1 Fundamentals of Piezoelectricity

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1.1 Introduction

The topic of the following chapter is relatively difficult and includes different areas of knowledge. The piezoelectric phenomenon is a complex one and covers concepts of electronics as well as most of the areas of classical physics such as: mechanics, elasticity and strength of materials, thermodynamics, acoustics, wave's propagation, optics, electrostatics, fluids dynamics, circuit theory, crystallography etc. Probably, only a few disciplines of engineering and science need to be so familiar to so many fields of physics. Current bibliography on this subject is vast though dispersed in research publications, and few of the books on this topic are usually compilations of the authors' research works. Therefore, they are not thought for didactic purposes and are difficult to understand, even for postgraduates. The objective of this chapter is to help understand the studies and research on piezoelectric sensors and transducers, and their applications. Considering the multidisciplinary nature, this tutorial's readers can belong to very different disciplines. They can even lack the necessary basic knowledge to understand the concepts of this chapter. This is why the chapter starts providing an overview of the piezoelectric phenomenon, doing consciously initial simplifications, so that the main concepts, which will be progressively introduced, prevail over the accessories. The issues covered in this chapter must be understood without the help of additional texts, which are typically included as references and are necessary to study in depth specific topics. Finally, the quartz crystal is introduced as a micro-gravimetric sensor to present the reader an application of the piezoelectric phenomenon, which will be dealt with along the following chapters.

A.A. Vives (ed.), *Piezoelectric Transducers and Applications*, doi: 10.1007/978-3-540-77508-9_1,

1.2 The Piezoelectric Effect

The word *Piezoelectricity* comes from Greek and means "electricity by pressure" (*Piezo* means pressure in Greek). This name was proposed by Hankel [1] in 1881 to name the phenomenon discovered a year before by the Pierre and Jacques Curie brothers [2]. They observed that positive and negative charges appeared on several parts of the crystal surfaces when comprising the crystal in different directions, previously analysed according to its symmetry.

Figure 1.1a shows a simple molecular model; it explains the generating of an electric charge as the result of a force exerted on the material. Before subjecting the material to some external stress, the gravity centres of the negative and positive charges of each molecule coincide. Therefore, the external effects of the negative and positive charges are reciprocally cancelled. As a result, an electrically neutral molecule appears. When exerting some pressure on the material, its internal reticular structure can be deformed, causing the separation of the positive and negative gravity centres of the molecules and generating little dipoles (Fig. 1.1b). The facing poles inside the material are mutually cancelled and a distribution of a linked charge appears in the material's surfaces (Fig. 1.1c). That is to say, the material is polarized. This polarization generates an electric field and can be used to transform the mechanical energy used in the material's deformation into electrical energy.

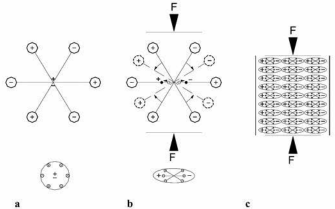

Fig. 1.1. Simple molecular model for explaining the piezoelectric effect: **a** unperturbed molecule; **b** molecule subjected to an external force, and ***c*** polarizing effect on the material surfaces