Preface

The tendency of people to
take small things as important
has resulted in many great things.

G.C. Lichtenberg

Aberration-corrected electron microscopy is a key term in the headline of numerous research reports which involve state-of-the-art electron microscopy equipment. The implementation of spherical aberration correctors in transmission electron microscopes has directly and indirectly enabled revolutionary applications which a little more than ten years ago would not have been feasible or even thinkable. Nonetheless, aberration correction is not the only advancement which enriches the repertoire of experiments that can be carried out in electron microscopes. Besides aberration correction, electron microscopes have been brought to application which, for instance, provide temporal resolution to study dynamics on the nanosecond scale. Another branch of instrument development focuses on *in situ* measurements. Devices have been realized which enable the study of materials and their evolution in liquid media or in controlled gaseous atmospheres, or which make it feasible to monitor the very basic deformation mechanism of materials. This involves the controlled deformation of nanometer-sized objects. Furthermore, many of the analytical capabilities of electron microscopes can nowadays be considered to be comparable to dedicated analytical instruments, which, however, do not provide the unique spatial resolution that is inherent for electron microscopes. Yet, spatial resolution is often indispensable for systematically analyzing complex nanostructured materials. Of course, there are many more directions in the development of state-of-the-art electron microscopy equipment. Nevertheless, many of these developments can potentially benefit from aberration-corrected electron optics. As such, the correction of the resolution-limiting aberration of conventional electron microscopy has to be considered as one of the great inventions which has advanced materials science and our experimental understanding of matter. There is no reason why this trend should not be continued.

Although aberration-corrected electron microscopy has many facets, the primary advantage of overcoming the fundamental geometrical limitation of round electron lenses is the enhanced resolution in atomic-resolution imaging. This book is about spherical aberration-corrected electron microscopy, focusing on this particular aspect: on the application of spherical aberration correctors for atomic-resolution imaging in the broad-beam transmission mode, as well as in the scanning transmission mode. This book does not provide a review of recent experimental achievements that have become possible through the application of top-notch microscopes. This work shall serve as an introductory text which explains some of the fundamental concepts in aberration-corrected microscopy. The text also addresses practical aspects. For instance, it outlines strategies on how to optimize the electron optical setup in order to improve the data that can be collected with an aberration-corrected microscope. The central topic is spherical aberration correction, yet, some of the very recent developments, which go beyond spherical aberration correction, are also elucidated in the text.

The bulk of this book was written in 2009, i.e., roughly ten years after the successful implementation of the first spherical aberration correctors in (scanning) transmission electron microscopes. This book was written with the intention of providing a text which bridges between application-oriented reviews about aberration-corrected electron microscopy and advanced physics textbooks which focus on the electron optical concepts underlying this key technology in electron microscopy imaging.

During the time I have worked with advanced and, in particular, aberration-corrected electron microscopes, I have had the privilege of being guided by various very knowledgable persons to whom I owe many thoughts that went into this text. Without exceptions, my friends, colleagues and collaborators have been my teachers. I would especially like to acknowledge Drs. Peter Hartel, Heiko Müller and Maximilian Haider from CEOS GmbH, who introduced me to the field of aberration-corrected electron microscopy and who have always been very supportive in any matter that arose in the practical handling and optimization of aberration-corrected instruments. I would like to acknowledge Drs. Ondrej Krivanek and Niklas Dellby from NION Company for open conversations, instructive explanations and for sharing their expertise with me. I further wish to thank my former colleagues at FEI Company, in particular Drs. Stephan Kujawa, Bert Freitag, Peter Tiemeijer, Sergei Lopatin, Maarten Bischoff, Michiel van der Stam and Hans van Lin. I would like to acknowledge former colleagues at the National Center for Electron Microscopy at the Lawrence Berkeley National Laboratory and collaborators of the TEAM project, namely Drs. Quentin Ramasse, Marta D. Rossell, Prof. Masashi Watanabe, Christian Kisielowski, Prof. Andrew Minor, Peter Denes, Ulrich Dahmen, and Drs. Andrew Lupini, Juan-Carlos Idrobo and Steve Pennycook from Oak Ridge National Laboratory. I wish to thank Prof. Nigel Browning who to a great extent paved the way for me to work with high-end electron-optical instruments. In addition, I would like to thank the following persons with whom I have collaborated on research projects that helped me to understand topics addressed in this book: Dr. Sandra Van Aert from Antwerp University and Prof. Joanne Etheridge, Drs. Christian Dwyer and Philip Nakashima from Monash University. I would like to express my gratitude to Dr. Helge Heinrich and Prof. Gernot Kostorz, who introduced me to various fields in materials science and in particular to electron microscopy, and taught me the scientific way of addressing research topics during my Ph.D. studies at ETH Zurich. Special thanks go to the staff of the library at ETH Zurich, whom I numerous times challenged, deliberately, but not unintentionally, in retrieving source texts which were of extraordinary value to me. Finally, I would like to thank Marta D. Rossell and my parents Gaby and Peter Erni for their patience, understanding and continuous support.

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