
PHYSICS OF SEMICONDUCTOR DEVICES

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B: The last (valence) energy band is completely filled with electrons at $T=0K$, but the next (empty) energy band overlaps with it (*i.e.*: an empty energy band shares a range of common energy values; $E_g < 0$).

C: The last (valence) energy band is completely filled with electrons and no empty band overlaps with it ($E_g > 0$).

In cases A and B, electrons with the highest energies can easily acquire an infinitesimal amount of energy and jump to a slightly higher permitted energy level, and move through the crystal. In other words, electrons can leave the atom and move in the crystal without receiving any energy. A material with such a property is a *metal*. In case C, a significant amount of energy (equal to E_g or higher) has to be transferred to an electron in order for it to "jump" from the valence band into a permitted energy level of the conduction band. This means that an electron must receive a significant amount of energy before leaving an atom and moving "freely" in the crystal. A material with such properties is either an *insulator* or a *semiconductor*.

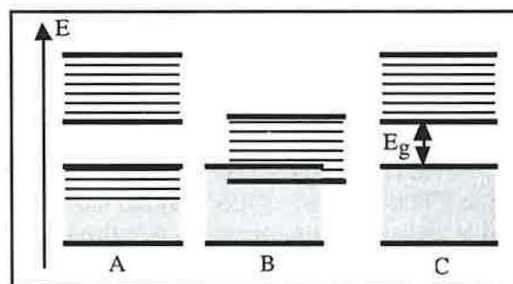


Figure 1.11: Valence band (bottom) and conduction band in a metal (A and B) and in a semiconductor or an insulator (C).^[6]

The distinction between an insulator and a semiconductor is purely quantitative and is based on the value of the energy gap. In a semiconductor E_g is typically smaller than 2 eV and room-temperature thermal energy or excitation from visible-light photons can give electrons enough energy for "jumping" from the valence into the conduction band. The energy gap of the most common semiconductors are: 1.12 eV (silicon), 0.67 eV (germanium), and 1.42 eV (gallium arsenide). Insulators have significantly wider energy bandgaps: 9.0 eV (SiO_2), 5.47 eV (diamond), and 5.0 eV (Si_3N_4). In these materials room-temperature thermal energy is not large enough to place electrons in the conduction band.