NanoScience and Technology

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(Eds.)

# Nanoscale Characterisation of Ferroelectric Materials

## Scanning Probe Microscopy Approach

Springer

# Nanoscale Characterisation Of Ferroelectric Materials

Patrick Vollmar

**Nanoscale Characterisation Of Ferroelectric Materials:**

**Nanoscale Characterisation of Ferroelectric Materials** Marin Alexe,Alexei Gruverman,2013-03-09 Among the main trends in our daily society is a drive for smaller faster cheaper smarter computers with ever increasing memories To sustain this drive the com puter industry is turning to nanotechnology as a source of new processes and func tional materials which can be used in high performance high density electronic systems Researchers and engineers have been focusing on ferroelectric materials for a long time due to their unique combination of physical properties The ability of ferroelectrics to transform electromagnetic thermal and mechanical energy into electrical charge has been used in a number of electronic applications most recently in nonvolatile computer memories Classical monographs such as Ferro electricity by E Fatuzzo and W J Mertz served as a comprehensive introduction into the field for several generations of scientists However to meet the challenges of the nano era a solid knowledge of the ferroelectric properties at the nano scale needs to be acquired While the science of ferroelectrics from micro to lar ger scale is well established the science of nanoscale ferroelectrics is still terra in cognita The properties of materials at the nanoscale show strong size dependence which makes it imperative to perform reliable characterization at this size range One of the most promising approaches is based on the use of scanning probe microscopy SPM which has revolutionized materials research over the last dec ade **Handbook of Advanced Dielectric, Piezoelectric and Ferroelectric Materials** Z-G Ye,2008-03-20 This comprehensive book covers recent developments in advanced dielectric piezoelectric and ferroelectric materials Dielectric materials such as ceramics are used to manufacture microelectronic devices Piezoelectric components have been used for many years in radioelectrics time keeping and more recently in microprocessor based devices Ferroelectric materials are widely used in various devices such as piezoelectric electrostrictive transducers and actuators pyroelectric infrared detectors optical integrated circuits optical data storage and display devices The book is divided into eight parts under the general headings High strain high performance piezo and ferroelectric single crystals Electric field induced effects and domain engineering Morphotropic phase boundary related phenomena High power piezoelectric and microwave dielectric materials Nanoscale piezo and ferroelectrics Piezo and ferroelectric films Novel processing and new materials Novel properties of ferroelectrics and related materials Each chapter looks at key recent research on these materials their properties and potential applications Advanced dielectric piezoelectric and ferroelectric materials is an important reference tool for all those working in the area of electrical and electronic materials in general and dielectrics piezoelectrics and ferroelectrics in particular Covers the latest developments in advanced dielectric piezoelectric and ferroelectric materials Includes topics such as high strain high performance piezo and ferroelectric single crystals Discusses novel processing and new materials and novel properties of ferroelectrics and related materials Formation of Ferroelectricity in Hafnium Oxide Based Thin Films Tony Schenk,2017-03-15 In 2011 B scke et al reported the unexpected discovery of ferroelectric properties in hafnia based thin films which has since initiated many

further studies and revitalized research on the topic of ferroelectric memories In spite of many efforts the unveiling of the fundamentals behind this surprising discovery has proven rather challenging In this work the originally claimed Pca21 phase is experimentally proven to be the root of the ferroelectric properties and the nature of this ferroelectricity is classified in the frame of existing concepts of ferroelectric materials Parameters to stabilize this polar phase are examined from a theoretical and fabrication point of view With these very basic questions addressed the application relevant electric field cycling behavior is studied The results of first order reversal curves impedance spectroscopy scanning transmission electron microscopy and piezoresponse force microscopy significantly advance the understanding of structural mechanisms underlying wake up fatigue and the novel phenomenon of split up merging of transient current peaks The impact of field cycling behavior on applications like ferroelectric memories is highlighted and routes to optimize it are derived These findings help to pave the road for a successful commercialization of hafnia based ferroelectrics **Ferroelectric Crystals for Photonic Applications** Pietro Ferraro,Simonetta Grilli,Paolo De Natale,2008-09-02 The idea to write a new book in the eld of ferroelectric crystals arose from some considerationsreportedinthefollowing Inthelast5years severalgroupsallaround the world in the eld of engineering and characterization of ferroelectric crystals have published more than 300 papers The motivation for such an intense research activity is referable to the fact that the ferroelectric crystals are a key element for the most attractive and useful photonic and optoelectronic devices In fact during the 60ies the scientists realized that the ferroelectric crystals could have been ciently used to generate new unavailable frequencies taking advantage of the freshly proposed birefringent phase matching method The synchronized rush for the development of novel coherent sources and for the discovery of the best suited nonlinear crystals for mixing and generation had started Consequently the range of applications of ferroelectric crystals has enormously widened in the last years es cially based on the use of periodically poled structures i e PPLN PPLT PPKTP or PPKTA to quasi phase match optical interactions A new generation of sources is nding increasing applications in various elds including high sensitivity trace gas monitoring and any kind of advanced spectroscopic set ups thus replacing old style gas lasers like Argon ion or dye lasers New possibilities are also being plored to engineer ferroelectric crystals with two or three dimensional geometries Results from this eld will allow developing photonic devices combining photonic band gap properties and nonlinear conversion processes i e nonlinear photonic crystals **Advanced Materials Interfaces** Ashutosh Tiwari,Hirak K. Patra,Xuemei Wang,2016-06-22 Advanced Material Interfaces is a state of the art look at innovative methodologies and strategies adopted for interfaces and their applications The 13 chapters are written by eminent researchers not only elaborate complex interfaces fashioned of solids liquids and gases but also ensures cross disciplinary mixture and blends of physics chemistry materials science engineering and life sciences Advanced interfaces operate fundamental roles in essentially all integrated devices It is therefore of the utmost urgency to focus on how newly discovered fundamental constituents and interfacial progressions can be materialized and used for precise

purposes Interfaces are associated in wide multiplicity of application spectrum from chemical catalysis to drug functions and the advancement is funnelled by fine tuning of our fundamental understanding of the interface effects Nanoscale Phenomena in Ferroelectric Thin Films Seungbum Hong,2013-11-27 This book presents the recent advances in the field of nanoscale science and engineering of ferroelectric thin films It comprises two main parts i e electrical characterization in nanoscale ferroelectric capacitor and nano domain manipulation and visualization in ferroelectric materials Well known le adingexperts both in relevant academia and industry over the world U S Japan Germany Switzerland Korea were invited to contribute to each chapter The first part under the title of electrical characterization in nanoscale ferroelectric capacitors starts with Chapter 1 Testing and characterization of ferroelectric thin film capacitors written by Dr I K Yoo The author provides a comprehensive review on basic concepts and terminologies of ferroelectric properties and their testing methods This chapter also covers reliability issues in FeRAMs that are crucial for commercialization of high density memory products In Chapter 2 Size effects in ferroelectric film capacitors role ofthe film thickness and capacitor size Dr I Stolichnov discusses the size effects both in in plane and out of plane dimensions of the ferroelectric thin film The author successfully relates the electric performance and domain dynamics with proposed models of charge injection and stress induced phase transition The author s findings present both a challenging problem and the clue to its solution of reliably predicting the switching properties for ultra thin ferroelectric capacitors In Chapter 3 Ferroelectric thin films for memory applications nanoscale characterization by scanning force microscopy Prof A **Materials Challenges and Testing for Supply of Energy and Resources** Thomas Böllinghaus,Jürgen Lexow,Teruo Kishi,Masaki Kitagawa,2012-01-10 One major goal of the World Materials Research Institute Forum WMRIF is to promote young scientists in the field of materials science and engineering To enhance the international knowledge exchange between young postdoctoral scientists all over the world WMRIF meanwhile regularly organizes joint workshops among the member institutes These workshops also represent an increasingly appreciated platform to get known to each other and to build co operations For such workshops various topics are selected pointing to future perspectives and challenges in the field of Materials Science and Engineering This time the presentations of the workshop focused on the four subjects Challenges in conclusive realistic and system oriented materials testing Materials challenges for water supply Materials challenges in the extraction and recovery of scarce elements and minerals Materials challenges for nuclear fission and fusion This book comprises the peer reviewed contributions during the 2nd International Workshop for Young Materials Scientists at BAM Federal Institute for Materials Research and Testing Berlin Germany It also provides a very informative overview of recent results for all materials scientists **Perovskites and Related Mixed Oxides** Pascal Granger,Vasile I. Parvulescu,Serge Kaliaguine,Wilfrid Prellier,2016-02-23 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 **FIB Nanostructures** Zhiming M. Wang,2014-01-04 FIB Nanostructures reviews a range of methods including milling etching deposition and implantation applied to manipulate structures at the nanoscale Focused Ion Beam FIB is an important tool for manipulating the structure of materials at the nanoscale and substantially extends the range of possible applications of nanofabrication FIB techniques are widely used in the semiconductor industry and in materials research for deposition and ablation including the fabrication of nanostructures such as nanowires nanotubes nanoneedles graphene sheets quantum dots etc The main objective of this book is to create a platform for knowledge sharing and dissemination of the latest advances in novel areas of FIB for nanostructures and related materials and devices and to provide a comprehensive introduction to the field and directions for further research Chapters written by leading scientists throughout the world create a fundamental bridge between focused ion beam and nanotechnology that is intended to stimulate readers interest in developing new types of nanostructures for application to semiconductor technology These applications are increasingly important for the future development of materials science energy technology and electronic devices The book can be recommended for physics electrical engineering and materials science departments as a reference on materials science and device design **Piezoelectric Nanomaterials for Biomedical Applications** Gianni Ciofani,Arianna Menciassi,2012-03-31 Nanoscale structures and materials have been explored in many biological applications because of their novel and impressive physical and chemical properties Such properties allow remarkable opportunities to study and interact with complex biological processes This book analyses the state of the art of piezoelectric nanomaterials and introduces their applications in the biomedical field Despite their impressive potentials piezoelectric materials have not yet received significant attention for bio applications This book shows that the exploitation of piezoelectric nanoparticles in nanomedicine is possible and realistic and their impressive physical properties can be useful for several applications ranging from sensors and transducers for the detection of biomolecules to sensible substrates for tissue engineering or cell stimulation **Electroceramic-Based MEMS** Nava Setter,2006-03-30 The book is focused on the use of functional oxide and nitride films to enlarge the application range of MEMS

microelectromechanical systems including micro sensors micro actuators transducers and electronic components for microwaves and optical communications systems Applications emerging applications fabrication technology and functioning issues are presented and discussed The book covers the following topics Part A Applications and devices with electroceramic based MEMS Chemical microsensors Microactuators based on thin films Micromachined ultrasonic transducers Thick film piezoelectric and magnetostrictive devices Pyroelectric microsystems RF bulk acoustic wave resonators and filters High frequency tunable devices MEMS for optical functionality Part B Materials fabrication technology and functionality Ceramic thick films for MEMS Piezoelectric thin films for MEMS Materials and technology in thin films for tunable high frequency devices Permittivity tunability and loss in ferroelectrics for reconfigurable high frequency electronics Microfabrication of piezoelectric MEMS Nano patterning methods for electroceramics Soft lithography emerging techniques The book is addressed to engineers scientists and researchers of various disciplines device engineers materials engineers chemists physicists and microtechnologists who are working and or interested in this fast growing and highly promising field The publication of this book follows a Special Issue on electroceramic based MEMS that was published in the Journal of Electroceramics at the beginning of 2004 The ten invited papers of that special issue were adapted by the authors into chapters of the present book and five additional chapters were added **Nano-Engineering at Functional Interfaces for Multidisciplinary Applications** Sai Sathish Ramamurthy,Seemesh Bhaskar,Narendra Reddy,2024-10-18 Nano Engineering at Functional Interfaces for Multi disciplinary Applications Electrochemistry Photoplasmonics Antimicrobials and Anticancer Applications provides a comprehensive overview of the fundamentals and latest advances of nano engineering strategies for the design development and fabrication of novel nanostructures for different applications in the fields of photoplasmonics and electrochemistry as well as antibacterial and anticancer research areas The book begins with an introduction to the fundamentals and characteristics of nanostructured interfaces and their associated technologies including an overview of their potential applications in different fields The following chapters present a thorough discussion of the synthesis processing and characterization methods of nanomaterials with unique functionalities suitable for energy harvesting food and textile applications electrocatalysis biomedical applications and more It then concludes outlining research future directions and potential industrial applications Presents the advantages and impact of nano engineering in technological advances with up to date discussions on their applications Covers research directions and potential future applications of nano engineering in industry Includes case studies that illustrate important processes Fundamentals of Friction and Wear Enrico Gnecco,Ernst Meyer,2007-05-26 In the past twenty years powerful tools such as atomic force microscopy have made it possible to accurately investigate the phenomena of friction and wear down to the nanometer scale Readers of this book will become familiar with the concepts and techniques of nanotribology explained by an international team of scientists and engineers actively involved and with long experience in this field Edited by two pioneers in the field Fundamentals of

Frictions and Wear at the Nanoscale is suitable both as first introduction to this fascinating subject and also as a reference for researchers wishing to improve their knowledge of nanotribology and to keep up with the latest results in this field

**Atomic Force Microscopy for Energy Research** Cai Shen,2022-04-26 Atomic force microscopy AFM can be used to analyze and measure the physical properties of all kinds of materials at nanoscale in the atmosphere liquid phase and ultra high vacuum environment It has become an important tool for nanoscience research In this book the basic principles of functional AFM techniques and their applications in energy materials such as lithium ion batteries solar cells and other energy related materials are addressed FEATURES First book to focus on application of AFM for energy research Details the use of advanced AFM and addresses many types of functional AFM tools Enables readers to operate an AFM instrument successfully and to understand the data obtained Covers new achievements in AFM instruments including electrochemical strain microscopy and how AFM is being combined with other new methods such as infrared IR spectroscopy With its substantial content and logical structure Atomic Force Microscopy for Energy Research is a valuable reference for researchers in materials science chemistry and physics who are working with AFM or planning to use it in their own fields of research especially energy research **Handbook of Force Transducers** Dan Mihai Stefanescu,2011-03-16 Part I introduces the basic Principles and Methods of Force Measurement according to a classification into a dozen of force transducers types resistive inductive capacitive piezoelectric electromagnetic electrodynamic magnetoelastic galvanomagnetic Hall effect vibrating wires micro resonators acoustic and gyroscopic Two special chapters refer to force balance techniques and to combined methods in force measurement Part II discusses the Strain Gauge Force Transducers Components evolving from the classical force transducer to the digital intelligent one with the incorporation of three subsystems sensors electromechanics and informatics The elastic element EE is the heart of the force transducer and basically determines its performance A 12 type elastic element classification is proposed stretched compressed column or tube bending beam bending and or torsion shaft middle bent bar with fixed ends shear beam bending ring yoke or frame diaphragm axial stressed torus axisymmetrical and voluminous EE with emphasis on the optimum location of the strain gauges The main properties of the associated Wheatstone bridge best suited for the parametrical transducers are examined together with the appropriate electronic circuits for SGFTs The handbook fills a gap in the field of Force Measurement both experts and newcomers no matter of their particular interest finding a lot of useful and valuable subjects in the area of Force Transducers in fact it is the first specialized monograph in this inter and multidisciplinary field **Atomic Force Microscopy, Scanning Nearfield Optical Microscopy and Nanoscratching** Gerd Kaupp,2006-10-24 Making a clear distinction is made between nano and micro mechanical testing for physical reasons this monograph describes the basics and applications of the supermicroscopies AFM and SNOM and of the nanomechanical testing on rough and technical natural surfaces in the submicron range down to a lateral resolution of a few nm New or improved instrumentation new physical laws

and unforeseen new applications in all branches of natural sciences around physics chemistry mineralogy materials science biology and medicine and nanotechnology are covered as well as the sources for pitfalls and errors It outlines the handling of natural and technical samples in relation to those of flat standard samples and emphasizes new special features Pitfalls and sources of errors are clearly demonstrated as well as their efficient remedy when going from molecularly flat to rough surfaces The academic or industrial scientist learns how to apply the principles for tackling their scientific or manufacturing tasks that include roughness far away from standard samples **Lateral Alignment of Epitaxial Quantum Dots** Oliver G. Schmidt,2007-08-17 This book describes the full range of possible strategies for laterally aligning self assembled quantum dots on a substrate surface beginning with pure self ordering mechanisms and culminating with forced alignment by lithographic positioning The text addresses both short and long range ordering phenomena and introduces future high integration of single quantum dot devices on a single chip Contributions by well known experts ensure that all relevant quantum dot heterostructures are elucidated from diverse perspectives Single Molecule Chemistry and Physics Chen Wang,Chunli Bai,2006-09-22 Single molecule studies constitute a distinguishable category of focused search in nanoscience and nanotechnology This book is dedicated to the troduction of recent advances on single molecule studies It will be illustrated that studying single molecules is both intellectually and technologically ch lenging and also o ers vast potential in opening up new scienti c frontiers We wish to present the readers with several di erent techniques for studying single molecules such as electron tunneling methods interaction force m surement techniques optical spectroscopy plus a number of directions where further progress could be pursued We hope the work may assist the readers especially graduate students and those who wish to explore single molecules to become familiarized with the pace of the progress in this eld and the relevant primary techniques Due to limitation of space we are not able to elaborate on the technical details of all of the experimental methods that are vital in single molecule studies so introductions to only selected experimental methods are touched in the context Since the technical details and theoretical analysis of these techniqueshavealreadybeenthoroughlycoveredinmanyliteratures weonly provide introductions to the basic principles of the detection techniques here and focus on their experimental achievements in the area of single molecule studies These techniques have proven to be highly e ective when indep dently used The combinationof those techniques could lead to further vances in the detection capabilities Raman Spectroscopy for Nanomaterials Characterization Challa S.S.R. Kumar,2012-03-30 First volume of a 40 volume series on nanoscience and nanotechnology edited by the renowned scientist Challa S S R Kumar This handbook gives a comprehensive overview about Raman spectroscopy for the characterization of nanomaterials Modern applications and state of the art techniques are covered and make this volume essential reading for research scientists in academia and industry Nanostructures Christophe Jean Delerue,Michel Lannoo,2013-06-29 Progress in nanoscience is becoming increasingly dependent on simulation and modelling This is due to a combination of

three factors the reduced size of nano objects the increasing power of computers and the development of new theoretical methods This book represents the first attempt to provide the theoretical background needed by physicists engineers and students to simulate nanodevices semiconductor quantum dots and molecular devices It presents in a unified way the theoretical concepts the more recent semi empirical and ab initio methods and their application to experiments The topics include quantum confinement dielectric and optical properties non radiative processes defects and impurities and quantum transport This guidebook not only provides newcomers with an accessible overview requiring only basic knowledge of quantum mechanics and solid state physics but also provides active researchers with practical simulation tools

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