

Preface

Based on my experience I have selected the parts of basic science that were helpful to my own research of solar cells, specifically on CdS based thin-film cells. As any, even somewhat more comprehensive treatises, a selection was made to include, beyond basic material science and the description of space charge effects, mostly CdS/Cu₂S and CdS/CdTe solar cells. These treatments are more comprehensive, including most recent references. The descriptions are excellent examples for the theoretical analysis of most other thin-film solar cells. The other thin-film solar cells, the CIS-group and amorphous Silicon are discussed in three shorter chapters at the end of this book.

Overall the book is structured to address most aspects of thin-film solar cells, starting from the history of their development and covering all features of these including most recent technologies, commercial viewpoints, and global material resources.

Commercial solar cells are based on materials that are handed to us often more than half a century ago and grown or deposited by conventional methods, doped to produce homo- or hetero-junction and then treated in various ways to improve their performance. All of this has become a routine and the selection of the processes was done often in respect to production economics, with an eye to minimize long term cell degradation. Only a few researchers were involved to search for new ways to make these cells or use totally new materials in the hope for performance improvement or economic production advantages and had to look for more basic material science properties.

This is one of the reasons behind composing this book. The other one is to help for a better understanding of solar cell operation.

In organizing this book I want to provide a toolbox for scientists and engineers for designing new solar cells, improving the conventional ones and understand better their operation. This toolbox needs to cover a wide field from the understanding of the material science aspects of the building blocks and structure of solar cells to the electronic configuration with its influence on the separate parts of the cell, and finally of the solar cell itself, analyzing it and interpreting its performance.

This is a complex field with constantly new developments, and to attempt a comprehensive description is impossible in a reasonable and useful single volume. Therefore a selection was made between basic facts and useful results that have more principle value than going into detail for which a long list of cited literature exists. This excludes more extensive description of analytical tools that are not dealt with in detail here, and many more fields of the rapidly developing science. But the book should give the foundation from which to build further research in the field.

As any selection, this is subjective to the judgment of the author and his specific experience. It will be therefore more detailed in the fields relating to cadmium sulfide and other adjacent fields that have proven helpful in designing my research and relating to the development of a variety of thin film solar cells. Whenever possible within the constraints of this book, important solar cell developments were guidance to select.

At many junctures, possible problems are pointed out in conventional manufacturing processes, or from model analyses that could lead to costly misjudgments and can be avoided by following some of the suggestions listed in this book.

In all, different segments of this book are more helpful to production engineers at the bench, while others may guide researchers into the development of new solar cells. Since it is open ended in which direction further investigation will lead, I have included some small sections of the book in fields that are not relevant to present solar cells, but may stimulate excursion into adjacent fields that provide already a wealth of evidence to stimulate creative advances. Many helpful tables are scattered throughout the text. The literature citations attempt to be more comprehensive, including historical publications of specific and related fields. An extensive subject index and a listing of useful formulae is appended.

In summary, this book is a compendium giving a comprehensive description of the basic physics relevant to the design and the analysis of solar cell materials. It starts from the basics of material science, describing the material and its growth, defect and electrical properties, the basics of its interaction with photons and the involved statistics, proceeding to space charge effects in semiconductors and *pn*-junctions. Most attention is given to analyze homo- and hetero-junction solar cells using various models and applying the field-of-direction analysis for discussing current voltage characteristics, and helping to discover the involvement of high-field effects in solar cells. The comprehensive coverage of the main topics of—and relating to—solar cells with extensive reference to literature helps scientists and engineers at all levels to reach a better understanding and improvement of solar cell properties and their production.

Appreciation: The book is based on four decades of teaching material science and solar cells, and equally important the constant interaction with my students and colleagues. The list is too long, but a very few may be mentioned with appreciation: Ulrich Kümmel, Peter Voss, Gustavo Dussel and Hank Hadley who worked with me early in my carrier. More recently I am especially grateful to many colleagues of the Institute of Energy Conversion (IEC) of the University of Delaware who directed me to recent development with extensive literature especially Bob Birkmeire, the director of IEC and his senior scientists, Steven Hegegedus and Brian McCandless.

I appreciate the dedicated work of Anita Schwarz from the Computer Program of the University of Delaware to facilitate my work in preparing the book. Special thanks are extended to Dieter Palme, a research associate over seven decades for helping me in the many aspects of completing this book. However, my deep gratitude rests with my wife, Renate, who has patiently forgiven me when at times I was a bit absentminded and has continued to encourage me throughout my endeavor.

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Handbook of the Physics of Thin-Film Solar Cells

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2013, XL, 882 p. 451 illus., Hardcover

ISBN: 978-3-642-36747-2