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Study on the Principle and Application of Piezoelectric Ceramics Energy Supply Technology

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ABSTRACT

Piezoelectric ceramic power generation technology to meet the requirements of environmental self-adaptive power supply. It has a long life, pollution-free, maintenance-free advantages, a broad application prospects. This paper analyzes the principle of piezoelectric effect, the advantages and disadvantages of common piezoelectric ceramics, and expounds the factors that affect the performance of piezoelectric ceramics. Through the analysis of the energy supply technology of piezoelectric ceramics, the future development direction and hot issues are summarized

1. Introduction

Piezoelectric ceramics is a kind of piezoelectric ceramic material with piezoelectric properties. The main difference from the typical piezoelectric quartz crystals that do not contain ferroelectric components is that the crystalline phases that make up their main constituents are ferritic grains. Since the ceramics are randomly oriented polycrystalline aggregates, the spontaneous polarization vectors of the individual ferroelectric grains are also chaotic. In order for the ceramic to exhibit a macroscopic piezoelectric characteristic, it must be polished after the piezoelectric ceramic is fired and placed at the end face of the counter electrode, under a strong DC electric field, so that the original chaotic orientation of the respective poles the orientation of the vector in the direction of the electric field is preferred. After the polarization of the piezoelectric ceramic, after the abolition of the electric field, will retain a certain degree of macroscopic residual polarization, so that the ceramic has a certain piezoelectric property [1]. When the piezoelectric element under the action of external deformation occurs, will cause the material inside and outside the positive and negative charge center occurs relative movement and produce electrical polarization, resulting in the two components on the surface of different charges. This is not the role of electric field, but because of the deformation of the polarization phenomenon known as the positive piezoelectric effect. When the stress is not too large, the polarization effect produced by the piezoelectric effect is linearly related to the stress.

$$P = d \cdot X \quad (1)$$

Where X is the stress, d is the piezoelectric strain constant, and P is the polarization intensity.

On the other hand, when an electric field is applied to the piezoelectric crystal, not only the polarization is generated but also the deformation is generated. This phenomenon of deformation caused by the electric field is called the inverse piezoelectric effect. When the electric field is not very strong, the strain is linearly related to the external electric field.

$$x = d \cdot E \quad (2)$$

Where x is the strain and E is the electric field.

If the ceramic sheet is added with a pressure F parallel to the direction of polarization, as shown in Figure 1, the ceramic sheet will produce a compression deformation (broken line in the figure), the distance between the positive and negative bound charges in the film becomes smaller [2]. Strength also becomes smaller. Therefore, the original charge on the electrode free charge, a part of the release, and the discharge phenomenon. When the pressure is removed, the ceramic pieces are restored (this is an expansion process). At this time, the distance between the positive and negative charges of the film becomes large and the polarization intensity becomes large, so that a part of the charge is adsorbed on the electrode and the charging phenomenon occurs. This is a mechanical effect into an electrical effect, or from the mechanical energy into electricity phenomenon, is the positive piezoelectric effect.

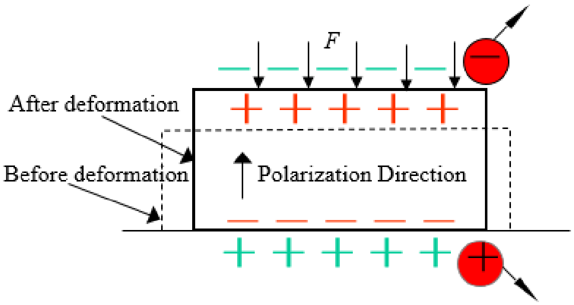

Figure 1: Positive piezoelectric effect diagram

Likewise, if an additional electric field is added to the ceramic sheet as in the direction of polarization, as shown in Figure 2. Since the direction of the electric field is the same as the direction of the polarization intensity, the effect of the electric field increases the polarization intensity. At this time, the distance between the positive and negative charge in the ceramic sheet is also increased, that is, the ceramic sheet is elongated in the direction of polarization (dotted line in the figure). Similarly, if the direction of the applied electric field is opposite to the direction of polarization, the ceramic sheet is deformed in the direction of polarization. This is due to electrical effects into mechanical effects or from electrical energy into mechanical energy phenomenon, is the negative piezoelectric effect.

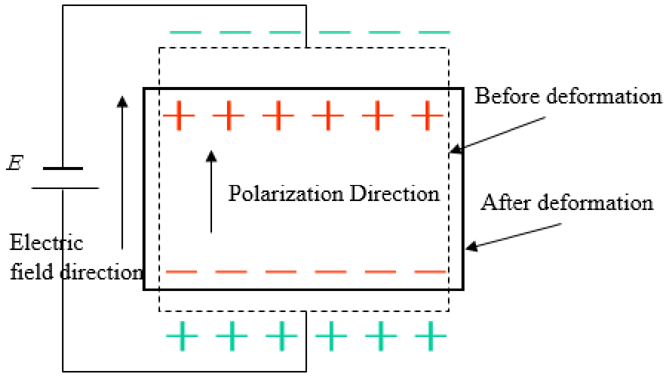

Figure 2: nverse piezoelectric effect diagram

Polarization of the piezoelectric crystal in the direction perpendicular to the polarization of the two surfaces there is bound charge, due to the adsorption of the outside world of different charges, and therefore not significant external electricity. As shown in Figure 1, when a force F parallel to the direction of polarization is applied to the piezoelectric crystal, the crystal will undergo compression and deformation (dotted lines in the figure), and the positive and negative constraints within the crystal.

The distance between the charge will be reduced and the polarization intensity will be reduced. At this time, the free charge part adsorbed on the crystal surface will be released. This is the discharge phenomenon. When the external force is removed, the crystal returns to the original state, The distance between the charge increases, the polarization intensity will increase, which also absorb part of the external free charge, which is charging phenomenon, when there is a wire connected, the wire will have a current. As shown in Figure 2, an electric field E parallel to the direction of polarization is applied to the piezoelectric crystal. Since the direction of the electric field is the same as the direction of the polarization intensity, the polarization intensity is increased so that the crystal appears in the direction of polarization In the figure, when the direction of the electric field is opposite to the direction of polarization, the crystal will produce compression deformation.

2. COMMONLY USED PIEZOELECTRIC MATERIALS

Piezoelectric ceramics, piezoelectric composites, piezoelectric composites, glass ceramics and relaxation electric single crystal, among which piezoelectric ceramics have excellent piezoelectricity, piezoelectric ceramics, piezoelectric ceramics, piezoelectric ceramics, Performance, application is also the most extensive. The At present, the piezoelectric materials widely used in energy collection are piezoelectric ceramics and piezoelectric polymers, mainly based on piezoelectric ceramic lead zirconate titanate and polyphenylene fluoride (PVDF) Although the two types of materials have power generation characteristics, but the performance of these two types of materials are quite different.

Piezoelectric ceramic material Lead zirconate titanate has the characteristics of fast frequency response, high efficiency of electromechanical energy conversion, high voltage-to-pressure ratio, light weight, no noise, easy to make all kinds of variable-demand supporting structure, High pressure breakdown, high temperature, anti-electromagnetic interference, in the ultrasound, salt spray, shock, vibration and other harsh environments to work properly, in addition to piezoelectric ceramic materials, low cost, suitable for large-scale promotion and application. But the piezoelectric ceramic material also has shortcomings, first of its high internal impedance caused by the output power is small, only for low power, low current, high voltage electronic devices; followed by the piezoelectric material brittle, cannot significantly bend, Which is limited in the design of the substrate for the displacement support structure used to support the piezoelectric material. Piezoelectric ceramic materials after decades of in-depth study, has made great progress, is one of the important functional materials, its development trend is mainly reflected in low-temperature sintering ceramic materials, new technology and new technology development, multi-functional The use of ferroelectric ceramics, lead-free piezoelectric ceramic materials, Nano-ceramic, transparent ceramics and other new ceramic materials research and application.

3. ANALYSIS OF INFLUENCING FACTORS OF PIEZOELECTRIC PROPERTIES

When the external exciting force is applied to the piezoelectric material, the piezoelectric energy supply means generates the charge and the voltage by the positive piezoelectric effect. Thus, the operational performance of the piezoelectric energy supply device is directly dependent on the piezoelectric properties of the piezoelectric material [3]. According to the different needs of the use of piezoelectric materials, the performance requirements are not the same. Electromechanical coupling coefficient, mechanical quality factor, relative dielectric constant, piezoelectric strain constant, piezoelectric voltage constant and other performance parameters can usually be used to characterize the performance of piezoelectric materials.

a. Electromechanical coupling coefficient

Under the action of external exciting force, the piezoelectric material converts the vibrating mechanical energy (or electric energy) into electrical energy (or vibration mechanical energy). The degree of energy conversion can be expressed by the electromechanical coupling coefficient K. It is a measure of piezoelectric material conversion performance of an important reference value.

$$K2 = \frac{\text{Mechanical energy conversion}}{\text{Enter the mechanical energy}} \tag{3}$$

Kp is the ability of piezoelectric materials to carry out mechanical energy - energy conversion. It is related to the piezoelectric coefficient, ε and elastic constant of the material, which is a more comprehensive parameter.

The electromechanical coupling coefficient reflects the conversion efficiency between the mechanical energy and the electric energy. Since the conversion cannot be complete, there is always a part of the energy that is lost in the form of heat energy, sound waves or the like, and K is always less than 1. Electromechanical coupling coefficient K according to the different ways of work, generally between 0.3-0.7. The size of the K value is mainly determined by the type of piezoelectric material, but it is also affected by the working environment, the supporting mode of the piezoelectric vibrator, the size and structure of the piezoelectric material. Electromechanical coupling coefficient reflects the comprehensive performance of piezoelectric materials. In general, when the piezoelectric material is used in a different working environment, the developer is required to select the appropriate electromechanical coupling coefficient, and the K value is usually as high as possible.

b. Quality factor

The ratio of the mechanical energy stored in the resonant material to the mechanical energy loss in a vibration cycle is called the mechanical quality factor, and the cause is the presence of internal friction. It is a dimensionless physical quantity. The mechanical quality factor Q is used to indicate how much energy the piezoelectric element consumes due to the internal damping effect during vibration. The piezoelectric material does not only overcome the internal mechanical frictional losses during the vibration process, but also overcomes the loss of external loads.

$$Q_m = 2\pi \frac{\text{Vibrator storage of mechanical energy}}{\text{The energy consumed by the vibrator}} \tag{4}$$

The mechanical quality factor can be calculated from the equivalent circuit.

$$Q_m = \frac{1}{C_1 W_S R_1} \tag{5}$$

Where R_1 is the equivalent resistance, W_s is the series resonant frequency, and C_1 is the equivalent capacitance when the resonator resonates.

The presence of the mechanical quality factor Q indicates that it is not possible for any piezoelectric material to convert the external input mechanical energy into electrical energy. The smaller the mechanical quality factor, the greater the mechanical damping, the more easy the components heat, the greater the energy loss.

c. Piezoelectric voltage constant

The piezoelectric voltage constant g reflects the relationship between the electric potential generated by the strain and the electric field generated by the stress.

d. Frequency constants

Frequency constants are usually selected piezoelectric ceramic important parameters, the value is equal to the size and resonant frequency of the product. In the external electric field, the piezoelectric element will produce different deformation and vibration frequency, when the two frequencies are equal, the piezoelectric element of the mechanical deformation of the largest, the largest output mechanical energy; the other hand, when the external vibration, the piezoelectric components in the resonance Frequency with the largest power output.

4. CONCLUSIONS

Piezoelectric power supply has the unique characteristics which other traditional power supply does not have. The research of piezoelectric power generation technology has been paid more and more attention. Through the principle of piezoelectric effect, the advantages and disadvantages of common piezoelectric ceramics are expounded. Performance factors, as well as the piezoelectric ceramic energy supply technology for the analysis of the late to do the foundation.

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