A Demonstrator Platform for Coupled Multiscale Simulation

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***Abstract*—In this communication we intend to present the CoMSON Demonstrator Platform, a software tool designed to help researchers test and validate models and algorithms for coupled simulation of nanoelectronic circuits and devices.**

Keywords—Coupled Simulation and Optimization of Devices and Circuits for Nanoelectronics

I. Current challenges in numerical modeling for nanoelectronics

Currently, to design new integrated circuits or to port existing designs to a new technological platform, designers follow a path composed of different, almost independent, steps. At each stage of this path different software tools are used to support the design flow. Process simulators are used to predict geometries, doping profiles and other physical parameters of devices that can be produced in a given technological process. Device simulators are then used to predict electrical/thermal behavior of the new devices. Using physical considerations, often based on the drift-diffusion framework with simplifying assumptions on geometry, doping profiles, material parameters, one has to define compact models to describe the device behavior with simple, explicit analytical expressions. Very often *a priori* considerations lack predictiveness and accurate *a posteriori* calibration of model parameters based on numerical simulations and experimental data is needed. The compact device models are used in circuit simulations to predict the behavior of new circuit topologies or to evaluate the performance of existing topologies implemented with new technologies. Finally, an optimization step is used to maximize circuit performance by perturbing device parameters in the vicinity of the given values.

This design flow presents some disadvantages that are becoming more relevant as CMOS technology is scaled down to its physical limits. To be as accurate as possible, compact models have grown to include several hundreds of parameters with little or no connection with physical characteristics of the devices. The lack of connection between model parameters and physical properties renders, on one hand, very delicate and cumbersome the parameter calibration stage and, on the other hand, it makes it almost impossible to perform an optimization of the circuits based on the geometry and doping profiles of the devices. The latter effect is even more evident at the current stage of technological advancement where not only device dimensions are being scaled but completely new device geometries are being considered (DG, Tri-Gate, GAA, FinFET, nanotubes...)

II. Coupled simulation

A possible approach to the solution of the problems described above is to create simulation tools where the behavior of the devices is represented not by evaluating the explicit analytical relations given by the compact models but by performing a direct simulation based on more accurate physical models taking into account the complete 2D/3D device geometry and realistic doping profiles as obtained by process simulation. This clearly comes at the cost of a great increase in computational effort, but the advantages are many-fold. First of all the use of few physically based design variables instead of many fitting parameters gives designers a much higher level of understanding which can lead faster to better design decisions and, furthermore, it can greatly help the construction of automatic optimization tools. To achieve this goal, though, many open problems still need to be solved. Apart from the computational cost (which will need to be reduced as much as possible, for example via Model Order Reduction techniques, or parallelization, but cannot be expected to be anywhere close to that of compact models) the coupling itself can lead to instability and convergence issues that need to be addressed properly by resorting to suitable numerical schemes. For this reason within the EU project CoMSON (http://www.comson.org) a Demonstrator Platform (http://www.comson.org/dem) will be developed to connect numerical simulation tools available throughout the nodes of the CoMSON consortium through a common interface. In this way, researchers willing to be confronted with the problems arising in the framework of coupled simulation will be given the opportunity to abstract from the implementation of the basic tools (device simulator, circuit simulator, heat transfer simulator,...) and to concentrate on the coupling itself. The architecture of the Demonstrator Platform will be the main focus of this communication. It has been designed to achieve the following objectives:

- providing a fast prototyping environment in which new and existing algorithms can be tested compared and assessed
- allowing application of the algorithms, once assessed, to real life industrial problems.

To better demonstrate the structure of the Demonstrator Platform and its use we will resort to a practical example. We will consider device/circuit coupling strategies belonging to three different classes:

- based on straight forward iteration between solution of device and network equations, as used, for example, in [1]
- based on the extension of the device simulator by considering the network equations as general boundary conditions, such an approach is used in [2] (in the case of stationary semiconductor equations) and in [3] (in the case of evolutionary semiconductor equations) to derive analytical results for the coupled system.
- based on extension of the circuit simulator by adding the spatially discretized semiconductor equations to the system of network equations, this approach was applied in [4] for the numerical analysis of the coupled system and, together with a staggered solution approach, in [5] for the simulation of the electro-thermal behavior of an operational amplifier.

by implementing solvers based on such different coupling strategies, we will demonstrate the flexibility of the Demonstrator Platform architecture and its ability to provide more insight in new numerical algorithms by confronting them with real life test problems of industrial relevance and by comparing their performance and robustness. Morover, we will show how the abstraction layer provided by the Demonstrator Platform can be exploited for further generalization of the implemented algorithms by extending the coupling strategies considered to the case where more complex semiconductor models (namely the Quantum-Corrected Drift-Diffusion class of models as described in [6]) are used for device simulation.

Acknowledgment

The work described here is partly financially supported by the European Commission in the framework of the CoMSON RTN project.

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