Preface

Wo Licht ist, ist auch Schatten!
(*"More light, more shadow!" or simpler: "Nothing is perfect"*)
—Johann Wolfgang von Goethe, from Götz von Berlichingen, Act I

There exist already about ten books (e.g. [1–8]) – not counting the many conference proceedings volumes – on the different aspects of Si-based photonics including also the issue of silicon-based light emission. Why is now another one needed about this subject, and even more, exclusively about a special type of light emitters?

This book summarizes all aspects of the development of rare earth (RE) containing MOS devices fabricated by ion implantation as the key technology and critically reflects the related references throughout the different chapters. This work was mainly done in the course of the last 10 years. Preliminary work for this goal, undertaken mostly in the nineties, was based on the introduction of group IV elements (Si, Ge, Sn) into the thermally grown silicon dioxide leading to the highest power efficiency values in the blue–violet wavelength range. This success inspired us to use the REs as means of exploring other wavelength ranges with the same or even higher power efficiencies.

After an historical introduction of the REs and silicon-based light emission, Chap. 1 presents a review of electroluminescence from MOS-type light emitters, based on silicon and its technology. The achievement of an optimized material for electrically driven light emission, that is, efficient emission with reasonable reliability, is only possible with a deep knowledge of the materials properties determining the electro-optical (or photonic) properties (see Chap. 2). Especially intrinsic defects, hydrogen as well as the behaviour of the REs themselves were of interest. In this respect, we concentrated on the formation and the properties of clusters as a process neutralizing the emission abilities of the single RE atoms. The electrical properties of the RE-containing thermally grown silicon dioxide layers are in the focus of Chap. 3. Especially, the charge transport and trapping of electrons and holes are of special interest because it is only on the basis of knowing these properties that a deeper understanding of the reliability issues is possible. The core of the interest in the subject of this book focuses on the electroluminescence properties, which have never been worked out and reported before with the intensity presented here (see Chaps. 4 and 5). The combination of experience in MOS technology, ion implantation and RE physics and chemistry has created a unique bunch of results in the course of our work. The ion beam processing experience of the people at the research centre at Rossendorf, and partly, also at Jülich has offered the possibility to study the properties of the wide range of REs described here. Besides the EL spectra reported in Chap. 4, one of the main challenges during this work was the study and optimization of the EL efficiency as well as the exploration of different sensitization effects (see Chap. 5). Several known and newly developed methods were employed to increase the efficiency of a device concept that normally leads to strong degradation effects in the operation mode needed here, that is, hot electron generation and transport inside thermally grown silicon dioxide. The final solution of all these efforts was the introduction of the LOCOS processing in combination with the use of a dielectric double layer with silicon oxynitride on top of silicon dioxide. The related electrical degradation and EL quenching issues are described in Chap. 6.

Finally one question remains, at least from the viewpoint of an engineering driven physicist with responsibility for the society from which he gets the money for his research work: what is all this good for? First, it has to be claimed that the principal driving force for these efforts is the creation of a Si-based light source. This dates back about 20 years to the finding of Canham et al. [9] that porous silicon can emit light if excited by UV irradiation. The Si-based light source is the main obstacle to the dream of one day replacing electron/hole driven information processing by a photon driven one. This dream has pushed many people worldwide exactly these 20 years, because most of the other components necessary to realize silicon photonics, such as receivers, modulators, waveguides, etc., are available. And in the present days, 20 years is quite a long time to wait for such a development.

Looking back at the history of key technology development steps, after the invention of the wheel and the wagon more than 5,000 years ago at the dawn of the Bronze Age at several places on the globe, the next logical step to invent a self-moving wagon took several millennia until the construction of steam engine-driven locomotives at the end of the eighteenth century. The nineteenth century finished after this steam engineering period with revolutionary developments in the mastering of electricity and telegraphy/telephony for energy and information management. The field effect as the main principle of the MOS transistor dominating the Si technology up to now was invented in the 1920s by Lilienfeld [10], leading to the invention of the integrated circuit by Kilby and Noyce [11] at the end of the 1950s, that is, only about 30 years of time went by between these two important steps of technology.[1] Thus, all these point to an exponential invention cycle. After that time, a tremendous development of the device integration occurred, quite well described by Moore's law, which now leads to questions such as: "More Moore" or "More than Moore"?!

If looking from the point-contacted Ge-block of the bipolar transistor invented in 1947 at Bell Labs to the FinFet (ca. 2000) with geometrical measures in the

[1] Interestingly, J. Kilby claimed in his Nobel Price Lecture in 2000 that the idea itself, i.e. to build all electronics into one single block, was developed by G. Dummer from the English Royal Radar and Signals Establishment in the early 1950s.

low nanometre-range, one can only speak of a shocking development. It was clear that this revolution of information processing in close combination with the related materials technology led to the revolution in nano and biotechnology during the last 20 years.

But now we also have been already waiting for 20 years for the full photonic circuit with the integrated, electrically driven Si-based light source, what seems to brake the feeling about an exponential development quite a bit. The older and younger history teaches us that exponential developments sooner or later will descend into saturation or will come to a sudden end. So, are these 20 long years already an indication of saturation?

Nevertheless, our approach to use the RE-based light emitters with their limitations regarding efficiency and wear-out behaviour was devoted to applications where the light sources have to deliver certain efficiency at limited lifetime and should be of some use for the human society. This is finally described in Chap. 7 as Si-based optical biosensing using fluorescence. The check of important liquids such as drinking water or milk for estrogens and other critical substances is one of those tasks that save the human genes from too much further disturbances.

Acknowledgements

This book would not have been possible without the help of many colleagues who supported us in manifold ways ranging from experimental assistance to stimulating discussions about physics and beyond. We are especially grateful to C. Cherkouk, T. Gebel, D. Grambole, M. Helm, A. Kanjilal, J. Lehmann, A. Mrotzek, A. Mücklich, S. Prucnal, J. Sun, M. Voelskow and R. A. Yankov (presently or formerly at the Research Centre Dresden-Rossendorf); A. Nazarov, I. N. Osiyuk, I. P. Tjagulskii and S. Tjagulskii (Nat. Academy of Science, Kyiv); C. Buchal and S. Mantl (Research Centre Jülich); H. Fröb and K. Leo (Technical University of Dresden); J. Biskupek and U. Kaiser (University of Ulm); R. Frank and G. Gauglitz (University of Tübingen); B. Garrido and P. Pellegrino (University of Barcelona); T. Gregorkiewicz (University of Amsterdam) and A. Revesz (Revesz Associates, Bethesda, USA).

Dresden, Germany *Lars Rebohle*
August 2010 *Wolfgang Skorupa*

http://www.springer.com/978-3-642-14446-2

Rare-Earth Implanted MOS Devices for Silicon Photonics
Microstructural, Electrical and Optoelectronic
Properties

Rebohle, L.; Skorupa, W.

2010, XVIII, 174 p. 120 illus., 3 illus. in color., Hardcover
ISBN: 978-3-642-14446-2