Computational Microelectronics HW.6

EECS, 20204003

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1. Double Gate FET

1) Numerical Expression

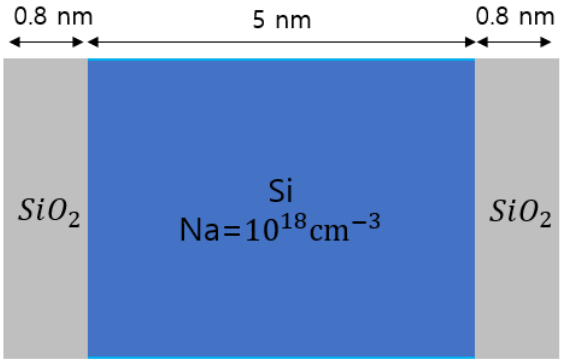

Fig. 1 Double Gate FET

$$\mathbf{A}=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \epsilon_1 & -2\epsilon_1 & \epsilon_1 & 0 & 0 \\ 0 & \epsilon_1 & -\epsilon_2-\epsilon_1 & \epsilon_2 & 0 \\ 0 & 0 & \epsilon_2 & -2\epsilon_2 & \epsilon_2 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix},$$

$$b(ii,1)=(\Delta x)^2 \frac{qN_{accpetor}}{\varepsilon_0} \quad \text{(on Silicon region)}$$

$$b(ii,1)=(\Delta x)^2 \frac{qN_{accpetor}}{2\varepsilon_0} \quad \text{(at Si-Oxide interfaces)}$$

$$b(ii,1)=0 \quad \text{(on Oxide region)}$$

$$b(1,1)=0.33374+V_g \quad \text{(at Metal-Oxide interface)}$$

$$b(N,1)=0.33374+V_g \quad \text{(at Oxide-Metal interface)}$$

HW6 is using same model that we used in HW5. However, in HW6, gate contact should be considered. As a result, electrostatic potential is not zero at Metal-Oxide interface, Moreover, more gate voltage will be applied to device. Voltage step will be 0.1V. The electron density can be calculated by using equation below. After that, Poisson equation will be solved again using electron density.

$$n = n_{int}\exp\left(\frac{q\phi}{k_B T}\right)$$

2) Results

a) Electrostatic Potential before updated $(V_{gs} = 0V, 0.5V, 1V)$

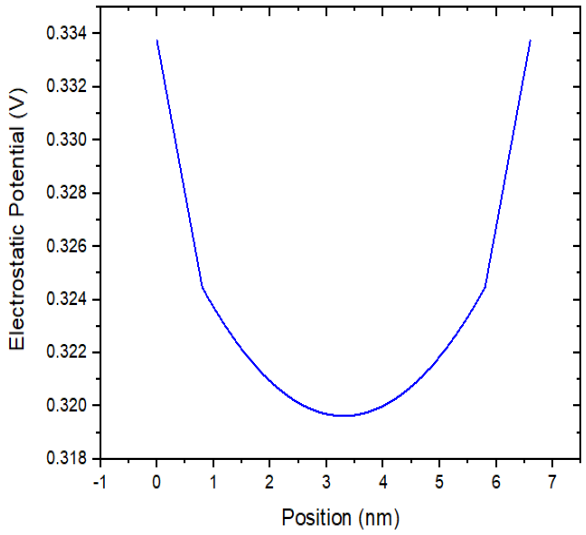

Fig 2. Position vs. Potential graph which is solved numerically when $V_{gs} = 0V$.

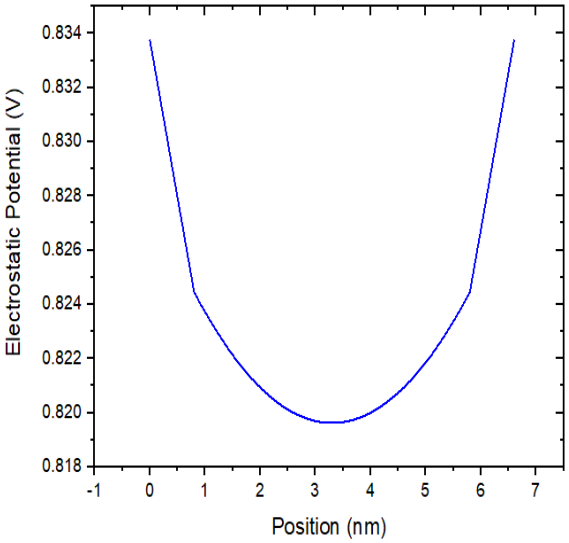

Fig 3. Position vs. Potential graph which is solved numerically when $V_{gs} = 0.5V$.

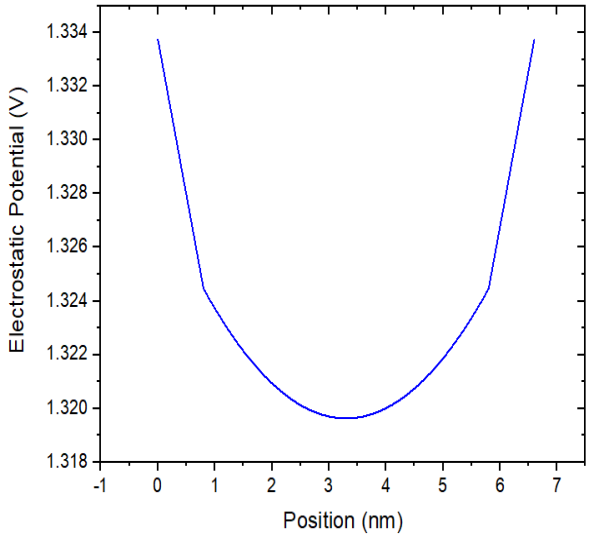

Fig 4. Position vs. Potential graph which is solved numerically when $V_{gs} = 1V$.

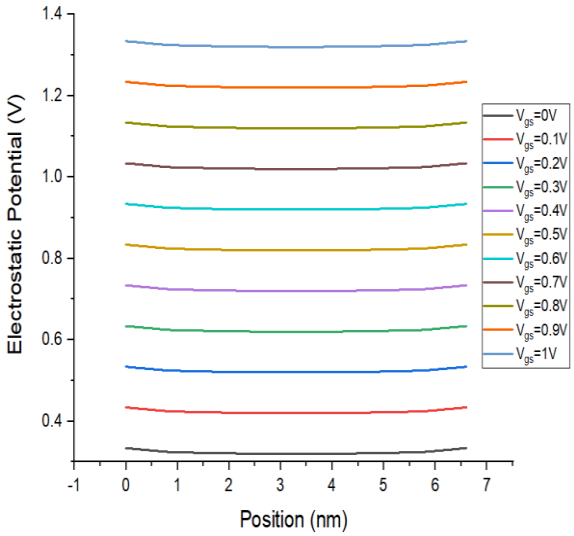

Fig 5. Position vs. Potential graph which is solved numerically when $V_{gs} = 0$~$1V$.

Compare to HW5 whose gate bias 0V, HW6 has gate bias higher than zero. Moreover, the gate work function which is 4.3eV is considered.

b) Electron Density ($\mathbf{V_{gs} = 0V, 0.1V, 0.2V, 1V}$)

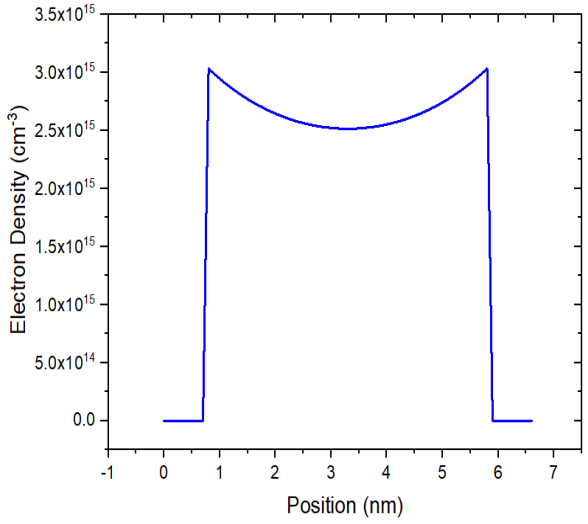

Fig 6. Position vs. Electron Density graph which is solved numerically when $V_{gs} = 0V$.

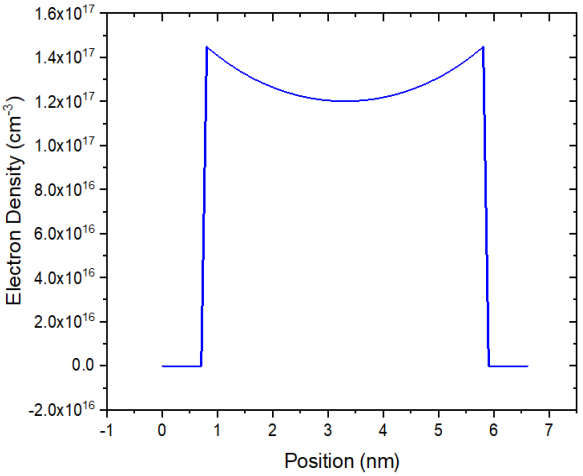

Fig 7. Position vs. Electron Density graph which is solved numerically when $V_{gs} = 0.1V$.

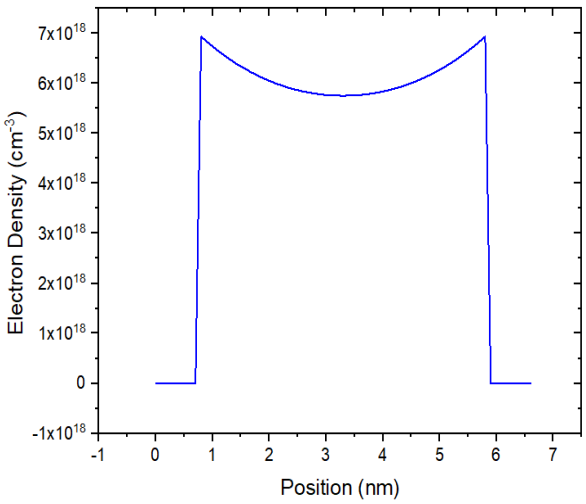

Fig 8. Position vs. Electron Density graph which is solved numerically when $V_{gs} = 0.2V$.

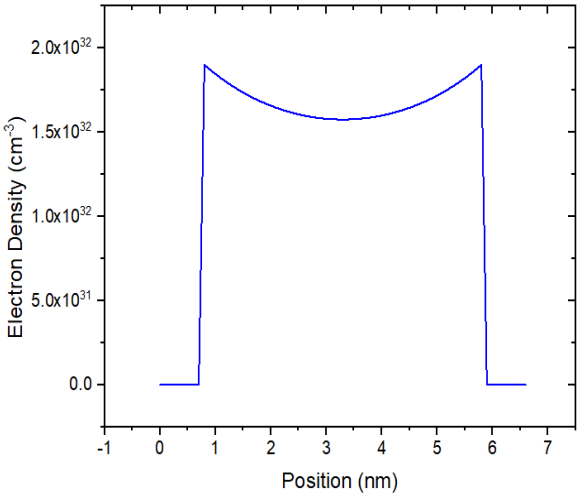

Fig 9. Position vs. Electron Density graph which is solved numerically when $V_{gs} = 1V$

When gate bias is about 0.1~0.2V, electron density exceeds the acceptor concentration which is $10^{18}\mathrm{cm}^{-3}$. If more voltage is applied to 1V, electron density is more than $10^{32}\mathrm{cm}^{-3}$ which cannot be realistic solution.

3) **Potential Vs. Potential updated. ($V_{gs} = 0V \sim 1V$)**

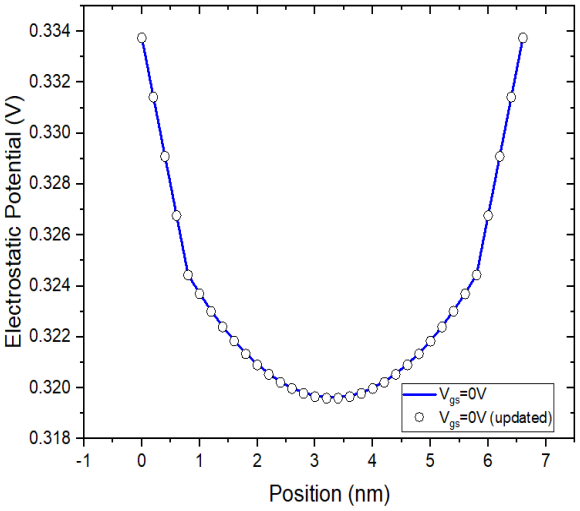

Fig 10. Potential and updated potential is compared when $V_{gs} = 0V$.

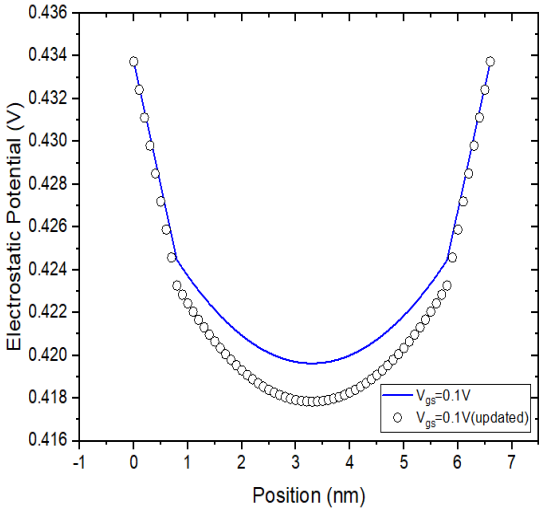

Fig 11. Potential and updated potential is compared when $V_{gs} = 0.1V$.

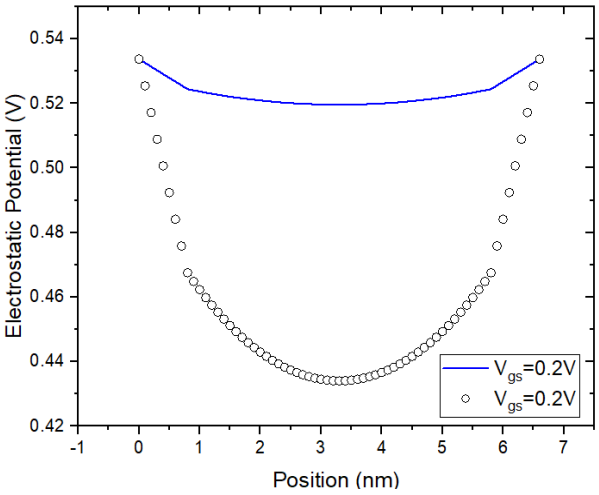

Fig 12. Potential and updated potential is compared when $V_{gs} = 0.2V$.

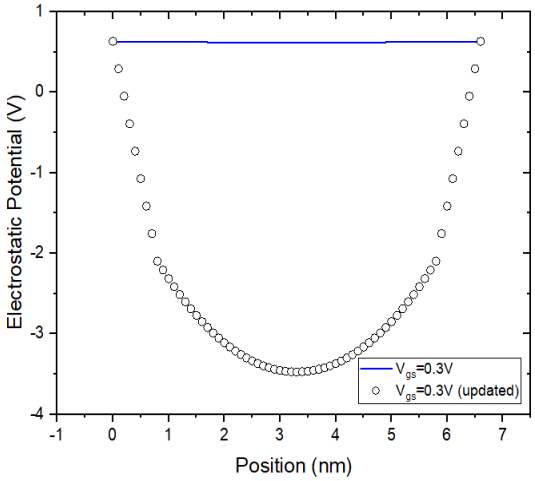

Fig 13. Potential and updated potential is compared when $V_{gs} = 0.3V$.

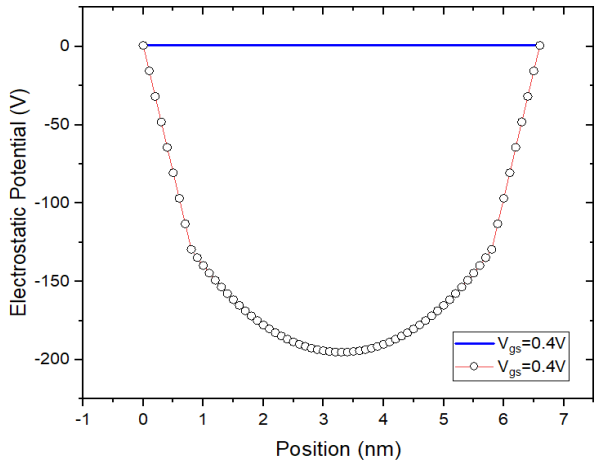

Fig 14. Potential and updated potential is compared when $V_{gs} = 0.4V$.

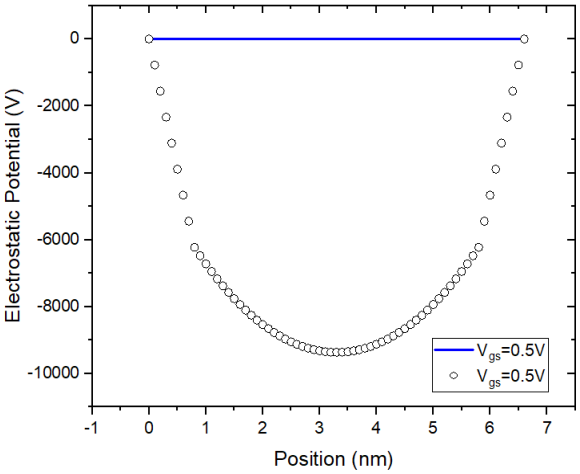

Fig 15. Potential and updated potential is compared when $V_{gs} = 0.5V$.

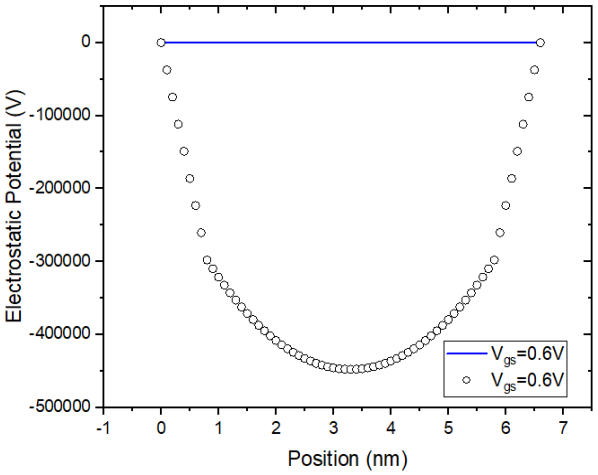

Fig 16. Potential and updated potential is compared when $V_{gs} = 0.6V$.

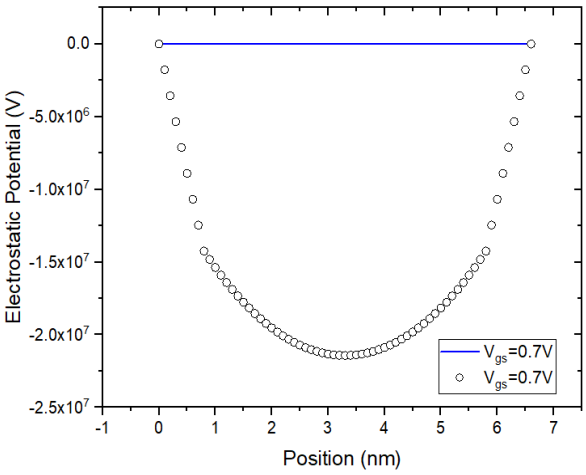

Fig 17. Potential and updated potential is compared when $V_{gs} = 0.7V$.

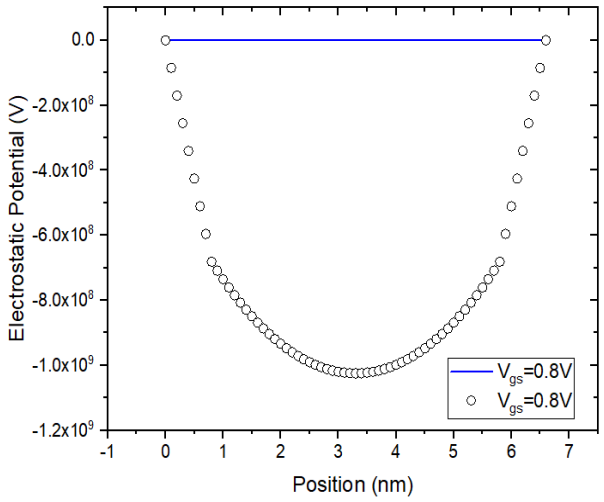

Fig 18. Potential and updated potential is compared when $V_{gs} = 0.8V$.

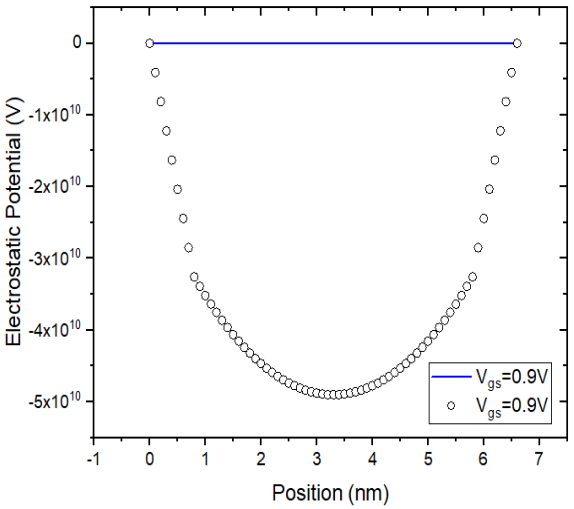

Fig 19. Potential and updated potential is compared when $V_{gs} = 0.9V$.

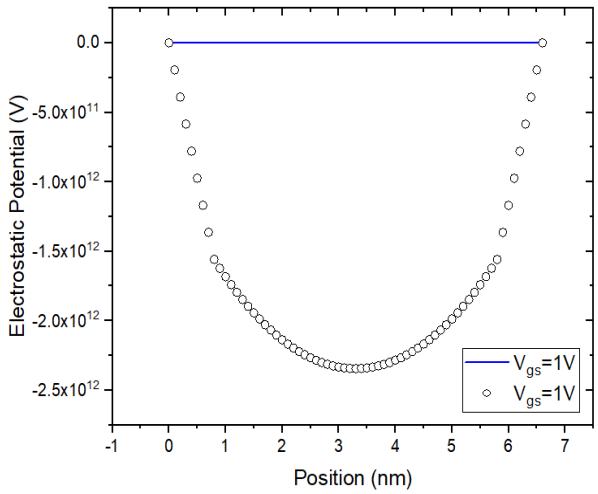

Fig 20. Potential and updated potential is compared when $V_{gs} = 1V$.

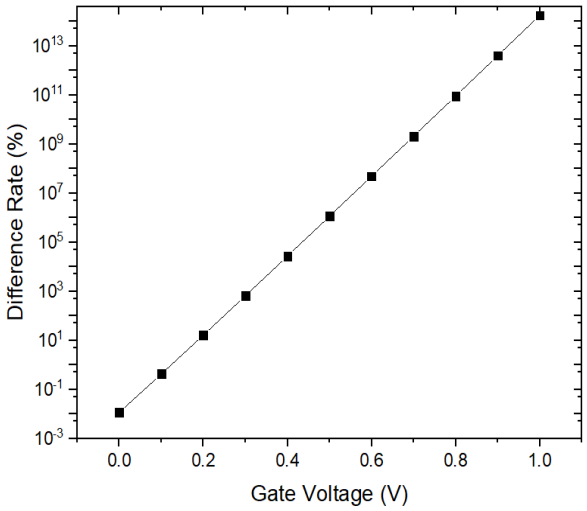

Fig 21. Gate voltage vs. difference rate which shows how much updated potential has changed from original potential.

$$\text{Difference rate}(\%) = \frac{|\phi_{\text{original}} - \phi_{\text{updated}}|}{\phi_{\text{original}}} \times 100$$

About 0.1V~0.2V, potential has very large difference with updated potential which is solved using electron density. As the gate bias increases, potential gets higher and when the gate bias reaches 1V, it becomes about -10^{12}. Fig. 21 shows that how much updated potential has changed from original potential. This result cannot be realistic self-consistent solution. Consequently, more methods should be used to treat this problem.