Compact Modeling Activities in the Cfaed

Dr.-Ing. Martin Claus

Leader of Device Modeling Group for Emerging Electronics
Center for advancing electronics Dresden (cfaed)
Technische Universität Dresden, Germany,
martin.claus@tu-dresden.de

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German Cluster of Excellence
Center for Advancing Electronics Dresden
9 emergent technologies (Carbon, Nanowires, Organic, . . .)
60 principle investigators from EE, Computer Science, Chemistry, Physics, Biology, Mathematics

Centered at Dresden, close connection to semicond. industry (Infineon, Global Foundries, Intel, . . .)
Funding volume: 34 Mio. EUR
First funding period: 01.11.2012 - 31.10.2017
Selected Cfaed technologies

**Nanowire Path**
NW-based reconfigurable circuits and nanosensing

**Carbon Path**
CNT-based circuits for high-frequency applications

**Organic Path**
Organic electronics for information processing

**Chemical Information Processing Path**
Building chemical processors
Cfaed vision: From material science to system design
Device and circuit behavior predicted by the models must match the behavior after fabrication.
Role of Device Modeling in the Cfaed

Device modeling
(physics- and technology based)

Device optimization/benchmarkeding
(device geometry, technology)

Circuit design and simulation

System design and simulation

Technology

Path demonstrators

Compact modeling
CM links the circuit designer with the circuit technology

Two perspectives

Device modeling delivers input for the technology

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Role of Device Modeling in the Cfaed

General tasks and goals:

1. Development of **multi-scale simulation framework** and application **for device optimization**
2. Development of **compact models for circuit design**
3. Development of suitable electrical **device characterization techniques** for device performance evaluation and model verification
4. Benchmark **circuit design studies for evaluation of performance potential**

→ Support **technology and circuit design within Cfaed**

Tight cooperation with technology groups essential for success!
Reasonable number of devices with reproducible behavior needed!
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Modeling Activities in the Carbon Path

Modeling Group for Emerging Electronics
Motivation for Carbon Path

Requirements on RF front-end technology:

- High data volume and high-speed data transmission
- Technology option: provide transistors with high device linearity (i.e. constant $g_m$) working in GHz regime
- CNTFETs provide high linearity @ GHz under specific conditions!
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Device design for GHz operation

GHz operation demands specific device design - optimization by multi-scale simulation framework

Fabrication of HF layout according to suggestions of modeling group

Experimental data shows 3 GHz performance! (SoA is 5 GHz @ same channel length)

Still room for technology improvements!

However, early circuit design studies mandatory for reasonable evaluation of performance potential of CNTFET technology!

CNTFET compact model essential!
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A Semiphysical Large-Signal Compact Carbon Nanotube FET Model for Analog RF Applications

Michael Schröter, Senior Member, IEEE, Max Haferlach, Aníbal Pacheco-Sanchez, Sven Mothes, Paulius Sakalas, Member, IEEE, and Martin Claus
CCAM – compact model (CM) for CNTFETs

- Semi-physical compact model
- Includes all layout parasitics
- Worldwide unique CM which allows analog HF circuit design
- Enables circuit design and optimization

Availability

- Various PDKs for circuit design ready for use
- Release of CCAM at nanohub.org
First CNT-based single-stage L-band RF amplifier

- 11 dB linear gain with 10 dB input/output return loss at 1.3 GHz

Good matching between experimental results and model

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Modeling Activities in the Organic Path

Modeling Group for Emerging Electronics
Structural optimization of organic FETs

- Experimentally verified modeling and simulation platform
- Guiding technology development by providing optimized device architectures
- Close collaboration with technology groups within CfAED

Current flow in a bottom-gate top-contact architecture.

Current flow in a vertical architecture.
Design of test structures for material screening

- Fabrication TCAD optimized test structures for screening of organic materials
- Large number of identical test structures allows excellent model verification

\[ I_d(A) \]

\[ V_{gs}(V) \]

\[ \mu_{eff} \approx 0.01 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1} \]
Compact model development based on experimental data and TCAD

- Good agreement between experimental data, calibrated TCAD and compact model
- However, large variation in organic materials makes unified physics-based approach difficult
A. Pacheco  Contact resistance extraction method and mobility definitions for carbon nanotube field-effect transistors

S. Mothes  Toward RF-linearity in Schottky barrier CNTFETs

M. Claus  Multi-scale Simulation Framework for CNTFETs

G. Darbandy  Compact Model and Device Design of OFETs and VOFETs

G. Darbandy  Simulation and Modeling of reconfigurable NW FETs

T. Nardmann  Compact Modeling and Experimental Characterization for Ultra-High Data Transmission

A. Pawlak  Device Modeling for CoolBaseStation ICs