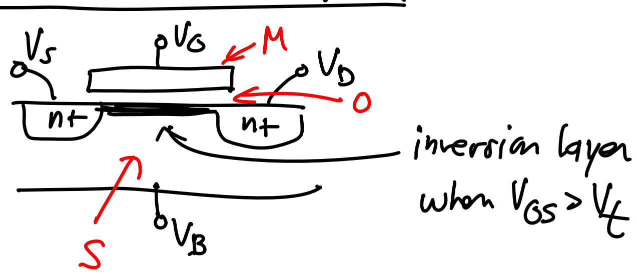
Lecture 24: MOS CV

- **Announcements**:
- HW#10 due tomorrow at 8 a.m.
- Lab 1 Report will due Tuesday, Dec. 2, at 8 a.m. in the 143 homework box
- HW#11 will be online, but not due till about 2 weeks
- -----------------------------------
- **Lecture Topics**:
  - Advanced Isolation
  - MOS CV
  - Extracting gate oxide thickness, x_{ox}
  - Extracting substrate concentration, N_A
  - Problems when measuring CV Curves
- -----------------------------------
- **Last Time**:
- Going through the Advanced Isolation Handout
- Now, continue, but skip through quickly
- Just read through the rest of the pages on your own
- More important to talk about MOS for your lab

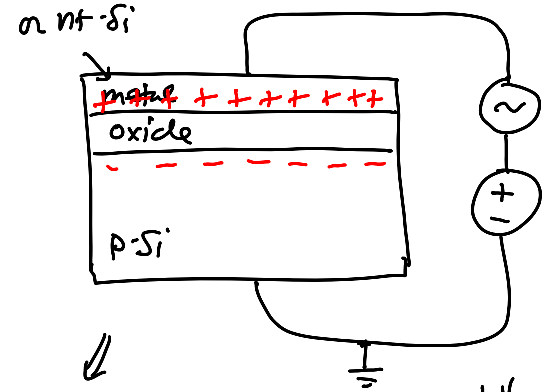
Review MOS Device Physics



CV-Curves

Capacitance-Voltage

$i = C\frac{dv}{dt}$

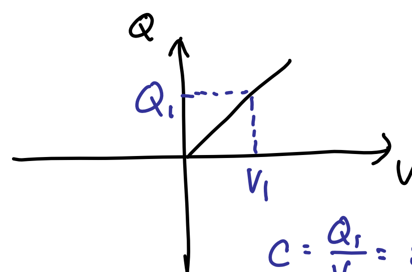


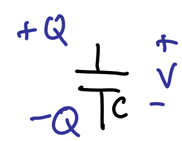
used to measure a small-signal capacitance

Like the bias voltage applied in an MOS ckt.

$$C_G(V_G) = \frac{\delta Q_G}{\delta V_G} = \frac{dQ_G}{dV_G}$$

Ideal Linear Capacitor:



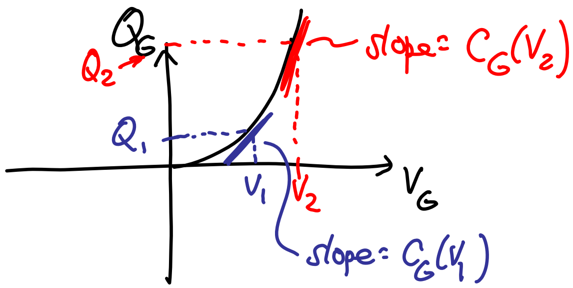


$Q = CV \rightarrow C = \frac{Q}{V}$

$C = \frac{Q_1}{V_1} =$ slope

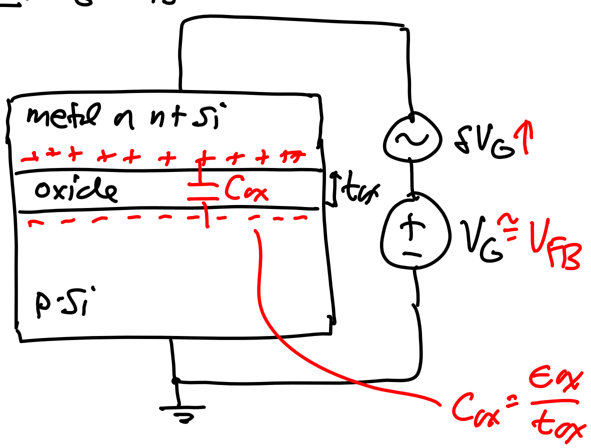
Copyright © 2014 Regents of the University of California

Nonlinear Semiconductor Capacitor:

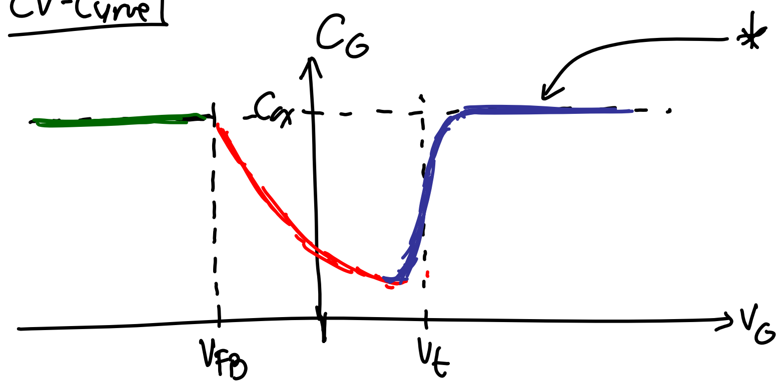


⇒ an MOS system is basically a voltage-controllable capacitor

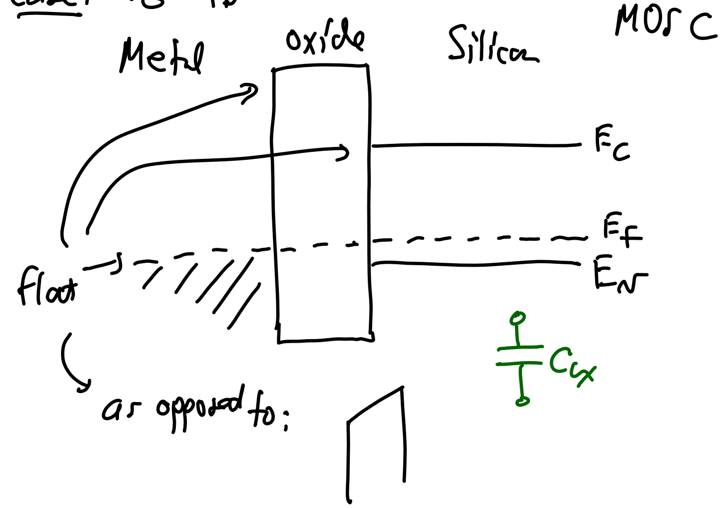
Case: $V_G \approx V_{FB}$



CV-Curve

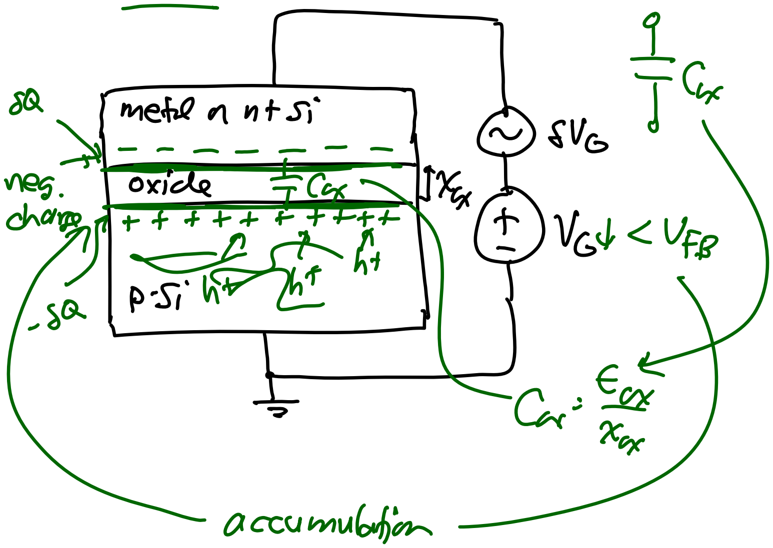


Case: $V_G = V_{FB}$ → zero charge state for the MOS C



Copyright © 2014 Regents of the University of California

Case: $V_G < V_{FB}$



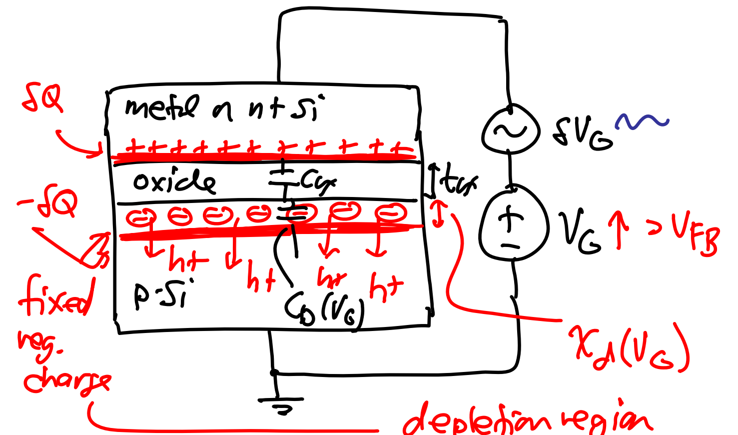
x_{ox}: gate oxide thickness

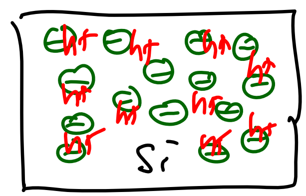
C_{ox}: gate oxide capacitance [C per unit area]

① Apply V_G → neg. charge at metal-oxide interface
→ pos. charge forms at the oxide-Si interface (equal & opposite charge)
(h+'s from the p-type Si just accumulate to form this charge layer)

② Vary δV_G → charge modulates at oxide interfaces

Case: $V_G > V_{FB}$ (but $V_G < V_t$) ← threshold voltage





⇒ holes + fixed neg. charge → neutral Si material

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

$C_D(V_G) = \frac{\epsilon_{Si}}{x_d(V_G)}$ ← permittivity of Si

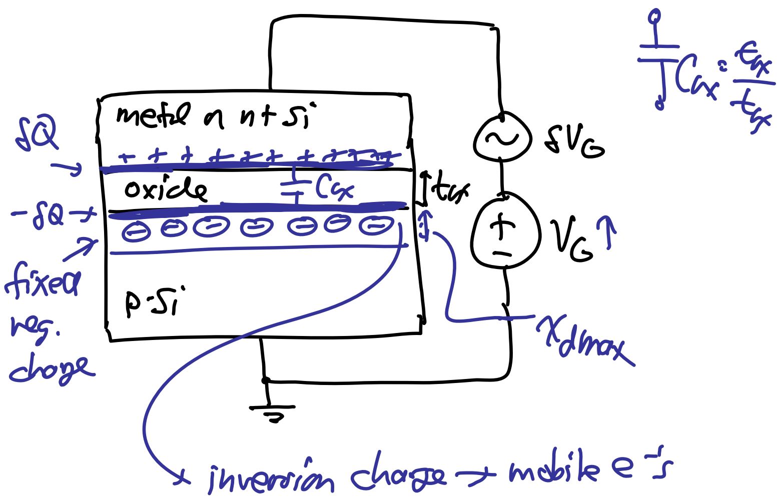
$$x_d(V_G) = \sqrt{\frac{2\epsilon_{Si}}{q}\frac{1}{N_A}|\phi_s|}$$

$|\phi_s|$: potential drop in the depletion region of the Si

N_A: p-type doping conc. in Si substrate

Copyright © 2014 Regents of the University of California

Case: $V_G > V_t$



Case: $V_G \uparrow$ slowly, δV_G varies slowly, i.e., at low frequency → slow enough for the inversion layer to form

Case: $V_G \uparrow$ slowly, δV_G varies fast, i.e., high frequency

Copyright © 2014 Regents of the University of California