Micromechanics Overall Properties Of Heterogeneous Materials Second Edition North Holland Series In Applied Mathematics And Mechanics

This volume presents selected papers from the 7th International Congress on Computational Mechanics and Simulation held at IIT Mandi, India. The papers discuss the development of mathematical models representing physical phenomena and applying modern computing methods and simulations to analyse them. The studies cover recent advances in the fields of nano mechanics and biomechanics, simulations of multiscale and multiphysics problems, developments in solid mechanics and finite element method, advancements in computational fluid dynamics and transport phenomena, and applications of computational mechanics and techniques in emerging areas. The volume will be of interest to researchers and academics from civil engineering, mechanical engineering, aerospace engineering, materials engineering/science, physics, mathematics and other disciplines.

This book presents the micromechanics of random structure heterogeneous materials, a multidisciplinary research area that has experienced a revolutionary renascence at the overlap of various branches of materials science, mechanical engineering, applied mathematics, technical physics, geophysics, and biology. It demonstrates intriguing successes of unified rigorous theoretical methods of applied mathematics and statistical physics in material science of microheterogeneous media. The prediction of the behaviour of heterogeneous materials by the use of properties of constituents and their microstructure is a central problem of micromechanics. This book is the first in micromechanics where a successful effort of systematic and fundamental research of the microstructure of the wide class of heterogeneous materials of natural and synthetic nature is attempted. The uniqueness of the book lies in its development and expressive representation of statistical methods quantitatively describing random structures which are at most adopted for the forthcoming evaluation of a wide variety of macroscopic transport, electromagnetic, strength, and elastoplastic properties of heterogeneous materials.

Within the last decade, several industrialized countries have stressed the importance of advanced manufacturing to their economies. Many of these plans have highlighted the development of additive manufacturing techniques, such as 3D printing which, as of 2018, are still in their infancy. The objective is to develop superior products, produced at lower overall operational costs. For these goals to be realized, a deep understanding of the essential ingredients comprising the materials involved in additive manufacturing is needed. The combination of rigorous material modeling theories, coupled with the dramatic increase of computational power can potentially play a significant role in the analysis, control, and design of many emerging additive manufacturing processes. Specialized materials and the precise design of their properties are key factors in the processes. Specifically, particle-functionalized materials play a central role in this field, in three main regimes: (1) to enhance overall filament-based material properties, by embedding particles within a binder, which is then passed through a heating element and the deposited onto a surface, (2) to “functionalize” inks by adding particles to freely flowing solvents forming a mixture, which is then deposited onto a surface and (3) to directly deposit particles, as dry powders, onto surfaces and then to heat them with a laser, e-beam or other external source, in order to fuse them into place. The goal of these processes is primarily to build surface structures which are extremely difficult to construct using classical manufacturing methods. The objective of this monograph is introduce the readers to basic techniques which can allow them to rapidly develop and analyze particulate-based materials needed in such additive manufacturing processes. This monograph is broken into two main parts: “Continuum Method” (CM) approaches and “Discrete Element Method” (DEM) approaches. The materials associated with methods (1) and (2) are closely related types of continua (particles embedded in a continuous binder) and are treated using continuum approaches. The materials in method (3), which are of a discrete particulate character, are analyzed using discrete element methods.

This book offers over 400 never before published and rigorously refereed papers demonstrating the connections between nanoscale phenomena and the critical properties of dozens of engineered and natural materials—from polymer composites to human bone. Information is presented on new techniques for studying and quantifying the behavior of materials at nanoscale levels and linking this data to macroscale properties such as strength, fatigue, and failure points. The techniques include novel experiments and uses of instrumentation, as well as modeling and numerical methods. Virtually all the analyses in this book are offered here for the first time. They include information of value for materials investigators in defense, civil engineering, biomaterials, and transportation

This accessible text presents a unified approach of treating the microstructure and effective properties of heterogeneous media. Part I deals with the quantitative characterization of the microstructure of heterogeneous via theoretical methods; Part II treats a wide variety of effective properties of heterogeneous materials and how they are linked to the microstructure, accomplished by using rigorous methods.

From July 10th through July 13th, 1994, an informal workshop co-organized by RILEM committees 116-PCD and 123-MME was held at Saint-Remy-Ies Chevreuse, France, and attended by 38 delegates from 16 countries. Twenty-nine papers were presented, converging the general subjects of modelling micro structures and predicting durability of concrete and other cement-based materials. A short summary follows: G. M. Idom's paper entitled "Modelling Research for Concrete Engineering" serves as an introduction to the workshop, presenting an overview of modelling research with the conelusion that the broad practica1 objective is to produce high-quality concrete. This means that many characteristics, ranging from rheology to alkali-silica reaction, must be modelled. In other words, the system must be understood. Idom's paper sets the stage for papers in two general areas: 1) models and 2) transport properties. After this, abrief survey of the develop ment of microstructurally-based models is presented. A elose relationship between computer power and speed is suggested. The first group of papers on models covers the subjects of scale and resolution. Most models define and predict characteristics of the pore system, which range in scale from nanometer to millimeter. Various types ofnetworks are proposed in these papers. A good microstructural model must describe the pores and other phases at ascale appropriate to the properties that the model predicts. Also, a good model should be based on fundamental knowledge. In the case of cement-based materials, the important properties may depend on the microstructure, especially the porosity, at several scales.

Mechanical properties of composite materials can be improved by tailoring their microstructures. Optimal microstructures of composites, which ensure desired properties of composite materials, can be determined in computational experiments. The subject of this book is the computational analysis of interrelations between mechanical properties (e.g., strength, damage resistance stiffness) and microstructures of composites. The methods of mesomechanics of composites are reviewed, and applied to the modelling of the mechanical behaviour of different groups of composites. Individual chapters are devoted to the computational analysis of the microstructure- mechanical properties relationships of particle reinforced composites, functionally graded and particle clusters reinforced composites, interpenetrating phase and unidirectional fiber reinforced composites, and machining tools materials.

Presents Concepts That Can Be Used in Design, Processing, Testing, and Control of Composite Materials Introduction to the Micromechanics of Composite Materials weaves together the basic concepts, mathematical fundamentals, and formulations of micromechanics into a systemic approach for understanding and modeling the effective material behavior of composite materials. As various emerging composite materials have been increasingly used in civil, mechanical, biomedical, and materials engineering, this textbook provides students with a fundamental understanding of the mechanical behavior of composite materials and prepares them for further research and development work with new composite materials. Students will understand from reading this book: The basic concepts of micromechanics such as RVE, eigenstrain, inclusions, and in homogeneities How to master the constitutive law of general composite material How to use the tensorial indicial notation to formulate the Eshelby problem Common homogenization methods The content is organized in accordance with a rigorous course. It covers micromechanics theory, the microstructure of materials, homogenization, and constitutive models of different types of composite materials, and it enables students to interpret and predict the effective mechanical properties of existing and emerging composites through microstructure-based modeling and design. As a prerequisite, students should already understand the concepts of boundary value problems in solid mechanics. Introduction to the Micromechanics of Composite Materials is suitable for senior undergraduate and graduate students.

Multi-scale modelling of composites is a very relevant topic in composites science. This is illustrated by the numerous sessions in the recent European and International Conferences on Composite Materials, but also by the fast developments in multi-scale modelling software tools, developed by large industrial players such as Siemens (Virtual Material Characterization toolkit and MultiMechanics virtual testing software), MSC/e-Xstream (Digimat software), Simulia (micromechanics plug-in in Abaqus), HyperSizer (Multi-scale design of composites), Altair (Altair Multiscale Designer) This book is intended to be an ideal reference on the latest advances in multi-scale modelling of fibre-reinforced polymer composites, that is accessible for both (young) researchers and end users of modelling software. We target three main groups: This book aims at a complete introduction and overview of the state-of-the-art in multi-scale modelling of composites in three axes: • ranging from prediction of homogenized elastic properties to nonlinear material behaviour • ranging from geometrical models for random packing of unidirectional fibres over meso-scale geometries for textile composites to orientation tensors for short fibre composites • ranging from damage modelling of unidirectionally reinforced composites over textile composites to short fibre-reinforced composites The book covers the three most important scales in multi-scale modelling of composites: (i) micro-scale, (ii) meso-scale and (iii) macro-scale. The nano-scale and related atomistic and molecular modelling approaches are deliberately excluded, since the book wants to focus on continuum mechanics and there are already a lot of dedicated books about polymer nanocomposites. A strong focus is put on physics-based damage modelling, in the sense that the chapters devote attention to modelling the different damage mechanisms (matrix cracking, fibre/matrix debonding, delamination, fibre fracture,...) in such a way that the underlying physics of the initiation and growth of these damage modes is respected. The book also gives room to not only discuss the finite element based approaches for multi-scale modelling, but also much faster methods that are popular in industrial software, such as Mean Field Homogenization methods (based on Mori-Tanaka and Eshelby solutions) and variational methods (shear lag theory and more advanced theories). Since the book targets a wide audience, the focus is put on the most common numerical approaches that are used in multi-scale modelling. Very specialized numerical methods like peridynamics modelling, Material Point Method, eXtended Finite Element Method (XFEM), isogeometric analysis, SPH (Smoothed Particle Hydrodynamics),... are excluded. Outline of the book The book is divided in three large parts, well balanced with each a similar number of chapters:

In this, its second corrected printing, Zohdi and Wriggers' illuminating text presents a comprehensive introduction to the subject. The authors include in their scope basic homogenization theory, microstructural optimization and multifield analysis of heterogeneous materials. This volume is ideal for researchers and engineers, and can be used in a first-year course for graduate students with an interest in the computational micromechanical analysis of new materials.

Unsaturated Polyester Resins: Fundamentals, Design, Fabrication, and Applications explains the preparation, techniques and applications relating to the use of unsaturated polyester resin systems for blends, interpenetrating polymer networks (IPNs), gels, composites and nanocomposites, enabling readers to understand and utilize the improved material properties that UPRs facilitate. Chapters cover unsaturated polyester resins and their interaction at the macro, micro and nano levels, in-depth studies on the properties and analysis of UPR based materials, and the applications of UPR based composites, blends, IPNs and gels across a range of advanced commercial and industrial fields. This is a highly detailed source of information on unsaturated polyester resins, supporting academics, researchers and postgraduate students working with UPRs, polyesters, polymeric or composite materials, polymer chemistry, polymer physics, and materials science, as well as scientists, R&D professionals and engineers in industry. Covers the use of unsaturated polyester resin systems for blends, IPNs, gels, composites and nanocomposites Presents cutting-edge techniques for the analysis and improvement of properties of advanced UPR-based materials Unlocks the potential of unsaturated polyester resins in high-performance materials for a range of advanced applications

The work deals with the thermomechanical mechanical behavior of microstructured materials, which has attracted considerable interest from both the academic and the industrial research communities. The past decade has witnessed major progress in the development of analytical as well as numerical modeling approaches and of experimental methods in this field. Considerable research efforts have been aimed at obtaining microstructure-property correlations and at studying the damage and failure behavior of microstructured materials. The book combines an overview of important analytical and numerical modeling approaches in continuum micromechanics and is aimed at academic and industrial researchers, such as materials scientists, mechanical engineers, and applied physicists, who are working or planning to work in the field of mechanics of microstructured materials such as composites, metals and ceramics.

Micromechanics of Composites: Multipole Expansion Approach, Second Edition outlines substantial recent progress in the development of the multipole expansion method and focuses on its application to actual micromechanical problems. The book covers micromechanics topics such as conductivity and elasticity of particulate and fibrous composites, including those with imperfect and partially debonded interfaces, nanocomposites, cracked solids, and more. Complete analytical solutions and accurate numerical data are presented in a unified manner for the multiple inhomogeneity models of finite, semi-, and infinite heterogeneous solids. This new edition has been updated to include the theories and techniques of the multipole expansion method. Two entirely new chapters covering the conductivity and elasticity of composites with ellipsoidal inhomogeneities and anisotropic constituents have been added. A special emphasis is made on the heterogeneous solids with imperfect interfaces, including the nanoporous and nanocomposite materials. Gives a systematic account on the multipole expansion method, including its theoretical foundations, analytical and numerical techniques, and a new, dipole moment-based approach to the homogenization problem Contains detailed analytical and numerical analyses of a variety of micromechanical multiple inhomogeneity models, providing clear insight into the physical nature of the problems under study Provides a reliable theoretical framework for developing the full-field based micromechanical theories of a composite's strength, brittle/fatigue damage development, and other properties

The main goal of the book is a coherent treatment of the theory of propagation in materials of nonlinearly elastic waves of displacements, which corresponds to one modern line of development of the nonlinear theory of elastic waves. The book is divided on five basic parts: the necessary information on waves and materials; the necessary information on nonlinear theory of elasticity and elastic materials; analysis of one-dimensional nonlinear elastic waves of displacement – longitudinal, vertically and horizontally polarized transverse plane nonlinear elastic waves of displacement; analysis of one-dimensional nonlinear elastic waves of displacement – cylindrical and torsional nonlinear elastic waves of displacement; analysis of two-dimensional nonlinear elastic waves of displacement – Rayleigh and Love nonlinear elastic surface waves. The book is addressed first of all to people working in solid mechanics – from the students at an advanced undergraduate and graduate level to the scientists, professionally interesting in waves. But mechanics is understood in the broad sense, when it includes mechanical and other engineering, material science, applied mathematics and physics and so forth. The genesis of this book can be found in author's years of research and teaching while a head of department at SP Timoshenko Institute of Mechanics (National Academy of Sciences of Ukraine), a member of Center for Micro and Nanomechanics at Engineering School of University of Aberdeen (Scotland) and a professor at Physical-Mathematical Faculty of National Technical University of Ukraine "KPI". The book comprises 11 chapters. Each chapter is complemented by exercises, which can be used for the next development of the theory of nonlinear waves.

With its discussion of strategies for modeling complex materials using new numerical techniques, mainly those based on the finite element method, this monograph covers a range of topics including computational plasticity, multi-scale formulations, optimization and parameter identification, damage mechanics and nonlinear finite elements.

This book discusses recent findings and advanced theories presented at two workshops at TU Berlin in 2017 and 2018. It underlines several advantages of generalized continuum models compared to the classical Cauchy continuum, which although widely used in engineering practice, has a number of limitations, such as: • The structural size is very small. • The microstructure is complex. • The effects are localized. As such, the development of generalized continuum models is helpful and results in a better description of the behavior of structures or materials. At the same time, there are more and more experimental studies supporting the new models because the number of material parameters is higher.

This highly acclaimed series provides survey articles on the present state and future direction of research in important branches of applied mechanics

Most industrial and natural materials exhibit a macroscopic behaviour which results from the existence of microscale inhomogeneities. The influence of such inhomogeneities is commonly modelled using probabilistic methods. Most of the approaches to the evaluation of the safety of structures according to probabilistic criteria are somewhat scattered, however, and it is time to present such material in a coherent and up-to-date form. Probabilities and Materials undertakes this task, and also defines the great tasks that must be tackled in coming years. For engineers and researchers dealing with materials, geotechnics, solid mechanics, soil mechanics, statistics and stochastic processes. The expository nature of the book means that no prior knowledge of statistics or probability is required of the reader. The book can thus serve as an excellent introduction to the nature of applied statistics and stochastic modelling.

New and unpublished U.S. and international research on multifunctional, active, biobased, SHM, self-healing composites -- from nanolevel to large structures New information on modeling, design, computational engineering, manufacturing, testing Applications to aircraft, bridges, concrete, medicine, body armor, wind energy This fully searchable CD-ROM contains 135 original research papers on all phases of composite materials. The document provides cutting edge research by US, Canadian, and Japanese authorities on matrix-based and fiber composites from design to damage analysis and detection. Major divisions of the work include: Structural Health Monitoring, Multifunctional Composites, Integrated Computational Materials Engineering, Interlaminar Testing, Analysis-Shell Structures, Thermoplastic Matrices, Analysis Non-classical Laminates, Bio-Based Composites, Electrical Properties, Dynamic Behavior, Damage/Failure, Compression-Testing, Active Composites, 3D Reinforcement, Dielectric Nanocomposites, Micromechanical Analysis, Processing, CM Reinforcement for Concrete, Environmental Effects, Phase-Transforming, Molecular Modeling, Impact.

Mechanics of Time-Dependent Materials and Processes in Conventional and Multifunctional Materials represents one of eight volumes of technical papers presented at the Society for Experimental Mechanics Annual Conference on Experimental and Applied Mechanics, held at Uncasville, Connecticut, June 13-16, 2011. The full set of proceedings also includes volumes on Dynamic Behavior of Materials, Mechanics of Biological Systems and Materials; MEMS and Nanotechnology; Optical Measurements, Modeling and, Metrology; Experimental and Applied Mechanics, Thermomechanics and Infra-Red Imaging, and Engineering Applications of Residual Stress.

Demonstrates the simplicity and effectiveness of Mathematica as the solution to practical problems in composite materials. Designed for those who need to learn how micromechanical approaches can help understand the behaviour of bodies with voids, inclusions, defects, this book is perfect for readers without a programming background. Thoroughly introducing the concept of micromechanics, it helps readers assess the deformation of solids at a localized level and analyse a body with microstructures. The author approaches this analysis using the computer algebra system Mathematica, which facilitates complex index manipulations and mathematical expressions accurately. The book begins by covering the general topics of continuum mechanics such as coordinate transformations, kinematics, stress, constitutive relationship and material symmetry. Mathematica programming is also introduced with accompanying examples. In the second half of the book, an analysis of heterogeneous materials with emphasis on composites is covered. Takes a practical approach by using Mathematica, one of the most popular programmes for symbolic computation Introduces the concept of micromechanics with worked-out examples using Mathematica code for ease of understanding Logically begins with the essentials of the topic, such as kinematics and stress, before moving to more advanced areas Applications covered include the basics of continuum mechanics, Eshelby's method, analytical and semi-analytical approaches for materials with inclusions (composites) in both infinite and finite matrix media and thermal stresses for a medium with inclusions, all with Mathematica examples Features a problem and solution section on the book’s companion website, useful for students new to the programme

Here is an accurate and timely account of micromechanics, which spans materials science, mechanical engineering, applied mathematics, technical physics, geophysics, and biology. The book features rigorous and unified theoretical methods of applied mathematics and statistical physics in the material science of microheterogeneous media. Uniquely, it offers a useful demonstration of the systematic and fundamental research of the microstructure of the wide class of heterogeneous materials of natural and synthetic nature.

Phase transition phenomena in solids are of vital interest to physicists, materials scientists, and engineers who need to understand and model the mechanical behavior of solids during various kinds of phase transformations. This volume is a collection of 29 written contributions by distinguished invited speakers from 14 countries to the IUTAM Symposium on Mechanics of Martensitic Phase Transformation in Solids, the first IUTAM Symposium focusing on this topic. It contains basic theoretical and experimental aspects of the recent advances in the mechanics research of martensitic phase transformations. The main topics include microstructure and interfaces, material instability and its propagation, micromechanics approaches, interaction between plasticity and phase transformation, phase transformation in thin films, single and polycrystalline shape memory alloys, shape memory polymers, TRIP steels, etc. Due to the multidisciplinary nature of the research covered, this volume will be of interest to researchers, graduate students and engineers in the field of theoretical and applied mechanics as well as materials science and technology.

This book summarizes research advances in micromechanics modeling of ductile fractures made in the past two decades. The ultimate goal of this book is to reach manufacturing frontline designers and materials engineers by providing a user-oriented, theoretical background of micromechanics modeling. Accordingly, the book is organized in a unique way, first presenting a vigorous damage percolation model developed by the authors over the last ten years. This model overcomes almost all difficulties of the existing models and can be used to completely accommodate ductile damage developments within a single-measure microstructure frame. Related void damage criteria including nucleation, growth and coalescence are then discussed in detail: how they are improved, when and where they are used in the model, and how the model performs in comparison with the existing models. Sample forming simulations are provided to illustrate the model’s performance.

Prominent scientists present the latest achievements in computational methods and mechanics in this book. These lectures were held at the CMM 2009 conference.

A comprehensive overview is given in this book towards a fundamental understanding of the micromechanics of the overall response and failure modes of advanced materials, such as ceramics and ceramic and other composites. These advanced materials have become the focus of systematic and extensive research in recent times. The book consists of two parts. The first part reviews solids with microdefects such as cavities, cracks, and inclusions, as well as elastic composites. To render the book self-contained, the second part focuses on the fundamentals of continuum mechanics, particularly linear elasticity which forms the basis for the development of small deformation micromechanics. In Part 1, a fundamental and general framework for quantitative, rigorous analysis of the overall response and failure modes of microstructurally heterogeneous solids is systematically developed. These expressions apply to broad classes of materials with inhomogeneities and defects. While for the most part, the general framework is set within linear elasticity, the results directly translate to heterogeneous solids with rate-dependent or rate-independent inelastic constituents. This application is specifically referred to in various chapters. The general exact correlations obtained between the overall properties and the microstructure are then used together with simple models, to develop techniques for direct quantitative evaluation of the overall response which is generally described in terms of instantaneous overall moduli or compliance. The correlations among the corresponding results for a variety of problems are examined in great detail. The bounds as well as the specific results, include new observations and original developments, as well as an in-depth account of the state of the art. Part 2 focuses on Elasticity. The section on variational methods includes some new elements which should prove useful for application to advanced modeling, as well as solutions of composites and related heterogeneous bodies. A brief modern version of elements in vector and tensor algebra is provided which is particularly tailored to provide a background for the rest of this book. The data contained in this volume as Part 1 includes new results on many basic issues in micromechanics, which will be helpful to graduate students and researchers involved with rigorous physically-based modeling of overall properties of heterogeneous solids.

- self-contained and well illustrated - complete and comprehensive derivation of mechanical/mathematical results with enphasis on issues of practical importance - combines classical subjects of fracture mechanics with modern topics such as microheterogeneous materials, piezoelectric materials, thin films, damage - mechanically and mathematically clear and complete derivations of results

As multi-phase metal/alloy systems and polymer, ceramic, or metal matrix composite materials are increasingly being used in industry, the science and technology for these heterogeneous materials has advanced rapidly. By extending analytical and numerical models, engineers can analyze failure characteristics of the materials before they are integrated into the design process. Micromechanical Analysis and Multi-Scale Modeling Using the Voronoi Cell Finite Element Method addresses the key problem of multi-scale failure and deformation of materials that have complex microstructures. The book presents a comprehensive computational mechanics and materials science–based framework for multi-scale analysis. The focus is on micromechanical analysis using the Voronoi cell finite element method (VCFEM) developed by the author and his research group for the efficient and accurate modeling of materials with non-uniform heterogeneous microstructures. While the topics covered in the book encompass the macroscopic scale of structural components and the microscopic scale of constituent heterogeneities like inclusions or voids, the general framework may be extended to other scales as well. The book presents the major components of the multi-scale analysis framework in three parts. Dealing with multi-scale image analysis and characterization, the first part of the book covers 2D and 3D image-based microstructure generation and tessellation into Voronoi cells. The second part develops VCFEM for micromechanical stress and failure analysis, as well as thermal analysis, of extended microstructural regions. It examines a range of problems solved by VCFEM, from heat transfer and stress-strain analysis of elastic, elastic-plastic, and viscoplastic material microstructures to microstructural damage models including interfacial debonding and ductile failure. Establishing the multi-scale framework for heterogeneous materials with and without damage, the third part of the book discusses adaptive concurrent multi-scale analysis incorporating bottom-up and top-down modeling. Including numerical examples and a CD-ROM with VCFEM source codes and input/output files, this book is a valuable reference for researchers, engineers, and professionals involved with predicting the performance and failure of materials in structure-materials interactions.

Summary: A Generalized Multiscale Analysis Approach brings together comprehensive background information on the multiscale nature of the composite, constituent material behaviour, damage models and key techniques for multiscale modelling, as well as presenting the findings and methods, developed over a lifetime's research, of three leading experts in the field. The unified approach presented in the book for conducting multiscale analysis and design of conventional and smart composite materials is also applicable for structures with complete linear and nonlinear material behavior, with numerous applications provided to illustrate use. Modeling composite behaviour is a key challenge in research and industry; when done efficiently and reliably it can save money, decrease time to market with new innovations and prevent component failure.

This book presents new results in the knowledge and simulations for composite nano-materials. It includes selected, extended papers presented in the thematic ECCOMAS conference on Composites with Micro- and Nano-Structure (CMNS) – Computational Modelling and Experiments. It contains atomistic and continuum numerical methods and experimental validation for composite materials reinforced with particles or fibres, porous materials, homogenization and other important topics.

The book will concentrate on the application of micromechanics to the analysis of practical engineering problems. Both classical composites represented by carbon/carbon textile laminates and applications in Civil Engineering including asphalts and masonry structures will be considered. A common denominator of these considerably distinct material systems will be randomness of their internal structure. Also, owing to their complexity, all material systems will be studied on multiple scales. Since real engineering, rather than academic, problems are of the main interest, these scales will be treated independently from each other on the grounds of fully uncoupled multi-scale analysis. Attention will be limited to elastic and viscoelastic behaviour and to the linear heat transfer analysis. To achieve this, the book will address two different approaches to the homogenization of systems with random microstructures. In particular, classical averaging schemes based on the Eshelby solution of a solitary inclusion in an infinite medium represented by the Hashin-Shtrikman variational principles or by considerably simpler and more popular Mori-Tanaka method will be compared to detailed finite element simulations of a certain representative volume element (RVE) representing accommodated geometrical details of respective microstructures. These are derived by matching material statistics such as the one- and two-point probability functions of real and artificial microstructures. The latter one is termed the statistically equivalent periodic unit cell owing to the assumed periodic arrangement of reinforcements (carbon fibres, carbon fibre tows, stones or masonry bricks) in a certain matrix (carbon matrix, asphalt mastic, mortar). Other types of materials will be introduced in the form of exercises with emphases to the application of the Mori-Tanaka method in the framework of the previously mentioned uncoupled multi-scale analysis

This is the first book to introduce Green-function-based multiscale theory and the corresponding finite element method, which are readily applicable to composites and random media. The methodology is considered to be the one that most effectively tackles the uncertainty of stress propagation in complex heterogeneities of random media, and which presents multiscale theory from distinctive scale separation and scale-coupling viewpoints. Deliberately taking a multiscale perspective, it covers scale separation and then scale coupling. Both micromechanics and novel scale-coupling mechanics are described in relation to variational principles and bounds, as well as in the emerging topics on percolation and scale-coupling computation. It gives detail on the different bounds encountered, covering classical second and third order, new fourth order, and innovative ellipsoidal variations. Green-function-based multiscale theory is addressed to applications in solid mechanics and transport of complex media ranging from micro- and nano-composites, polycrystals, soils, rocks, cementitious materials, to biological materials. It is useful as a graduate textbook in civil and mechanical engineering and as a reference.

This book gives an overview of the research projects within the SFB 404 "Mehrfeldprobleme in der Kontinuumsmechanik". The book is for researchers and graduate students in applied mechanics and civil engineering.

This book presents selected topics on processing and properties of ferroelectric materials that are currently the focus of attention in scientific and technical research. Ferro-piezoelectric ceramics are key materials in devices for many applications, such as automotive, healthcare and non-destructive testing. As they are polycrystalline, non-centrosymmetric materials, their piezoelectricity is induced by the so-called poling process. This is based on the principle of polarization reversal by the action of an electric field that characterizes the ferroelectric materials. This book was born with the aim of increasing the awareness of the multifunctionality of ferroelectric materials among different communities, such as researchers, electronic engineers, end-users and manufacturers, working on and with ferro-piezoelectric ceramic materials and devices which are based on them. The initiative to write this book comes from a well-established group of researchers at the Laboratories of Ferroelectric Materials, Materials Science Institute of Madrid (ICMM-CSIC). This group has been working in different areas concerning thin films and bulk ceramic materials since the mid-1980s. It is a partner of the Network of Excellence

on Multifunctional and Integrated Piezoelectric Devices (MIND) of the EC, in which the European Institute of Piezoelectric Materials and Devices has its origin.
In concept and execution, this book covers the field of EAP with careful attention to all its key aspects and full infrastructure, including the available materials, analytical models, processing techniques, and characterization methods. In this second edition the reader is brought current on promising advances in EAP that have occurred in electric EAP, electroactive polymer gels, ionomeric polymer-metal composites, carbon nanotube actuators, and more.