Integrated electron density for double gate MOS

Assignment #8

20202010 Hyunsuk Shin

In this assignment, we solve the Poisson equation by Newton-Raphson method. The figure 1 shows our sample structure.

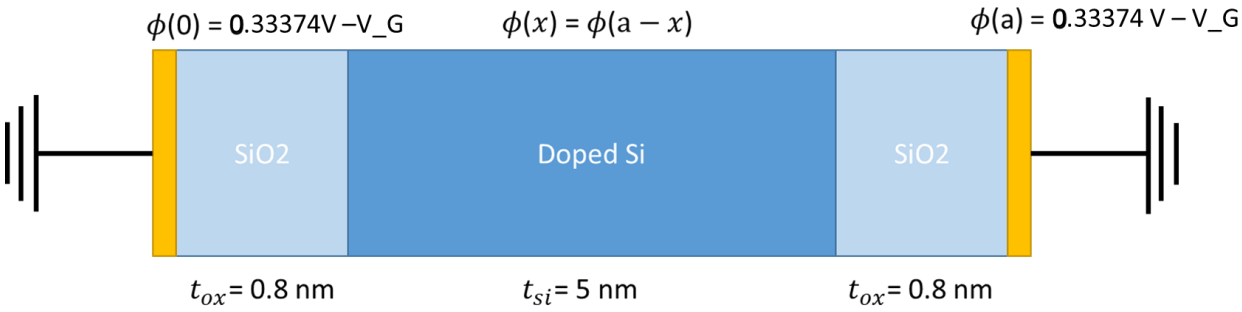

Figure 1. Schematic image for double gate MOS

For this assignment, the gate voltage varies from 0 to 1V. A electrostatic potential ϕ will be calculated first with respect to different gate voltage. Then, the electron density through the semiconducting layer will be calculated. Finally, we will get an integration of the electron density through the channel region.

To solve this problem by Newton-Raphson method, we should set the Jacobian matrix and residue vector carefully. The figure 2 shows the Jacobian and residue for my code.

$$J\delta\phi = -r$$

```
    for ii = 2 : N-1
%%%%%%%%%%%%%%%%%Laplacian part%%%%%%%%%%%%%%%%%%%%%%%%
            if (ii < j1 || ii>j2)
                res(ii,1) = eps_ox*phi(ii+1,gate) - 2*eps_ox*phi(ii,gate) + eps_ox*phi(ii-1,gate);
                Jaco(ii,ii-1) = eps_ox; Jaco(ii,ii) = -2*eps_ox; Jaco(ii,ii+1) = eps_ox;
            elseif (ii==j1)
                res(ii,1) = eps_si*phi(ii+1,gate) - (eps_si+eps_ox)*phi(ii,gate) + eps_ox*phi(ii-1,gate) ;
                Jaco(ii,ii-1) = eps_ox; Jaco(ii,ii) = -(eps_ox+eps_si); Jaco(ii,ii+1) = eps_si;
            elseif (ii==j2)
                res(ii,1) = eps_ox*phi(ii+1,gate) - (eps_si+eps_ox)*phi(ii,gate) + eps_si*phi(ii-1,gate);
                Jaco(ii,ii-1) = eps_si; Jaco(ii,ii) = -(eps_ox+eps_si); Jaco(ii,ii+1) = eps_ox;
            else
                res(ii,1) = eps_si*phi(ii+1,gate) - 2*eps_si*phi(ii,gate) + eps_si*phi(ii-1,gate);
                Jaco(ii,ii-1) = eps_si; Jaco(ii,ii) = -2*eps_si; Jaco(ii,ii+1) = eps_si;
            end
        end
%%%%%%%%%%%%%%%%%charge part%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for ii = j1:j2
            if(ii==j1)
                res(ii,1) = res(ii,1) - coef*(Nacc+ni*exp(phi(ii,gate)/V_T))*0.5;
                Jaco(ii,ii) = Jaco(ii,ii) - coef*ni*exp(phi(ii,gate)/V_T)/V_T*0.5;
            elseif (ii==j2)
                res(ii,1) = res(ii,1) - coef*(Nacc+ni*exp(phi(ii,gate)/V_T))*0.5;
                Jaco(ii,ii) = Jaco(ii,ii) - coef*ni*exp(phi(ii,gate)/V_T)/V_T*0.5;
            else
                res(ii,1) = res(ii,1) - coef*(Nacc+ni*exp(phi(ii,gate)/V_T));
                Jaco(ii,ii) = Jaco(ii,ii) - coef*ni*exp(phi(ii,gate)/V_T)/V_T;
            end
        end

        update = Jaco\(-res);
        phi(:,gate) = phi(:,gate) + update;
    end
```

Figure 2. Jacobian matrix and residue vectors

Once we get the all electrostatic potential, now we can calculate the electron density and integrated electron density. The figure 3 shows my code for electron densities.

```
for ii = j1:j2   %{ Semiconducting layer 에서 존재하는 carrier density %}
    elec(ii,gate) = ni*exp(phi(ii,gate)/V_T);
    if (ii==j1 || ii==j2)
        int_elec(gate,1) = int_elec(gate,1) + Deltax/2*elec(ii,gate);   %{ 경계에서의 적분이라 ½ 를 곱해주었음 %}
    else
        int_elec(gate,1) = int_elec(gate,1) + Deltax/2*elec(ii,gate);
    end
end
```

Results

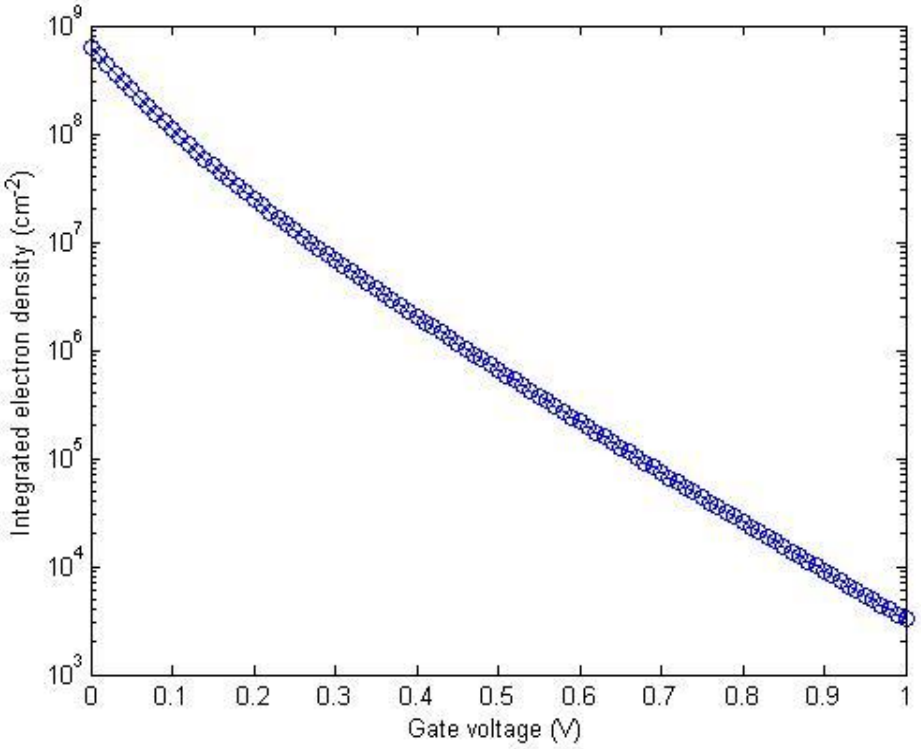

Figure 4 Integrated electron density – Gate voltage graph.