Semiconductors Probed by Ultrafast Laser Spectroscopy
Volume I

Edited by

R. R. ALFANO

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Preface

Over the past decade, we have seen dramatic advances in the generation of ultrafast laser pulses and their applications to the study of phenomena on a picosecond (10^{-12} sec) time scale. New developments have extended this technology into the femtosecond (10^{-15} sec) time regime. The design of sophisticated techniques based on these laser pulses has given rise to instruments with extremely high temporal resolution. Ultrafast laser technology offers the possibility of studying and discovering key processes unresolved in the past. A new era of time-resolved spectroscopy has emerged. Today, ultrafast laser spectroscopy is one of the most active areas of science since it can be used in a diverse number of fields: solid-state physics, biology, and chemistry.

Semiconductors are the driving force behind the high-technology explosion of this century. With today's need for faster communication and computer systems, understanding the microscopic world of semiconductors is essential. This is required in order to find the basic limitations on speed and operational capacity. The world of semiconductors is inhabited by many species: electrons, holes, optical phonons, acoustic phonons, plasmons, magnons, excitons, and coupled modes, including polaritons, polarons, and excitonic molecules. The time scale for the excitations in this world is measured in subpicoseconds. Therefore, fundamental information on the mechanisms, interactions, and dynamics, and the various processes they spawn, is obtained from direct time measurements on the ultrafast time scale from 10^{-14} to 10^{-9} sec. Of course, the frequency domain is used in combination with the time domain to sort out the spectral ''figure prints'' of the excitation mode. Some of the processes that have been recently investigated are the cooling and thermalization rates of hot carriers, the lifetimes of phonons, the formation time of excitons, the screening of optical-phonon–carrier interactions, the dynamics of ballastic transport, and the mechanism of laser annealing. The capability of measuring the intervalley scattering times and momentum relaxation times will aid in the development of small-scale devices.

Thus far, a great deal of information has been obtained which has enhanced our understanding of the dynamics in the underlying world of semiconductors. These developments are most often found in original research contributions and in review articles scattered in journals. Textbooks do not cover these subjects in great detail. There is a need for a book that covers the various aspects of ultrafast phenomena that occur in semiconductors and the methods used to study them.

This treatise, published in two volumes, reviews current progress on the experimental and theoretical understanding of ultrafast events that occur in semiconductors on a picosecond and nanosecond time scale. The content of the articles is a mixture of theoretical and experimental material. Overviews of the important breakthroughs and developments in the understanding of fast events during the past ten years are presented. The reader will find chapters that review the basic principles, contain surveys of research results, and present the current thinking of experts in the ultrafast semiconductor field. The volumes should prove to be useful source books and give the scientist, engineer, and graduate student an opportunity to find most of the necessary and relevant material in one presentation. Through these volumes we hope to stimulate future research on the understanding of the fast physics in semiconductors and explore semiconductor technology to produce ever faster electronics and computer devices.

The volumes are organized into nine parts—where various areas of semiconductor physics are reviewed in the first eight parts and ultrafast laser techniques are covered in the ninth part. Part IX complements Part V of the book I edited entitled "Biological Events Probed by Ultrafast Laser Spectroscopy" (Academic Press, 1982).

Summarizing the highlights of the nine parts of the treatise:

In Part I, chapters are written on the relaxation of energy and the momentum of hot carriers.

In Part II, chapters review the relaxation of nonequilibrium electron–hole plasmas and phonons.

In Part III, chapters discuss the dynamics of excitons, polaritons, and excitonic molecules.

In Part IV, chapters cover the transient transport and diffusion of carriers.

In Part V, chapters review the research on optoelectronic devices and on the fast electronic properties of carriers in the amorphous state.

In Part VI, chapters discuss the physical mechanisms that operate during and after the interaction of an intense laser pulse with a semiconductor. This subject is still highly controversial.

In Part VII, chapters discuss the relaxation of carriers in nonmagnetic and magnetic semiconductors.

In Part VIII, chapters cover transient optical pulse propagation in linear and nonlinear media.

In Part IX, chapters review the various methods of time-resolved spectroscopy and update subpicosecond laser design.

I wish to thank the contributors for their cooperation in this endeavor. Special thanks are given to Mrs. M. Gibbs for her secretarial assistance, and particularly to Y. Budansky for technical drawings, Dr. A. Doukas for technical advice, and Academic Press for their cooperation and editorial aid. I gratefully acknowledge the AFOSR, ONR, NASA, NIH, NSF, and Hamamatsu Corporation for their foresight and support of ultrafast laser research at The Institute for Ultrafast Spectroscopy and Lasers at CCNY over the years.

I dedicate these books to my friend and co-worker, Dr. Stanley L. Shapiro.

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