A Python Program to Compute Electron Concentration as a Function of the Electron Quasi-Fermi Energy Level

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Abstract: This article presents a Python program to compute the electron concentration as a function of the relative position of the electron quasi-Fermi energy levels with reference to conduction band edge. The open-source program is made freely available (GitHub URL below).

Keywords: Python program, Quasi-Fermi Level, electron

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Introduction

The carrier Quasi-Fermi level function for n-type is expressed as [1]

$$n = N_c e^{-(E_c - E_{Fn})/kT}$$

Where

- N_C is the effective density of states in the conduction band
- E_C is the conduction band edge
- E_{Fn} is the electron quasi-fermi level
- k is the Boltzmann constant.
- T is the temperature in Kelvin

Program

```
import numpy as np
import matplotlib.pyplot as plt

# Constants
k = 8.617e-5  # Boltzmann constant (eV/K)
T = 300         # Temperature (K)
Nc = 2.8e19  # Effective density of states in the conduction band (cm^-3)

# energy difference range (Ec - EFn) in eV
Ec_minus_EFn = np.linspace(0, 1, 1000)  # Range of (Ec - EFn) from 0 to 1 eV

# Calculate electron concentration n
n = Nc * np.exp(-Ec_minus_EFn / (k * T))

# Plot n vs (Ec - EFn)
```

```
plt.figure(figsize=(10, 6))
plt.plot(Ec_minus_EFn, n, label=r"$n = N_c e^{-(E_c - E_{Fn}) / kT}$", color="blue")
plt.title("Electron Concentration ($n$) vs. Energy Difference ($E_c - E_{Fn}$)")
plt.xlabel("Energy Difference ($E_c - E_{Fn}$) [eV] ")
plt.ylabel("Electron Concentration $n$ ($cm^{-3}$)")
plt.xscale("log")  # Logarithmic scale for concentration
plt.grid(True, linestyle="--", linewidth=0.5)
plt.legend()
plt.tight_layout()
plt.show()
```

Plot

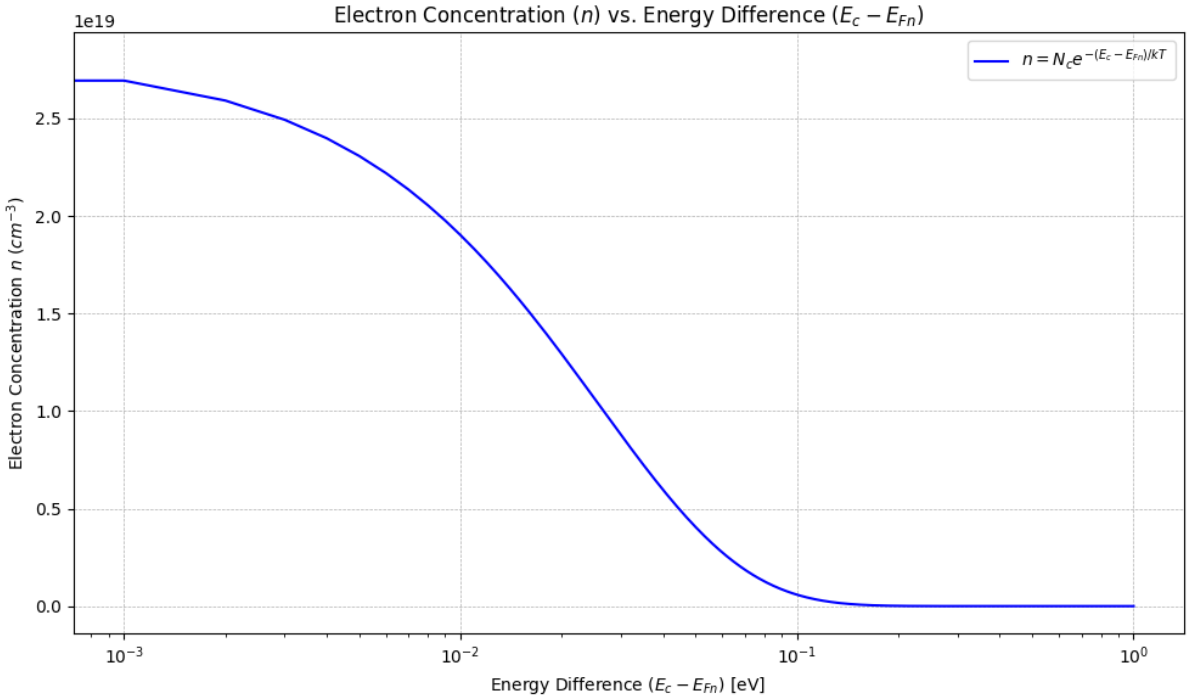

Fig. 1. Electron concentration (n) vs Energy difference $(E_c - E_{Fn})$

GitHub URL

https://github.com/SemEhub/SemEHub_Vol1/blob/main/SH-2024-V02-07

References

[1] Chenming Hu, *Modern semiconductor devices for integrated circuits*. Upper Saddle River, N.J.: Prentice Hall, 2010.