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Buchbesprechung

Microwave noise in semiconductor devices

by H. L. Hartnagel, R. Katilius, and A. Matulionis,
XVIII+ 293 pages, John Wiley & Sons, New York 2001

Electric fluctuations (electric noise) are irregular temporary deviations of observables – current, voltage, resistance, frequency, etc. – from their averages. The fluctuations result from discrete nature of charge carriers and their chaotic motion. Noise is commonly viewed as the limiting factor of device performance. However, there is also another aspect, now fully realized and widely exploited. Fluctuations of *macroscopic* observables result from *microscopic* random processes. Every source of fluctuations is associated with some microscopic mechanism accompanied by *dissipation*. Measuring fluctuations *out of equilibrium*, where the Nyquist theorem does not work, provides the researcher with *new information* about the system – new as compared to that available from measuring average values of the observables and responses to external perturbations. Interpretation of experimental results on noise in terms of microscopic theory allows one to discuss microscopic origin of the associated fluctuations, helps to control the noise, suggests possible ways for elimination of the dominant sources of noise through improvement of material technology and circuit design.

Because of these – and many other – reasons, it is a pleasure for me to present to the readers of FREQUENZ the recent book on physical backgrounds of fluctuations and noise in semiconductor devices at microwave frequencies. The book presents the first systematic treatment of microwave fluctuations in semiconductors and semiconductor structures under non-equilibrium conditions. The book has resulted from a very close and fruitful collaboration of experts in the seemingly different fields – a solid-state theorist, one of the authors of the contemporary kinetic (microscopic) theory of fluctuations in non-equilibrium (R. K.), an expert in microwave noise in low-dimensional heterostructures of contemporary high-speed electronics (A. M.), and an expert in advanced semiconductor microwave engineering (H. L. H.).

The reader is led, smoothly enough, from the elaborated description of stochastic phenomena in semiconductors at high applied electric fields, through presentation of results of microwave noise measurements in biased channels and interpretation of these results on the basis of kinetic theory of fluctuations, towards applications in micro- and nano-electronics. The noise sources are resolved and ways to reduce them are revealed. Unique is the physical content of the book. Correct and convincing reasoning leads the reader from the very beginning to the victorious end: to a rather deep understanding of such non-trivial problems as additional correlation in non-equilibrium electron gas, possibilities and advantages of noise spectroscopy, discussion of high-speed low-noise operation in up-to-date devices, etc.

Numerous illustrations (over 100) present in detail experimental data for semiconductor structures designed for ultrafast electronics, together with the results of simulation based on the microscopic theory. Examples include a transition from shot noise to hot-electron noise in forward-biased planar-doped diodes, current fluctuations due to real-space transfer of hot electrons between parallel two-dimensional electron gas channels, transverse resonant-tunneling transfer of hot electrons, and simulation of noise performance of a high-electron-mobility transistor at millimeter-wave frequencies, among others. Time constants of ultrafast kinetic processes resolved through microwave noise experiments are listed in the tables. The described approaches and experimental techniques are of great interest for progress in recent developments of wide-band-gap semiconductor devices and other branches of advanced microwave electronics.

The book consists of 20 chapters. It is worthy to enumerate them here. The kinetic theory of fluctuations and its corollaries are systematically presented in chapters from 3 to 7: *Kinetic theory of fluctuations; Effect of interelectron collisions on fluctuation phenomena; Boltzmann–Langevin equation; Fluctuations and diffusion; Features of hot-electron fluctuation spectra*; as well as in chapters 12 and 19: *Hot-electron noise in doped semiconductors (theory); Spatially inhomogeneous fluctuations.*

In chapters from 8 to 11, 13, and 14, microwave noise properties of classical semiconductors are described and interpreted in terms of the kinetic theory: *Experimental techniques; Hot-electron microwave noise in elementary semiconductors; Hot-electron microwave noise in GaAs and InP; Length-dependent hot-electron noise; Electronic noise and diffusion in standard-doped n-type GaAs.*

Results of experimental investigation of microwave noise in low-dimensional structures and devices are presented and discussed in chapters from 15 to 18, and 20: *Electronic sub-bands in quantum wells; Hot-electron noise in AlGaAs/GaAs 2DEG channels; Hot-electron noise in InP-based 2DEG channels; Cut-off frequencies of fast and ultrafast processes; Monte Carlo approach to microwave noise in devices.*

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About the article

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