Lecture14

# Physics and Engineering of CMOS Devices

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Physics and Engineering of CMOS Devices, Ken Uchida, Tokyo Tech, July 21, 2010

#### Announcement

#### **Final Exam**

Date: July 28, 2010 Time: 10:40-12:10 Place: S633

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Consider MOS capacitor with the gate oxide thickness of  $t_{ox}$  and substrate impurity concentration of  $N_{sub}$ .

- a. Describe what the flat band condition is.
- b. Based on the fully depleted condition, derive the depletion capacitance C<sub>d</sub>.

Consider a MOS transistor with channel length L, width W, gate oxide thickness  $t_{ox}$ , substrate impurity concentration  $N_{sub}$ , mobility  $\mu$ , and threshold voltage  $V_{th}$ . The gate voltage of  $V_g$  and drain voltage of  $V_d$  are applied. The substrate is grounded.

- a. Derive the analytical MOS transistor model describing the drift current ( $V_{g} > V_{th}$ ).
- b. Derive the analytical MOS transistor model describing the diffusion current ( $V_g < V_{th}$ ).
- c. Describe what the subthreshold slope is. State how the subthreshold slope can be improved.

The performance of MOS transistors have been improved by diminishing the transistor sizes (scaling of MOS transistors).

- a. Supposing that the sizes of transistors are scaled by a factor of 1/k (k>1) and the voltage is scaled by a factor of  $1/\alpha$  ( $\alpha>1$ ), calculate the impact of scaling on the power density.
- b. State the short channel effects (SCE).
- c. How can we avoid (reduce) the SCE?

At the interface of gate oxide and semiconductor, the inversion layer is formed. In the inversion layer, electrons are confined by gate oxide potential and electric field.

- Describe the characteristics of the inversion layer formed at (100) Si interface. What kinds of valley are formed? Please answer effective masses of each valley and energy relationship between valleys.
- b. Based on the energy structures described above. State how the mobility can be improved.
- c. Describe the effect of uniaxial stress along <100> and
  <110> directions on the energy structures.