Computational Microelectronics HW.15

EECS, 20204003

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1. $N^{+}NN^{+}$ Device , Drift-Diffusion calculation

1) Numerical Expression

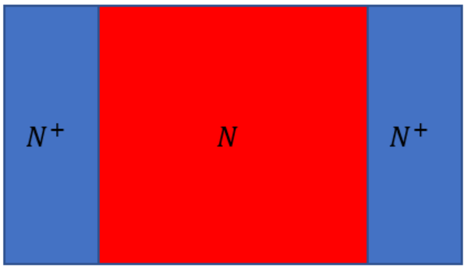

Fig. 1 $N^{+}NN^{+}$ Device

위의 소자는 이번 과제에서 사용할 Model이다. 총 길이가 600nm일 때는 100nm, 400nm,100nm 이고, 도핑 농도는 $5\times10^{17}cm^{-3}, 2\times10^{15}cm^{-3}, 5\times10^{17}cm^{-3}$이다. 60nm일 때는 10nm, 40nm, 10nm이고, 도핑 농도는 $5\times10^{19}cm^{-3}, 2\times10^{17}cm^{-3}, 5\times10^{19}cm^{-3}$이다.

지난번 PN junction과 달리, 전자 농도가 매우 크므로, hole 농도는 고려하지 않아도 될 것이다.

residue 함수는 아래와 같다.

$$\boldsymbol{r_{2i-1}} = K_{si}(\varphi_{i+1} - 2\varphi_i + \varphi_{i-1}) + (\Delta x)^2 q \frac{1}{\varepsilon_0} N_{dop}^{+} - (\Delta x)^2 q \frac{1}{\varepsilon_0} \mathrm{n_i}$$

$$\boldsymbol{r_{2i}} = \frac{n_{i+1}+n_i}{2}\frac{\phi_{i+1}-\phi_i}{\Delta x} - \frac{k_B T}{q}\frac{n_{i+1}-n_i}{\Delta x} - \frac{n_i+n_{i-1}}{2}\frac{\phi_i-\phi_{i-1}}{\Delta x} + \frac{k_B T}{q}\frac{n_i-n_{i-1}}{\Delta x}$$

각각에 해당하는 Jacobian 요소 값들은 아래와 같다.

$$J_{2i-1,2i+1} = \frac{\partial r}{\partial \phi_{i+1}} = \mathrm{K_{si}} \qquad J_{2i-1,2i} = \frac{\partial r}{\partial n_i} = -(\Delta x)^2 q \frac{1}{\varepsilon_0} \qquad J_{2i-1,2i-1} = \frac{\partial r}{\partial \phi_i} = -2\mathrm{K_{si}} \qquad J_{2i,2i-3} = \frac{\partial r}{\partial\, \phi_{i-1}} = \mathrm{K_{si}}$$

$$J_{2i,2i+2} = \frac{\partial r}{\partial n_{i+1}} = \frac{1}{2}\frac{\phi_{i+1}-\phi_i}{\Delta x} - \frac{k_B T}{q}\frac{1}{\Delta x} \qquad J_{2i,2i+1} = \frac{\partial r}{\partial \phi_{i+1}} = \frac{n_{i+1}+n_i}{2}\frac{1}{\Delta x}$$

$$J_{2i,2i} = \frac{\partial r}{\partial n_i} = \frac{1}{2}\frac{\phi_{i+1}-\phi_i}{\Delta x} + 2\frac{k_B T}{q}\frac{1}{\Delta x} - \frac{1}{2}\frac{\phi_i-\phi_{i-1}}{\Delta x} \qquad J_{2i,2i-1} = \frac{\partial r}{\partial \phi_i} = -\frac{n_{i+1}+n_i}{2}\frac{1}{\Delta x} - \frac{n_i+n_{i-1}}{2}\frac{1}{\Delta x}$$

$$J_{2i,2i-2} = \frac{\partial r}{\partial n_{i-1}} = -\frac{1}{2}\frac{\phi_i-\phi_{i-1}}{\Delta x} - \frac{k_B T}{q}\frac{1}{\Delta x} \qquad J_{2i,2i-3} = \frac{\partial r}{\partial \phi_{i-1}} = \frac{n_i+n_{i-1}}{2}\frac{1}{\Delta x}$$

이를 이용하여 self-consistent loop를 형성하고, 전자 농도를 구한다.

2) Results

A) Electron Density when total length is 600nm.

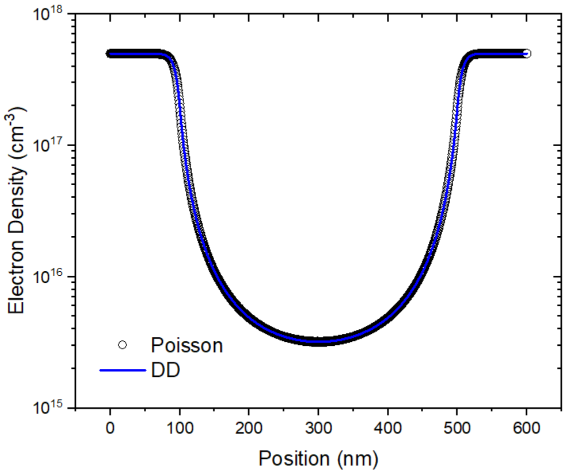

Fig 2. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 0.5nm spacing.

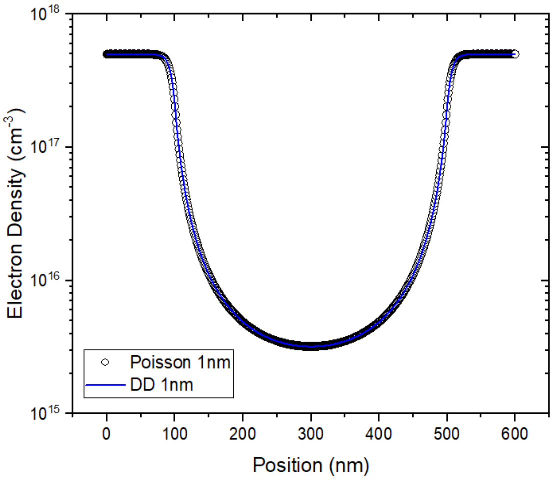

Fig 3. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 1nm spacing.

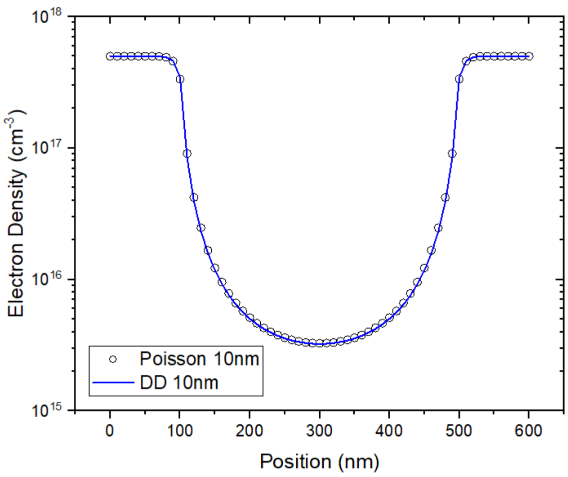

Fig 4. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 10nm spacing.

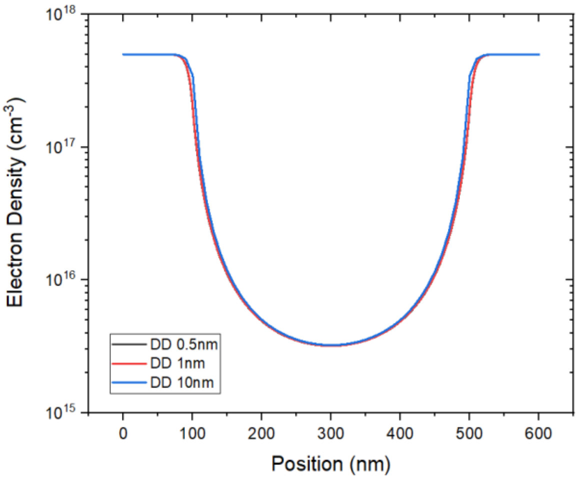

Fig 5. Position vs. log scaled electron density graph. Each of them is solved by Poisson and Continuity equations with different spacing.

총 길이가 600nm 일 때, spacing을 다르게 하여 non-linear Poisson과 Poisson-Continuity equation을 풀었을 때 결과이다. 대부분의 결과에서 비슷하게 나왔으며, 다만 spacing이 커지면서, 그래프에서는 약간씩 달라지는 모습을 보였다.

B) Electron Density when total length is 60nm.

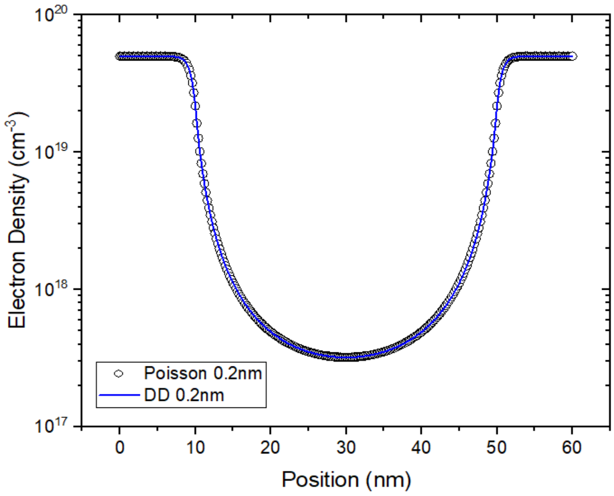

Fig 6. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 0.2nm spacing.

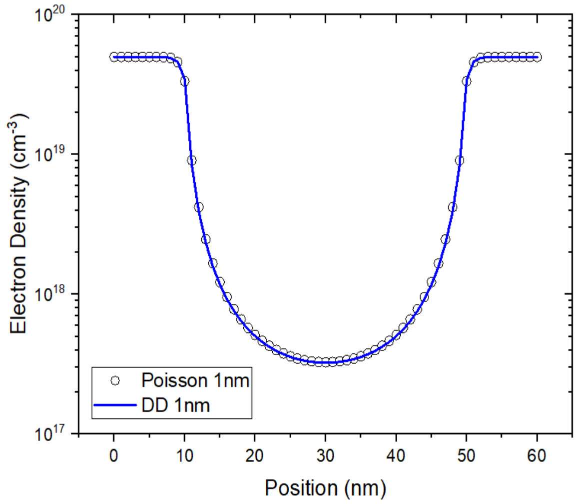

Fig 7. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 1nm spacing.

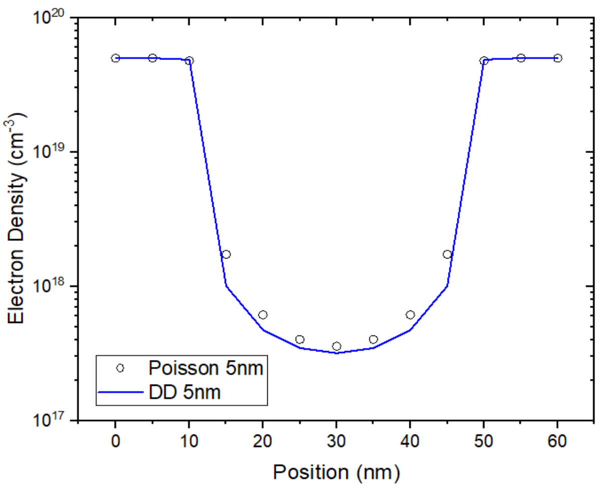

Fig 8. Position vs. log scaled electron density graph. Blue line represents the electron density which is solved by Drift-Diffusion method. Black circles are results from non-linear Poisson Solver. Both of them are solved with 5nm spacing.

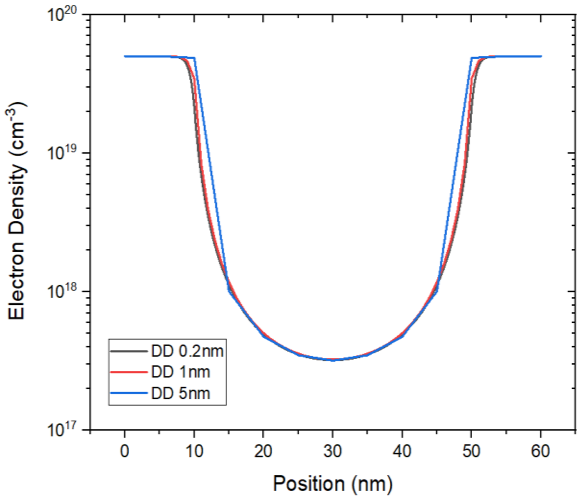

Fig 9. Position vs. log scaled electron density graph. Each of them is solved by Poisson and Continuity equations with different spacing.

총 길이가 60nm 일 때, spacing을 다르게 하여 non-linear Poisson과 Poisson-Continuity equation을 풀었을 때 결과이다. Spacing이 5nm일 때는 값이 잘 맞지 않는 것을 확인할 수 있다.

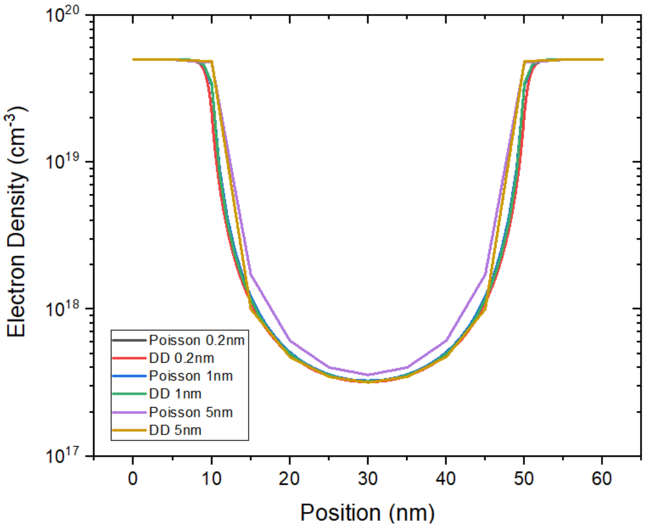

Fig 10. Position vs. log scaled electron density graph. Each of them is solved by non-linear Poisson equation and Poisson-Continuity equation with different spacing.

특히 위와 같이 여러 개의 그림을 같이 그렸을 때, non-linear Poisson의 결과 값이 Spacing이 클 때 값이 다름을 확인할 수 있다.