Carleton University

Course: ELEC 4700 Modelling of Integrated Device

Assignment No: 1

Monte-Carlo Modeling of Electron Transport

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Introduction:

This report is for ELEC 4700 in response to the call for an assignment report. The assignment was to model carriers as a population of electrons in an N-type Si semiconductor crystal (Monte-Carlo model). These particles are then to be giving velocities using the Maxwell-Boltzmann distribution. Lastly, an enhancement is to put the system to test by adding a bottle neck boundary. This report will detail the results from the built simulation, observation of results, discussion of results, answers to specific questions asked in the assignment and conclusions derived. Samples of the code used to perfume these models will also be produced within the sections.

Electron Modelling:

Few questions:

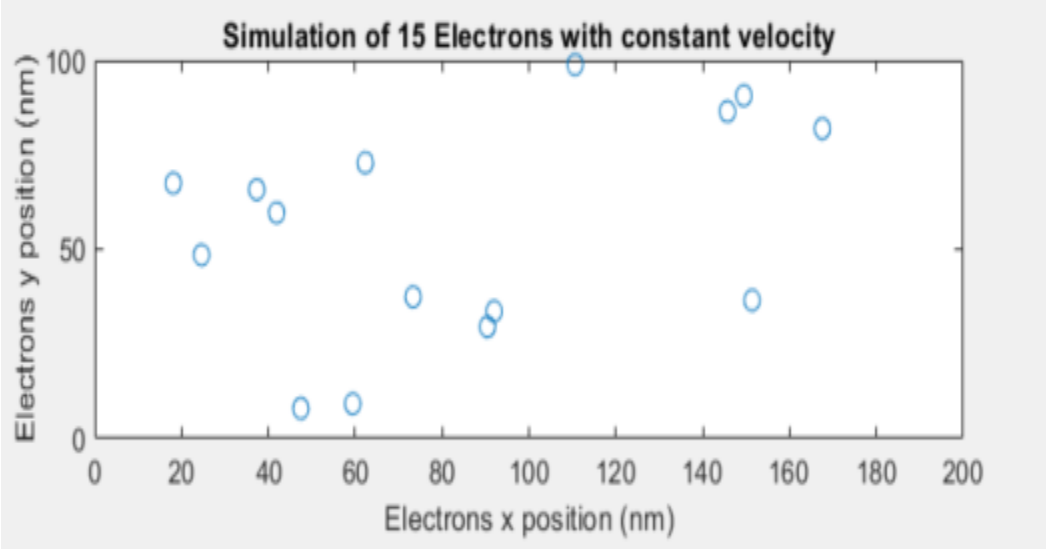
a) What is the thermal velocity vth? Assume T = 300 K.
With mn = effective mass = $0.26 \times mo$
T = 300K
K = 1.28×10^{-23}
Vth = $\sqrt{\frac{(2\times k\times T)}{mn}}$
=1.8702×10^{5} m/s

b) If the mean time between collisions is τmn = 0.2 ps what is the mean free path?

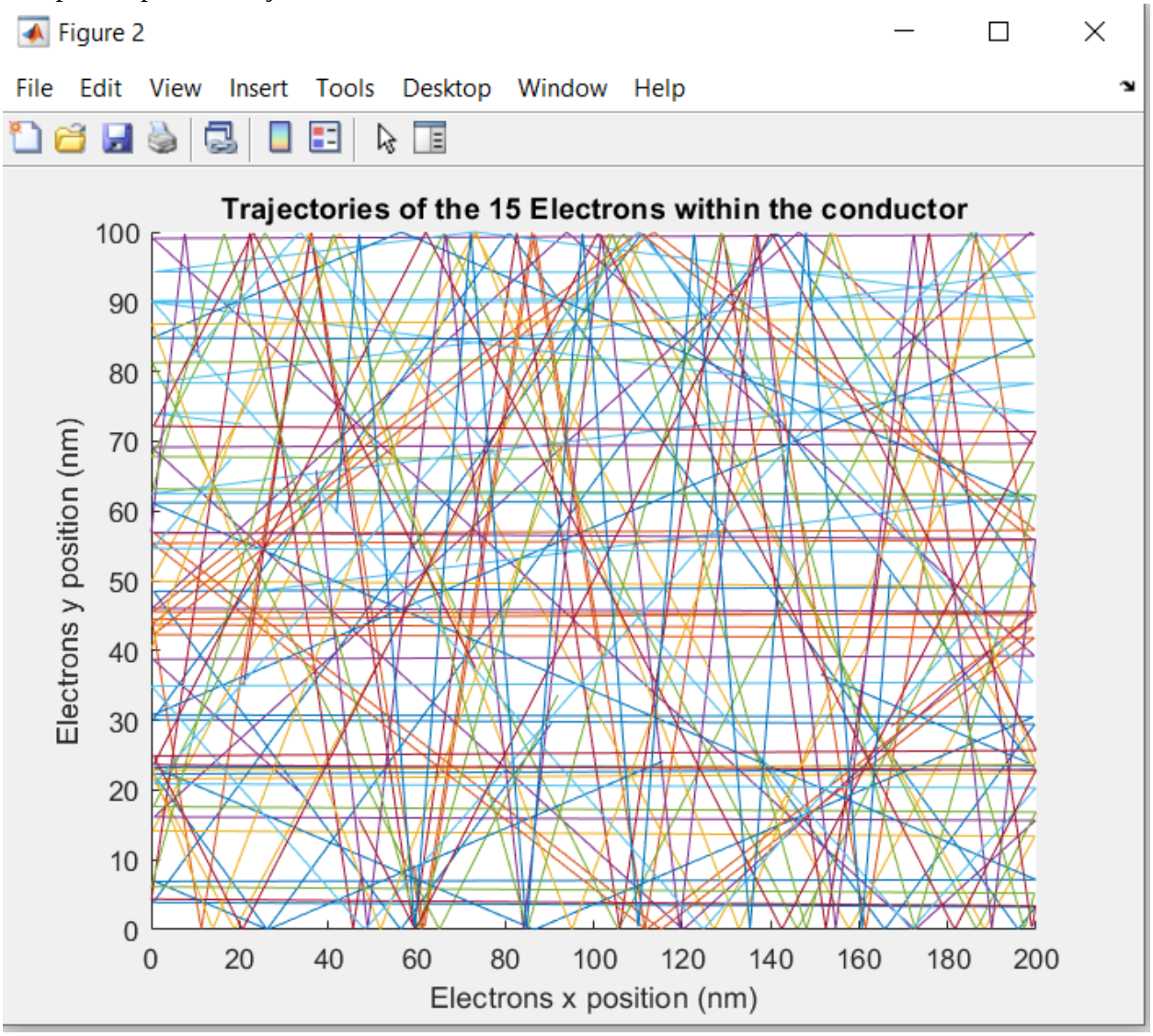
MFP = τmn * Vth = 3.7404×10^{-8} m

c)

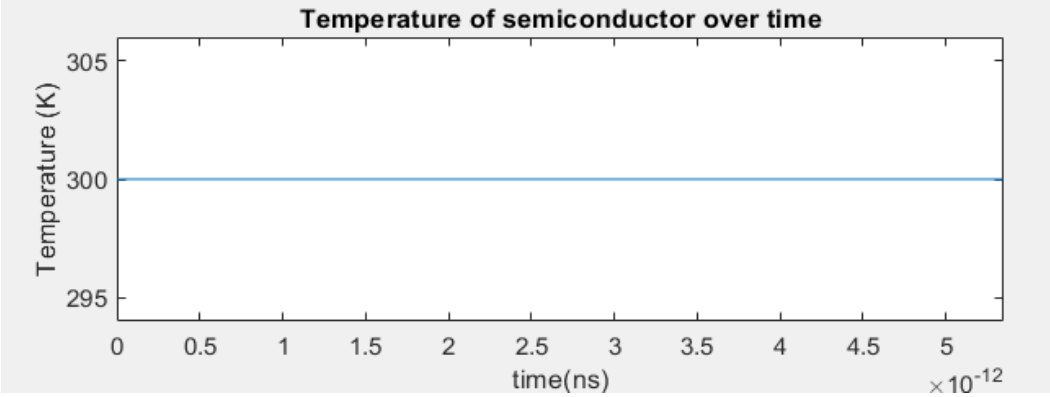
i. A simulation of the particles was first created. An end picture of the the simulation is below:



2-D plot of particle trajectories:



ii. Temperature plot



Code Used for Q1:

```
close all;
clc
%Kwabena Gyasi Bawuah
%101048814
%UNTITLED Summary of this function goes here
%   Detailed explanation goes here
%electron spec
 global C

    addpath ../geom2d/geom2d

    C.q_0 = 1.60217653e-19;             % electron charge
    C.hb = 1.054571596e-34;             % Dirac constant
    C.h = C.hb * 2 * pi;                    % Planck
constant
    C.m_0 = 9.10938215e-31;             % electron mass
    C.kb = 1.3806504e-23;               % Boltzmann
constant
    C.eps_0 = 8.854187817e-12;          % vacuum
permittivity
    C.mu_0 = 1.2566370614e-6;           % vacuum
permeability
    C.c = 299792458;                    % speed of light
    C.g = 9.80665; %metres (32.1740 ft) per s²

    T = 300;
    k = 1.38e-23;
    mn = 0.26*C.m_0; %effective mass
    tmn = 0.2e-12;    % Mean time between collisions
```

```
    vth = sqrt((2*C.kb*T)/mn);% Thermal velocity

    freepath = vth*tmn   % mean free path

    ConductorL = 200e-9;
    ConductorW = 100e-9;

    dpoints = 5e4;
    ecount = 15; %the number of electron to show on plot

    Step= ConductorW/vth/100;
    sims = 1000;

%     Xpos = rand(1,ecount).*ConductorW;
%     Ypos = rand(1,ecount).*ConductorL;
    traj=zeros(sims,ecount*2);
    temp=zeros(sims, 1);
    deltaT = 1e-9/vth;

    %to bring in the robotics system toolbox in order to
use state
    %declare initial state
    for i = 1: dpoints
        angle = rand*2*3.14;
        state(i,:)= [ConductorL*rand ConductorW*rand
vth*cos(angle) vth*sin(angle)];
    end
    %initial array of temp
    temp(:,1)= 300;
    %to iterate over 1000 time steps for plot points
    for i = 1 :sims
    state(:,1:2)=state(:,1:2)+Step.*state(:,3:4);
    %specifying the particles reactions at boundary
    out = state(:,1)> ConductorL;
    state(out,1) = state(out,1)-ConductorL;

    out = state(:,2) < 0;
    state(out,2) = -state(out,2);
    state(out,4) = -state(out,4);

    out = state(:,2)> ConductorW;
    state(out,2)= 2 * ConductorW - state(out,2);
    state(out,4)= -state(out,4);
```

```
    out = state(:,1)< 0;
    state(out,1)=state(out,1)+ ConductorL;

    %iterating over array of visible electrons
    for out = 1:ecount
        traj(i, (2 * out):(2 * out + 1)) = state(out, 1 :
2);
    end

    %plot on every 5 iteration steps
     if mod(i,5)==0
        figure (1)
        subplot(2,1,1);
        plot(state(1:ecount,1)./1e-9,state(1:ecount,2)./1e-
9,'o')
        xlim([0 ConductorL/1e-9])
        ylim([0 ConductorW/1e-9])
        xlabel('Electrons x position (nm)')
        ylabel('Electrons y position (nm)')
        title('Simulation of 15 Electrons with constant
velocity')

        subplot(2,1,2);
        plot(Step*(0:i-1),temp(1:i));
        xlim([0 Step*sims])
        ylim([min(temp)*0.98 max(temp)*1.02]);
        xlabel('time(ns)');
        ylabel('Temperature (K)');
        title('Temperature of semiconductor over time');
     end
    end

    %iterate over the visible particles and show thier
    %paths
    figure(2)
    hold on;
    xlim([0 ConductorL/1e-9]);
    ylim([0 ConductorW/1e-9]);
    xlabel('Electrons x position (nm)');
    ylabel('Electrons y position (nm)');
    title('Trajectories of the 15 Electrons within the
conductor');
    for i = 1: ecount
    plot(traj(:,i*2)./1e-9, traj(:,i*2+1)./1e-9, '-');
```

```
end
```

Collisions with Mean Free Path (MFP):

Enhancements:

Conclusion: