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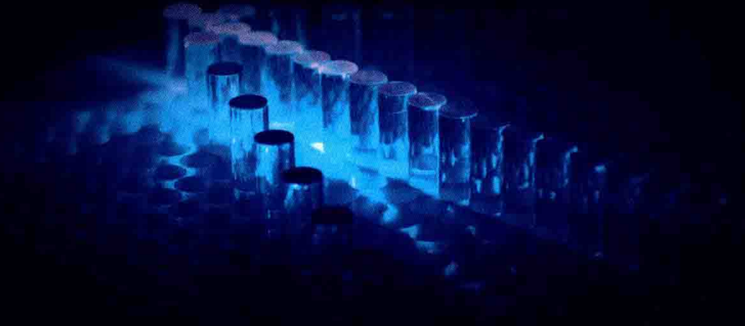
Edited by

Bernard Gil



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15. N. Miura: *Physics of semiconductors in high magnetic fields*
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17. S. Maekawa, S. O. Valenzuela, E. Saitoh, T. Kimura: *Spin current*
18. B. Gil: *III-nitride semiconductors and their modern devices*

Preface

When I met Sönke Adlung, of Oxford University Press, during the annual meeting of the European Materials Research Society in Strasbourg in June 1996, he was taking care of the exhibition booth in his editorial role, while I was co-organizing a symposium dedicated to visible-light emitters.

Nitrides were booming world-wide at that time. During the preceding three years, many researchers, including myself, had reoriented their research activities to nitrides after several Japanese researchers, including Prof Isamu Akasaki and Drs Hiroshi Amano and Shuji Nakamura, had made significant breakthroughs in various scientific areas such as materials science and device physics. These breakthroughs had led to the realization and commercialization of blue light-emitting diodes based on nitride semiconductors. More recently, in January 2006, a blue laser was demonstrated in Japan. Most of the attendees at the visible-light symposium had come to Strasbourg to hear, in a very crowded conference room, the talk by Shuji Nakamura, planned for Friday the 7th, so that they could see with their own eyes the coherent blue light-ray of a nitride-based laser exciting the fluorescence of a paper screen.

During the afternoon of that Friday, Sönke, with whom I was chatting in front of the OUP booth, suggested that I edit a book dedicated to nitrides. *Group III Nitride Semiconductor Compounds: Physics and Applications* was edited one and-a-half years later in 1998, and it was followed by *Low-Dimensional Nitride Semiconductors* in 2002. Today you are holding *III-Nitride Semiconductors and their Modern Devices.*

Ten years have passed since the second volume of this series was published. We believed a few months ago, in light of recent new developments in the field, that it was time to offer a modernized compilation of today's research activities. We kept the initial format: a book accessible to the larger community, including PhD students at the beginning of their studies and not yet familiar with the world of semiconductor physics. Light emission/detection is a newly developing area. Therefore, I asked Professor Amano of Nagoya University, one of the fathers of nitrides, to write a general introductory chapter to provide an overview of the needs and realizations in that area. His chapter combines a review of economic issues and societal needs, together with growth aspects, physics characterization, and device realizations. All other chapters were written by leading researchers in specific fields. Dr Izabella Grzegory has been growing bulk gallium nitride since the beginning of her career. I had in my hands some very tiny pieces of her transparent gallium nitride bulk crystal as early as January 1986! I found it natural to ask her to take care of the chapter dedicated to the homoepitaxial challenge, and she wrote it in collaboration with her colleagues at Warsaw: Michal Bockowski, Piotr Perlin, Czeslaw Skierbiszewski, Tadeusz Suski, Marcin Sarzynski, Stanislaw Krukowski, and Sylwester Porowski. They share it with us here, and they indicate how far they have advanced since their early studies in Poland at the end of the 1970s. Nitrides being often deposited by using modern epitaxial growth techniques (see for instance, the first book of this series), to review the status of the research at the nitride–silicon interface is of value. I asked Professor Alois Krost and Dr Armin Dadgar, of the Otto-von-Guericke-University at Magdeburg, to address this message at the dawn 2013. This constitutes the third chapter, which precedes the chapter dedicated to the growth of bulk aluminium nitride (a very promising substrate for the years to come), written by Zlatko Sitar and Ronny Kirste of the North Carolina State University at Raleigh. Since the beginning of the 1980s, semiconductor quantum dots have been known to be, beyond the scope of promising concepts, efficient adimensional localization centers for electrons and holes, offering the possibility of realizing low-threshold lasing. We now know that quantum dots are useful for realizing single-photon sources and entangled-photon pair-emitters. Andre Strittmatter, of the Technical University of Berlin, agreed to write the fifth chapter, dedicated to the growth of such light-emitters. Band-gap engineering issues are particularly important regarding the growth of heterostructures on lattice mismatched substrates. Chapters 6 and 7 were written by researchers at the Ecole Polytechnique Fédérale de Lausanne and Mie University, respectively. Aluminum indium nitride was initially proposed by Professor Marc Ilegems (now retired) and Dr Jean François Carlin. I thus naturally asked the colleagues that are currently holding Marc's stick to accept the burden of reviewing the status and importance of the AlInN alloy at the composition lattice-matched to GaN. Drs Raphaël Butté, Gatien Cosendey, Lorenzo Lugani, Marlene Glauser, Antonino Castiglia, Guillaume Perillat-Merceroz, Jean-François Carlin, and Professor Nicolas Grandjean did this very nicely. Aluminum-rich AlGaN alloys are also very important for targeting deep-ultraviolet applications. These alloys are treated by an internationally recognized expert in the area of crystal growth of chalcopyrites and nitrides: Professor Hideto Miyake, of Mie University. There are tremendous developments these days regarding the properties of light-emitters grown on non-polar or semipolar orientations. Writing such a chapter, while retaining clarity and a reasonable length, required considerable effort by Professor Michael Kneissl and Dr Tim Wernicke of the Technical University and Ferdinand-Braun-Institute at Berlin. The result is impressive. In Chapter 9, Drs Rudeesun Songmuang and Eva Monroy address the single-nanowire devices, which was quite challenging from the beginning. Dr Jean-Yves Duboz, of the Centre of Research on Hetero-Epitaxy and its Applications, in Valbonne, agreed to write on advanced photonic and nanophotonic devices, the topic of Chapter 10. Dr Yvon Cordier, of the Centre of Research on Hetero-Epitaxy and Applications, Valbonne, and Drs Tatsuya Fujishima, Bin Lu, Elison Matioli, and Professor Tomás Palacios, of the Massachusetts Institute of Technology, Cambridge, next address nitride-based electron devices, widely investigated for the next generation of high-power and high-frequency applications.

The potentialities of having large conduction-band offsets in nitride heterostructures enables targeting of intersubband transitions in low-dimensional nitrides, which are in particular investigated at the Institute of Fundamental Electronics by Drs Maria Tchernycheva and François Julien. They both accepted my invitation to write the chapter dedicated to applications of nitride heterostructures in the mid-infrared. The large oscillator strength of nitrides paves the way to fascinating optical properties, among which is the slow-light propagation phenomenon. Drs Tatiana Shubina and Mikhail Glazov, of the IOFFE Institute in St Petersburg, together with Dr Nikolay Gippius of the General Physics Institute of the Russian Academy of Sciences, in Moscow, placed aside the Cyrillic alphabet in order to write the thirteenth chapter, and I share the responsibility with them. Then follow three chapters dedicated to very prospective issues. Nitride devices and their biofunctionalization for biosensing applications are treated in a fourteenth chapter by my office neighbor Professor Csilla Gergely at Montpellier, and Walter R. L. Lambrecht and Atchara Punya, of the Department of Physics at Case Western Reserve University, Cleveland, address, in a very didactical way, the physics of heterovalent ternary II-IV-N2 compounds and perspectives for a new class of materials that are, *mutatis mutandis*, the analogs of the chalcopyrites. Finally, it has been proposed recently by Professor Alexey Kavokin to produce a radiative relaxation process between a forbidden excitonic transition populated by non-linear two-photon spectroscopy and an allowed one. Two photons are successively emitted—the first by cascading at an energy in the terahertz frequency region, and the second occurring at the host material band-gap energy. This process arm-twists the black-body radiation law, and may lead to a new class of THz emitters. I have asked Drs Oleksandr Kyriienko and Ivan Shelykh, of the University of Iceland, in Reykjavik, and the Division of Physics and Applied Physics, Anyang Technological University of Singapore, and Professor Alexey Kavokin, of the University of Southampton, to provide readers with sufficient elements for them to eventually handle this kind of research. The cover picture represents a photonic billiard designed by Didier Felbacq, realized and shined with a blue laser by Emmanuel Rousseau.

This book obviously departs from perfection, and is not exhaustive. I deeply hope, however, that it fulfils most of the needs of people in academic laboratories and most of the companies. To conclude, I would like to acknowledge all the contributors, and in addition, Jessica White, Sönke Adlung, Gandhimathi Ganesan, and Victoria Mortimer at Oxford University Press.

Bernard Gil
Montpellier, November 2012

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