



Never stop thinking

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Experience using the XMOD Hicum Master Toolkit HMT

by
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- HMT: What is done?
- HMT: Some parameter extraction problems
- HMT: Need for more flexibility
- HMT: What is the right future concept?

What is done?

Laboratory Report

Notes to the XMOD-Toolkit HMT, Version 2.4

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Subject: Device – Construction, - Modeling, - Simulation

Index: HICUM Level 2 model parameter extraction


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Notes to HMT24_051202.doc

- Since Mai 2005 the HMT Versions 1.2, 2.4 and 2.6 have been tested at Infineon Technologies
- Two feedback reports delivered to XMOD (Ir294 and 309) including proposals to improve usability of HMT
- Many of the proposals are realized by XMOD
- Very fruitful and sufficient collaboration with XMOD, including a visit in Munich and many long phone call discussions
- Many thanks to Bertrand Ardouin for his excellent customer support !

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- HMT: What is done?
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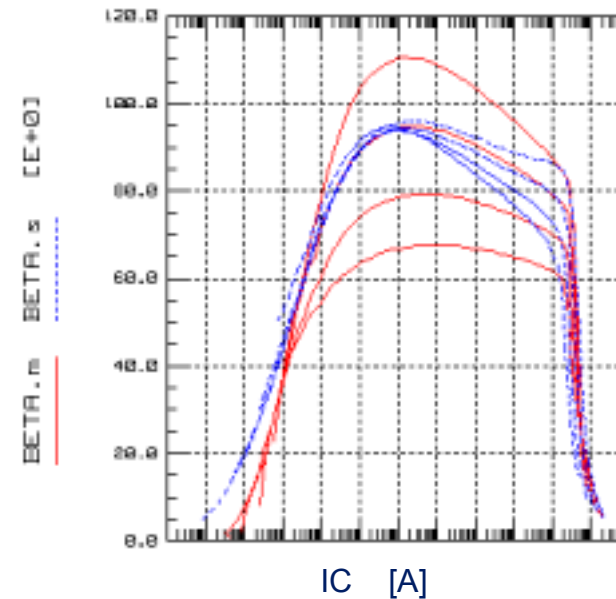
Problem: Beta temperature modeling using HL2

- HICUM L2 temperature modelling of beta is not sufficient
- Example is simulated using ADS (hpeesofsim 2005A.412 Mar 24 2006) and ICCAP2004
- It looks like the nonideal base current does not depend on temperature

$$I_{JBEI} = IBEIS \cdot \left[\exp\left(\frac{U_{B'E'}}{M_{BEI} \cdot U_T}\right) - 1 \right] + IREIS \cdot \left[\exp\left(\frac{U_{B'E'}}{M_{REI} \cdot U_T}\right) - 1 \right]$$

$$I_{xS}(T) = I_{xS}(T_0) \left(\frac{T}{T_0}\right)^{\frac{3}{Mx}} \exp\left(\frac{VGB}{Mx \cdot U_T} \left(\frac{T}{T_0} - 1\right) - ALB \cdot \Delta T\right)$$

Plot HMT_FG_TEMP/PLL/FG/fgumml_beta_plot (0n)
Beta(VBE, TEMP)



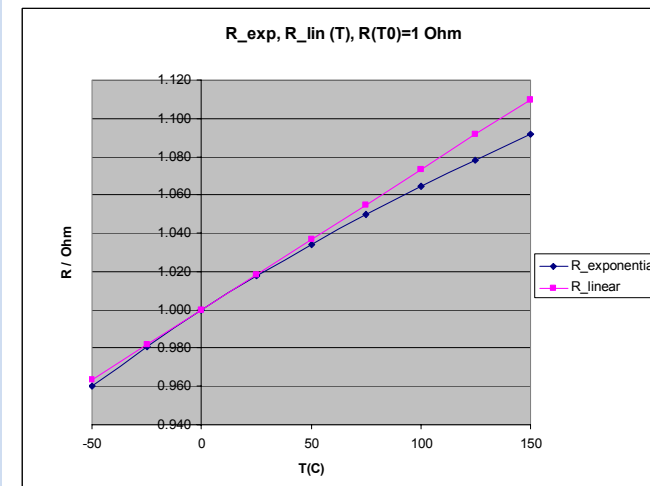
red = measured

blue = simulated

Problem: Rx temperature parameter extraction

	HICUM L2	HMT / Tradica
Equation	$RE(T) = RE(T_0) \left(\frac{T}{T_0} \right)^{ZETA_{RE}}$ (1)	$R_E(T) = R_E(T_0) [1 + a_1 \Delta T + a_2 \Delta T^2]$ (2)
		$R_E(T) \approx R_E(T_0) [1 + a_1 \Delta T]$
Parameter	ZETARE	$a_1 = a_{rke}, a_2$
Unit	-	1/K

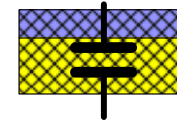
- In HL2 series resistor temperature modelling is based on an exponential function and the model parameter ZETARx (-)
- However, HMT / TRADICA offers a temperature modelling parameter a_rx (1/K), which belongs to a linear approach
- Why the HL2 model parameter extraction tool uses an equation different from the model HL2 itself?
- The best way to extract the HL2 model parameter ZETARX is an optimization of equ (1) on measured data
- Use of equ (2) makes parameter extraction unnecessary complicated



Problem : BE oxide capacitance calculation

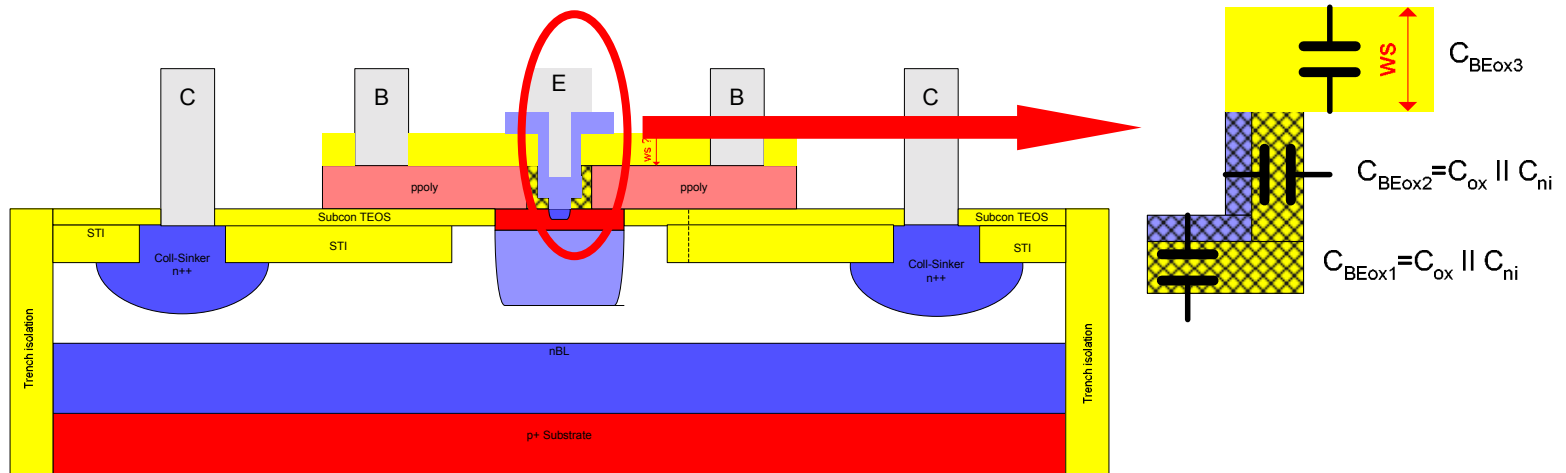
$$\bar{C}_{Eox} = \frac{\epsilon_{ox} \epsilon_0}{w_{S,eff}}$$

$$w_{s,eff} = \epsilon_{ox} \left(\frac{w_{ox}}{\epsilon_{ox}} + \frac{w_n}{\epsilon_n} \right)$$



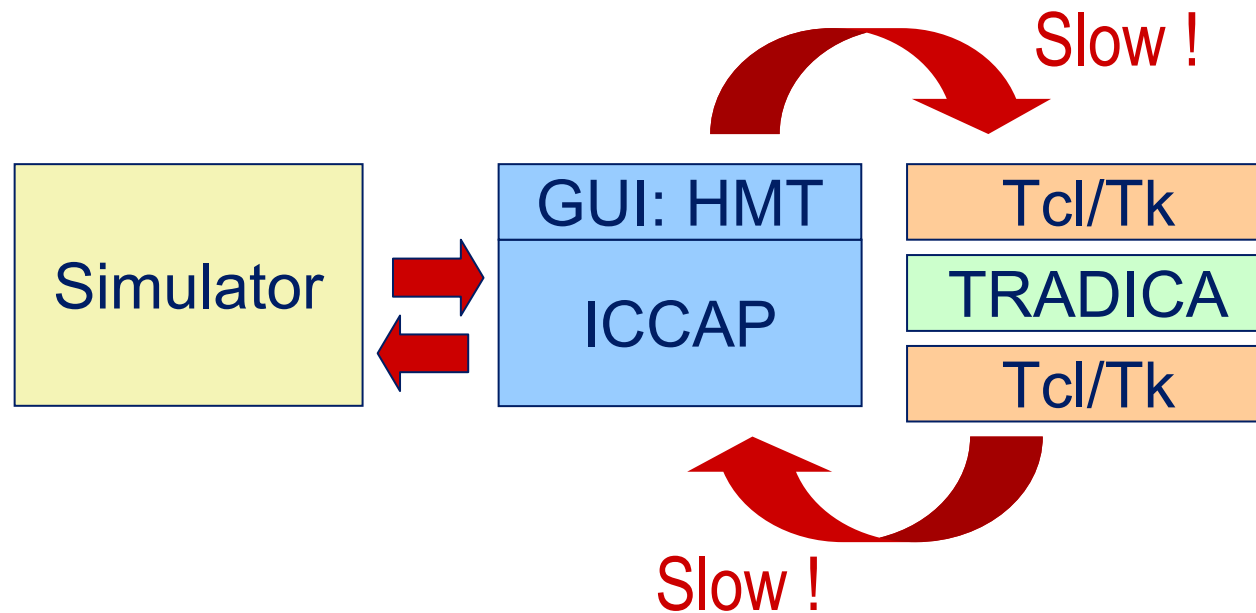
- The BE oxide cap is calculated by TRADICA using an area normalized effective thickness $w_{s,eff}$ (equations from Tradica manual 5.2 p.206, definition of w_s appropriate to cross section on p.86)
- However, this approach is only appropriate for a series of two capacitances
- Real spacer structures may be more complicated
- It would be better to use in HMT /Tradica simply a **perimeter specific oxide capacitance c_{beox_p}**
- The same is valid for the BC oxide capacitance, it would be better to use an perimeter specific oxide capacitance c_{bcx_p}

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Problem: Missing optimization possibility

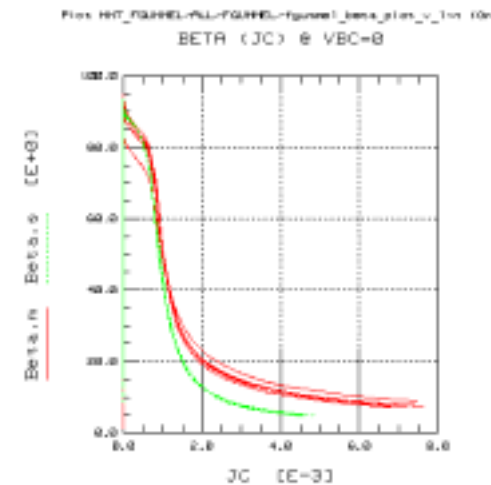
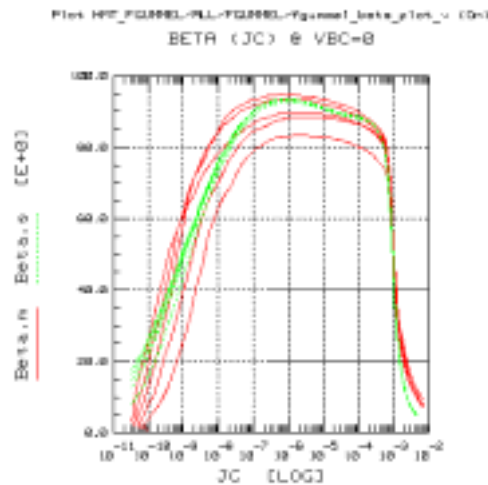
- Optimization for parameter extraction is basically impossible in HMT. Why?
- For each simulation the absolute model parameters must be first calculated using TRADICA
- These absolute values are not saved in HMT
- That is, for each simulation TRADICA must run (TRADICA is part of the optimization loop)
- This makes an optimization impossible, because the loop is too slow
- Example: RTH extraction using optimization on IB instead of extraction on beta



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Problem: Flexibility (1)

- HMT is based on a certain parameter extraction strategy, that is a certain order of model parameter extraction steps
- However, if the user needs other or additional steps / extraction methods, the only way is to change the HMT code (complicated)



- Example 1: the user needs different or additional plots to appear (fwd gummel y-lin additional to fwd gummel y-log)
- Example 2: the use of Gamma_B and Gamm_C (which are intended to divide the collector current into perimeter and area part) is mandatory in HMT
- However, in some cases this approach does not work and a normalization to the area only would be sufficient

Problem: Flexibility (2)

wrong

```
* (c) Infineon AG 2006, all rights reserved
* technology : bxxx
* HICUM/Level2 v2.1 / SPECTRE TRADICA A5.2
subckt n040 ( C B E S )
Q C B E S MOD
model MOD bht type = npn tnom = 25.00
+ c10 = 1E-30 qp0 = ...
```

right

```
subckt n040 ( C B E S )
parameters
+ area=1
*Q C B E S MOD
model MOD bht type = npn tnom = 25.00
+ c10 = 1E-30

npl40w105_v2 (C B E S) MOD m=area
ends
```

- Spectre scs – file syntax problem appeared with the scs files created
- Current mirror results wrong by factor 2
- The reason was the model call Q C B R S MOD
- Another example are the equations inserted for statistical modeling
- Need to define the subcircuit by user

```
inline subckt n01b (c b e s)
parameters
+ area=1
+ aeoff=0.00000000000012345
+ cmatch_is=12345e-8/sqrt(2)
+ cmatch_bf=12345e-8/sqrt(2)
+ is_corr=npn_is_tol*(1+(npn_is_mat)*cmatch_is/sqrt(aeoff*area))
// -----npn-----
model n01b_npn bjt type=npn
+ is=12345E-19*is_corr
```

Problem: Flexibility (3)

- In all semiconductor companies the design environment is historically grown
- Certain restrictions and request are exist: name conventions, syntax requests, subcircuit model used or not, subcircuit definitions, user defined equations for global and local model parameter variations
- The modelling engineer must accomplish this, delivering model files for the process design kits (PDKs)
- Conclusion: the a toolkit like HMT must deliver the flexibility, to create the model files as they expected

PDK model file
of company 1:
Header 1
Filename 1
Subcircuit 1
MC equations 1

PDK model file
of company 2:
Header 2
Filename 2
Subcircuit 2
MC equations 2

PDK model file
of company 3:
Header 3
Filename 3
Subcircuit 3
MC equations 3

PDK model file
of company 4:
Header 4
Filename 4
Subcircuit 4
MC equations 4

PDK model file
of company 5:
Header 5
Filename 5
Subcircuit 5
MC equations 5

More flexibility is needed:

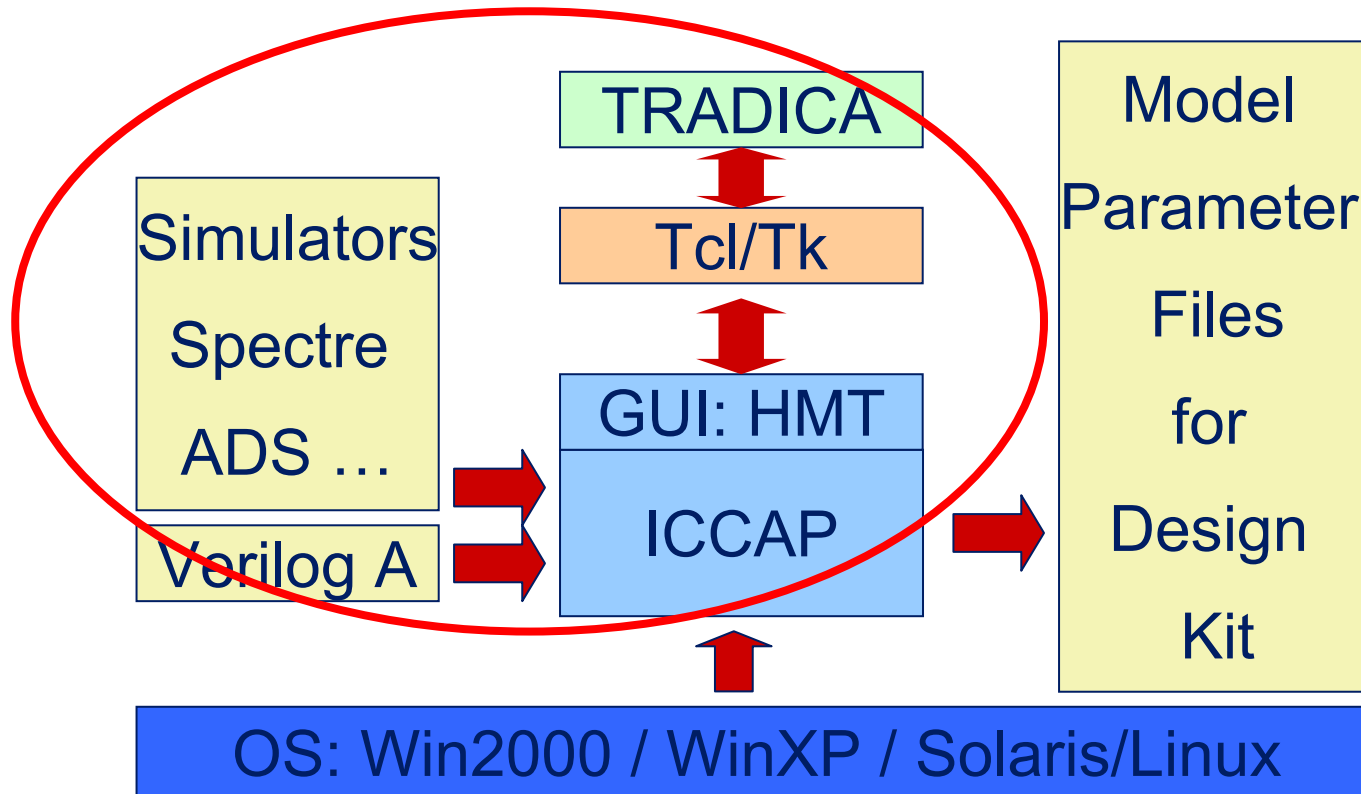
for defining plots,

for incorporating user specific extractions steps,

for writing user specific PDK model files

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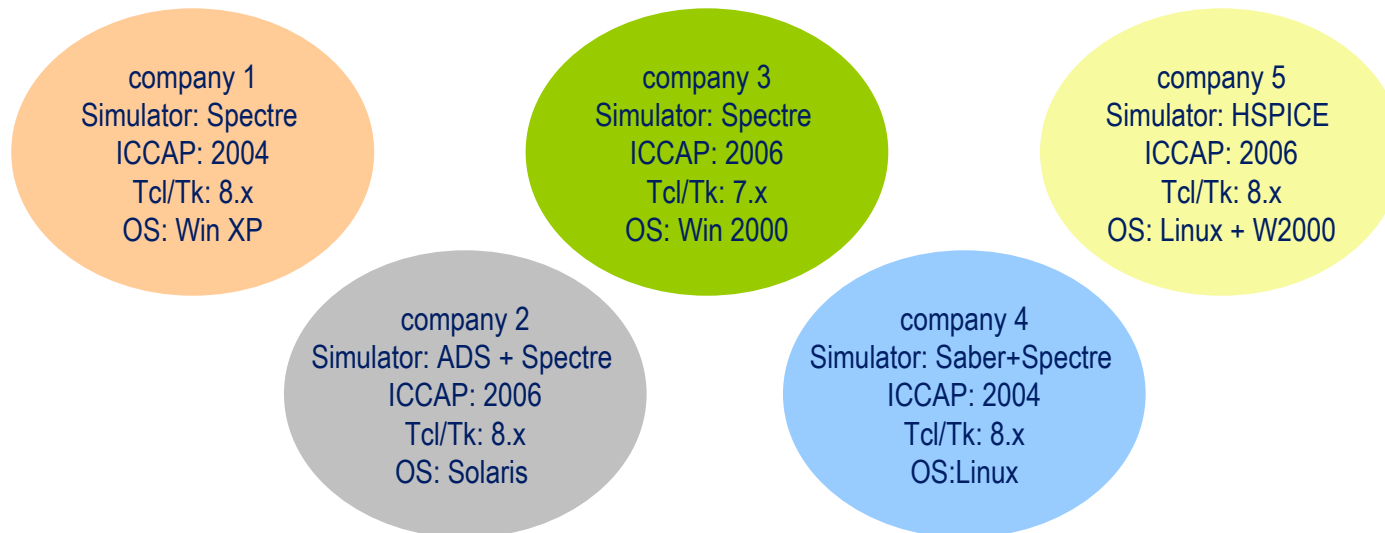
What is the right future concept for scaled model parameter extraction in ICCAP?



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- In HMT four components have to run together: Simulator, ICCAP+GUI, Tcl/TK, Tradica on three different operating system
- Complicated installation, especially in environments, in which user is not administrator
- Malfunctions are likely, because of continuously changing software versions for all components
- Problems appeared: different licence periods, Tcl scripts not running, model parameter files not running in the design environment

for scaled model parameter extraction in ICCAP?



- For XMOD it is nearly impossible to foresee the different configurations and environments, which may exist in different companies
- The result: increasing support effort to solve problems for customers
- The way out: minimize the components used for scaling to
a) the simulator and b) ICCAP only

The better concept for HMT3.0: whole scaling is realized in ICCAP!