ELEC 4700

ASSIGNMENT – 1 Monte-Carlo Modeling of Electron Transport

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Introduction

The purpose of this assignment was to learn how to model electron movements in an N-type silicon semiconductor crystal which has a nominal region size of 200nm x 100nm. The electrons were modelled using a simplistic Monte-Carlo model.

1 - Electron Modelling

The electrons that were modelled had an effective mass of 0.26m_o (where m_o is the rest mass of an electron). The Thermal velocity of an electron is the velocity an electron has if its kinetic energy is approximately the same as the average energy of the total amount of electrons in a semiconductor. The thermal velocity of the electron was calculated using the formula below;

sqrt((kb * T) / effMass)

where kb is the Boltzmann constant, effMass is the effective mass of the electron and T is the temperature measured in Kelvin. The mean free path was calculated by multiplying the thermal velocity of the particle by the mean free time of 0.2ps. The thermal velocity that was obtained by the simulation was $1.3224\ X\ 10^5 m/s$ which means the mean free path is:

$$\text{MFP} = 1.3224 \times 10^5 \times 0.2\times10^{-12} = 2.6448 \times 10^{-8}\ \text{m}$$

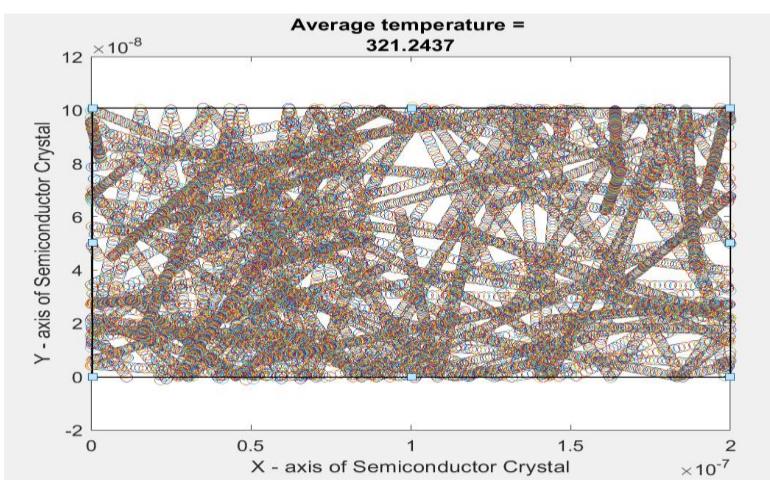

Figure 1 2-D plot of Electron Movement

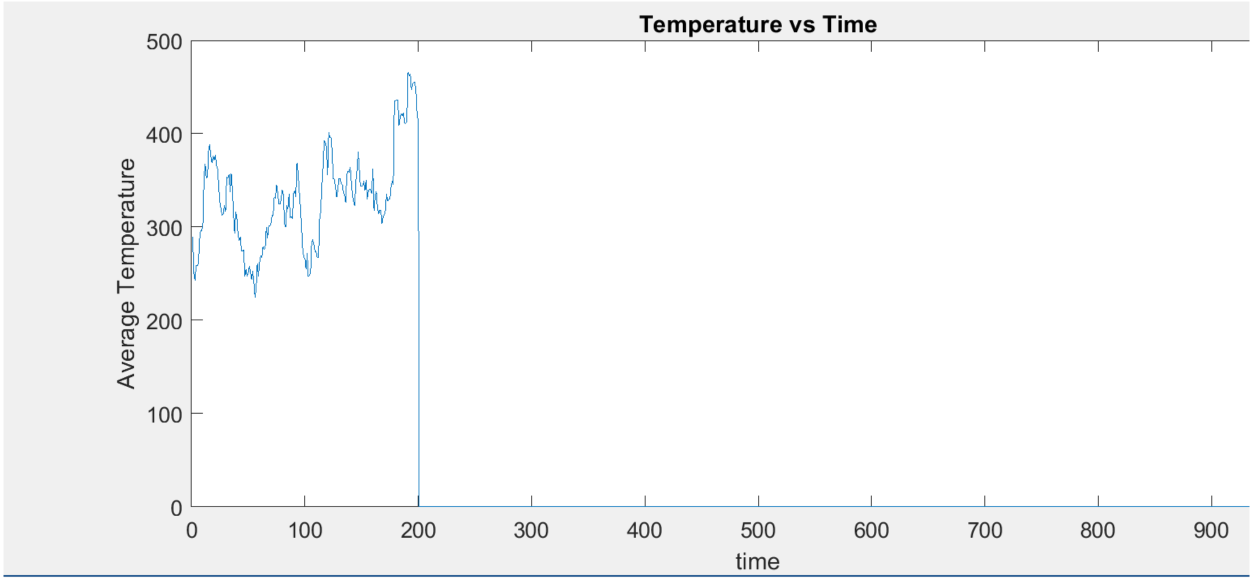

Figure 2 Temperature vs Time with Scattering

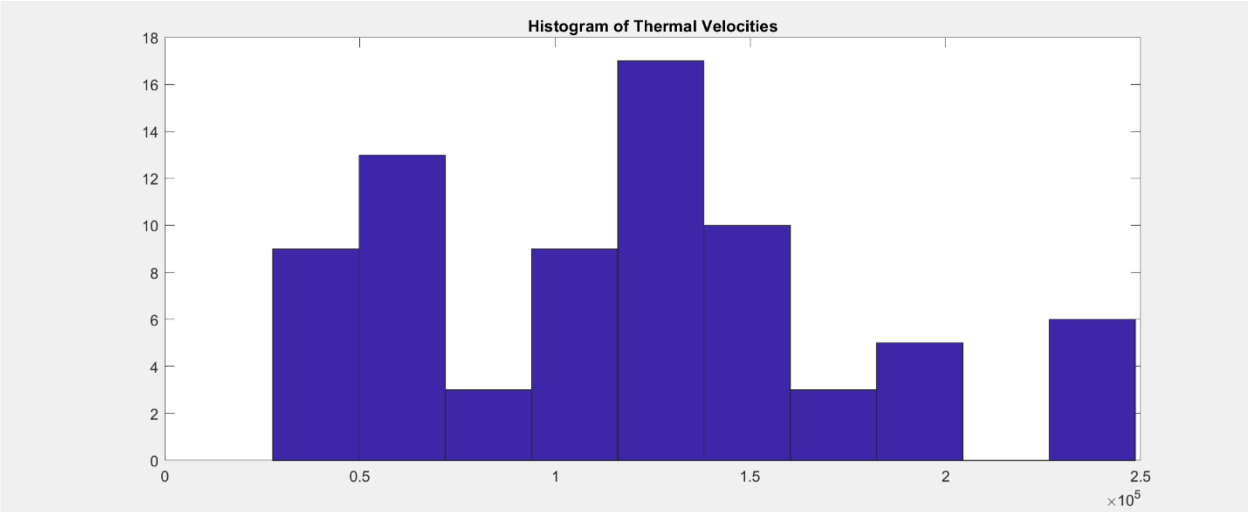

Figure 3 Histogram of Velocity Distribution with 200 Iterations and 75 Electrons

2 - Collisions with Mean Free Path (MFP)

For this part, random velocities were assigned to each of the electrons and this was done using a Maxwell Boltzmann distribution using the formula below .

Standard deviation = vTherm/(sqrt(2))

The electron particles were then assigned random velocities shown below xvel = randn(1, numofelec) .* standardev

yvel = randn(1, numofelec) .* standardev

vrms = sqrt((xvel .^ 2) + (yvel .^ 2))

The probability of scattering was calculated using the formula

pscat = 1 - (exp((-1 * timestep) / (0.2 * 10 ^ -12)))

The value obtained was approximately 0.035. The average temperature over time fluctuated but overall, the values were roughly 300 Kelvins.

3 - Enhancements

For this section, two rectangles were added to the upper and lower boundaries of the semiconductor crystal with the dimensions of .85xwidth and 1.15xlength of the semiconductor region. This formed a bottleneck which can be visible in figure 6. The boundaries were made to be specular. Two plots were made to indicate the temperature map and the electron density map in figure 5 and figure 4 respectively.

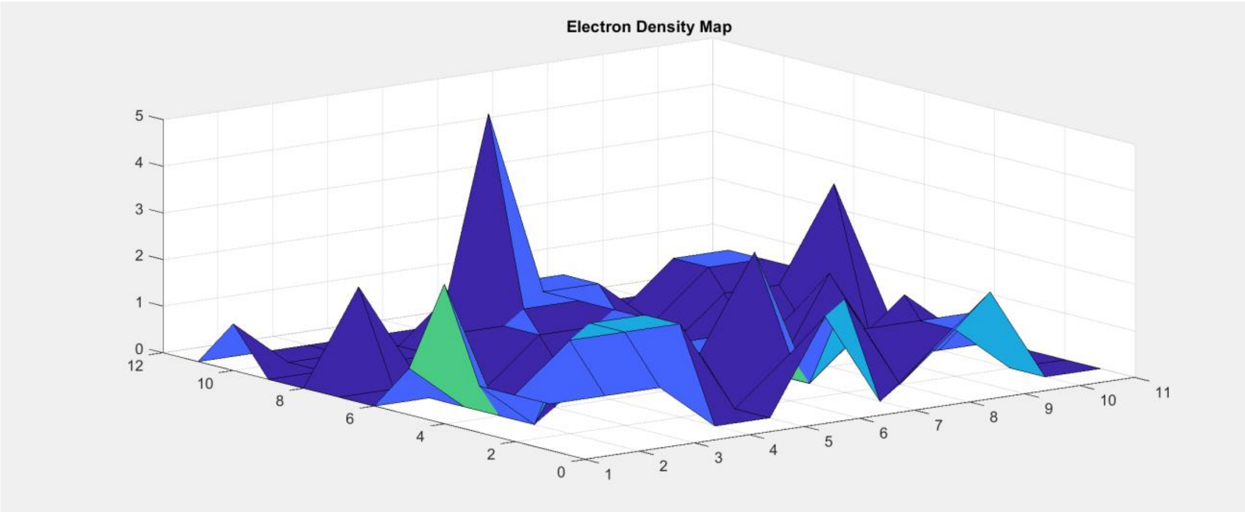

Figure 4 Electron Density Map in 3D

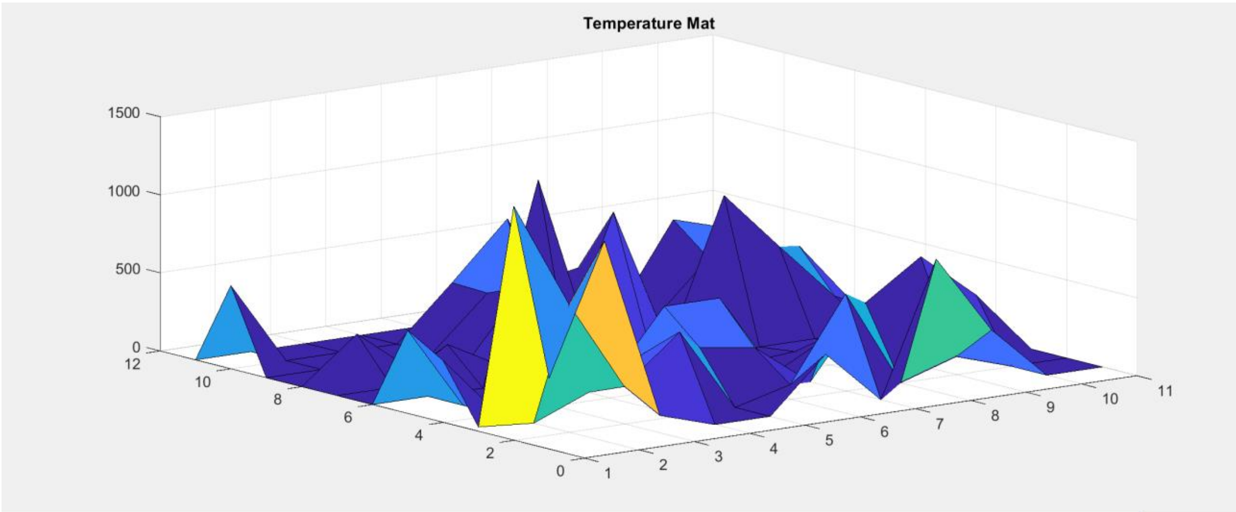

Figure 5 Temperature Map 3D

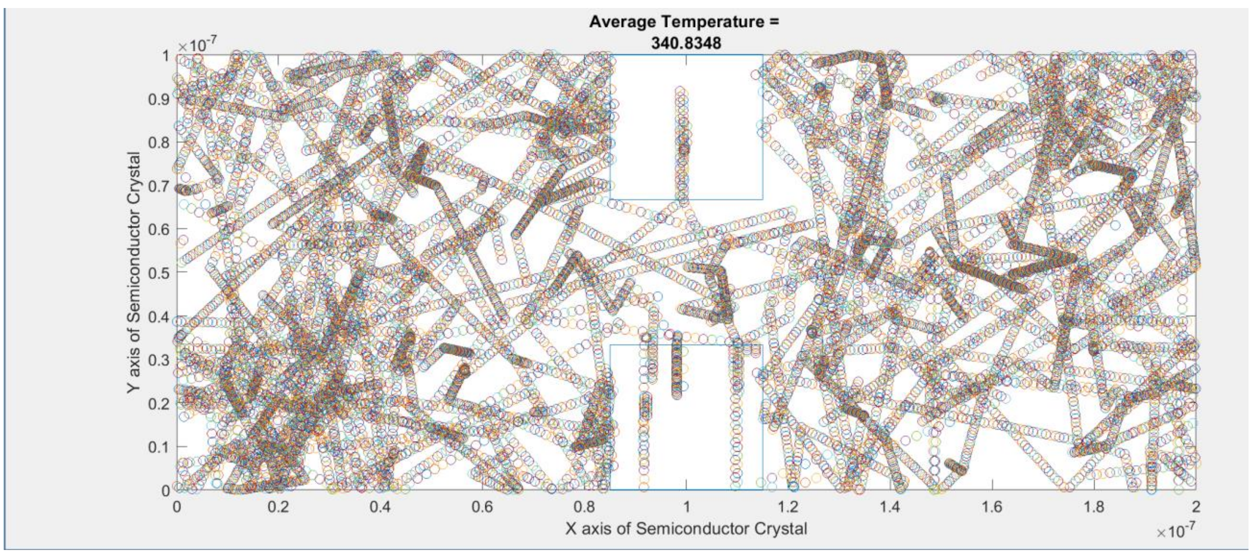

Figure 6 2D plot of Electron Trajectories after Enhancements

Conclusion

This experiment in the end was informative. The only problem encounted was that the electron tend to seep into the box on just the y boundaries of the enhancement bottlenecks.