5.4.3. High injection effects

High injection effects occur in a bipolar junction transistor, just like in a p-n diode. Since under forward active bias condition only the base-emitter diode is forward biased, one only has to explore the high-injection effects of the base-emitter diode. Again is it the lower doped side of the p-n diode where high injection will occur first so that we examine the high-injection condition in the base region. The onset of high injection is therefore expected if the collector current is equal or larger than:

$$I_{C,high-injcetion} \geq q\frac{D_{n.B}N_B}{w_B'} \tag{5.4.7}$$

Or:

$$V_{BE} \geq 2V_t \ln\frac{N_B}{n_i} \tag{5.4.8}$$

As for a p-n diode, high injection modifies the ideality factor of the collector current, making it approximately equal to 2. The ideality factor of the base current however remains unchanged since the minority carrier density in the emitter does not exceed the majority carrier density in the emitter until:

$$V_{BE} \geq 2V_t \ln\frac{N_E}{n_i} \tag{5.4.9}$$

The net effect is that the current gain decreases with increasing bias, or:

$$b = b_0 \exp(-\frac{V_{BE}}{2V_t}) \tag{5.4.10}$$

This current gain reduction is by itself already a good reason to not bias a bipolar junction transistor into high-injection. High-injection also reduces the transit time through the base, as discussed in section 5.5.3, which further reduces its usefulness. In most practical cases and especially when the base is thin and highly doped, high injection will not even be observed in a bipolar transistor, as the effect of series resistances will be dominant instead. Heterojunction bipolar transistors have a much higher base doping so that high-injection does not occur in such devices.