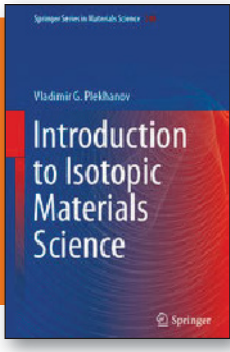

Introduction to Isotopic Materials Science

By Vladimir G. Plekhanov

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The properties of semiconductors are determined not only by their shape and dimensions, strain, dopant concentrations, and junctions with other materials, but also, the concentration of their isotopes. Isotope concentrations influence the thermal, elastic, and luminescent properties of semiconductors. Its largest effect is on lattice vibrations. Thus, changing the isotope concentration affects the lattice constants, coefficients of thermal expansion, and thermal conductivity of the material. For example, the thermal conductivity of isotopically pure ^{28}Si is 60% higher at room temperature and 600% higher at 20 K compared to natural silicon, which is composed of three isotopes, ^{28}Si (92.2%), ^{29}Si (4.7%), and ^{30}Si (3.1%).

This book focuses on how the properties of semiconductors change with isotope concentrations and how this can be used to enhance device performance. To understand this dependency, for each property, Plekhanov first describes the physical theory of how the interactions of atoms and their electrons lead to specific properties. For example, he explains how energy bandgaps are formed from a lattice of atoms, the concepts of densities of state and electron effective mass, and excitons in quantum wells with little or no reference to isotopes. This background sets the stage for discussing how the semiconductor properties change with specific isotopes. Brief reviews are given on how the energy bandgap changes with isotope concentrations for many different semiconductors, including silicon, germanium, diamond, lithium hydride, cadmium sulfide, zinc oxide, and many others.

Isotope concentration strongly affects phonon properties, since these depend on the mass of the atoms involved. Thus, the thermal conductivity is highest in elemental semiconductors that are isotopically pure and is lowest in semiconductors with a mixture of isotopes due to isotopic disorder. Besides theory and factual data, Plekhanov also covers the specialized methods for measuring the properties of semiconductors with different isotope concentrations, such as inelastic neutron scattering, to determine the phonon dispersion. His coverage also examines how phonon-related properties change with isotope concentrations, including Raman peak positions and peak widths. The effects of varying isotope concentrations are interspersed with other techniques employed to vary the properties of electrons in semiconductors, such as the use of quantum wells.

The underlying physics for many devices is explained, including light-emitting diodes, optical fibers, resonant-tunneling diodes, field-effect transistors, and radiation detectors. Again, most of this is general, with little reference to isotope effects. The most recent topics covered are on the isotope effects in carbon nanotubes and quantum computing. The lengthy section on the requirements for quantum computing ends by describing the importance of isotopic purity in this application to maximize the coherence times in silicon and diamond. These descriptions of devices and applications are well-written, covering the most salient aspects of these technologies.

This book is nicely illustrated with many black and white figures, mostly plots of physical data, with some device schematics. It references more than 700 papers, including many classic textbooks on solid-state physics. Most of the references are from prior to 2010, the exception being more recent studies of carbon nanotubes and quantum computing. This book is a mixture of theory and experimental observations. It does not include any problems, which would make it difficult to use as a textbook. Still, it is a good supplemental source for a solid-state physics course.

In summary, this is a good introduction to semiconductor physics and a comprehensive overview of the many different ways in which isotopes influence material properties and can be exploited to improve device performance and achieve completely novel device functions.

***Reviewer: James H. Edgar**, Distinguished Professor at Kansas State University.*