Preface

A carbon nanotube is a honeycomb lattice rolled into a cylinder. The diameter of a carbon nanotube is of nanometer size and the length of the nanotube can be more than 1μm. The nanotube diameter is much smaller in size than the most advanced semiconductor devices obtained so far. Thus the availability of carbon nanotubes may have a large impact on semiconductor physics because of its very small size and the special electronic properties that are unique to carbon nanotubes. Because of the large variety of possible helical geometries known as chirality, carbon nanotubes provide a family of structures with different diameters and chiralities. One of the most significant physical properties of carbon nanotubes is their electronic structure which depends only on their geometry, and is unique to solid state physics. Specifically, the electronic structure of a single-wall carbon nanotube is either metallic or semiconducting, depending on its diameter and chirality, and does not requiring any doping. Thus we can imagine that the smallest possible semiconductor devices are likely to be based on carbon nanotubes. Further, the energy gap of semiconducting carbon nanotubes can be varied continuously from 1 eV to 0 eV, by varying the nanotube diameter. Thus, in principle, it may be possible to specify the desired semiconducting properties using only carbon atoms with a specified geometric structure.

The purpose of this book is to define the structure of carbon nanotubes as clearly as possible, starting from basic physics and chemistry. Since the uniqueness in the electronic structure comes directly from the uniqueness of the electronic structure of graphite, this volume provides background information about the structure and properties of graphite and related carbon materials. From our definition of the structure of carbon nanotubes, we can explain the electronic structure and phonon dispersion relations based on simple physical models, which the reader can follow with a pen and paper. Thus the contents of the book are rather theoretically oriented, and experimental results are used primarily to provide evidence for the validity of the theory. This is actually the

way that the field of carbon nanotubes developed. At an early stage, the theory stimulated experiments in carbon nanotube physics, since obtaining sufficient quantities of pure carbon nanotubes has been difficult in practice. The early experiments were made through electron microscope observation. The direct evidence provided by electron microscopy for the existence of carbon nanotubes was sensational to many physicists and chemists, and because of this fascination, the field of carbon nanotubes has grown explosively, with many active research groups worldwide working independently or in collaborative research projects.

In this book, using basic ideas of the lattice, electronic and phonon structures, the physical properties are discussed in the terminology of carbon nanotubes, which are characterized by the chiral index (n, m). The chiral index (n, m) consists of a set of integers which specify each carbon nanotube uniquely. Since quantum effects are prominent in nanotube physics, the magnetic and transport quantum effects are very significant. Although progress in the field is still at an early stage, the book focuses on the basic principles behind the physical properties. Another unique property of a carbon nanotube is its stiffness, corresponding to the upper limit of the best carbon fibers, which are commonly used as a strong light-weight material. The special properties of carbon nanotubes are explained in the various chapters in this book.

Thus the physical properties of carbon nanotubes provide a new dimension for solid state physics, based on the great variety of possible geometries that are available for carbon nanotubes. In order to expand this field into the future, many researchers in different fields of science should contribute to this field. The authors hope that readers from any field of science can read this book without any special background requirements. This book is not intended to be a collection of all activities on carbon nanotubes worldwide because this field is already so extensive, and is moving forward so rapidly at the present time. When this book was started three years ago, the present status of the field could not have been anticipated. Thus future progress is beyond our imagination. We hope that through this book, we will find many new friends in this field. So please enjoy the book and please communicate to the authors any comments you might have about this book.

The authors would like to acknowledge many carbon nanotube researchers who have contributed to the contents of the book. The authors also thank the New Energy Development Organization (NEDO) of the Japanese Ministry for

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Finally the authors wish to say to readers: "Welcome to Carbon Nanotube Physics."

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