

Metasurface For Characterization Of The Polarization State

This book addresses fabrication as well as characterization and modeling of semiconductor nanostructures in the optical regime, with a focus on nonlinear effects. The visible range as well as near and far infrared spectral region will be considered with a view to different envisaged applications. The book covers the current key challenges of the research in the area, including: exploiting new material platforms, fully extending the device operation into the nonlinear regime, adding re-configurability to the envisaged devices and proposing new modeling tools to help in conceiving new functionalities.

- Explores several topics in the field of semiconductor nonlinear nanophotonics, including fabrication, characterization and modeling of semiconductor nanostructures in the optical regime, with a focus on nonlinear effects
- Describes the research challenges in the field of optical metasurfaces in the nonlinear regime
- Reviews the use and achievements of all-dielectric nanoantennas for strengthening the nonlinear optical response
- Describes both theoretical and experimental aspects of photonic devices based on semiconductor optical nanoantennas and metasurfaces
- Gathers contributions from several leading groups in this research field to provide a thorough and complete overview of the current state of the art in the field of semiconductor nonlinear nanophotonics

Costantino De Angelis has been full professor of electromagnetic fields at the University of Brescia since 1998. He is an OSA Fellow and has been responsible for several university research contracts in the last 20 years within Europe, the United States, and Italy. His technical interests are in optical antennas and nanophotonics. He is the author of over 150 peer-reviewed scientific journal articles. Giuseppe Leo has been a full professor in physics at Paris Diderot University since 2004, and in charge of the nonlinear devices group of MPQ Laboratory since 2006. His research areas include nonlinear optics, micro- and nano-photonics, and optoelectronics, with a focus on AlGaAs platform. He has coordinated several research programs and coauthored 100 peer-reviewed journal articles, 200 conference papers, 10 book chapters and also has four patents. Dragomir Neshev is a professor in physics and the leader of the experimental photonics group in the Nonlinear Physics Centre at Australian National University (ANU). His activities span over several branches of optics, including nonlinear periodic structures, singular optics, plasmonics, and photonic metamaterials. He has coauthored 200 publications in international peer-reviewed scientific journals.

In recent years, we have witnessed a rapid expansion of using super-thin metasurfaces to manipulate light or electromagnetic wave in a subwavelength scale. However, most designs are confined to a passive scheme and monofunctional operation, which hinders considerably the promising applications of the metasurfaces. Specifically, the tunable and multifunctional metasurfaces enable to facilitate switchable functionalities and multiple functionalities which are extremely essential and useful for integrated optics and microwaves, well alleviating aforementioned issues. In this book, we introduce our efforts in exploring the physics principles, design approaches, and numerical and experimental demonstrations on the fascinating functionalities realized. We start by introducing in Chapter 2 the "merging" scheme in constructing multi-functional metadevices, paying particular attention to its shortcomings issues. Having understood the merits and disadvantages of the "merging" scheme, we then introduce in Chapter 3

another approach to realize bifunctional metadevices under linearly polarized excitations, working in both reflection and transmission geometries or even in the full space. As a step further, we summarize our efforts in Chapter 4 on making multifunctional devices under circularly polarized excitations, again including designing principles and devices fabrications/characterizations. Starting from Chapter 5, we turn to introduce our efforts on using the "active" scheme to construct multifunctional metadevices under linearly polarized wave operation. Chapter 6 further concentrates on how to employ the tunable strategy to achieve helicity/frequency controls of the circularly polarized waves in reflection geometry. We finally conclude this book in Chapter 7 by presenting our perspectives on future directions of metasurfaces and metadevices.

This book presents the technology of millimetre waves and Terahertz (THz) antennas. It highlights the importance of moderate and high-gain aperture antennas as key devices for establishing point-to-point and point-to-multipoint radio links for far-field and near-field applications, such as high data-rate communications, intelligent transport, security imaging, exploration and surveillance systems. The book provides a comprehensive overview of the key antenna technologies developed for the mm wave and THz domains, including established ones – such as integrated lens antennas, advanced 2D and 3D horn antennas, transmit and reflect arrays, and Fabry-Perot antennas – as well as emerging metasurface antennas for near-field and far-field applications. It describes the pros and cons of each antenna technology in comparison with other available solutions, a discussion supplemented by practical examples illustrating the step-by-step implementation procedures for each antenna type. The measurement techniques available at these frequency ranges are also presented to close the loop of the antenna development cycle. In closing, the book outlines future trends in various antenna technologies, paving the way for further developments. Presenting content originating from the five-year ESF research networking program 'Newfocus' and co-authored by the most active and highly cited research groups in the domain of mm- and sub-mm-wave antenna technologies, the book offers a valuable guide for researchers and engineers in both industry and academia.

This book provides a first integrated view of nanophotonics and plasmonics, covering the use of dielectric, semiconductor, and metal nanostructures to manipulate light at the nanometer scale. The presentation highlights similarities and advantages, and shows the common underlying physics, targets, and methodologies used for different materials (optically transparent materials for nanophotonics, vs opaque materials for plasmonics). Ultimately, the goal is to provide a basis for developing a unified platform for both fields. In addition to the fundamentals and detailed theoretical background, the book showcases the main device applications. Ching Eng (Jason) Png is Director of the Electronics and Photonics Department at the Institute of High Performance Computing, Agency for Science Technology and Research, Singapore. Yuriy A. Akimov is a scientist in the Electronics and Photonics Department at the Institute of High Performance Computing, Agency for Science Technology and Research, Singapore. This volume collects the main results of the Author's Ph.D. course in Electromagnetics and Mathematical Models for Engineering, attended at 'Sapienza' University of Rome from November 2011 to February 2015, in the Electromagnetic Fields 1 Lab of the Department of Information Engineering, Electronics and Telecommunications, under

the tutoring of Prof. Alessandro Galli.

Plasmonics is an emerging field mainly developed within the past two decades. Due to its unique capabilities to manipulate light at deep subwavelength scales, plasmonics has been commonly treated as the most important part of nanophotonics. Plasmonic-assisted optical microscopy techniques, especially super-resolution microscopy, have shown tremendous potential and attracted much attention. This book aims to collect cutting-edge studies in various optical imaging technologies with advanced performances that are enabled or enhanced by plasmonics. The basic working principles, development details, and potential future direction and perspectives are discussed. Edited by Zhaowei Liu, a prominent researcher in the field of super-resolution microscopy, this book will be an excellent reference for anyone in the field of nanophotonics, plasmonics, and optical microscopy.

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.

Electromagnetic metamaterials—from fundamental physics to advanced engineering applications This book presents an original generalized transmission line approach associated with non-resonant structures that exhibit larger bandwidths, lower loss, and higher design flexibility. It is based on the novel concept of composite right/left-handed (CRLH) transmission line metamaterials (MMs), which has led to the development of novel guided-wave, radiated-wave, and refracted-wave devices and structures. The authors introduced this powerful new concept and are therefore able to offer readers deep insight into the fundamental physics needed to fully grasp the technology. Moreover, they provide a host of practical engineering applications. The book begins with an introductory chapter that places resonant type and transmission line metamaterials in historical perspective. The next six chapters give readers a solid foundation in the fundamentals and practical applications: Fundamentals of LH MMs describes the fundamental physics and exotic properties of left-handed metamaterials TL Theory of MMs establishes the foundations of CRLH structures in three progressive steps: ideal transmission line, LC network, and real distributed structure Two-Dimensional MMs develops both a transmission matrix method and a transmission line method to address the problem of finite-size 2D metamaterials excited by arbitrary sources Guided-Wave Applications and Radiated-Wave Applications present a number of groundbreaking applications developed by the authors The Future of MMs sets forth an expert view on future challenges and prospects This engineering approach to metamaterials paves the way for a new generation of microwave and photonic devices and structures. It is recommended for electrical engineers, as well as physicists and optical engineers, with an interest in practical negative refractive index structures and materials.

The book presents an engineering approach for the development of metamaterials and metasurfaces with emphasis on application in antennas. It offers an in-depth study, performance analysis and extensive characterization on different types of metamaterials and metasurfaces. Practical examples included in the book will help readers to enhance

performance of antennas and also develop metamaterial-based absorbers for a variety of applications. Key Features Provides background for design and development of metamaterial structures using novel unit cells Gives in-depth performance study of miniaturization of microstrip antennas Discusses design and development of both transmission and reflection types, metasurfaces and their practical applications. Verifies a variety of Metamaterial structures and Metasurfaces experimentally The target audience of this book is postgraduate students and researchers involved in antenna designs. Researchers and engineers interested in enhancing the performance of the antennas using metamaterials will find this book extremely useful. The book will also serve as a good reference for developing artificial materials using metamaterials and their practical applications. Amit K. Singh is Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Technology Jammu, India. He is a Member of the IEEE, USA. Mahesh P. Abegaonkar is Associate Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Senior Member of the IEEE, USA. Shibani Kishen Koul is Emeritus Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Life Fellow of the Institution of Electrical and Electronics Engineers (IEEE), USA, a Fellow of the Indian National Academy of Engineering (INAE), and a Fellow of the Institution of Electronics and Telecommunication Engineers (IETE).

The dielectric metasurfaces have been widely recognized as a low-loss platform allowing for manipulation of the near- and far-fields. However, the field of light-emitting dielectric metasurfaces is less developed. The main objective of this thesis is to demonstrate how dielectric metasurfaces can improve and control the emission of nanoscale light sources coupled to them. This includes the experimental realization of coupled photonic systems consisting of emitters and dielectric metasurfaces, development of optical setups for characterization of the emission properties, and numerical simulations to support the experimental data and to analyze the underlying physical mechanisms.

This book presents the latest research findings, methods and development techniques, challenges and solutions concerning UPC from both theoretical and practical perspectives, with an emphasis on innovative, mobile and Internet services. With the proliferation of wireless technologies and electronic devices, there is a rapidly growing interest in Ubiquitous and Pervasive Computing (UPC), which makes it possible to create a human-oriented computing environment in which computer chips are embedded in everyday objects and interact with the physical world. Through UPC, people can go online even while moving around, thus enjoying nearly permanent access to their preferred services. Though it has the potential to revolutionize our lives, UPC also poses a number of new research challenges.

This book presents innovative ideas and technical contributions in the area of metasurfaces and antenna technologies. On the one hand, it presents an effective method to analyze metasurfaces constituted by metallic texture with certain geometries. It shows how this method can be applied to the design of metasurface (MTS) antennas for deep space communications and other planar microwave devices. On the other hand, the book reports on a general methodology developed for analyzing flat devices realized by using modulated MTSs, which opens new design possibilities for a large number of microwave devices based on the manipulation of SWs. Finally, a novel approach of reconfigurability, which is based on a class of checkerboard MTS, is explored. All in all, this book covers important insights and significant results on the emerging topic of metasurfaces, from theoretical and computational aspects to experiments.

Provides a comprehensive discussion of planar transmission lines and their applications, focusing on physical understanding, analytical approach, and circuit models Planar transmission lines form the core of the modern high-frequency communication, computer, and other related technology. This advanced text gives a complete overview of the technology and

acts as a comprehensive tool for radio frequency (RF) engineers that reflects a linear discussion of the subject from fundamentals to more complex arguments. Introduction to Modern Planar Transmission Lines: Physical, Analytical, and Circuit Models Approach begins with a discussion of waves on transmission lines and waves in material medium, including a large number of illustrative examples from published results. After explaining the electrical properties of dielectric media, the book moves on to the details of various transmission lines including waveguide, microstrip line, co-planar waveguide, strip line, slot line, and coupled transmission lines. A number of special and advanced topics are discussed in later chapters, such as fabrication of planar transmission lines, static variational methods for planar transmission lines, multilayer planar transmission lines, spectral domain analysis, resonators, periodic lines and surfaces, and metamaterial realization and circuit models. Emphasizes modeling using physical concepts, circuit-models, closed-form expressions, and full derivation of a large number of expressions Explains advanced mathematical treatment, such as the variation method, conformal mapping method, and SDA Connects each section of the text with forward and backward cross-referencing to aid in personalized self-study Introduction to Modern Planar Transmission Lines is an ideal book for senior undergraduate and graduate students of the subject. It will also appeal to new researchers with the inter-disciplinary background, as well as to engineers and professionals in industries utilizing RF/microwave technologies.

Optical metasurface is an emerging concept in the field of nano optics, nano photonics, and silicon photonics. This dissertation is a summary of the author's research in the field of optical metasurface including a complete process of design, simulation, fabrication and characterization of optical metasurface. The major contribution of this study lies in visible band metalens, which is of great interest in the field of imaging and sensing.

This book addresses space science and communication – one of the main pillars of space science sustainability, an area that has recently become of great importance. In this regard, research and development play a crucial role in sustainability development. However, obtaining essential data in the physical world to interpret the universe and to predict what could happen in the future is a challenging undertaking. Accordingly, providing valid information to understand trends, evaluate needs, and create sustainable development policies and programs in the best interest of all the people is indispensable. This book was prepared in conjunction with the fifth meeting of the 2017 International Conference on Space Science and Communication (IconSpace2017), held in Kuala Lumpur, Malaysia on 3-5 May 2017 to introduce graduate students, researchers, lecturers, engineers, geospatialists, meteorologists, climatologists, astronomers and practitioners to the latest applications of space science, telecommunications, meteorology, remote sensing and related fields. The individual papers discuss a broad range of space science and technology applications, e.g. the formation of global warming from space, environmental and remote sensing, communication systems, and smart materials for space applications.

Conventional optical components, such as lenses, mirrors, waveplates and polarizers, have been widely developed and used in many electronic and optical devices. Because these components are bulky, they are not suitable for miniaturization and integration. In recent years, metasurfaces have emerged as a platform to realize the transformation of the field of optical devices as they have the potential to revolutionize the way light is controlled on a chip. Metallic nanostructures are intrinsically lossy in the optical spectral region due to the absorption in metals. In addition, the design parameters of metasurfaces have limitations for controlling the optical phase-front in the full range of 0

to $2[\pi]$. These restrictions lead to the introduction of several undesirable losses, including reflection, diffraction, and polarization conversion. Compared to metallic nanostructures, dielectric metasurfaces have several significant advantages such as high transmission efficiency because they do not suffer from the intrinsic nonradiative losses in metals. All-dielectric metasurfaces can allow a diverse range of practical efficient wave-shaping applications of novel materials. In this dissertation, we report on the experimental study of the anomalous transmission effect in ultrathin metallic gratings, where the metal thickness is much thinner than the skin depth. In particular, incident TM polarized waves are reflected while incident TE polarized waves are transmitted. The anomalous transmission strongly depends on the metal width, thickness and refractive indices of the surrounding dielectric material. We systematically investigate and demonstrate the anomalous effect and determine the optimized nanostrip thickness and width by introducing a shadow-mask fabrication approach. The combined effect of thickness and width is experimentally investigated, and shown to match well with theoretical analysis. The main advantage of our ultrathin metal gratings lies in insertion loss reduction by utilizing the ultrathin metallic film fabrication. This advantage makes our structure readily suitable for a variety of applications including high efficiency metasurfaces, polarization steering, and polarization dependent spectral filter applications. Also, we explore the design, fabrication, and characterization of dielectric metasurface lens created by varying the density of subwavelength low refractive index nanoholes in a high refractive index substrate, resulting in a locally variable effective refraction index. It is demonstrated that constructed graded index lenses can overcome diffraction effects when the aperture to wavelength ratio ($D/[\lambda]$) is smaller than 40. Our design parameters for engineering the effective refractive index of a composite dielectric are created by controlling the density of deeply subwavelength low index nanoholes in a high index dielectric layer (e.g., Si). The phase of the optical wavefront incident on such a composite dielectric is modulated by the local effective index of the layer. We have demonstrated that the microlenses can be made polarization dependent by asymmetric design as well as polarization independent by symmetric design operating with radiation from a broad spectral range. The main advantages of our dielectric nanosurface lenses include further reduction of insertion loss by adding antireflection (AR) coating of element size and weight via submicron thickness fabrication and miniaturization. Such advantages make our structure readily suitable for a variety of applications, such as microlens arrays, high resolution CCD sensors, and other miniature imaging systems. The experimental results demonstrate the practical potential of polarization and position dependent graded index components by asymmetric designs. We envision using Cartesian and polar coordinate designs for future nanohole region realizations, such as space variant circular nanohole patterns or space invariant elliptical nanohole patterns.

Dielectric Metamaterials: Fundamentals, Designs, and Applications links fundamental Mie scattering theory with the latest dielectric metamaterial research, providing a valuable reference for new and experienced researchers in the field. The book begins with a historical, evolving overview of Mie scattering theory. Next, the authors describe how to apply Mie theory to analytically solve the scattering of electromagnetic waves by subwavelength particles. Later chapters focus on Mie resonator-based metamaterials, starting with microwaves where particles are much smaller than the free space

wavelengths. In addition, several chapters focus on wave-front engineering using dielectric metasurfaces and the nonlinear optical effects, spontaneous emission manipulation, active devices, and 3D effective media using dielectric metamaterials. Highlights a crucial link in fundamental Mie scattering theory with the latest dielectric metamaterial research spanning materials, design and applications Includes coverage of wave-front engineering and 3D metamaterials Provides computational codes for calculating and simulating Mie resonances

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MULTIFUNCTIONAL ANTENNAS AND ARRAYS FOR WIRELESS COMMUNICATION SYSTEMS Offers an up-to-date discussion of multifunctional antennas and arrays for wireless communication systems Multifunctional Antennas and Arrays for Wireless Communication Systems is a comprehensive reference on state-of-the-art reconfigurable antennas and 4G/5G communication antennas. The book gives a unique perspective while giving a comprehensive overview of the following topics: Frequency reconfigurable antennas Pattern reconfigurable antennas Polarization reconfigurable antennas Reconfigurable antennas using Liquid Metal, Piezoelectric, and RF MEMS MIMO and 4G/5G wireless communication antennas Metamaterials and metasurfaces in reconfigurable antennas Multifunctional antennas for user equipments (UEs) Defense related antennas and applications Flat panel phased array antennas The book is a valuable resource for the practicing engineer as well as for those within the research field. As wireless communications continuously evolves, more and more functionally will be required, and thus multifunctional antennas and RF systems will be necessary. These multifunctional antennas will require a degree of reconfigurability, and this book discusses various methods which enable this. The main topics of frequency, pattern, and polarization reconfigurability is first discussed. Methods utilizing unique materials and devices, both real and artificial are discussed. The book also delves into 4G/5G antennas as it relates to MIMO, and millimeter-wave phased arrays. Finally, there is a section on defense related multifunctional RF antenna systems.

Space–time transformations as a design tool for a new class of composite materials (metamaterials) have proved successful recently. The concept is based on the fact that metamaterials can mimic a transformed but empty space. Light rays follow trajectories according to Fermat's principle in this transformed electromagnetic, acoustic, or elastic space instead of laboratory space. This allows one to manipulate wave behaviors with various exotic characteristics such as (but not limited to) invisibility cloaks. This book is a collection of works by leading international experts in the fields of electromagnetics,

plasmonics, elastodynamics, and diffusion waves. The experimental and theoretical contributions will revolutionize ways to control the propagation of sound, light, and other waves in macroscopic and microscopic scales. The potential applications range from underwater camouflaging and electromagnetic invisibility to enhanced biosensors and protection from harmful physical waves (e.g., tsunamis and earthquakes). This is the first book that deals with transformation physics for all kinds of waves in one volume, covering the newest results from emerging topical subjects such as transformational plasmonics and thermodynamics.

Backscattering and RF Sensing for Future Wireless Communication Discover what lies ahead in wireless communication networks with this insightful and forward-thinking book written by experts in the field. **Backscattering and RF Sensing for Future Wireless Communication** delivers a concise and insightful picture of emerging and future trends in increasing the efficiency and performance of wireless communication networks. The book shows how the immense challenge of frequency saturation could be met via the deployment of intelligent planar electromagnetic structures. It provides an in-depth coverage of the fundamental physics behind these structures and assesses the enhancement of the performance of a communication network in challenging environments, like densely populated urban centers. The distinguished editors have included resources from a variety of leading voices in the field who discuss topics such as the engineering of metasurfaces at a large scale, the electromagnetic analysis of planar metasurfaces, and low-cost and reliable backscatter communication. All of the included works focus on the facilitation of the development of intelligent systems designed to enhance communication network performance. Readers will also benefit from the inclusion of: A thorough introduction to the evolution of wireless communication networks over the last thirty years, including the imminent saturation of the frequency spectrum An exploration of state-of-the-art techniques that next-generation wireless networks will likely incorporate, including software-controlled frameworks involving artificial intelligence An examination of the scattering of electromagnetic waves by metasurfaces, including how wave propagation differs from traditional bulk materials A treatment of the evolution of artificial intelligence in wireless communications Perfect for researchers in wireless communications, electromagnetics, and urban planning, **Backscattering and RF Sensing for Future Wireless Communication** will also earn a place in the libraries of government policy makers, technologists, and telecom industry stakeholders who wish to get a head start on understanding the technologies that will enable tomorrow's wireless communications. Discover a comprehensive exploration of recent developments and fundamental concepts in the applications of metasurfaces. In **Electromagnetic Metasurfaces: Theory and Applications**, distinguished researchers and authors Karim Achouri and Christophe Caloz deliver an introduction to the fundamentals and applications of metasurfaces and an insightful analysis of recent and future developments in the field. The book describes the precursors and history of metasurfaces before continuing on to an exploration of the physical insights that can be gleaned from the material parameters of the metasurface. You'll learn 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 its material parameters to its physical structures. The authors provide examples to illustrate all the concepts discussed in the book to improve and simplify reader understanding. **Electromagnetic Metasurfaces** concludes with an incisive discussion of the likely future directions and research

opportunities in the field. Readers will also benefit from the inclusion of: A thorough introduction to metamaterials, the concept of metasurfaces, and metasurface precursors An exploration of electromagnetic modeling and theory, including metasurfaces as zero-thickness sheets and bianisotropic susceptibility tensors A practical discussion of susceptibility synthesis, including four-parameters synthesis, more than four-parameters synthesis, and the addition of susceptibility components A concise treatment of scattered-field analysis, including approximate analytical methods, and finite-difference frequency-domain techniques Perfect for researchers in metamaterial sciences and engineers working with microwave, THz, and optical technologies, *Electromagnetic Metasurfaces: Theory and Applications* will also earn a place in the libraries of graduate and undergraduate students in physics and electrical engineering. 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 its material parameters to physical structures. The book finishes with a discussion of the future of the field.

While our five senses are doing a reasonably good job at representing the world around us on a macro-scale, we have no existing intuitive representation of the nanoworld, ruled by laws entirely foreign to our experience. This is where molecules mingle to create proteins; where you wouldn't recognize water as a liquid; and where minute morphological changes would reveal how much 'solid' things, such as the ground or houses, are constantly vibrating and moving. Following in the footsteps of *Nano-Society and Nanotechnology: The Future is Tiny*, this title introduces a new collection of stories demonstrating recent research in the field of nanotechnology. This drives home the fact that a plethora of nanotechnology R&D will become an integral part of improved and entirely novel materials, products, and applications yet will remain entirely invisible to the user. The book gives a personal perspective on how nanotechnologies are created and developed, and will appeal to anyone who has an interest in the research and future of nanotechnology. Reviews of *Nanotechnology: The Future is Tiny*: 'The book is recommended not only to all interested scientists, but also to students who are looking for a quick and clear introduction to various research areas of nanotechnology' *Angew. Chem.*, 2017, 56(26), 7351–7351 'Once you start reading you will find it very difficult to stop' *Chromatographia*, 2017, 80, 1821

Encyclopedia of Interfacial Chemistry: Surface Science and Electrochemistry summarizes current, fundamental knowledge of interfacial chemistry, bringing readers the latest developments in the field. As the chemical and physical properties and processes at solid and liquid interfaces are the scientific basis of so many technologies which enhance our lives and create new opportunities, its important to highlight how these technologies enable the design and optimization of functional materials for heterogeneous and electro-catalysts in food production, pollution control, energy conversion and storage, medical applications requiring biocompatibility, drug delivery, and more. This book provides an interdisciplinary view that lies at the intersection of these fields. Presents fundamental knowledge of interfacial chemistry, surface science and electrochemistry and provides cutting-edge research from academics and practitioners across various fields and global regions

Dielectric Metamaterials and Metasurfaces in Transformation Optics and Photonics addresses the complexity of electromagnetic responses from arrays of dielectric resonators, which are often omitted from consideration when using simplified metamaterials concepts. The book's authors present a thorough consideration of dielectric resonances in different environments which is needed to design optical and photonic devices. *Dielectric metamaterials and photonic*

crystals are compared, with their effects analyzed. Design approaches and examples of designs for invisibility cloaks based on artificial media are also included. Current challenge of incorporating artificial materials into transformation optics-based and photonics devices are also covered. Presents advanced concepts of utilizing artificial materials for optical and photonic device applications Includes design approaches of materials for transformation optics, cloaking, applications and examples of these designs Compares photonic crystals and metamaterials, their effects, properties and characteristics

Written by the leading experts in the field, this text provides systematic coverage of the theory, physics, functional designs, and engineering applications of advanced engineered electromagnetic surfaces. All the essential topics are included, from the fundamental theorems of surface electromagnetics, to analytical models, general sheet transmission conditions (GSTC), metasurface synthesis, and quasi-periodic analysis. A plethora of examples throughout illustrate the practical applications of surface electromagnetics, including gap waveguides, modulated metasurface antennas, transmit arrays, microwave imaging, cloaking, and orbital angular momentum (OAM) beam generation, allowing readers to develop their own surface electromagnetics-based devices and systems. Enabling a fully comprehensive understanding of surface electromagnetics, this is an invaluable text for researchers, practising engineers and students working in electromagnetics antennas, metasurfaces and optics.

Discusses the basic physical principles underlying the science and technology of nanophotonics, its materials and structures This volume presents nanophotonic structures and Materials. Nanophotonics is photonic science and technology that utilizes light/matter interactions on the nanoscale where researchers are discovering new phenomena and developing techniques that go well beyond what is possible with conventional photonics and electronics. The topics discussed in this volume are: Cavity Photonics; Cold Atoms and Bose-Einstein Condensates; Displays; E-paper; Graphene; Integrated Photonics; Liquid Crystals; Metamaterials; Micro-and Nanostructure Fabrication; Nanomaterials; Nanotubes; Plasmonics; Quantum Dots; Spintronics; Thin Film Optics Comprehensive and accessible coverage of the whole of modern photonics Emphasizes processes and applications that specifically exploit photon attributes of light Deals with the rapidly advancing area of modern optics Chapters are written by top scientists in their field Written for the graduate level student in physical sciences; Industrial and academic researchers in photonics, graduate students in the area; College lecturers, educators, policymakers, consultants, Scientific and technical libraries, government laboratories, NIH.

The THz quantum-cascade vertical-external-cavity surface-emitting-laser (QC-VECSEL) is a recently developed approach for designing high-power, electrically pumped THz lasers with excellent beam quality and broadband tunability. The key component of the QC-VECSEL is an amplifying reflectarray metasurface, based on a subwavelength array of surface radiating metal-metal waveguide antenna elements loaded with QC-laser gain material. Despite its importance, the gain properties of the QC-metasurface are designed by simulation and have only been verified indirectly through observation of the QC-VECSEL lasing characteristics, or by passive FTIR reflectance measurements at room-temperature. THz time-domain spectroscopy (TDS) has been widely used to investigate gain spectra and laser dynamics of THz QC-lasers based on various ridge waveguide geometries. In this thesis, I describe my construction of a THz TDS system and present the first direct spectral measurement using reflection-mode THz TDS of an amplifying QC-metasurface resonant at 2.6 THz under different conditions. The large surface-radiating aperture of the metasurface (1.5 1.5 mm² in this case) eases free-space TDS measurements compared to ridge waveguide QC-devices with sub-wavelength sized facets.

This book covers device design fundamentals and system applications in optical MEMS and nanophotonics. Expert authors showcase examples of how fusion of nanoelectromechanical (NEMS) with nanophotonic elements is creating powerful new photonic devices and systems including MEMS micromirrors, MEMS tunable filters, MEMS-based adjustable lenses and apertures, NEMS-driven variable silicon nanowire waveguide couplers, and NEMS tunable photonic crystal nanocavities. The book also addresses system applications in laser scanning displays, endoscopic systems, space telescopes, optical telecommunication systems, and biomedical implantable systems. Presents efforts to scale down mechanical and photonic elements into the nano regime for enhanced performance, faster operational speed, greater bandwidth, and higher level of integration. Showcases the integration of MEMS and optical/photonic devices into real commercial products. Addresses applications in optical telecommunication, sensing, imaging, and biomedical systems. Prof. Vincent C. Lee is Associate Professor in the Department of Electrical and Computer Engineering, National University of Singapore. Prof. Guangya Zhou is Associate Professor in the Department of Mechanical Engineering at National University of Singapore.

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): 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)
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Metasurfaces for General Control of Reflection and Transmission (Sergei Tretyakov, Viktor Asadchy and Ana Díaz-Rubio)
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Frequency mixing is an essential nonlinear process with extensive applications in photonics, chemistry, biology, and energy sciences. Traditional nonlinear crystals have weak nonlinear responses and light beams need long propagation distances in the crystals to accumulate a significant wave mixing in practice. However, wave mixing in such bulky crystals results in stringent phase-matching requirements and bulk nonlinear crystals are not compatible with modern “flat” optics concept that enables complete control of the phase-front of the output beam but requires optical medium with subwavelength thickness. Fortunately, the emerging of metasurfaces has provided an efficient method to generate the large nonlinear response on nanoscale. The metasurfaces have enabled the development of “flat” optical elements with the intrinsic benefit of small thickness, intricate control of the optical wavefront, and, in case of nonlinear optical elements, relaxed phase-matching constraints. In my Ph.D. dissertation, I focus on the second-order intersubband polaritonic nonlinear metasurfaces. These structures combine enormous intersubband nonlinear response in III-V semiconductor heterostructures and field enhancement of plasmonic nano-resonators. Our earlier research has demonstrated giant nonlinear responses for the second harmonic generation in metasurfaces. In this dissertation, I propose several approaches to improve the performance of second harmonic generation metasurfaces and extend their functionality to difference-frequency and sum-frequency generation in the mid-infrared range. For the first part of this study, I have demonstrated new multiquantum-well designs for second harmonic generation with materials have much narrower linewidth compared with previous materials. This leads to a conversion efficiency of 1.2%. Second, I have demonstrated the mid-infrared difference-frequency generation in polaritonic nonlinear metasurface for the first time. The optimization of the metasurface, the theoretical investigation of the saturation effect, the fabrication of the metasurface, and the experimental characterization of the metasurface have been discussed. The effective nonlinear susceptibility is 340 nm/V and the difference frequency generation conversion efficiency of this metasurface is 0.13%. I have also demonstrated the mid-infrared sum-frequency generation in a polaritonic nonlinear metasurface. Both the theoretical analysis of the saturation effect and the experimental characterization of the metasurface have been illustrated. The upconversion efficiency of this metasurface is 0.03% and the nonlinear susceptibility is

158 nm/V. In addition, as the prospect of the SFG metasurfaces, the performance of metasurfaces under extremely high pump intensity has been discussed and the metasurface designs for high conversion efficiency have been proposed. For the last part of this study, metasurfaces in the THz range have been explored. These metasurfaces are designed to generate 4~6 THz with a difference-frequency generation process from polaritonic metasurfaces at room temperature. The theoretical analysis, sample design, and preliminary experimental results have been discussed

Dielectric Metamaterials: Fundamentals, Designs and Applications links fundamental Mie scattering theory with the latest dielectric metamaterial research, providing a valuable reference for new and experienced researchers in the field. The book begins with a historical, evolving overview of Mie scattering theory. Next, the authors describe how to apply Mie theory to analytically solve the scattering of electromagnetic waves by subwavelength particles. Later chapters focus on Mie resonator-based metamaterials, starting with microwaves where particles are much smaller than the free space wavelengths. In addition, several chapters focus on wave-front engineering using dielectric metasurfaces and the nonlinear optical effects, spontaneous emission manipulation, active devices, and 3D effective media using dielectric metamaterials. Highlights a crucial link in fundamental Mie scattering theory with the latest dielectric metamaterial research spanning materials, design and applications Includes coverage of wave-front engineering and 3D metamaterials Provides computational codes for calculating and simulating Mie resonances

This book is a printed edition of the Special Issue "Metasurfaces: Physics and Applications" that was published in *Applied Sciences*

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 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.

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