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

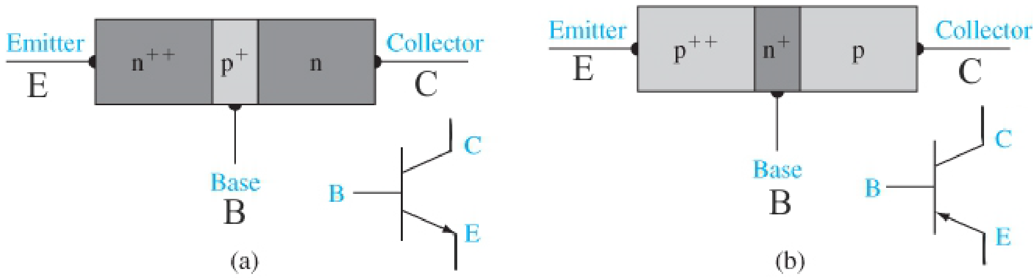

Figure 12.1 | Simplified block diagrams and circuit symbols of (a) npn and (b) pnp bipolar transistors.

- Notation: ++ implies heavy doping concentration whereas + implies a moderate doping concentration.

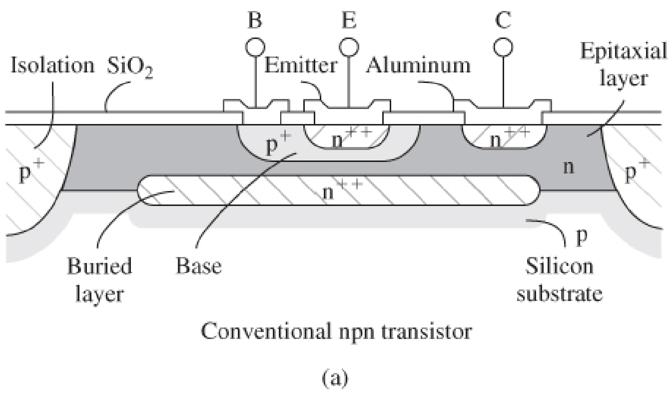

Figure 12.2 | Cross section of (a) a conventional integrated circuit npn bipolar transistor *(From Muller and Kamins [4].)*

- Buried n^{++} layer lowers resistance (and power loss).
- p^{+} regions on either side provide isolation between transistors built on same wafer (or thick oxide regions can be used).
- Note that emitter and collector are NOT symmetrical.

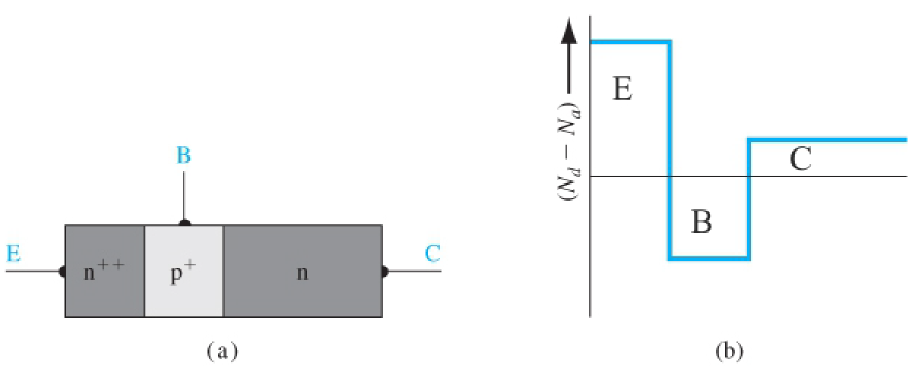

Figure 12.3 | Idealized doping profile of a uniformly doped npn bipolar transistor.

- $N_d \sim 10^{19}$ cm^{-3} for emitter. $N_a \sim 10^{17}$ cm^{-3} for base. $N_d \sim 10^{15}$ cm^{-3} for collector.