An Introduction To Metamaterials And Waves In Composites

The rapid development of technology based on metamaterials coupled with the recent introduction of the transformation optics technique provides an unprecedented ability for device designers to manipulate and control the behavior of electromagnetic wave phenomena. Many of the early metamaterial designs, such as negative index materials and electromagnetic bandgap surfaces, were limited to operation only over a very narrow bandwidth. However, recent groundbreaking work reported by several international research groups on the development of broadband metamaterials has opened up the doors to an exciting frontier in the creation of new devices for applications ranging from radio frequencies to visible wavelengths. This book contains a collection of eight chapters that cover recent cutting-edge contributions to the theoretical, numerical, and experimental aspects of broadband metamaterials.

Metamaterials and plasmonics are cross-disciplinary fields that are emerging into the mainstream of many scientific areas. Examples of scientific and technical fields which are concerned are electrical engineering, micro- and nanotechnology, microwave engineering, optics, optoelectronics, and semiconductor technologies. In plasmonics, the interplay between propagating electromagnetic waves and free-electron oscillations in materials are exploited to create new components and applications. On the other hand, metamaterials refer to artificial composites in which small artificial elements, through their collective interaction, creates a desired and unexpected macroscopic response function that is not present in the constituent materials. This book charts the state of the art of these fields. In May 2008, world-leading experts in metamaterials and plasmonics gathered into a NATO Advanced Research Workshop in Marrakech, Morocco. The present book contains extended versions of 22 of the presentations held in the workshop, covering the general aspects of the field, as well as design and modelling questions of plasmonics and metamaterials, fabrication issues, and applications like absorbers and antennas.

Requiring no advanced knowledge of wave propagation, An Introduction to Metamaterials and Waves in Composites focuses on theoretical aspects of metamaterials, periodic composites, and layered composites. The book gives novices a platform from which they can start exploring the subject in more detail. After introducing concepts related to elasticity, acoustics, and electrodynamics in media, the text presents plane wave solutions to the equations that describe elastic, acoustic, and electromagnetic waves. It examines the plane wave expansion of sources as well as scattering from curved interfaces, specifically spheres and cylinders. The author then covers electrodynamic, acoustic, and elastodynamic metamaterials. He also describes examples of transformations, aspects of acoustic cloaking, and applications of pentamode materials to acoustic cloaking. With a focus on periodic composites, the text uses the Bloch-Floquet theorem to find the effective behavior of composites in the quasistatic limit, presents the quasistatic equations of elastodynamic and electromagnetic waves, and investigates Brillouin zones and band gaps in periodic structures. The final chapter discusses wave propagation in smoothly varying layered media, anisotropic density of a periodic layered medium, and quasistatic homogenization of laminates. This book provides a launch pad for research into elastic and acoustic metamaterials. Many of the ideas presented have yet to be realized experimentally—the book encourages readers to explore these ideas and bring them to technological maturity.

An Introduction to Metamaterials and Nanophotonics
The book describes analytical methods (based primarily on classical modal synthesis), the Finite Element Method (FEM), Boundary Element Method (BEM), Statistical Energy Analysis
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(SEA), Energy Finite Element Analysis (EFEA), Hybrid Methods (FEM-SEA and Transfer Path Analysis), and Wave-Based Methods. The book also includes procedures for designing noise and vibration control treatments, optimizing structures for reduced vibration and noise, and estimating the uncertainties in analysis results. Written by several well-known authors, each chapter includes theoretical formulations, along with practical applications to actual structural-acoustic systems. Readers will learn how to use vibroacoustic analysis methods in product design and development; how to perform transient, frequency (deterministic and random), and statistical vibroacoustic analyses; and how to choose appropriate structural and acoustic computational methods for their applications. The book can be used as a general reference for practicing engineers, or as a text for a technical short course or graduate course.

Metamaterials have provided applications in spectral ranges covering radio frequencies and ultraviolet. However, most applications have been extrapolated to the visible or near-infrared after being developed at the GHz level. This is due to technological reasons since fabrication of microwave antennas is not as demanding as THz resonators or plasmonic nanostructures. Accordingly, this book has been divided into three parts. In the first part, fundamentals of metamaterials and metadevices are discussed, while describing recent advances in the field. In the second part, the discussion is extended to the different spectral ranges focusing on the strategies for enabling the reconfigurability of metadevices. Given the increasing interest in THz applications, these can be found in the third part.

This book discusses bulk solids that derive their mechanical properties not from those of their base materials, but from their designed microstructures. Focusing on the negative mechanical properties, it addresses topics that reveal the counter-intuitive nature of solids, specifically the negativity of properties that are commonly positive, such as negative bulk modulus, negative compressibility, negative hygroexpansion, negative thermal expansion, negative stiffness phase, and negative Poisson’s ratio. These topics are significant not only due to the curiosity they have sparked, but also because of the possibility of designing materials and structures that can behave in ways that are not normally expected in conventional solids, and as such, of materials that can outperform solids and structures made from conventional materials. The book includes illustrations to facilitate learning, and, where appropriate, reference tables. The presentation is didactic, starting with simple cases, followed by increasingly complex ones. It provides a solid foundation for graduate students, and a valuable resource for practicing materials engineers seeking to develop novel materials through the judicious design of microstructures and their corresponding mechanisms.

Metamaterials: Theory, Design, and Applications goes beyond left-handed materials (LHM) or negative index materials (NIM) and focuses on recent research activity. Included here is an introduction to optical transformation theory, revealing invisible cloaks, EM concentrators, beam splitters, and new-type antennas, a presentation of general theory on artificial metamaterials composed of periodic structures, coverage of a new rapid design method for inhomogeneous metamaterials, which makes it easier to design a cloak, and new developments including but not limited to experimental verification of invisible cloaks, FDTD simulations of invisible cloaks, the microwave and RF applications of metamaterials, sub-wavelength imaging using anisotropic metamaterials, dynamical metamaterial systems, photonic metamaterials, and magnetic plasmon effects of metamaterials.

Metamaterials—artificially structured materials with engineered electromagnetic properties—have enabled unprecedented flexibility in manipulating electromagnetic waves and producing new functionalities. This book details recent advances in the study of optical metamaterials, ranging from fundamental aspects to up-to-date implementations, in one unified treatment. Important recent developments and applications such as superlens and cloaking devices are also treated in detail and
made understandable. The planned monograph can serve as a very timely book for both newcomers and advanced researchers in this extremely rapid evolving field. Textbook conceptions of light-matter interactions have been challenged by two recent material advances - the development of metamaterials and the introduction of parity-time (PT)-symmetric media. Metamaterials allow considerable control over the electric and magnetic fields of light, so that the permittivity, permeability, and refractive index can be tuned throughout positive, negative, and near-zero values. They have enabled negative refraction, optical lensing below the diffraction limit of light, and invisibility cloaking. Complementarily, PT-symmetric media allow control over electromagnetic field distributions in systems with balanced amounts of gain and loss, so that light propagation can be asymmetric and directional. They have enabled lossless Talbot revivals, unidirectional invisibility, and, combined with non-linear media, optical isolators. In this thesis, I will elaborate on our efforts to make new types of optical and asymmetric metamaterials, including metamaterials with negative optical permeability, metamaterials in liquid phase, and parity-time symmetric metamaterials. In the first part, I will describe our theoretical and experimental works on plasmonic metamaterials both in the solid state and liquid phase. Here we have designed and demonstrated the first liquidic metamaterial, utilizing protein directed assembly to synthesize the constituent metamolecules. Both individual metamolecules and the bulk metamaterial solution show a strong isotropic magnetic polarizability at optical frequencies. Our calculations also indicate that these meta-molecules could enable negative refractive index liquids. In the second part, I will introduce the concept of PT-symmetric nanophotonic materials. We show how planar metallo-dielectric structures with balanced inclusion of gain and loss can be used for a variety of applications, including i) directional nanophotonic waveguides and modulators; ii) directional metamaterials that have different refractive indices when viewed from different sides; and iii) at Veselago lenses which can overcome the Rayleigh diffraction limit of conventional optical microscopy. Further, I will show how these metamaterials can be used to control the emission of the electric, magnetic, and chiral emitters and suggest a non-chiral platform for enantio-specific identification and selection.

The purpose of this chapter is to familiarize the reader with metamaterials and describe terahertz (THz) spectroscopy within metamaterials research. The introduction provides key background information on metamaterials, describes their history and their unique properties. These properties include negative refraction, backwards phase propagation, and the reversed Doppler Effect. The history and theory of metamaterials are discussed, starting with Veselago's negative index materials work and Pendry's publications on physical realization of metamaterials. The next sections cover measurement and analyses of THz metamaterials. THz Time-domain spectroscopy (THz-TDS) will be the key measurement tool used to describe the THz metamaterial measurement process. Sample transmission data from a metamaterial THz-TDS measurement is analyzed to give a better understanding of the different frequency characteristics of metamaterials. The measurement and analysis sections are followed by a section on the fabrication process of metamaterials. After familiarizing the reader with THz metamaterial measurement and fabrication techniques, the final section will provide a review of various methods by which metamaterials are made active and/or tunable. Several novel concepts were demonstrated in recent years to achieve such
metamaterials, including photoconductivity, high electron mobility transistor (HEMT), microelectromechanical systems (MEMS), and phase change material (PCM)-based metamaterial structures.

This book is the first systematic exposition on the emerging domain of wireless power transfer in ad hoc communication networks. It selectively spans a coherent, large spectrum of fundamental aspects of wireless power transfer, such as mobility management in the network, combined wireless power and information transfer, energy flow among network devices, joint activities with wireless power transfer (routing, data gathering and solar energy harvesting), and safety provisioning through electromagnetic radiation control, as well as fundamental and novel circuits and technologies enabling the wide application of wireless powering. Comprising a total of 27 chapters, contributed by leading experts, the content is organized into six thematic sections: technologies, communication, mobility, energy flow, joint operations, and electromagnetic radiation awareness. It will be valuable for researchers, engineers, educators, and students, and it may also be used as a supplement to academic courses on algorithmic applications, wireless protocols, distributed computing, and networking.

This book offers a unified presentation of metamaterials building from fundamental nanophotonic principles.

This textbook bridges the gap between university courses on electrodynamics and the knowledge needed to successfully address the problem of electrodynamics of metamaterials. It appeals to both experimentalists and theoreticians who are interested in the physical basics of metamaterials and plasmonics. Focusing on qualitative fundamental treatment as opposed to quantitative numerical treatment, it covers the phenomena of artificial magnetization at high frequencies, and discusses homogenization procedures and the basics of quantum dynamics in detail. By considering different phenomena it creates a self-consistent qualitative picture to explain most observable phenomena. This allows readers to develop a better understanding of the concepts, and helps to create a conceptual approach, which is especially important in educational contexts. This clearly written book includes problems and solutions for each chapter, which can be used for seminars and homework, as well as qualitative models that are helpful to students.

This book analyzes the updated principles and applications of nonlinear approaches to solve engineering and physics problems. The knowledge on nonlinearity and the comprehension of nonlinear approaches are inevitable to future engineers and scientists, making this an ideal book for engineers, engineering students, and researchers in engineering, physics, and mathematics. Chapters are of specific interest to readers who seek expertise in optimization, nonlinear analysis, mathematical modeling of complex forms, and non-classical engineering problems. The book covers methodologies and applications from diverse areas such as vehicle dynamics, surgery simulation, path planning, mobile robots, contact and scratch analysis at the micro and nano scale, sub-structuring techniques, ballistic projectiles, and many more.

"This text book has been written as lecture notes for the master and postgraduate (licentiate) course on Metamaterials and Nanophotonics which is taught at the School of Electrical Engineering of Aalto University (Finland) from 2016. The course material is suitable for students specializing in electrical engineering and applied physics,
especially electromagnetics, nanoscience, and optics. The reader will develop understanding of light-matter interaction at nano (subwavelength) scale and acquire knowledge of recent developments of the theory of optical properties of nanostructures, nanostructured materials and surfaces, as well as their applications. The book presents a unified view covering both metamaterials and nanophotonics from the fundamental, basic-principles point of view, offering short, focused, basic explanations of fundamental ideas behind new developments in this field in its generality"--

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 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 fascinating book is a treatise on real space-age materials. It is a mathematical treatment of a novel concept in material science that characterizes the properties of dynamic materials—that is, material substances whose properties are variable in space and time. Unlike conventional composites that are often found in nature, dynamic materials are mostly the products of modern technology developed to maintain the most effective control over dynamic processes.

Since the concept was first proposed at the end of the 20th Century, metamaterials have been the subject of much research and discussion throughout the wave community. More than 10 years later, the number of related published articles is increasing significantly. On the one hand, this success can be attributed to dreams of new physical objects which are the consequences of the singular properties of metamaterials. Among them, we can consider the examples of perfect lensing and invisibility cloaking. On other hand, metamaterials also provide new tools for the design of well-known wave functions such as antennas for electromagnetic waves. The goal of this book is to propose an overview of the concept of metamaterials as a perspective on a new practical tool for wave study and engineering. This includes both the electromagnetic spectrum, from microwave to optics, and the field of acoustic waves. Contents

Metamaterials operating at terahertz (THz) region of the electromagnetic spectrum have remained a promising area of study not only for realizing technologies in a historically underdeveloped spectral regime, but also as a scientific tool for exploring and controlling fundamental physical phenomena at meV energy scales in a variety of condensed matter systems. In this thesis, I will present several projects in which metamaterials and more traditional condensed matter systems are integrated into hybrid metamaterial systems. We leverage these systems to realize new practical THz devices, as well as to couple to and control quantum phenomena in condensed matter systems. I will begin with an introduction to the conceptual, numerical, and experimental techniques in the THz metamaterial toolbox. The first research endeavor I will discuss is a metamaterial system that incorporates perhaps the simplest material: air. This metamaterial perfect absorber with a continuously tunable air dielectric layer allows for comprehensive exploration of metamaterial absorber systems, and demonstrates some unique phenomena owing to its lossless dielectric layer. Next I will introduce an applications oriented device; an electrically actuated broadband terahertz switch which transitions from a non-reflective, transmissive state to a fully absorptive state. It employs an all dielectric metamaterial layer to suppress reflections and trap light, and an electrically actuated phase change material, VO2 to transition between states. The final section of this dissertation will explore strong coupling effects between a metamaterial and the superconducting c-axis Josephson plasmon in the layered cuprate, La\(^{2-x}\)Sr\(^x\)CuO\(_4\). Preliminary measurements are first presented then followed by high field THz measurements in which complex nonlinear behavior is observed.
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 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.

In this thesis computational studies on electromagnetic properties of metamaterials and applications are introduced. The studies include an introduction to the time-domain transmission line modelling (TLM) method and the fundamental scattering properties of metamaterials. The first major objective of the thesis is directed to predicting the resonant frequencies of some forms of cut-wire (CW) metamaterials by using approximate equivalent circuits. The second objective is the improvement of metamaterial simulation efficiency based on two approaches: a simulation method based on retrieved metamaterial electromagnetic properties and one based on digital filtering (DF) techniques. By using the DF techniques, metamaterials are effectively modelled and the simulation times are significantly reduced. The third objective is focused on studying CW metamaterial as potential absorbers by deliberately including conductive losses. The proposed CW metamaterials are found to exhibit customisable absorptance characteristics with arbitrary polarisation. This metamaterial absorber study includes an experimental validation.

This book discusses theoretical and experimental advances in metamaterial structures, which are of fundamental importance to many applications in microwave and optical-wave physics and materials science. Metamaterial structures exhibit time-reversal and space-inversion symmetry breaking due to the effects of magnetism and chirality. The book addresses the characteristic properties of various symmetry breaking processes by studying field-matter interaction with the use of conventional electromagnetic waves and novel types of engineered fields: twisted-photon fields, toroidal fields, and magnetoelectric fields. In a system with a combined effect of simultaneous breaking of space and time inversion symmetries, one observes the magnetochiral effect. Another similar phenomenon featuring space-time inversion symmetries is related to use of magnetoelectric materials. Cross-coupling of the electric and magnetic components in these material structures, leading to the appearance of new magnetic modes with an electric excitation channel – electromagnons and skyrmions – has resulted in a wealth of strong optical effects such as directional dichroism, magnetochiral dichroism, and rotatory power of the fields. This book contains multifaceted contributions from international leading experts and covers the essential aspects of symmetry-breaking effects, including theory, modeling and design, proven and potential applications in practical devices, fabrication, characterization and measurement. It is ideally suited as an introduction and basic reference work for researchers and graduate students entering this field.

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. 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 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 aeronautical industries.

This book highlights the symmetry properties of acoustic fields and describes the gauge invariance approach, which can be used to reveal those properties. Symmetry is the key theoretical framework of metamaterials, as has been demonstrated by the successful fabrication of acoustical metamaterials. The book first provides the necessary theoretical background, which includes the covariant derivative, the vector potential, and invariance in coordinate transformation. This is followed by descriptions of global gauge invariance (isotropy), and of local gauge invariance (anisotropy). Sections on time reversal symmetry, reflection invariance, and invariance of finite amplitude waves round out the coverage.

To meet the demands of students, scientists and engineers for a systematic reference source, this book introduces, comprehensively and in a single voice, research and development progress in emerging metamaterials and derived functional metadevices. Coverage includes electromagnetic, optical, acoustic, thermal, and mechanical metamaterials and related metadevices. Metamaterials are artificially engineered composites with designed properties beyond those attainable in nature and with applications in all aspects of materials science. From spatially tailored dielectrics to tunable, dynamic materials properties and unique nonlinear behavior, metamaterial systems have demonstrated tremendous flexibility and functionality in electromagnetic, optical, acoustic, thermal, and mechanical engineering. Furthermore, the field of metamaterials has been extended from the mere pursuit of various exotic properties towards the realization of practical devices, leading to the concepts of dynamically-reconfigurable metadevices and functional metasurfaces. The book explores the fundamental physics, design, and engineering aspects, as well as the full array of state-of-the-art applications to electronics, telecommunications, antennas, and energy harvesting. Future challenges and potential in regard to design, modeling and fabrication are also addressed. 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 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): PrefaceElectromagnetic 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, Raúl Rodríguez-Berral and Carlos Molero)Electromagnetic Metasurfaces: Synthesis, Realizations and Discussions (Karim Aouchi and Christophe Caloz)Metasurfaces for General Control of Reflection and Transmission (Sergei Tretyakov, Viktar Asadchy and Ana Díaz-Rubio)Scattering at the Extreme with Metamaterials and Plasmonics (Francesco Monticone and Andrea Alù)All-Dielectric Nanophotonics: 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, Alessandro Alberucci, Gaetano Assanto, Yu G Rapoport, Vladimir V Grimalsky, Vasyl M Ivchenko and Eugen N Tkachenko)Metamaterial Catheter Receivers for Internal Magnetic Resonance Imaging (Richard R A Symns, Ian R Young and Laszlo Solymar)Microwave Sensors Based on Symmetry Properties and Metamatieral Concepts (Jordi Naqui, Ali K Horestanl, Christophe Fumeaux and Ferran Martín)Volume 2: Elastic, Acoustic, and Seismic Metamaterials (Richard Craster and Sébastien Guenneau): PrefaceDynamic 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 Kaiïna 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 (Stéphane Brûlé, Stefan Enoch, Sébastien Guenneau and 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 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. This new edition of the well-received introduction to solid-state physics provides a comprehensive overview of the basic theoretical and experimental concepts of materials science. Experimental aspects and laboratory details are highlighted in separate panels that enrich text and emphasize recent developments. Notably, new material in the third edition includes sections on important new devices, aspects of non- periodic structures of matter, phase transitions, defects, superconductors and nanostructures. Students will benefit significantly from solving the exercises given at the end of each chapter. This book is intended for university students in physics, materials science and electrical engineering. It has been
thoroughly updated to maintain its relevance and usefulness to students and professionals. Complex-media electromagnetic (CME) describes the study of electromagnetic fields in materials with complicated response properties. This truly multidisciplinary field commands the attentions of scientists from physics and optics to electrical and electronic engineering, from chemistry to materials science, to applied mathematics, biophysics, and nanotechnology. This book is a collection of essays to explain complex mediums for optical and electromagnetic applications. All contributors were requested to write with two aims: first, to educate; second, to provide a state-of-the-art review of a particular subtopic. The vast scope of CME exemplified by the actual materials covered in the essays should provide a plethora of opportunities to the novice and the initiated alike.

The terahertz regime of the electromagnetic spectrum was largely unexplored due to the lack of technology needed to generate and detect the radiation. However, in the last couple of decades, there has been a dramatic increase in tools needed to harness the radiation. This remarkable progress made in the development of terahertz sources, components, and detectors has resulted in an ever-increasing inquisitiveness of the applications of terahertz technology in a wide range of fields including medicine, pharmaceuticals, security, sensing, and quality assurance. This book, Terahertz Spectroscopy - A Cutting Edge Technology, presents an overview of the recent advances in terahertz technology and their application in a vast array of fields. The scientists and students are encouraged to read and share the content of this volume. The book also provides a good starting point for researchers who are new to the terahertz regime. The various chapters of the book have been written by renowned scientists in different parts of the world who are at the forefront of terahertz research fields. It is our (InTech publisher, editor, and authors) hope that this book will enhance knowledge and stimulate more interest and future research in terahertz technology.

Metamaterials: Beyond Crystals, Noncrystals, and Quasicrystals is a comprehensive and updated research monograph that focuses on recent advances in metamaterials based on the effective medium theory in microwave frequencies. Most of these procedures were conducted in the State Key Laboratory of Millimeter Waves, Southeast University, China. The book conveys the essential concept of metamaterials from the microcosmic structure to the macroscopic electromagnetic properties and helps readers quickly obtain needed skills in creating new devices at microwave frequencies using metamaterials. The authors present the latest progress on metamaterials and transformation optics and provide abundant examples of metamaterial-based devices accompanied with detailed procedures to simulate, fabricate, and measure them. Comprised of ten chapters, the book comprehensively covers both the fundamentals and the applications of metamaterials. Along with an introduction to the subject, the first three chapters discuss effective medium theory and artificial particles. The next three chapters cover homogeneous metamaterials (super crystals), random metamaterials (super noncrystals), and inhomogeneous metamaterials (super quasicrystals). The final four chapters examine gradient-index inhomogeneous
metamaterials, nearly isotropic inhomogeneous metamaterials, and anisotropic inhomogeneous metamaterials, after which the authors provide their conclusions and closing remarks. The book is completely self-contained, making it easy to follow. This book introduces fundamental principles as well as applications of metasurfaces, i.e. electromagnetically thin structures manipulating EM wave propagation. The authors describe the precursors and history of metasurfaces before moving on to explore the physical insights that can be gained from the material parameters of the metasurface. They also present how to compute the fields scattered by a metasurface, with known material parameters, being illuminated by an arbitrary incident field, as well as how to realize a practical metasurface and relate it its material parameters to physical structures. The book finishes with a discussion of the future of the field.

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 and scattering in phononic crystals.

Nonlinear Electrodynamics is a systematic introduction to metamaterial structures. Unique in its attention to nonlinearity in metamaterials, this book addresses guided waves, beams, pulses, and solutions, trapped rainbows and cover complex structures, and topics in magneto-optics. It is an irreplaceable text for researchers, professionals, and students in plasmonics, optics, and metamaterials.

The purpose of this book is to provide an up-to-date introduction to the time-domain finite element methods for Maxwell’s equations involving metamaterials. Since the first successful construction of a metamaterial with both negative permittivity and permeability in 2000, the study of metamaterials has attracted significant attention from researchers across many disciplines. Thanks to enormous efforts on the part of engineers and physicists, metamaterials present great potential applications in antenna and radar design, sub-wavelength imaging, and invisibility cloak design. Hence the efficient simulation of electromagnetic phenomena in metamaterials has become a very important issue and is the subject of this book, in which various metamaterial modeling equations are introduced and justified mathematically. The development and practical implementation of edge finite element methods for metamaterial Maxwell’s equations are the main focus of the book. The book finishes with some interesting simulations such as backward wave propagation and time-domain cloaking with metamaterials.

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