Fermi Distribution for Dopant Levels

Advanced

- The *correct* Fermi distribution for most dopant levels, i.e. the probability that an electron is occupying an energy level belonging to a dopant atom is

$$f(E, E_F, T) = \frac{1}{\frac{1}{2} \cdot \exp\left(\frac{E_n - E_F}{kT}\right) + 1}$$

  - The reason for the factor **1/2** instead of the usual **1** is that there is a *spin degeneracy*, i.e. the energy is the same for different spins.
  - $\mathbf{f_{Dop}(E,T)}$ is thus the probability that the level is occupied by an electron of *either* spin. This applies to group **III** acceptors, or group **V** donors as doping elements for group **IV** semiconductors.

- There also might be cases were dopants can accommodate *two* electrons (which then must have paired spin). The Fermi distribution formulated for acceptors in this case is

$$f(E, E_F, T) = \frac{1}{2 \cdot \exp\left(\frac{E_n - E_F}{kT}\right) + 1}$$

- If we allow also *excited* states of the dopant, we obtain the fully generalized Fermi distribution

$$f(E_r, E_F, T) = \frac{1}{\Sigma g_r \cdot \exp\left(\frac{E_r - E_F}{kT}\right) + 1}$$

  - With $\mathbf{E_r}$ **=** energy of the ***r***-th state; $\mathbf{g_r}$ **=** degeneracy/spin factor.

- Interesting, but rather irrelevant as long as we simply assume *completely ionized* donors and acceptors.