

# Preface to the Second Edition

In fall 2014, Claus Ascheron (Springer-Verlag) asked me to consider a second extended and updated edition of the present textbook. I was very grateful for this possibility, and therefore I quickly agreed to that proposal because of several reasons:

- From the appearance of the first edition in 2005, I have got positive and stimulating feedback from readers including students, scientists, and even lecturers. This feedback was very important for me, because it convinced me that my original idea of writing a pure textbook about the basics of thin-film optics and spectroscopy, including the mathematical derivations of all formulas and combining them with the illustration of the underlying physical concepts, was correct and useful. It is therefore my pleasure to improve, update, and correct parts of this textbook, while preserving the original didactic concept and logical detail of the text.
- I am very grateful to Prof. Andreas Tünnermann, Fraunhofer IOF Jena and Friedrich Schiller University (FSU) Jena, for giving me the regular possibility for composing and reading a lecture course on Thin Film Optics at Abbe School of Photonics, FSU Jena. I have been giving these lectures every year for master students of physics or photonics, starting from 2009. These students (who practically come from all over the world) provide a further vital source of critical feedback to my Thin Film Optics course. It was my pleasure to modify or change certain illustrations or derivations in this textbook as a result of this fruitful cooperation with my students.
- Over the years of teaching, I was able to detect several errors of small or medium significance, as well as some insufficient, inappropriate, or sometimes misleading explanations in the original (first) edition. The second edition supplies a highly welcome and suitable frame for improving the text and figures where possible.
- At the time when the first edition of this book appeared, a german student of physics usually finished his study obtaining the degree of a diploma physicist (Diplomphysiker). Today, the study is subdivided into two sections: a first one

which is finished by obtaining the Bachelor degree, and a second one for obtaining the master degree. It is not my duty to judge the sense or non-sense of this change, anyway a textbook written for use in a university course must consider this development at least when defining the pursued audience. Therefore I spent some time on the study of modern textbooks on physics written for use in the Bachelor period. I have come to the conclusion that the present textbook should be useful for anyone who has already obtained the Bachelor degree in physics, i.e., Bachelor knowledge should be sufficient to benefit from reading this book. I am grateful to Springer-Verlag and Walter de Gruyter GmbH for the generous supply of complimentary lecturer copies of several relevant modern textbooks.

- It is one thing to supply the reader with derivations of all the equations which are so useful in thin-film optics practice. The other thing is to provide suitable practical examples which verify the relevance of the theoretical approaches in practice. When having flipped through the book you may have obtained the feeling that my primary strength is not of experimental nature—I may convince you that you are absolutely right with that. It is more important for me to cooperate with highly skilled experimentators, who have at the same time strongest theoretical background, and are ready to get the most out of their experimental setups to demonstrate the superior use of a coherent interaction of experimental and theoretical efforts. It was one of the basic shortcomings of the first edition that I had not yet established such cooperations so that the practical examples might have been not so convincing. When preparing the second edition, I had the privilege to benefit from an extremely fruitful cooperation with Steffen Wilbrandt (IOF), who supplied me with high quality experimental samples prepared by electron beam evaporation without or with plasma assistance. I am also grateful to Hanno Heiße, Heidi Haase, and Josephine Wolf for corresponding technical assistance. Mikhael Trubetskov, OptiLayer GmbH, was kind enough to provide me with selected design calculations for dispersive mirrors. Experimental material concerning sputtered double band rugate filters has been contributed by Peter Frach and co-workers, Fraunhofer FEP.

My thanks are due to all of the mentioned persons, without their effort I would not have been able to provide these practical examples.

I would like to emphasize it once more in this context, that the present book is intended to serve as a textbook for introducing the reader into the fundamentals of thin film optics. From the first edition of this book, to my knowledge, these fundamentals have not changed. Therefore, the reference list at the end of this second edition is practically the same as in the first edition. Any updates rather concern the practical examples, and for convenience, in these cases the corresponding references have directly been included into the main text. So that the references scattered through the text refer to the sources of concrete (experimental) examples, while the reference chapter at the end of this book summarizes primary literature relevant for understanding the fundamentals.

In 2014, I authored another monograph entitled “Optical Coatings: Material Aspects in Theory and Practice”, Springer 2014. That monograph stresses a more phenomenological and illustrative approach to the material side of thin-film optics; it is not a textbook, instead it is rather complimentary to the present book by both content and logical approach, except of course some necessary overlap when reviewing the basics. None of these two books shall and can replace the other one: If you are seeking for a quantitative approach and its derivation, read the present book, if you are seeking for a coherent illustration on how this quantitative approach appears to be reflected in practice, read the other. Or even better, read both of them.

But I would like to turn your attention to a last aspect: Surface optics and thin-film optics are interdisciplinary and of highest practical relevance. They have strongest impact on our daily life and benefit from the sometimes challenging feedback they have generated. It is one of my passions therefore to look on artwork, literature and even landscapes through the eyes of a thin film physicist: Seeking and finding stimulating allusions and analogies between art and sciences. Therefore, I had pleasure including plenty of relevant classical literature citations into the “material aspects” book. In the present book, instead, artwork created by local Jena artists is used to provide an atmospherical background to the corresponding book chapters. I am so grateful to Brenda Mary Doherty and Astrid Leiterer for permission to present their beautiful pictures or sculptures here in a scientific context. Alexander Stendal provided me with several drawings highlighting the essence of wave propagation in inhomogeneous or dispersive media from daily experience.

Finally, I would like to express my deepest thanks to Prof. Alexander Tikhonravov, the head of the Research Computing Center of M.V. Lomonosov Moscow State University (MSU) and one of my teachers from my studying times, for supplying a concise and elaborate foreword to the present edition of this book. In addition to his scientific reputation, I highly appreciate Alexander as a university teacher, so that this foreword does not only provide valuable information to the potential reader of this book, but is also a very encouraging and stimulating feedback to me.

Jena

Olaf Stenzel

# Preface to the First Edition

The present monograph represents itself a tutorial to the field of optical properties of thin solid films. It is neither a handbook for the thin-film practitioner, nor an introduction to interference coatings design, nor a review on the latest developments in the field. Instead, it is a textbook which shall bridge the gap between ground level knowledge on optics, electrodynamics, quantum mechanics, and solid state physics on one hand, and the more specialized level of knowledge presumed in typical thin-film optical research papers on the other hand.

In writing this preface, I feel it makes sense to comment on three points, which seem to me equally important. They arise from the following (mutually interconnected) three questions:

1. Who can benefit from reading this book?
2. What is the origin of the particular material selection in this book?
3. Who encouraged and supported me in writing this book?

Let me start with the first question, the intended readership of this book. It should be of use for anybody, who is involved into the analysis of optical spectra of a thin-film sample, no matter whether the sample has been prepared for optical or other applications. Thin-film spectroscopy may be relevant in semiconductor physics, solar cell development, physical chemistry, optoelectronics, and optical coatings development, to give just a few examples. The book supplies the reader with the necessary theoretical apparatus for understanding and modeling the features of the recorded transmission and reflection spectra.

Concerning the presumed level of knowledge one should have before reading this book, the reader should have some idea on Maxwell's equations and boundary conditions, should know what a Hamiltonian is and for what it is good to solve Schrödinger's equation. Finally, basic knowledge on the band structure of crystalline solids is presumed. The book should thus be understandable to anybody who listened the ground courses in physics at any university.

The material selection was strongly influenced always by the individual experience on working with and supervising physics students as well as Ph.D. students.

To a large extent, it stems from teaching activities at Chemnitz University of Technology, Institute of Physics, where I was involved into university research on thin-film properties, and read several courses on applied spectroscopy topics as a lecturer. This university time stands for the more “academic” features of the book. It must be mentioned, that in that time I authored a textbook on thin-film optics in German “Das Dünnschichtspektrum” with emphasis on the formal treatment of the optical response of thin solid films. But the present monograph is by no means a translation of that German book. The reason is, that in fall 2001, I changed to the Optical Coating Department at the Fraunhofer Institute of Applied Optics and Precision Engineering (IOF) in Jena, Germany. From that time, my working field shifted to more applied research projects on the development of optical coatings, primarily for the visible or near infrared spectral regions. It is the *combination* of university teaching until 2001 with more applied research work at the Fraunhofer Institute, which defines the individual content and style of the present monograph.

Finally, let me acknowledge the support of colleagues, co-workers, and friends in writing this book. First of all, I acknowledge Dr. Claus Ascheron and Dr. Norbert Kaiser for encouraging me to write it. Thanks are due to Dr. Norbert Kaiser for critical reading of several parts of the manuscript. The book could never have been written without the technical assistance by Ellen Kämpfer, who took the part of writing plenty of equations, formatting graphics and finally the whole text to make the manuscript publishable. Further technical support was supplied by Martin Bischoff.

Concerning the practical examples integrated into this book, e.g., the measured optical spectra of organic and inorganic thin-solid films, so it should be emphasized that all of them have been obtained in the course of research work at Chemnitz University (until summer 2001) and the Fraunhofer IOF (from fall 2001). Therefore, thanks are due to the former members of the (unfortunately no more existing) research group on thin-film spectroscopy (at Chemnitz University of Technology, Institute of Physics, Department of Optical Spectroscopy and Molecular Physics), and to the researchers in the Optical Coatings Department of the Fraunhofer IOF in Jena. The book benefited from the stimulating research atmosphere in these facilities.

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An Introduction

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