Description

1. Field of the Invention

The present invention relates to a piezoelectric vibration component, specifically a piezoelectric vibration component which uses an energy trapped type thickness slip vibration mode. Furthermore, a piezoelectric vibration component according to the present invention can be used as a piezoelectric trap, a piezoelectric filter, a piezoelectric discriminator, or a piezoelectric oscillator.

2. Description of the Prior Art

From Japanese Journal of Applied Physics/Supplement vol. 26, Supplement 26-1, 1987, pages 107 - 149, Tokyo, Japan; T. Inoue and al.: "Trapped-energy piezoelectric ceramic resonators and filters with internal electrodes" a piezo-vibrator is known which operates in a thickness slip vibration mode.

From Patent Abstracts of Japan, vol. 9, No. 248 (E-360) (1971), 4th Oktober 1985; & JP-A-60 134 618 of 17-07-1985 a thickness shear vibrator is known, in which the polarization axis may have different angles with respect to the long axis of its rectangular shape.

Fig. 8 shows a piezoelectric trap element which is one conventional example of a member of a piezoelectric vibration component. Piezoelectric substrate 21 is formed into a rectangular shape from a ceramic or other piezoelectric material. The substrate is processed so that the direction of polarization axis P is parallel to the long side of the piezoelectric substrate 21. Furthermore, a vibrating electrode member 22 and a terminal member 23 are formed by vapor deposition, sputtering, or other thin film formation technique on the front and back surfaces of piezoelectric substrate 21. With this piezoelectric vibration element D, energy trap-type thickness slip vibrations are set up in piezoelectric substrate 21 when an alternating current signal is applied to vibrating electrode member 22. The resonance frequency fo of these vibrations is determined by the thickness of the piezoelectric substrate 21, the mass of the vibrating electrode member 22, and other factors.

Moreover, this piezoelectric vibration element D forms piezoelectric vibration member 26 (Fig. 9) when a lead terminal (not shown in the figures) is soldered to terminal member 23, and packaging resin layer 24 is formed around piezoelectric vibration element D by an epoxy resin or other packaging resin. Therefore, as shown in Fig. 9, piezoelectric substrate 21 is held firmly at a position inside packaging resin layer 24, and a hollow vibration space 25 is formed between packaging resin layer 24 and vibrating electrode member 22 so that the vibrations in vibrating electrode member 22 are not damped by packaging resin layer 24.

Because piezoelectric vibration element D is thus covered by packaging resin layer 24 to form piezoelectric vibration member 26, clamping stress from packaging resin layer 24 may be applied, and thermal stress between packaging resin layer 24 and piezoelectric substrate 21 may occur due to the difference in the coefficients of thermal expansion of packaging resin layer 24 and piezoelectric substrate 21, or to changes in the operating temperature. If stress F is applied, due to one of these factors, in the clamping direction to piezoelectric substrate 21, a change (shift) from the design value will occur in resonance frequency fo as indicated by A in Fig. 4. Thus, the greater stress F becomes, the greater becomes the change Δ-f in the resonance frequency. Possible reasons for this include the following. Specifically, due to contraction deformation in the length and width directions of piezoelectric substrate 21 caused by stress F, elongation deformation in the thickness direction of piezoelectric substrate 21 arises at vibrating electrode member 22 enclosed within vibration space 25. Thus, the frequency of the standing wave occurring in the thickness direction of piezoelectric substrate 21 in vibrating electrode member 22 decreases, and it may be concluded that as the result the frequency of the wave propagated in the lengthwise direction increases.

Therefore, in a conventional piezoelectric vibration component, when stress is applied to the piezoelectric substrate from the external resin layer, a large change proportional to the resonance frequency will occur which decreases the reliability of the piezoelectric vibration component. In particular, because a change in the resonance frequency occurs due to the thermal stress accompanying a temperature change, there have been problems in the thermal characteristics of piezoelectric vibration components. To resolve these problems in conventional components, research has been advanced in the development of new piezoelectric materials characterized by minimal change in the resonance frequency, and in the development of suitable packaging resins to achieve a minimal difference in the coefficients of thermal expansion between the piezoelectric substrate and the packaging material.

The present invention has as its objective to reduce the change in the resonance frequency produced in conjunction with temperature changes, and improve the characteristics of the piezoelectric vibration component.

To this end, we inventors prepared various piezoelectric vibration elements using a piezoelectric substrate processed with the polarity aligned in the lengthwise direction and in which the length of the long side and short side of the piezoelectric substrate was changed. A compression stress was applied to these various piezoelectric vibration element materials, and the change in the resonance frequency at

that time was measured. As a result of these measurements, it was found that the rate of change of the resonance frequency to stress (the tangent of lines A and B in Fig. 4) increased proportionally to the length of the long side of the piezoelectric substrate. However, piezoelectric vibration elements have already been reduced as much as possible in size due to the demand for the micronization of components, and there is a limit to how much the length of the piezoelectric substrate can be reduced due to the dimensions of the vibration electrode member and other technological restrictions. Therefore, we further extended the scope of our experiments and manufactured a piezoelectric vibration element in which the polarization axis is parallel for all intents and purposes to the short side of the piezoelectric substrate (in a conventional piezoelectric vibration element, the direction of the polarization axis is parallel to the long side of the substrate). These samples were then used in tests in which the amount of compression stress applied to the piezoelectric substrate was varied and the resonance frequency was measured, and it was found that the change in the resonance frequency was small.

A comparison of the change in the resonance frequency of piezoelectric vibration elements of the same dimensions when the polarization axis is parallel to the long side and when parallel to the short side is shown in the graph of Fig. 4. The x-axis is the stress applied in the clamping direction, and the y-axis shows the change in resonance frequency. Line A represents the piezoelectric vibration element in which the polarization axis is parallel to the long side of the piezoelectric substrate, and B represents the piezoelectric vibration element in which the polarization axis is parallel to the short side of the piezoelectric substrate. As is obvious from the graph, the change (and the rate of change) in the resonance frequency is significantly less in a piezoelectric vibration element with the polarization axis parallel to the short side of the piezoelectric substrate than in a piezoelectric vibration element in which the polarization axis is parallel to the long side of the piezoelectric substrate.

From the above experiments, we came to a conclusion that the change in the resonance frequency can be more efficiently reduced not by shortening the length of the long side of the piezoelectric substrate, but by actually reducing the dimension of the piezoelectric substrate in the direction of the polarization axis.

SUMMARY OF THE INVENTION

A piezoelectric vibration component according to the present invention is an energy trapped type, thickness slip vibration mode piezoelectric vibration component comprising vibration electrode members on the front and back surfaces of a piezoelectric substrate having long and short sides, and characterized by the alignment of the polarization axis in the direction of the short side of said piezoelectric substrate.

In the present invention, because the polarization axis of the piezoelectric substrate is aligned more with the short side than with the long side of the piezoelectric substrate, the length of the piezoelectric substrate in the direction of the polarization axis is shorter when compared with a conventional piezoelectric substrate in which the polarization axis is parallel to the long side of the piezoelectric substrate even when using substrates of equal dimensions. As a result, based on the findings obtained from the experiments as described above, the change in the resonance frequency of the piezoelectric vibration component when stress is applied can be reduced.

Thus, in a piezoelectric vibration component covered by an external resin packaging layer, even if thermal stress occurs between the piezoelectric substrate and the packaging layer due to a change in operating temperature or other conditions, the change in the resonance frequency caused by this stress can be reduced, and a piezoelectric vibration component with excellent thermal characteristics can be obtained. Likewise, the change in resonance frequency caused by clamping stress applied to the piezoelectric substrate by contraction during the hardening of the packaging resin can also be reduced, and a piezoelectric vibration component with small fluctuations in the resonance frequency can be obtained.

Moreover, the present invention also reduces the change in resonance frequency by the simple method of changing the direction of the polarization axis from the direction of a conventional component (aligned with the long side of the piezoelectric substrate), and is therefore not accompanied by the technical problems arising from making the piezoelectric substrate smaller when the length of the long side aligned with the polarization axis of the piezoelectric vibration element is shortened. Moreover, because it is not necessary to develop new piezoelectric substrate materials with a small change in the resonance frequency, and the change in the resonance frequency can be reduced using the same packaging resins and piezoelectric materials having the same Young's modulus and coefficient of thermal expansion as current materials, the present invention can be easily implemented.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description taken in conjunction with preferred embodiments thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and in which:

Figs. 1 and 2 are the front and back plan views,

respectively, of a piezoelectric vibration component according to a first embodiment of the present invention;

Fig. 3 is a circuit diagram showing an equivalent circuit of the piezoelectric vibration component shown in Figs. 1 and 2;

Fig. 4 is a graph showing the change in the resonance frequency of a piezoelectric vibration component according to the present invention and that according to a conventional embodiment;

Fig. 5 is a perspective view showing an alternative embodiment of the present invention;

Figs. 6(a) and 6(b) are front and back views, respectively, of an alternative embodiment according to the present invention;

Fig. 7 is a circuit diagram showing an equivalent circuit of the piezoelectric vibration component shown in Figs. 6(a) and 6(b);

Fig. 8 is a top plan view of a piezoelectric vibration component according to prior art; and

Fig. 9 is a cross-sectional view of the piezoelectric vibration component of Fig. 8 provided in a packaging resin layer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is described herein below with reference to the accompanying drawings.

Referring to Figs. 1 and 2, front and back plan views, respectively, of a piezoelectric vibration element A is shown. Piezoelectric vibration element A is provided with a vibration electrode member 2 to generate energy trap-type vibrations, and terminal member 3 to connect a lead terminal (not shown) on the front and back of a thin piezoelectric substrate 1.

Piezoelectric substrate 1 is formed from a piezoelectric ceramic material into rectangular thin sheet, and then baked. Furthermore, this piezoelectric substrate 1 is polarized by applying a voltage in a direction parallel to the short side of the substrate, and therefore has a polarization axis P in the direction parallel to the short side of the substrate as indicated by a bold line arrow shown in Figs. 1 and 2. Of course, while this alignment is said to be parallel, there is a certain width of allowance for error. On the front and back surfaces of the piezoelectric substrate 1 are formed metallic thin film vibration electrode member 2, terminal member 3, and connection conductors 6, 7 using a vapor deposition, sputtering, or other thin film formation technology. Vibration electrode member 2 places vibration electrode 4 on the front surface of piezoelectric substrate 1 and common electrode 5 on the back of piezoelectric substrate 1 in opposition, thus producing the vibrations of the thickness slip vibration mode between vibration electrode 4 and common electrode 5.

In the embodiment shown in Figs. 1 and 2, two vibration electrode members 2, 2 are formed on piezoelectric substrate 1, such that vibration electrodes 4, 4 are connected respectively to terminal members 3, 3 on both sides of the front surface through connection conductors 6, 6, and common electrode 5 on the back is connected to terminal member 3 in the center via common connection conductor 7. An electrical equivalent circuit is shown in Fig. 3, in which two terminal oscillators 8, 8 connected in parallel.

This piezoelectric vibration element A can produce energy trap-type thickness slip vibrations by applying an AC signal to vibration electrode member 2, and the resonance frequency fo of these vibrations is largely determined by the thickness of piezoelectric substrate 1. Furthermore, because the direction of polarization axis P is parallel to the short side, the length of piezoelectric substrate 1 in the direction of polarization axis P is much shorter in a piezoelectric substrate of the same dimensions. Also, as is clear from the aforementioned experiments, the change Δf in the resonance frequency, when stress is applied to piezoelectric vibration element A, is smaller. Therefore, a piezoelectric vibration element A with good thermal characteristics is obtained, specifically, an element is obtained in which the change Δf in the resonance frequency is small even if thermal stress occurs between the substrate and the resin packaging layer covering piezoelectric vibration element A. Also, the ratio of change $\Delta f/fo$ of the resonance frequency to the temperature change ΔT is reduced. For example, in a piezoelectric trap using a piezoelectric substrate of which the length of the long side is L=6.7 mm and the length of the short side is 2.8 mm, the ratio of change $(\Delta f/\Delta T)/fo$ will be -50 ppm/°C when the polarization axis is aligned with the long side, but the same will be +5 ppm/°C when the polarization axis is aligned with the short side. It is understood that the ratio of change has been improved by one tenth.

Referring to Fig. 5, an alternative embodiment according to the present invention is shown. A strip electrode layer 9 of a metallic thin film is formed on the front and back of a rectangular piezoelectric substrate 1 sheet. At the center of piezoelectric substrate 1 on opposing strip electrode layers 9 is the two terminal-type vibration electrode member 2, and at the ends of strip electrode layers 9 are terminal members 3, thus forming an energy trap-type thickness slip vibration mode piezoelectric vibration element B. In a piezoelectric vibration element B of this type too, the change in resonance frequency can be minimized by aligning the direction of polarization axis P parallel to the short side of piezoelectric substrate 1.

Referring to Figs. 6(a) and 6(b), front and back views of a piezoelectric vibration element C is shown, in which two vibration electrode members 2, 2 comprised of a pair of divided electrodes 10a, 10b and common electrode 11 are formed on piezoelectric

substrate 1, thus forming an energy trap-type thickness slip vibration mode piezoelectric vibration element C connected in parallel to two three terminal oscillators 12, as shown in Fig. 7. In this type of piezoelectric vibration element C, the change in resonance frequency can be minimized by aligning the direction of polarization axis P parallel to the short side of piezoelectric substrate 1.

It is to be noted that an energy trap-type thickness slip vibration mode piezoelectric vibration element according to the present invention can be constructed other than those described above. Furthermore, according to a preferred embodiment, the direction of the polarization axis is parallel to the short side of the piezoelectric substrate, but it is not necessary for the direction of the polarization axis to be literally parallel to the direction of the short side. In other words, the change in resonance frequency can be made less than that of a conventional element by aligning the polarization axis closer to the short side direction than to the long side direction of the piezoelectric substrate. Therefore, in a rectangular piezoelectric substrate as described above, it is sufficient for the angle formed by the polarization axis and the direction of the short side to be less than 45 degrees. However, in a parallel quadrilateral the angle will not necessarily be less than 45 degrees.

According to the present invention, the change in the resonance frequency when stress is applied to the piezoelectric substrate can be reduced. Therefore, an element with excellent thermal characteristics in which the change in the resonance frequency will be small even if thermal stress is applied to the piezoelectric vibration element from the resin packaging layer by a change in the operating temperature or other conditions can be achieved. Furthermore, a piezoelectric vibration element with high reliability in which the variation in resonance frequency is small and the change in the resonance frequency caused by contraction during hardening of the packaging resin is minimal can be obtained. Moreover, the invention can be achieved by the simple method of changing the orientation of the polarization axis from the direction of conventional elements, and can be implemented easily without the difficulties presented by developing new materials or reducing the size of the piezoelectric substrate.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. A piezoelectric vibration component (A) of an energy trapped type in which vibrating electrode members (2) are deposited on both front and back faces of a piezoelectric substrate (1) which has long and short sides and which operates in a thickness slip vibration mode, said piezoelectric vibration component (A) **characterized** in that the polirization axis (P) is aligned in the direction of the short side (S) of the piezoelectric substrate (1) in order to reduce the temperature coefficient.

Patentansprüche

1. Piezoelektrische Vibrator-Komponente (A) vom energie-angelagerten Typ, bei der vibrierende Elektrodenelemente (2) sowohl an der Vorderseite als auch an der Rückseite eines piezoelektrischen Substrats (1) aufgebracht sind, das lange und kurze Seiten hat, und in einem Dickengleit-Vibrationsmodus arbeitet, dadurch **gekennzeichnet**, daß die Polarisationsachse (P) in Richtung der kurzen Seite (S) des piezoelektrischen Substrats (1) ausgerichtet ist, um den Temperaturkoeffizienten zu reduzieren.

Revendications

1. Composant vibrant piézoélectrique (A) du type à énergie piégée, dans lequel des éléments formant électrodes de vibration (2) sont disposés sur les faces avant et arrière d'un substrat piézoélectrique (1) qui a un grand et un petit côtés et qui fonctionne suivant un mode de vibration à glissement en épaisseur, ledit composant vibrant piézoélectrique (A) étant caractérisé en ce que l'axe de polarisation (P) est aligné dans la direction du petit côté (S) du substrat piézoélectrique (1) afin de réduire le coefficient de température.

substrate 1, thus forming an energy trap-type thickness slip vibration mode piezoelectric vibration element C connected in parallel to two three terminal oscillators 12, as shown in Fig. 7. In this type of piezoelectric vibration element C, the change in resonance frequency can be minimized by aligning the direction of polarization axis P parallel to the short side of piezoelectric substrate 1.

It is to be noted that an energy trap-type thickness slip vibration mode piezoelectric vibration element according to the present invention can be constructed other than those described above. Furthermore, according to a preferred embodiment, the direction of the polarization axis is parallel to the short side of the piezoelectric substrate, but it is not necessary for the direction of the polarization axis to be literally parallel to the direction of the short side. In other words, the change in resonance frequency can be made less than that of a conventional element by aligning the polarization axis closer to the short side direction than to the long side direction of the piezoelectric substrate. Therefore, in a rectangular piezoelectric substrate as described above, it is sufficient for the angle formed by the polarization axis and the direction of the short side to be less than 45 degrees. However, in a parallel quadrilateral the angle will not necessarily be less than 45 degrees.

According to the present invention, the change in the resonance frequency when stress is applied to the piezoelectric substrate can be reduced. Therefore, an element with excellent thermal characteristics in which the change in the resonance frequency will be small even if thermal stress is applied to the piezoelectric vibration element from the resin packaging layer by a change in the operating temperature or other conditions can be achieved. Furthermore, a piezoelectric vibration element with high reliability in which the variation in resonance frequency is small and the change in the resonance frequency caused by contraction during hardening of the packaging resin is minimal can be obtained. Moreover, the invention can be achieved by the simple method of changing the orientation of the polarization axis from the direction of conventional elements, and can be implemented easily without the difficulties presented by developing new materials or reducing the size of the piezoelectric substrate.

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