Review Article Complex Thermoelectric Materials

Comprising two volumes, Thermoelectrics and Its Energy Harvesting reviews the dramatic improvements in technology and application of thermoelectric energy with a specific intention to reduce and reuse waste heat and improve novel techniques for the efficient acquisition and use of energy. This volume, Modules, Systems and Applications in Thermoelectric Devices, highlights the progress made in the field over the past several years, with a particular emphasis on the development and application of advanced materials. The book covers a wide range of topics, from the basics of thermoelectric principles to the latest research in material science and device engineering. It is a valuable resource for researchers, engineers, and students interested in the field of thermoelectric energy conversion.

Thermal Energy
Thermal Conductivity
Continuum Theory
and Modeling of Thermoelectric Materials
Organic Electronics
Chemistry, Physics, and Materials Science of Thermoelectric Materials
Introduction to Organic Electronic and Optoelectronic Materials and Devices, Second Edition
Inorganic Thermoelectric Materials
Molecular Beam Epitaxy
Thermoelectric Materials
Research Methods for the Architectural Profession
Inorganic Thin Films
X-Ray Spectroscopy with Synchrotron Radiation
Nanoscience
Editor’s Pick 2021
Multicomponent Silicides for Thermoelectric Materials
High Temperature Materials and Mechanisms
Proceedings ICT Thermoelectric Energy Conversion
Materials for Sustainable Energy
Simulation with Entropy
Thermodynamics
Naval Research Reviews
Pulsed Laser Deposition of Thin Films
Modules, Systems, and Applications in Thermoelectric Devices
Advanced PEDOT Thermoelectric Materials
Energy Saving Coating Materials
Advanced Thermoelectric Materials
for Energy Harvesting Applications
Materials Processing and Crystal Growth for Thermoelectric Devices
Advances in Nanostructured Composites
Nanoscience
Abstracts
Biopolymer Thin Films and Coatings
Functional Materials:
Electrical, Dielectric, Electromagnetic, Optical And Magnetic Applications (Second Edition)
The Thermoelectrics Handbook
Advances in Thermoelectric Materials
Recent Trends in Thermoelectric Materials Research: Part Two
Recent Trends in Thermoelectric Materials Research: Part Three
New Materials for Thermoelectric Applications: Theory and Experiment
Nanogenerators in Korea
Annual Review of Materials Science
CRC Handbook of Thermoelectrics
Nanoscience and Technology

Since its inception in 1966, the series of numbered volumes known as Semiconductors and Semimetals has distinguished itself through the careful selection of well-known authors, editors, and contributors. The Willardson and Beer series, as it is widely known, has succeeded in producing numerous landmark volumes and chapters. Not only did many of these volumes make an impact at the time of their publication, but they continue to be well-cited years after their original release. Recently, Professor Ecke R. Weber of the University of California at Berkeley joined as a co-editor of the series. Professor Weber, a well-known expert in the field of semiconductor materials, will further contribute to continuing the series' tradition of publishing timely, highly relevant, and long-lasting volumes. Some of the recent volumes, such as Hydrogen in Semiconductors, Imperfections in III/V Materials, Epitaxial Microstructures, High-Speed Heterostructure Devices, Oxygen in Silicon, and others promise that this tradition will be maintained and even expanded. Reflecting the truly interdisciplinary nature of the field that the series covers, the volumes in Semiconductors and Semimetals have been and will continue to be of great interest to physicists, chemists, materials scientists, and device engineers in modern industry.

Thermoelectric devices convert a heat flux directly into electrical power. They afford opportunities to achieve efficiency savings in a variety of applications, through the conversion of otherwise waste heat into useful electrical energy. Operated in reverse mode, they provide effective thermal management in areas ranging from cooling of electronic components to battery conditioning in electric vehicles. Implementation of thermoelectric technology requires materials with improved performance and stability, containing readily-available and inexpensive elements. A range of thermoelectric materials for use in different temperature regimes has emerged. Knowledge of the complex relationship between composition, structure and physical properties is central to understanding the performance of these advanced materials. This book provides both an introduction to the field of thermoelectrics and a survey of the state-of-the-art. Chapters review the important new families of advanced materials that have emerged and taken the field beyond traditional thermoelectric materials such as Bi2Te3, PbTe and SiGe. The emphasis is on the relationship between chemical composition, structure over a range of length scales and the physical properties that underlie performance. Edited by a leader in the field, and with contributions from global experts, Inorganic Thermoelectric Materials serves as an introduction to thermoelectric materials and is accessible to advanced undergraduates and postgraduates, as well as experienced researchers.

Composites and nanocomposites are used in cases where long durability and strength of components are required; i.e., where high stress levels, erosion processes and multiphase environments are present, including the parts under collision and impact, the parts under rotating motion and erosion (like excavation drills in oil and gas wells). The first volume of
this book aims to provide a guide for fabrication of new nanocomposites mainly based on carbon nanotubes and graphene. The main topics of this volume are: Application of Nano-powders for Formation of Metal Matrix of Composites, Conjugated Polymer Nanocomposites, Biopolymer Nanocomposites, Dental Nanocomposites, Graphene-based Nanocomposites for Electrochemical Energy Storage, Polymer/Filler Composites for Optical Diffuse Reflectors, Synthesis and Applications of LDH-Based Nanocomposites, Rubber—CNT Nanocomposites, Nanocomposite Fibers with Carbon Nanotubes, Fabrications of Graphene Based Nanocomposites for Electrochemical Sensing of Drug Molecules, Recent Advances in Graphene Metal Oxide Based Nanocomposites.

It has been almost thirty years since the publication of a book that is entirely dedicated to the theory, description, characterization and measurement of the thermal conductivity of solids. The recent discovery of new materials which possess more complex crystal structures and thus more complicated phonon scattering mechanisms have brought innovative challenges to the theory and experimental understanding of these new materials. With the development of new and novel solid materials and new measurement techniques, this book will serve as a current and extensive resource to the next generation researchers in the field of thermal conductivity. This book is a valuable resource for research groups and special topics courses (8-10 students), for 1st or 2nd year graduate level courses in Thermal Properties of Solids, special topics courses in Thermal Conductivity, Superconductors and Magnetic Materials, and to researchers in Thermoelectrics, Thermal Barrier Materials and Solid State Physics.

Synchrotron radiation has been a revolutionary and invaluable research tool for a wide range of scientists, including chemists, biologists, physicists, materials scientists, geophysicists. It has also found multidisciplinary applications with problems ranging from archeology through cultural heritage to paleontology. The subject of this book is x-ray spectroscopy using synchrotron radiation, and the target audience is both current and potential users of synchrotron facilities. The first half of the book introduces readers to the fundamentals of storage ring operations, the qualities of the synchrotron radiation produced, the x-ray optics required to transport this radiation, and the detectors used for measurements. The second half of the book describes the important spectroscopic techniques that use synchrotron x-rays, including chapters on x-ray absorption, x-ray fluorescence, resonant and non-resonant inelastic x-ray scattering, nuclear spectroscopies, and x-ray photoemission. A final chapter surveys the exciting developments of free electron laser sources, which promise a second revolution in x-ray science. Thanks to the detailed descriptions in the book, prospective users will be able to quickly begin working with these techniques. Experienced users will find useful summaries, key equations, and exhaustive references to key papers in the field, as well as outlines of the historical developments in the field. Along with plentiful illustrations, this work includes access to supplemental Mathematica notebooks, which can be used for some of the more complex calculations and as a teaching aid. This book should appeal to graduate students, postdoctoral researchers, and senior scientists alike.

This book is a printed edition of the Special Issue "Materials Processing and Crystal Growth for Thermoelectrics" that was published in Crystals.

The latest volume in the well-established AMN series, this ready reference provides an up-to-date, self-contained summary of recent developments in the technologies and systems for thermoelectricity. Following an initial chapter that introduces the fundamentals and principles of thermoelectricity, subsequent chapters discuss the synthesis and integration of various bulk thermoelectric as well as nanostuctured materials. The book then goes on to discuss characterization techniques, including various light and mechanic microscopy techniques, while also summarizing applications for thermoelectric materials, such as micro- and nano-thermoelectric generators, wearable electronics and energy conversion devices. The result is a bridge between industry and scientific researchers seeking to develop thermoelectric generators.

Thermoelectric devices could play an important role in making efficient use of our energy resources but their efficiency would need to be increased for their wide scale application. There is a multidisciplinary search for materials with an enhanced thermoelectric responses for use in such devices. This volume covers the latest ideas and developments in this research field, covering topics ranging from the fabrication and characterization of new materials, particularly those with strong electron correlation, use of nanostructured, layered materials and composites, through to theoretical work to gain a deeper understanding of thermoelectric behavior. It should be a useful guide and stimulus to all working in this very topical field.

This book covers the combined subjects of organic electronic and optoelectronic materials/devices. It is designed for classroom instruction at the senior college level. Highlighting emerging organic and polymeric optoelectronic materials and devices, it presents the fundamentals, principle mechanisms, representative examples, and key data.

This textbook provides a basic understanding of the principles of the field of organic electronics through to their applications in organic devices. Useful for the student and practitioner, it is both a teaching text and a resource that is a jumping-off point for learning, working and innovating in this rapidly growing field.

Learn more about foundational and advanced topics in polymer thin films and coatings besides species with this powerful two-volume resource The two-volume Inorganic and Organic Thin Films: Fundamentals, Fabrication, and Applications delivers a foundational resource for current researchers and commercial users involved in the design and fabrication of thin films. The book offers newcomers to the field a thorough description of new design theory, fabrication methods, and applications of advanced thin films. Readers will discover the physics and chemistry underlying the manufacture of new thin films and coatings in this leading new resource that promises to become a handbook for future applications of the technology. This one-stop reference brings together all important aspects of inorganic and polymeric thin films and coatings, including construction, assembly, deposition, functionality, patterning, and characterization. Explorations of their applications in industries as diverse as information technology, new energy, biomedical engineering, aerospace,
and oceanographic engineering round out this fulsome exploration of one of the most exciting and rapidly developing areas of scientific and industrial research today. Readers will also learn from: A comprehensive introduction to the progress of thin films and coatings as well as fundamentals in functional thin films and coatings An exploration of multi-layered magnetic thin films for electron transport control and signal sensing, including giant magnetoresistance, colossal magnetoresistance, tunneling magnetoresistance, and the quantum anomalous Hall effect An in time summary of high-quality magneto-optics, nanophotonics, spin waves and spintronics using bismuth-substituted iron garnet thin films as examples A thorough discussion of template-assisted fabrication of nanostructure thin films for ultrasensitive detection of chemicals and biomolecules A treatment of biomass derived functional films and coatings Perfect for materials scientists and inorganic chemists, Inorganic and Organic Thin Films will also earn a place in the libraries of solid state physicists and physical chemists working in private industry, as well as polymer and surface chemists who seek to improve their understanding of thin films and coatings.

Edited by major contributors to the field, this text summarizes current or newly emerging pulsed laser deposition application areas. It spans the field of optical devices, electronic materials, sensors and actuators, biomaterials, and organic polymers. Every scientist, technologist and development engineer who has a need to grow and pattern, to apply and use thin film materials will regard this book as a must-have resource.

Energy Saving Coating Materials: Design, Process, Implementation and Developments provides comprehensive information regarding recent materials advancements and design aspects and integration for infra-red radiation regulators, along with future developments of zero emission buildings. The key opportunities and challenges for the usage of existing heat regulation materials and their implementation for commercial aspects are explored. The fundamental interaction between electromagnetic waves and materials are discussed, along with materials synthesis, design and integration of coatings for smart window applications. This book presents recent developments of innovative technologies comprising energy saving materials and coatings which are key considerations for achieving vital energy saving milestones. Provides knowledge-based information on the optical properties of materials and their utility for solar energy harvesting and energy saving applications Discusses innovative coatings for smart windows applications, including the progressive development of radiative cooling and cool paint Previews future developments for the synthesis, design and integration of heat regulative materials

Since its inception in 1966, the series of numbered volumes known as Semiconductors and Semimetals has distinguished itself through the careful selection of well-known authors, editors, and contributors. The Willardson and Beer series, as it is widely known, has succeeded in producing numerous landmark volumes and chapters. Not only did many of these volumes make an impact at the time of their publication, but they continue to be well-cited years after their original release. Recently, Professor Eicke R. Weber of the University of California at Berkeley joined as a co-editor of the series. Professor Weber, a well-known expert in the field of semiconductor materials, will further contribute to continuing the series' tradition of publishing timely, highly relevant, and long-impacting volumes. Some of the recent volumes, such as Hydrogen in Semiconductors, Imperfections in III/V Materials, Epitaxial Microstructures, High-Speed Heterostructure Devices, Oxygen in Silicon, and others promise that this tradition will be maintained and even expanded. Thermoelectric materials may be used for solid state refrigeration or power generation applications via the large Peltier effect in these materials. To be an effective thermoelectric material, a material must possess a large Seebeck coefficient, a low resistivity and a low thermal conductivity. Due to increased need for alternative energy sources providing environmentally friendly refrigeration and power generation, thermoelectric materials research experienced a rebirth in the mid 1990's. Semiconductors and Semimetals, Volume 70: Recent Trends in Thermoelectric Materials Research: Part Two provides an overview of much of this research in thermoelectric materials during the decade of the 1990's. New materials and new material concepts such as quantum well and superlattice structures gave hope to the possibilities that might be achieved. An effort was made to focus on these new materials and not on materials such as BiTe alloys, since such recent reviews are available. Experts in the field who were active researchers during this period were the primary authors to this series of review articles. This is the most complete collection of review articles that are primarily focused on new materials and new concepts that is existence to date.

PEDOT is currently the most widely used polymeric material in research and development. Over the past 10 years, PEDOT has been investigated for potential organic thermoelectric applications because of its superior thermoelectric and mechanical properties compared with other conductive polymers. However, many challenges remain to be solved before it is translated into key technologies. Advanced PEDOT Thermoelectric Materials summarizes current progress and the challenges of PEDOT thermoelectric materials, while clarifying directions for future development. This book provides a comprehensive overview of chemical, physical, and technical information about this organic thermoelectric polymer. The authors also give details about the theoretical basis of PEDOT, including preparation and characterization, and its development as a high-performance thermoelectric material. Provides an overview of techniques to optimize the thermoelectric performance of PEDOT materials. Introduces the fundamentals of PEDOT, including material synthesis, characterization, preparation, thermal transport, and more. Discusses emerging applications in thermoelectric devices and future directions.

The search for cleaner, cheaper, smaller and more efficient energy technologies has to a large extent been motivated by the development of new materials. The aim of this collection of articles is therefore to focus on what materials-based solutions can offer and show how the rationale design and improvement of their physical and chemical properties can lead to energy-production alternatives that have the potential to compete with existing technologies. In terms of alternative means to generate electricity that utilize renewable energy sources, the most dramatic breakthroughs for both mobile (i.e., transportation) and stationary applications are taking place in the fields of solar and fuel cells. And from an energy-storage perspective, exciting developments can be seen emerging from the fields of rechargeable batteries and hydrogen storage.

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Ten years ago, D.M. Rowe introduced the bestselling CRC Handbook of Thermoelectrics to wide acclaim. Since then, increasing environmental concerns, desire for long-life electrical power sources, and continued progress in miniaturization of electronics has led to a substantial increase in research activity involving thermoelectrics. Reflecting the latest trends and developments, the Thermoelectrics Handbook: Macro to Nano is an extension of the earlier work and covers the entire range of thermoelectrics disciplines. Serving as a convenient reference as well as a thorough introduction to thermoelectrics, this book includes contributions from 99 leading authorities from around the world. Its coverage spans from general principles and theoretical concepts to material preparation and measurements; thermoelectric materials; thermoelements, modules, and devices; and thermoelectric systems and applications. Reflecting the enormous impact of nanotechnology on the field-as the thermoelectric properties of nanostructured materials far surpass the performance of conventional materials-each section progresses systematically from macro-scale to micro/nano-scale topics. In addition, the book contains an appendix listing major manufacturers and suppliers of thermoelectric modules. There is no longer any need to spend hours plodding through the journal literature for information. The Thermoelectrics Handbook: Macro to Nano offers a timely, comprehensive treatment of all areas of thermoelectrics in a single, unified reference.

Research Methods for the Architectural Profession introduces research as a systematic process, describes how to formulate research questions, provides an in-depth explanation of different research methods (qualitative, quantitative, and experimental), and explains how to select appropriate research methods and execute research studies. It describes the process of documentation, knowledge dissemination, and application of research results in architectural design and practice. Most importantly, it provides guidelines for integrating research into profession and uses extensive case-studies and practice-relevant examples to illustrate main concepts, procedures, and applications. Integrating research into practice is essential for developing new knowledge, solving design and technical problems, overcoming different types of challenges present in the contemporary profession, and improving the design outcomes. Innovation requires a much stronger correlation between research and design, and it is pertinent for the future of architectural practice that research becomes an integral part of architectural process. This book provides a roadmap for successfully integrating research into architectural design and for establishing innovative practices, regardless of a firm's size. Written by an architecture professor with an extensive research and professional background—specifically focusing on integrating research into practice—and richly illustrated with over 150 color images, this reference will be useful for both students and practitioners.

In science as well as industry, the impetus of research on bio-based polymers has recently expanded into new terrains. The need to replace fossil-based materials with sustainable and renewable sources is one of the main drivers for the emergence and the development of new and environmentally friendly materials. While some materials applications of bio-based polymers are already very well established, for instance, in paper and textiles, others have just emerged with thin films and coatings being a recent and particular area of interest. Thin films in general are an enormous field of research both fundamentally and from an applied perspective, with uses ranging from corrosion resistance to photovoltaics and sensors. Since bio-based materials are a relatively novel source material for thin films, the research in this area is at a fresh, exciting stage at the moment.

The use of high-temperature materials in current and future applications, including silicone materials for handling hot foods and metal alloys for developing high-speed aircraft and spacecraft systems, has generated a growing interest in high-temperature technologies. High Temperature Materials and Mechanisms explores a broad range of issues relate Thermoelectrics is the science and technology associated with thermoelectric converters, that is, the generation of electrical power by the Seebeck effect and refrigeration by the Peltier effect. Thermoelectric generators are being used in increasing numbers to provide electrical power in medical, military, and deep space applications where combinations of their desirable properties outweigh their relatively high cost and low generating efficiency. In recent years there also has been an increase in the requirement for thermoelectric coolers (Peltier devices) for use in infrared detectors and in optical communications. Information on thermoelectrics is not readily available as it is widely scattered throughout the literature. The Handbook centralizes this information in a convenient format under a single cover. Sixty of the world’s foremost authorities on thermoelectrics have contributed to this Handbook. It is comprised of fifty-five chapters, a number of which contain previously unpublished material. The contents are arranged in eight sections: general principles and theoretical considerations, material preparation, measurement of thermoelectric properties, thermoelectric materials, thermoelectric generation, generator applications, thermoelectric refrigeration, and applications of thermoelectric cooling. The CRC Handbook of Thermoelectrics has a broad-based scope. It will interest researchers, technologists, and manufacturers, as well as students and the well-informed, non-specialist reader.
Beyond its identification with the second law of thermodynamics, entropy is a formidable tool for describing systems in their relationship with their environment. This book proposes to go through some of these situations where the formulation of entropy, and more precisely, the production of entropy in out-of-equilibrium processes, makes it possible to forge an approach to the behavior of very different systems. Whether for dimensioning structures; influencing parameter variability; or optimizing power, efficiency, or waste heat reduction, simulations based on entropy production offer a tool that is both compact and reliable. In the case of systems marked by complexity, it appears to be the only way. In that sense, realistic optimization can be carried out, integrating within the same framework both the system and all the constraints and boundary conditions that define it. Simulations based on entropy give the researcher a powerful analytical framework that crosses the disciplines of physics and links them together.

This volume: Chemistry, Physics and Materials Science of Thermoelectric Materials: Beyond Bismuth Telluride contains a series of topical articles that were presented as invited lectures by prominent leaders in this field at a workshop held in Traverse City, Michigan in the summer of 2002. These articles place the state of the art, regarding design principles, candidate materials and systems and current advances in context and should serve as a useful source of insights into this field for both beginning students and practitioners alike.

Advanced Thermoelectric Materials for Energy Harvesting Applications is a research-intensive textbook covering the fundamentals of thermoelctricity and the process of converting heat energy into electrical energy. It covers the design, implementation, and performance of existing and advanced thermoelectric materials. Chapters examine such topics as organic/inorganic thermoelectric materials, performance and behaviors of thermoelectric devices, and energy harvesting applications of thermoelectric devices.

The book details sources of thermal energy, methods of capture, and applications. It describes the basics of thermal energy, including measuring thermal energy, laws of thermodynamics that govern its use and transformation, modes of thermal energy, conventional processes, devices and materials, and the methods by which it is transferred. It covers 8 sources of thermal energy: combustion, fusion (solar) fission (nuclear), geothermal, microwave, plasma, waste heat, and thermal energy storage. In each case, the methods of production and capture and its uses are described in detail. It also discusses novel processes and devices used to improve transfer and transformation processes.

The field of functional materials has grown tremendously over the last 5-10 years, due to its richness in both science and applications. This timely compendium covers the science and applications of functional materials in a comprehensive manner that is suitable for readers who do not have background on the electrical, dielectric, electromagnetic, optical and magnetic properties of materials. Prior knowledge of quantum mechanics or solid state physics is also not required. Only a semester of introductory materials science suffices. This unique reference text is tutorial in style and includes numerous example problems, which are lacking in several competing books in the market. The must-have volume benefits undergraduate and graduate students in materials science, mechanical engineering, electrical engineering and aerospace engineering.

This volume presents the latest research results in the thermodynamics and design of thermoelectric devices, providing a solid foundation for thermoelectric element and module design in the technical development process, and a valuable tool for any application development.

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Fossil fuels led the 21st century industrial revolution but caused some critical problems such as exhaustion of resources and global warming. Also, current power plants require too much high cost and long time for establishment and facilities to provide electricity. Thus, developing new power production systems with environmental friendliness and low-cost is critical global needs. There are some emerging energy harvesting technologies such as thermoelectric, piezoelectric, and triboelectric nanogenerators, which have great advantages on eco-friendly low-cost materials, simple fabrication, and various operating sources. Since the introduction of various energy harvesting technologies, many novel designs and applications as power suppliers and physical sensors in the world have been demonstrated based on their unique advantages. In this Special Issue, we would like to address and share basic approaches, new designs, and industrial applications related to thermoelectric, piezoelectric, and triboelectric devices which are on-going in Korea. With this Special Issue, we aim to promote fundamental understanding and to find novel ways to achieve industrial product manufacturing for energy harvesters.

This book provides a comprehensive review of the current state of the art in silicon compounds for thermoelectric applications. Silicides are materials with good initial thermoelectric properties, which can be enhanced through tuning of their micro- and macrostructure. These compounds present various conduction mechanisms and complex band structures. Moreover, some are isotropic, and others anisotropic, which is highly beneficial for device tailoring. Silicides are a particularly attractive material for sensors, thermoelectric generators, and other applications because they are environmentally friendly, abundant, and low cost. This concise volume covers fundamentals and applications for an audience of
materials scientists, chemists, solid-state physicists, and engineers.

How can you design good thermoelectric materials? This book covers thermoelectric material concepts and synthesis techniques in particular focusing methods for enhancing current materials designs to achieve the greatest thermoelectric efficiencies. This book is ideal for researchers and advanced students of materials science, physics, and energy.

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