In this book the research of the last decade by the authors regarding deterministic solvers for the Boltzmann transport equation is summarized. The work was started by the third author, who was interested in electronic noise of semiconductor devices. At first glance the use of a deterministic solver seems to be strange, because all groups working at that time on noise in devices solved the Boltzmann transport equation with the stochastic Monte Carlo method, which inherently contains noise and was regarded as the best method to do so. But it soon became clear that the Monte Carlo method, which is also inherently transient, was too slow to calculate noise in the technically relevant frequency range with sufficient accuracy. A deterministic solver on the other hand could yield truly stationary solutions, and exact small-signal analysis could be performed directly in the frequency domain covering the full frequency range. Unfortunately, the deterministic solvers have not only advantages compared to the Monte Carlo method but also disadvantages. The biggest obstacle in the application of deterministic solvers was the huge memory requirement (about 100 GBytes for a realistic 2D device simulation including noise), which is by orders of magnitude larger than the one of the Monte Carlo method. This is the reason, why the interest in deterministic solvers had almost vanished by the end of the last millennium. When this project was started, deterministic solvers still required expensive supercomputers. Fortunately, Moore’s law held during the last decade and nowadays computers with sufficient memory are available at a reasonable price. Thus, progress in semiconductor technology solved the biggest problem in applying deterministic solvers to the Boltzmann transport equation.

This work was started in earnest when the third author joined the Institute of Electron Devices and Circuits at the Technical University of Braunschweig in Braunschweig, Germany. A little later the second author joined this institute, which is headed by Prof. Dr. Bernd Meinerzhagen. Both authors are very grateful for his support of their work and his valuable advice. In 2006, the third author became a professor at the Bundeswehr University in Neubiberg, Germany and soon after the first author joined this new group. His position was first funded by the Deutsche Forschungsgemeinschaft (DFG) and later by the Bundeswehr University,
for which the first and third author are most grateful. The authors would like to thank all persons who have supported or contributed to this work. Without the very memory efficient linear solver ILUPACK developed by Prof. Dr. Matthias Bollhöfer of the TU Braunschweig and his help the project would have faltered early on. The third author gratefully acknowledges discussions with Prof. Dr. Christian Ringhofer of the Arizona State University about the maximum entropy dissipation scheme. At the Bundeswehr University our work has profited from contributions by Dr. Mindaugas Ramonas, Dr. Tanh Viet Dinh, and Gregor Matz. The authors gratefully acknowledge financial support by the EU through the project DotFive under grant agreement no 216110 (FP7/2007-2013). The fruitful collaboration with the group of Prof. Dr. Michael Schröter of the TU Dresden regarding SiGe HBTs was most helpful, especially the supply of experimental data by Dr. Paulius Sakalas and the feedback by the first user of our code, Gerald Wedel. The second author gratefully thanks his colleagues M. Klawitter and Dr. A. Kuligk of Institute of Electron Devices and Circuits (TU Braunschweig) for helpful discussions. The first author gratefully acknowledges many fruitful discussions with Dr. Seonghoon Jin of Synopsys about the inclusion of full band effects.

The first author is very grateful to his wife (Young Min Yoon), his children (Jin Gi and Lena), and all other family members. Especially, the endless love and support from his parents (Tae Suk Hong and Jin Sook Kim) are greatly appreciated. The first year of the first author’s research was partially supported by a Korea Research Foundation grant by the Korean Government (MOEHRD) under contract number KRF-2007-357-D00159.

The second author gratefully thanks his friends, his family including two sons Anh-Tri (Chip) and Sy-Tien (Mos), and his grandparents who had unfortunately gone too soon to see their grandson’s achievements.

The authors thank Prof. Dr. Siegfried Selberherr of the TU Vienna and editor of this Springer series for the opportunity to publish this work and his encouragement.

Neubiberg and Braunschweig

Sung-Min Hong
Anh-Tuan Pham
Christoph Jungemann

June 2011
Deterministic Solvers for the Boltzmann Transport Equation
Hong, S.-M.; Pham, A.-T.; Jungemann, C.
2011, XVIII, 227 p., Hardcover
ISBN: 978-3-7091-0777-5