Computational Microelectronics
Lecture 14 Poisson Equation

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Nonlinear Poisson Equation

Nonlinear Poisson equation

- In the last lectures,
  - Laplace equation
  - Source-free Poisson equation
  - Poisson equation with fixed charges
  - We are now ready to solve the nonlinear Poisson equation:

$$\nabla \cdot [\epsilon(\mathbf{r})\nabla\phi] + qn_{int}(\mathbf{r}) \exp\left(-\frac{\phi(\mathbf{r})}{V_T}\right) - qn_{int}(\mathbf{r}) \exp\left(\frac{\phi(\mathbf{r})}{V_T}\right)$$
$$+ qN_{dop}^{+}(\mathbf{r}) = 0$$

Discretization

- When the nonlinear Poisson equation is considered,
  - We have additional terms:

$$\epsilon(x_{i+0.5})\frac{\phi(x_{i+1})-\phi(x_i)}{x_{i+1}-x_i}-\epsilon(x_{i-0.5})\frac{\phi(x_i)-\phi(x_{i-1})}{x_i-x_{i-1}}$$
$$+q\left(n_{int}\exp\left(-\frac{\phi(x_i)}{V_T}\right)-n_{int}\exp\left(\frac{\phi(x_i)}{V_T}\right)+N_{dop}^{+}(x_i)\right)(x_{i+0.5}$$

Double-gate example

- Electrostatic potential
  - Even when V_G = 0 V, the boundary values of ϕ are not 0 V. (0.33374 V in this example)

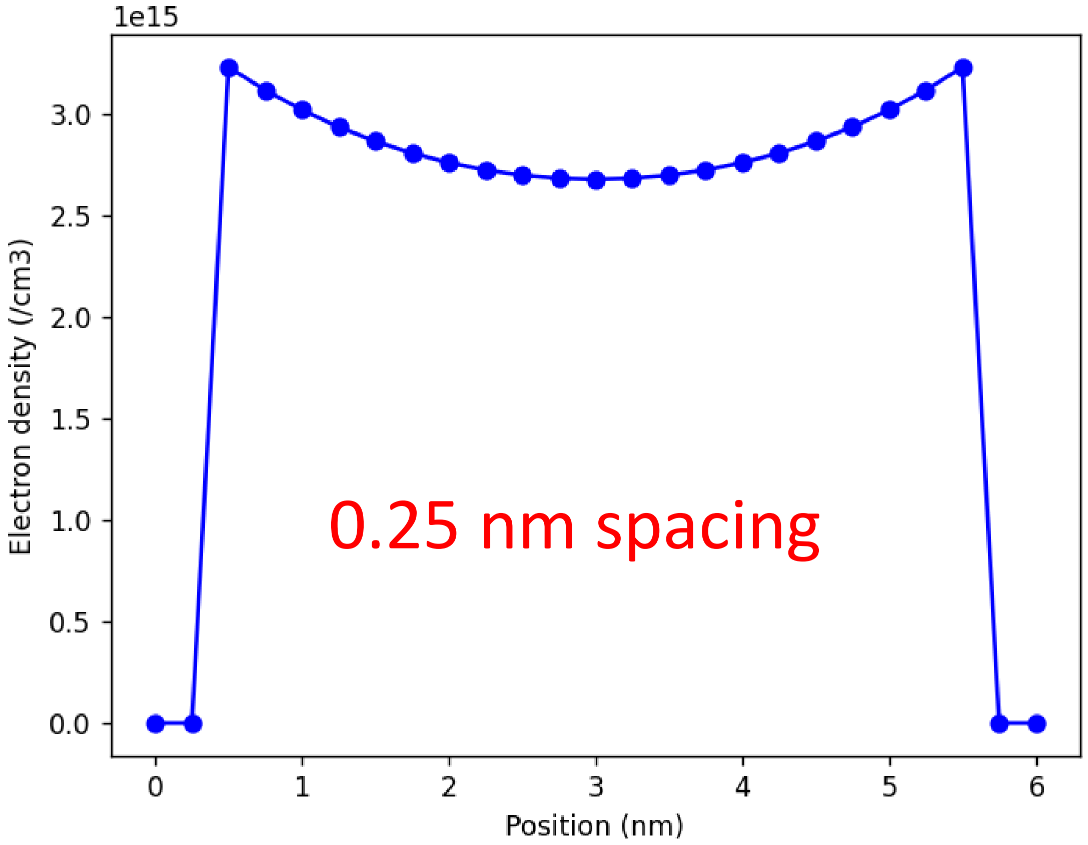
$$-q\phi + (E_{Vac} - E_i) = \Phi$$

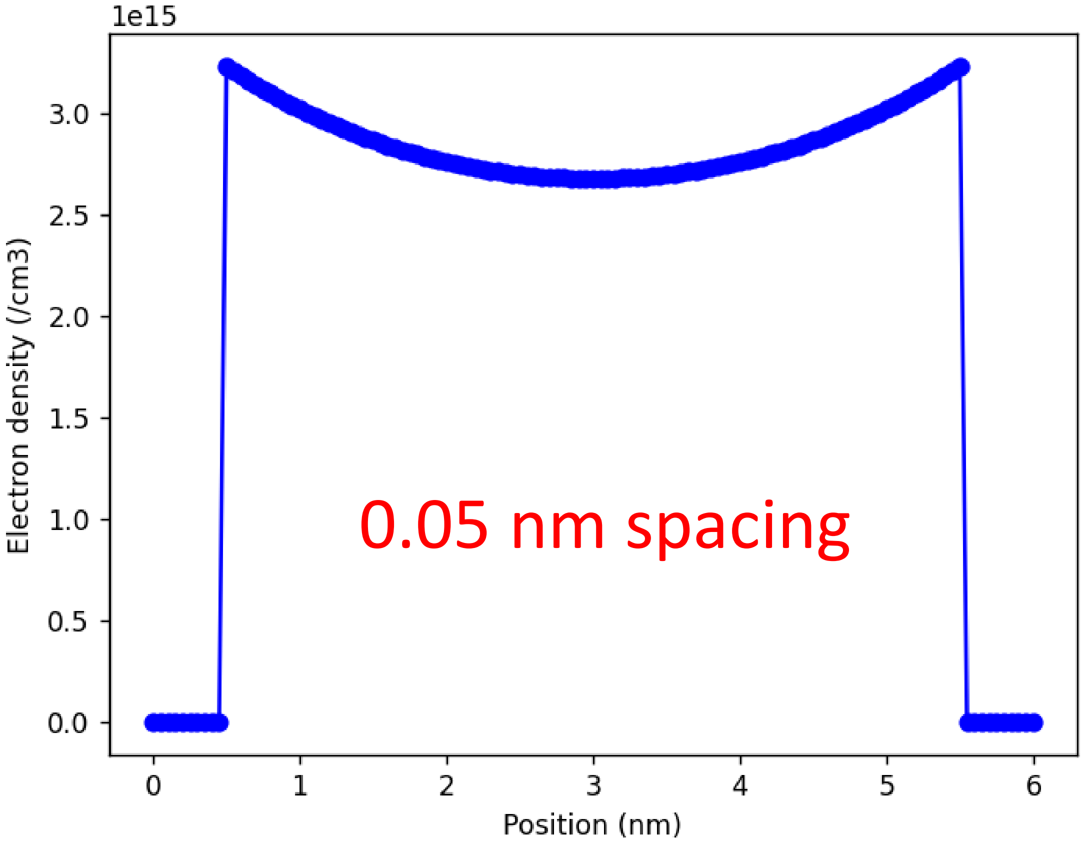
Workfunction

~ 4.63 eV in silicon

Its solution

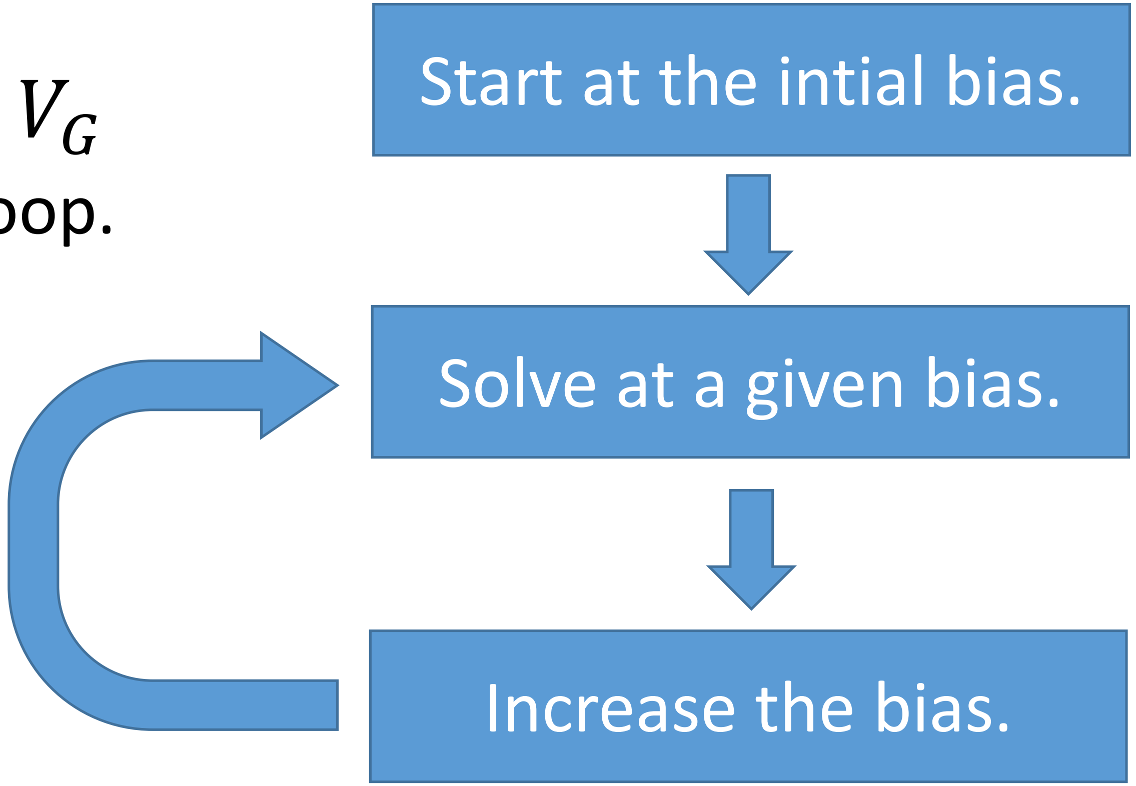
- Electron density at V_G = 0 V
  - Change the number of grid points.





Bias ramping

- Ramp up the gate voltage, V_G
  - Simply add an outermost loop.

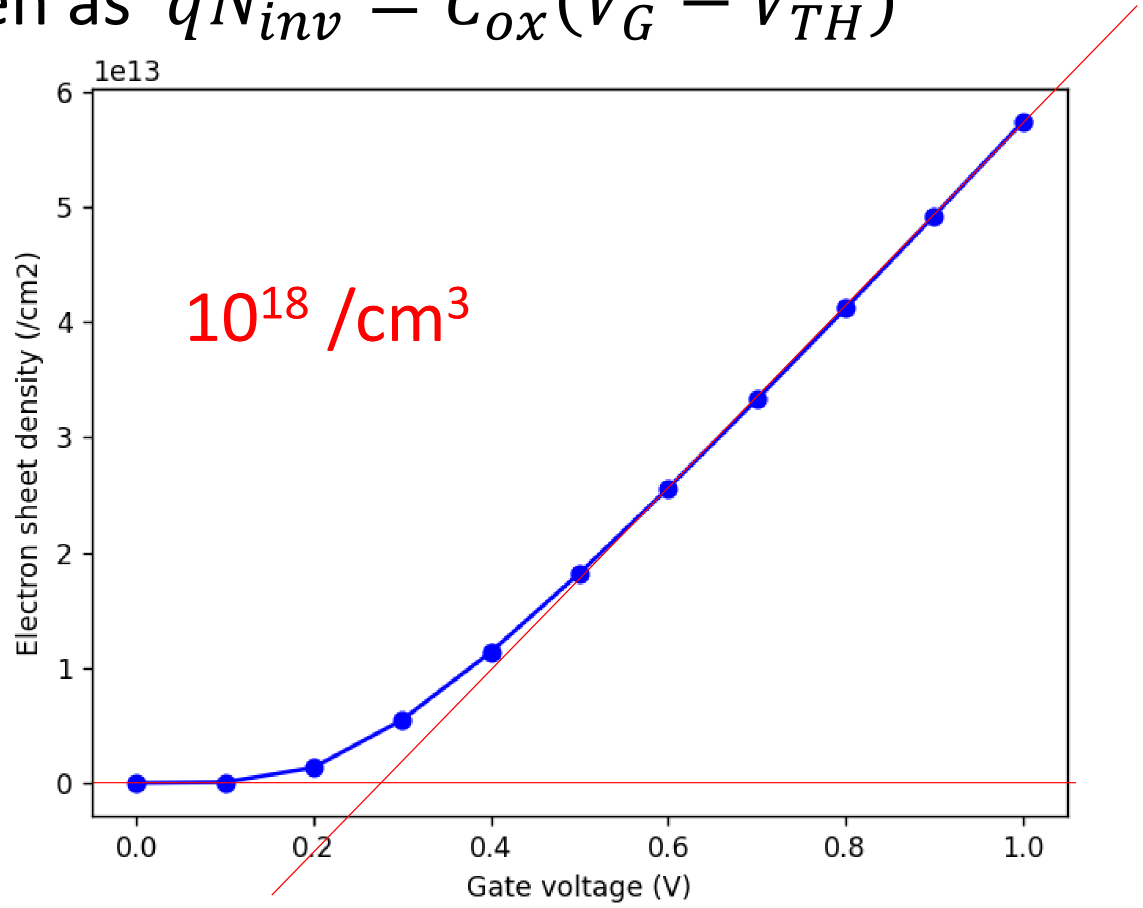


  - The boundary values of ϕ are given as

$$\phi = \phi_0 + V_G$$

Its solution

- Inversion charge as a function of V_G
  - It can be written as $qN_{inv} = C_{ox}(V_G - V_{TH})$



Thank you!