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MICROELECTRONIC DEVICES AND CIRCUITS

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Dedicated to the memory of my father, Clifton G. Fonstad, Sr.

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CHAPTER 9

THE MOS CAPACITOR

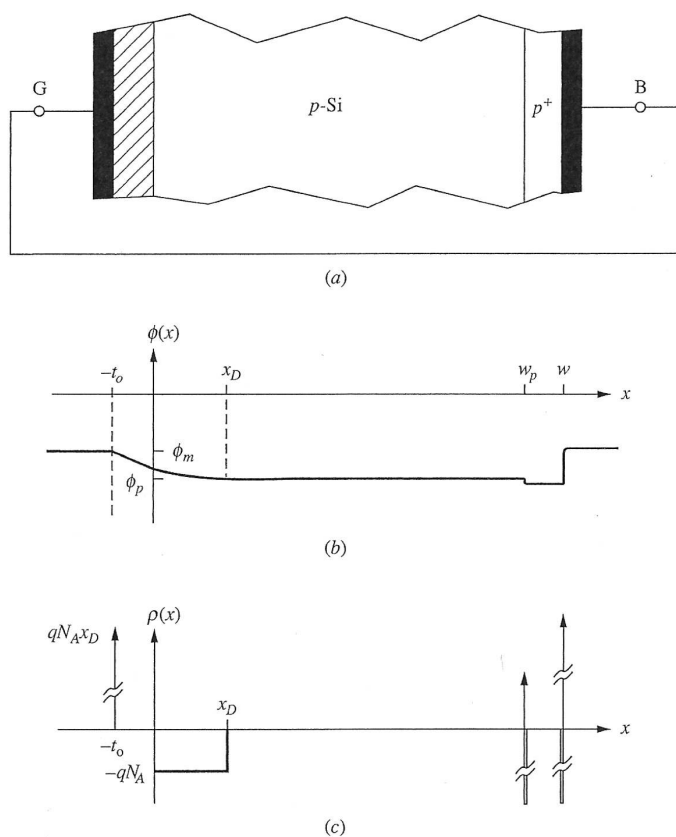
In modern semiconductor electronics there are a number of fundamental structures, including the p - n junction, the metal-semiconductor contact, and the metal-oxide-semiconductor capacitor. We discussed p - n junctions in Chaps. 6 and 7, and Appendix E deals with metal-semiconductor contacts. In this chapter we focus our attention on the metal-oxide-semiconductor (MOS) capacitor structure.

The MOS capacitor forms the heart of an important family of devices called *MOS field effect transistors*, or MOSFETs. In much the same way that understanding p - n junctions is central to understanding the operation of bipolar junction transistors, understanding the MOS capacitor is central to understanding the operation of MOSFETs. The MOS capacitor is also a useful device in its own right (i.e., as a capacitor), and the MOS capacitor structure is also useful as an optical sensor.

We will begin our study of the MOS capacitor in this chapter by looking at this structure in thermal equilibrium. We will then study what happens when we apply voltage to an MOS capacitor and look at the unique features that make the MOS capacitor so useful in devices.

9.1 THE MOS CAPACITOR IN THERMAL EQUILIBRIUM

To form an MOS capacitor we start with a sample of uniformly doped semiconductor, say p -type silicon, with an ohmic contact on one side. The other side is covered with a thin insulating layer; in the case of silicon this is usually silicon dioxide, SiO_2 , or a combination of silicon dioxide and silicon nitride, Si_3N_4 . A thin film of metal—aluminum is a common example—deposited on this insula-

**FIGURE 9.2**

(a) One-dimensional MOS capacitor structure with its terminals shorted and in thermal equilibrium; (b) the variation in the electrostatic potential relative to intrinsic silicon through this structure; and (c) the corresponding net charge distribution.

9.2.1 Flat-band

Consider first applying a voltage v_{GB} to the left-hand capacitor electrode, which we label G for "gate," relative to the ohmic contact, which we label B for "back," that is negative. The potential at the interface between the oxide and the semiconductor, $\phi(0)$, decreases toward ϕ_p , and the depletion region width also decreases. At the same time the positive charge is removed from the capacitor electrode (i.e., at $x = -t_o$). For some particular applied voltage, there will be no depletion of the semiconductor and the potential at the surface of the semiconductor will equal that in its bulk [i.e., $\phi(0) = \phi_p$]. This situation, illustrated in Figs. 9.3a and b, is called the *flat-band* condition, and the corresponding applied voltage V_{FB} is an important