Scalable Electrical Model for a SOI-RF-LDMOS Including Drain Drift Region Resistance Self-Heating Effects

FTM
SP & HV
Device Characterization & Modeling

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Outlines

- Introduction
  - Work background
    - application, technology etc.
- Modeling self-heating effects
  - Choice of electrical and thermal model
  - Thermal parameters relationships, principles and assumptions
- Model description
- Results
- Conclusions

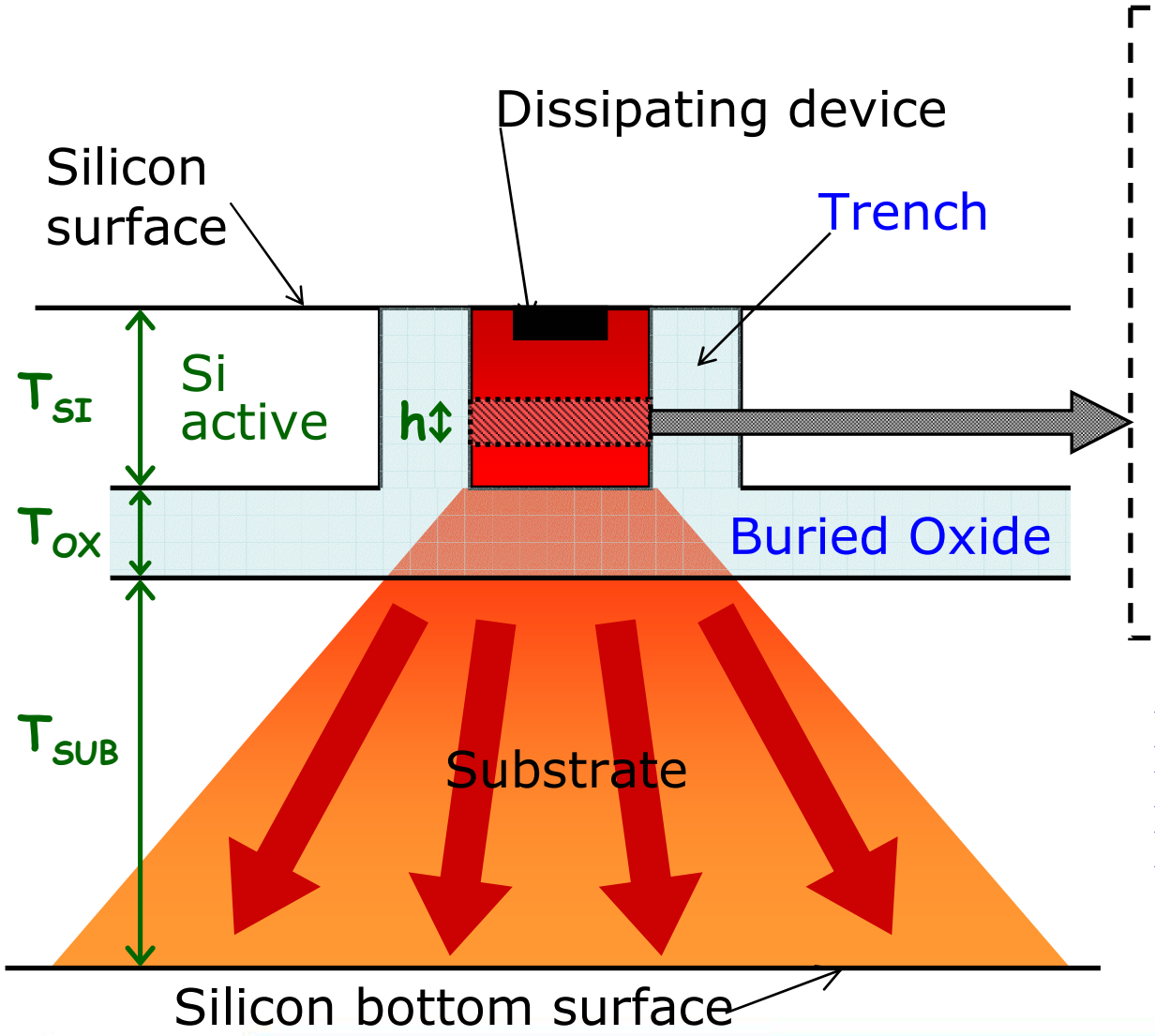
Introduction

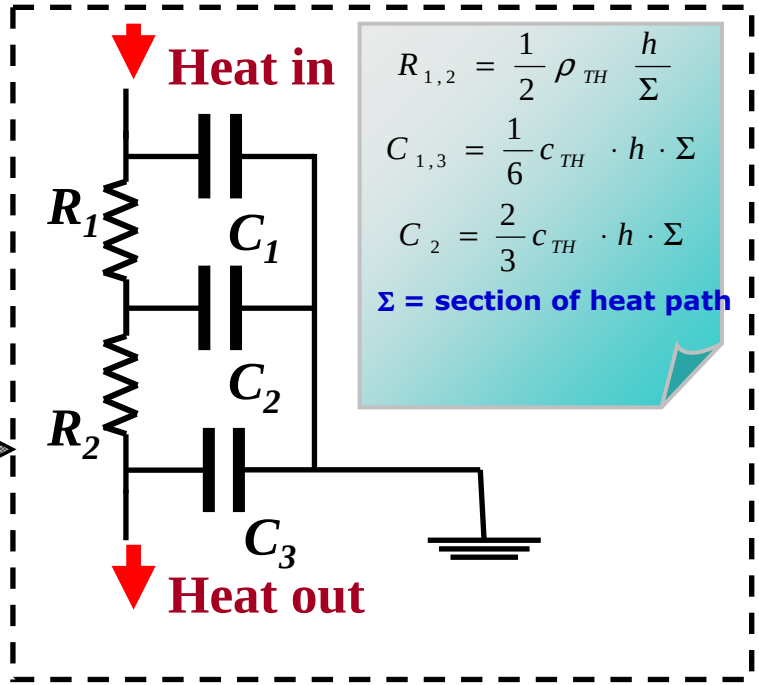
- Purpose
  - An electrical model which includes thermal behaviors of intrinsic MOS and its drift region, and represents the best compromise among accuracy, simulation time and difficulty of extraction.
- Device and Process
  - *n*-channel RF-LDMOS
  - SOI-C-RF LDMOS 8 Technology
- Application
  - Power amplifier for cellular phones
- Advantages and Drawbacks for SOI Technologies
  - Advantages: no parasitic effects through the substrate thanks to buried oxide (BOX). More performing devices.
  - Drawbacks: Self-Heating-Effects (SHE) due to the poor thermal conductivity of buried oxide. Reduction of current capability.

Modeling Self Heating Effect

- Model for Intrinsic MOS w/ thermal node
  - Berkeley BSIMSOI
- Heat spreading model
  - 3D distributed thermal network
    - Best of Accuracy
    - Physical simulation (not our case)
  - Vertical distributed thermal network

45° heat spreading Distributed Model





- *Cth* well defined
- Good accuracy in transient
- Big simulation time

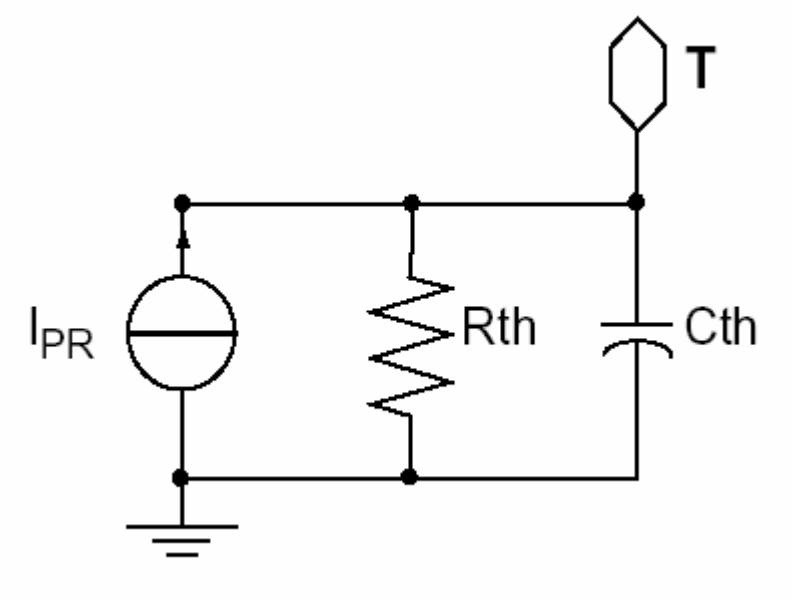
Modeling Self Heating Effect/2

- For RF application (GHz), *Cth* is insensitive

- A simple thermal RC seems to be convenient:
  - Advantages: Simulation time
  - Drawbacks: Lower accuracy in transient simulation, not needed in RF simulation
  - Rth can be easily calculated
    - $Rth = Rth_{Si} + Rth_{ox} + Rth_{Sub}$

Thermal Capacitance Extraction

- Based on simulations
  - Transient analysis on a power step response of a RC circuit.

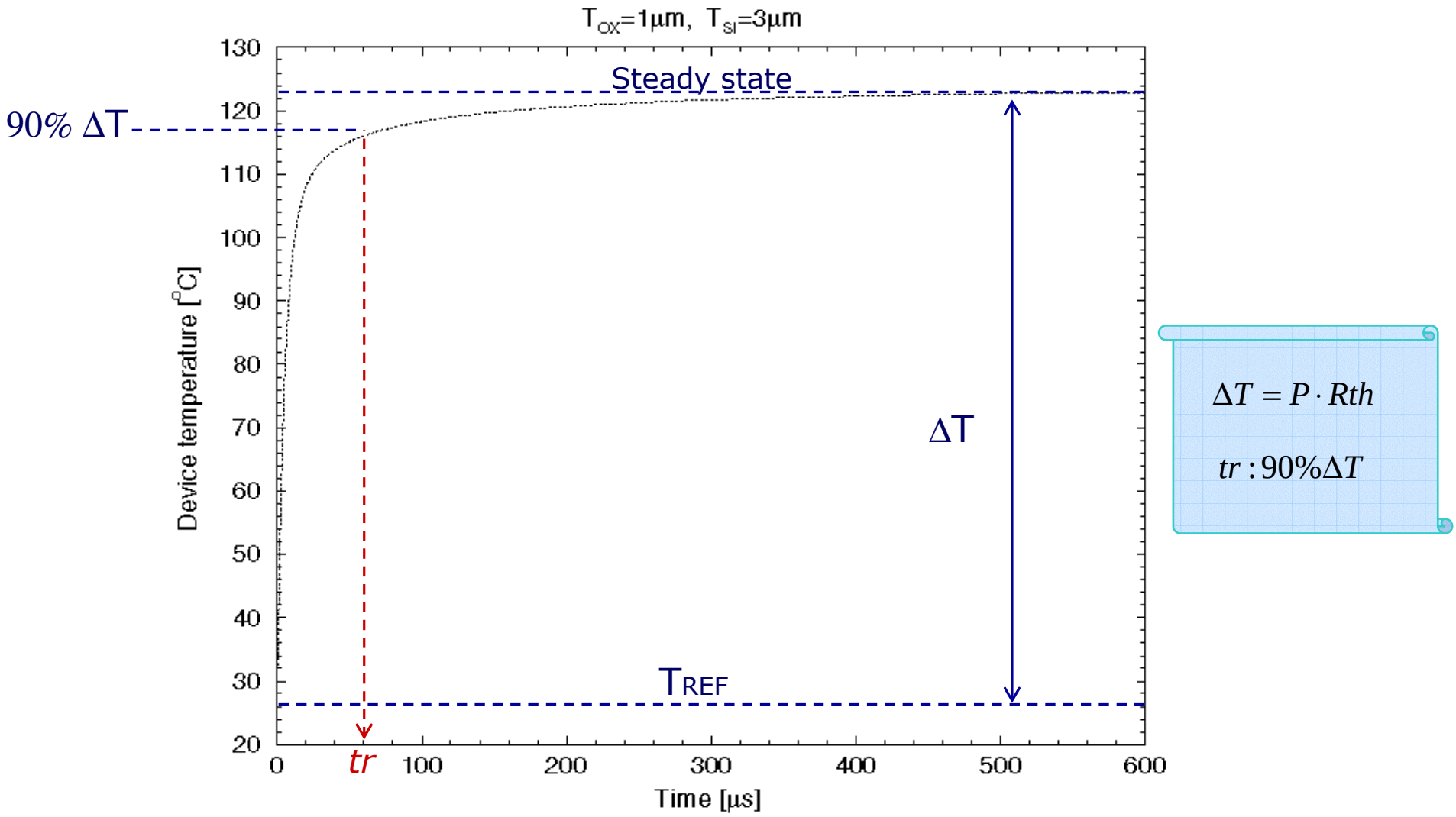


$$V(t) = P \cdot Rth \cdot (1 - e^{-t/\tau}) \quad [°C]$$

$$\tau = Rth \cdot Cth \quad [s]$$

- Power generated by DMOS model:
  - I_{PR} [W]: Total dissipated power on drain/source series resistances
- Assumption: 90%ΔT of Distributed RC is equivalent of single RC

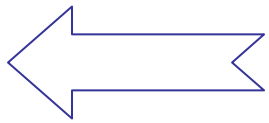
Power Step response for a distributed thermal network



$$\Delta T = P \cdot Rth$$

$$tr : 90\%\Delta T$$

Cth Extraction/ formulae

- Injected power $I_{PR} = I_D(V_D - V_{CH}) + R_{SMET} \cdot I_S^{\,2}$
- Temperature @ node T $V(t) = P \cdot Rth \cdot (1 - e^{-t/\tau})$ | $\Delta T = P \cdot Rth$
- *tr* calculation $0.9 \cdot \Delta T = \Delta T \cdot (1 - e^{-tr/\tau})$ | $\tau = Rth \cdot Cth$; $tr: 90\% \Delta T$
- Cth calculation $Cth = \frac{tr}{Rth} \cdot \ln 10$ 

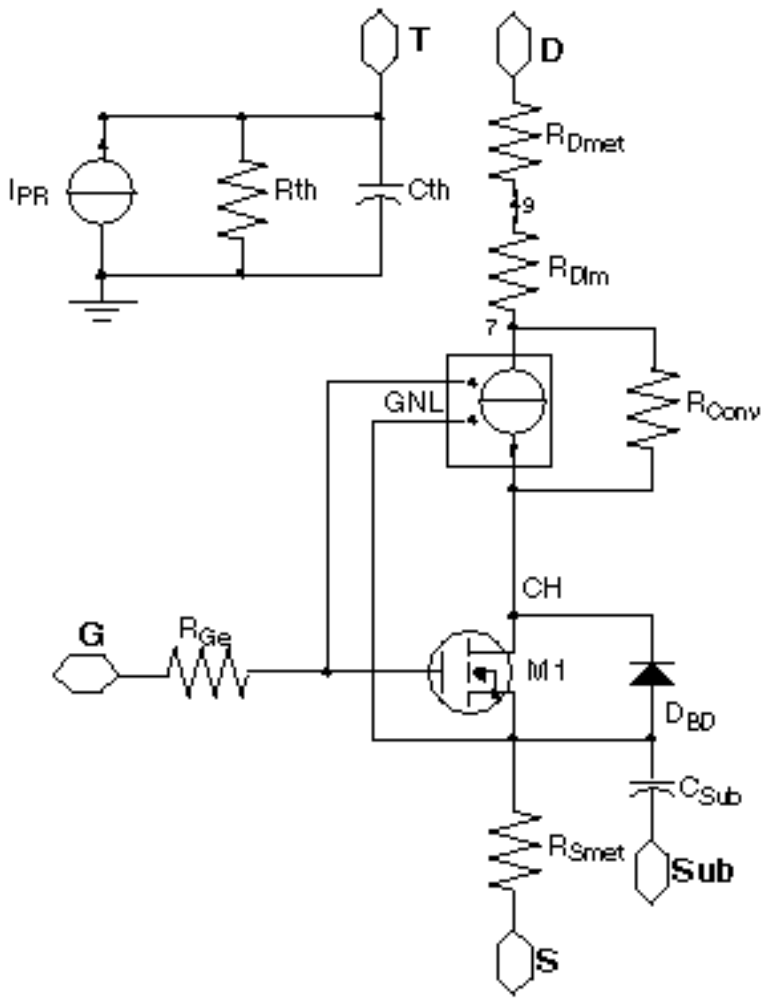
Model Scalability

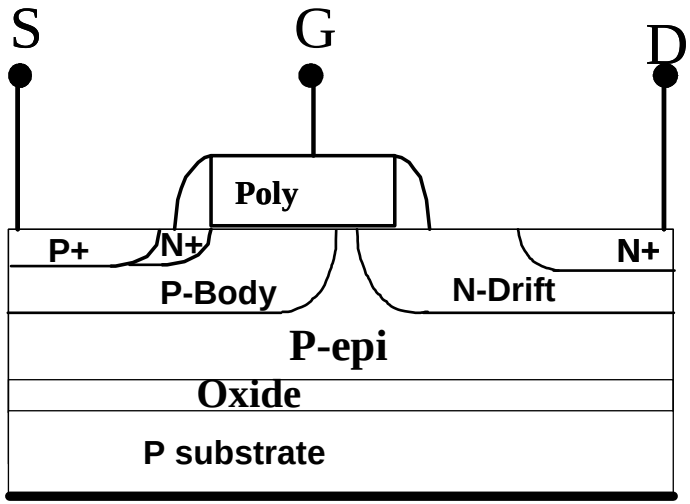
- Sub circuit is composed by
  - Intrinsic MOS
    - BSIMSOI -> scalable
  - Drain drift resistor *f*(*w*)
  - Metal resistors *f*(*w,area)*
  - *Rth f*(*w,area*)
  - *Cth* expression is extracted from *tr* vs. *w* fitting

$$tr = Tw_1 \cdot w + Tw_2 \cdot \left[1 - \frac{Tw_3}{\left(\frac{w}{1e-6} \right)^{xtp} + Tw_3} \right]$$

Fitting parameters:
Tw_1,Tw_2,Tw_3,xtp
(square device)

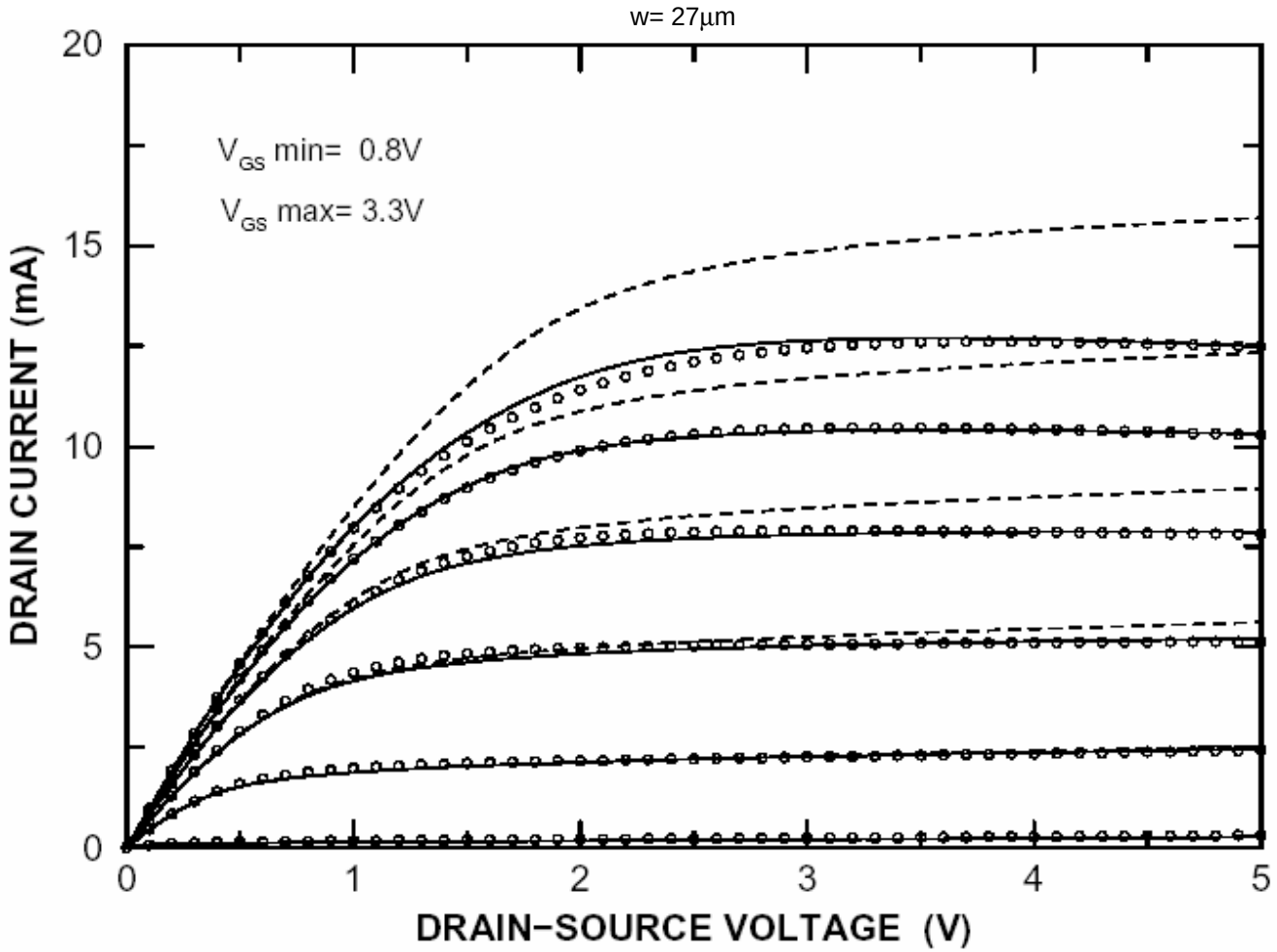
SOI-C-RF LDMOS





- M1: Berkeley BSIMSOI
- GNL: VCCS
  - f(V(T),V(7-CH),V_{GS})
- R_{Conv}:convergence Resistor
- R_{Dlm}:n^+-layer resistance
  - f(V(T))
- $R_{D,Smet}$: metal pattern resistance
  - f(layout parameters)
- R_{Ge}:Poly-Gate resistance
- D_{BD}:Body-Drain diode

SHE Effects simulation comparison

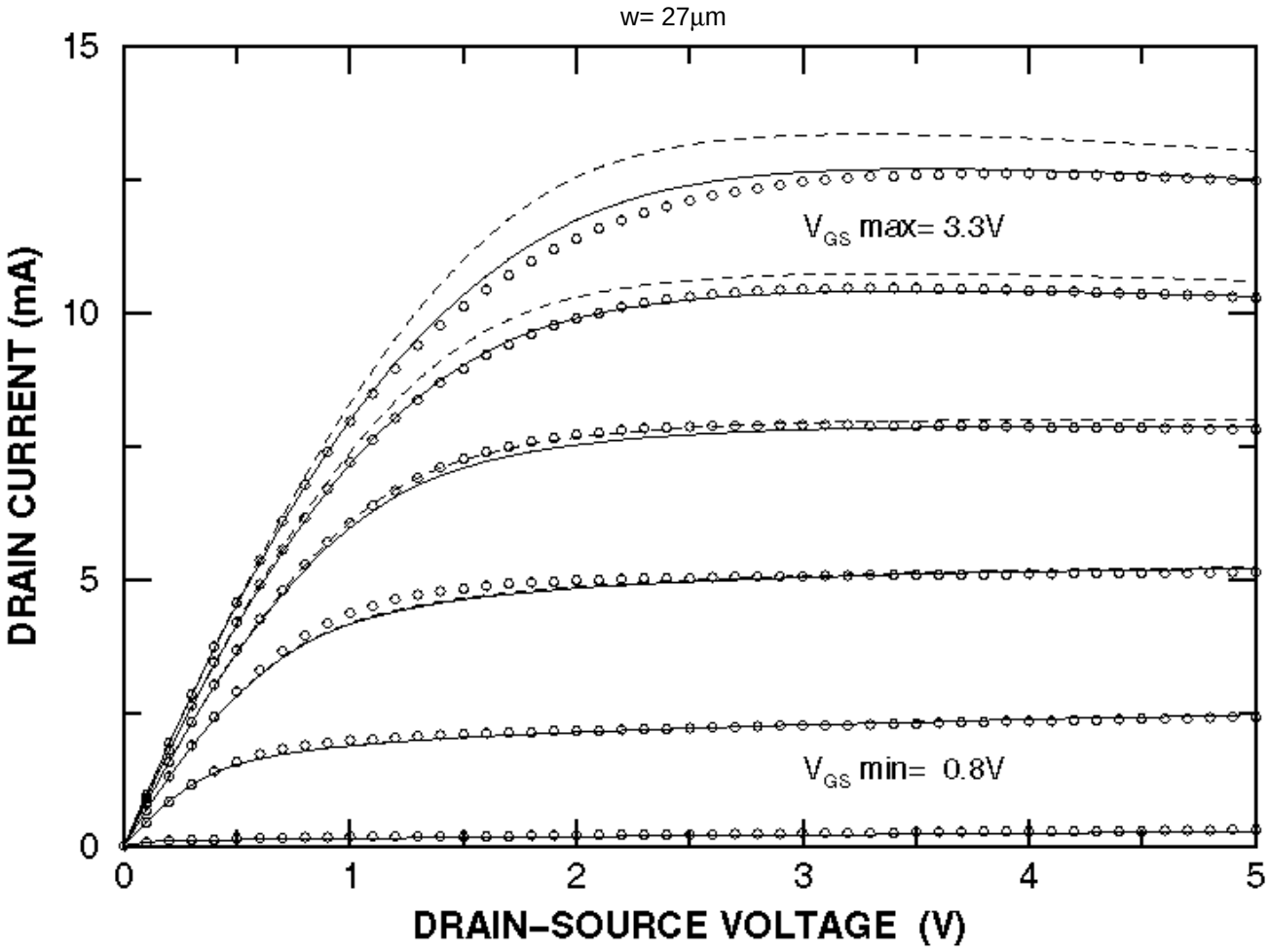


All SHE ON

All SHE OFF

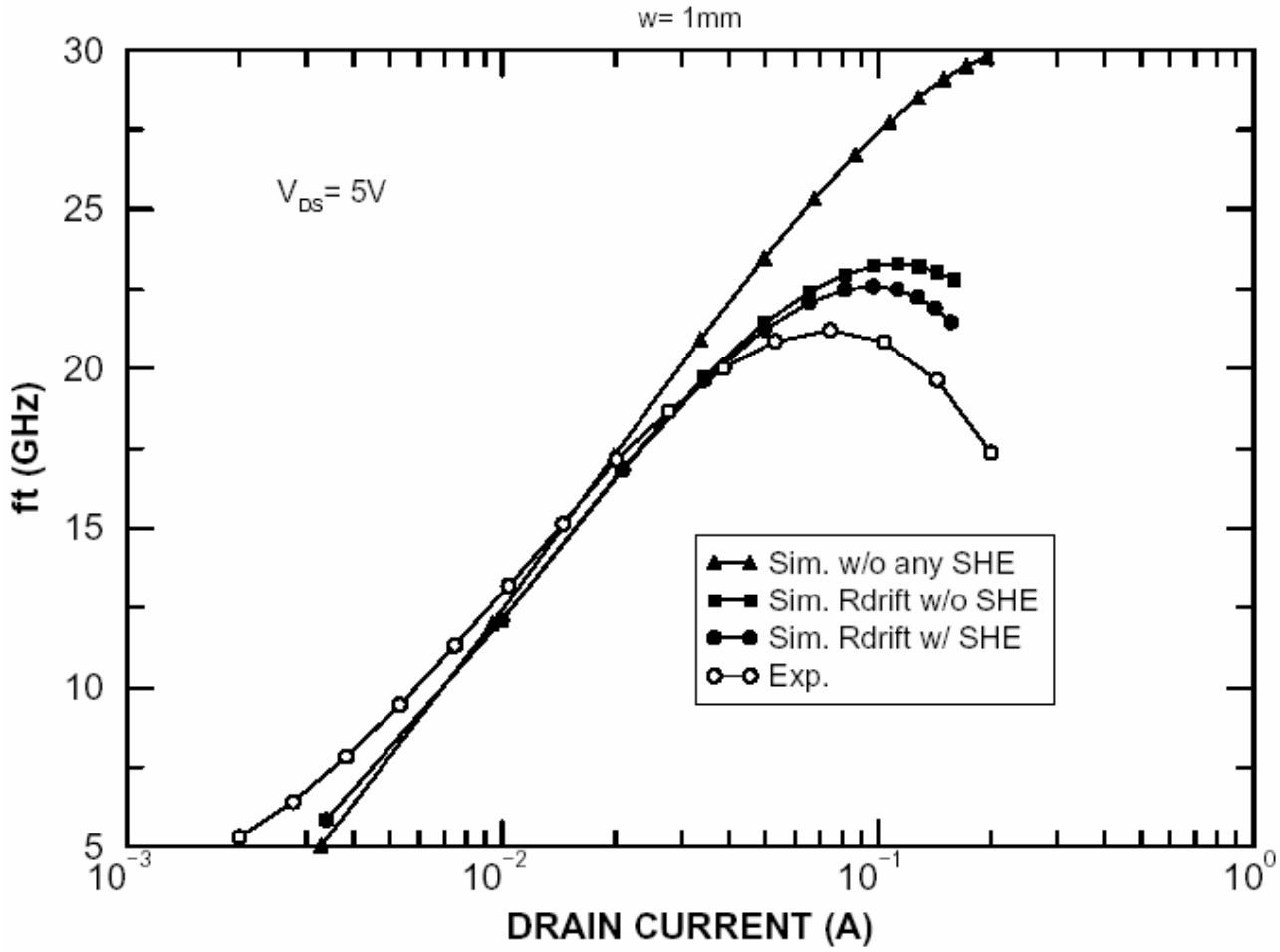
Exp.

Drain Rdrift w/ and w/o SHE

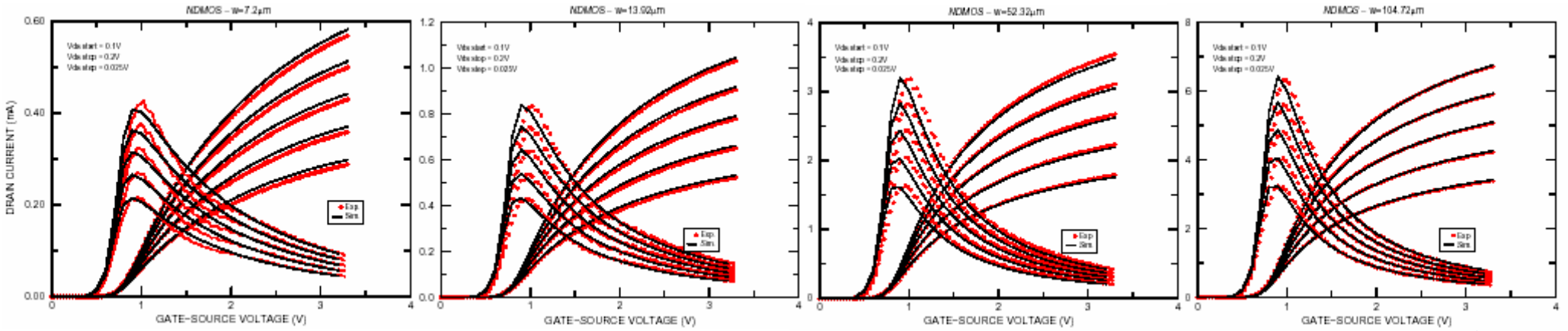


Rdrift w/o SHE
All SHE ON
Exp.

SHE on RF simulation performances



Model Scalability Accuracy



Conclusions

- A fully scalable electrical model which takes into account self heating effects of a LDMOS has been extracted.
- The thermal effects of the resistance of drain drift region have been modeled and successfully included in the model.
- The presented approach on extracting an electrical model which take into account SHE by mean of a simple RC is very satisfying thanks to the results obtained in terms of accuracy and scalability.

References

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  - www-device.eecs.berkeley.edu/~bsimsoi/