

Acoustic Metamaterials And Phononic Crystals Preamble

This book is the first of 2 special volumes dedicated to the memory of Gérard Maugin. Including 40 papers that reflect his vast field of scientific activity, the contributions discuss non-standard methods (generalized model) to demonstrate the wide range of subjects that were covered by this exceptional scientific leader. The topics range from micromechanical basics to engineering applications, focusing on new models and applications of well-known models to new problems. They include micro–macro aspects, computational endeavors, options for identifying constitutive equations, and old problems with incorrect or non-satisfying solutions based on the classical continua assumptions. The new concept of metamaterial is increasingly attracting the interest of physicists and mechanical engineers. Such materials are obtained by suitably assembling multiple individual elements but usually arranged in (quasi-)periodic substructures in order to show exotic global mechanical properties. Indeed, the particular shape, geometry, size, orientation and arrangement of their constituting elements can affect, the propagation of waves of light or sound in a manner not observed in natural materials, creating material properties which may give rise to unexpected engineering applications. Particularly

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promising in the design and description of metamaterials are those micro-structures which present high contrasts in their mechanical properties: these micro-structures, once homogenized, may produce generalized continuum media, for example, second gradient or micromorphic. Many scientific challenges related to the application of generalized continuum theories to the characterization and conception of high-performance metamaterials can be identified. In this book we identify and discuss four main potential fields of applications of generalized continuum theories, namely, mechanical behavior of fibrous composite reinforcements, wave propagation in metamaterials, mechanical behavior of concrete and mechanically driven remodeling of bone in presence of bio-resorbable materials. For each field, we underline how the use of a generalized continuum theory can be of help for describing how the presence of microstructure can affect the global mechanical behavior of the considered metamaterials. Covers four main fields of the application of continuum theories Learn how to apply generalised continuum theory to describe the effects of microstructure on the mechanical behavior of materials Decipher the material properties which aid your engineering applications This book presents a selection of cutting-edge methods that allow readers to obtain novel models for nonlinear solid mechanics. Today, engineers

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need more accurate techniques for modeling solid body mechanics, chiefly due to innovative methods like additive manufacturing—for example, 3D printing—but also due to miniaturization. This book focuses on the formulation of continuum and discrete models for complex materials and systems, and especially the design of metamaterials. It gathers outstanding papers from the international conference IcONSOM 2019

Phononic crystals and acoustic metamaterials are heterogeneous materials that enable manipulation of elastic waves. An important characteristic of these heterogeneous systems is their ability to tailor the propagation of elastic waves due to the existence of band gaps -- frequency ranges of strong wave attenuation. In this Thesis, I report discoveries of three new types of band gaps: i) Band gaps induced by geometric frustration in periodic acoustic channel networks; ii) Band gap induced by high connectivity in periodic beam lattices; and iii) Topological band gaps in gyroscopic phononic crystals that protects one-way edge waves. The investigations presented here shed new light on the rich dynamic properties of phononic crystals and acoustic metamaterials, opening avenues for new strategies to control mechanical waves in elastic systems.

Multi-scale Theory and Computation, Volume 52, the latest release in the Advances in Applied Mechanics series, draws together recent, significant advances

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in various topics in applied mechanics. Published since 1948, the book aims to provide authoritative review articles on topics in the mechanical sciences. While the book is ideal for scientists and engineers working in various branches of mechanics, it is also beneficial to professionals who use the results of investigations in mechanics in various applications, such as aerospace, chemical, civil, environmental, mechanical and nuclear engineering. Includes contributions from world-leading experts that are acquired by invitation only Beneficial to scientists, engineers and professionals who use the results of investigations in mechanics in various applications, such as aerospace, chemical, civil, environmental, mechanical and nuclear engineering Covers not only traditional topics, but also important emerging fields This book provides an in-depth analysis as well as an overview of phononic crystals. This book discusses numerous techniques for the analysis of phononic crystals and covers, among other material, sonic and ultrasonic structures, hypersonic planar structures and their characterization, and novel applications of phononic crystals. This is an ideal book for those working with micro and nanotechnology, MEMS (microelectromechanical systems), and acoustic devices. This book also: Presents an introduction to the fundamentals and properties of phononic crystals Covers simulation techniques for the analysis of phononic crystals

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Discusses sonic and ultrasonic, hypersonic and planar, and three-dimensional phononic crystal structures Illustrates how phononic crystal structures are being deployed in communication systems and sensing systems

In the last few decades, metamaterials have revolutionized the ways in which waves are controlled, and applied in physics and practical situations. The extraordinary properties of metamaterials, such as their locally resonant structure with deep subwavelength band gaps and their ranges of frequency where propagation is impossible, have opened the way to a host of applications that were previously unavailable.

Acoustic metamaterials have been able to replace traditional treatments in several sectors, due to their better performance in targeted and tunable frequency ranges with strongly reduced dimensions.

This is a training book composed of nine chapters written by experts in the field, giving a broad overview of acoustic metamaterials and their uses.

The book is divided into three parts, covering the state-of-the-art, the fundamentals and the real-life applications of acoustic metamaterials.

Acoustic metamaterials are of growing interest due to their ability to manipulate the propagation of acoustic waves in an extraordinary manner to benefit various applications, such as communications, biosensing, and medical diagnosis and therapy.

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Among various construction methods of acoustic metamaterials, artificially engineered elastic periodic structures, known as phononic crystals (PCs), are the strongest candidates since they exhibit complete phononic band gaps and negative refractions due to the periodicity of the structure. In this book, a new class of acoustic metamaterials-gradient-index phononic crystal (GRIN PC)-is introduced to overcome the limitations of regular PCs and further enrich the control over acoustic waves. GRIN PCs with different gradient profiles are designed to guide acoustic waves in extraordinary manners that are not shown in nature or regular PCs. A practical method for tuning the phononic band gaps of a PC is investigated. The concepts presented in this book serve as important foundations for the future development of acoustic devices.

Photonic band gap crystals offer unique ways to tailor light and the propagation of electromagnetic waves. In analogy to electrons in a crystal, EM waves propagating in a structure with a periodically-modulated dielectric constant are organized into photonic bands separated by gaps in which propagating states are forbidden. Proposed applications of such photonic band gap crystals, operating at frequencies from microwave to optical, include zero- threshold lasers, low-loss resonators and cavities, and efficient microwave antennas. Spontaneous emission is suppressed for photons in

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the photonic band gap, offering novel approaches to manipulating the EM field and creating high-efficiency light-emitting structures. Photonic Band Gap Materials identifies three most promising areas of research. The first is materials fabrication, involving the creation of high quality, low loss, periodic dielectric structures. The smallest photonic crystals yet fabricated have been made by machining Si wafers along (110), and some have lattice constants as small as 500 microns. The second area is in applications. Possible applications presented are microwave mirrors, directional antennas, resonators (especially in the 2 GHz region), filters, waveguides, Y splitters, and resonant microcavities. The third area covers fundamentally new physical phenomena in condensed matter physics and quantum optics. An excellent review of recent development, covering theoretical, experimental and applied aspects. Interesting and stimulating reading for active researchers, as well as a useful reference for non-specialists.

Phononics: Interface Transmission Tutorial Book Series provides an investigation of modern systems that includes a discrete matrix description. Classical continuous systems relying on the use of differential equations are recalled, showing that they generally have a specific limit on their corresponding modern matrix formulation. A detailed description of the mathematical languages that enables readers to find

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the composite system linear transmission properties is provided in the appendix. The physical model is described with exacting detail, and the bibliography is built to cite—in chronological order—all the scientists that have contributed over many years. Each volume is written with the aim of providing an up-to-date and concise summary of the present knowledge of interface transmission science, thus fostering the exchange of ideas among scientists interested in different aspects of interface transmission. The book serves as an introduction to advanced graduate students, researchers, and scientists with little study on the subject, and is also useful to help keep specialists informed on general progress in the field. Offers a unique approach on phononics from the interfacial transmission point-of-view Teaches the modern physics of interface transmission, in particular, phononics through composite systems Authored and edited by world-leading experts on interface transmission

This book highlights the acoustical metamaterials' capability to manipulate the direction of sound propagation in solids which in turn control the scattering, diffraction and refraction, the three basic mechanisms of sound propagation in solids. This gives rise to several novel theories and applications and hence the name new acoustics. As an introduction, the book mentions that symmetry of acoustic fields is the theoretical framework of

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acoustical metamaterials. This is then followed by describing that acoustical metamaterials began with locally resonant sonic materials which ushered in the concept of negative acoustic parameters such as mass density and bulk modulus. This complies with form invariance of the acoustic equation of motion which again exemplifies the symmetry property of acoustic fields.

Deals not only with the properties of the radiation modes inside the crystals but also with their peculiar optical response to external fields. A general theory of linear and nonlinear optical response is presented in a clear and detailed fashion using the Green's function method. Important recent developments such as the enhancement of stimulated emission, second harmonic generation, quadrature-phase squeezing, and low-threshold lasing are likewise treated in detail and made understandable.

Numerical methods are also emphasised. This book provides both introductory knowledge for graduate and undergraduate students and important ideas for researchers.

Advances in Energy Harvesting Methods presents a state-of-the-art understanding of diverse aspects of energy harvesting with a focus on: broadband energy conversion, new concepts in electronic circuits, and novel materials. This book covers recent advances in energy harvesting using different transduction mechanisms; these include methods of

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performance enhancement using nonlinear effects, non-harmonic forms of excitation and non-resonant energy harvesting, fluidic energy harvesting, and advances in both low-power electronics as well as material science. The contributors include a brief literature review of prior research with each chapter for further reference.

Phononic crystals are artificial periodic structures that can alter efficiently the flow of sound, acoustic waves, or elastic waves. They were introduced about twenty years ago and have gained increasing interest since then, both because of their amazing physical properties and because of their potential applications. The topic of phononic crystals stands as the cross-road of physics (condensed matter physics, wave propagation in inhomogeneous and periodic media) and engineering (acoustics, ultrasonics, mechanical engineering, electrical engineering). Phononic crystals cover a wide range of scales, from meter-size periodic structures for sound in air to nanometer-size structures for information processing or thermal phonon control in integrated circuits. Phononic crystals have a definite relation with the topic of photonic crystals in optics. The marriage of phononic and photonic crystals also provides a promising structural basis for enhanced sound and light interaction. As the topic is getting popular, it is nowadays presented and discussed at various international conferences. After the first ten

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years during which the topic has remained mainly theoretical with a few proof-of-concept demonstrations in the literature, the evolution has been towards applications, instrumentation, and novel designs. The physical explanations for various effects are now well understood and efficient numerical methods and analysis tools have been developed. The book contains a comprehensive set of finite element model (FEM) scripts for solving basic phononic crystal problems. The scripts are short, easy to read, and efficient, allowing the reader to generate for him(her)self band structures for 2D and 3D phononic crystals, to compute Bloch waves, waveguide and cavity modes, and more.

Acoustic Metamaterials and Phononic Crystals
Springer Science & Business Media

This book presents the current knowledge about nonlinear localized travelling excitations in crystals. Excitations can be vibrational, electronic, magnetic or of many other types, in many different types of crystals, as silicates, semiconductors and metals. The book is dedicated to the British scientist FM Russell, recently turned 80. He found 50 years ago that a mineral mica muscovite was able to record elementary charged particles and much later that also some kind of localized excitations, he called them quodons, was also recorded. The tracks, therefore, provide a striking experimental evidence of quodons existence. The first chapter by him

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presents the state of knowledge in this topic. It is followed by about 18 chapters from world leaders in the field, reviewing different aspects, materials and methods including experiments, molecular dynamics and theory and also presenting the latest results. The last part includes a personal narration of FM Russell of the deciphering of the marks in mica. It provides a unique way to present the science in an accessible way and also illustrates the process of discovery in a scientist's mind.

About the book: This book is the first comprehensive review on acoustic metamaterials; novel materials which can manipulate sound waves in surprising ways, which include collimation, focusing, cloaking, sonic screening and extraordinary transmission. It covers both experimental and theoretical aspects of acoustic and elastic waves propagating in structured composites, with a focus on effective properties associated with negative refraction, lensing and cloaking. Most related books in the field address electromagnetic metamaterials and focus on numerical methods, and little (or no) experimental section. Each chapter will be authored by an acknowledged expert, amongst the topics covered will be experimental results on non-destructive imaging, cloaking by surface water waves, flexural waves in thin plates. Applications in medical ultrasound imaging and modeling of metamaterials will be emphasized too. The book can serve as a reference for researchers who wish to build a solid foundation of wave propagation in this class of novel materials.

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Absorbers and diffusers are two of the main design tools for altering the acoustic conditions of rooms, semi-enclosed spaces and the outdoor environment. Their correct use is important for delivering high quality acoustics. Unique and authoritative, this book describes how to effectively measure, model, design and apply diffusers and absorbers. It is a resource for new and experienced acousticians, seeking an understanding of the evolution, characteristics and application of modern diffusers. Absorption is a more established technology and so the book blends traditional designs with modern developments. The book covers practical and theoretical aspects of absorbers and diffusers and is well illustrated with examples of installations and case studies. This new edition brings Acoustic Absorbers and Diffusers up-to-date with current research, practice and standards. New developments in measurement, materials, theory and practice since the first edition (published in 2004) are included. The sections on absorbers are extended to include more about noise control.

This thesis proposes novel designs of phononic crystal plates (PhPs) allowing ultra-wide controllability frequency ranges of guided waves at low frequencies, with promising structural and tunability characteristics. It reports on topology optimization of bi-material-layered (1D) PhPs allowing maximized relative bandgap width (RBW) at target filling fractions and demonstrates multiscale functionality of gradient PhPs. It also introduces a multi-objective topology optimization method for 2D porous PhPs allowing both maximized RBW and in-plane stiffness and addresses the critical

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role of considering stiffness in designing porous PhPs. The multi-objective topology optimization method is then expanded for designing 2D porous PhPs with deformation induced tunability. A variety of innovative designs are introduced which their maximized broadband RBW is enhanced by, is degraded by or is insensitive to external finite deformation. Not only does this book address the challenges of new topology optimization methods for computational design of phononic crystals; yet, it demonstrated the suitability and applicability of the topological designs by experimental validation.

Furthermore, it offers a comprehensive review of the existing optimization-based approaches for the design of finite non-periodic acoustic metamaterial structures, acoustic metamaterial lattice structures and acoustic metamaterials under perfect periodicity.

Transformation electromagnetics is a systematic design technique for optical and electromagnetic devices that enables novel wave-material interaction properties. The associated metamaterials technology for designing and realizing optical and electromagnetic devices can control the behavior of light and electromagnetic waves in ways that have not been conventionally possible. The technique is credited with numerous novel device designs, most notably the invisibility cloaks, perfect lenses and a host of other remarkable devices.

Transformation Electromagnetics and Metamaterials: Fundamental Principles and Applications presents a comprehensive treatment of the rapidly growing area of transformation electromagnetics and related metamaterial technology with contributions on the

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subject provided by a collection of leading experts from around the world. On the theoretical side, the following questions will be addressed: “Where does transformation electromagnetics come from?,” “What are the general material properties for different classes of coordinate transformations?,” “What are the limitations and challenges of device realizations?,” and “What theoretical tools are available to make the coordinate transformation-based designs more amenable to fabrication using currently available techniques?” The comprehensive theoretical treatment will be complemented by device designs and/or realizations in various frequency regimes and applications including acoustic, radio frequency, terahertz, infrared, and the visible spectrum. The applications encompass invisibility cloaks, gradient-index lenses in the microwave and optical regimes, negative-index superlenses for sub-wavelength resolution focusing, flat lenses that produce highly collimated beams from an embedded antenna or optical source, beam concentrators, polarization rotators and splitters, perfect electromagnetic absorbers, and many others. This book will serve as the authoritative reference for students and researchers alike to the fast-evolving and exciting research area of transformation electromagnetics/optics, its application to the design of revolutionary new devices, and their associated metamaterial realizations.

Metamaterials represent a new emerging innovative field of research which has shown rapid acceleration over the last couple of years. In this handbook, we present the

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richness of the field of metamaterials in its widest sense, describing artificial media with sub-wavelength structure for control over wave propagation in four volumes.

Volume 1 focuses on the fundamentals of electromagnetic metamaterials in all their richness, including metasurfaces and hyperbolic metamaterials.

Volume 2 widens the picture to include elastic, acoustic, and seismic systems, whereas Volume 3 presents

nonlinear and active photonic metamaterials. Finally,

Volume 4 includes recent progress in the field of nanoplasmonics, used extensively for the tailoring of the unit cell response of photonic metamaterials. In its

totality, we hope that this handbook will be useful for a wide spectrum of readers, from students to active

researchers in industry, as well as teachers of advanced courses on wave propagation. Contents: Volume 1:

Electromagnetic Metamaterials (Ekaterina Shamonina):

Preface
Electromagnetic Metamaterials: Homogenization and Effective Properties of Mixtures (Ari

Sihvola)
Effective Medium Theory of Electromagnetic and

Quantum Metamaterials (Mário G Silveirinha)
Hyperbolic

Metamaterials (Igor I Smolyaninov)
Circuit and Analytical

Modelling of Extraordinary Transmission Metamaterials

(Francisco Medina, Francisco Mesa, Raul Rodríguez-

Berral and Carlos Molero)
Electromagnetic Metasurfaces:

Synthesis, Realizations and Discussions (Karim Achouri

and Christophe Caloz)
Metasurfaces for General Control

of Reflection and Transmission (Sergei Tretyakov, Viktor

Asadchy and Ana Díaz-Rubio)
Scattering at the Extreme

with Metamaterials and Plasmonics (Francesco

Monticone and Andrea Alù)
All-Dielectric Nanophotonics:

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Fundamentals, Fabrication, and Applications (Alexander Krasnok, Roman Savelev, Denis Baranov and Pavel Belov) Tunable Metamaterials (Ilya V Shadrivov and Dragomir N Neshev) Spatial Solitonic and Nonlinear Plasmonic Aspects of Metamaterials (Allan D Boardman, Alesandro Alberucci, Gaetano Assanto, Yu G Rapoport, Vladimir V Grimalsky, Vasyi M Ivchenko and Eugen N Tkachenko) Metamaterial Catheter Receivers for Internal Magnetic Resonance Imaging (Richard R A Syms, Ian R Young and Laszlo Solymar) Microwave Sensors Based on Symmetry Properties and Metamaterial Concepts (Jordi Naqui, Ali K Horestani, Christophe Fumeaux and Ferran Martín) Volume 2: Elastic, Acoustic, and Seismic Metamaterials (Richard Craster and Sébastien Guenneau): Preface Dynamic Homogenization of Acoustic and Elastic Metamaterials and Phononic Crystals (Richard Craster, Tryfon Antonakakis and Sébastien Guenneau) Acoustic Metamaterial (Nicholas Fang, Jun Xu, Navid Nemati, Nicolas Viard and Denis Lafarge) Flat Lens Focusing of Flexural Waves in Thin Plates (Patrick Sebbah and Marc Dubois) Space–Time Cloaking (Martin W McCall and Paul Kinsler) Soda Cans Metamaterial: Homogenization and Beyond (Fabrice Lemoult, Geoffroy Lerosey, Nadège Kaïna and Mathias Fink) New Trends Toward Locally-Resonant Metamaterials at the Mesoscopic Scale (Philippe Roux, Matthieu Rupin, Fabrice Lemoult, Geoffroy Lerosey, Andrea Colombi, Richard Craster, Sébastien Guenneau, William A Kuperman and Earl G Williams) Seismic Metamaterials: Controlling Surface Rayleigh Waves Using Analogies with Electromagnetic Metamaterials

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(Stéphane Brûlé, Stefan Enoch, Sébastien Guenneau and

This volume includes a comprehensive theoretical treatment and current state-of-the art applications of the quartz crystal microbalance (QCM). It discusses interface circuits and the study of viscoelasticity and micromechanics as well as surface roughness with the QCM. Coverage also details the broad field of analytical applications of piezoelectric sensors.

Since structure-borne sound plays an important role in noise control, material testing and machine diagnosis, the relevant properties of the most important elements of a construction (plates, beams and shells) are investigated. Measurement techniques, equations of motion, formulas for wave speeds, resonance frequencies, impedances, transmission coefficients etc. are given. The different damping mechanisms and the radiation properties are treated. The statistical energy analysis (SEA) is also presented. This new edition has been enlarged to include also waves on orthotropic plates, and the vibration and radiation of cylindrical shells.

This book offers an essential introduction to the notions of sound wave topology, duality, coherence and wave-mixing, which constitute the emerging new science of sound. It includes general principles and specific examples that illuminate new non-conventional forms of sound (sound topology), unconventional quantum-like behavior of phonons (duality), radical linear and nonlinear phenomena associated with loss and its control (coherence), and exquisite effects that emerge

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from the interaction of sound with other physical and biological waves (wave mixing). The book provides the reader with the foundations needed to master these complex notions through simple yet meaningful examples. General principles for unraveling and describing the topology of acoustic wave functions in the space of their Eigen values are presented. These principles are then applied to uncover intrinsic and extrinsic approaches to achieving non-conventional topologies by breaking the time reversal symmetry of acoustic waves. Symmetry breaking can impart topological immunity to wave degradation from imperfection scattering and catalyze controlled coherence. In the intrinsic case and the phonon representation of acoustic waves, the self-interaction/interference of a wave through its supporting medium exposes the notion of duality in the quantum statistics (i.e. boson vs. fermion characterized by the symmetry of multiple particle states) and how the quantum analogue behaviors of sound can be exploited in the form of novel sound-based information transfer and processing devices. By considering media that mix different types of waves, the book addresses the interaction of sound with other physical and biological waves but also brings to light examples of extrinsic processes that can lead to symmetry breaking. The coherent conversion of sound into other types of waves as well as the sound-induced non-conventional topology of elastic, electronic, spin and biological waves are presented in the case of media exhibiting elasto-electronic, photo-elastic, magneto-elastic effects and

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biological mechano-transduction.

Magnonics: Interface Transmission Tutorial Book Series provides up-to-date and concise summaries of the present knowledge of interface transmission science.

The series' volumes foster the exchange of ideas among scientists interested in different aspects of interface transmission, with each release designed as a text, a reference, and a source. The series serves as an introduction to advanced graduate students, researchers and scientists with little acquaintance with the subject, and is also useful in keeping specialists informed about general progress in the field. A detailed description of mathematical languages is provided in an appendix, enabling readers to find composite system linear transmission properties. All scientists who contribute to these volume have worked in interface transmission in composite systems over many years, providing a thorough and comprehensive understanding of magnonics. Offers a unique approach to magnonics from an interfacial transmission point-of-view Teaches the modern physics of interface transmission, and in particular, magnonics through composite systems Authored and edited by world-leading experts on Interface Transmission

This comprehensive book presents all aspects of acoustic metamaterials and phononic crystals. The emphasis is on acoustic wave propagation phenomena at interfaces such as refraction, especially unusual refractive properties and negative refraction. A thorough discussion of the mechanisms leading to such refractive phenomena includes local resonances in metamaterials

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and scattering in phononic crystals.

Leading experts explore the exotic properties and exciting applications of electromagnetic metamaterials. *Metamaterials: Physics and Engineering Explorations* gives readers a clearly written, richly illustrated introduction to the most recent research developments in the area of electromagnetic metamaterials. It explores the fundamental physics, the designs, and the engineering aspects, and points to a myriad of exciting potential applications. The editors, acknowledged leaders in the field of metamaterials, have invited a group of leading researchers to present both their own findings and the full array of state-of-the-art applications for antennas, waveguides, devices, and components. Following a brief overview of the history of artificial materials, the publication divides its coverage into two major classes of metamaterials. The first half of the publication examines effective media with single (SNG) and double negative (DNG) properties; the second half examines electromagnetic band gap (EBG) structures. The book further divides each of these classes into their three-dimensional (3D volumetric) and two-dimensional (2D planar or surface) realizations. Examples of each type of metamaterial are presented, and their known and anticipated properties are reviewed. Collectively, *Metamaterials: Physics and Engineering Explorations* presents a review of recent research advances associated with a highly diverse set of electromagnetic metamaterials. Its multifaceted approach offers readers a combination of theoretical, numerical, and experimental perspectives for a better understanding

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of their behaviors and their potential applications in components, devices, and systems. Extensive reference lists provide opportunities to explore individual topics and classes of metamaterials in greater depth. With full-color illustrations throughout to clarify concepts and help visualize actual results, this book provides a dynamic, user-friendly resource for students, engineers, physicists, and other researchers in the areas of electromagnetic materials, microwaves, millimeter waves, and optics. It equips newcomers with a basic understanding of metamaterials and their potential applications. Advanced researchers will benefit from thought-provoking perspectives that will deepen their knowledge and lead them to new areas of investigation.

Graduate-level text assembles and interprets contributions to field of composite materials for a comprehensive account of mechanical behavior of heterogeneous media. Subjects include macroscopic stiffness properties and failure characterization. 1979 edition.

This book provides a comprehensive and thorough treatment on fundamentals and applications of light propagation through inhomogeneous media. The authors present a description of the phenomena, components and technology used in GRIN Optics, and analyze various applications.

This volume, available for the first time in paperback, is a standard work on the physical aspects of acoustics. Starting from first principles, the authors have successfully produced a unified and thorough treatment

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of the subjects of generation, propagation, absorption, reflection, and scattering of compressional waves in fluids, progressing to such topics as moving sound sources, turbulence, and wave-induced vibration of structures. Material is included on viscous and thermal effects, on the acoustics of moving media, on plasma acoustics, on nonlinear effects, and on the interaction between light and sound. Problems, with answers in many cases, are given at the end of each chapter. They contain extensions to further applications, thus enhancing the reference value of the book. Many of the examples worked out in the text and in the problem solutions were not previously published. Anyone familiar with calculus and vector analysis should be able to understand the mathematical techniques used here. This book deals with the subject of optical and electronic negative refraction (NR) and negative index materials (NIM). Diverse approaches for achieving NR and NIM are covered, such as using photonic crystals, phononic crystals, split-ring resonators (SRRs) and continuous media, focusing of waves, guided-wave behavior, and nonlinear effects. It is perhaps the most comprehensive book on the new class of negative refraction materials, covering all aspects of negative refraction and negative index materials.

Written by the department head of materials science and engineering at MIT, this concise and stringent introduction takes readers from the fundamental theory to in-depth knowledge. It sets out with a theoretical scheme for the design of desirable periodic structures, then presents the experimental techniques that allow for

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fabrication of the periodic structure and exemplary experimental data. Subsequently, theory and numerical data are used to demonstrate how these periodic structures control the photonic, acoustic, and mechanical properties of materials, concluding with examples from these three important fields of applications. The result is must-have knowledge for both beginners and veterans in the field.

This book presents the most recent theoretical developments and numerical/experimental validations of new metamaterials and phononic crystals for the broadband absorption of elastic waves and vibrations in structures. These nine chapters explore many aspects of phononic crystals and acoustic/elastic metamaterials, including sound attenuation/absorption, extraordinary transmission, wave broadband mitigation, wave steering, cloaking via the transformation method, optimization of phononic crystals, and active acoustic metamaterials.

This book presents a *liber amicorum* dedicated to Wolfgang H. Müller, and highlights recent advances in Prof. Müller's major fields of research: continuum mechanics, generalized mechanics, thermodynamics, mechanochemistry, and geomechanics. Over 50 of Prof. Müller's friends and colleagues contributed to this book, which commemorates his 60th birthday and was published in recognition of his outstanding contributions.

Introduction to Photonic and Phononic Crystals and Metamaterials, by Arthur R. McGurn, presents a study of the fundamental properties of optical and acoustic materials which have been of recent interest in nanoscience and device technology. The level of the presentations is appropriate for advanced undergraduates, beginning graduate students, and researchers not directly involved in the field. References are

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given to guide the reader to more advanced study in these fields. Discussions of the physics of photonic and phononic crystals focus on the transmission properties of optical and acoustic radiation arising from their diffractive interaction in these engineered materials. The frequency transmission and non-transmission bands of radiation are explained in terms of the symmetry properties of the photonic and phononic artificial crystal structures. Basic applications of these properties to a variety of their technological applications are examined. The physics of metamaterials is discussed along with their relationships to the ideas of resonance. Properties of negative index of refraction, perfect lens, and unusual optical effects the new optics of metamaterial media makes available are examined. Related effects in acoustics are also covered. Basic principles of surface acoustic and electromagnetic waves are explained. These form an introduction to the fundamental ideas of the recently developing fields of plasmonics and surface acoustics. This book presents selected papers presented at the 8th International Conference "Design, Modeling and Experiments of Advanced Structures and Systems" (DeMEASS VIII, held in Moscow, Russia in May 2017) and reflects the modern state of sciences in this field. The contributions contain topics like Piezoelectric, Ferroelectric, Ferroelastic and Magnetostrictive Materials, Shape Memory Alloys and Active Polymers, Functionally Graded Materials, Multi-Functional Smart Materials and Structures, Coupled Multi-Field Problems, Design and Modeling of Sensors and Actuators, Adaptive Structures. Metamaterials have attracted enormous interests from both physics and engineering communities in the past 20 years, owing to their powerful ability in manipulating electromagnetic waves. However, the functionalities of traditional metamaterials are fixed at the time of fabrication. To control

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the EM waves dynamically, active components are introduced to the meta-atoms, yielding active metamaterials. Recently, a special kind of active metamaterials, digital coding and programmable metamaterials, are proposed, which can achieve dynamically controllable functionalities using field programmable gate array (FPGA). Most importantly, the digital coding representations of metamaterials set up a bridge between the digital world and physical world, and allow metamaterials to process digital information directly, leading to information metamaterials. In this Element, we review the evolution of information metamaterials, mainly focusing on their basic concepts, design principles, fabrication techniques, experimental measurement and potential applications. Future developments of information metamaterials are also envisioned.

This book delivers a comprehensive and up-to-date treatment of practical applications of metamaterials, structured media, and conventional porous materials. With increasing levels of urbanization, a growing demand for motorized transport, and inefficient urban planning, environmental noise exposure is rapidly becoming a pressing societal and health concern. Phononic and sonic crystals, acoustic metamaterials, and metasurfaces can revolutionize noise and vibration control and, in many cases, replace traditional porous materials for these applications. In this collection of contributed chapters, a group of international researchers reviews the essentials of acoustic wave propagation in metamaterials and porous absorbers with viscothermal losses, as well as the most recent advances in the design of acoustic metamaterial absorbers. The book features a detailed theoretical introduction describing commonly used modelling techniques such as plane wave expansion, multiple scattering theory, and the transfer matrix method. The following chapters give a detailed consideration of acoustic wave propagation in

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viscothermal fluids and porous media, and the extension of this theory to non-local models for fluid saturated metamaterials, along with a description of the relevant numerical methods. Finally, the book reviews a range of practical industrial applications, making it especially attractive as a white book targeted at the building, automotive, and aeronautic industries.

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