Preface

This book is a natural continuation of the author's two previous books: "*An Introduction to the Theory of Piezoelectricity*" (Springer, New York, 2005) and "*The Mechanics of Piezoelectric Structures*" (World Scientific, New Jersey, 2006), which discuss the three-dimensional exact theories for piezoelectric materials and various two-, one- and zero-dimensional approximate theories for piezoelectric structures. The development of these theories was strongly influenced by the need for analyzing piezoelectric devices.

Piezoelectric materials are widely used to make various devices including transducers for converting electrical energy to mechanical energy or vice-versa, sensors, actuators, and resonators and filters for telecommunication, control and time-keeping. A few piezoelectric devices were analyzed in the above two books as examples. The present book attempts to present a systematic treatment of piezoelectric devices. However, there are many piezoelectric devices, and it is impossible to cover all of them in a single book. The present book is limited by the research of the author.

In the analysis of piezoelectric devices, very few exact solutions from the three-dimensional equations can be obtained. Numerical methods are usually needed. Another method to simplify the problems so that theoretical analyses are possible is to use lower-dimensional structural theories of plates, shells, and rods. These two approaches are both very useful in the modeling and design of piezoelectric devices; however, the author's personal experience is more on the structural side.

This book is mainly on resonant piezoelectric devices operating at a particular resonant frequency and mode of a structure. Both surface acoustic waves (SAW) and bulk acoustic waves (BAW) have been used for devices. The book is mainly on BAW devices.

Following a brief summary of the three-dimensional theories of electroelastic bodies in the first chapter, two chapters are spent on plate thickness-shear resonators. Mass sensors, fluid sensors, angular rate sensors (gyroscopes), acceleration sensors, pressure sensors, and temperature sensors are discussed in the subsequent chapters. These devices are mostly based on frequency shifts in resonators, except that for gyroscopes where angular rate induced charge, current and/or voltage are also discussed in addition to frequency shifts.

The remaining chapters are on power handling devices. These include piezoelectric generators, transformers, energy transmission through an elastic wall by acoustic waves, and acoustic wave amplifiers made from piezoelectric semiconductors.

The linear theory of piezoelectricity is sufficient for most of these devices, except that the linear theory for small fields superposed on a bias is necessary for the acceleration sensors, pressure sensors, and temperature sensors discussed in this book. The theory for small fields superposed on a bias is a consequence of the nonlinear theory, and the nonlinear theory of electroelasticity itself is employed only in a few scattered problems.

The book is strongly influenced by the author's own research. No effort is made on literature review. However, review articles known to the author on various subjects treated in this book are provided as references.

Due to the use of quite a few stress tensors and electric fields in nonlinear electroelasticity, a list of notations is provided in Appendix 1. Material constants of some common piezoelectric materials, especially those used in this book, are given in Appendix 2.

I would like to take this opportunity to thank Ms. Michelle Sitorius of the College of Engineering at UNL for her editing assistance with the book, Professor Ji Wang of Ninbo University for Figs. 3.10.2, 3.10.4, 3.11.2 and 3.11.4, and Mr. Xuechun Shen, a graduate student of the Department of Engineering Mechanics at UNL, for Figs. 2.6.2 through 2.6.7, and 3.6.2.

JSY
Lincoln, Nebraska
February, 2006