

Preface

Models of circuit elements which are sufficiently simple to be incorporated in circuit simulators and are sufficiently accurate to make the outcome useful to circuit designers are called compact. The conflicting objectives of model simplicity and accuracy make the compact modeling field an exciting and challenging research area for device physicists, electronic engineers and applied mathematicians. Continued down-scaling of semiconductor devices has made it necessary to incorporate new physical phenomena, while extended applications have led to the inclusion of the secondary and ternary effects in order to achieve the required model accuracy. In addition several rigid requirements in terms of model continuity and qualitative behavior (“benchmarks”) have been imposed over the years. At the same time, the increased size of the integrated circuits, that can now be subjected to the full SPICE analysis, disallowed proportional increase in the model execution time. Hence considerable effort went into compact model reformulation in such a way that dramatically increased accuracy and model sophistication are accomplished without prohibitive decrease in the computational efficiency.

The models of MOS transistors underwent revolutionary change in the last few years and are now based on new principles. The recent models of diodes, passive elements, noise sources and bipolar transistors were developed along the more traditional lines. Following this evolutionary development they became highly sophisticated and much more capable to reflect the increased demands of the advanced integrated circuit technology. The latter depends on the compact models for the shortening of the design cycle and eliminating the elements of overdesign which is often undesirable in today’s competitive environment. At the same time, statistical modeling of semiconductor devices received new significance following the dramatic reduction of the device dimensions and of the power supply voltage. Finally, despite the complexity of the fabrication process, the multi-gate MOS transistors are now seriously considered for the purpose of controlling the small geometry effects. To evaluate the potential impact of these devices on the IC design, compact models of these devices, preferably based on the same principles as the models of traditional MOSFETs, are becoming important.

The last comprehensive description of the compact models of various semiconductor devices reflects the state of the art in late 1980s [2]. While remaining an in-

fluent and valuable source of information, it can no longer serve the needs of the compact modeling community in the 21st century. In this volume we present contemporary compact models of both active and passive semiconductor devices and discuss general modeling techniques. Given the limited size of the book, and the wide choice of compact models available today, the selection of the topics represented an interesting problem. In the end, it was decided to include compact models which are both heavily used in the industry and at the same time are theoretically significant. For experimental devices like multiple-gate transistors where the optimal choice of the compact models is not yet entirely clear, we have presented two particularly promising approaches. We have also included chapters on the MOSFET noise theory, benchmarking of MOSFET compact models, modeling of the power MOSFET, and overview of the bipolar modeling field. The book concludes with two chapters describing the variability modeling including some recent developments in the field. Once again, since the field of variability modeling is far from maturity, we present several alternative approaches to the subject.

The present volume is comprehensive but is in no way encyclopedic. It does not include several popular and experimental models that have already been described in considerable detail in a book form [1, 5, 6, 8, 11, 13, 15]. Another important subject that is not covered, is the application of behavioral languages in the compact modeling field. Many of the models discussed in this book (e.g. PSP, PSP-SOI, MOSVAR, R3) were developed using verilog-A language which not only significantly reduces the development time, but eliminates numerous potential sources of errors and simplifies model implementation in circuit simulators [10, 12, 14]. Furthermore, we concentrate on the most recent developments in the compact modeling. The reader interested in the evolution of the field can find extensive information in [2, 3, 7, 9] while [4] contains a useful tutorial on compact MOSFET models.

We hope that this volume will be useful to the engineers actively involved in the design of integrated circuits, developing compact models and for the graduate students of the corresponding disciplines.

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