Obtaining isothermal data with standard measurement equipment

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OUTLINE

- Introduction
- Physical simulation
- Isotherming of measures
- Results
- Discussion
- Perspectives

Introduction (1/2)

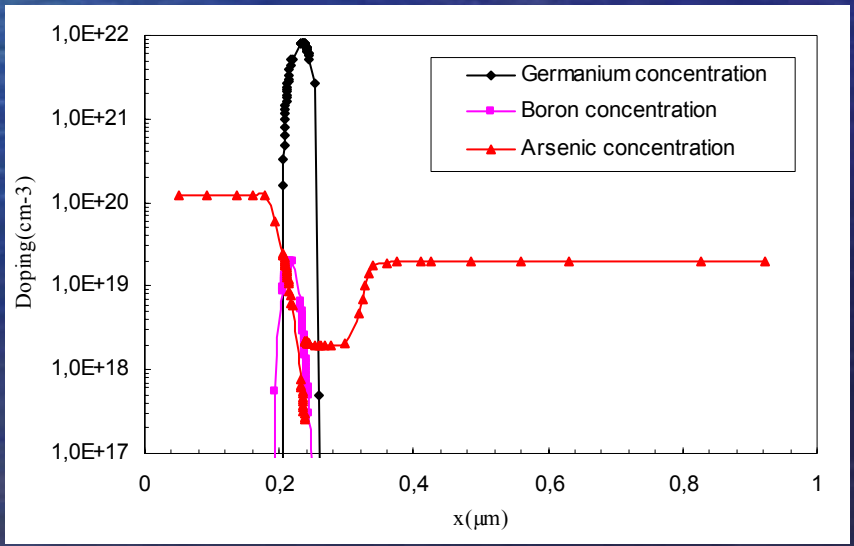
- Selfheating occurs
  - High current densities –> high power
  - Deep trench –> heat flow limited to 1 direction

Introduction (2/2)

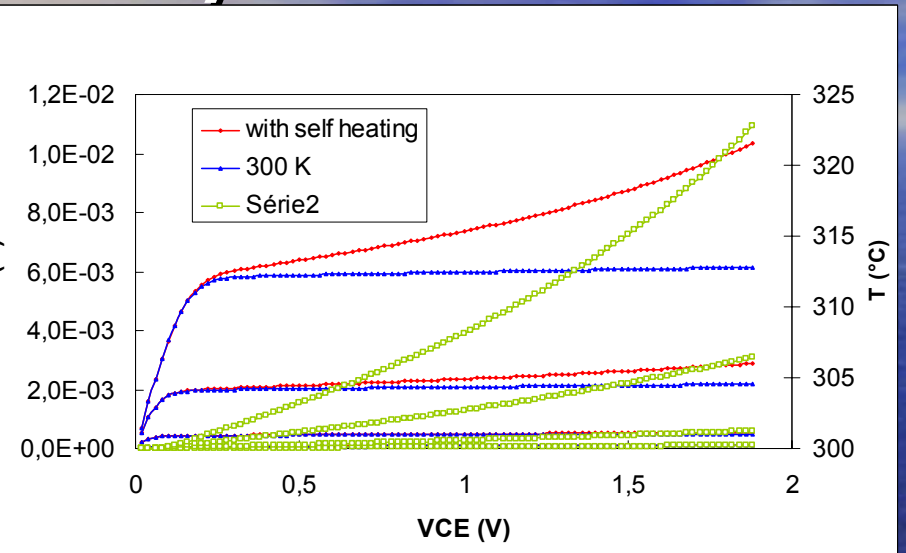
- Standard measurement performed @ TNOM const and known
- But T_{DEVICE} is not const, and not known due to selfheating
- Change of physical parameters
  - Mobility, Energy gap, n_i intrinsic carrier density
- Change of electrical parameters
  - Saturation currents, current gain, resistances, transit time, capacitances

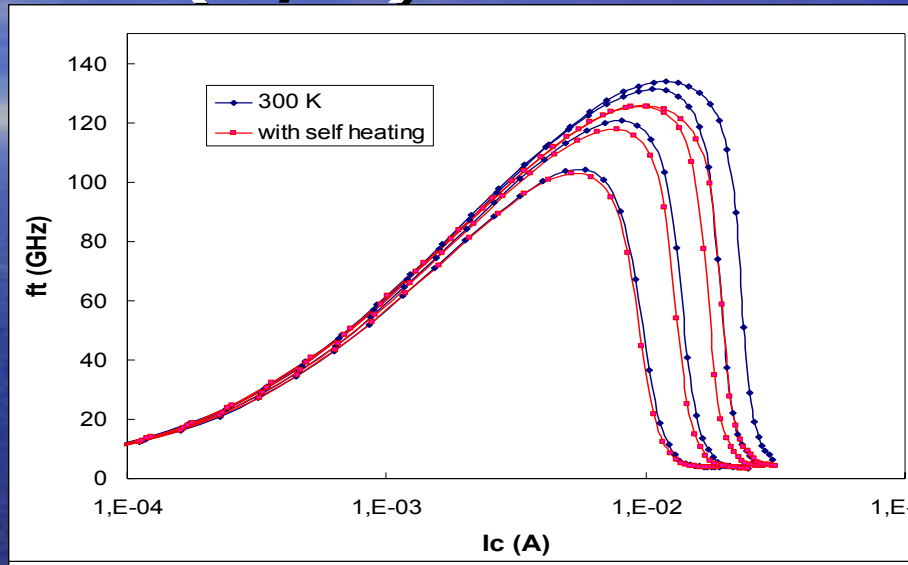
Physical simulation (1/2)

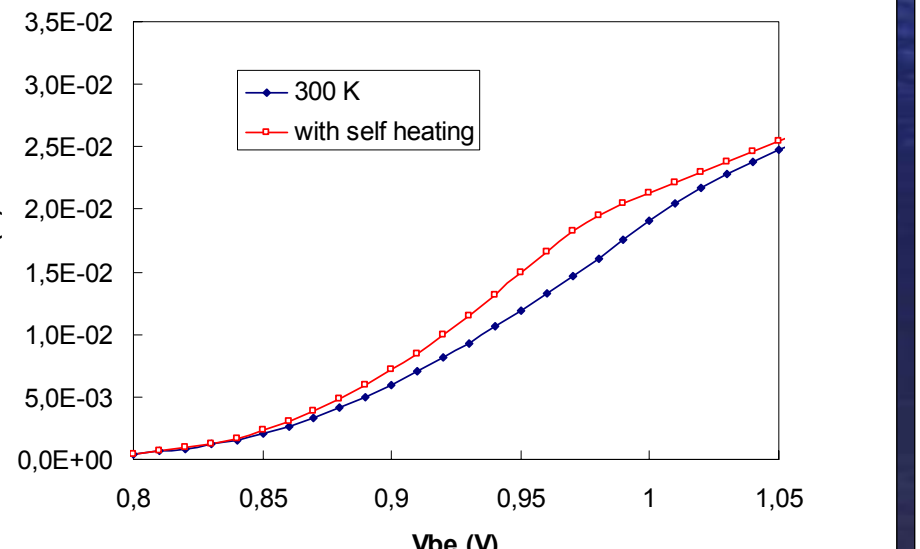
- DESSIS-ISE device and circuit simulator
  - Multidimensional (1, 2 and 3 D)
  - electro-thermal

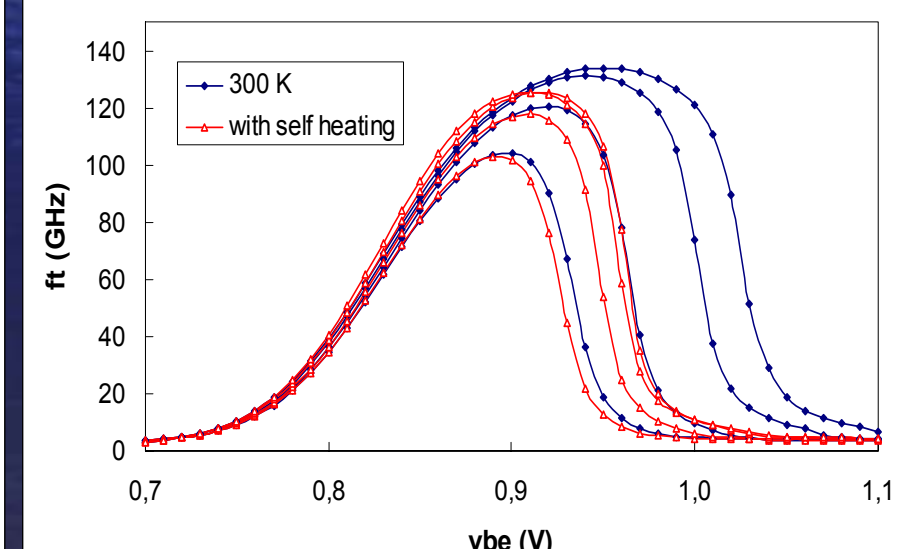


Physical simulation (2/2)









Solutions

- Continue like in the past (ignore the effect)
- Development of a new extraction strategy

  e.g. Simultaneous extraction of isothermal parameter and temperature effect parameter
- Use of standard extraction -> Isothermal data
  - ✓ Pulsed measurements (listen to Franz and Jörg)
  - ✓ Isotherming of measurements (listen to me)

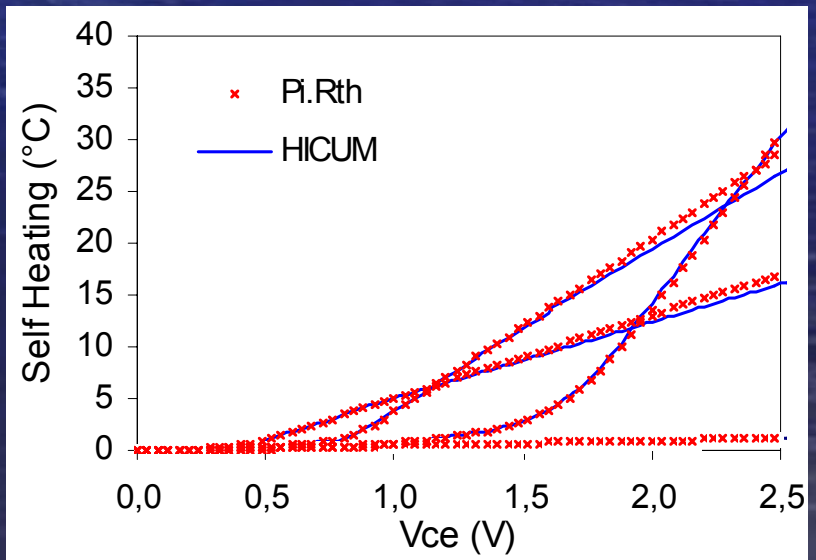
Isotherming of measures (1/5)

- Step 1: calculate the internal transistor temperature:

$$T_i = T_{WAFER} + \Delta T = T_{WAFER} + Z_{TH} P_i$$

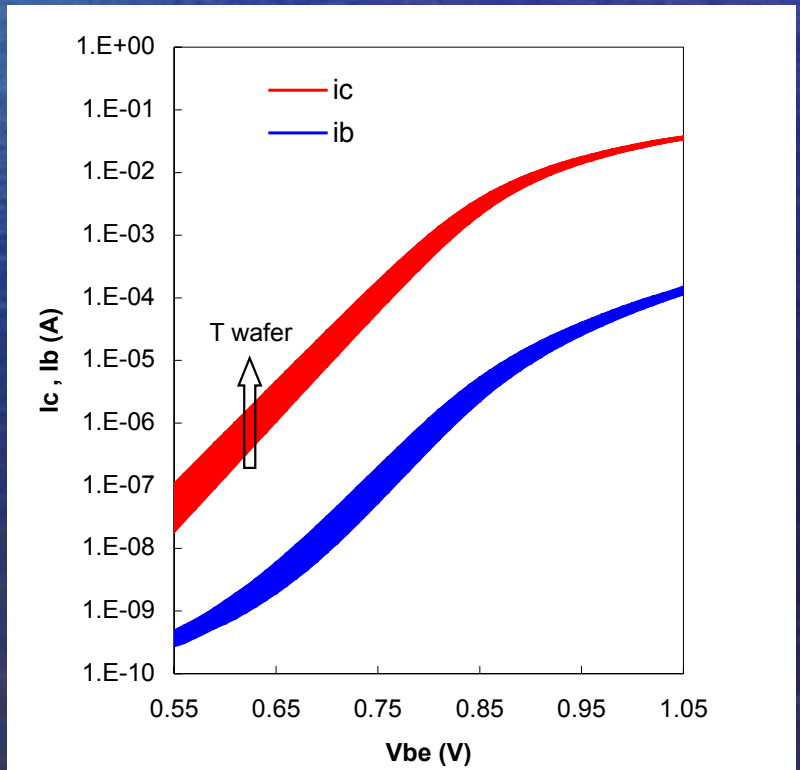
- Verification:
  Temperature rise on the Early Plot:

  equation above compared to Hicum



Isotherming of measures (2/5)

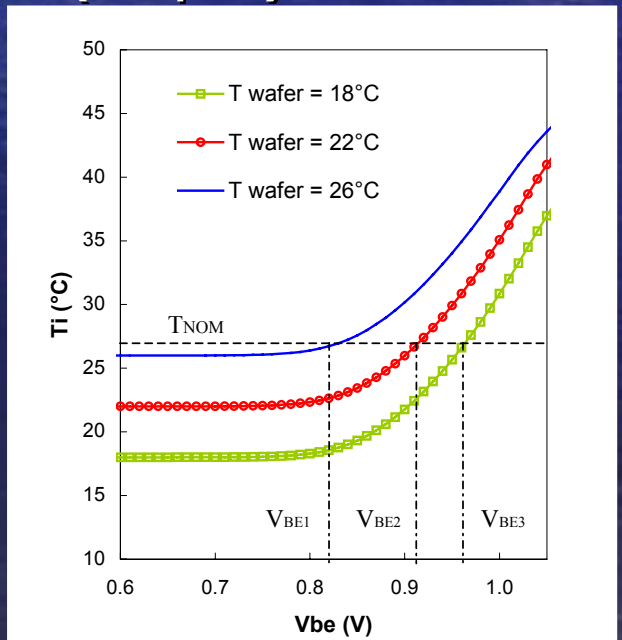
- Step 2: Make many measures @ different temperatures (between T_{NOM} and T_{NOM}-ΔT_{MAX})



Isotherming of measures (3/5)

- Step 3: Combining Step 1 and Step 2
  For each measured characteristics (step 2) the temperature rise due to power dissipation is plotted using the analytical equation (step 1)

- Gummel Plot:

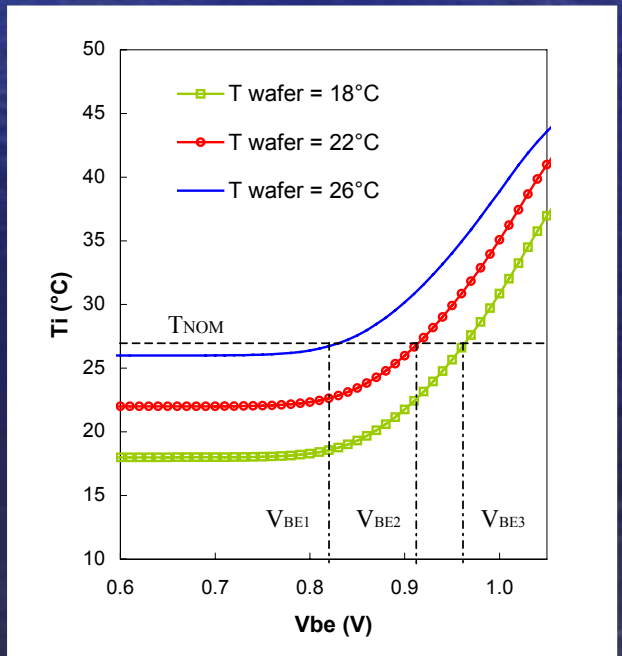


Isotherming of measures (4/5)

- Step 4: Data processing:
  On each temperature curve the points are determined where the internal temperature T_i is equal to T_{nom}.

- Solve numerically the equation $T_i = f(V_B) = T_{nom}$ and you will find

  $V_B(Ti = 27°C)$.



Isotherming of measures (5/5)

- Step 5:
  - Search for each $V_B(Ti = 27°C)$ the corresponding $I_C(V_B(Ti = 27°C))$ value.
  - All the couples of points [$V_B(Ti = 27°C)$, $I_C(V_B(Ti = 27°C))$] represent an isothermal curve.
- Step 6: Data post processing

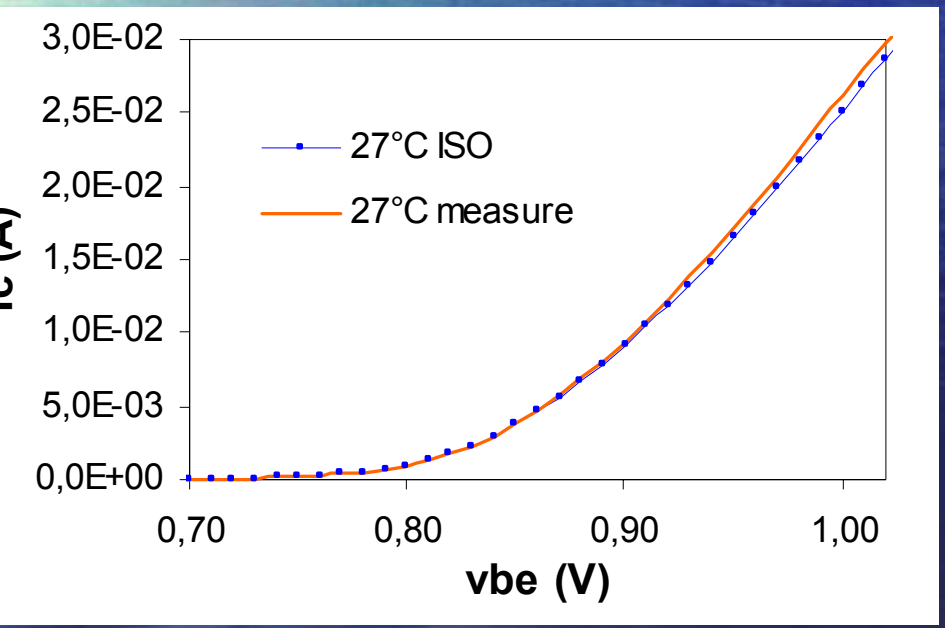
  -Interpolation procedure to recover a constant sweep on V_B

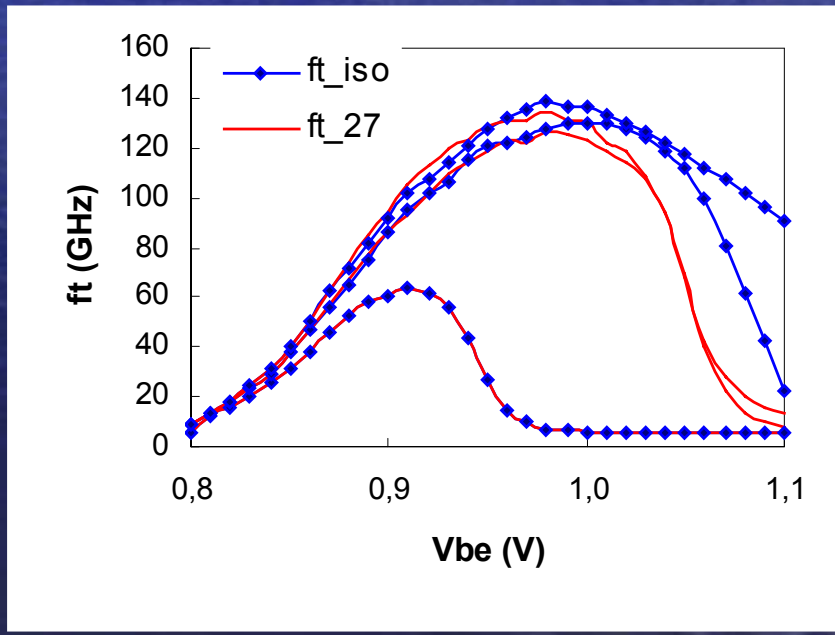
  -Useful for subsequent parameter extraction and simulation
- Step 7: This operation is repeated for all DC and AC measurements

Results

- BiCMOS SiGe ST Microelectronics technology

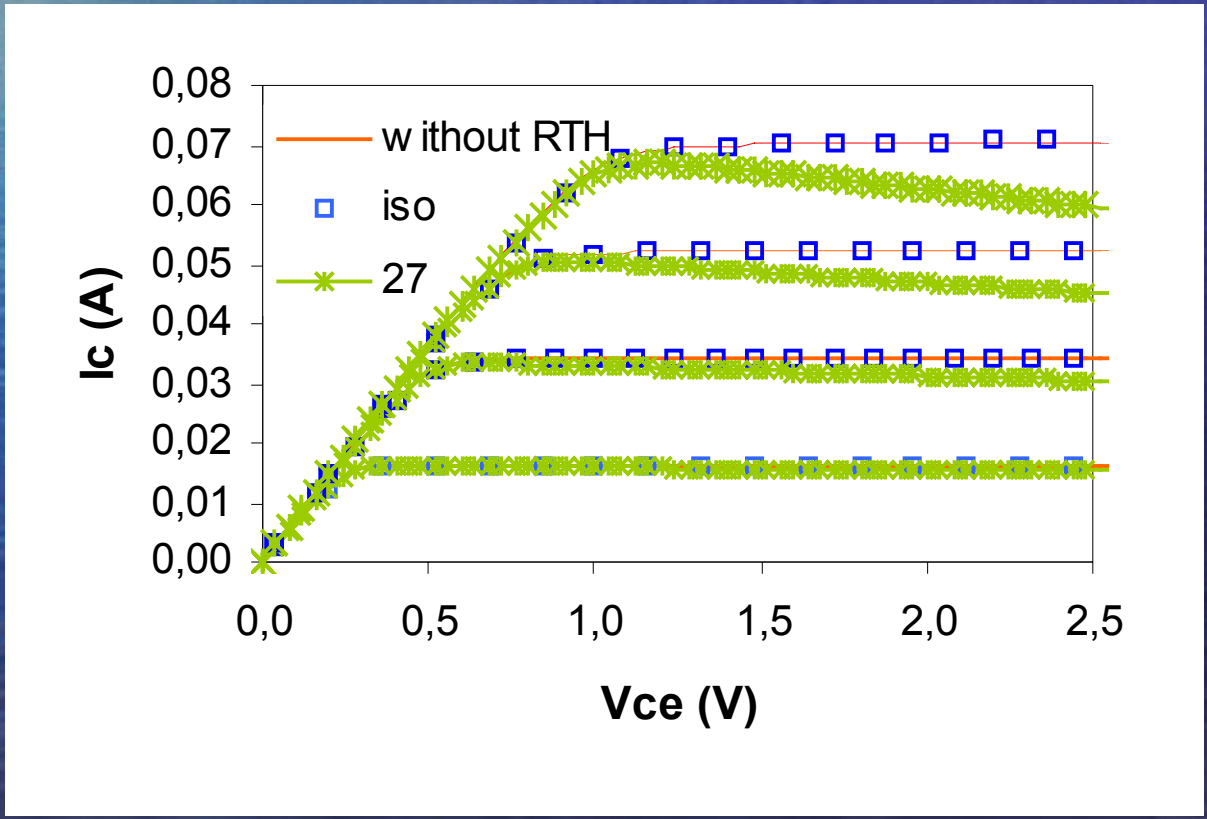
  f_T of 150 GHz; emitter area: 0.25 * 12.65 µm².





Method validation

- Synthetic data



Conclusion

- New method to get isothermal data
- No specific equipment used
- No ambiguity: Is the pulse short enough

Perspectives

- Selfheating is a key issue
- Selfheating will change standard parameter extraction
  - first step: RTH
  - Temperature dependence of resistances and ev. Capacitances
  - Temperature dependence of transit time (using isothermal data)
- Standard strategy (modify the extraction routines !!)