

Proposal for modeling the barrier effect in the bipolar compact model Hicum L0

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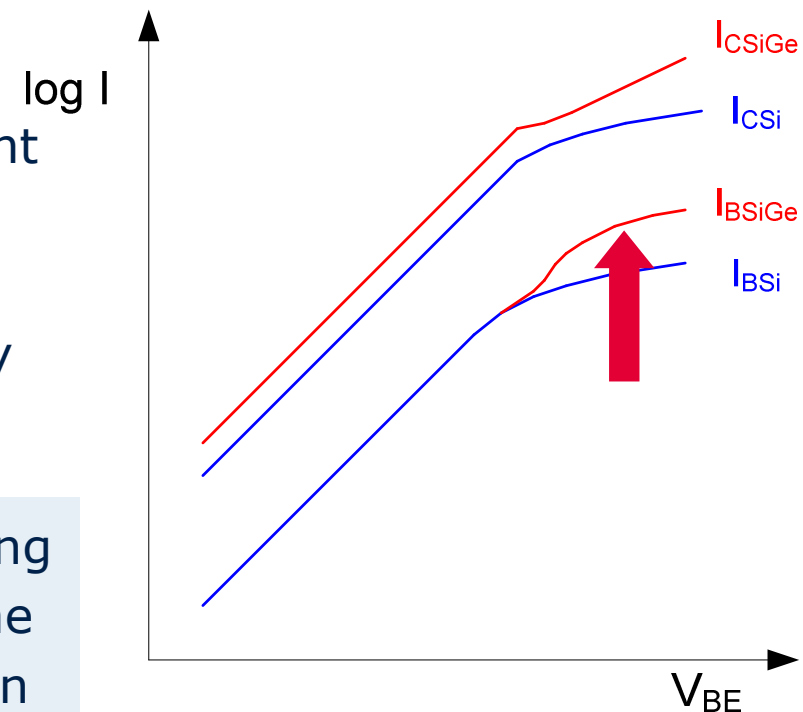


Never stop thinking

Modeling the barrier effect in Hicum L0

- SiGe-Transistors show often a kink in the high base current region , called the "barrier effect"
- The effect was investigated by different authors, e.g. Tiwari [1], Peter et.al., [2], Sadovnikov et. al. [3]
- Cressler and Niu gave a nice summary about this effect, they wrote :

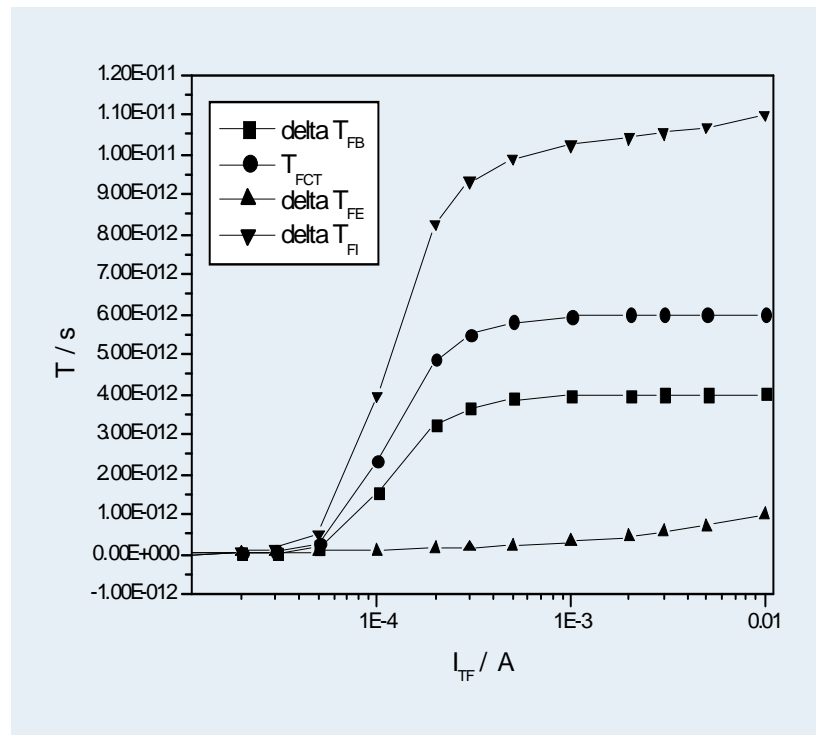
"The sudden increase in J_B accompanying the barrier onset in a SiGe HBT is the result of the accumulation of holes in the base region due to HBE (heterojunction barrier effect)"
[4, p.241]



SiGe base current barrier effect

Modeling the barrier effect in Hicum L2

- In HICUM L2 the three current dependent T_{FT} parts and the appropriate charges are calculated separately



Base Part ΔT_{FB}

$$\Delta T_{FB} = (1 - FTHC) \cdot THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right]$$

Collector Part T_{FCT}

$$T_{FCT} = FTHC \cdot THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right]$$

Emitter Part ΔT_{FE}

$$\Delta T_{FE} = TEF0 \left(\frac{I_{TF}}{I_{CK}} \right)^{GTE}$$

Modeling the barrier effect in Hicum L2

- This allows to use the absolute base charge Q_{bf} for modeling the barrier effect
- The additional base current, created by the barrier effect, is calculated by the following approach [5]:

$$I_{bh_rec} = \frac{Q_{bf}}{TBHREC}$$

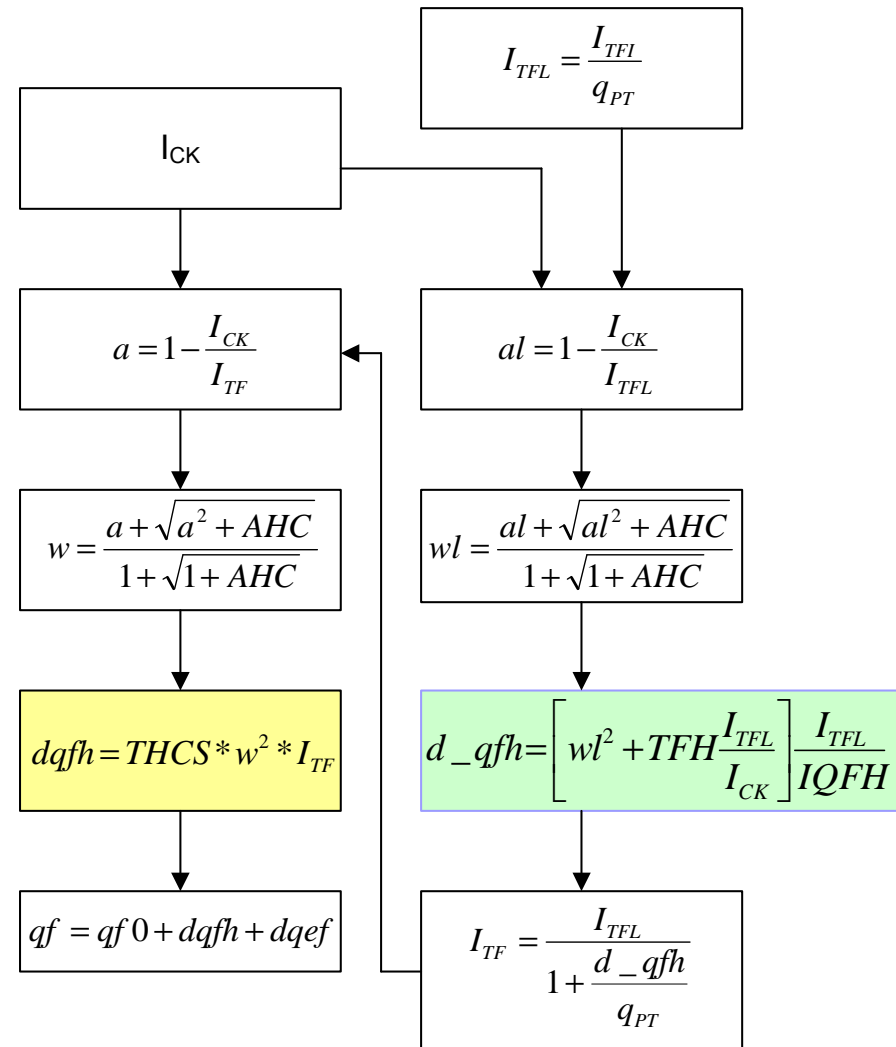
with the new model parameter TBHREC

Modeling the barrier effect in Hicium L0

- In Hicium L0 v1.12 , however, base and collector charge are merged into ONE current dependent charge component
- Additional, we have to decide between to different high current charge components:

- d_qfh is used for the transfer current I_{TF}

- dqfh is used for the total minority charge qf



Modeling the barrier effect in Hicum L0

- To model the barrier effect, we have to multiply the ideal BE current with a operating point dependent factor $f_{Barrier}$

$$I_{jbe} = I_{be} * f_{Barrier} + I_{re}$$

- If no barrier effect appears (low V_{be}), we need $f_{Barrier} = 1$
- If barrier effect appears (high V_{be}), we need $f_{Barrier} > 1$
- This could be realized normalizing the charge dq_{fh} to qf_0 , like:

$$f_{Barrier} = 1 + \frac{dq_{fh}}{qf_0}$$

- However, this overestimates the increase of I_B , because only the base component of dq_{fh} is responsible for the I_B increase

Modeling the barrier effect in Hicum L0

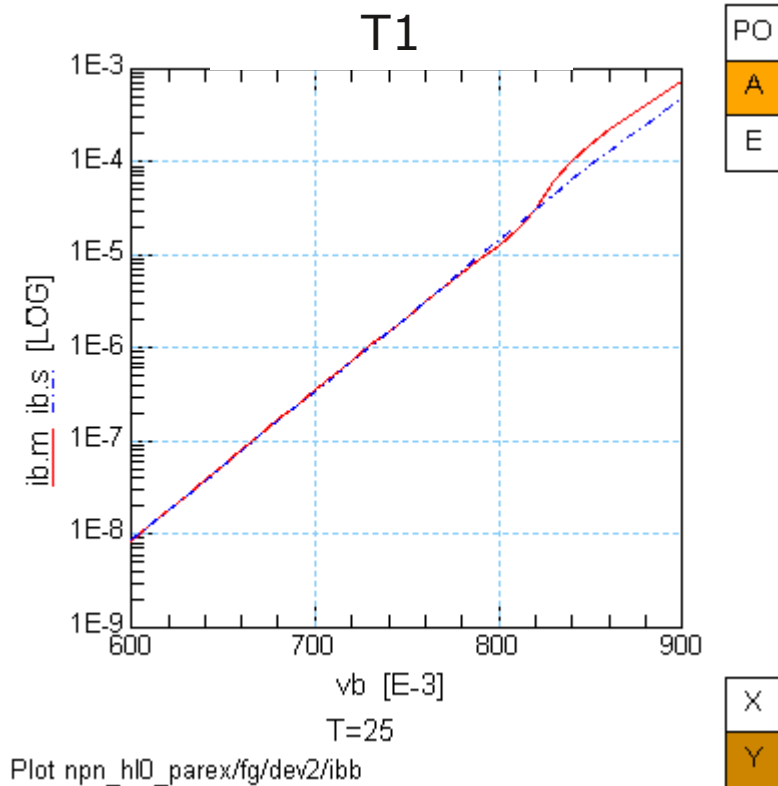
- That is why we have to split $dqfh$ using a multiplier $(1-FTHC)$. We end up with the following approach:

$$f_{Barrier} = 1 + \frac{(1-FTHC) * dqfh}{qf0}$$

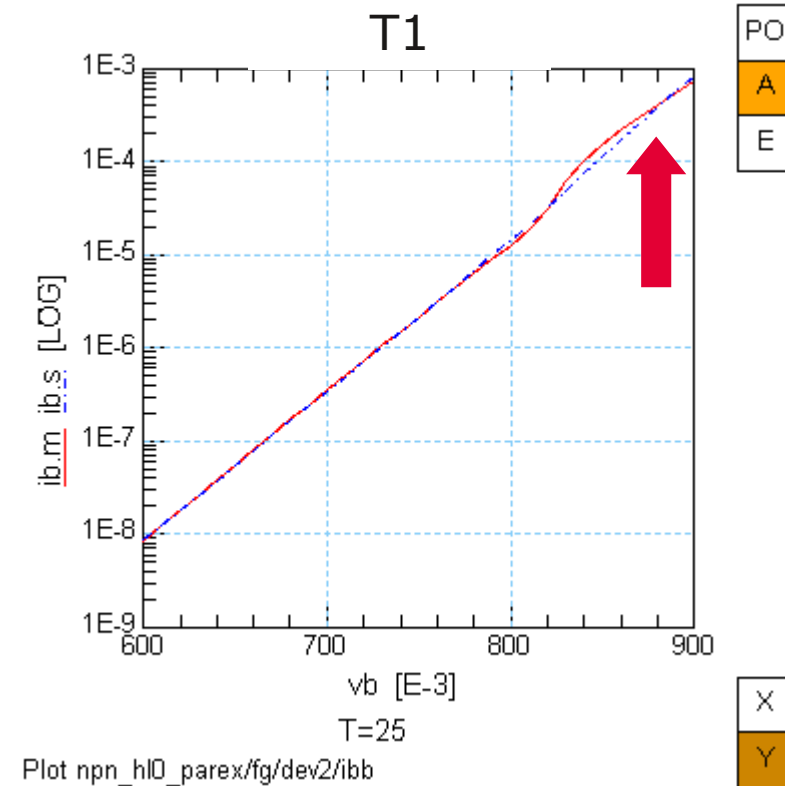
$$I_{jbe} = I_{be} * f_{Barrier} + I_{re}$$

Note: The model parameter FTHC is used here in the same meaning as in Hicum L2.

Modeling the barrier effect in Hicum L0 Results

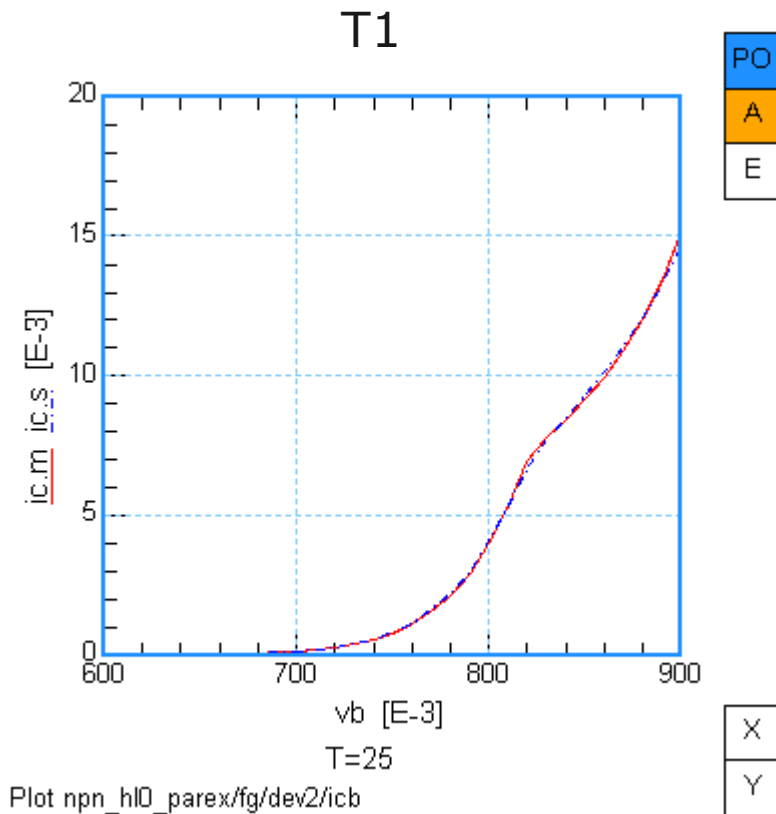


$I_b = f(V_{be}), V_c = 1V$
 $FTHC = 1$
 no barrier effect

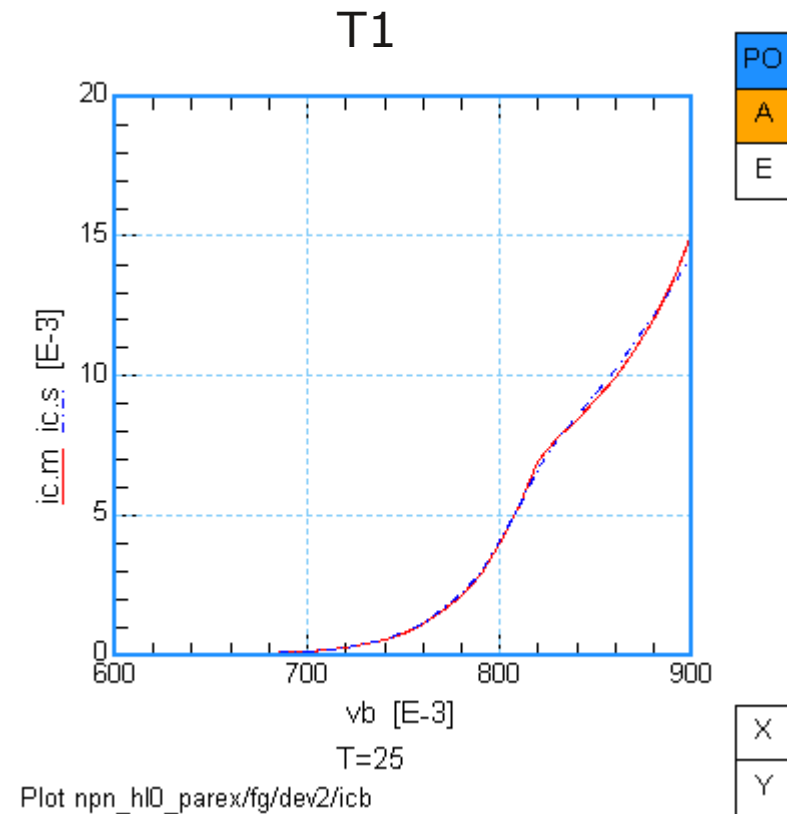


$I_b = f(V_{be}), V_c = 1V$
 $FTHC = 0.95$
 with barrier effect

Modeling the barrier effect in Hicum L0 Results



$I_c=f(V_{be}), V_c=1V$
 $FTHC=1, IQFH=357\mu A$
 no barrier effect



$I_c=f(V_{be}), V_c=1V$
 $FTHC=0.95, IQFH=393\mu A$
 with barrier effect
 IQFH is slightly adjusted

Modeling the barrier effect in Hicum L0

Summary



- SiGe-Transistors show often a kink in the high base current region, called the “barrier effect”
- This effect is modeled in HICUM L2 using the base minority charge Q_{fb} and the additional model parameter TBHREC
- In HICUM L0 this way is blocked, because base and collector part of the minority charge are merged in the charge dq_{fh}
- A possible solution of the problem is to use a multiplier $f_{Barrier}$ for the ideal base current. It is defined using a fraction of dq_{fh} only.
- The model parameter FTHC, known already from HICUM L2, was introduced as the split factor. It may be extracted fitting the base current in the high V_{be} range.

Modeling the barrier effect in Hicium L0

References



1. Tiwari, S.: "A New Effect at High Currents in Heterostructure Bipolar Transistors", Electron Device Letters, vol.9, no.3, 1988, p.142 - 144
2. Peter, M.S.; Slotbom, J.W.; Terpstra, D.: "Impact Ionisation and Neutral Base Recombination in SiGe HBT's", BCTM 1999
3. Sadovnikov, A.; Krakowski, T.; El_Diwany: "Influence of the Extrinsic Base on the Base Current Kink in SiGe BJTs", ISTDM 2004
4. Cressler, John, Niu, Guofu: "Silicon-Germanium Heterojunction Bipolar Transistors", Artech House, 2002
5. Schroeter, M.: "Hicium Level2 v2.2, Summary of extensions and changes", March 2005