HW5 Ox-Si-Ox Poisson

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Poisson equation with fixed-source case. The net charge density here is $\rho(x) = qp(x) - qn(x) + qN_{dop}^{+}(x)$. We assume that all mobile carriers are depleted. Thus, the Poisson equation is,

$$\frac{d}{dx}\left[\epsilon(x)\frac{d}{dx}\phi(x)\right] = -qN_{dop}^{+}(x)$$

$\epsilon_{ox} = 3.9\epsilon_0$	$\epsilon_{si} = 11.7\epsilon_0$	$\epsilon_{ox} = 3.9\epsilon_0$

The thickness of oxide layer is 0.8nm, that of silicon is 5nm. The silicon layer is doped with p-type dopants. The dopant is negatively charged. $N_{dop}^{+} = -N_{acc}$. And we will consider three different values of $N_{acc} = 10^{17}, 10^{18}, 10^{19} cm^{-3}$.

Analytic solution.

We can divide the part of oxide and silicon.

$$Oxide\ part: \frac{d}{dx}\left[\epsilon_{ox}\frac{d}{dx}\phi_{ox}(x)\right] = 0, \qquad 0 < x < 0.8nm \ \&\ 5.8nm < x < 6.6nm$$

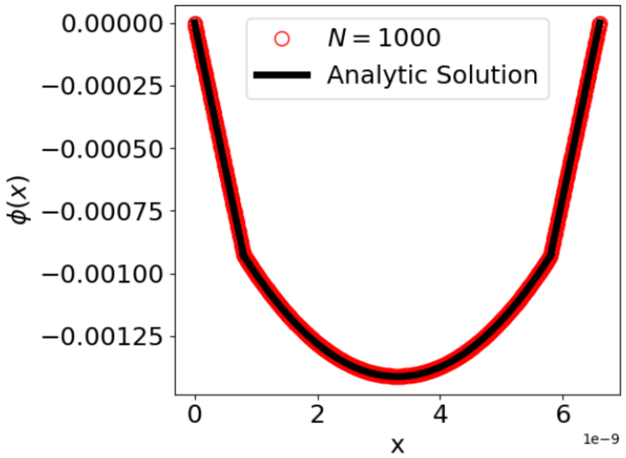
$$Silicon\ Part: \frac{d}{dx}\left[\epsilon_{si}\frac{d}{dx}\phi_{si}(x)\right] = qN_{acc}, \qquad 0.8nm < x < 5.8nm$$

Thus, the potential of the oxide would be linear and that of silicon would be quadratic. The quadratic solution has the form of $\phi_{si}(x) = \frac{1}{2}\frac{qN_{acc}}{\epsilon_{si}}(x-3.3)^2 + \phi_{min}$. The main problem is also at the interface where $x = 0.8nm, 5.8nm$. $\epsilon_{si}\frac{d\phi_{si}}{dx}_{x=0.8+} = \epsilon_{ox}\frac{d\phi_{ox}}{dx}_{x=0.8-}$. Therefore the potential at $x = 0.8nm$, $\phi(0.8) = -\frac{qN_{acc}0.8nm*5nm}{2\epsilon_{ox}}$. Now we could make analytic solution with above results which are :

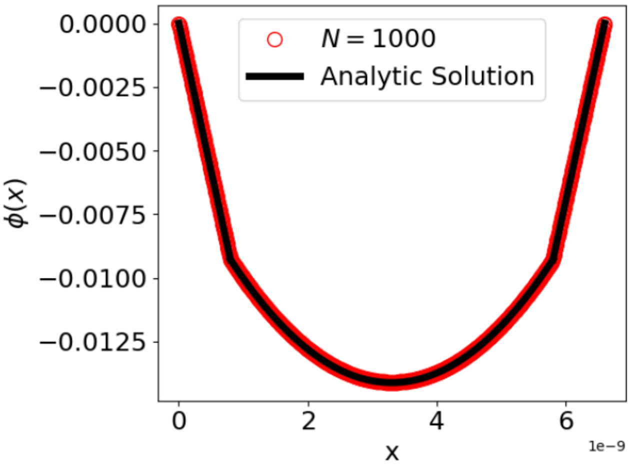
$$\begin{aligned}
\phi(x) = & -\frac{qN_{acc}}{2\epsilon_{ox}}5x, & 0 < x < 0.8nm \\
= & \frac{qN_{acc}}{2\epsilon_{si}}(x-3.3)^2 - \frac{qN_{acc}}{2}\left(\frac{0.8*5}{\epsilon_{ox}} + \frac{1}{\epsilon_{si}}\left(\frac{5}{2}\right)^2\right), & 0.8nm < x < 5.8nm \\
= & \frac{qN_{acc}}{2\epsilon_{ox}}5(x-6.6), & 5.8nm < x < 6.6nm
\end{aligned}$$

Result : we made 1000 by 1000 matrix to compute Poisson equation numerically.

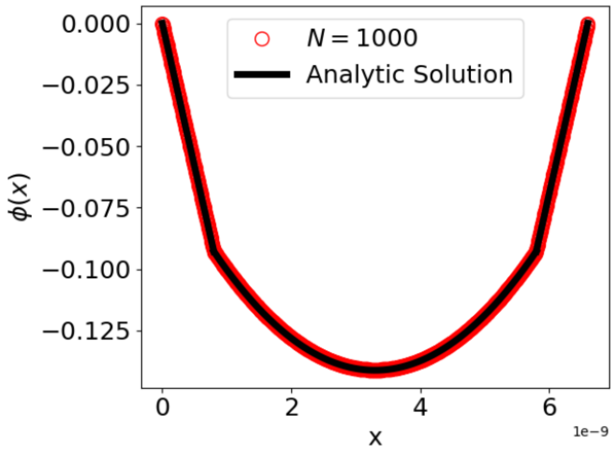
i) $N_{acc} = 10^{23} m^{-3}$



i) $N_{acc} = 10^{24} m^{-3}$



i) $N_{acc} = 10^{25} m^{-3}$



We could find that only the decimal points of ϕ are different by N_{acc}.