ELEC 4700

Assignment 1

Monte-Carlo Modeling of Electron Transport

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Date Submitted: 2021/02/07

1)

In the absence of a electric field, electrons in a semiconductor display random motion, the average velocity of this motion is called thermal velocity. Equation (1) is used to calculate thermal velocity of a single electron; the average thermal velocity of the system (v drift) is always zero when no external electric fields are present.

$$v_{rms} = \sqrt{\frac{3kT}{m}} \qquad eq(1)$$

Where $k = 1.380 \times 10^{-23}$ (Boltzmann's constant); m = 9.109×10^{-31}; $T = 300K$.

The resulting $v_{rms} = 116.768 \times 10^{3} m/s$.

2)

The average distance the electron travels between collisions is called the mean free path. Mean free path can be calculated using equation (2).

$$\lambda = \mathrm{v_{rms}} \times \tau \quad \mathrm{eq}(2)$$

The resulting $\lambda = (116.768 \times 10^{3}) \times (0.2 \times 10^{-12}) = 23.35\ nm$

3)

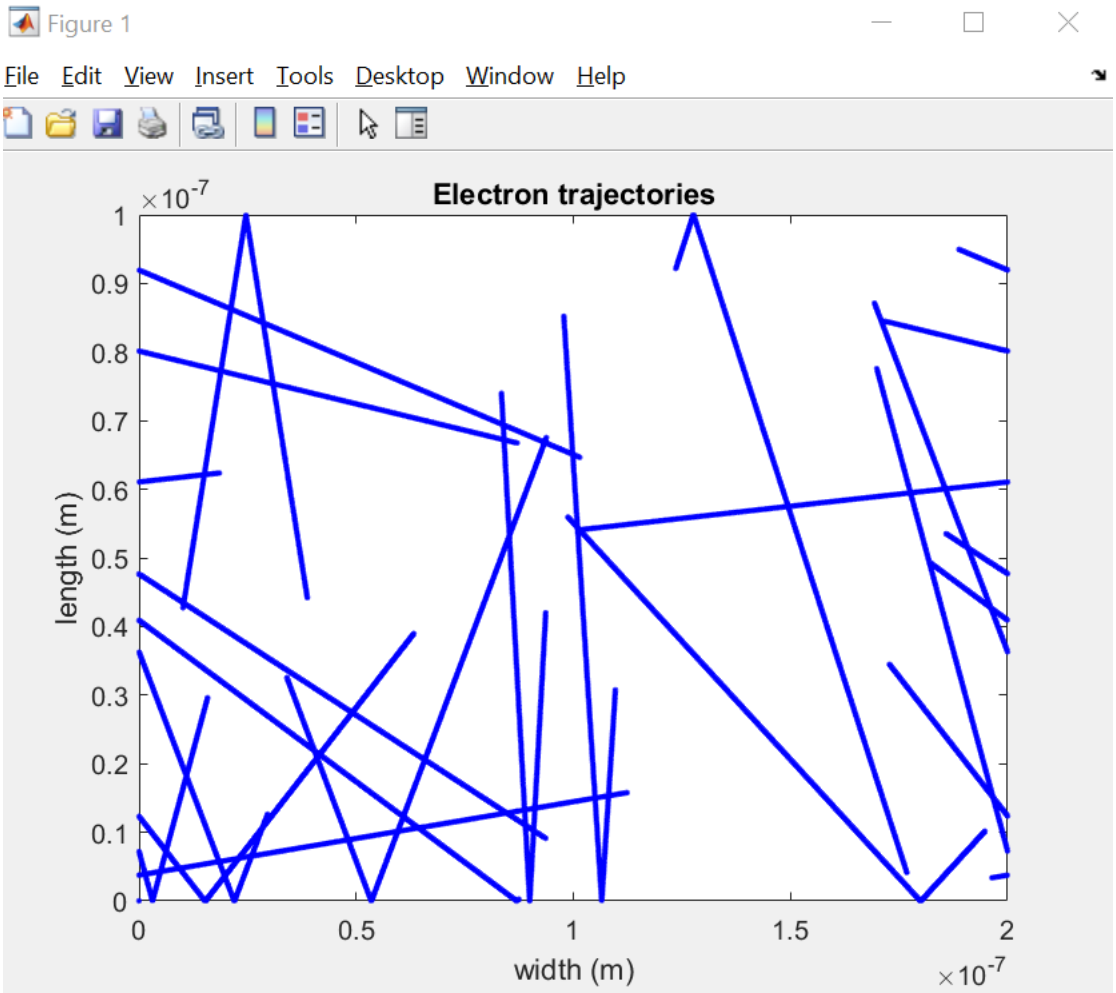

Figure 1: 2-D plot of particle trajectories

4)

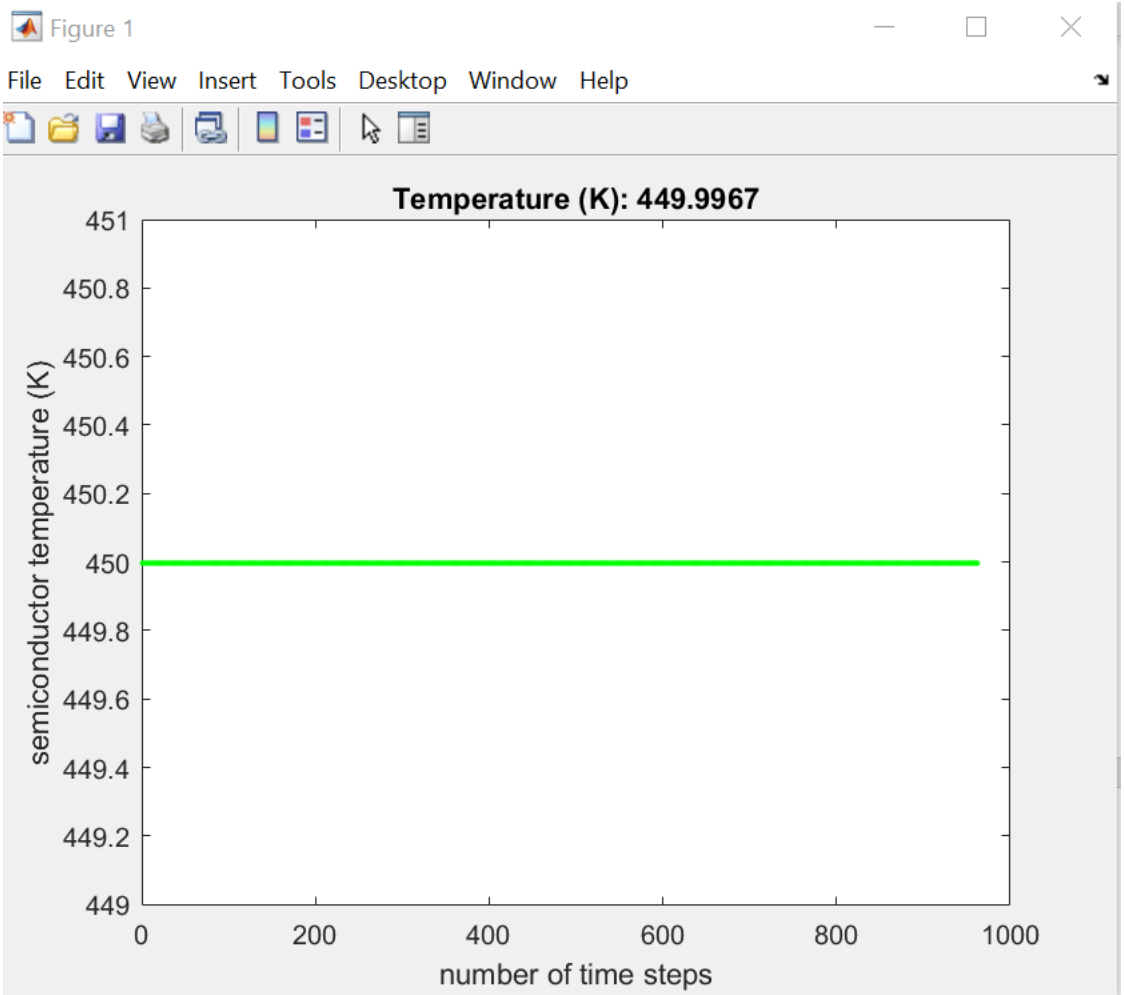

Figure 2: Semiconductor temperature over the course of simulation (rest mass is used for KE calculation)

5)

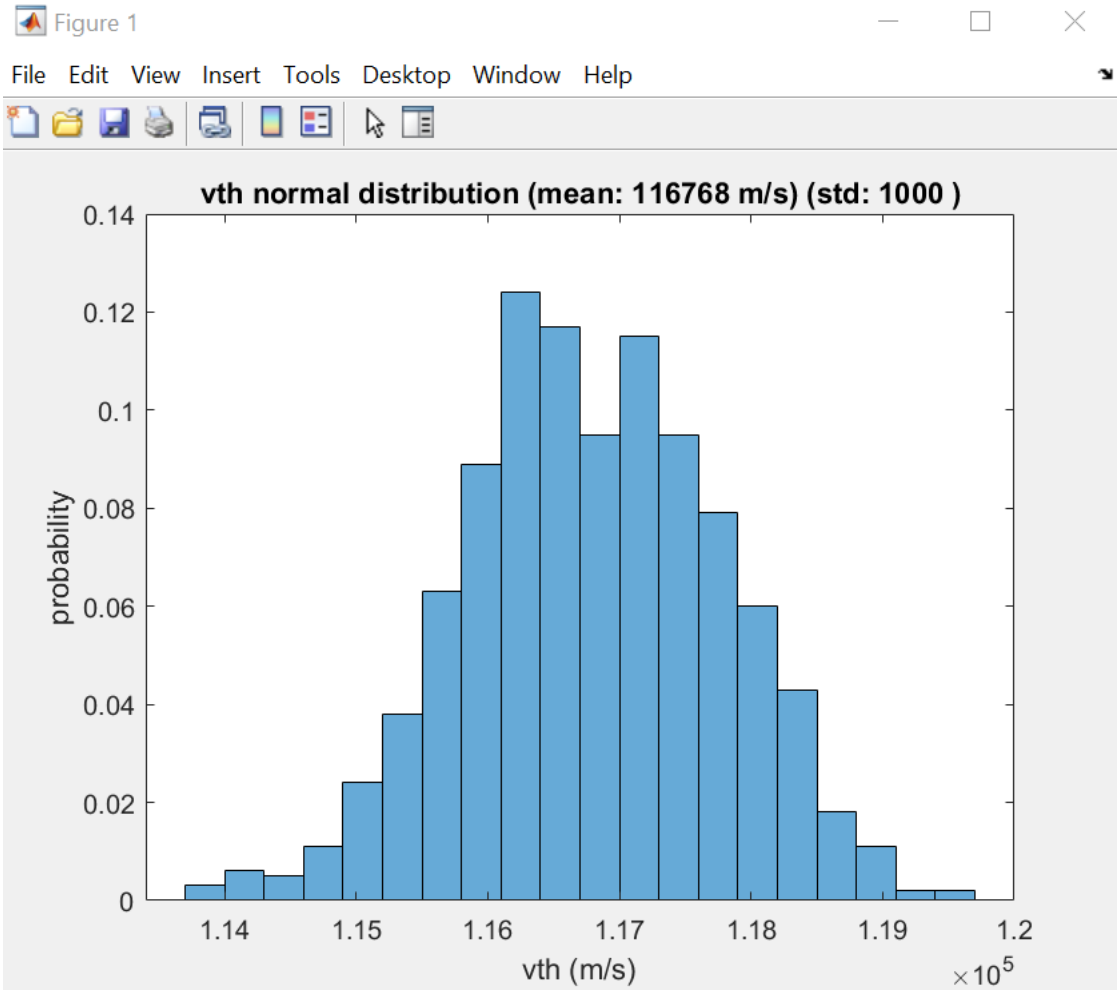

Figure 3: Histogram of vth(thermal velocity of electrons) for normal distribution

6)

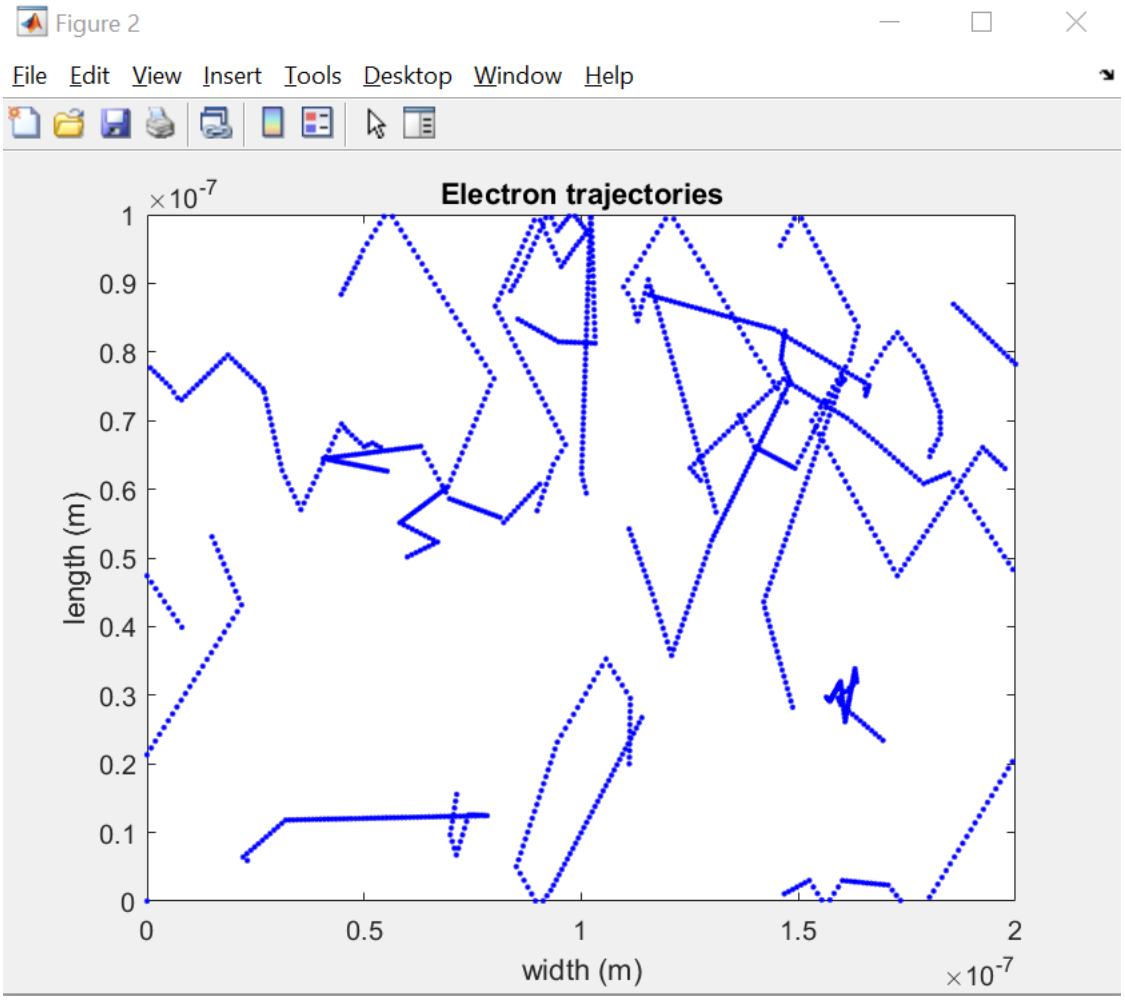

Figure 4: 2-D plot of particle trajectories with scattering

7)

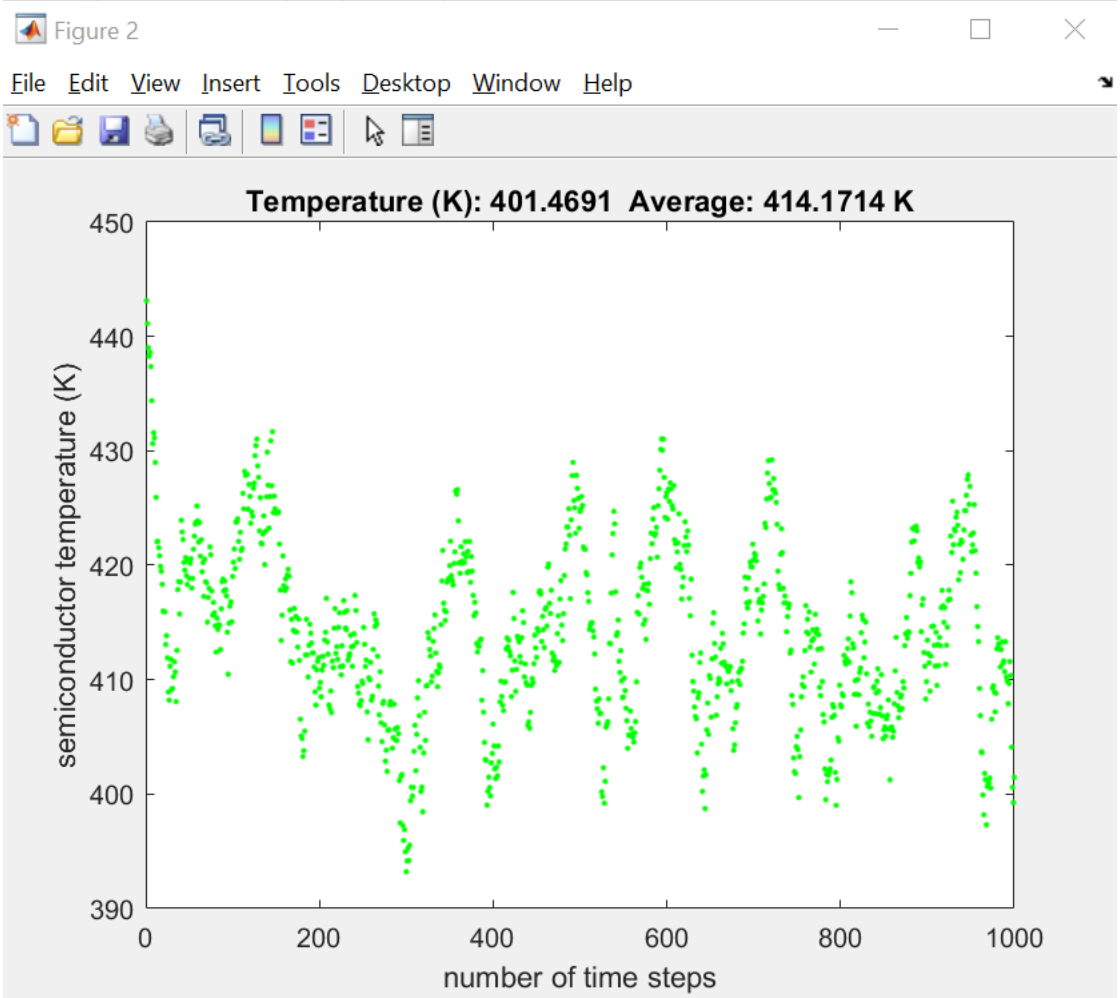

Figure 5: Semiconductor temperature over the course of simulation with scattering. (rest mass is used for KE calculation)

8)

The mean free path calculation for a normal electron velocity distribution with a mean of 116768m/s and a standard deviation of 1000 is: (RMS= standard deviation)

$$\lambda = v_{rms} \times \tau \quad eq(2)$$

The resulting $\lambda = (1000) \times (0.2 \times 10^{-12}) = 0.2\, nm$

9)

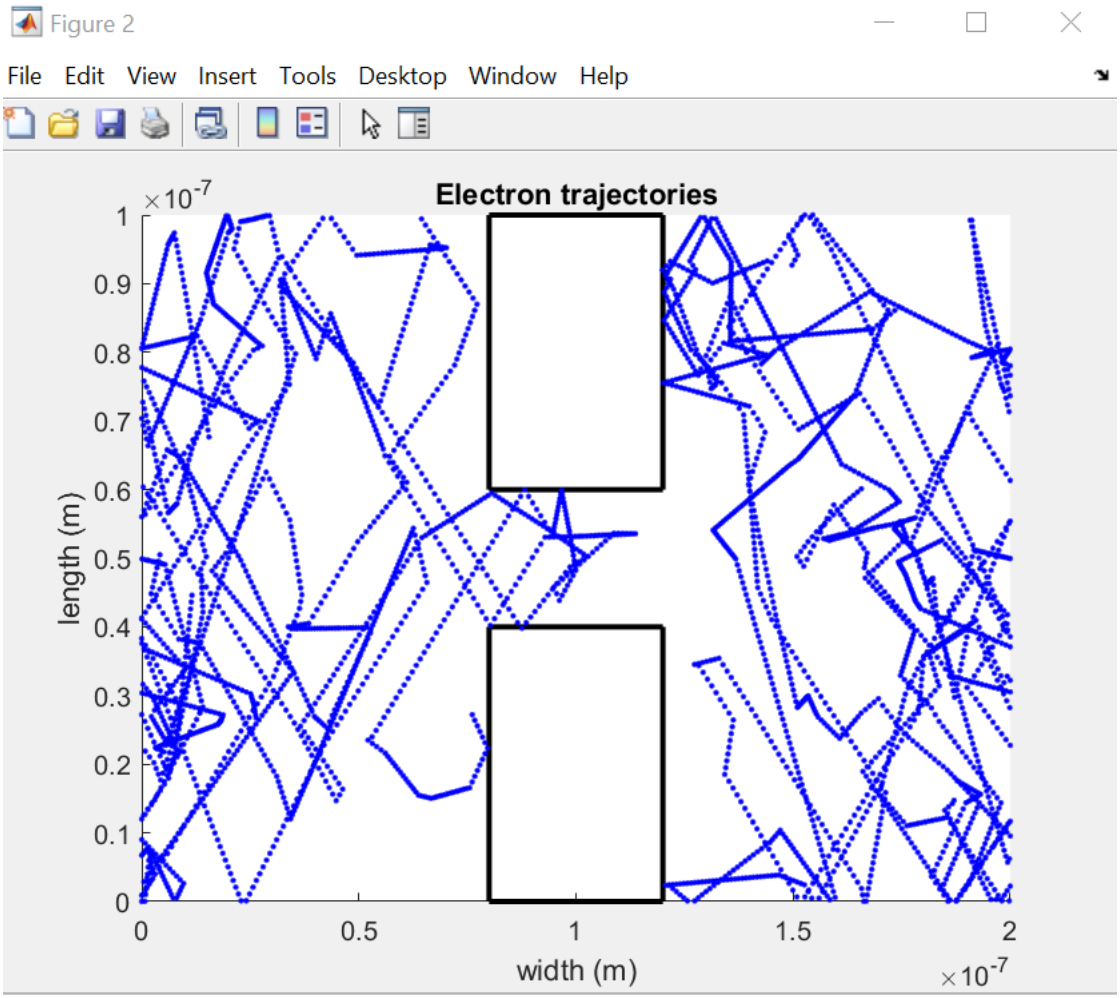

Figure 6: 2-D plot of particle trajectories with bottle neck

10)

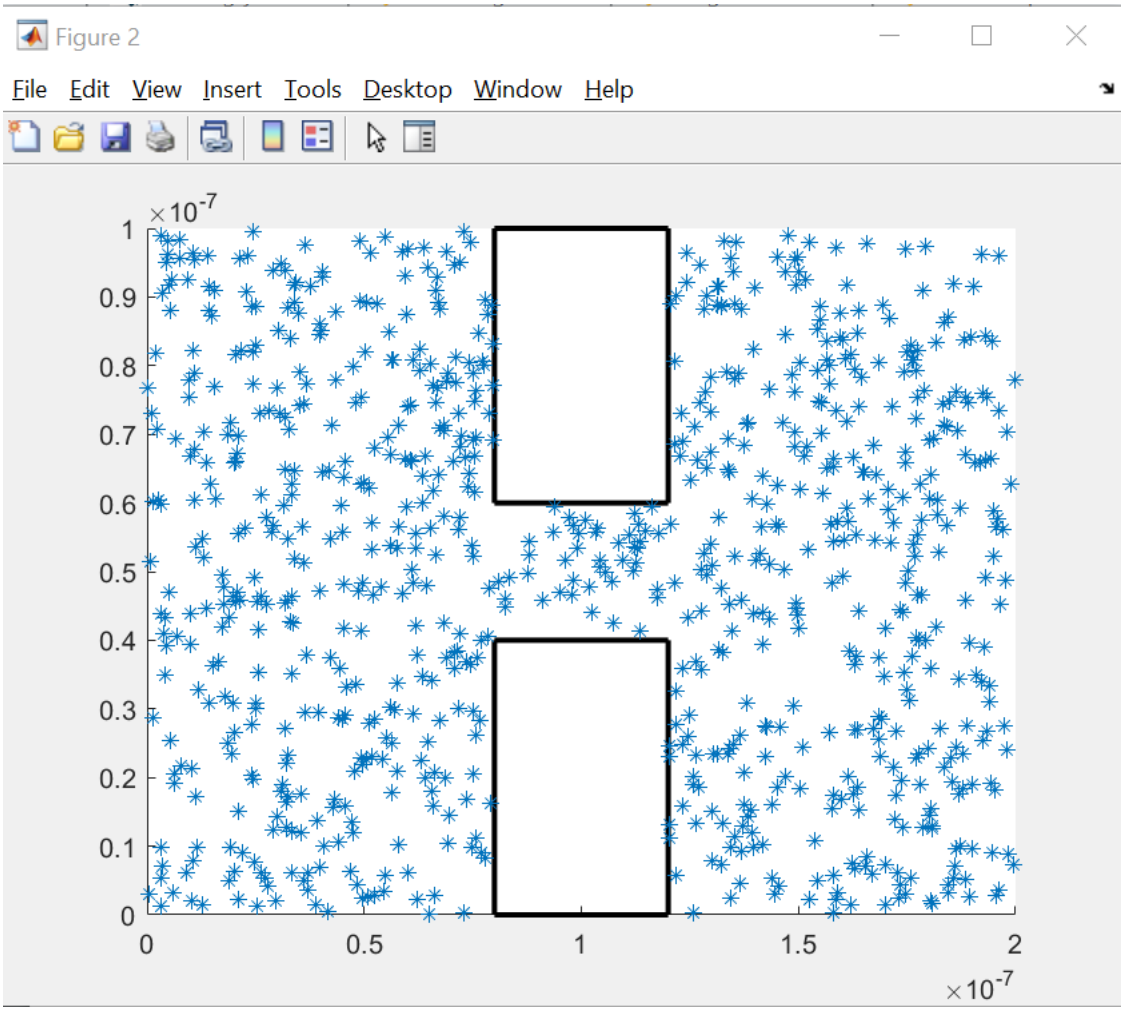

Figure 7: Electron density map

11)

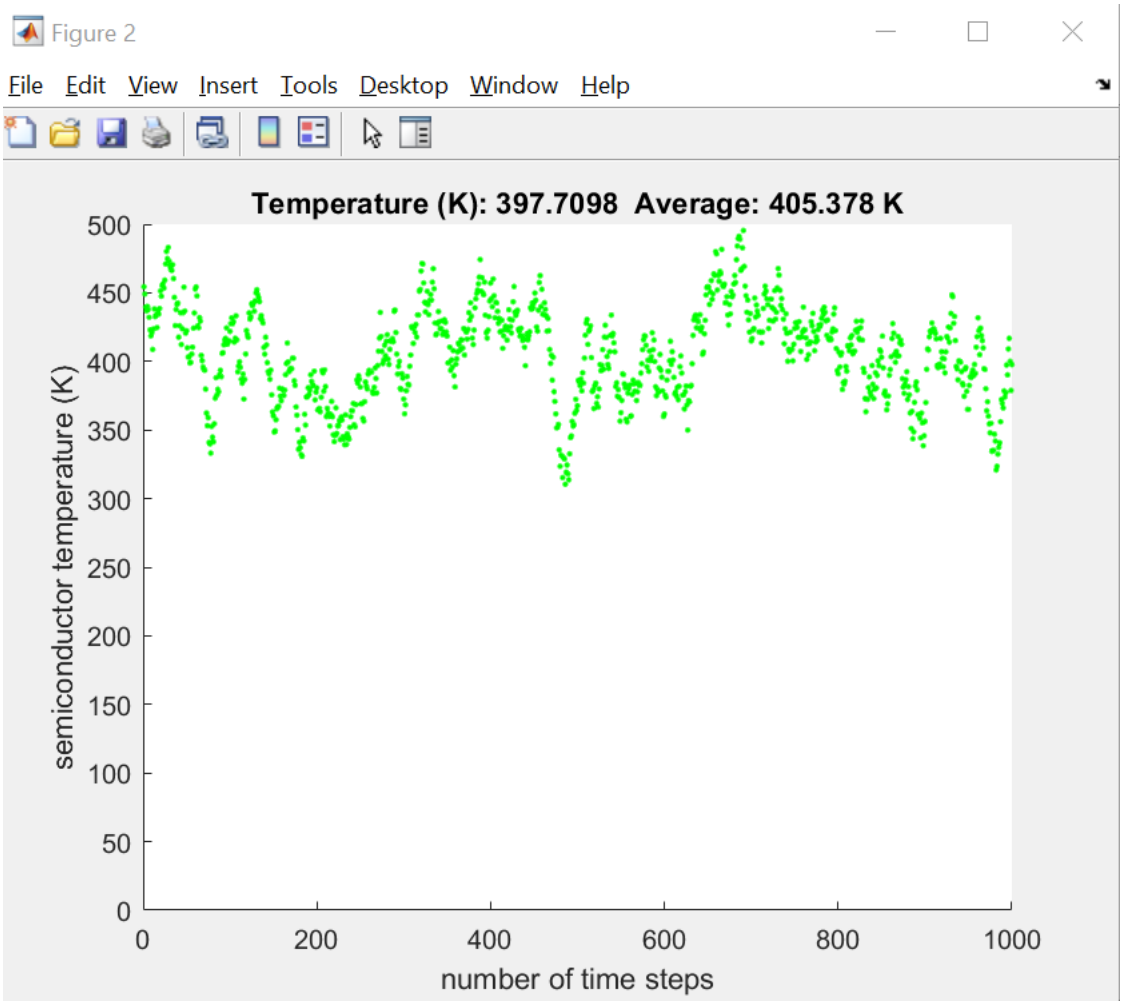

Figure 8: Temeprature plot of the semiconductor with a bottle neck