Piezoelectricity An Introduction To The Theory And Applications Of Electromechanical Phenomena In Crystals

Discovered in 1880, piezoelectric materials play a key role in an innovative market of several billions of dollars. Recent advances in applications derive from new materials and their development, as well as to new market requirements. With the exception of quartz, ferroelectric materials are used for they offer both high efficiency and sufficient versatility to meet adequately the multidimensional requirements for application. Consequently, strong emphasis is placed on tailoring materials and technology, whether one deals with single crystals, ceramics or plastic materials. Tailoring requires a basic understanding of both physical principles and technical possibilities and limitations. This report elucidates these developments by a broad spectrum of examples, comprising ultrasound in medicine and defence industry, frequency control, signal processing by SAW-devices, sensors, actuators, including novel valves for modern motor management. It delivers a mutual fertilization of technology push and market pull that should be of interest not only to materials scientists or engineers but also to managers who dedicate themselves to a sound future-oriented R&D policy.

Dynamic Fracture of Piezoelectric Materials focuses on the Boundary Integral Equation Method as an efficient computational tool. The presentation of the theoretical basis of piezoelectricity is followed by sections on fundamental solutions and the numerical realization of the boundary value problems. Two major parts of the book are devoted to the solution of problems in homogeneous and inhomogeneous solids. The book includes contributions on coupled electro-mechanical models, computational methods, its validation and the simulation results, which reveal different effects useful for engineering design and practice. The book is self-contained and well-illustrated, and it serves as a graduate-level textbook or as extra reading material for students and researchers.

As a continuation of the author's previous book An Introduction to the Theory of Piezoelectricity (Springer, New York, 2005) on the three-dimensional theory of piezoelectricity, this book covers one- and two-dimensional theories of piezoelectric structures including rods, beams, plates and shells. In addition to the so-called low-frequency motions of extension and bending, high-frequency motions of thickness shear and thickness stretch are also considered for certain applications unique in resonant piezoelectric devices. Both single-layer and multi-layer structures are treated. Nonlinear effects due to large deflection or large shear deformation are also discussed. The emphasis in on the development of structural theories with various levels of sophistication for different applications in piezoelectric devices. The book is heavily influenced by R D Mindlin's early contributions to this field. It is destined to be one of the most systematic and comprehensive books on piezoelectric structures. This second edition is a major reorganization of the first edition with multiple additions as well as deletion of chapters and sections.

Volume I of this complete, systematic survey by an expert in the field examines the fundamental properties of crystals and various formulations of piezoelectric theory, including production and measurement. 1946 edition.

Provides in-depth knowledge on lead-free piezoelectrics - for state-of-the-art, environmentally friendly electrical and electronic devices! Lead zirconate titanate ceramics have been market-dominating due to their excellent properties and flexibility in terms of compositional modifications. Driven by the Restriction of Hazardous Substances Directive, there is a growing concern on the toxicity of lead. Therefore, numerous research efforts were devoted to lead-free piezoelectrics from the beginning of this century. Great progress has been made in the development of high-performance lead-free piezoelectric ceramics which are already used, e.g., for power electronics applications. Lead-Free Piezoelectric Materials provides an in-depth overview of principles, material systems, and applications of lead-free piezoelectric materials. It starts with the fundamentals of piezoelectricity and lead-free piezoelectrics. Then it discusses four representative lead-free piezoelectric material systems from background introduction to crystal structures and properties. Finally, it presents several applications of lead-free piezoelectrics including piezoelectric actuators, and transducers. The challenges for promoting applications will also be discussed. Highly attractive: Lead-free piezoelectrics address the growing concerns on exclusion of hazardous substances used in electrical and electronic devices in order to protect human health and the environment Thorough overview: Covers fundamentals, different classes of materials, processing and applications Unique: discusses fundamentals and recent advancements in the field of lead-free piezoelectrics Lead-Free Piezoelectric Materials is of high interest for material scientists, electrical and chemical engineers, solid state chemists and physicists in academia and industry.

This text is an introduction to the dynamics of active structures and to the feedback control of lightly damped flexible structures; the emphasis is placed on basic issues and simple control strategies that work. Now in its third edition, more chapters have been added, and comments and feedback from readers have been taken into account, while at the same time the unique premise of bridging the gap between structure and control has remained. Many examples and problems bring the subject to life and take the audience from theory to practice. The book has chapters dealing with some concepts in structural dynamics; electromagnetic and piezoelectric transducers; piezoelectric beam, plate and truss; passive damping with piezoelectric transducers; collocated versus non-collocated control; active damping with collocated systems; vibration isolation; state space approach; analysis and synthesis in the frequency domain; optimal control; controllability and observability; stability; applications; tendon control of cable structures; active control of large telescopes; and semi-active control. The book concludes with an exhaustive bibliography and index. This book is intended for structural engineers who want to acquire some background in vibration control; it can be used as a textbook for a graduate course on vibration control or active structures. A solutions manual is available through the publisher to teachers using this book as a textbook.

Exploiting new advanced structures and electromechanical systems, e. g. , adaptive structures, high-precision systems, micro electromechanical systems, distributed sensors/actuators, precision manipulation and controls, etc. , has been becoming one of the mainstream research and development activities (structure & motion) in recent years. These new systems and devices could bring a new technological revolution in modern industries and further, directly or indirectly, impact human life. In the search for and research in innovative technologies, it is proved that piezoelectric materials are very versatile in both sensor and actuator applications. Consequently, piezoelectric technology has been widely applied to a large number of industrial applications and devices, varying from thin-film micro sensors/actuators to large space structures in addition to those relatively conventional applications, e. g. , sensors, actuators, hydrophones, precision manipulators, mobile robots, micro motors, etc. There have been a few books on piezoelectricity published in the past; however, a unified presentation of piezoelectric shells and distributed senSing/control applications is still lacking. This book is intended to fill the gap and to pro~de practising engineers and researchers with an introduction to advanced piezoelectric shell theories and distributed sensor/actuator technologies in structural identification and control. This book represents a collection of the author's recent research and development on piezoelectric shells and related applications to distributed measurement and control of continuaj it reflects six best-paper awards, including [xviii] • Contents. two ASME Best-Paper Awards in recent years.

The first contemporary text specializing on the dynamic problems of piezoelectric crystal plates for resonant acoustic wave devices (such as resonators, filters, and sensors) since H F Tiersten''s publication in 1969. This book provides an up-to-date, systematic and comprehensive presentation of theoretical results on waves and vibrations in quartz crystal plates. It expounds on the application of the theories of elasticity and piezoelectricity in acoustic wave devices made from crystal plates through a coverage spanning from classical results on acoustic wave resonators, up to present-day applications in acoustic wave sensors.This text begins with the exposition of the simplest thickness modes and various frequency effects in them due to electrodes, mass loading, contact with fluids, air gaps, etc., and continues on to the more complicated shear-horizontal modes, as well as straight-crested modes varying along the digonal axis of rotated Y-cut quartz. Modes varying in both of the in-plane directions of crystal plates are also addressed.The analysis within are based on the three-dimensional theories of piezoelectricity and anisotropic elasticity with various approximations when needed. Both free vibration modes (stationary waves) and propagating waves are studied in this text. Forced vibration is also treated in a few places.This book is intended to serve as an informative reference to personnel who employ piezoelectric crystal plates in the course of their profession.

This collection of 32 major review papers provides a complete understanding of the physics of piezoelectricity. With a thorough overview of applications and a major section exploring measurements and standards, this volume gives a systematic derivation of piezoelectric coefficients and equations of state for coupling mechanical, electrical, and thermal fields. A useful graduate text for design engineers, materials scientists, chemists, metallurgists, and condensed matter physicists.

This volume covers important subjects in the field of piezoelectric devices and applications with the latest research on piezoelectricity, acoustic waves, manufacturing technology, and design techniques. It includes up-to-date research and information on materials, new products, technological trends, and design methods of benefit to academics and researchers in the piezoelectric device industry. Contributors to this volume include prominent experts such as Clemens Ruppel of Epcos, Daining Fang of Tsinghua University, Tong-Yi Zhang of University of Science and Technology, Hong Kong, and CS Lam of TXC Corporation. A number of papers have been dedicated to Professor Harry F Tiersten of Resselear Polytechnic Institute, who passed away in 2006, for his contributions to the fundamental theory of piezoelectricity and methods for acoustic wave device analysis.

This comprehensive handbook and ready reference details all the main achievements in the field of perovskite-based and related mixed-oxide materials. The authors discuss, in an unbiased manner, the potentials as well as the challenges related to their use, thus offering new perspectives for research and development on both an academic and industrial level. The first volume begins by summarizing the different synthesis routes from molten salts at high temperatures to colloidal crystal template methods, before going on to focus on the physical properties of the resulting materials and their related applications in the fields of electronics, energy harvesting, and storage as well as electromechanics and superconductivity. The second volume is dedicated to the catalytic applications of perovskites and related mixed oxides, including, but not limited to total oxidation of hydrocarbons, dry reforming of methane and denitrogenation. The concluding section deals with the development of chemical reactors and novel perovskite-based applications, such as fuel cells and high-performance ceramic membranes. Throughout, the contributions clearly point out the intimate links between structure, properties and applications of these materials, making this an invaluable tool for materials scientists and for catalytic and physical chemists.

APC International s first textbook on piezoelectric ceramics covers general principles of piezoelectricity and behaviors of piezoelectric ceramic elements; the fundamental mathematics of piezoelectricity; traditional and experimental applications for piezoelectric materials, and related physical principles for each application: audible sound producers, flow meters, fluid level sensors, motors, pumps, delay lines, transformers, other apparatus; and provides an introduction to single crystals, composites, and other latest-generation piezoelectric materials. Contents: Introduction Piezoelectric Principles piezoelectricity / piezoelectric constants behavior / stability of piezoelectric ceramic elements new materials: relaxors / single crystals / others characteristics of piezoelectric materials from APC International, Ltd. Generators generators solid state batteries Sensors axial sensors flexional sensors special designs and applications: composites / SAW sensors / others Actuators axial and transverse actuators: simple / compound (stack) / multilayer flexional actuators / flextensional devices applications for piezoelectric actuators Transducers audible sound transducers generating ultrasonic vibrations in liquids or solids transmitting ultrasonic signals in air or water flow meters / fluid level sensors / delay lines / transformers / composites Miscellaneous securing a piezoelectric ceramic element attaching electrical leads testing performance.

A continuation of the author's previous book “An Introduction to the Theory of Piezoelectricity” (Springer, New York, 2005) on the three-dimensional theory of piezoelectricity, this volume covers lower dimensional theories for various piezoelectric structures and device applications. The development of two-, one- and zero-dimensional theories for high frequency vibrations of piezoelectric plates, shells, beams, rings curved bars and parallelepipeds is systematically presented. In addition to linear piezoelectricity, certain nonlinear effects are also considered and examples for device applications are provided.The material emphasizes dynamic theories and high frequency motions as well as device applications as there are relatively few books on piezoelectric structures, especially for high frequency theories. The volume is destined to be one of the most systematic and comprehensive books on piezoelectric structures.

Piezoelectricity has been a steadily growing field, with recent advances made by researchers from applied physics, acoustics, materials science, and engineering. This collective work presents a comprehensive treatment of selected advanced topics in the subject. The book is written for an intermediate graduate level and is intended for researchers, mechanical engineers, and applied mathematicians interested in the advances and new applications in piezoelectricity.

The ultrasonic motor, invented in 1980, utilizes the piezoelectric effect in the ultrasonic frequency range to provide the motive force. (In conventional electric motors the motive force is electromagnetic). The result is a motor with unusually good low-speed high-torque and power-to-weightcharacteristics. It has already found applications in camera autofocus mechanisms, medical equipment subject to high magnetic fields, and motorized car accessories. Its applications will increase as designers become more familiar with its unique characteristics.This book is the result of a collaboration between the inventor and an expert in conventional electric motors: the result is an introduction to the general theory presented in a way that links it to conventional motor theory. It will be invaluable both to motor designers and to those who designwith and use electric motors as an introduction to this important new invention.

Random fields are a necessity when formulating stochastic continuum theories. In this book, a theory of random piezoelectric and piezomagnetic materials is developed. First, elements of the continuum mechanics of electromagnetic solids are presented. Then the relevant linear governing equations are introduced, written in terms of either a displacement approach or a stress approach, along with linear variational principles. On this basis, a statistical description of second-order (statistically) homogeneous and isotropic rank-3 tensor-valued random fields is given. With a group-theoretic foundation, correlation functions and their spectral counterparts are obtained in terms of stochastic integrals with respect to certain random measures for the fields that belong to orthotropic, tetragonal, and cubic crystal systems. The target audience will primarily comprise researchers and graduate students in theoretical mechanics, statistical physics, and probability.

Piezoelectric Transducers and Applications provides a guide for graduate students and researchers to the current state of the art of this complex and multidisciplinary area. The book fills an urgent need for a unified source of information on piezoelectric devices and their astounding variety of existing and emerging applications. Some of the chapters focus more on the basic concepts of the different disciplines involved and are presented in a didactic manner. Others go deeper into the complex aspects of specific fields of research, thus reaching the technical level of a scientific paper. Among other topics resonant sensors, especially bulk acoustic wave thickness shear mode resonators, chemical and bio-sensors, as well as broadband ultrasonic systems are treated in-depth.

The need for new types of sensors is more critical than ever. This is due to the emergence of increasingly complex technologies, health and security concerns of a burgeoning world population, and the emergence of terrorist activities, among other factors. Depending on their application, the design, fabrication, testing, and use of sensors, all require various kinds of both technical and nontechnical expertise. With this in mind, Introduction to Sensors examines the theoretical foundations and practical applications of electrochemical, piezoelectric, fiber optic, thermal, and magnetic sensors and their use in the modern era. Incorporating information from sensor-based industries to review current developments in the field, this book: Presents a complete sensor system that includes the preparation phase, the sensing element and platform, and appropriate electronics resulting in a digital readout Discusses solid-state electronic sensors, such as the metal oxide semiconductor (MOS) capacitor, the micromachined capacitive polymer, and the Schottky diode sensors Uses the two-dimensional hexagonal lattice as an example to detail the basic theory associated with piezoelectricity Explores the fundamental relationship between stress, strain, electric field, and electric displacement The magnetic sensors presented are used to determine measurands such as the magnetic field and semiconductor properties, including carrier concentration and mobility. Offering the human body and the automobile as examples of entities that rely on a multiplicity of sensors, the authors address the application of various types of sensors, as well as the theory and background information associated with their development and the materials used in their design. The coverage in this book reveals the underlying rationale for the application of different sensors while also defining the properties and characteristics of each.

Second in two-volume series covers properties and techniques of quartz, Rochelle salt, ferroelectric crystals, various applications of piezoelectricity, pyroelectricity, optical properties of crystals, and atomic theory of piezoelectricicty. 1946 edition.

This book describes the application of piezoelectric materials, particularly piezoceramics, in the wide field of actuators and sensors. It gives a step-by-step introduction to the structure and mechanics of piezoelectric beam bending actuators in multilayer technology, which are of increasing importance for industrial applications. The book presents the suitability of the developed theoretical aspects in a memorable way.

Future robots are expected to work closely and interact safely with real-world objects and humans alike. Sense of touch is important in this context, as it helps estimate properties such as shape, texture, hardness, material type and many more; provides action related information, such as slip detection; and helps carrying out actions such as rolling an object between fingers without dropping it. This book presents an in-depth description of the solutions available for gathering tactile data, obtaining aforementioned tactile information from the data and effectively using the same in various robotic tasks. The efforts during last four decades or so have yielded a wide spectrum of tactile sensing technologies and engineered solutions for both intrinsic and extrinsic touch sensors. Nowadays, new materials and structures are being explored for obtaining robotic skin with physical features like bendable, conformable, and stretchable. Such features are important for covering various body parts of robots or 3D surfaces. Nonetheless, there exist many more hardware, software and application related issues that must be considered to make tactile sensing an effective component of future robotic platforms. This book presents an in-depth analysis of various system related issues and presents the trade-offs one may face while developing an effective tactile sensing system. For this purpose, human touch sensing has also been explored. The design hints coming out of the investigations into human sense of touch can be useful in improving the effectiveness of tactile sensory modality in robotics and other machines. Better integration of tactile sensors on a robot’s body is prerequisite for the effective utilization of tactile data. The concept of semiconductor devices based sensors is an interesting one, as it allows compact and fast tactile sensing systems with capabilities such as human-like spatio-temporal resolution. This book presents a comprehensive description of semiconductor devices based tactile sensing. In particular, novel Piezo Oxide Semiconductor Field Effect Transistor (POSFET) based approach for high resolution tactile sensing has been discussed in detail. Finally, the extension of semiconductors devices based sensors concept to large and flexile areas has been discussed for obtaining robotic or electronic skin. With its multidisciplinary scope, this book is suitable for graduate students and researchers coming from diverse areas such robotics (bio-robots, humanoids, rehabilitation etc.), applied materials, humans touch sensing, electronics, microsystems, and instrumentation. To better explain the concepts the text is supported by large number of figures.

Piezoelectric materials are attracting significant research efforts and resources worldwide. The major thrust areas include structural health monitoring, bio-mechanics, bio-medicine and energy harvesting. Engineering and technological applications of this smart material warrants multi-dimensional theoretical and experimental knowledge and expertise in fields of mechanics, instrumentation, digital electronics and information technology, over and above the specific domain knowledge. This book presents, from theory to practice, the application of piezoelectric smart materials in engineering domains such as structural health monitoring (SHM), bio-mechanics, bio-medical engineering and energy harvesting.

This guide to the current state of the art of this complex and multidisciplinary area fills an urgent need for a unified source of information on piezoelectric devices and their astounding variety of existing and emerging applications.

This book offers an introduction to piezoelectric shells and distributed sensing, energy harvesting and control applications. It familiarizes readers with a generic approach of piezoelectric shells and fundamental electromechanics of distributed piezoelectric sensors, energy harvesters and actuators applied to shell structures. The book is divided into two major parts, the first of which focuses on piezoelectric shell continua, while the second examines distributing sensing, energy harvesting and control of elastic continua, e.g., shells and plates. The exploitation of new, advanced multifunctional smart structures and structronic systems has been one of the mainstream research and development activities over the years. In the search for innovative structronics technologies, piezoelectric materials have proved to be very versatile in both sensor and actuator applications. Consequently, the piezoelectric technology has been applied to a broad range of practical applications, from small-scale nano- and micro-sensors/actuators to large-scale airplane and space structures and systems. The book provides practicing engineers and researchers with an introduction to advanced piezoelectric shell theories and distributed sensor/energy harvester/actuator technologies in the context of structural identification, energy harvesting and precision control. The book can also be used as a textbook for graduate students. This second edition contains substantial new materials, especially energy harvesting and experimental components, and has been updated and corrected for a new generation of readers.

This book is based on lecture notes for a graduate course that has been offered at University of Nebraska-Lincoln on and off since 1998. The course is intended to provide graduate students with the basic aspects of the continuum modeling of electroelastic interactions in solids. A concise treatment of linear, nonlinear, static and dynamic theories and problems is presented. The emphasis is on formulation and understanding of problems useful in device applications rather than solution techniques of mathematical problems. The mathematics used in the book is minimal. The book is suitable for a one-semester graduate course on electroelasticity. It can also be used as a reference for researchers. I would like to take this opportunity to thank UNL for a Maude Hammond Fling Faculty Research Fellowship in 2003 for the preparation of the first draft of this book. I also wish to thank Ms. Deborah Derrick of the College of Engineering and Technology at UNL for editing assistance with the book, and Professor David Y. Gao of Virginia Polytechnic Institute and State University for recommending this book to Kluwer for publication in the series of Advances in Mechanics and Mathematics. JSY Lincoln, Nebraska 2004 Preface Electroelastic materials exhibit electromechanical coupling. They experience mechanical deformations when placed in an electric field, and become electrically polarized under mechanical loads. Strictly speaking, piezoelectricity refers to linear electromechanical couplings only.