General Introduction

The piezoelectric effect was discovered by the Curie brothers in 1880. Since then, many applications have come into being: time base, precision actuators, sonar, echographic probe and, more recently, radio-frequency filters for mobile phones. This field is set to be further developed because of the growing need for actuators and sensors of all sorts, especially for communication and healthcare. Piezoelectricity is very well adapted to these fields as it links the electrical or electronic world to the mechanical world in a linear manner. This is why mastering good piezoelectric materials is fundamental for developing these applications. In the microsystems framework, great advances in thin-film piezoelectric materials have been achieved since the middle of the 1990s. Lead zirconate titanate ($Pb(Zr,Ti)O_3$ called PZT) and aluminum nitride (AlN) are, today, the spearheads of these thin-film materials, as we will see in detail in this book.

This book begins with a chapter that endeavors to specify the microscopic properties of dielectrics: ferroelectricity, piezoelectricity, pyroelectricity and electrostriction. Certain notions of crystallography are taken up, since the crystalline nature of matter produces a good part of these properties.

Chapter 2 is devoted to thermodynamic notions indispensable for the precise description of the state of equilibrium and energy exchanges. It is this approach that enables us to define electromechanical coupling.

Next, we take on the description of paraelectric-ferroelectric phase transition, which is very useful for describing the piezoelectrics of ferroelectric nature, such as those of the perovskite family (PZT, for example).

Chapter 4 is dedicated to the study of stress-strain relations, indispensable for putting the piezoelectric effect in the form of an equation.

Chapter 5 describes dielectric materials by adding stresses to the main fields, such as electric displacement. The notion of dielectric relaxation is also taken up. Once these bases have been expanded on, we go into detail about the piezoelectric formalism in a macroscopic but also microscopic way, even if the latter is less useful for applications in Chapter 6.

Chapter 7 is a rather detailed exposition on the acoustic formalism adapted to piezoelectric films. Acoustic filters and the main applications of acoustic resonators are also approached from an analytical angle.

Chapter 8 is dedicated to electrostrictive nonlinear effect, less well-known, but very important for describing the piezoelectric linear effect of perovskites and increasingly used in applications.

The next chapter endeavors to describe the principle means of electric characterizations of these piezoelectric films: macroscopic then local piezoelectric measurements, ferroelectric, dielectric measurement and finally, leakage current measurement.

Next we move on to the application chapters. Chapter 10 is reserved for resonators and filters that use piezoelectric thin films. This application is currently the most beautiful industrial piezoelectric film success. Chapter 11, most of all, is devoted to electrostrictive thin films used for variable frequency resonators. Although this solution is not yet industrially exploited, it constitutes a real alternative for the future. Chapter 12 discusses electrostrictive resonators. The last chapter describes some thin-film piezoelectric transducers, after having given a few figures of merit essential for choosing materials depending on the function of the target applications.