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Piezo-Active Composites

Microgeometry–Sensitivity Relations

With 61 Figures

Springer

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To our colleagues, friends and loved ones

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

We have a paradox in the method of science. The research man may often think and work like an artist, but he has to talk like a bookkeeper, in terms of facts, figures, and logical sequences of thought.

H. D. Smyth

Composites based on ferroelectrics are heterogeneous materials that contain two or more components and are characterised by ferroelectric, piezoelectric, pyroelectric and other important properties. These materials have been manufactured and developed since the late 1970s, and their properties are the focus of attention by specialists in physics of active dielectrics, mechanics of heterogeneous media, piezoelectric materials science, etc. The composites in the poled state exhibit a remarkable ability to convert mechanical energy into electric energy and vice versa as a result of the electromechanical coupling and piezoelectric effect. Due to various adaptive characteristics and possibilities to vary and tailor their properties under the application of external electric and/or mechanical fields, these composites are often regarded as an important group of smart materials [1, 2]. The studies on their properties and other characteristics require a multidisciplinary effort of specialists and are impossible without a good physics-mathematical basis and understanding of the classical *composition–structure–properties* relations.

The aim of the present monograph is to describe and discuss the relations between the microgeometry and piezoelectric sensitivity of composites based on either ferroelectric ceramics or single crystals. In this monograph, we develop the

materials science concepts on the *composition–structure–properties* relations in the piezo-active composites and the analytical approach [1, 2] to show different "faces" of the piezoelectric sensitivity. Links between the microgeometry and piezoelectric properties of the composites are, as a rule, intricate [1–5], however one can reveal and describe the main factors and microgeometric features that influence the piezoelectric sensitivity at specific connectivity patterns. Despite a large number of the connectivity patterns [1, 2] related to the two- and three-component composites, one can mention a few composite types (2–2, 1–3, 0–3, and 3–3) that have been under intensive study in the last decades. Some advantages of the piezoelectric sensitivity are first discussed in the context of the piezoelectric coefficients of four types (d_{ij}^*, e_{ij}^*, g_{ij}^*, and h_{ij}^*). As is known, these parameters are used to fully describe links between mechanical and electric fields in piezoelectric media [6]. In keeping with modern trends in materials science and engineering, numerous examples of the piezoelectric sensitivity are analysed and compared, and these examples are also of value for potential piezotechnical (sensors, actuators and transducers), energy-harvesting, hydroacoustic and other applications. The novelty of the present monograph consists in the first systematisation of many authors' results on the piezoelectric sensitivity and microgeometric features of modern composites based ferroelectrics, and links between the microgeometry and piezoelectric sensitivity for a series of two- and three-component composites form the mainstream of this scientific work. Hereby, we remember the following phrase: "Science answers the question why, and art the question why not" (Sol Le Witt).

Answering the question why in the present monograph, we fill a gap in the description of the piezoelectric performance of modern anisotropic composites characterised by various microgeometric and symmetry features. This new work represents an international edition written by three specialists working in adjacent areas of science and engineering, in the areas where the piezo-active composites are of academic interest and importance for applications.

The monograph has been written on the basis of the authors' research results obtained at the Southern Federal University (Russia), University of Bath (UK) and University of Rome Tor Vergata (Italy). 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 heterogeneous ferroelectric, piezoelectric and related materials, studying and improving their effective properties for specific applications and so on. The present monograph will be of benefit to all specialists looking to understand the important links between the microgeometric and sensitivity characteristics of the modern piezo-active composites. Some chapters and sections of the monograph may be a basis for a university course devoted to composites based on ferroelectrics, their properties and potential applications.

Based on our knowledge, experience and 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 advanced composite materials.

Rostov-on-Don, Russia — Prof. Dr. Vitaly Yu. Topolov
Bath, UK — Prof. Dr. Christopher R. Bowen
Rome, Italy — Prof. Dr. Paolo Bisegna

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