Touchstones of a Quality Compact Model

Authors frequently submit manuscripts to the *Transactions* in the area of Compact Modeling. It is a subject of much scholarly activity and one of widespread interest to our readers, many of whom are practitioners of semiconductor technology. The reasons for the popularity of this subject area are of course only known to the readers, but it is not unlikely that it is due to the popularity of the models themselves, which in turn may be due to the comparative ease of use which is a prominent feature of most compact models. Simulations using compact models are relatively quick and do not require powerful, high-speed computers to execute. Yet, because of their form, the underlying physics is easy to discern.

The Editorial Board of the *Transactions* intends to continue to encourage original submissions in this field, but as we do in all subject areas that fall within our scope, we are keenly interested in maintaining and even elevating the quality of the papers we publish in this area. One means of accomplishing this objective is to become more rigorous in rejecting papers that may be technically sound, but are not particularly original or may deal with a narrow, perhaps even trivial aspect of device physics. Conversely, another means is to encourage and stimulate more high quality submissions, which immediately begs the question "What is the definition of high quality?"

Defining quality is not a simple task. However, in may be sufficient to describe some of the attributes of a quality model and thereby prescribe the content of what might be a quality paper on the subject. To wit, a quality model ought to be usable in some way when applied to real devices. It should comprehend all relevant effects of realistic short channel devices. In general, models are more credible if they match experimental data. (An exception might be devices so new that neither samples nor data are readily available.) However, sometimes this is not sufficient since models with large numbers of fitting parameters are really more mathematical and empirical than physical. These types of models miss one of the key attributes of a good compact model *viz*. the ability to gain an insight into the physics that dominates the operation of the device under study. On the other hand, models that are too narrow in scope miss another key attribute, that is the ability to provide sufficient accuracy to obviate the need to conduct full-blown simulations with all of the concomitant resource demands.

Many compact modeling submissions are related to subthreshold analyses which can be very useful for threshold voltage analysis including quantifying of drain-induced barrier lowering effects and subthreshold slopes. Often, they are based upon idealized abstractions of devices that have the benefit of enabling analytic solutions and if the purpose is simply to elucidate the controlling mechanisms of the device, then this purpose is served. However, often the intent is not explicit and the reader is left with the impression that the model is predictive. Authors may unwittingly contribute to this impression by using TCAD simulations to "verify" the accuracy of the analytic solution, but the simulations are often of the same idealized devices. That is, a demonstration of consistency with TCAD simulations is not necessarily proof that the analytic solution is predictive; rather it may only be a proof that calculations can be used to match the results of numerical methods in specific cases. The question of predictive ability is still open and depends upon whether the simulation, and hence the matching analytic solution, is of a realizable device. This is especially true of modern devices such as multi-gate, three-dimensional MOSFETs where non-idealities have significant effects.

Obviously compact models should be analytical with no differentials, derivatives or integrals. Model parameters should be comparatively easy to extract and their relationship to other parameters should be physically justified. There are other characteristics, one or a few of which, a quality model should exhibit. As an aid to authors, reviewers and editors, we catalog some of these characteristics. A quality compact model should

- incorporate new physics that improves the accuracy or predictive ability of existing models in a meaningful way, and/or

- it should demonstrate a novel method or approach that improves the efficiency of the simulations without loss of accuracy, and/or

- it should take an existing phenomenological or semi-empirical model and establish the physical foundations of the model and/or

- it should provide new insight into the functioning, performance characteristics, reliability, or limits of conventional devices and ideally should even suggest a means of improvement, and/or

- it should provide new insights into how existing models are related, and/or

- it should be predictive of new behaviors which can be subsequently observed and/or,

- it should clarify the domain of validity of existing models.

By no means is this meant to be a comprehensive list. Nevertheless, we anticipate that it is ample in aggregate to convey the sense of what the Editorial Board considers to be the key features of a quality manuscript on compact modeling.

Finally, we end with a few simple suggestions for authors that when followed could expedite the review process and may even improve the chances of acceptance of a manuscript dealing with compact modeling.

a) When presenting results that are compared with simulation results, authors should state which models were turned on in the simulations.

b) When presenting results that are compared with simulation results, authors should include a table that identifies the simulation parameters and the analytical model parameters (physical as well as fitting) used to generate the model traces. If the simulation parameters differ from the corresponding analytical physical parameters, authors should explain why.

c) When presenting results that are compared with simulation results, authors should only show relevant comparison plots with correct models turned on. For example if the compact model considers field-dependent mobility when reporting transport properties, then the corresponding TCAD plots should not be reported using constant mobility.

d) When reporting subthreshold voltages extracted from simulations, authors should state the method of extraction and if by constant current method they should state the current cut-off value used.

e) Authors should actually read and understand the references they cite. Specifically, cited references should actually substantiate the claims made by the author.

It is our passion to continuously improve the quality of the articles we publish. Our hope is that by describing its facets we can quicken the march.

Doug Verret

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