Lecture18

Sung-Min Hong (smhong@gist.ac.kr)

Semiconductor Device Simulation Lab.

School of Electrical Engineering and Computer Science

Gwangju Institute of Science and Technology

GIST Lecture on November 4, 2020

Our achievement

- We can now solve the drift-diffusion equation.
  - However, it has been tested only at the equilibrium condition.
- Today's goal
  - Apply our code to nonequilibrium cases.
  - Calculate the current as a function of the voltage.

Implementation (1)

- The bias voltage is considered.

```
res = zeros(2*N,1);
Jaco = sparse(2*N,2*N);
res(1,1) = phi(1,1) - thermal*log(Ndon(1,1)/ni);
Jaco(1,1) = 1.0;
for ii=2:N-1
   res(2*ii-1,1) = eps_si*(phi(ii+1,1)-2*phi(ii,1)+phi(ii-1,1)) + coef*(Ndon(ii,1)-
elec(ii,1));
   Jaco(2*ii-1,2*ii+1) =    eps_si;
   Jaco(2*ii-1,2*ii-1) = -2*eps_si;
   Jaco(2*ii-1,2*ii-3) =    eps_si;
   Jaco(2*ii-1,2*ii  ) = -coef;
end
res(2*N-1,1) = phi(N,1) - thermal*log(Ndon(N,1)/ni) – V_applied;
Jaco(2*N-1,2*N-1) = 1.0;
```

Implementation (2)

- The continuity equation (No change at all)

```
for ii=1:N-1 % edge-wise construction
   n_av = 0.5*(elec(ii+1,1)+elec(ii,1));
   dphidx = (phi(ii+1,1)-phi(ii,1))/Deltax;
   delecdx = (elec(ii+1,1)-elec(ii,1))/Deltax;
   Jn = n_av * dphidx – thermal * delecdx;
   res(2*ii,1) = res(2*ii,1) + Jn;
   Jaco(2*ii,2*ii+2) = Jaco(2*ii,2*ii+2) + 0.5*dphidx – thermal / Deltax;
   Jaco(2*ii,2*ii  ) = Jaco(2*ii,2*ii  ) + 0.5*dphidx + thermal / Deltax;
   Jaco(2*ii,2*ii+1) = Jaco(2*ii,2*ii+1) + n_av / Deltax;
   Jaco(2*ii,2*ii-1) = Jaco(2*ii,2*ii-1) - n_av / Deltax;
   res(2*ii+2,1) = res(2*ii+2,1) - Jn;
   Jaco(2*ii+2,2*ii+2) = Jaco(2*ii+2,2*ii+2) - 0.5*dphidx + thermal / Deltax;
   Jaco(2*ii+2,2*ii  ) = Jaco(2*ii+2,2*ii  ) - 0.5*dphidx - thermal / Deltax;
   Jaco(2*ii+2,2*ii+1) = Jaco(2*ii+2,2*ii+1) - n_av / Deltax;
   Jaco(2*ii+2,2*ii-1) = Jaco(2*ii+2,2*ii-1) + n_av / Deltax;
end
```

Implementation (3)

- Overall structure

```
for bias=0:10
   V_applied = 0.05 * bias;
   for newton=1:10
      (Jaco and res are constructed here. Copy-and-paste)
      update = Jaco \ (-res);
      phi = phi + update(1:2:2*N-1,1);
      elec = elec + update(2:2:2*N,1);
      norm(update(1:2:2*N-1,1),inf)
   end
end
```

Terminal current

- We want to calculate the terminal current.
  - Remember the convention for any terminal current.
  - "Incoming current density contributes positively."
  - Therefore, for the right contact located at $x = 600$ nm, the x-component of $\mathbf{J}_n$ contributes negatively.

$$J_{n,x} = -q\mu_n \left(n\frac{d\phi}{dx} - V_T \frac{dn}{dx} \right)$$

  - Finally, the *terminal current per unit area* (for the right contact) is

$$\frac{I_{Right}}{Area} = q\mu_n \left(n\frac{d\phi}{dx} - V_T \frac{dn}{dx} \right)$$

Homework#16

- Due: AM08:00, November 9 (Next Monday)
- Problem#1
  - Calculate the IV curve of the long and short structures.