Lecture 1: Administration & Overview

- This Lecture: Administration & Overview
- Reading: Handouts
- Lecture Topics:
  - Course information
  - Syllabus
- ----------
- Welcome to EE 143: "Microfabrication Technology"
- This is our course on wafer-level fabrication of transistor integrated circuits and other micro-devices, such as MEMS
  - Pass out course info sheet
  - Pass out course syllabus
  - Add lab section: Monday, 9-12 a.m. – is this okay? (not for 2, but it seems 2 others want to move to the Monday section, so this should work out)
  - Show calendar and settle the office hours
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- Goals of the course:
  - Teach the skills needed to design and fabricate micro- and nano-devices, including integrated circuits and micro electromechanical systems (MEMS)
  - Design emphasis: This is NOT a survey course; you will be expected to design and layout physical MOS devices (and MEMS devices, if there's time)
- Hands-on emphasis: Give you actual hands-on experience fabricating micro-devices using a wafer-level process in a cleanroom

- The mechanics of the course are summarized in the course handouts, given out in lecture today
  - Course Information Sheet
    - —Course description
    - —Course mechanics
    - —Textbooks
    - —Grading policy
  - Syllabus
    - —Lecture by lecture timeline w/ associated reading sections
    - —Midterm Exam: Thursday, Oct. 30
    - —Final Exam: Friday, Dec. 19, 8-11 a.m.

IC History & Review of Devices:

- Reading: Jaeger, Chpt. 1
- Lecture Topics:
  - History of IC's
  - Devices of Interest
    - —MOS transistor
    - —Micromechanical structure
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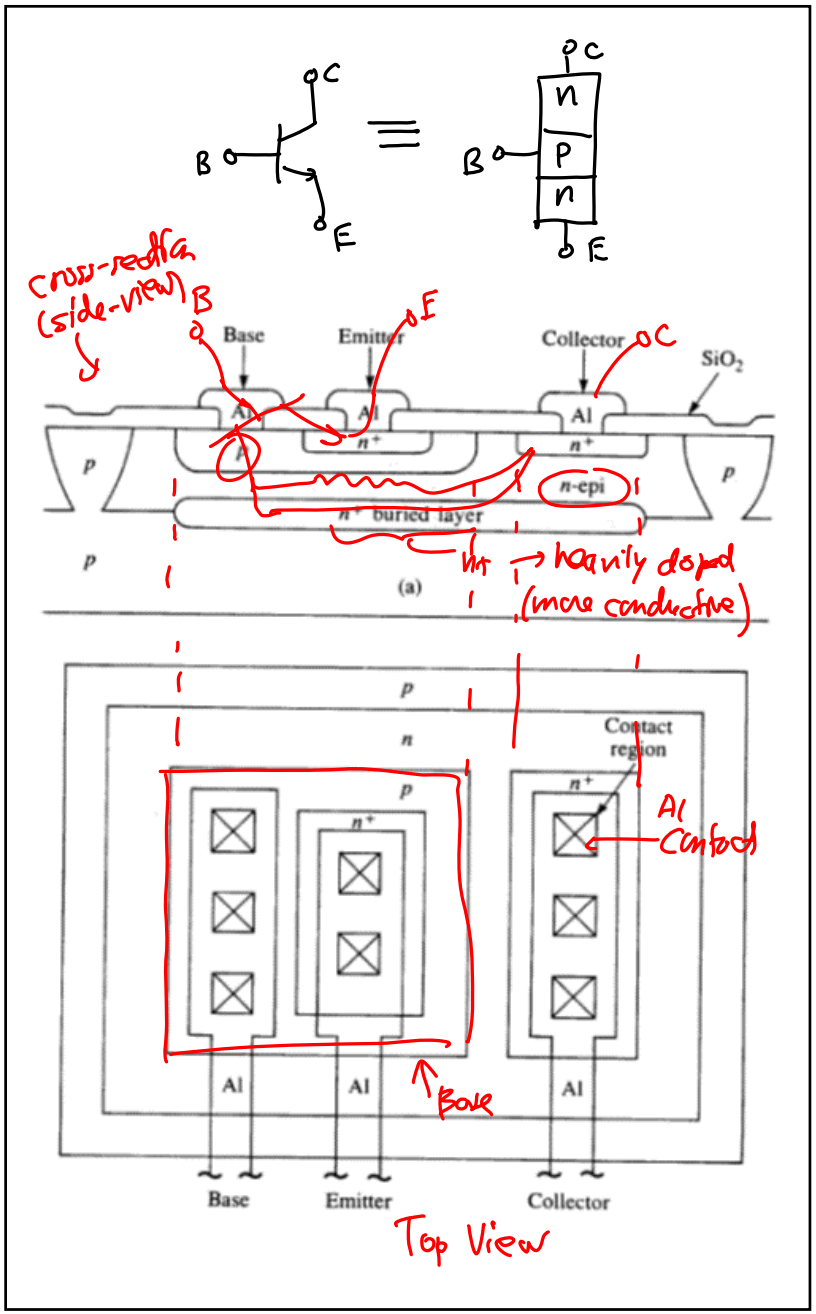
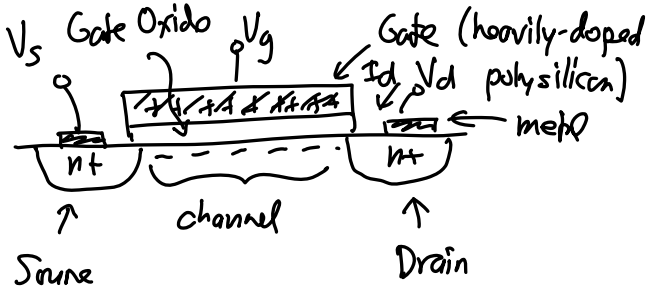
- History of IC's:
  - 1834: Difference Engines (mechanical computers)
    - —Gears, cranks, levers, decimal, pipelining!
  - 1904: Vacuum tube invented
    - —Yielded the ENIAC vacuum tube computer
  - 1925: J. Lilenfield proposed the MOSFET transistor
    - —Problem: knowledge of materials not sufficient to get this to work
  - (instead)
  - 1947: Invention of the transistor (Bardeen, Brattein, Shockley)
  - 1949: Invention of the Bipolar Xsistor (Shockley)
  - 1956: First digital logic gates (Harris)
  - 1959: Invention of planar silicon processing (Kilby, Noyce)
  - Then a slew of bipolar technologies
    - —TTL (1965)
    - —ECL (1967)
    - —MTL/I2L (1972)
    - —SiGe heterostructures (1990's)

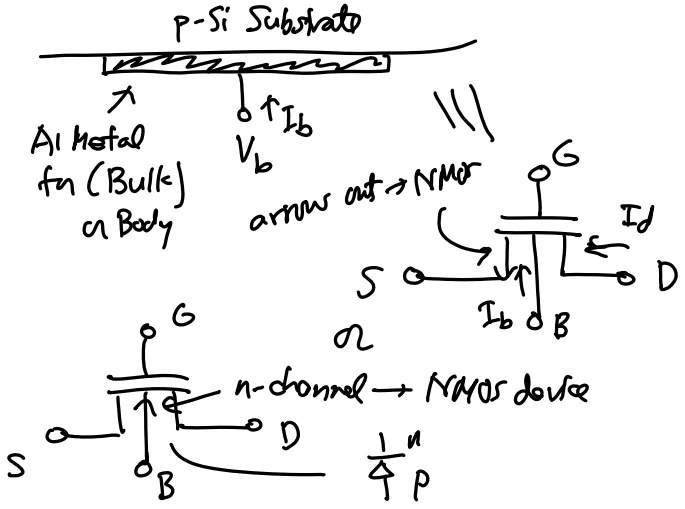


- Bipolar ruled during the 60's and 70's, because it was faster than anything else, incl. MOS
- But soon, its excessive power consumption caught up, and MOS began to come into favor as small channel lengths boosted the speed of MOS

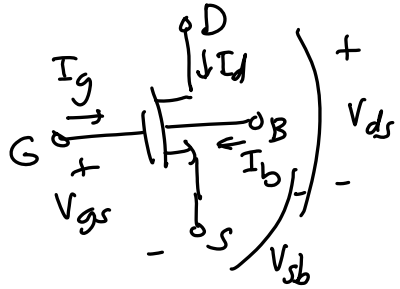
MOS Structure, Symbol, and Equations

(cross-section of MOS device)





NMOS Transistor Mathematical Model



① Cut-off Region: ($V_{gs} \leq V_t$)

$I_g = I_b = 0$; $I_d = 0$

② Linear (or Triode) Region: ($V_{gs} - V_{tn} \geq V_{ds} \geq 0$)

$$I_g = I_b = 0 \; ; \; I_d = \mu_n C_{ox} \frac{W}{L}\left(V_{gs} - V_{tn} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$= k_n\left(V_{gs} - V_{tn} - \frac{V_{ds}}{2}\right)V_{ds}$$

③ Saturation Region: ($V_{ds} \geq V_{gs} - V_{tn} \geq 0$)

$$I_g = I_b = 0 \; ; \; I_d = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{gs} - V_{tn})^2(1 + \lambda V_{ds})$$

$$= \frac{1}{2} k_n (V_{gs} - V_{tn})^2 (1 + \lambda V_{ds})$$

where: $\mu_n \triangleq$ e- mobility in the channel

$C_{ox} \triangleq$ gate oxide capacitance per unit area

$k_n = k_n' \frac{W}{L} = \mu_n C_{ox} \frac{W}{L}$

$I_g = I_b = 0$ for all regions (at least for dc)

$$V_{th} = f(V_{SB}) = V_{to} + \gamma\left(\sqrt{V_{SB} - 2|\phi_{f1}|} - \sqrt{2|\phi_{f1}|}\right)$$

Body Factor $\rightarrow$ $\gamma = \frac{1}{C_{ox}}\sqrt{2q\epsilon_s N_{sub}}$ $\leftarrow$ substrate doping conc.