Oxidation: another diffusion-based process

Silicon Dioxide: the structure

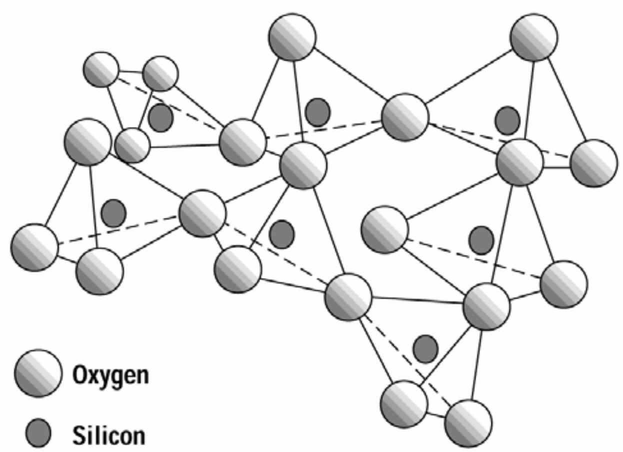


Figure 4.7 The physical structure of SiO_2 consists of silicon atoms sitting at the center of oxygen polyhedra.

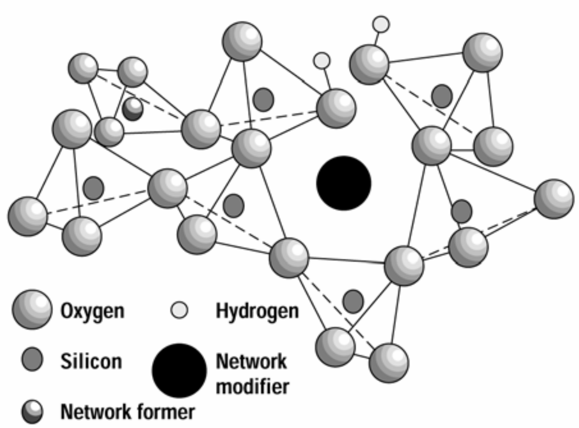
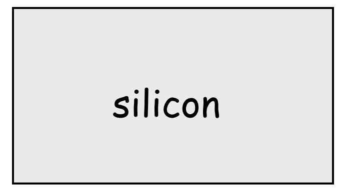
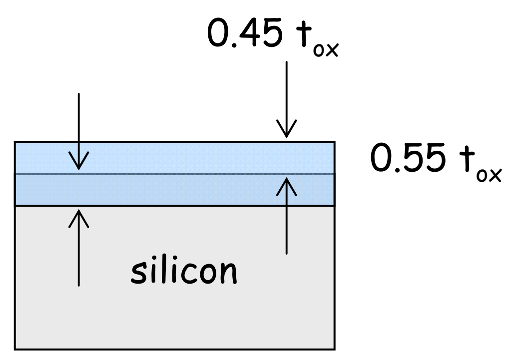


Figure 4.8 Schematic of impurities and imperfections in SiO_2.

Not single crystalline



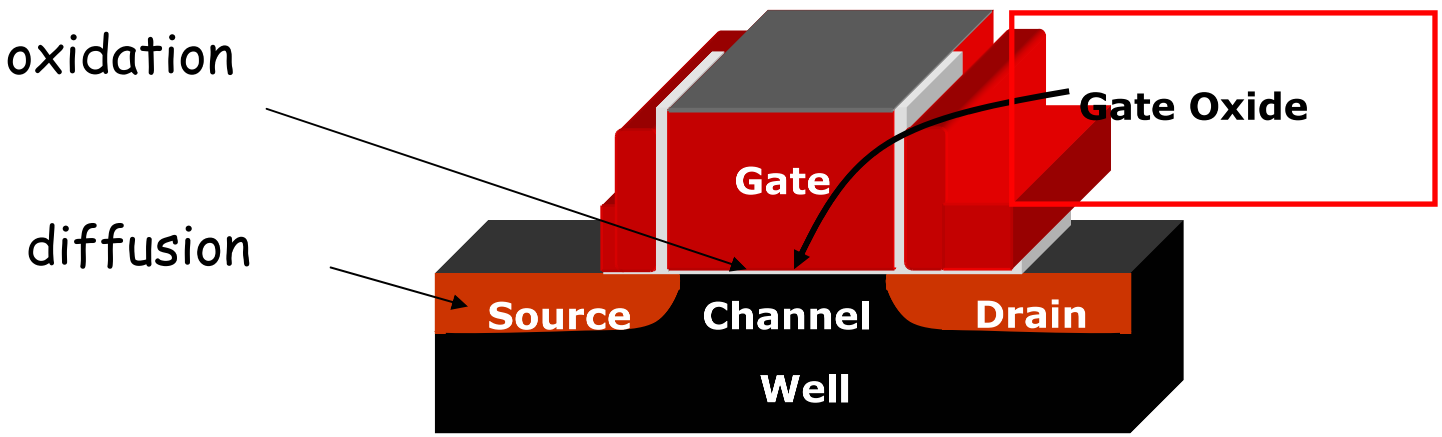


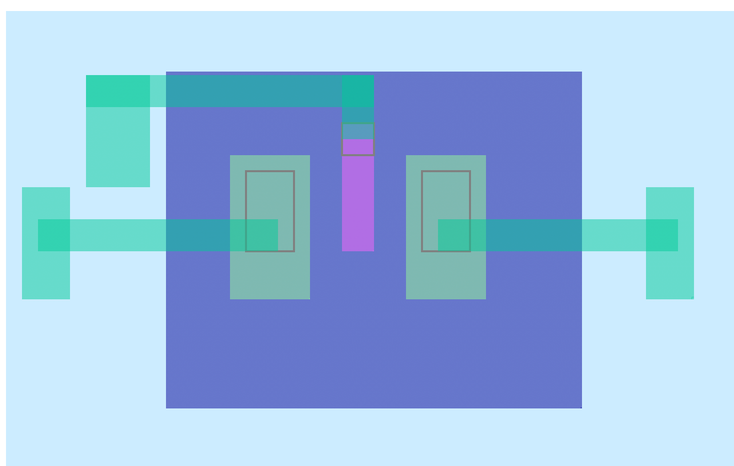
In forming oxide of thickness tox, utilize 0.45 t_{ox} of silicon:

Diffusion of oxidant *into* silicon to form oxide

Building a 3D Structure, layer by layer

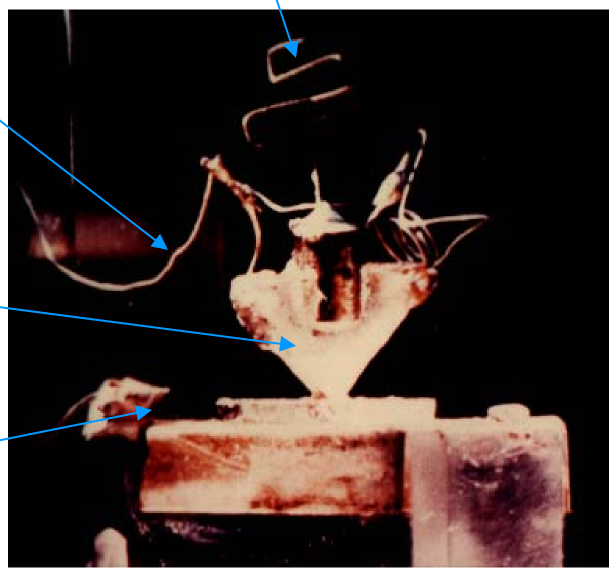
The critical role of the gate oxide





Well
Source and drain
Gate
Windows
Metal interconnects

The switch from Germanium to Silicon



First transistor: 1948
Bardeen, Brattain, Shockley

TABLE 1.1

Transistor Sales 1954–1966

Year	*Germanium Units*	*Silicon Units*
1954	1.3	0.02
1955	3.6	0.09
1956	12.4	0.42
1957	27.7	1.0
1958	45.0	2.1
1959	77.5	4.8
1960	119	8.8
1961	178	13.0
1962	214	26.6
1963	249	50.1
1964	289	117
1965	334	273
1966	369	481

Note: All units in millions.

Source: Electronic Industries Association Yearbook, 1967.

Runyan & Bean, Semiconductor IC Processing Technology

Oxidation

The Deal-Grove Model: setting it up

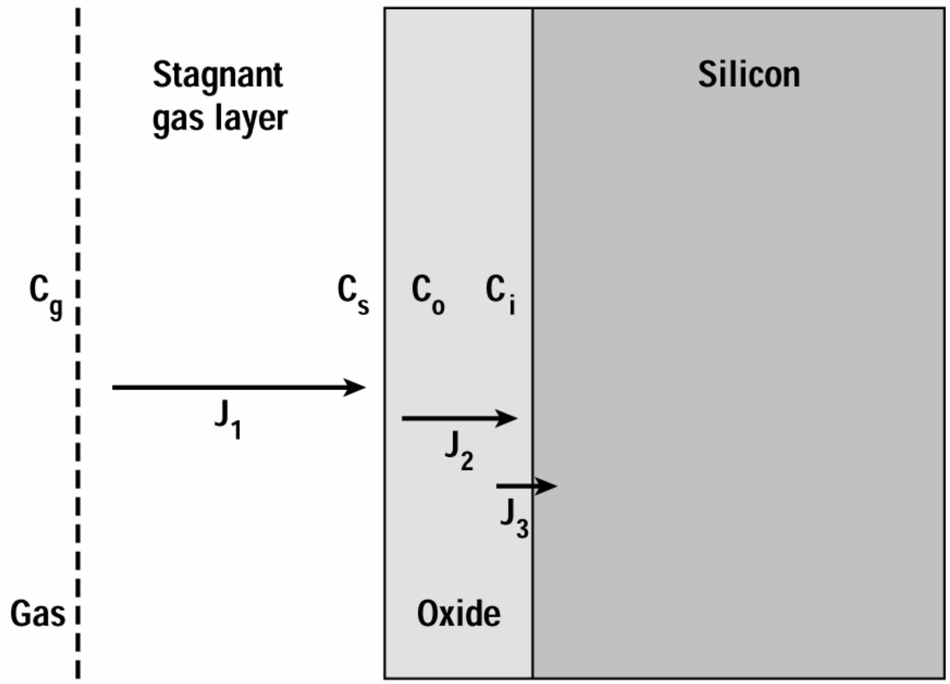


Figure 4.1 Schematic diagram of the oxidant flows during oxidation.

Rates of Oxidation; B/A and B

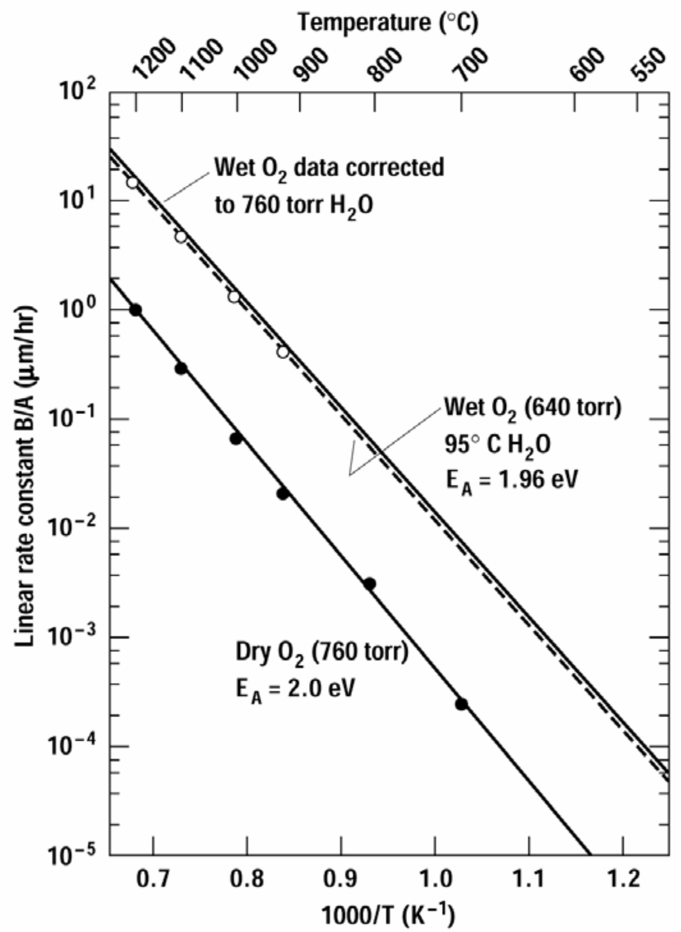


Figure 4.3 Arrhenius plot of the ratio *(B/A)* of the oxidation parameters *(after Deal and Grove)*.

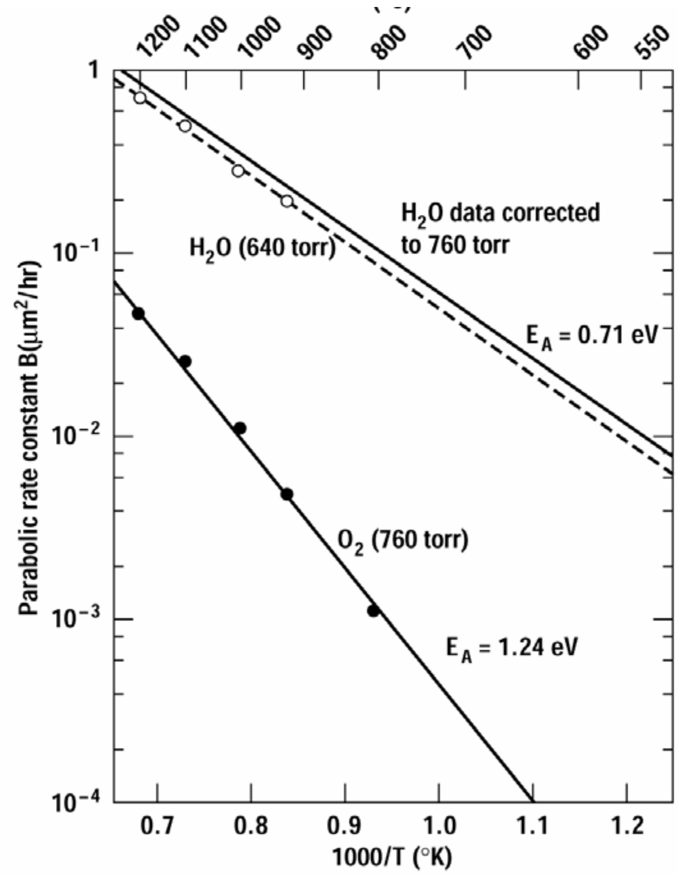


Figure 4.2 Arrhenius plot of the *B* oxidation coefficient. The wet parameters depend on the H_2O concentration and therefore on the gas flows and pyrolysis conditions *(after Deal and Grove)*.

Where the does temperature dependence come in?

High Pressure Oxidation

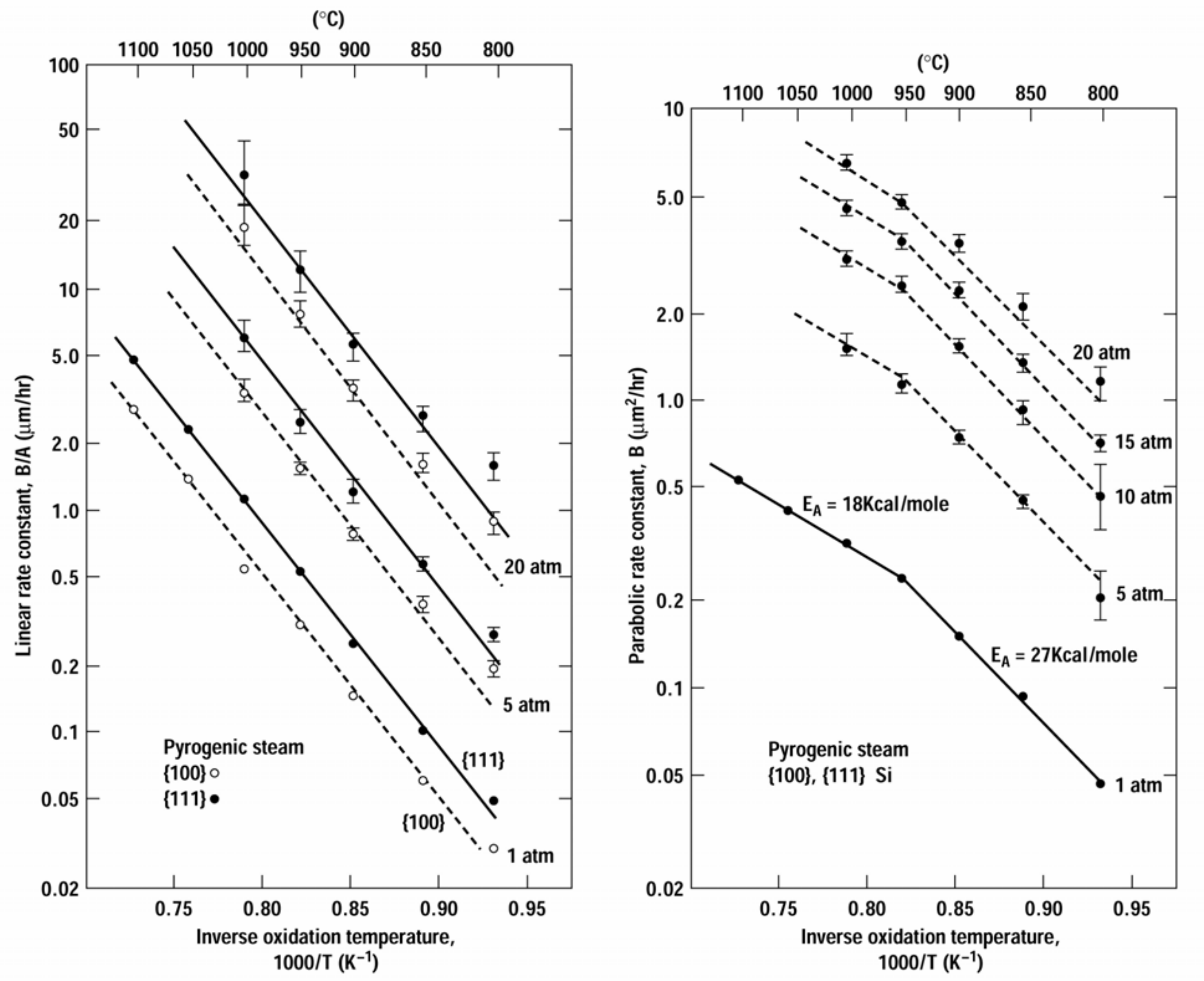


Figure 4.5 High pressure studies of the parabolic and linear rate coefficients in steam *(after Razouk et al., reprinted by permission, The Electrochemical Society).*

Segregation Coefficient (m)

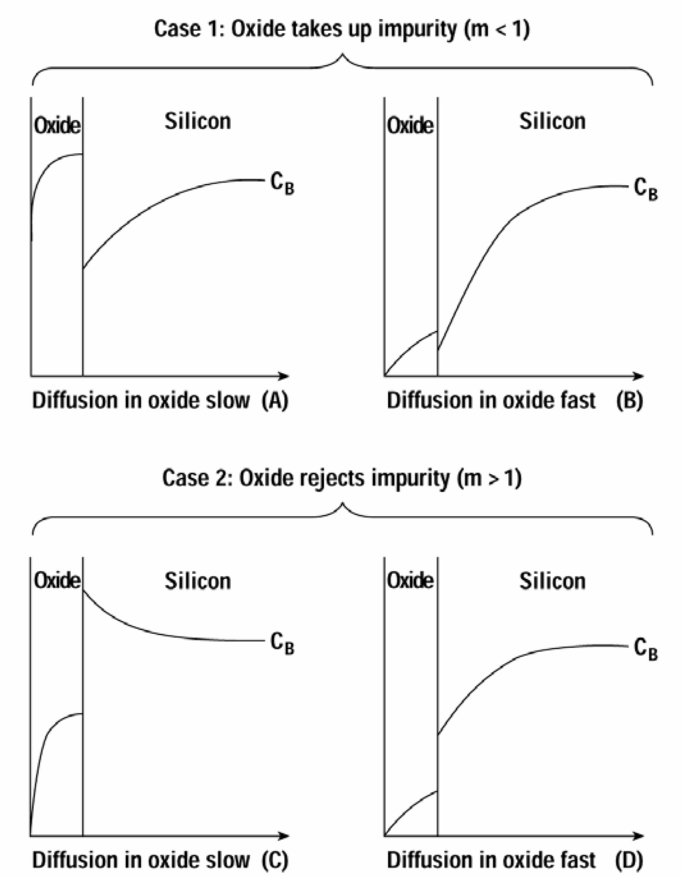


Figure 4.16 The effect of thermal oxidation on the impurity distribution in silicon and silicon dioxide. (A) Slow diffusion in oxide, *m* , 1 (boron in neutral or oxidizing ambient); (B) fast diffusion in oxide, *m* , 1 (boron in hydrogen ambient); (C) slow diffuser in oxide, *m* . 1 (phosphorus, arsenic); (D) fast diffuser in oxide, *m* . 1 (gallium) *(after Grove et al.)*.

If the silicon is initially doped, and then oxidized, the dopant may prefer to be either in the semiconductor, or at the interface (PHOSPHORUS) or in the oxide (BORON)

$$m = \frac{\text{concentration of impurity in Si}}{\text{concentration in oxide}}$$

Oxidation Rate: Dependence on Doping

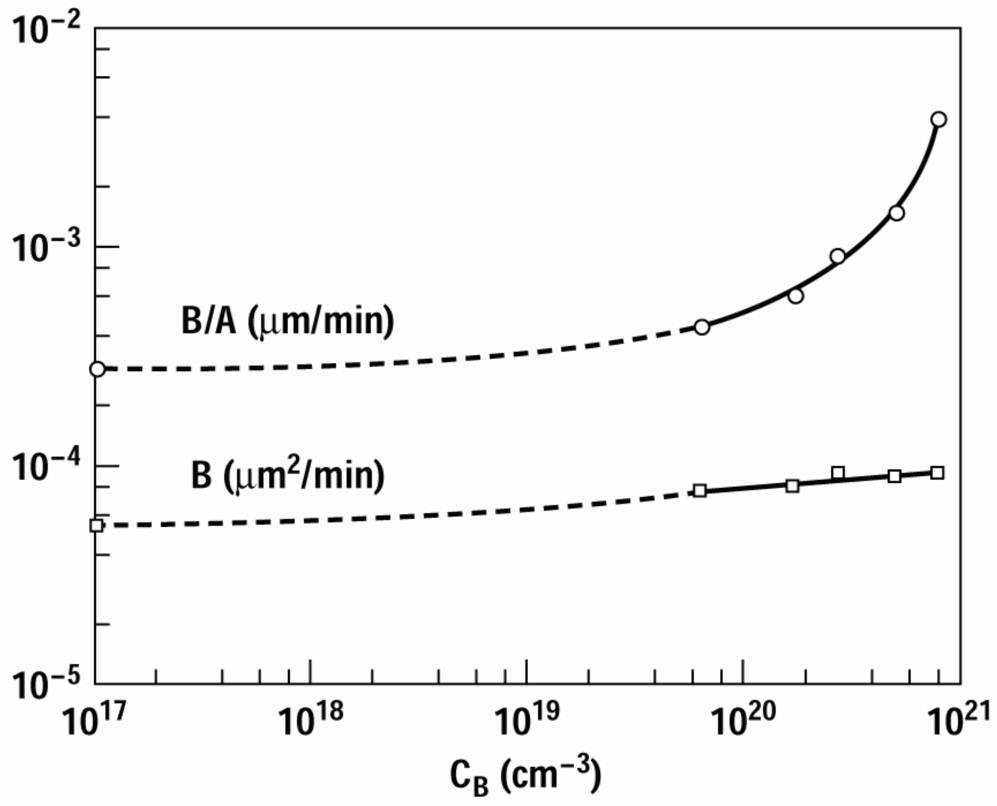


Figure 4.19 Oxidation rate coefficients for dry oxygen at 900?C as functions of the surface concentration of phosphorus *(after Ho et al., reprinted by permission, The Electrochemical Society).*

Doping Dependence: Boron

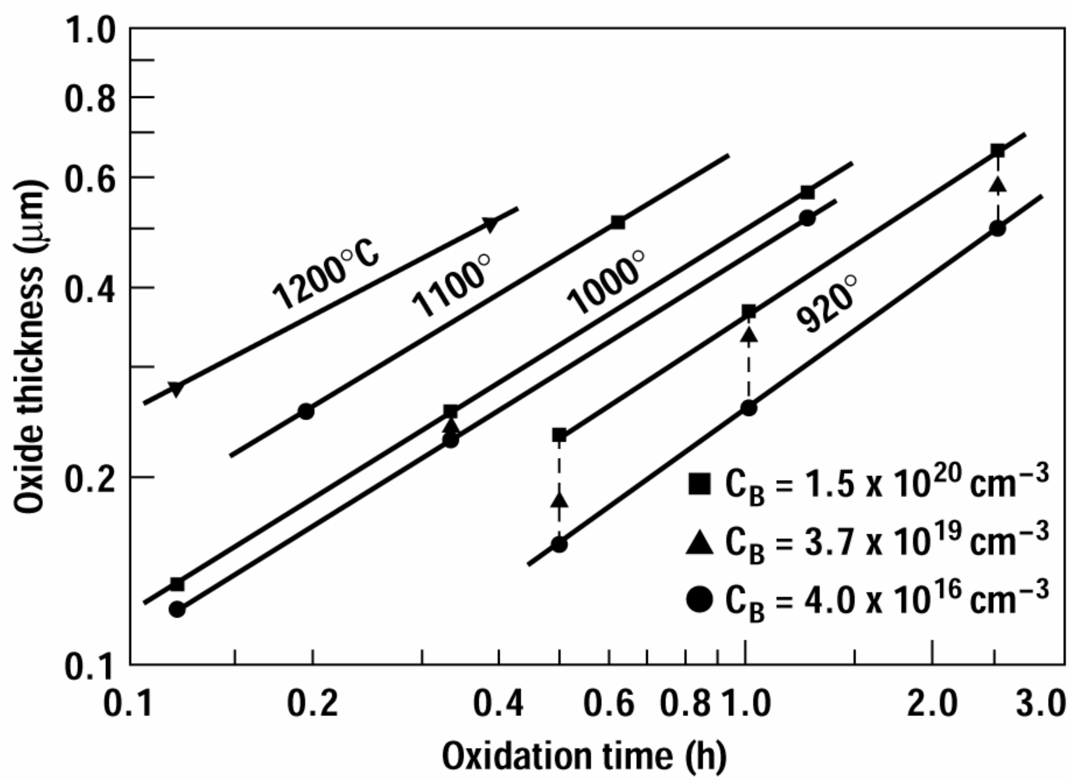


Figure 4.18 Silicon dioxide thickness versus wet oxidation time for three different surface concentrations of boron *(after Deal et al., reprinted by permission, The Electrochemical Society).*

Impurities in Oxides

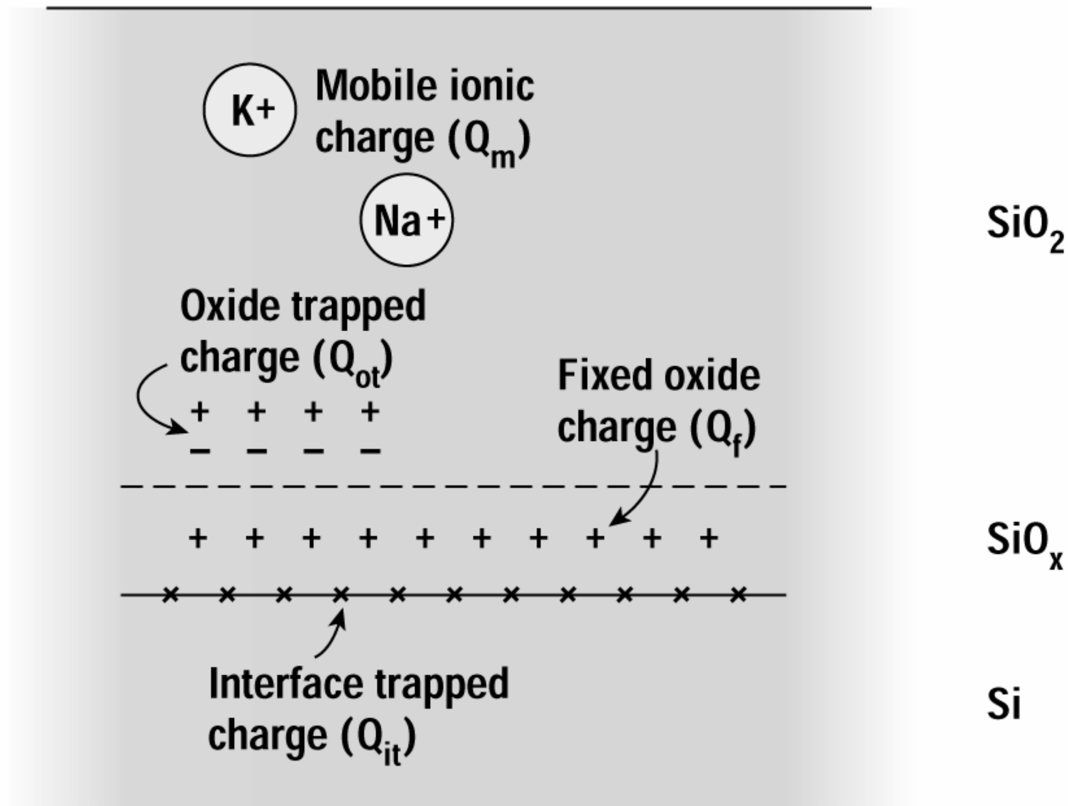


Figure 4.14 Silicon–silicon dioxide structure with mobile, fixed charge, and interface states *(© 1980, IEEE, after Deal)*.