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TITLE OF THE INVENTION

END FACE REFLECTION TYPE SURFACE WAVE RESONATOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a surface wave resonator utilizing a surface wave of an SH type such as a BGS wave (Bleustein-Gulyaev-Shimizu wave) or a Love wave, and more particularly, to an end face reflection type surface wave resonator in which a surface wave is reflected by a pair of end faces opposed to each other.

DESCRIPTION OF THE PRIOR ART

An end face reflection type surface wave resonator utilizing a surface wave of an SH type such as a BGS wave or a Love wave has been known. Fig. 1 is a perspective view showing one example of a conventional end face reflection type surface wave resonator.

A surface wave resonator 1 is constructed using a piezoelectric substrate 2 in a square plane shape. The piezoelectric substrate 2 is composed of a piezoelectric material such as lead titanate zirconate series piezoelectric ceramics, an $LiNbO_3$ piezoelectric single crystal or an $LiTaO_3$ piezoelectric single crystal. If the piezoelectric substrate 2 is composed of piezoelectric ceramics, the piezoelectric substrate 2 is subjected to polarization processing in a direction indicated by an arrow

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P as shown.

A pair of comb electrodes 3 and 4 is formed on an upper surface 2a of the piezoelectric substrate 2. The comb electrodes 3 and 4 constitute an interdigital transducer (hereinafter abbreviated as an IDT). The comb electrodes 3 and 4 respectively have electrode fingers 3a to 3c and 4a to 4c.

In the end face reflection type surface wave resonator 1, AC voltages are applied from the comb electrodes 3 and 4, whereby the BGS wave is excited, and the BGS wave propagates in a direction indicated by an arrow X as shown. The BGS wave is reflected by both end faces 2b and 2c of the piezoelectric substrate 2.

In the above described end face reflection type surface wave resonator 1, a frequency spectrum determined by the IDT and a frequency determined by the dimensions between the end faces 2b and 2c are matched with each other, thereby to obtain effective resonance characteristics. In the surface wave resonator 1, the surface wave is reflected between the end faces 2b and 2c, whereby the resonance characteristics are extracted, as described above. Therefore, the smoothness of the end faces 2b and 2c and the dimensions between the end faces 2b and 2c must be maintained with high precision. The surface wave resonator 1 has been conventionally fabricated through the following steps.

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Specifically, as shown in a perspective view of Fig. 2, a piezoelectric plate 5 is prepared, and the above described comb electrodes 3 and 4 are formed on the upper surface of the piezoelectric plate 5, which constitute the IDT. Thereafter, grooves 6 and 7 are formed downward from the upper surface of the piezoelectric plate 5, thereby to form the above described end faces 2b and 2c. That is, in order to accurately form the end faces 2b and 2c, the grooves 6 and 7 are formed by subjecting the piezoelectric plate 5 to groove processing with high precision. Thereafter, a piezoelectric plate portion below the bottoms 6a and 7a of the grooves 6 and 7 is cut, thereby to obtain the surface wave resonator 1.

In the surface wave resonator 1, the width of the electrode fingers 3a and 4c on both sides which are formed along the end faces 2b and 2c out of the electrode fingers 3a to 3c and 4a to 4c is set to one-half the width of the other electrode fingers. That is, letting λ be the wavelength of the surface wave, the width of the electrode fingers 3a and 4c is $\lambda/8$, and the width of the other electrode fingers is $\lambda/4$. The electrode fingers 3a and 4c are formed by previously forming a plurality of electrode fingers having a width of $\lambda/4$ and then forming the grooves 6 and 7 so that the width of the outermost electrode fingers is one-half the width $\lambda/4$, that is, $\lambda/8$.

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The end face reflection type surface wave resonator 1 has the above described structure. If the number of pairs of electrode fingers constituting the IDT is decreased and therefore, the width W of the surface wave resonator 1 is decreased, however, the surface wave resonator 1 is liable to be unstable when it is mounted on a case substrate, a base of a hermetic seal case, a printed circuit board or the like. If one comb electrode 13 constituting an IDT has two electrode fingers 13a and 13b and the other comb electrode 14 has only a single electrode finger 14a, as shown in Fig. 3, for example, the width W of a surface wave resonator 11 becomes much smaller than the thickness t of a piezoelectric substrate 12. Consequently, the surface wave resonator 11 becomes unstable if it is disposed on the piezoelectric substrate 12 in a direction as shown. As a result, the surface wave resonator 11 is liable to fall so that an end face 12b or 12c is directed downward, and electrical connecting work such as die bonding becomes difficult.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an end face reflection type surface wave resonator and a method of fabricating the same, in which the stability of chips is enhanced even if the number of pairs of electrode fingers is small, thereby to make it possible to perform work such as die bonding stably and reliably.

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An end face reflection type surface wave resonator according to the present invention is an end face reflection type surface wave resonator utilizing a surface wave of an SH type, which comprises a piezoelectric substrate and an IDT formed on one major surface of the piezoelectric substrate, a groove being so formed as to extend from the one major surface to the other major surface of the piezoelectric substrate and in a direction orthogonal to the surface wave propagating direction in order to construct an end face on which the surface wave is to be reflected on at least one side of the IDT.

As described in the foregoing, in the end face reflection type surface wave resonator according to the present invention, the groove is formed on the major surface, on which the IDT is formed, of the piezoelectric substrate so as to extend toward the other major surface and in the direction orthogonal to the surface wave propagating direction, and at least one end face on which the surface wave is to be reflected is formed by forming the groove. In the piezoelectric substrate, therefore, a piezoelectric substrate portion is connected to the outside of the groove. Accordingly, the dimensions in the surface wave propagating direction of the surface wave resonator, that is, the width of the surface wave resonator is increased by the piezoelectric substrate portion remaining outside the

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groove, thereby to stabilize the surface wave resonator.

According to the present invention, at least one end face on which the surface wave is to be reflected is formed by forming at least one groove in the piezoelectric substrate. Consequently, the width of the piezoelectric substrate portion outside the groove is controlled irrespective of the dimensions between end faces for obtaining resonance characteristics, thereby to make it possible to provide an end face reflection type surface wave resonator which is stable in shape. Accordingly, it is possible to enhance the stability of the surface wave resonator in the handling of the surface wave resonator including electrical connecting work such as die bonding, thereby to make it possible to enhance the productivity of components or apparatuses using the end face reflection type surface wave resonator.

In addition, an end face reflection type surface wave resonator has end faces at the both sides of an IDT. Thus, a pair of the grooves are preferably formed so as to construct the end faces at the both sides of the IDT. With the pressent invention, however, only one end face of the end faces may be formed by the formation of the groove, in which case another end face is formed by cutting the piezoelectric substrate according to the conventional method. Accordingly, with the present invention, at least one end face is

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formed by forming at least one groove.

It is confirmed that work such as die bonding becomes difficult if the width W of the above described surface wave resonator is smaller than two-thirds the thickness t of the piezoelectric substrate. Accordingly, the dimensions of the piezoelectric substrate portion outside the groove is preferably determined so that the width W of the surface wave resonator is larger than two-thirds the thickness t of the piezoelectric substrate.

A method of fabricating a surface wave resonator according to the present invention is a method of fabricating an end face reflection type surface wave resonator, which comprises the steps of forming an IDT on a piezoelectric plate, forming a groove extending from one major surface to the other major surface of the piezoelectric plate and in a direction orthogonal to the surface wave propagating direction in order to construct an end face on which a surface wave is to be reflected on at least one side of the IDT in the surface wave propagating direction, and dividing the piezoelectric plate in an area outside the groove, thereby to obtain the end face reflection type surface wave resonator.

In the method of fabricating the surface-wave resonator according to the present invention, the IDT is formed on the piezoelectric plate and the groove is formed on at least one

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side of the IDT, as described above, thereby to construct the end face on which the surface wave is to be reflected. The piezoelectric plate is divided in the area outside the groove after the groove is formed. Consequently, it is possible to fabricate the end face reflection type surface wave resonator according to the present invention having the piezoelectric substrate portion outside the groove. In the fabricating method according to the present invention, the division is preferably made so that the width W of a piezoelectric substrate obtained by the division is larger than two-thirds the thickness t of the piezoelectric substrate as described above.

In the method of fabricating the end face reflection type surface wave resonator according to the present invention, at least one groove is formed to form the end face on which the surface wave is to be reflected, as described above, after which the piezoelectric plate is only divided outside the groove, thereby to make it possible to provide the end face reflection type surface wave resonator according to the present invention. Accordingly, it is possible to provide the end face reflection type surface wave resonator superior in stability without increasing the number of steps.

More preferably, the division of the piezoelectric plate outside the groove is made by forming a second groove

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extending from at least one major surface to the other major surface of the piezoelectric plate, that is, further forming a second groove outside the groove formed in order to construct the end face on at least one side of the IDT, and dividing a piezoelectric substrate portion between the bottom of the second groove newly formed and the other major surface by exerting an external force or dividing the piezoelectric substrate portion by machining. A method of forming the second groove to divide the piezoelectric plate is thus employed, thereby to make it possible to prepare a structure in which a lot of IDTs are formed on one major surface of a mother piezoelectric plate, as in the conventional example, and a second groove for separating the surface wave resonator is further formed after groove processing for forming the end face. In other words, it is possible to obtain a structure in which a lot of surface wave resonators are connected to each other through the second groove newly formed. Consequently, it is possible to measure the characteristics of each of the surface wave resonators, for example, in a state where the surface wave resonators are connected to each other in the mother piezoelectric plate.

In the surface wave resonator according to the present invention, at least one end face on which the surface wave is to be reflected is constructed by forming the above

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described groove, and the piezoelectric substrate portion is further provided outside the groove.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing a conventional end face reflection type surface wave resonator;

Fig. 2 is a perspective view for explaining the steps of fabricating the conventional end face reflection type surface wave resonator;

Fig. 3 is a perspective view for explaining the problems of the conventional end face reflection type surface wave resonator;

Fig. 4 is a perspective view for explaining the steps of fabricating an end face reflection type surface wave resonator according to an embodiment;

Fig. 5 is a perspective view showing the end face reflection type surface wave resonator according to the embodiment; and

Fig. 6 is a perspective view for explaining a modified example of the end face reflection type surface wave resonator according to the embodiment.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment will be described with reference to the drawings, thereby to clarify the present invention.

Fig 4 is a perspective view for explaining a method of fabricating a surface wave resonator according to one embodiment of the present invention.

A piezoelectric plate 21 is first prepared. The piezoelectric plate 21 is composed of piezoelectric ceramics such as lead titanate zirconate series piezoelectric ceramics or a piezoelectric single crystal such as an $LiNbO_3$ piezoelectric single crystal or an $LiTaO_3$ piezoelectric single crystal. If the piezoelectric plate 21 is composed of piezoelectric ceramics, the piezoelectric plate 21 is subjected to polarization processing in a direction indicated by an arrow P as shown. That is, the piezoelectric plate 21 is subjected to polarization processing in a direction parallel to a major surface 21a of the piezoelectric plate 21.

A pair of comb electrodes 23 and 24 is formed on the major surface 21a of the piezoelectric plate 21. The comb electrodes 23 and 24 are composed of a conductive material such as aluminum or copper. In addition, the comb electrodes 23 and 24 can be formed by a suitable method such as a method of forming a thin film composed of a conductive material on the upper surface of the piezoelectric plate 21

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by a process such as evaporation, plating or sputtering and then patterning the thin film.

The comb electrode 23 has electrode fingers 23a and 23b, while the comb electrode 24 has a single electrode finger 24a. Letting λ be the wavelength of a surface wave, the width of the electrode finger 24a is $\lambda/4$, while a pitch between the adjacent electrode fingers is also $\lambda/4$. The width of the electrode fingers 23a and 23b positioned on both sides is $8/\lambda$.

The width $\lambda/8$ of the electrode fingers 23a and 23b is adjusted in forming grooves 25 and 26 as described later. Specifically, electrode fingers having the same width $\lambda/4$ as that of the electrode finger 24a are first formed in areas where the electrode fingers 23a and 23b are to be formed. Grooves 25 and 26 extending from the major surface 21a toward the other major surface 21b of the piezoelectric plate 2 are then formed. The grooves 25 and 26 are formed in order to form end faces 22b and 22c on which a BGS wave excited by applying AC voltages from the comb electrodes 23 and 24 is to be reflected. Therefore, the grooves 25 and 26 are formed using a dicer or the like so that the end faces 22b and 22c are in such positions as to reduce the width of the electrode fingers 23a and 23b to half, whereby the width of the electrode fingers 23a and 23b is determined as described above.

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Since the grooves 25 and 26 are provided in order to form the end faces 22b and 22c as described above, the direction in which the grooves 25 and 26 extend is a direction orthogonal to the surface wave propagating direction and is a direction parallel to the electrode fingers 23a, 23b and 24a.

Furthermore, as apparent from Fig. 4, the bottoms 25a and 26a of the grooves 25 and 26 are at such a depth as not to lead to the other major surface 21b. The grooves 25 and 26 must have a certain depth so that the excited BGS wave can be reliably reflected by the end faces 22b and 22c. Since the surface wave of an SH type propagates near the surface of a piezoelectric substrate, the grooves 25 and 26 need not have such a depth as to lead to the other major surface 21b. In the present embodiment, therefore, the depth of the grooves 25 and 26 is approximately one-half the thickness t of the piezoelectric plate 21, as shown. In order to form the end faces 22b and 22c on which the surface wave of an SH type such as the BGS wave is to be reliably reflected, however, it is desirable that the depth of the grooves 25 and 26, that is, the height of the end faces 22b and 22c is in the range of 1 λ to 7 λ with respect to the wavelength λ.

Second grooves 27 and 28 are then formed outside the grooves 25 and 26. The second grooves 27 and 28 are

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provided so as to separate a surface wave resonator obtained in the present embodiment from the other portions of the piezoelectric plate 21. Although the grooves 27 and 28 extend parallel to the grooves 25 and 26, the grooves 27 and 28 need not be formed parallel to the grooves 25 and 26. Since it is preferable in terms of standardization of the shape of products that the plane shape of the surface wave resonator finally obtained is rectangular, however, the grooves 27 and 28 are preferably formed parallel to the grooves 25 and 25 as in the present embodiment.

Furthermore, the bottoms 27a and 28a of the grooves 27 and 28 do not lead to the other major surface 21b. Specifically, a surface wave resonating portion 29 according to the present embodiment which is constructed by forming the grooves 27 and 28 is connected to the other portions of the piezoelectric plate 21. If a lot of surface wave resonating portions each having a structures as shown in Fig. 4 are formed in a mother piezoelectric plate 21, therefore, the characteristics can be measured, for example, on the mother piezoelectric plate 21 without cutting each of the surface wave resonating portions.

The above described surface wave resonating portion 29 is then cut in a portion below the bottoms 27a and 28a of the grooves 27 and 28, thereby to make it possible to obtain a surface wave resonator 30 as shown in Fig. 5.

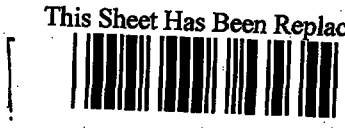
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In the end face reflection type surface wave resonator 30, a piezoelectric substrate 22 is constructed by the above described cutting. An IDT which is constituted by the above described comb electrodes 23 and 24 is formed on one major surface of the piezoelectric substrate 22. In addition, end faces 22b and 22c are constructed by forming the above described grooves 25 and 26, whereby the surface wave is reflected between the end faces 22b and 22c. Specifically, the resonance characteristics are determined by the dimensions of the IDT and the dimensions d between the end faces 22b and 22c. On the other hand, the width of the surface wave resonator 30 becomes the distance W between outer side surfaces of piezoelectric substrate portions 22d and 22e which exist outside the grooves 25 and 26. Accordingly, the overall width W of the resonator 30 can be made larger than the thickness d of the piezoelectric substrate 22 even if the number of pairs of electrode fingers in the IDT is very small and therefore, the dimensions d between the end faces 22b and 22c are small, as in the surface wave resonator 30 according to the present embodiment.

In order to stably perform work such as die bonding, the width W of the surface wave resonator 30 must be larger than two-thirds the thickness t of the piezoelectric substrate 22. Consequently, the width W is preferably

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determined so as to be larger than two-thirds the thickness t of the piezoelectric substrate 22. In the fabricating method according to the present embodiment, the width W may be determined by matching the distance between the above described grooves 27 and 28 with the width W in forming the grooves 27 and 28, thereby to make it possible to easily control the width W.

Although in the above described embodiment, the second grooves 27 and 28 are formed after forming the grooves 25 and 26, and the piezoelectric substrate portion below the bottoms 27a and 28a of the grooves 27 and 28 is further cut to obtain the piezoelectric resonator 30, the surface wave resonator 30 can be obtained also by cutting the piezoelectric plate 21 so that piezoelectric substrate portions having a certain width remain outside the grooves 25 and 26 without forming the grooves 27 and 28.

Furthermore, although in the above described embodiment, description was made of a structure in which one IDT is formed, the end face reflection type surface wave resonator according to the present invention may have two or more sets of IDTs.

Additionally, although in the above described embodiment, description was made of a structure in which the grooves 27 and 28 are formed on both sides of the IDT in order to form the end faces on which the BGS wave is to be

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reflected, the groove in the present invention may be formed on only one side of the IDT. Specifically, a surface wave resonator 31 in which a groove 26 is formed on only one side of an IDT may be used, as shown in Fig. 6. Also in the case, the same effect as that in the above described embodiment is obtained. That is, the width of a piezoelectric substrate portion 22e outside the groove 26 is controlled, thereby to make it possible to obtain an end face reflection type surface wave resonator which is stable in shape.

The surface wave resonator 31 shown in Fig. 6 is the same as the surface wave resonator 30 shown in Fig. 5 except that the groove 26 and the piezoelectric substrate portion 22e are provided on only one side of the IDT. Consequently, the same portions are assigned the same reference numerals and hence, the description thereof is not repeated.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

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What is Claimed is:

1. An end face reflection type surface wave resonator utilizing a surface wave of an SH type, comprising:

a piezoelectric substrate; and

an interdigital transducer formed on one major surface of said piezoelectric substrate,

a groove being so formed as to extend from the one major surface to the other major surface of said piezoelectric substrate and in a direction orthogonal to the surface wave propagating direction in order to construct an end face on which the surface wave is to be reflected on at least one side of said interdigital transducer.

2. The end face reflection type surface wave resonator according to claim 1, wherein

said groove is so formed as to extend from the one major surface to the other major surface of said piezoelectric substrate and in the direction orthogonal to the surface wave propagating direction in order to construct end faces on which the surface wave is to be reflected on both sides of said interdigital transducer.

3. The end face reflection type surface wave resonator according to claim 1, wherein

said groove is so formed as to extend from the one major surface to the other major surface of said piezoelectric substrate and in the direction orthogonal to

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the surface wave propagating direction in order to construct an end face on which the surface wave is to be reflected on only one side of said interdigital transducer.

4. The end face reflection type surface wave resonator according to claim 1, wherein

the width W of said end face reflection type surface wave resonator is larger than two-thirds the thickness t of said piezoelectric substrate.

5. The end face reflection surface wave resonator according to claim 1, wherein

the depth of said groove is in the range of λ to 7 λ when λ is taken as the wavelength of the surface wave.

6. A method of fabricating an end face reflection type surface wave resonator, comprising the steps of:

forming an interdigital transducer on a piezoelectric plate;

forming a first groove extending from one major surface to the other major surface of said piezoelectric plate and in a direction orthogonal to the surface wave propagating direction in order to construct an end face on which a surface wave is to be reflected on at least one side of said interdigital transducer in the surface wave propagating direction; and

dividing said piezoelectric plate in an area outside said groove, thereby to obtain the end face reflection type

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surface wave resonator.

7. The method according to claim 6, wherein

said groove is so formed as to extend from the one major surface to the other major surface of said piezoelectric plate and in the direction orthogonal to the surface wave propagating direction in order to construct end faces on which the surface wave is to be reflected on both sides of said interdigital transducer.

8. The method according to claim 6, wherein

said groove is so formed as to extend from the one major surface to the other major surface of said piezoelectric plate and in the direction orthogonal to the surface wave propagating direction in order to construct an end face on which the surface wave is to be reflected on only one side of said interdigital transducer.

9. The method according to claim 6, wherein

the width W of said end face reflection type surface wave resonator is larger than two-thirds the thickness t of said piezoelectric plate.

10. The method according to claim 6, wherein

the depth of said groove is in the range of λ to 7λ when λ is taken as the wavelength of the surface wave.

11. The method according to claim 6, wherein

said step of dividing said piezoelectric plate in an area outside said groove is carried out by forming a second

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groove extending from the one major surface to the other major surface of said piezoelectric plate in the area outside said groove and dividing a piezoelectric plate portion below said second groove.

12. The method according to claim 11, wherein said second groove is formed parallel to said first groove.