ROYAL INSTITUTE
OF TECHNOLOGY

Semiconductor Devices
Spring 2019

Lecture 9

This Lecture

- Reading
  - Chapter 6, sections 1-2 & 4-6
  - Section 3 will be covered later
- Concepts:
  - The complementary Metal-oxide-semiconductor CMOS
  - Threshold voltage including body effect
  - Simple IV theory for the ON-state of the transistor (OFF-state covered in chapter 8)
  - Connecting the circuit/layout/device fabrications

Figure 6.1 (a) Basic MOSFET structure and (b) IV characteristics.

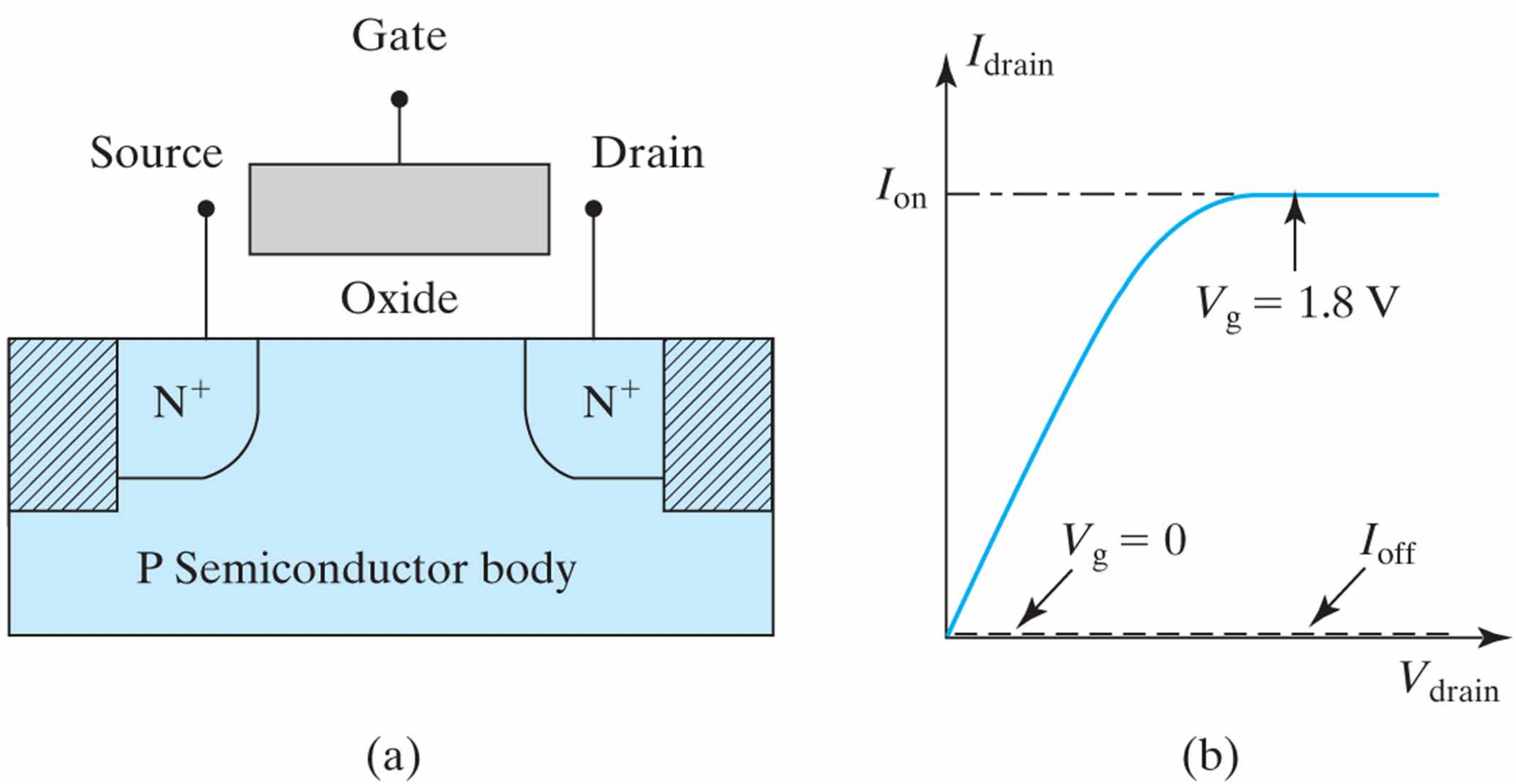

Figure 6.5 Gate oxides as thin as 1.2 nm can be manufactured reproducibly. Individual Si atoms are visible in the substrate and in the polycrystalline gate. (From [3]. © 1999 IEEE.)

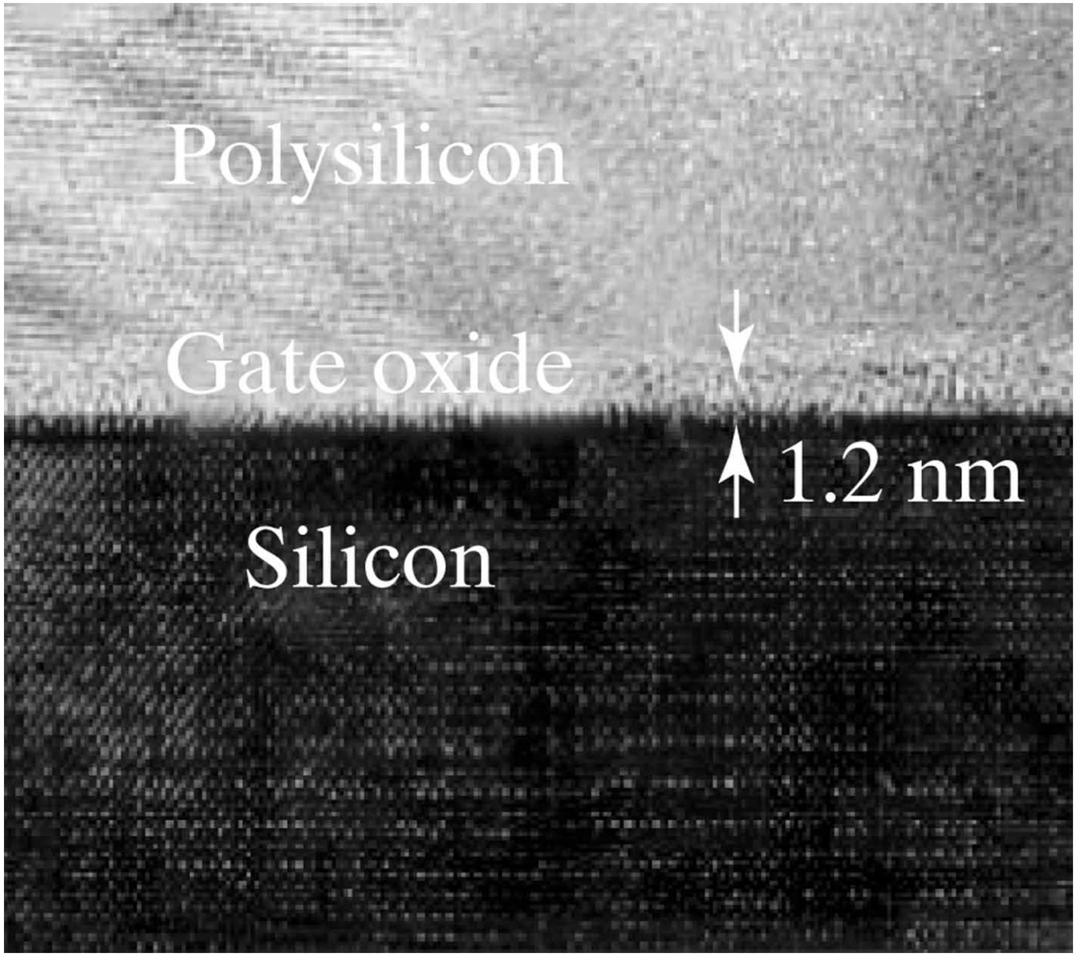

Figure 6.6 Schematic drawing of an N-channel MOSFET in the off state (a) and the on state (b). (c) and (d) show a P-channel MOSFET in the off and the on states.

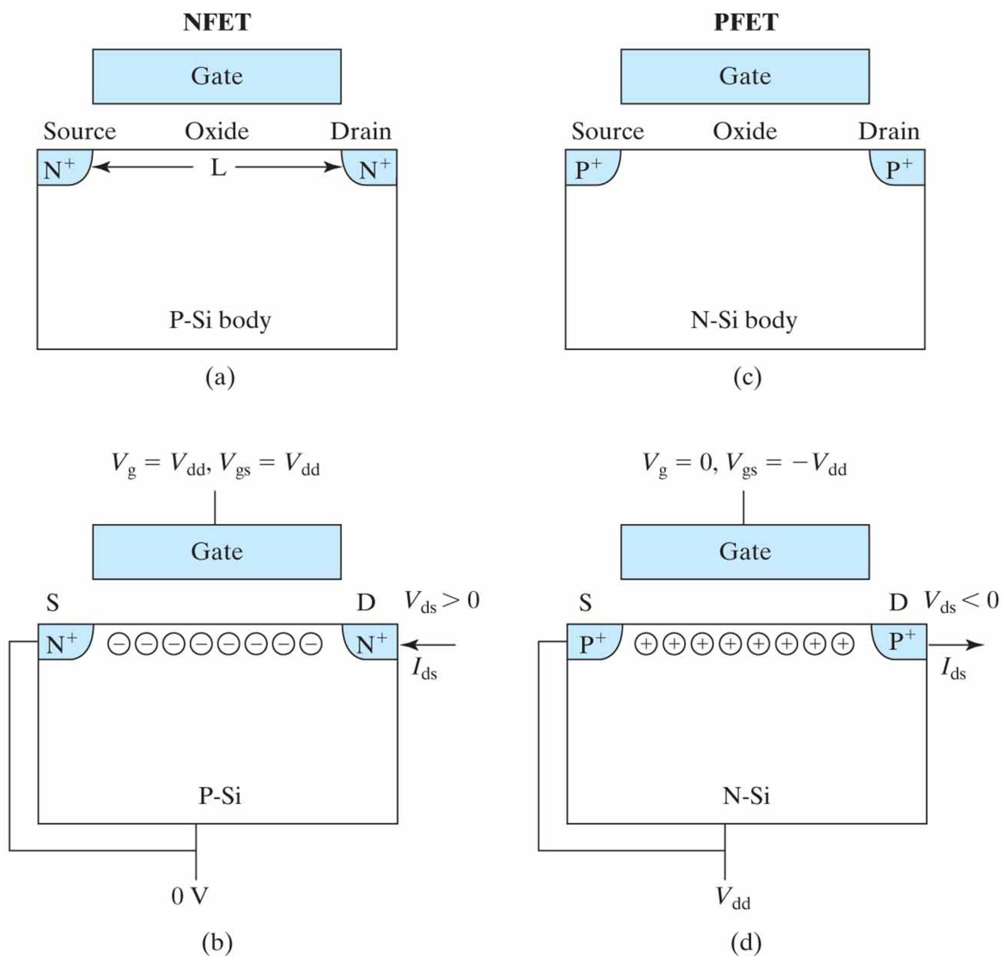

Figure 6.7 Three views of a CMOS inverter. (a) A CMOS inverter consists of a PFET **pull-up device** and an NFET **pull-down device**. (b) Integration of NFET and PFET on the same chip. For simplicity, trench isolation (see Fig. 6–1), which fills all the surface area except for the diffusion regions and the channel regions, is not shown. (c) Layout of a CMOS inverter.

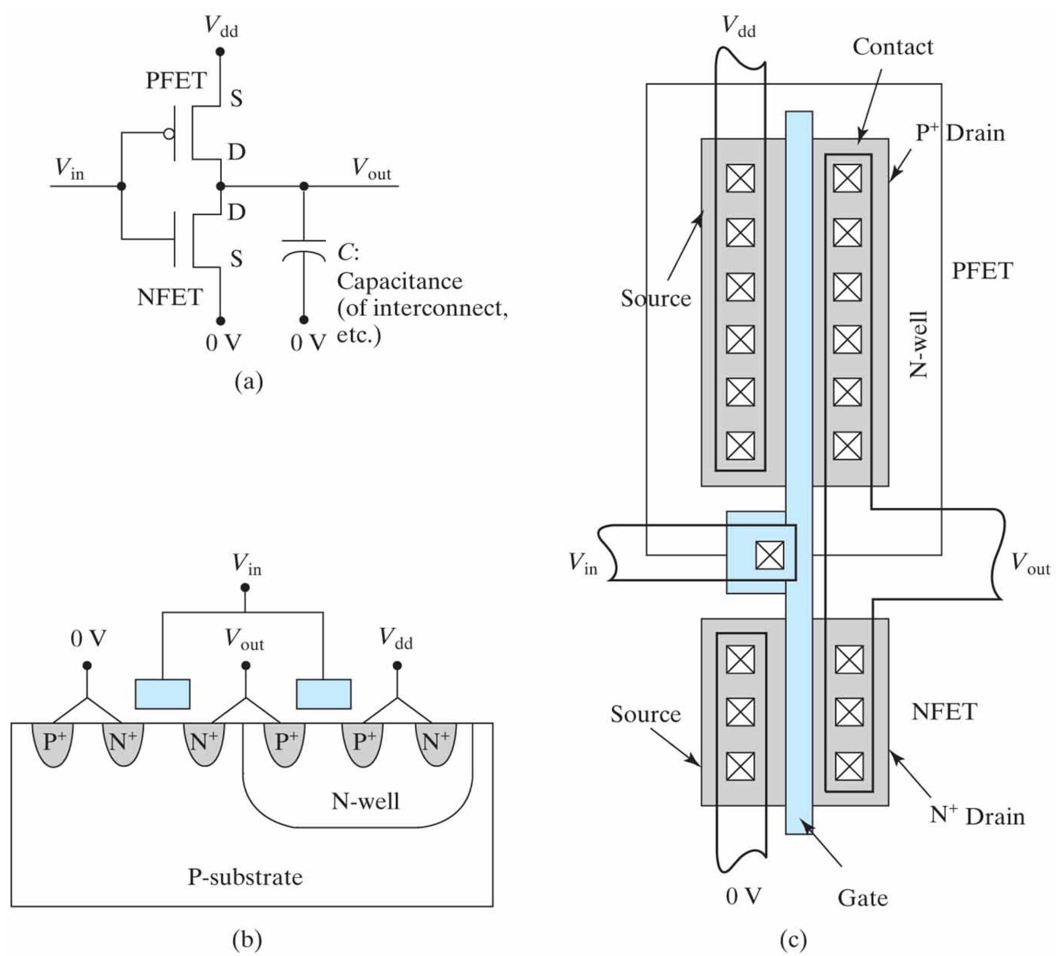

Figure 6.8 Surface mobility is a function of the average of the electric fields at the bottom and the top of the inversion charge layer, $\mathscr{E}_b$ and $\mathscr{E}_t$.

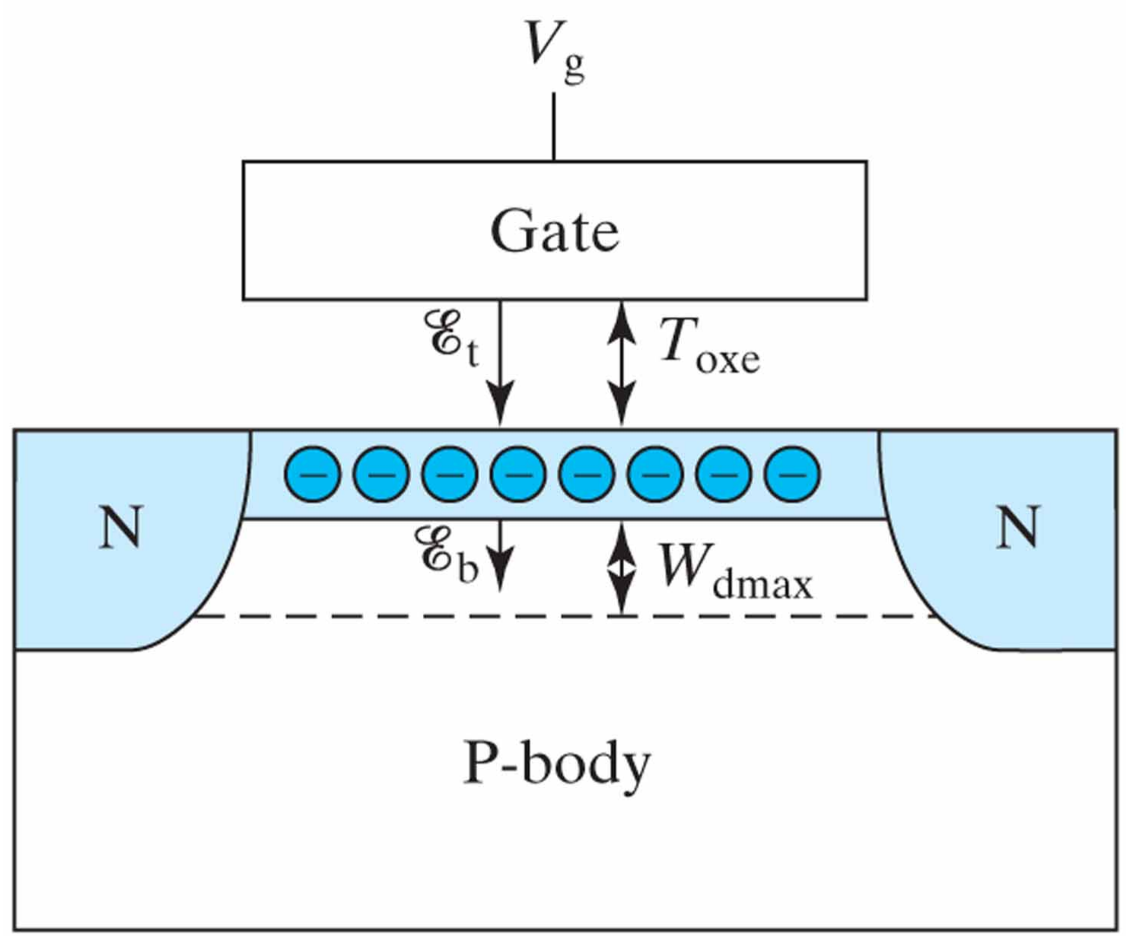

Figure 6.13 (a, b) The inversion layer can be viewed as a conductive film that is coupled to V_g through the oxide capacitance and coupled to V_b through the depletion-layer capacitance. The drain is open-circuited. (c) V_t is an approximately linear function of the body to source bias voltage. The polarity of the body bias is normally that which would reverse bias the body-source junction.

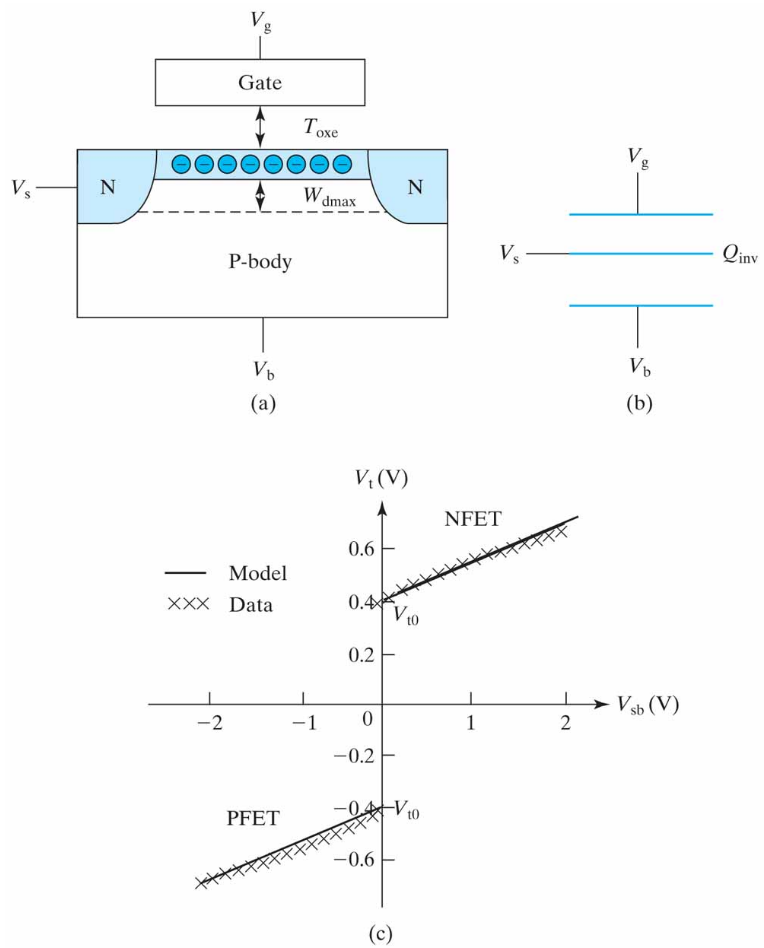

Figure 6.14 Comparison of a steep retrograde doping profile and a uniform doping profile.

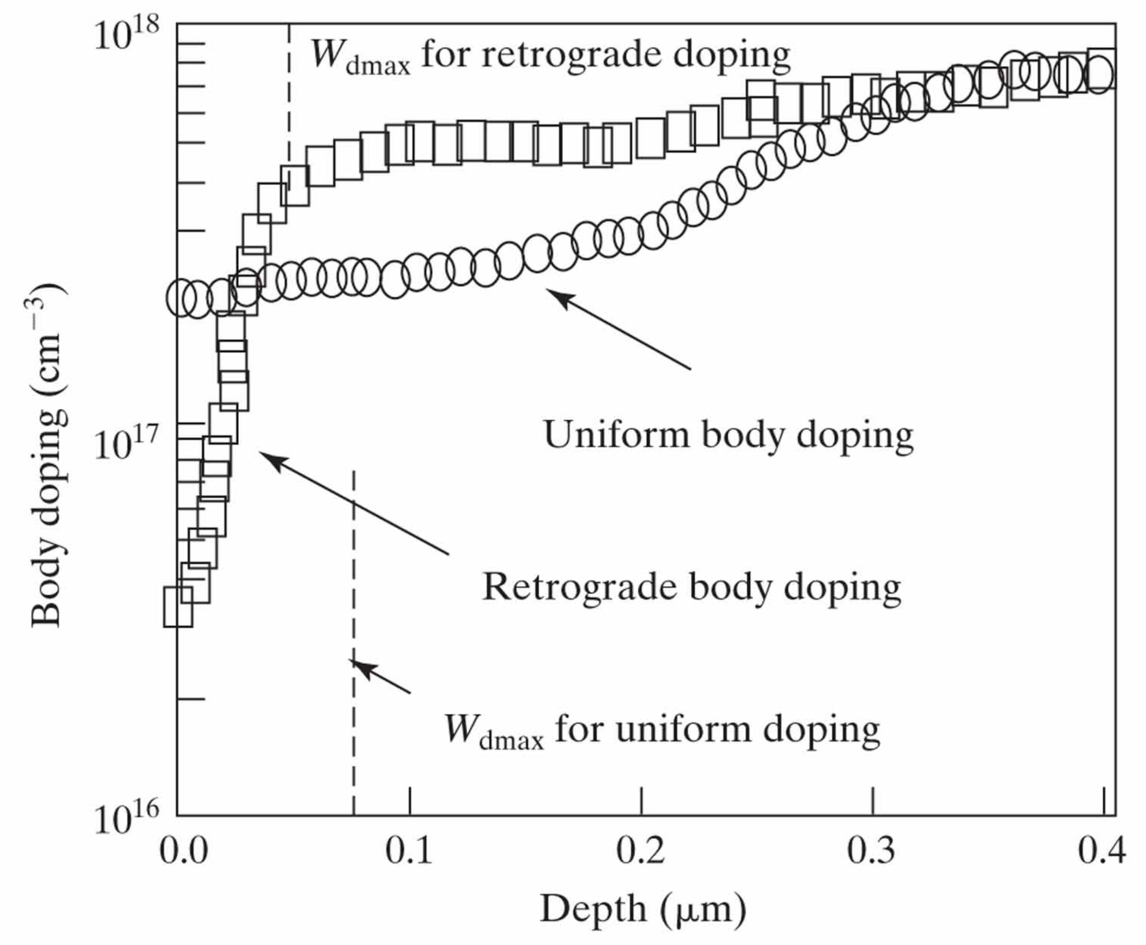

Figure 6.15 When $V_{ds} \neq 0$, the channel voltage V_c is a function of x.

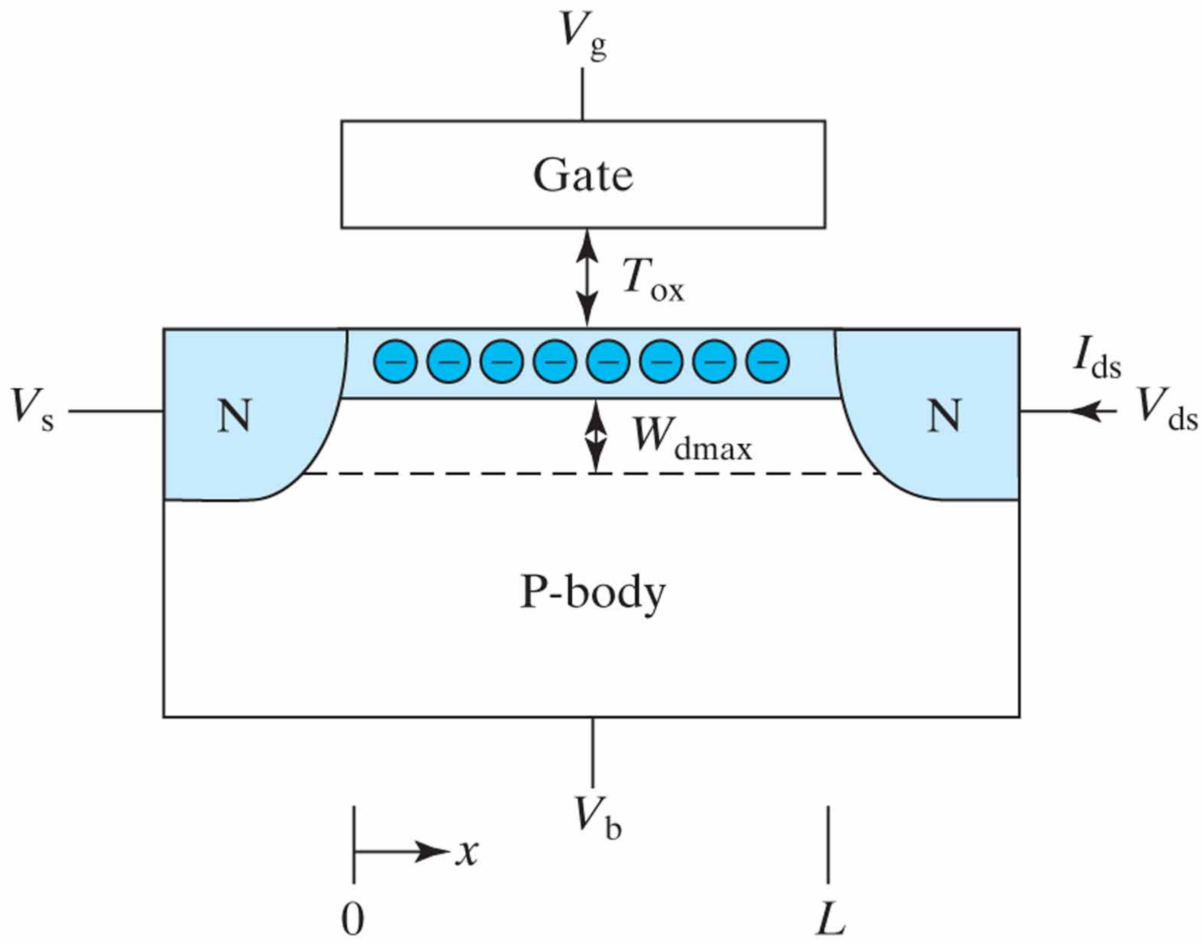

Figure 6.16 MOSFET IV characteristics.

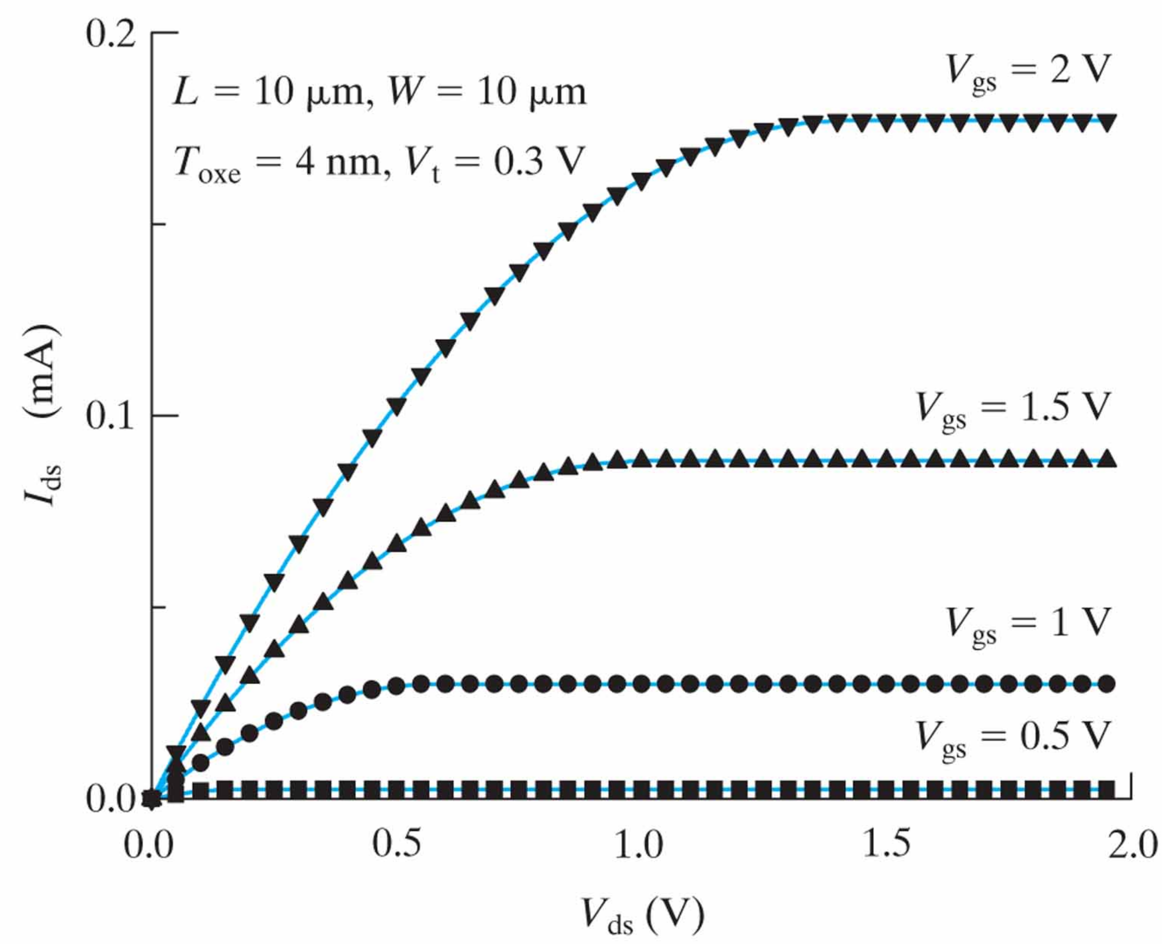

Figure 6.17 (a)−(d) $V_{ds} = V_{dsat}$ and (e)−(h) $V_{ds} > V_{dsat}$. Current does not change when V_{ds} increases beyond V_{dsat}. (d) and (h) are $E_c(x)$ from the energy band diagrams.