Piezoelectricity — a phenomenon of the direct conversion of electrical and mechanical energy — has been discovered by Pierre and Jacques Curie about 135 years ago. Since that time, it is an excellent example of coupled field phenomena in physics. It attracted a lot of interest from the application point of view not only in its static (or quasistatic) form, but also in the properties of mechanically resonating bodies excited piezoelectrically, i.e. piezoelectric resonators. Such elements are nowadays used as resonant sensors, in electronic circuits, acoustical systems, actuators and ultrasonic motors or in energy harvesting devices. Piezoelectric resonators were treated in the literature as you can see from the comprehensive, although not exhaustive, list of books published within the last three decades. Although many literature sources cover various aspects of piezoelectric resonators and their applications, the fundamental literature is more than five decades old. Comprehensive textbook covering all fundamental properties of piezoelectric resonators for ceramic materials is not easily available. Specialized monography published on piezoelectric resonators — J. Zelenka: Piezoelectric resonators and their applications, Elsevier, Amsterdam 1986 — is also 30 years old already. Moreover, it is devoted specifically to quartz resonators, but not to piezoelectric resonators made from ferroelectric ceramics.

The authors would like to bridge this gap in specialized literature by this textbook focused specifically on the fundamentals of piezoelectric resonators based on crystallographically highly symmetrical material, i.e., ferroelectric ceramics. Its piezoelectricity is a result of material anisotropy imposed by poling in ceramic material. We can profit from the basic piezoelectricity and ferroelectricity phenomena explanations and descriptions published in the previous book — J. Tichý, J. Erhart, E. Kittinger, J. Přívratská: Fundamentals of piezoelectric sensorics: Mechanical, dielectric, and thermodynamical properties of piezoelectric materials, Springer Verlag, Berlin, Heidelberg 2010. Therefore we can recommend this book for the basic reading on piezoelectricity phenomena and materials and to cover and explain piezoelectric ceramic resonators only. The textbook and the above-mentioned book are complementary in this sense. Piezoelectricity phenomena and
materials are also briefly treated in the textbook, but with simplifications and an emphasis on ceramic materials. Description of tensors, crystallographic symmetry and coupled field thermodynamics is however referenced to some of the specialized books. Linear piezoelectricity is used for all resonators and their property derivations. The textbook could help the reader not only in finding answers to the resonance parameters of piezoelectric ceramic resonators in comprehensive tables, but also to profit from the detailed derivations for each resonator and to learn methods useful in reader’s own research. The textbook is based mainly on authors’ experience with piezoelectric resonator research and teaching gained at the Piezoelectricity Research Laboratory at the Technical University of Liberec. Literature sources dealing with piezoelectric resonators are carefully reviewed, although fully exhaustive list of all applications and resonator types could not be included. We therefore limited this textbook to the basic resonator shapes and vibration modes, and application of resonators for the material property measurement and the piezoelectric transformer modeling, which two of the authors (J.E. and P.P.) studied theoretically as well as experimentally during last decade. List of references related to piezoelectric resonators is provided for the reader’s convenience.

Authors completed the manuscript according to their own specialization in the field of piezoelectric resonators — i.e. J. Erhart prepared Chaps. 1, 2, 4, 5 (together with P. Půlpán) and Appendix A, M. Pustka completed Chap. 3 (with examples of measured resonators prepared by J. Erhart), Appendices B, C, D and prepared drawings of resonator figures and schemes. Finally, P. Půlpán contributed to Chap. 5 and edited all graphs for the manuscript. Final edition of the whole manuscript was prepared by all authors in cooperation.

Textbook content is organized in five chapters and four Appendices. Chap. 1 is devoted to the fundamentals of piezoelectricity, history of the phenomenon discovery, its basic description by tensors, crystallography and thermodynamics of coupled fields. Properties of the main piezoelectric ceramic materials are briefly reviewed in Chap. 2, serving also as the property tables for the reader’s own material application research. An example of mechanically textured ceramic material and related calculation of the effective symmetry is included. Chap. 3 is focused on the properties of piezoelectric resonators in detailed derivations. General method of immittance (i.e. impedance or admittance) complex function is presented and applied for each calculated resonator. Resonators in the form of bars, plates, discs, rings or tubes are described for various vibration modes. Immittance and equivalent electrical circuit parameters are derived for each resonator. Comprehensive table of all calculated resonators is given for the reader’s convenience in Appendix D. The applications of piezoelectric resonators for the material property measurement according to piezoelectric standard procedures are presented in Chap. 4. The resonators needed to measure all coefficients for full tensors of electromechanical properties are covered including Poisson’s ratio measurement and experimental error analysis. Chapter 4 is completed by derivations of thermal stability for the resonance frequency for bar, plate or disc shaped resonators. Finally, Chapter 5 serves as an example of piezoelectric ceramic resonator
application in more advanced structures — piezoelectric transformers. It describes mathematical modeling for the various shapes of piezoelectric transformers working in different vibration modes (bar, plate, disc and ring) by immittance method. Numerical examples of transformer parameter optimization are included, experimental data are however referenced to the previously published literature only. Appendices A, B and C contain material tensors and equations in Cartesian or cylindrical coordinates, respectively.

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