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[54] ACOUSTIC WAVE DEVICE FOR CONVERTING BULK MODE WAVES TO SURFACE WAVES AND VICE VERSA

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.**.....**310/8,** 310/8.2, 310/9.5, 310/9.7, 310/9.8, 333/30 R, 333/72, 330/5.5

[51] **Int. Cl.** **H01v 7/00**

[58] **Field of Search**.....310/8, 8.2, 8.3, 9.5–9.8; 181/.5 R, .5 AG, .5 T, .5 FS, .5 F, .5 H, .5 BN; 333/30 R, 72, 30 M; 330/5.5, 174

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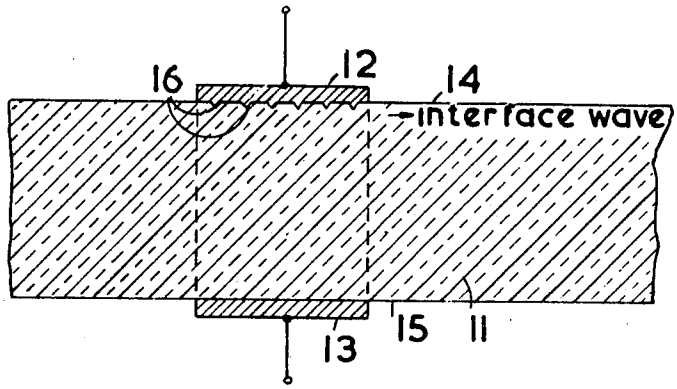
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[57] **ABSTRACT**

An acoustic wave device comprising a body of material having two generally plane, parallel surfaces facing each other, means for launching a bulk acoustic standing wave system in the body between the two surfaces or for detecting such a standing wave system, at least one of the two surfaces having a shaped profile arranged to launch a wave having a component consisting of an interface wave on the boundary of the body and being derived from energy trapped in the said bulk standing wave system or to receive an interface wave developed on the boundary of the body and to convert at least part of it into a bulk standing wave.

9 Claims, 3 Drawing Figures



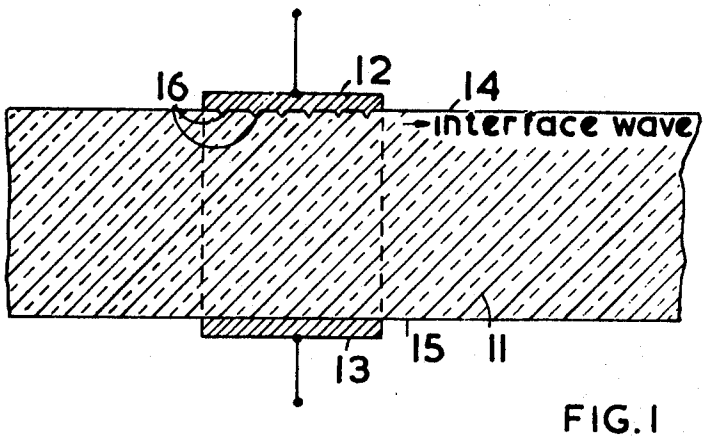


FIG. 1

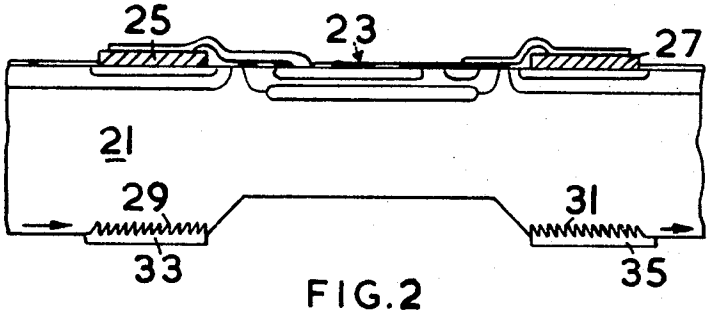


FIG. 2

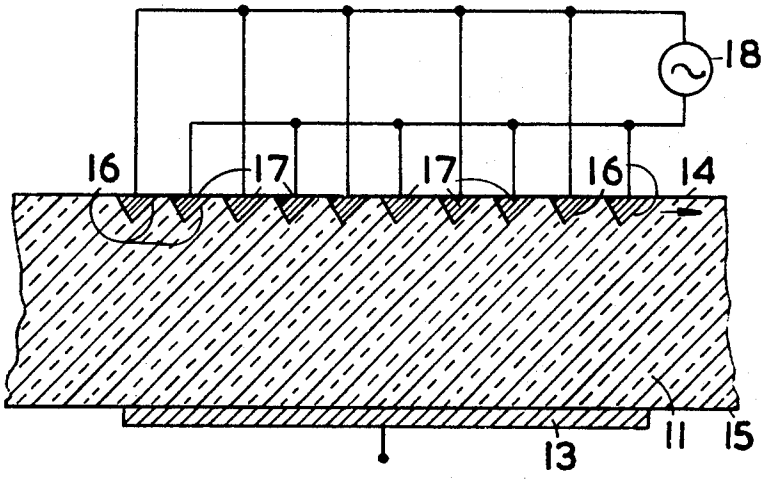


FIG. 3

ACOUSTIC WAVE DEVICE FOR CONVERTING BULK MODE WAVES TO SURFACE WAVES AND VICE VERSA

BACKGROUND OF THE INVENTION

The present invention relates to an acoustic wave device. Such a device may be used for producing in a body of material an acoustic wave having at least a component consisting of a surface or interface wave on the surface of the body. It may also be used for converting an acoustic surface or interface wave into a bulk wave which may be detected electrically.

In the present specification and claims the expression "interface wave" will be used to cover both surface waves and interface waves.

It is known that energy may be trapped in a standing acoustic wave system set up between small electrodes on opposite faces of a suitably oriented dielectric plate. Such a system can be arranged to resonate at frequencies corresponding to odd multiples of a bulk acoustic wave half wavelength. Resonance corresponds to constructive interference between bulk waves multiply reflected between opposite faces of the body. The quality of resonance is a function of the perfection of reflection from the faces of the body.

The present invention uses this fact by providing a shaped profile in at least one surface of the body whereby the quality of resonance is lowered and reflection losses occur. At least part of these losses is propagated in the form of an interface wave.

SUMMARY OF THE INVENTION

According to the present invention there is provided an acoustic wave device comprising a body of material having two generally plane, parallel surfaces facing each other, means for launching a bulk acoustic standing wave system in the body between the two generally plane, parallel surfaces, at least one of the two generally plane, parallel surfaces of the body having a shaped profile arranged to launch a wave having at least a component consisting of an interface wave on the boundary of the body and being derived from energy trapped in the said bulk standing wave system.

According to the present invention there is also provided an acoustic wave device comprising a body of material having two generally plane, parallel surfaces facing each other, means for detecting a bulk acoustic standing wave system developed in the body between the two generally plane, parallel surfaces, at least one of the two generally plane, parallel surfaces of the body having a shaped profile arranged to receive an interface wave developed on the boundary of the body and to convert at least a part of it into a bulk standing wave.

According to an aspect of the invention there is provided an acoustic wave device comprising a body of material carrying a pair of contacts on opposite faces of the body adapted to produce a bulk acoustic standing wave system in the body, at least one surface of the body having a shaped profile arranged to launch a wave having at least a component consisting of an interface wave on a boundary of the body, and being derived from energy trapped in the said bulk standing wave system.

Preferably the material comprises piezo-electric material, and the generally plane, parallel surfaces are spaced apart by a distance such as to produce a resonant structure corresponding to odd multiples of a bulk acoustic wave half wavelength. The profile preferably comprises a plurality of perturbations in the surface repeated regularly at intervals of one wavelength of the interface wave, each perturbation preferably being asymmetric in cross-section.

Examples of materials for producing devices embodying the invention are quartz, lithium niobate, cadmium sulphide, zinc oxide. Some variants of the device may be constructed in non-piezo-electric materials such as sapphire and silicon, provided suitable arrangements are made for acoustic coupling into the system. Electrostriction may provide an alternative mechanism for coupling energy into the system, as may magnetostriction.

A device according to the invention may act as a generator or receiver of interface waves or may be used as a parametric amplifier or mixer by the introduction of non-linearity into the material in which the standing wave system is formed.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described by way of example with reference to the accompanying drawing in which:

FIG. 1 is a cross-section of an acoustic wave generator,

FIG. 2 is a cross-section of part of an integrated circuit, and

FIG. 3 is a cross-section of a generator combining the principle of FIG. 1 with a ladder comb generator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 a plate of piezo-electric material **11** carries a pair of electrodes **12** and **13** on opposite surfaces **14** and **15** thereof. The surfaces **14** and **15** are generally plane and parallel and facing one another. The thickness of the plate is arranged to be such that a standing wave system can be set up between the electrodes **12** and **13** which form a resonant structure corresponding to odd multiples of the bulk acoustic wave half wavelength.

The surface **14** which carries the electrode **12** has a shaped profile comprising a series of parallel grooves **16** running across the surface **14** beneath the electrode **12**. The grooves **16** are parallel and spaced apart at intervals of one Rayleigh wavelength, and each groove **16** in cross-section has the shape of an asymmetric triangle, as shown in the figure. The electrode **12** is arranged to fill the grooves **16**.

In operation, the grooves **16** introduce acoustic loss from the resonator in the form of directionally launched quasi-interface waves which proceed along the surface **14** in a direction perpendicular to the grooves **16**. The sense in which the interface waves are propagated in that direction is determined by the asymmetrical shape of the grooves **16**, and in the example shown the interface wave proceeds in a direction from the steeper sides of the grooves **16** towards the less steep sides of the grooves.

By way of example, for an energy trapping resonator operating at 100 MHz in the fifth longitudinal wave harmonic, L will be typically 50 μ and the plate thickness d will be $(5/2) \times 50 = 125\mu$ thick where L represents the wavelength of a longitudinal bulk wave. If the grooves **16** are spaced at multiples of one Rayleigh wavelength (say $R = 20\mu$ where R is the wavelength of an interface wave), acoustic loss will be introduced into the resonator and the quasi interface waves will be launched. These waves will, in this example, since $d = 6R$, be indistinguishable from conventional interface waves. (Viktorovs criterion.)

It is possible to select the shaped profile in such a manner as to optimize balance between stored and radiated acoustic energy, and to minimize generation of spurious bulk waves in the system.

It is possible to construct embodiments of the invention which provide a number of advantages including narrow bandwidth and high selectivity, and high generation efficiency together with conversely high sensitivity to incoming signals. By loading the shaped resonant face, the sensitivity can be increased at the expense of bandwidth. The invention may also allow improved matching to an external circuit.

For example a device has been made in lithium niobate in which the shaped face comprises a series of parallel grooves having an asymmetrical triangular cross-section. The steep sides of the grooves were at right angles to the general surface direction and the angle at the valley of the groove was 55°. With this structure the wave launched in the direction from the steeper sides of the grooves towards the less steep sides of the grooves was 9dB above the wave launched in the opposite direction.

FIG. 2 is a cross-section of part of an integrated circuit. A single crystal silicon chip **21** having generally plane parallel

sides carries an integrated circuit shown generally at **23** on one surface. The integrated circuit includes thin film transducers **25** and **27**. The transducer **25** is situated opposite part of the surface **29** which has a profile shaped like the profile **14** in FIG. **1**. Similarly the transducer **27** is situated opposite part of the surface **31** which has a profile shaped like the profile **14** in FIG. **1**.

An electrode **33** is deposited on the part of the surface **29** and an electrode **35** is deposited on the part of the surface **31**. The surface between the part of the surface **29** and the part of the surface **31** is treated in known manner to inhibit the propagation of acoustic interface waves.

The action of the device is as follows. An acoustic interface wave is propagated from a source not shown towards the electrode **33** and is there at least partially converted to a bulk acoustic wave. The bulk acoustic wave is detected by the transducer **25** and processed in the integrated circuit **23**. The resulting signal appears at the transducer **27** which launches a bulk acoustic wave which, as described in FIG. **1** above, produces a further interface wave and so on. Thus integrated circuit components and interface wave components may be mounted on the same silicon slice.

The introduction of non-linearity into the structure (for example by means of a stress sensitive p-n junction in the device, or use of very high amplitude acoustic input) causes it to act as a parametric amplifier or mixer. In the latter variant, the stability offered by mechanical resonance proves advantageous for the mixing of signals from fixed frequency sources such as TV transmitters. For example an interface wave passed through the device can be pumped by the acoustic standing wave.

It is also possible to combine a structure according to the present invention with other acoustic interface wave generating structures, such as interdigital and ladder comb generators. One such combination is shown in FIG. **2**. The valleys **16** of the surface deformation are filled in by conducting bars **17** connected alternately in two sets which are connected one set to each terminal of a source **18** of alternating voltage. This particular combination possesses the advantage of giving a nearly unidirectional acoustic interface wave launch. Insertion characteristics of the combination will vary with the corrugation profile.

The device according to the present invention finds application in the frequency range 0.1 to 500 MHz, the upper limit being set only by present-day fabrication difficulties.

We claim:

1. An acoustic wave device comprising a body of piezo-electric material carrying a pair of contacts on opposite faces of the body adapted to produce a bulk acoustic standing wave system in the body, said opposite faces being spaced apart by a distance such as to produce a resonant structure corresponding to an odd multiple of a bulk acoustic wave half wavelength, at least one surface of the body having a shaped profile arranged to launch a wave having at least a component consisting of an interface wave on a boundary of the body and being derived from energy trapped in the said bulk standing wave system, said shaped profile comprising a plurality of grooves in said surface, said grooves having triangular cross sections and being placed parallel to one another and perpendicular to the direction of propagation of interface waves.

2. An acoustic wave device comprising a body of material capable of supporting acoustic waves and carrying a pair of contacts on opposite faces of said body spaced apart by a distance such as to produce a resonant structure corresponding to an odd multiple of a bulk acoustic wave half wavelength, at least one surface of said body having a shaped profile arranged to launch a wave having at least a component consisting of an interface wave on a boundary of said body and being derived from energy trapped in said resonant structure.

3. An acoustic wave device as in claim **2** in which said shaped profile comprises a plurality of perturbations in the surface repeated regularly at intervals of one interface wavelength.

4. An acoustic wave device as in claim **3** in which each of said perturbations is asymmetric in cross-section.

5. An acoustic wave device as in claim **4** in which said perturbations consist of grooves in said surface of said body, said grooves having triangular cross-sections and being placed parallel to one another and perpendicular to the direction of propagation of interface waves.

6. An acoustic wave device comprising a body of material capable of supporting acoustic waves and carrying a pair of contacts on opposite faces of said body spaced apart by a distance such as to produce a resonant structure corresponding to an odd multiple of a bulk acoustic wave half wavelength, at least one surface of said body having a shaped profile arranged to receive a wave having at least a component consisting of an interface wave on a boundary of said body and operative to convert at least part of said wave into a bulk standing wave in said resonant structure.

7. An acoustic wave device as in claim **6** in which said shaped profile comprises a plurality of perturbations in the surface repeated regularly at intervals of one interface wavelength.

8. An acoustic wave device as in claim **7** in which each of said perturbations is asymmetric in cross-section.

9. An acoustic wave device as in claim **8** in which said perturbations consist of grooves in said surface of said body, said grooves having triangular cross-sections and being placed parallel to one another and perpendicular to the direction of propagation of interface waves.

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