# PREFACE

## OBJECTIVES

The primary purpose of this book is to convey insight into why semiconductors are the way they are, either because of how their atoms bond with one another, because of mistakes in their structure, or because of how they are produced or processed. The approach is to explore both the science of how atoms interact and to connect the results to real materials properties, and to show the engineering concepts that can be used to produce or improve a semiconductor by design. Along with this I hope to show some applications for the topics under discussion so that one may see how the concepts are applied in the laboratory.

The intended audience of this book is senior undergraduate students and graduate students early in their careers or with limited background in the subject. I intend this book to be equally useful to those teaching in electrical engineering, materials science, or even chemical engineering or physics curricula, although the book is written for a materials science audience primarily. To try to maintain the focus on materials concepts the details of many of the derivations and equations are left out of the book. Likewise I have not delved into the details of electrical engineering topics in as much detail as an electrical engineer might wish. It is assumed that students are familiar with these topics from earlier courses.

The core prerequisite subjects assumed for use of this book are basic chemistry, physics, and electrical circuits. The most essential topics from an intermediate level in these subjects are reviewed. Students taking my class are assumed to have had a condensed matter physics course and a semiconductor device theory course with significantly more detail than is covered in Chapters 2 and 3. Furthermore they are assumed to have had some organic chemistry (at least at the Freshman undergraduate level) and general materials science courses with significantly more information than I provide in the review in Chapter 4. In spite of these expectations my audience usually includes graduate students lacking background in at least one of these topics.

My background that applies to the material in this book includes more than 25 years doing research in semiconductor materials science and processing. My primary research over the past 18 years has concerned the fundamental materials science of the semiconductor $CuInSe_2$ and related compounds. This material is a fascinating study in all of the topics of materials science rolled into a single field. As such, the results appear from time to time in the book as illustrations. Given rising concerns about energy world wide, the book also makes reference to solar cells, properly known as photovoltaic devices, in several application sections. This also reflects my long study of that field.

## TOPICS AND USE OF THE BOOK

I have taught a class based on the material that is presented in this book for many years. I get through most of the topics, excluding detailed discussions of the applications, in one semester. Each chapter typically gets about three hours of lecture, although Chapters 6, 7, 9, and 12 often receive four to five lectures and Chapter 1 gets one hour. My students have generally been a mixture of senior undergraduate and graduate students. One of the common features of these students is that many, especially the graduate students, lack a strong background in some one of the underlying prerequisite subjects such as condensed matter physics, principles of electronic devices, or materials science. Therefore the book includes a brief review of these topics in Chapters 2-4 and I cover these subjects very quickly in the class. Even for the students with a background in all of these areas I usually find it helpful to review selected topics from these chapters. In presenting review topics I hope that the book can be useful to a student body that completely lacks a detailed background if the instructor is willing to go through this material.

One of the challenges in writing the book is that its intended audience does not have much background in quantum mechanics. Therefore, I cannot practically go into details about how the wave function interactions in Chapter 5 are calculated that lead to the matrix element values in the LCAO matrix (or into details of corrections to the LCAO that are used in real calculations today. I have attempted to present the material in such a way that a student without this background can understand the important take-home messages of the subject even if they are unfamiliar with how the values are derived. Of course, if one is doing tight binding theory these matrix elements may be considered fitting parameters, so what I am doing in Chapter 5 is not so much less sophisticated than tight binding theory anyway. One may also note that I have taken two approaches to the question of how atomic orbitals contribute to semiconductor band structures in Chapter 5, one almost purely visual – the Harrison diagram approach – and one semiquantitative, covering the basic approach of LCAO theory. Hence, hopefully the student will have different ways of remembering the relationships among orbitals, bonds, and bands. It is useful when covering the material to also make connections to the material in Chapter 2 on nearly free electron behaviors.

Chapters 6 and 7 are the core of the materials science in the book. They talk about how to engineer a semiconductor material to achieve given properties through modification of its structure and chemistry. Hence, they spend a considerable time on defects and how and why they form. Most of the preceding chapters are building up to these two in hopes that when the student gets here they will say to themselves “of course it should work this way, considering how the atoms are changing and how the bonds are forming.”

Chapters 8 and 9 cover less commonly applied materials of great value and interest in applications. Especially in the case of Chapter 9 the organic materials appear likely to increase greatly in range of application in the near future. Amorphous inorganic materials described in Chapter 8 are valueable to understand and preview of what one might expect for the organics in some respects. Many of the issues such as Coulomb blockades at contacts are the same.

Finally Chapters 10-12 cover some of the major methods of processing thin films. When I teach this class this material is covered between the material in Chapter 4 and the material in Chapter 5 but it could just as well be covered last. I put it in the middle because it provides a change of pace in the type of discussion I am presenting. When I was first developing this course together with a second course on dielectrics, metalizations, and other materials and processes used above the semiconductor surface I tried to separate the course into a materials course and a processing course. This did not work well because the two subjects are so heavily intertwined. It is hard to see why there would be problems in the materials without understanding their processing but it is equally hard to see why one should bother with complex processes unless one has an idea of how the material one is producing responds to defects. Likewise, it is difficult to see why a non-equilibrium process such as evaporation should be important to deposition of an alloy unless one sees how phase separation and defects affect the alloy property.

Of course the biggest problem with writing a book of this type is that the field, especially the organic materials topics, are progressing so rapidly that the book will be somewhat obsolete as soon as it is in print. To improve the longevity of the material covered I have attempted to stick with fundamental concepts and not deal with what I perceive to be passing fads. With luck I will have reason to add some of these topics to future editions.

## ACKNOWLEDGEMENTS

I wish to thank the many students who have suffered through the use of this book in draft form in my class and for all of their input. It has been an invaluable help. I also wish to thank the various colleages whose work I use to illustrate concepts in the book and whose contributions have been some of the most important in the field. I have tried to recognize them by name in the presentation of their figures. Finally, I wish to thank the staff at Kluwer who have been so patient. I hope their long wait pays off.

Angus Rockett

University of Illinois, 2007

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