Preface

The field of spectroscopy emerged in the seventeenth century when Isaac Newton discovered that sunlight consists of many different colors. The next milestone came when Maxwell formulated the theory of electromagnetism, in which he attributed differences in color to differences in wavelength. Furthermore, he predicted that electromagnetic waves can have any frequency (or, equivalently, wavelength) and that visible light itself is a kind of short wavelength electromagnetic wave. Since this discovery, the frequency range accessible by spectroscopic methods has expanded from a few Hz up to PHz (10^{15} Hz), and beyond. Recent developments in electrical and optical technologies have enabled new forms of spectroscopy to emerge, such as nonlinear spectroscopy. Spectroscopic techniques are no longer restricted to homogeneous gaseous, liquid, or solid materials, but have expanded to accommodate nanometer-scale materials including nanoparticles, thin films, and nano-composites.

This book, "Frontiers in Optical Methods: Nano-Characterization and Coherent Control," covers a broad range of recent advances in spectroscopy, especially in nano-materials and under extreme conditions. Spectroscopy basically involves the generation of light (electromagnetic waves) and the detection of material responses. Recent developments in the former area have been facilitated by technological advances involving two key light sources—lasers (especially ultrashort pulse lasers) and relativistic radiation from accelerators. Both sources provide intense and controllable broadband radiation, from the terahertz to X-ray ranges, and have become ubiquitous tools in the investigation of materials' properties. In the latter area, recent developments in electronics and imaging devices, as well as methods for improving sensitivity under extreme conditions (such as at high pressures or low temperatures) have provided important new insights into properties of materials that cannot be studied using conventional light. Within this book, you will find out how these techniques are applied in modern spectroscopy.

The main parts of this book are devoted to three major topics: I. Reflectance Spectroscopy, II. Ultrafast and Coherent Measurements, and III. Terahertz Technology.

In Part I, we discuss the extreme sensitivity of spectroscopy at visible and ultraviolet wavelengths, which is capable of detecting sub-monolayer films on well-characterized surfaces (K. Shudo and S. Ohno). The paper provided by

T. Nanba reviews microscopic spectroscopy at extremely high pressures. S. Kimura discusses the powerful accelerator light sources, and their role in broadband material spectroscopy.

In Part II, we summarize the recent advances in ultrashort-pulsed laser spectroscopy. Since the pulse duration can be made shorter than the timescale of various elementary excitations in materials, we are concerned with coherent dynamics. The impulsive excitation of solid materials by such lasers can induce coherent lattice vibrations (see the papers from K. Kato and O. Matsuda) and pulsed accelerator light sources enables the full characterization of the laser-induced atomic displacements (Y. Tanaka).

In Part III, coherent terahertz spectroscopy, which has rapidly increased in popularity, is reviewed (M. Tonouchi). Material characterization using ultrashort-pulsed laser-based terahertz sources is discussed by I. Katayama and K. Kitagishi. In combination with accelerator sources, the light intensity can be significantly enhanced (review by M. Kato), which is useful for nonlinear and microscopic spectroscopy. Recent electronic developments have also provided important breakthroughs in detection sensitivity, even to the point of a single terahertz photon (K. Ikushima).

This book thus presents a range of modern applications of advanced light sources as material probes, notably on the nanometer scale. Although the research presented in this book deals with specific topics, the underlying concepts are essential for the spectroscopic analysis of nanoscale materials and for spectroscopy at ultrafast timescales. The combination of these light sources with the sophisticated techniques presented can confidently be expected to expand the fields of nanoscale-, bio-, and complex materials spectroscopy, and to greatly enhance our understanding of quantum phenomena, especially in extreme conditions. It is our great hope that this book will thus help to expand the frontiers of materials science and its applications to new directions for the future.

Finally, this book is inspired by a review volume of the Journal of the Vacuum Society of Japan (in Japanese), and a number of figures are reprinted from the volume with permission by courtesy of the Vacuum Society of Japan. We would also like to thank Claus E. Ascheron and his coworkers at Springer-Verlag in Heidelberg for their help in completing this book.

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