



Proposal to Add NF/NR Parameters for Base and Collector Current into Mextram

March 9, 2006

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Issue

- As V_{be} increases, base-emitter depletion region shrinks (x0 x1) (Fig. 1)
- This change in depletion region changes the effective doping of Germanium in the base for SiGe HBT devices.
- As a result, the slope of I_b and I_c versus V_{be} changes with bias.

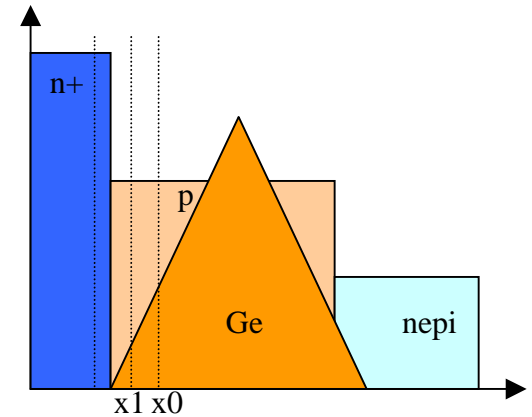
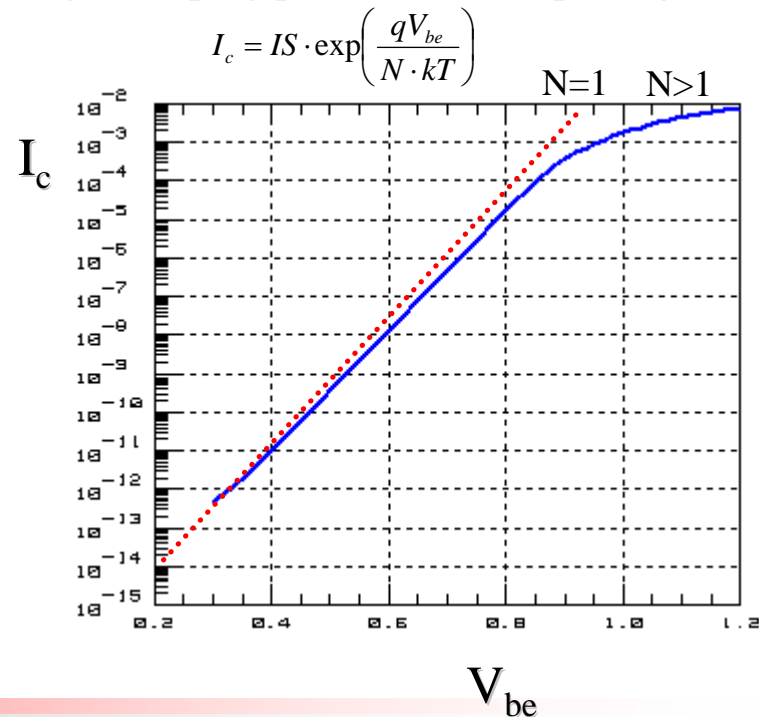
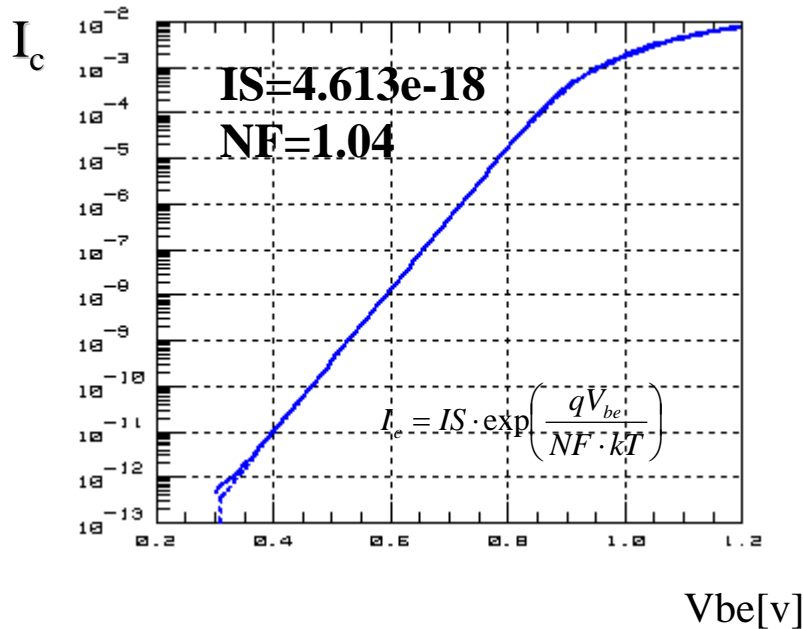


Fig. 1 Doping profile across n-p-n regions.



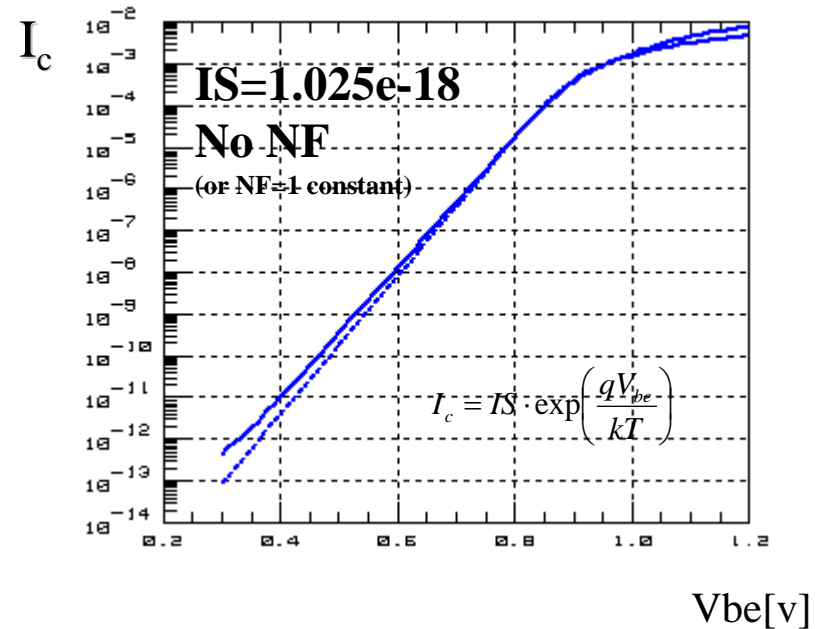
Comparison with GP Model

Gummel Poon



Since NF exists in the GP model, the slope can be fitted exactly.

Mextram504

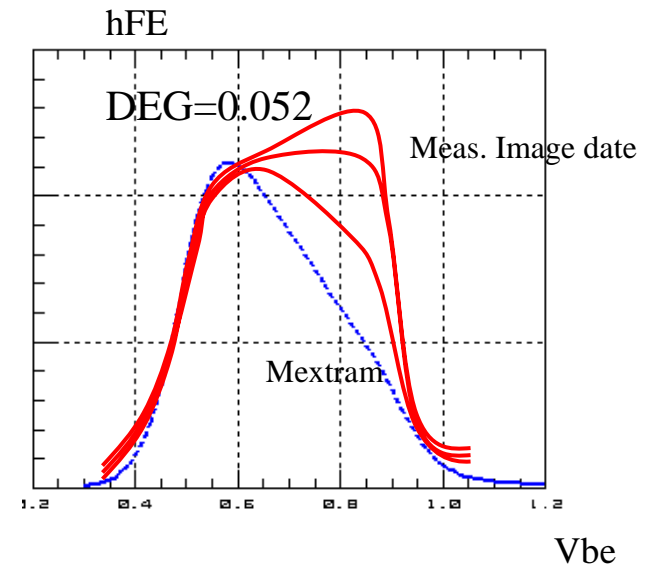
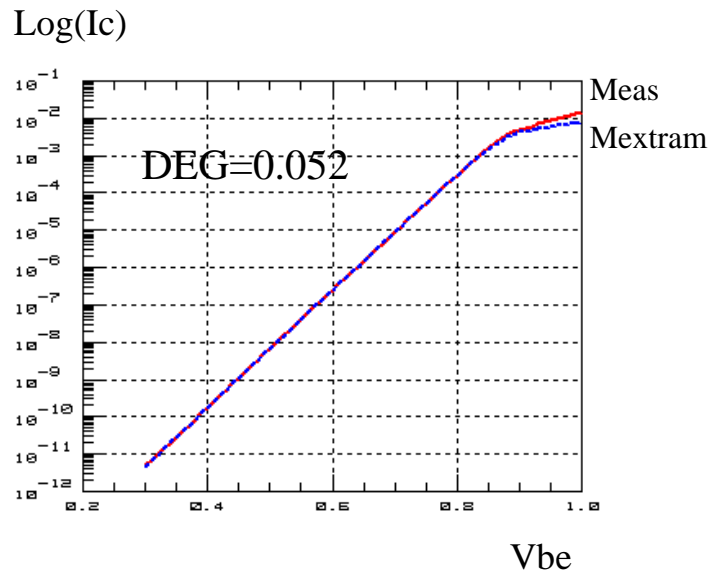


Since NF does not exist in the formulation for Mextram, the slope cannot be fitted.



Fitting I_c with DEG

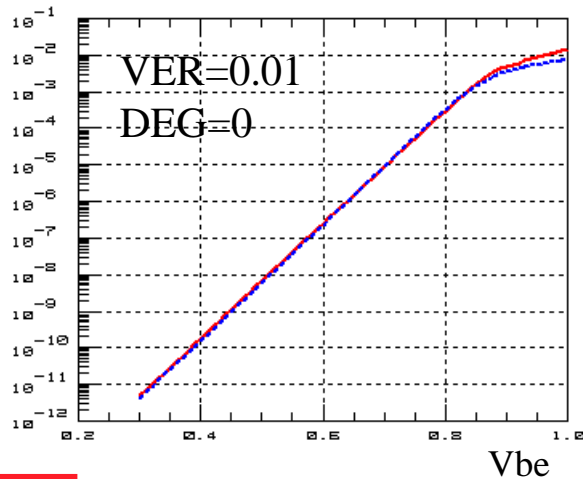
- I_c slope can be fitted using the DEG parameter.
- However, h_{FE} decreases.
- We have devices with different h_{FE} behavior.



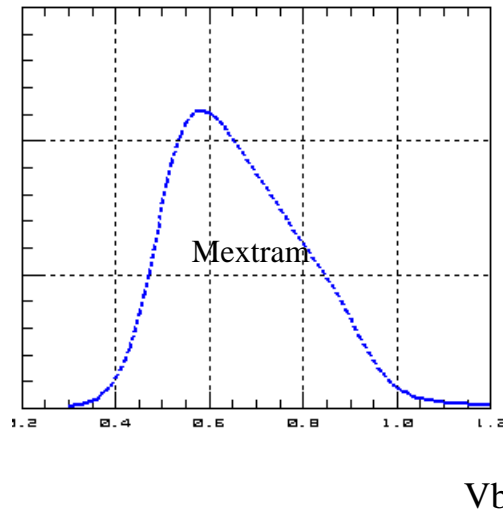
Fitting I_c with VER

- I_c slope can be fitted with the VER parameter.
- However, like DEG, h_{FE} always decreases.
- Abnormal effect on CJE is seen.

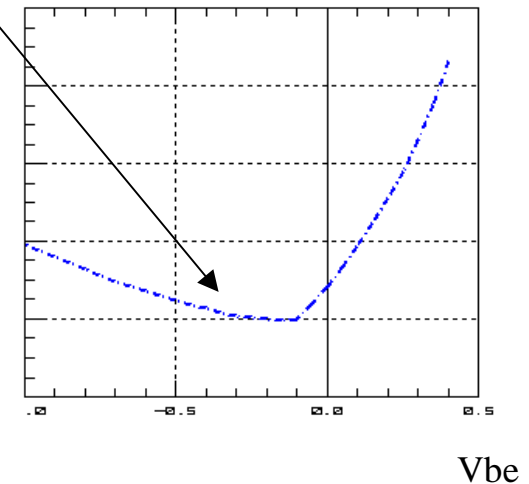
Log(I_c)



h_{FE}



CJE



Proposal: Add NF/NR to Ib

- Implementation in Mextram of NBF and NBR for Ib in the same way as NF in GP model would be desired for both forward and reverse cases, as there is no other way to adjust this for Ib:

$$I_{b,forward} = \frac{IS}{BF} \cdot \exp\left(\frac{qV_{be}}{NBF \cdot kT}\right)$$

$$I_{b,reverse} = \frac{IS}{BF} \cdot \exp\left(\frac{qV_{bc}}{NBR \cdot kT}\right)$$



Fitting Proposal for SiGe

- **Fit I_c using the DEG parameter.**
- **Fit I_b and hFE using the NBF and NBR parameters.**
- **Possible Problem: DEG may not be suitable for normal silicon bipolar device.**
 - DEG is a bandgap change parameter, but normal silicon bipolar devices don't have a change in bandgap.



Proposal for Si Bipolar: Additionally Add Independent NF/NR to Ic

- Implementation in Mextram of NF and NR for Ic in the same way as the GP model would be preferred for both forward and reverse cases:

$$I_{c,forward} = IS \cdot \exp\left(\frac{qV_{be}}{NF \cdot kT}\right)$$

$$I_{c,reverse} = IS \cdot \exp\left(\frac{qV_{bc}}{NR \cdot kT}\right)$$



Summary

■ For SiGe bipolar devices

- Fit I_c with DEG
- Fit I_b and hFE with new NBF and NBR parameters

■ For pure silicon bipolar devices

- Fit I_c with new NF and NR parameters
- Fit I_b and hFE with new NBF and NBR parameters.





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