Lecture7:
MOSFET, theshold voltage

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

Semiconductor Device Simulation Lab.
School of Electrical Engineering and Coumputer Science
Gwangju Institute of Science and Technology

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Review

- The MOSFET has three terminals.
  - The gate current, I_G, is zero. (Isolated by the dielectric material)
  - Source current (I_S) + drain current (I_D) = 0
  - Source is connected to the GND.
  - The gate-to-source voltage (V_{GS}) and drain-to-source voltage (V_{DS}) are variables.

- Therefore, we want to know

$$I_D(V_{GS}, V_{DS})$$

Oxide capacitance

- A problem from "General Physics" cource
  - Consider a dielectric layer (whose thickness is d) sandwiched by two parallel metal plates.
  - A voltage difference, V, is applied.
  - The area of the plates is A.
  - The charges are $+Q$ and $-Q$, respectively.
  - By applying the Gauss law,

$$Q = \epsilon|\mathbf{E}|A = \epsilon\frac{V}{d}A$$

  - Therefore, the capacitance *per unit area* becomes

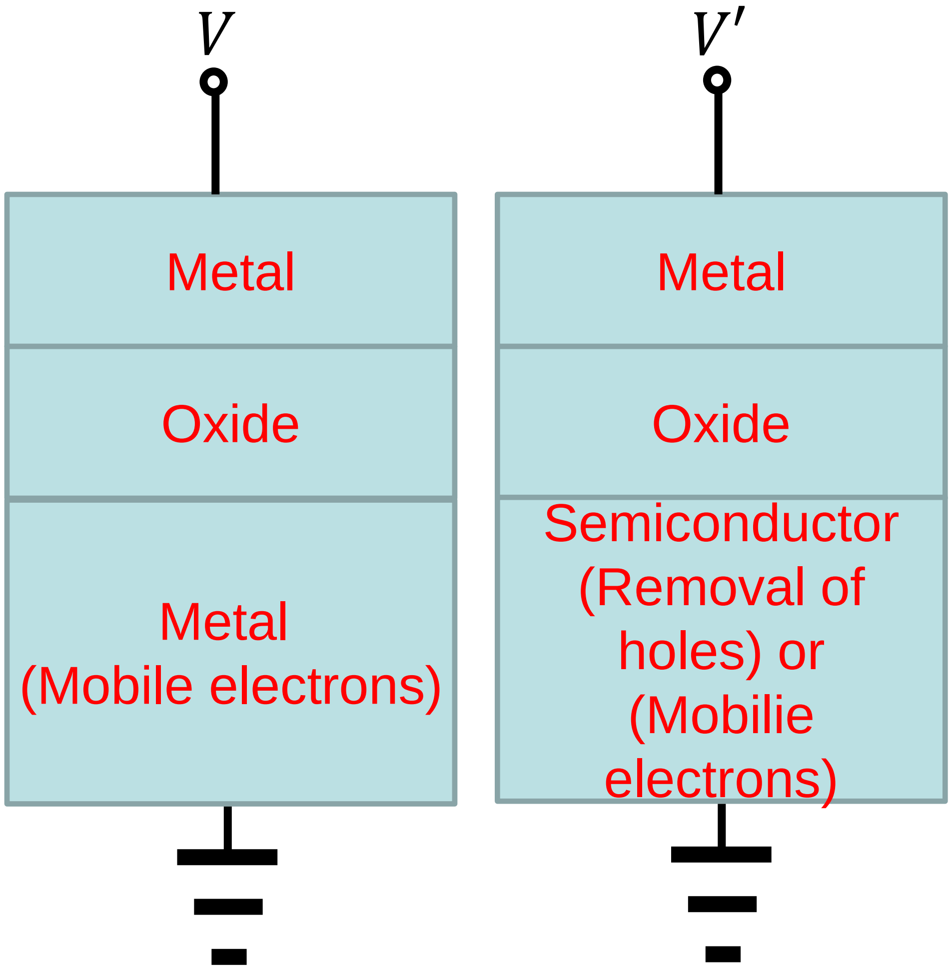
$$C = \frac{\epsilon}{d}$$

- The same problem in this course!

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$$

Difference?

- Threshold behavior
  - The semiconductor region can provide negative charges by two ways.
  - When the gate voltage is smaller than the theshold voltage (V_{TH}), the negative charge is provided by removal of holes from the interface. ➔ Depletion
  - When the gate voltage is larger than V_{TH}, the additional negative charge is provided by the mobile electrons. ➔ Inversion



Electron charge density

- When $V_{GS} < V_{TH}$,
  - The electron charge density vanishes.

$$Q_{elec} = 0$$

- When $V_{GS} > V_{TH}$,
  - The electron charge density is proportional to $V_{GS} - V_{TH}$.

$$Q_{elec} = C_{ox}(V_{GS} - V_{TH})$$

  - (Here, Q_{elec} and C_{ox} are quantites per unit area.)

Homework#4 (1)

- Due: 09:00, April 2
- Write a program, which reads a netlist file.
  - From the netlist file, determine the total number of unknown variables, N.
  - For each circuit element with two terminals, assign 4 variables. The first one is I_1. The second one is I_2. The third one is V_1. The fourth one is V_2.
  - For each circuit node (including the ground), assign 1 variable. It is the node voltage.
  - Build a $N \times 1$ vector, x. Each entry has its own meaning.
  - The first four entries are $[I_1\ I_2\ V_1\ V_2]^T$ of the first element.
  - The next four entries are $[I_1\ I_2\ V_1\ V_2]^T$ of the second element.
  - It is repeated until all elements are considered.
  - The last entries are for the node voltages.

Homework#4 (2)

- (Continued)
  - For example, consider a simple circuit with two circuit elements (a voltage source and a resistor) and two circuit nodes (`0` and `in`).
  - Then, $N = 10$. Also the vector is given as $x = [I_1^V \ \ I_2^V \ \ V_1^V \ \ V_2^V \ \ I_1^R \ \ I_2^R \ \ V_1^R \ \ V_2^R \ \ V_0 \ \ V_{in}]^T$.
  - Entries for the terminal currents are 1.
  - Entries for the terminal voltages are 2.
  - Entries for ther circuit nodes are 3.
  - In the above example, $x = [1 \ \ 1 \ \ 2 \ \ 2 \ \ 1 \ \ 1 \ \ 2 \ \ 2 \ \ 3 \ \ 3]^T$.
  - The program prints out the vector, x.

Homework#4 (3)

- Solve the following problems of the mid-term exam in 2017.
  - P17
  - P18
  - P19
  - P20
  - P21
  - P22
  - P23
  - P24