From *Semiconductor Physics and Devices: Basic Principles* (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

p type metal-oxide-semiconductor (MOS), separate

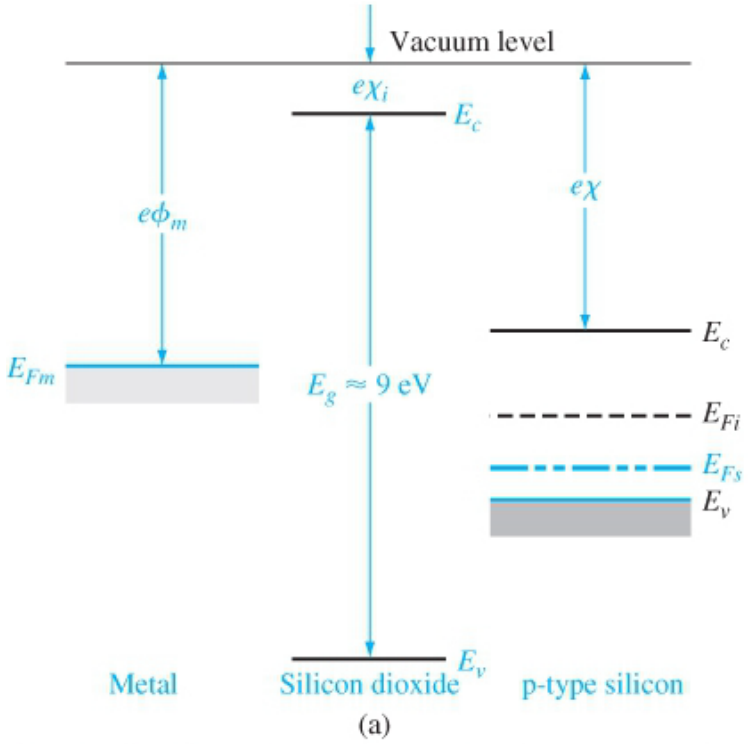


Figure 10.13 | (a) Energy levels in a MOS system prior to contact MOS structure in thermal equilibrium after contact.

- Metal work function ϕ_m is the potential (V) needed to free an electron from the **metal** to free space. The energy (J or eV) required is $e\phi_m$.
- Oxide electron affinity χ_i is the potential (V) needed to free an electron from the conduction band E_c of the **oxide** to free space. The energy (J or eV) required is $e\chi_i$. This energy is <u>in addition to</u> the bandgap E_g energy, i.e., energy required to raise an electron from the valence band E_v to the conduction band E_c.
- Electron affinity χ is the potential (V) needed to free an electron from the conduction band E_c of the **semiconductor substrate** to free space. The energy (J or eV) required is $e\chi$.
- For silicon dioxide (SiO_2), $E_g \sim 9$ eV while $e\chi_i \sim 0.9$ eV. For comparison, the bandgap energy E_g for an intrinsic silicon substrate is 1.12 eV at 300 K.

p type MOS, system

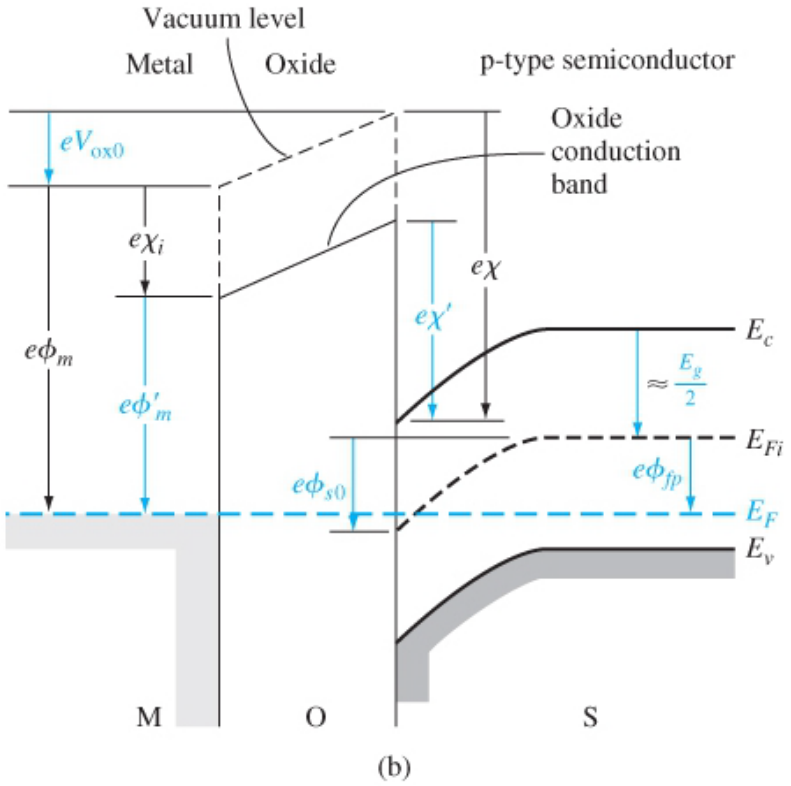
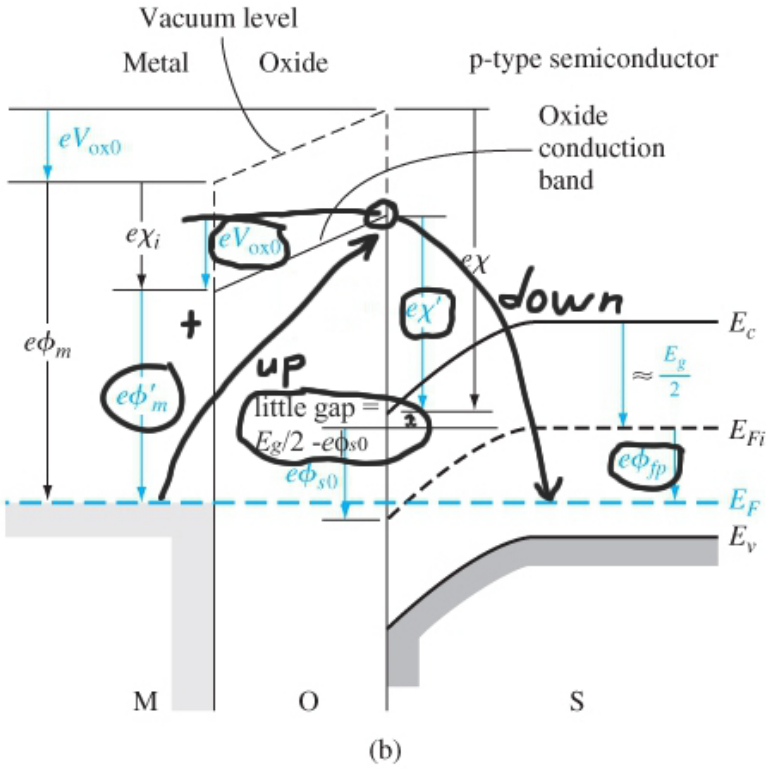


Figure 10.13 | (b) energy-band diagram through the MOS structure in thermal equilibrium after contact.

- Modified metal work function ϕ'_m is the potential (V) needed to move an electron from the **metal** to the conduction band E_c of the **oxide**. The energy (J or eV) required is $e\phi'_m$.
- Modified electron affinity χ' is the potential (V) needed to move an electron from the conduction band E_c of the **semiconductor substrate** (at boundary) to the conduction band E_c of the **oxide**. The energy (J or eV) required is $e\chi'$.
- The change in the potential <u>across the **oxide**</u> at zero bias is V_{ox0}. The energy (J or eV) change is eV_{ox0}.
- The surface potential in the **substrate** at zero bias is ϕ_{s0}. The energy (J or eV) change from in E_{Fi} from the bulk substrate to the surface is $e\phi_{s0}$.

Metal to p-type Substrate 'KVL'



(b)

Figure 10.13 | (b) energy-band diagram through the MOS structure in thermal equilibrium after contact.

- Going up from E_F in metal to top of the conduction band in the oxide takes $e\phi'_m + eV_{ox0}$.
- Going down the top of the conduction band in the oxide to E_F in the semiconductor takes $e\chi' + [E_g/2 - e\phi_{s0}] + e\phi_{fp}$.
- Therefore, $\boldsymbol{e\phi'_m + eV_{ox0} = e\chi' + [Eg - e\phi_{s0}] + e\phi_{fp}}$.
- Rearrange to get $V_{ox0} + \phi_{s0} = -[\phi'_m - (\chi' + E_g/2e + \phi_{fp})] = -\phi_{ms}$.
- Define metal-semiconductor work function $\phi_{ms} = \phi'_m - (\chi' + E_g/2e + \phi_{fp})$