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PATENT SPECIFICATION

(11) 1 464 229

(21) Application No. 42973/75 (22) Filed 20 Oct. 1975
(31) Convention Application No. 49/129111
(32) Filed 9 Nov. 1974 in
(33) Japan (JA)
(44) Complete Specification published 9 Feb. 1977
(51) INT CL² H01L 41/08
(52) Index at acceptance
H1E 1

(19)

(54) SHEAR-MODE QUARTZ CRYSTAL VIBRATOR

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company of 3—4, 4-Chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to shear-mode quartz crystal vibrators.

Quartz crystal wristwatches employing flexure-mode quartz crystal vibrators are currently in common use and their accuracy is considerably improved thereby. Flexure-mode quartz crystal vibrators have been used to date because they have a relatively low resonant frequency. However, the temperature-resonant frequency characteristics and stability of the frequency of vibration of flexure-mode quartz crystal vibrators are inferior compared to those of shear-mode quartz crystal vibrators. The reason why shear-mode quartz crystal vibrators, which have excellent electrical characteristics, have not been used in wristwatches, even though electronic circuits which can cope with relatively high frequencies of vibration are available, is that it has not been possible to manufacture relatively small-sized and low-priced shear-mode quartz crystal vibrators by conventional techniques.

According to the present invention there is provided a shear-mode quartz crystal vibrator comprising an elongate vibrating portion and at least one support portion, the vibrating portion and the or each support portion being formed from a single piece of material. The vibrating portion being wider in its central part than at its ends, the vibrator being made from a plate of quartz crystal material which is cut in a plane obtained by rotating the plane of a Y-cut plate about the X-axis through an angle between 50° and 60°.

Preferably the vibrator is formed by a photoetching technique.

In one embodiment a common support portion interconnects the ends of the vibrating portion.

The vibrating portion may have metallic portions thereon.

The vibrator may be enclosed within a casing which is either evacuated or contains an inert atmosphere.

Preferably electrodes are formed on opposite faces of the vibrating portion. The electrodes may be composed of chromium and/or gold films.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 is a perspective view of a conventional shear-mode quartz crystal vibrator;

Figure 2 is a perspective view of one embodiment of a shear-mode quartz crystal vibrator according to the present invention;

Figure 3 shows the orientation of a plate quartz material from which the vibrator of Figure 2 is made;

Figure 4 illustrates a step in the manufacture of the vibrator of Figure 2;

Figure 5 is a side view of another embodiment of a shear-mode quartz crystal vibrator according to the present invention; and

Figure 6 is a perspective view of a further embodiment of a shear-mode quartz crystal vibrator according to the present invention.

Throughout the drawings like parts have been designated by the same reference numerals.

Figure 1 illustrates a conventional shear-mode quartz crystal vibrator 1 which is relatively small size. A pair of electrodes 2 (only one shown) are deposited on opposite faces of the vibrator 1, the electrodes 2 being electrically connected to respective supports 3 upon which the vibrator is mounted. The mode of vibration of the vibrator 1 is thickness-shear vibration as shown by arrows in Figure 1 and its temperature-resonant frequency characteristic is in the form of a cubic curve. This conventional shear-mode quartz crystal vibrator is particularly suitable for use in a wristwatch.

Moreover, the size of the vibrator 1 can be reduced to a considerable extent.

However, the process by which the vibrator 1 is formed from natural quartz crystal material is relevant as far as its electrical characteristics are concerned. In other words, some processes, such as, for example, the use of a diamond cutter, may cause distortions in the vibrator. To avoid such distortions it is desirable to make the vibrator 1 by a lapping method to obtain excellent ageing characteristics and a high Q value. The vibrator 1, since it has eight planar faces requires either eight lapping operations or four lapping operations if opposite faces are lapped simultaneously. This makes it difficult to manufacture the vibrator 1 at a low price. Furthermore, due to the relatively large number of lapping operations it is difficult accurately to provide the vibrator 1 with a given resonant frequency thus necessitating a subsequent tuning operation on the vibrator once it has been made.

Figure 2 illustrates an embodiment of a shear-mode quartz crystal vibrator according to the present invention. The vibrator has a vibrating portion 4 and a support portion 5, the vibrating portion 4 being wider at its central part than at its ends by which it is connected to the support portions. A pair of electrodes 6 (only one shown) are deposited on opposite planar faces of the vibrator. The vibrator is secured to a mounting block 7 by a solder 8 and is connected to driving circuitry by electrical leads 9 which are in electrical contact with the electrodes 6. The vibrating portion 4 and the support portion 5 are integral and the vibrator is made from a single relatively thin plate of quartz crystal material. The electrodes 6 are preferably formed by means of a deposition technique. The mode of vibration of the vibrator is as shown by arrows in Figure 2 and it is excited by applying a voltage across the electrodes 6.

One process of making the vibrator of Figure 2 will now be described. Figure 3 illustrates the orientation of a relative thin plate 10 of natural quartz crystal material. In Figure 3 the axes X, Y, Z are the electrical mechanical and optical axes of the quartz crystal material. The plate 10 is cut in a plane obtained by rotating the plane of Y-cut plate about the X-axis through an angle between 50° and 60°. The plate 10, after having been cut, is lapped and polished sufficiently to remove distortions caused during cutting.

The vibrator is made from the plate 10 by the following photo-etching technique. Initially, metallic films, for example, of chromium and/or gold, are formed on the opposite planar faces of the vibrator. Next, as shown in Figure 4, the metallic films are partly removed by a photo-etching technique so that they have a shape 11. Then the plate 10 is soaked in, for example, a mixture of hydrofluoric acid and ammonium fluoride so that the unwanted portions of the plate 10 from which the metallic films have been removed are dissolved, and a plurality of interconnected vibrators, each as shown in Figure 2, are produced. These vibrators are then separated from one another by breaking connecting portions 12. In this example, the metallic films serve as masks during dissolving of the unwanted portions of the plate 10 as well as the electrodes of the completed vibrator. It will, of course, be appreciated that the shape of the electrodes may be different from the shape of the vibrator, although this will then increase a number of steps required to form the vibrator.

The vibrator of Figure 2 may be manufactured at a relatively low cost and may be mass-produced. It also has the following advantages:

(1) The vibrator can have any desired external shape and it can be made of relatively small size.

(2) The vibrator can be made to a relatively high degree of accuracy and thus the need for subsequent tuning to a given resonant frequency is reduced or avoided. This contributes to a reduction in manufacturing costs.

(3) The vibrator, due to its high accuracy, may be installed by automatic equipment, for example, in a wristwatch.

(4) a number of vibrators may be produced simultaneously from one plate of quartz crystal material so that the resulting vibrators have very similar characteristics.

Figure 5 illustrates another embodiment of a shear-mode quartz crystal vibrator according to the present invention. The vibrator shown in Figure 5 has a vibrating portion 4 of a convex shape and is manufactured using a photo-etching technique so that there is a relatively wide freedom of choice for the shape of the vibrator. Therefore, the vibrating portion 4 can easily be made to be wider at its central part than at its ends, as shown in Figure 5. The vibrator of Figure 5 vibrates in the so-called trapped-energy mode. The metallic portions 13 which are comparatively thick and which are provided on both sides of the vibrating portion 4, facilitating tuning of the vibrator to a given resonant frequency. The resonant frequency is adjusted minutely by irradiating the metallic portions 13 with a laser to melt and disperse the necessary amount of metal therefrom to produce the given resonant frequency. A metallic portion 14, which is comparatively thick, is provided on the support portion 5 to aid

soldering of the vibrator to a block, such as the block 7 in Figure 2, and the electrical connection one of the electrical leads 9.

Figure 6 illustrates a further embodiment of a shear-mode quartz crystal vibrator 15 according to the present invention. The vibrator 15 has two separate support portions 5 at the ends of the vibrating portion 4. Electrodes are provided on opposite faces of the vibrator and are connected to respective lead wires via the support portions, the two lead wires passing through a plug 16 which is hermetically sealed to a cap 17 to form a casing. The casing is evacuated or contains an inert atmosphere and totally encloses the vibrator.

WHAT WE CLAIM IS:—

1. A shear-mode quartz crystal vibrator comprising an elongate vibrating portion and at least one support portion, the vibrating portion and the or each support portion being formed from a single piece of material, the vibrating portion being wider in its central part than at its ends, the vibrator being made from a plate of quartz crystal material which is cut in a plane obtained by rotating the plane of a Y-cut plate about the X-axis through an angle between 50° and 60°.

2. A vibrator as claimed in claim 1 in which the vibrator is formed by a photoetching technique.

3. A vibrator as claimed in claim 1 or 2 in which a common support portion interconnects the ends of the vibrating portion.

4. A vibrator as claimed in any preceding claim in which the vibrating portion has metallic portions thereon.

5. A vibrator as claimed in any preceding claim in which the vibrator is enclosed within a casing which is either evacuated or contains an inert atmosphere.

6. A vibrator as claimed in any preceding claim in which electrodes are formed on opposite faces of the vibrating portion.

7. A vibrator as claimed in claim 6 in which the electrodes are composed of chromium and/or gold films.

8. A shear-mode quartz crystal vibrator substantially as herein described with reference to and as shown in Figures 2 to 6 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1977
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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Figure 6 illustrates a further embodiment of a shear-mode quartz crystal vibrator 15 according to the present invention. The vibrator 15 has two separate support portions 5 at the ends of the vibrating portion 4. Electrodes are provided on opposite faces of the vibrator and are connected to respective lead wires via the support portions, the two lead wires passing through a plug 16 which is hermetically sealed to a cap 17 to form a casing. The casing is evacuated or contains an inert atmosphere and totally encloses the vibrator.

WHAT WE CLAIM IS:—

1. A shear-mode quartz crystal vibrator comprising an elongate vibrating portion and at least one support portion, the vibrating portion and the or each support portion being formed from a single piece of material, the vibrating portion being wider in its central part than at its ends, the vibrator being made from a plate of quartz crystal material which is cut in a plane obtained by rotating the plane of a Y-cut plate about the X-axis through an angle between 50° and 60°.

2. A vibrator as claimed in claim 1 in which the vibrator is formed by a photoetching technique.

3. A vibrator as claimed in claim 1 or 2 in which a common support portion interconnects the ends of the vibrating portion.

4. A vibrator as claimed in any preceding claim in which the vibrating portion has metallic portions thereon.

5. A vibrator as claimed in any preceding claim in which the vibrator is enclosed within a casing which is either evacuated or contains an inert atmosphere.

6. A vibrator as claimed in any preceding claim in which electrodes are formed on opposite faces of the vibrating portion.

7. A vibrator as claimed in claim 6 in which the electrodes are composed of chromium and/or gold films.

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