Principles of Nonlinear Optical Spectroscopy

S. Mukamel (Oxford University Press, New York, 1995)
ISBN 0-19-509278-3

One of the most powerful tools for material characterization is the study of the material's interaction with the electromagnetic field. In the optical spectral range, numerous experimental techniques are developed to study fluorescence of materials, spontaneous and coherent Raman scattering, photon echoes, resonant gratings, hole burning, and many other important optical and physical processes. Various nonlinear optical effects differ in the order of response with respect to the applied fields and can be resonant or off-resonant. As the preface to the book notes, there is no common terminology and language for different nonlinear optics and spectroscopy disciplines, which creates a serious barrier among scientists working in diverse disciplines and leads to a duplication of efforts and techniques.

S. Mukamel provides a unifying description of the fundamental principles common to nonlinear optical and spectroscopic processes. *Principles of Nonlinear Optical Spectroscopy* is a theoretical book; however, many problems and techniques are illustrated with front-edge experimental results. This provides an important bridge between theory and experiment.

The introduction to the book describes briefly the existing experimental techniques and theoretical problems. The next two chapters contain quantum mechanics and mathematical techniques describing the wavefunction and density operator evolution in Hilbert and Liouville space. These two chapters, necessary for understanding the rest of the book, will be probably the most difficult for experimentalists far from theoretical physics. Chapter four describes elementary concepts of quantum electrodynamics related to optical polarization and radiation-matter interaction. Linear and nonlinear response functions and optical susceptibilities are introduced in the next two chapters. Semiclassical methods for simulating the response functions are discussed in chapter seven. The response functions are solved in the following chapter, using the second-order cumulant expansion.

Chapters 9 through 15 discuss the application of the developed nonlinear response formalism to various spectroscopic techniques. These chapters cover fluorescence, spontaneous Raman scattering, and coherent Raman scattering; photon echo; resonant gratings, impulsive pulse-probe, hole burning, and fluorescence spectroscopy; semiclassical approximations for the nonlinear response function (using Wigner phase-space representation); applications of this approach to pump-probe and hole burning spectroscopy; off-resonance Raman spectroscopy; and birefringence and dichroism spectroscopies.

The last two chapters treat the more complex problems of the approach for optically dense media with a finite density of chromophores and the many-body aspects and cooperative effects in the nonlinear response.

This book can be useful for researchers and research and development engineers working in nonlinear optics and materials science as well as for students. A better understanding of the basic principles common for different nonlinear optical techniques will help readers to systemize their knowledge of various, related disciplines and help researchers and optical engineers working in diverse fields to understand each other.

Reviewer: *Mikhail A. Noginov is a research faculty member at the Center for Nonlinear Optics and Materials, Department of Physics, Alabama A&M University. Noginov's main research interests and experience are in spectroscopic and dynamics study of laser, photorefractive, and other nonlinear optical materials; energy transfer and carrier transport in optical materials; and in laser physics.*

Interfaces in Crystalline Materials

A.P. Sutton and R.W. Balluffi
(Oxford University Press, New York, 1995)
ISBN: 0-19-851385-2

Many structural and electronic materials are used in the form of polycrystalline aggregates. Often the contributions of the internal interfaces can significantly influence the structure/property/performance paradigm of the material. Thus, over the past 50 years, materials scientists have studied the nature of interfaces in crystalline solids and the phenomena associated with such interfaces. This has been especially true in the past two decades because of the development of high resolution techniques for studying atomic structure and behavior and of improved modeling capability due to the advent of high speed computers. The rapid growth in knowledge of crystalline interfaces has far outpaced the status of the field presented in much earlier reviews on the subject.

Sutton and Balluffi have sought to fill this large gap. They have successfully created a scholarly, integrated, and up-to-date text on the vast subject of interfaces in crystalline solids. Clearly the book is intended for advanced students and serious scholars and researchers in solid state physics, physical metallurgy, and materials science who have a strong interest in the subject of interfaces and interfacial phenomena. It focuses on the fundamental aspects of structure, thermodynamics, kinetics, and properties of internal crystalline interfaces, both homophase and heterophase types whether sharp or diffuse in nature, in a broad range of materials (e.g., metals, ceramics, and semiconductors). Important aspects of crystalline interfaces are presented descriptively and in theoretical derivations of sufficient detail to be comprehended by serious readers but which require a working knowledge of a number of advanced mathematical techniques. Ample examples and many references to experimental findings are presented throughout to balance the theoretical mien.

Over 40% of the text concentrates on details of the structure of crystalline interfaces. First the geometry of interfaces is presented including a discussion of bicrystallography, the science concerned with the symmetries characterizing the structural order that exists in a bicrystal. Next, dislocation models for interfaces are extensively covered, followed by models of the interatomic forces at interfaces. Finally. experimental observations of atomic structure and associated structural models are detailed.

The remainder of the book is divided in roughly equal parts devoted to the thermodynamics, kinetic aspects, and properties of interfaces. Highlighting the thermodynamics section of the book are stress-strain effects, geometrical variables, capillarity, and solute segregation to interfaces. The kinetics section discusses diffusion at interfaces and the conservative and nonconservative motion of interfaces. The properties section deals with the electronic and mechanical properties of interfaces.

The authors have made an effort to systematize the nomenclature for describing interfaces in crystalline solids, trying to be consistent with that used in the closely related field of surface science. A standard set of symbols was adopted and a glossary of terms provided.

Because of the vastness of the field, the authors were unable to be all-inclusive and cover every aspect of interfaces in solids. Thus interfaces in amorphous solids and noncrystalline materials are not part of the book. A number of phenomena involving interfaces in crystalline solids, namely, some subjects of interest to the physical metallurgist such as corrosion, heterogeneous precipitation at interfaces, recrystallization, grain growth, texture evolution, grain boundary development during deformation, and interfacial fatigue have also been omitted. However, because of the text's strong emphasis on fundamentals, it should be a useful reference for the science community.

Reviewer: *Roy A. Vandermeer is a physical metallurgist whose interests include recrystallization modeling of metallic materials, grain boundary migration mechanisms in pure and impure metals, and phase transformations in steels and uranium alloys. A graduate of Illinois Institute of Technology, he has worked as a scientist at the Oak Ridge National Laboratory and as a professor at the University of Tennessee prior to his current position.*

Books for Review can be sent to Book Review Editor
MRS Bulletin
Materials Research Society
9800 McKnight Road
Pittsburgh, PA 15237-6006