

Preface

... functional composites make use of a number of underlying ideas including connectivity patterns leading to field and force concentration; the use of periodicity and scale in resonant structures; the symmetry of composite structures and its influence on physical properties; polychromatic percolation and coupled conduction paths; varistor action and other interfacial effects; sum, combination, and product properties; coupled phase transformation phenomena; and the important role that porosity and inner composites play in composite materials.

R. E. Newnham

... The essence of science: ask an impertinent question, and you are on the way to a pertinent answer.

J. Bronowski

After the well-known discoveries of piezoelectricity (1880) and ferroelectricity (1921), new active dielectric materials with a high performance have been created to meet the many demands of modern applications. Among these materials one can highlight poled ferroelectric ceramics, composites based on ferroelectrics and thin ferroelectric films. Composites based on ferroelectrics (i.e., heterogeneous materials that contain two or more components and are characterized by ferro-, piezo-, pyroelectric, and other important properties) have been manufactured and studied since the late 1970s. These materials are characterized by various electromechanical properties and a remarkable ability to convert mechanical energy into electric energy and vice versa. Due to various adaptive characteristics and possibilities to vary and tailor their properties in external fields, composite materials have been regarded as an important group of smart materials. The complex and intricate interconnections between microstructure, composition, and physical properties of the ferroelectric composites stimulates studies to predict and interpret the properties and related parameters of these materials under various conditions. These studies need a multi-disciplinary effort of specialists working in such areas as solid-state physics, physics of active dielectrics, materials science, mechanics of heterogeneous media, mechanics of electro-elastic media, mechanical engineering, computational materials science, etc. These studies are impossible without a good

physics—mathematical basis and understanding the principles of modern materials science and mechanical engineering.

This monograph is devoted to the analysis of the *microgeometry—properties—anisotropy* relations in modern piezo-active composites, and this analysis broadens the well-known materials science concepts on the *composition—structure—properties* relations. The advantages of the piezoelectric performance of the composites are discussed in the context of the orientation effects, first studied for three main connectivity patterns (2–2, 1–3, and 0–3). A link between the orientation effects and the anisotropy of effective piezoelectric coefficients and electromechanical coupling factors is also discussed in this monograph. Its novelty consists of the first systematization of many authors' results on the orientation effects, the anisotropy of the piezoelectric properties and their role in forming the considerable hydrostatic piezoelectric coefficients, electromechanical coupling factors, and other parameters in the composites based on either ferroelectric ceramics or relaxor-ferroelectric single crystals.

To the best of our knowledge, there are few monographs concerned with the piezo-active composites and their effective properties. Moreover, the orientation effects were not described in these monographs. Two monographs devoted to methods for prediction of the effective electromechanical properties for some connectivity patterns of the two-component piezo-composites were written in Russian and published in the USSR (Khoroshun LP, Maslov BP, Leshchenko PV, (1989) Prediction of Effective Properties of Piezo-active Composite Materials. Naukova Dumka, Kiev) and Russia (Sokolkin YuV, Pan'kov AA, (2003) Electroelasticity of Piezo-composites with Irregular Structures. Fizmatlit, Moscow). The third monograph (Topolov VYu, Bowen CR, (2009) Electromechanical Properties in Composites Based on Ferroelectrics. Springer, London) is concerned with the prediction of the effective properties in the two- and three-component composites, and different analytical schemes of averaging the properties of these materials having different connectivity and microgeometric characteristics are given hereby for comparison. This monograph develops ideas of the previous book (2009) and enables us to fill a gap in the description of the orientation effects in novel anisotropic piezoelectric materials. This new publication may be also characterized as an international edition written by three specialists working in adjacent areas of science and engineering.

This monograph summarizes and generalizes a series of the authors' publications on the performance and anisotropic characteristics of the two- and three-component composites based on either the traditional ferroelectric ceramics or modern relaxor-ferroelectric single crystals. This monograph has been written on the basis of the authors' research results obtained at the Southern Federal University (Russia), University of Rome "Tor Vergata" (Italy), and University of Bath (UK). The academic style of presentation of the research results and the discussion about these results indicate that the present monograph would be useful to engineers, postgraduate students, researchers, and lecturers, i.e., to many specialists working in the field of ferro-, piezoelectric, and related materials, dealing with their effective electromechanical properties and applications. This monograph

will be of benefit to all specialists looking to understand the anisotropic electromechanical properties and related parameters of the piezo-active composites. Some chapters and sections of the monograph may be a basis for a university course devoted to piezo-active materials and their electromechanical properties.

Based on our knowledge, experience, and new research results, we hope that the twenty-first century termed *The Century of New Materials and Technologies*, will lead to the fruitful development of new scientific directions in the field of modern smart materials and structures.

Rostov-on-Don, Russia
Rome, Italy
Bath, UK

Vitaly Yu. Topolov
Paolo Bisegna
Christopher R. Bowen

References

1. Khoroshun LP, Maslov BP, Leshchenko PV (1989) Prediction of effective properties of piezo-active composite materials. Naukova Dumka, Kiev (in Russian)
2. Sokolkin YuV, Pan'kov AA (2003) Electroelasticity of piezo-composites with irregular structures. Fizmatlit, Moscow (in Russian)
3. Topolov VYu, Bowen CR (2009) Electromechanical properties in composites based on ferroelectrics. Springer, London

Piezo-Active Composites

Orientation Effects and Anisotropy Factors

Topolov, V.Y.; Bisegna, P.; Bowen, C.R.

2014, XV, 169 p. 48 illus., 31 illus. in color., Hardcover

ISBN: 978-3-642-38353-3