SURFACE WAVE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a surface wave device employing a quartz substrate, and more particularly to a surface wave device which is formed by laminating a piezoelectric thin film on a quartz substrate and utilizes a higher-order mode of leakage elastic surface waves.

2. Description of the Related Art

Heretofore, surface wave devices have been widely employed as, e.g., band-pass filters in mobile communication equipment. The surface wave device has a structure that at least one interdigital transducer (IDT) comprising at least one pair of comb teeth electrodes is formed in contact with a piezoelectric substance. Such a surface wave device has been used in various application forms such as resonators and delay lines, in addition to the band-pass filters.

As substrate materials of surface wave devices, there are known piezoelectric single crystals such as $LiNbO_3$, $LiTaO_3$ and quartz. The structure that an IDT is formed on a substrate made of any one of those materials to oscillate the Rayleigh wave has been hitherto practiced.

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Japanese Unexamined Patent Publication No. 61-222312 discloses a surface wave device wherein a piezoelectric thin film is formed on a quartz substrate and comb teeth electrodes are formed on the piezoelectric thin film. This Publication describes that a surface wave having a sonic speed about 1.7 times that of the normal Rayleigh wave can be utilized by employing a quartz substrate which is ST-cut at the Eulerian angle set to substantially 90° and forming the electrodes such that the surface wave propagates in a direction at an angle of substantially 90° relative to the propagating direction due to the ST-cutting.

Surface wave devices employing quartz substrates have had the problem that, while the quartz substrate exhibits a good temperature characteristic, the Rayleigh wave which is one of surface waves oscillated by the quartz substrate has a low sonic speed.

Meanwhile, it is known that, in a surface wave device employing a quartz substrate, leakage elastic surface waves are also oscillated in addition to the Rayleigh wave and the sonic speeds of these leakage elastic surface waves are relatively high. However, the leakage elastic surface waves are attenuated to a large extent during transmission. From this reason, it has been hitherto regarded as difficult to employ the leakage elastic

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surface waves in practical use.

Thus, in spite of exhibiting a good temperature characteristic, quartz substrates have not been hitherto considered as materials suitable for surface wave devices operating at higher frequency, because of the low sonic speed of the Rayleigh wave, if utilized, and a difficulty in utilizing leakage elastic surface waves.

Further, as stated above, Japanese Unexamined Patent Publication No. 61-222312 discloses a surface wave device and describes that a surface wave having a high sonic speed can be utilized with a quartz substrate, i.e., by employing a quartz substrate which is ST-cut at the Eulerian angle set to substantially 90° and forming the electrodes such that the surface wave propagates in a direction at an angle of substantially 90° relative to the propagating direction due to the ST-cutting. However, it was confirmed that the surface wave described in the prior art as being utilizable according to the disclosed method is in fact a combination of two surface waves close to each other and, therefore, the prior art device has a difficulty in its application to a surface wave resonator and so on.

More specifically, a result shown in Fig. 14 was obtained by fabricating a surface wave device according to the conditions described in the above Publication and

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measuring an attenuation versus frequency characteristic of the surface wave device. The characteristic shown in Fig. 14 was resulted for a surface wave device wherein a quartz substrate used had the Eulerian angles (0°, 132.75°, 90°), the normalized film thickness H/λ of ZnO was 0.242, and the normalized film thickness of comb teeth electrode was 0.0207. Incidentally, H is the thickness of a piezoelectric thin film and λ is the wavelength of a surface wave.

As will be seen from Fig. 14, the normal Rayleigh wave appears at frequency indicated by arrow A and another surface wave is oscillated at frequency indicated by arrow B. Here, a value resulted by multiplying the frequency of the normal Rayleigh wave indicated by arrow A by 7.4λ is about 0.625 time a value resulted by multiplying the frequency of the surface wave indicated by arrow B by 7.4λ.

Accordingly, it is understood that the wave having a high sonic speed, described in the above-cited Japanese Unexamined Patent Publication No. 61-222312, corresponds to the wave indicated by arrow B in Fig. 14. However, the wave indicated by arrow B is already known as existing as an SSB wave and an ST wave which appear in close relation as shown. Because these two different waves are close to each other as indicated by arrow B in Fig. 14, a valley

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indicated by arrow C exists between the two waves.

In other words, although the above-cited Japanese Unexamined Patent Publication No. 61-222312 describes that a wave of a higher sonic speed than the normal Rayleigh wave A can be utilized, the wave of a higher sonic speed suggested to be practicable in the prior art appears in fact in the combined form of two waves close to each other and hance a valley is necessarily produced between the two waves. Accordingly, even if a surface wave resonator is constructed by using such a wave of a higher sonic speed, satisfactory characteristics can not be achieved. Also, when a resonator is fabricated by using such a wave of a higher sonic speed, the number of pairs of interdigitated electrodes must be increased, raising another problem that the size of the resonator is increased.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a surface wave device employing a quartz substrate, which can utilize a high sonic speed, is suitable for operation at higher frequency, and ensures satisfactory resonance and filtering characteristics.

As a result of carrying out intensive studies with a view of achieving the above object, the inventor of this application has accomplished the present invention based

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on the finding that the above object can be achieved by using a composite substrate comprising a quartz substrate on which a piezoelectric thin film such as ZnO is formed, and utilizing a higher-order mode of leakage elastic surface waves having a high sonic speed.

More specifically, according to a first broad aspect of the present invention, there is provided a surface wave device comprising a quartz substrate, a piezoelectric thin film formed on the quartz substrate, and comb teeth electrodes formed in contact with the piezoelectric thin film, the piezoelectric thin film being formed in such a thickness as able to oscillate a higher-order mode of leakage elastic surface waves so that the surface wave device operates with the higher-order mode of leakage elastic surface waves.

Heretofore, it has been regarded as difficult to employ leakage elastic surface waves in practical use because of large attenuation during transmission. Regardless of such customary knowledge in the art, the inventor of this application has considered that the attenuation of leakage elastic surface waves would be reduced by properly selecting the cut angle of a quartz substrate and the propagating direction of the waves, and a higher sonic speed could be obtained by utilizing a higher-order mode of leakage elastic surface waves. Based

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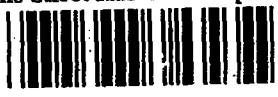


on that consideration, the inventor has fabricated and tested prototypes of surface wave devices utilizing a higher-order mode of leakage elastic surface waves. As a result, it has been found out that a surface wave device, which produces a high sonic speed and is suitable for operation at higher frequency, can be achieved by forming a piezoelectric thin film such as ZnO on a quartz substrate, forming comb teeth electrodes in contact with the piezoelectric thin film, and controlling the thickness of the piezoelectric thin film to be able to oscillate a higher-order mode of leakage elastic surface waves.

In other words, the present invention has been made on the basis of the finding experimentally confirmed in accordance with the above-mentioned concept suggesting itself to the inventor of this application. Such a concept is not simply on an extension of the past technical common sense that the practical use of leakage elastic surface waves is difficult because of large attenuation during transmission. Accordingly, it should be noted that the present invention is far from being found out from ordinary routine experiments.

According to a specific aspect of the present invention, given that the piezoelectric thin film has a thickness of H and the higher-order mode of leakage elastic surface waves has a wavelength of λ, the

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normalized thickness H/λ of the piezoelectric thin film with respect to that wavelength is in the range of from 0.28 to 0.6. In a composite substrate which is formed by laminating a piezoelectric thin film on a quartz substrate, the higher-order mode of leakage elastic surface waves can be surely oscillated by setting the normalized thickness H/λ of the piezoelectric thin film to fall in the above specific range. Although a numerical value of the normalized thickness H/λ of the piezoelectric thin film depends on the kind of the piezoelectric thin film used, the cut angle of the quartz substrate and so on, the higher-order mode of leakage elastic surface waves can be surely oscillated by setting the numerical value to be not less than 0.28.

The piezoelectric thin film can be formed of any suitable material so long as it exhibits piezoelectric properties. Usually employed is a thin film of ZnO, AlN, Ta_2O_5, CdS or the like. Preferably, as described in Claim 2, a thin film of ZnO is used as the piezoelectric thin film.

In a preferable form of the surface wave device according to the first aspect of the present invention, the piezoelectric thin film is made of ZnO and the normalized thickness H/λ of the piezoelectric thin film of ZnO is in the range of from 0.28 to 0.6.

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According to a second broad aspect of the present invention, there is provided a surface wave device comprising a quartz substrate, a piezoelectric thin film formed on the quartz substrate, and comb teeth electrodes formed in contact with the piezoelectric thin film, wherein the quartz substrate, the piezoelectric thin film and the comb teeth electrodes are formed to oscillate a higher-order mode of leakage elastic surface waves and prevent the higher-order mode of leakage elastic surface waves from attenuating during transmission.

Also, in the surface wave device according to the second broad aspect of the present invention, preferably, the piezoelectric thin film is made of ZnO.

Further, in the surface wave device according to the second broad aspect, preferably, the normalized thickness H/λ of the piezoelectric thin film is preferably in the range of from 0.28 to 0.6. This enables the higher-order mode of leakage elastic surface waves to be reliably oscillated.

In a preferable form of the surface wave device according to the second aspect of the present invention, as with the above preferable form, the piezoelectric thin film is made of ZnO and the normalized thickness H/λ of the piezoelectric thin film of ZnO is in the range of from 0.28 to 0.6.

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Additionally, in the surface wave device according to the second broad aspect of the present invention, the piezoelectric thin film may be made of one selected from the group consisting of AlN, Ta_2O_5 and CdS.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are a schematic plan view and a partial sectional view of a surface wave filter as one form of a surface wave device embodying the present invention.

Fig. 2 is a graph showing the relationship between the sonic speeds of surface waves and the normalized thickness H/λ of a ZnO thin film in composite substrates of quartz substrates / ZnO piezoelectric thin films when a quartz substrate of the Eulerian angles (0, 141, 0) was employed.

Fig. 3 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and a temperature characteristic TCD in surface wave devices fabricated in Embodiment 1.

Fig. 4 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in the surface wave devices fabricated in Embodiment 1.

Fig. 5 is a graph showing the relationship between

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the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in the surface wave devices fabricated in Embodiment 1.

Fig. 6 is a graph showing the relationship between the sonic speeds of surface waves and the normalized thickness H/λ of a ZnO thin film in composite substrates of quartz substrates / ZnO piezoelectric thin films when a quartz substrate of the Eulerian angles (0, 132.75, 89) was employed.

Fig. 7 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and a temperature characteristic TCD in surface wave devices fabricated in Embodiment 2.

Fig. 8 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in the surface wave devices fabricated in Embodiment 2.

Fig. 9 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in the surface wave devices fabricated in Embodiment 2.

Fig. 10 is a graph showing the relationship between the sonic speeds of surface waves and the normalized thickness H/λ of a ZnO thin film in composite substrates of quartz substrates / ZnO piezoelectric thin films when a

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quartz substrate of the Eulerian angles (0, 150, 0) was employed.

Fig. 11 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in surface wave devices fabricated in Embodiment 3.

Fig. 12 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and the electro-mechanical coupling coefficient in the surface wave devices fabricated in Embodiment 3.

Fig. 13 is a graph showing the relationship between the normalized thickness H/λ of a ZnO thin film and a temperature characteristic TCD in the surface wave devices fabricated in Embodiment 3.

Fig. 14 is a chart of an attenuation versus frequency characteristic for explaining a surface wave of high sonic speed which is utilized in a surface wave device disclosed in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A surface wave device embodying the present invention has no particular limitations in its specific form. The surface wave device can be constructed as, by way of example, a surface wave filter which is a transversal band-pass filter schematically shown in Figs. 1A and 1B.

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A surface wave filter 1 is constructed of a surface wave substrate 2 on which IDT's 3, 4 are formed with a predetermined spacing therebetween. The IDT's 3, 4 comprise respective pairs of comb teeth electrodes 3a, 3b, 4a, 4b, the paired ones of these electrodes being arranged in interdigitated relation. The surface wave substrate 2 has a structure that a piezoelectric thin film 2b is formed on a quartz substrate 2a. In such a structure, the IDT's 3, 4 may be formed on any of the upper and lower surfaces of the piezoelectric thin film 2b. Also, short-circuiting electrodes (not shown) may be formed on the upper or lower surface of the piezoelectric thin film 2b.

It is to be here noted that the surface wave device embodying the present invention is not limited to the surface wave filter mentioned above, and that the present invention is also applicable to various surface wave devices such as surface wave resonators and surface wave delay lines.

Embodiments of the present invention will be described hereinafter with reference to the drawings for clearer understanding of the invention.

Embodiment 1

Fig. 2 is a graph showing the sonic speeds of surface waves produced in surface wave substrates each comprising a quartz substrate with a piezoelectric thin film of ZnO

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formed thereon. The quartz substrate used had the Eulerian angles (0, 141, 0) and dimensions of 7.62 mm diameter x 0.5 mm thickness. The surface wave substrates were fabricated by forming ZnO thin films in various thicknesses all over the surfaces of the quartz substrates.

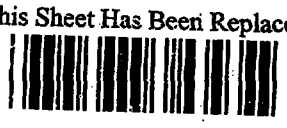
The sonic speeds of surface waves in the thus-fabricated various surface wave substrates having the ZnO thin films of different thicknesses were measured. The measurement of the sonic speeds was made as follows.

Measurement of the sonic speeds: IDT's covering the wavelength range of from 7 μm to 52 μm were formed on each of the surface wave substrates and the sonic speed was determined from the central frequency of a resulting SAW filter.

As is apparent from Fig. 2, when the normalized thickness H/λ of the ZnO thin film is zero, i.e., when the ZnO thin film is not formed, only the Rayleigh wave and a basic mode (LSAW1) of leakage elastic surface waves are oscillated. By contrast, for the surface wave substrates each comprising the quartz substrate on which the ZnO thin film is formed, the Sezawa wave as a higher-order mode of the Rayleigh wave and a higher-order mode (LSAW2) of leakage elastic surface waves are oscillated as well.

Also, as is apparent from Fig. 2, when the normalized

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thickness H/λ of the ZnO thin film is not less than 0.28, the higher-order mode (LSAW2) of leakage elastic surface waves is oscillated and shows a relatively high sonic speed. For example, when the normalized thickness H/λ of the ZnO thin film is 0.32, the sonic speed is 5000 m/sec which is 1.6 times a maximum value of the sonic speed of the Rayleigh wave, i.e., the sonic speed = 3170 m/sec of the Rayleigh wave in the quartz substrate without the ZnO thin film.

Accordingly, it is understood that when the surface wave substrate fabricated by forming a ZnO thin film on a quartz substrate of the Eulerian angles (0, 141, 0) is employed, a surface wave device having a high sonic speed can be achieved by selecting the normalized thickness H/λ of the ZnO thin film to be not less than 0.28.

Fig. 3 is a graph showing the relationship between a temperature characteristic (TCD) and the normalized thickness H/λ of a ZnO thin film in the surface wave devices each constructed of the surface wave substrate which was fabricated by forming a piezoelectric thin film on a quartz substrate of the Eulerian angles (0, 141, 0). As seen from Fig. 3, by contrast with the TCD in the quartz substrate without the ZnO thin film, the TCD in the surface wave substrates having the ZnO thin films laminated thereon shifts to the positive side. It can be

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therefore understood that the TCD value can be made closer to ± 0 by using a quartz substrate with a negative TCD value and laminating a ZnO thin film thereon, and hence that a surface wave device having a good temperature characteristic can be achieved.

Figs. 4 and 5 are graphs each showing the relationship between the electro-mechanical coupling coefficient and the normalized thickness H/λ of a ZnO thin film in the surface wave devices each constructed of the surface wave substrate which was fabricated by forming a piezoelectric thin film on a quartz substrate of the Eulerian angles (0, 141, 0). Fig. 4 shows characteristics resulted when IDT's, i.e., comb teeth electrodes, were formed on the upper surface of the ZnO thin film, and Fig. 5 shows characteristics resulted when IDT's were formed on the upper surface of the ZnO thin film and short-circuiting electrodes were formed at the interface between the ZnO thin film and the quartz substrate.

As is apparent from Figs. 4 and 5, in any of the surface wave devices, the higher-order mode LSAW2 of leakage elastic surface waves is oscillated and a relatively large electro-mechanical coupling coefficient is obtained.

Embodiment 2

Surface wave devices were fabricated in the same

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manner as in Embodiment 1 except that quartz substrates having the Eulerian angles (0, 132.75, 89) and being ST-cut at 89° for transmission were employed. Each of the quartz substrates used had dimensions of 7.62 mm diameter x 0.5 mm thickness.

Fig. 6 shows the relationship between the sonic speeds of surface waves and the normalized thickness H/λ of a ZnO thin film in the surface wave devices wherein the ZnO thin films were formed in various thicknesses. As is apparent from Fig. 6, in the case of employing the quartz substrate of the above cut angle, the higher-order mode LSAW2 of leakage elastic surface waves is also oscillated when the normalized thickness H/λ of the ZnO thin film is not less than 0.28. Further, when the normalized thickness H/λ of the ZnO thin film exceeds 0.6, a higher-order mode Sezawa2 of the Sezawa waves is oscillated rather than the higher-order mode LSAW2 of leakage elastic surface waves.

Accordingly, it is understood that, in the surface wave devices of Embodiment 2, the higher-order mode of leakage elastic surface waves is oscillated by selecting the normalized thickness H/λ of the ZnO thin film to be in the range of from 0.28 to 0.6, and hence that the higher-order mode of leakage elastic surface waves having a sonic speed higher than the maximum sonic speed available from

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the Rayleigh wave can be utilized.

Fig. 7 is a graph, corresponding to Fig. 3, showing the relationship between a temperature characteristic TCD and the normalized thickness H/λ of a ZnO thin film in the above surface wave devices. As is apparent from Fig. 7, in the surface wave devices each fabricated by forming a ZnO thin film on a quartz substrate of the Eulerian angles (0, 132.75, 89), it is also possible to shift the temperature characteristic TCD to the positive side by increasing the thickness of the ZnO thin film. It can be therefore understood that, as with the case of Embodiment 1, the surface wave device having a temperature characteristic value of about ± 0 can be achieved by a combination of a quartz substrate with a negative value of the temperature characteristic TCD and a ZnO thin film.

Figs. 8 and 9 are graphs, corresponding respectively to Figs. 4 and 5, each showing the relationship between the electro-mechanical coupling coefficient and the normalized thickness H/λ of a ZnO thin film in the surface wave devices each fabricated by forming a piezoelectric thin film on a quartz substrate of the Eulerian angles (0, 132.75, 89).

It can be understood that, in the case of using the quartz substrate of the Eulerian angles (0, 132.75, 89), the surface wave device having a sufficiently large

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electro-mechanical coupling coefficient can also be achieved by laminating a ZnO film on the quartz substrate.

Incidentally, Fig. 8 shows characteristics resulted when comb teeth electrodes were formed on the upper surface of the ZnO thin film, and Fig. 9 shows characteristics resulted when comb teeth electrodes were formed on the lower surface of the ZnO thin film.

Embodiment 3

Surface wave devices were fabricated in the same manner as in Embodiment 1 except that quartz substrates having the Eulerian angles (0, 150, 0) were employed. Fig. 10 shows the relationship between the sonic speeds of surface waves and the normalized thickness H/λ of a ZnO thin film in the surface wave devices wherein the ZnO thin films were formed in various thicknesses on the quartz substrates having such Eulerian angles.

As is apparent from Fig. 10, in the case of employing the quartz substrate of the Eulerian angles (0, 150, 0), the higher-order mode LSAW2 of leakage elastic surface waves is also oscillated and a very high sonic speed can be obtained when the normalized thickness H/λ of the ZnO thin film is in the range of from 0.28 to 0.6.

Figs. 11 and 12 each show the relationship between the electro-mechanical coupling coefficient and the normalized thickness H/λ of the ZnO thin film in the

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surface wave devices fabricated as mentioned above. Fig. 11 shows characteristics resulted when comb teeth electrodes were formed on the upper surface of the ZnO thin film, and Fig. 12 shows characteristics resulted when comb teeth electrodes were formed on the upper surface of the ZnO thin film and short-circuiting electrodes made of Al were formed at the entire interface between the ZnO thin film and the quartz substrate.

As is apparent from Figs. 11 and 12, in the case of using the quartz substrate of the Eulerian angles (0, 150, 0), the surface wave device having the sufficiently large electro-mechanical coupling coefficient can also be achieved by employing a surface wave substrate constructed by forming a ZnO film on the quartz substrate.

Fig. 13 is a graph showing the relationship between a temperature characteristic TCD and the normalized thickness H/λ of a ZnO thin film in the surface wave devices using the quartz substrates of the Eulerian angles (0, 150, 0). As is apparent from Fig. 13, in these surface wave devices, the temperature characteristic TCD of the higher-order mode LSAW2 of leakage elastic surface waves also shifts to the positive side by forming the ZnO thin film. It can be therefore understood that the surface wave device having a temperature characteristic TCD value of about ± 0 can be achieved by a combination of

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a quartz substrate with a negative value of the temperature characteristic TCD and a ZnO thin film.

As described above, with the surface wave device according to the first aspect of the present invention, since a piezoelectric thin film is formed on a quartz substrate, comb teeth electrodes are formed in contact with the piezoelectric thin film, and the thickness of the piezoelectric thin film is selected to be able to oscillate a higher-order mode of leakage elastic surface waves, it is possible to utilize the surface wave which has a higher sonic speed and a larger electro-mechanical coupling coefficient than obtainable with the conventional surface wave device constructed of a quartz substrate and utilizing the Rayleigh wave. Furthermore, the surface wave device is easily adaptable for operation at higher frequency.

In particular, by selecting the normalized thickness H/λ of the piezoelectric thin film to be in the range of from 0.28 to 0.6, the higher-order mode of leakage elastic surface waves can be surely oscillated.

With the surface wave device according to the second aspect of the present invention, in the construction wherein a piezoelectric thin film is formed on a quartz substrate and comb teeth electrodes are formed in contact with the piezoelectric thin film, the quartz substrate,

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the piezoelectric thin film and the comb teeth electrodes are formed to oscillate a higher-order mode of leakage elastic surface waves and prevent the higher-order mode of leakage elastic surface waves from attenuating during transmission. Therefore, it is possible to utilize the surface wave which has a higher sonic speed and a larger electro-mechanical coupling coefficient than obtainable with the conventional surface wave device constructed of a quartz substrate and utilizing the Rayleigh wave. Furthermore, the surface wave device is easily adaptable for operation at higher frequency.

Also, in the surface wave device according to the second aspect of the present invention, by selecting the normalized thickness H/λ of the piezoelectric thin film to be in the range of from 0.28 to 0.6, the higher-order mode of leakage elastic surface waves can be surely oscillated as with the foregoing device.

In addition, Japanese Unexamined Patent Publication No. 61-222312 describes that a wave of a higher sonic speed than the normal Rayleigh wave can be utilized in a surface wave device employing a quartz substrate, but the surface wave utilized in the prior art device according to the disclosed method is in fact a combination of an SSB wave and an STW wave, and a frequency characteristic necessarily produces a valley between two adjacent peaks.

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Therefore, when the prior art device is used as a surface wave resonator or a surface wave filter, satisfactory characteristics can not be achieved. Further, when a resonator is fabricated by using the prior art device, the number of pairs of interdigitated electrodes must be increased, resulting in another problem that the size of the resonator is increased. By contrast, in the surface wave device according to any of the first and second aspects of the present invention, since the higher-order mode of leakage elastic surface waves is utilized, i.e., since the surface wave utilized is not a combination of two waves, such a valley is not produced in a frequency characteristic. Accordingly, when a surface wave resonator or a surface wave filter is constructed by using the surface wave device according to any of the first and second aspects of the present invention, satisfactory resonance and filtering characteristics can be achieved. Further, since a sufficient resonance characteristic can be achieved without increasing the number of pairs of interdigitated electrodes, the size of the surface wave device can be reduced.

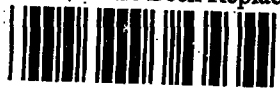
Consequently, the present invention can easily provide a surface wave device suitable for operation at higher frequency. In addition, since a quartz substrate having a good temperature characteristic is employed, it

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is possible to easily provide a surface wave device which has a good temperature characteristic, i.e., which can exhibit stable characteristics regardless of temperature changes in the ambient.

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WHAT IS CLAIMED IS:

1. A surface wave device comprising:

a quartz substrate,

a piezoelectric thin film formed on said quartz substrate, and

comb teeth electrodes formed in contact with said piezoelectric thin film,

said piezoelectric thin film being formed in such a thickness as able to ~~oscillate~~ generate a higher-order mode of leakage elastic surface waves so that said surface wave device operates with said higher-order mode of leakage elastic surface waves.

2. A surface wave device according to Claim 1, wherein said piezoelectric thin film is made of ZnO.

3. A surface wave device according to Claim 1, wherein given that said piezoelectric thin film has a thickness of H and said higher-order mode of leakage elastic surface waves has a wavelength of λ, the normalized thickness H/λ of said piezoelectric thin film with respect to said wavelength is in the range of from 0.28 to 0.6.

4. A surface wave device according to Claim 1, wherein

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said piezoelectric thin film is made of ZnO, and given that said piezoelectric thin film has a thickness of H and said higher-order mode of leakage elastic surface waves has a wavelength of λ, the normalized thickness H/λ of said piezoelectric thin film with respect to said wavelength is in the range of from 0.28 to 0.6.

5. A surface wave device according to Claim 1 or 3, wherein said piezoelectric thin film is made of one selected from the group consisting of AlN, Ta_2O_5 and CdS.

6. A surface wave device comprising:

a quartz substrate,

a piezoelectric thin film formed on said quartz substrate, and

comb teeth electrodes formed in contact with said piezoelectric thin film, wherein:

said quartz substrate, said piezoelectric thin film and said comb teeth electrodes are formed to ~~oscillate~~ generate a higher-order mode of leakage elastic surface waves and prevent said higher-order mode of leakage elastic surface waves from attenuating during transmission.

7. A surface wave device according to Claim 6, wherein said piezoelectric thin film is made of ZnO.

8. A surface wave device according to Claim 6, wherein given that said piezoelectric thin film has a thickness of H and said higher-order mode of leakage elastic surface waves has a wavelength of λ, the normalized thickness H/λ of said piezoelectric thin film with respect to said wavelength is in the range of from 0.28 to 0.6.

9. A surface wave device according to Claim 6, wherein said piezoelectric thin film is made of ZnO, and given that said piezoelectric thin film has a thickness of H and said higher-order mode of leakage elastic surface waves has a wavelength of λ, the normalized thickness H/λ of said piezoelectric thin film with respect to said wavelength is in the range of from 0.28 to 0.6.

10. A surface wave device according to Claim 6, wherein said piezoelectric thin film is made of one selected from the group consisting of AlN, Ta_2O_5 and CdS.

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