

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.
 - $f_{\text{Dop}}(E, T)$ 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 where 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

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

- With E_r = energy of the r -th state; g_r = degeneracy/spin factor.
- ▶ Interesting, but rather irrelevant as long as we simply assume *completely ionized* donors and acceptors.