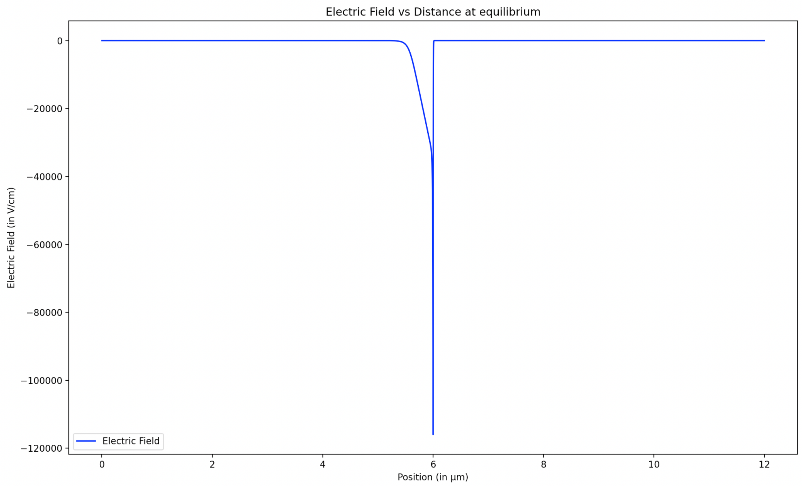
At V_A=0.1V

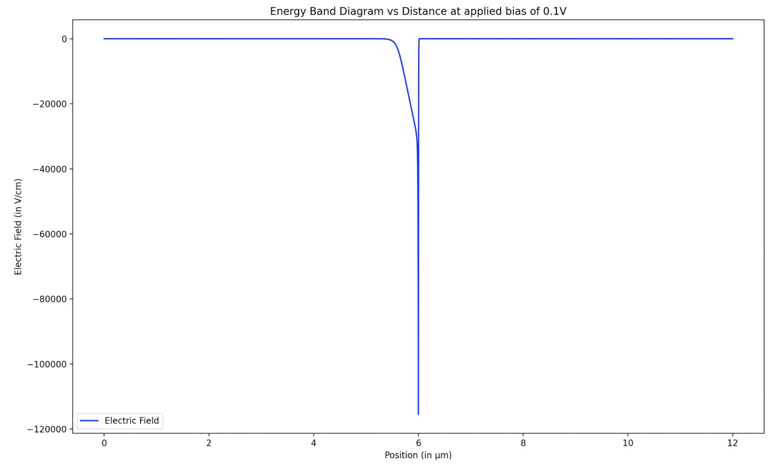


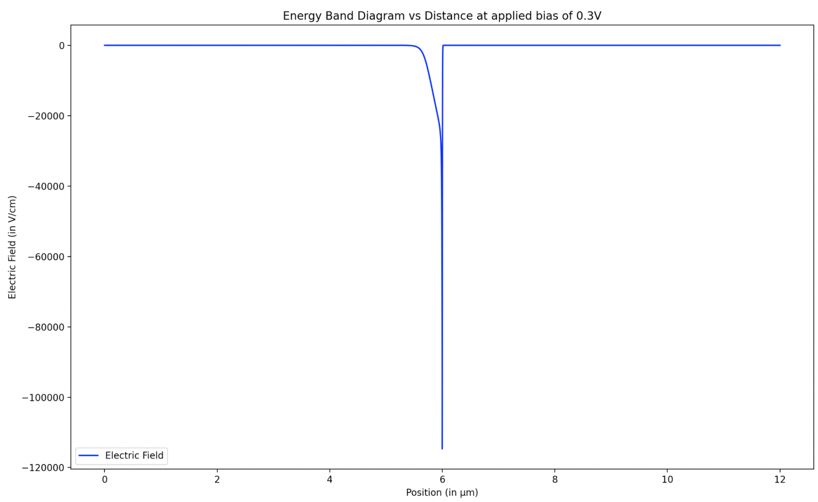
At V_A=0.3V



3) Electric Field-







4) I-V Characteristics-