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Raman Spectroscopy in Graphene Related Systems

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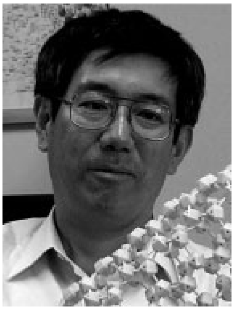

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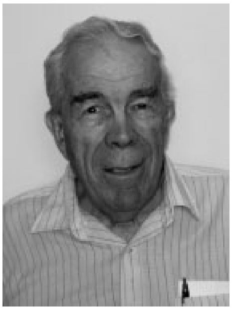

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A. J. and R. S. dedicate this book to the 80th birthday of
Professor Gene Dresselhaus (born Nov. 7, 1929) and
Professor Mildred S. Dresselhaus (born Nov. 11, 1930).

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Preface

Raman spectroscopy is the inelastic scattering of light by matter. Being highly sensitive to the physical and chemical properties of materials, as well as to environmental effects that change these properties, Raman spectroscopy is now evolving into one of the most important tools for nanoscience and nanotechnology. In contrast to usual microscopy-related techniques, the advantages of using light for nanoscience relate both to experimental and fundamental aspects. Experimentally, the techniques are widely available, relatively simple to perform, possible to carry out at room temperature and under ambient pressure, and require relatively simple or no special sample preparation. Fundamentally, optical techniques (normally using infrared and visible wavelengths) are nondestructive and noninvasive because they use the photon, a massless and chargeless particle, as a probe.

For understanding Raman spectroscopy, a combination of experiments and theory is important because some concepts of basic solid state physics are needed for explaining the behavior of the Raman spectra as a function of many experimental parameters, such as light polarization, the energy of the photon, temperature, pressure and changes in the environment. In this book, starting from some known example of physics and chemistry, we will explain how to use the basic concepts of molecular and solid state physics, together with optics to understand Raman scattering. Graphene, nanographite and carbon nanotubes (sp^2 carbons) are selected as the materials to be studied, due to their importance to nanoscience and nanotechnology, and because the Raman technique has been extremely successful in advancing our knowledge about these nanomaterials. It is possible to observe Raman scattering from one single sheet of sp^2-hybridized carbon atoms, the two-dimensional (2D) graphene sheet, as well as from a narrow strip of a graphene sheet rolled-up into a 1 nm diameter cylinder to form the one-dimensional (1D) single-wall carbon nanotube. These observations are possible simply by shining light on the nanostructure focused through a commonly available microscope. This book therefore focuses on the basic concepts of both Raman spectroscopy and sp^2 carbon nanomaterials, together with their interaction. The similarities and differences in the Raman spectra for different sp^2carbon nanomaterials, such as graphene and carbon nanotubes, provide a deep understanding of the Raman scattering capabilities that are emphasized in this book.

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There is a general feeling that Raman spectroscopy is too complicated for a non-specialist. Often, common users of Raman spectroscopy as a characterization tool for their samples only touch the surface of the capabilities of the Raman technique. This book is aimed to be sufficiently pedagogic and also detailed to help the general nanoscience and nanotechnology user of Raman spectroscopy to better utilize their instrumentation to yield more detailed information about their nanostructures than before. Our challenge was writing a book that would build from the most basic concept, the Schrödinger equation for the hydrogen atom, going up to the highest level use and application of Raman spectroscopy to study nanocarbons in general.

The book was initially structured for use in a course for graduate students in the Federal University of Minas Gerais (UFMG), Brazil, and it is organized in two parts. The first part gives the basic concepts of Raman spectroscopy and nanocarbons, addressing why we choose nanocarbons as prototype materials for writing this Raman book. The text is suitable for physicists, chemists, material scientists, and engineers, building a link between their languages, a link that is necessary for the future development of nanoscience. The second part gives a detailed treatment of the Raman spectroscopy of nanocarbons, addressing both fundamental material science and the use of Raman spectroscopy towards material applications. Again nanostructured sp^2-hybridized carbon materials are model systems, both due to the common interest that physicists, chemists, material scientists, and engineers have in these systems and because these systems are pertinent to the length scales where these fields converge. By giving more details, the second part gives examples of the large amount of physics one can learn from studying nanocarbons.

Even though the Raman effect was first observed in the early 1920s, we believe this book is the starting point for lots of new scientific perspectives that the "nano" generation is making possible. We hope the reader will be interested in Raman spectroscopy and will accept the challenges that many researchers are now trying to solve in applying this technique to study nanostructures. Problem sets are included at the end of each chapter, designed to provide a better understanding of the concepts presented in this book and to reinforce the learning process. We appreciate if the readers are willing to solve our problems and send the solutions to the authors to post on the web. The answers by the readers and students using this book can be posted on the following web page: http://flex.phys.tohoku.ac.jp/book10/index.html.

Finally, we strongly acknowledge all students and collaborators who have contributed to the development of this book.

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