The MOS capacitor is an important device for several reasons. Firstly, it allows us to understand the basic MOS phenomena for a simple one-dimensional structure. A good understanding of the MOS capacitor is a prerequisite for the A good understanding of the MOS capacitor is a prerequisite for the chapters that follow in this book. Secondly, the MOS capacitor is an important test structure used to obtain information about the MOS system, usually in a simpler manner than can be done with a MOS transistor. Finally, the MOS capacitor is an important semiconductor device in its own right, used in CCDs , analog circuits, memories and so on.

2.2 The Silicon/Silicon-Dioxide System

The silicon/silicon-dioxide (Si/SiO_2) system continues to be the most common semiconductor-insulator system used in MOS devices. Indeed, as mentioned in Chapter 1, it was the outstanding properties of the Si/SiO_2 interface which has made silicon technology dominant today. As the technology has progressed, various other insulators besides SiO_2 have been proposed, and have been used, as alternative gate dielectrics, though silicon continues as the only important CMOS substrate. Some of these alternative insulators are the oxynitrides, as well as various high-k insulators. Despite these advances, the Si/SiO_2 interface remains an important system, which is relatively well-understood. It also continues to provide a reference point to other semiconductor-insulator interfaces. In this section, therefore, we take a brief look at the Si/SiO_2 interface. In the following sections of this chapter, the theoretical basis which is developed for MOS phenomena is, in any case, quite independent of the exact details of the interface.

Figure 2.1 shows the physical structure of the MOS capacitor. The semiconductor is usually silicon. We will consider mainly the case of a p-type substrate, which corresponds to an n-channel MOS transistor. The insulator is usually silicon dioxide (SiO_2) and its thickness t_{ox} is in the range 1-20 nm (10–200 Å). The top "metal" may be aluminum or some other metal, or heavily-doped polysilicon in the case of silicon-gate technology. The metal (or polysilicon) layer is called the gate to which a gate voltage V_G can be applied.

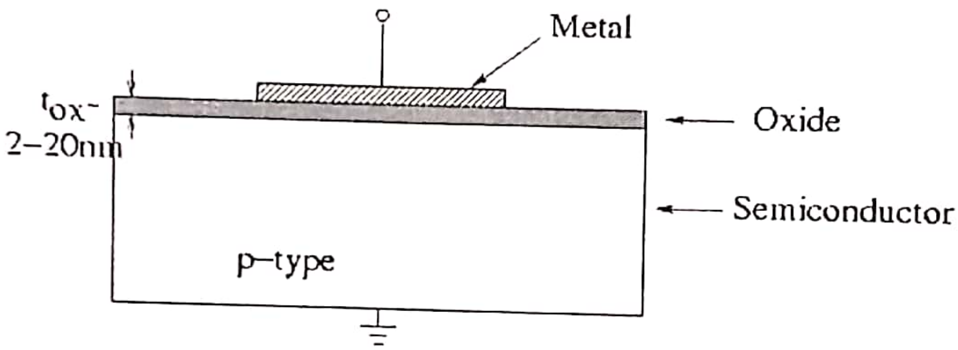

Figure 2.1. Physical structure of a MOS capacitor. Note that this is not drawn to scale; the typical thickness of the wafer is 300 μm, of the oxide (t_{ox}) 10 nm, and of the polysilicon gate 100 nm.

why silicon dioxide is such a good material for use in MOS devices. Besides the fact that SiO_2 (especially when thermally grown) forms an almost ideal interface with silicon, producing very few defects, we see that (1) it has a large bandgap – 9.1 eV – and therefore very few intrinsic carriers, and (2) it has large barriers for both electrons and holes in silicon (as well as the gate), so that the carriers can be effectively contained in the silicon, and do not get injected easily into the insulator.