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(54) 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 quartz crystal vibrators and, in particular, although not so restricted, to quartz crystal vibrators for time-pieces, e.g. wristwatches.

The present invention seeks to provide a highly accurate quartz crystal vibrator which is of relatively small size and which can be produced at relatively low cost.

The resonant frequency of a quartz crystal vibrator, operating by virtue of the piezo electric effect, is very stable and consequently quartz crystal vibrators are widely used to produce a time standard signal in a wrist-watch. The following conditions, however, must be observed when a quartz crystal vibrator is used in a wristwatch:

1. it must be of relatively small size
2. it must have a stable frequency of vibration
3. it must have a well defined frequency of vibration
4. it must be capable of being produced easily at relatively low cost.

The first condition may be satisfied by a quartz crystal vibrator made from a plate of extremely thin quartz crystal material e.g. one whose thickness is 200 microns or less. As such a vibrator can be mass-produced using photoetching techniques, the fourth condition referred to above may also be satisfied. To satisfy the second condition it is necessary to suitably design the cutting angle of the quartz crystal material, the shape of the vibrator, the configuration of the electrodes, the airtightness of a case within which the quartz crystal vibrator is mounted, etc. To satisfy the third condition it is necessary that the frequency of vibration of the quartz crystal vibrator is easily variable over a relatively wide range by providing a trimmer capacitor in a driving circuit of the quartz crystal

vibrator. To satisfy the fourth condition the structure of the case or the method of mounting the quartz crystal vibrator is of importance.

According to the present invention, there is provided a quartz crystal vibrator of the tuning fork type having a plurality of electrodes thereon and secured to a support member, the support member being made of electrically insulating material and having electrically conducting portions which are out of electrical contact with one another but each of which is in electrical contact with a respective electrode.

In one embodiment the support member forms part of the casing within which the vibrator is mounted.

The vibrator may comprise a plate of quartz crystal material having a pair of electrodes on each face, each electrode on one face being electrically connected to one of the electrodes on the other face. Thus each electrode on one face of the vibrator may have a portion which is secured to and in electrical contact with a respective electrically conducting portion of the support member.

In one embodiment said support member is made of quartz crystal material.

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

Figure 1 is a perspective view of one type of conventional quartz crystal vibrator;

Figure 2 is a section of the quartz crystal vibrator of Figure 1 taken on the line 2—2 thereof;

Figure 3 shows the quartz crystal vibrator of Figure 1 secured to a support member;

Figure 4 is a perspective view of the front face of one embodiment of a quartz crystal vibrator according to the present invention;

Figure 5 is a perspective view of the rear face of the quartz crystal vibrator of Figure 4;

Figure 6 is a section of the quartz crystal vibrator of Figure 4 taken on the line 6—6 thereof;

Figure 7 shows the quartz crystal vibrator

of Figure 4 secured to one form of support member;

Figure 8 shows the quartz crystal vibrator of Figure 4 secured to a casing; and

Figure 9 illustrates the manufacture and construction of the casing shown in Figure 8.

Referring to Figures 1 to 3 there is shown one form of conventional quartz crystal vibrator 4 of the tuning fork type and having two tines. The axes X, Y, Z shown in Figures 1 are the electrical, mechanical and optical axes respectively of the quartz crystal material of which the quartz crystal vibrator is made. The quartz crystal vibrator 4 is cut from a plate of quartz crystal material, the plate being obtained by rotating an X-cut plate around the X-axis through an angle α and further rotating it through an angle γ around the Y'-axis which is generated by the Y-axis as a result of the rotation through the angle α . The angle α is chosen so that it is between 0° and 10° and the angle γ is chosen so that it is between 50° and 70° or -50° and -70° (i.e. 290° and 310°). The actual values chosen for the angles α and γ depend upon the temperature characteristics etc. of the quartz crystal material. The quartz crystal vibrator 4 has a pair of spaced apart electrodes 1, 2 provided on its front surface and a grounding or earthing electrode 3 provided on its rear surface. When positive and negative voltages are applied to leads 5, 6 respectively, the lead 5 being connected to the electrode 2 and the lead 6 being connected to the electrode 1, the electric fields indicated by arrows in Figure 2 are generated in the quartz crystal material. These electric fields in turn generate strains in each tine, the strains adjacent the edges of the tine being opposed. If, therefore, an alternating current is applied across the leads 5, 6, the quartz crystal vibrator will perform symmetrical flexural vibrations.

The quartz crystal vibrator 4 is soldered to a metallic support member 7 (Figure 3) with the aid of a metallic film which is deposited on the rear face of the quartz crystal vibrator. Accordingly, the electrode 3 on the rear face is in electrical contact with the support member 7.

Referring to Figures 4 to 6 there is illustrated a quartz crystal vibrator 8 according to the present invention, the vibrator being of the tuning fork type and having two tines. The quartz crystal vibrator is cut from a plate of quartz crystal material in a similar manner to the conventional quartz crystal vibrator illustrated in Figures 1 and 2. The quartz crystal vibrator has a pair of spaced apart electrodes 9, 10 on its front face, and a pair of spaced apart electrodes 11, 12 on its rear face. The electrodes 11, 12 have portions 13, 14 respectively for securing the quartz crystal vibrator to a support member which will be described in connection

with Figures 7 to 9. A connection wire 15 electrically interconnects electrodes 10 and 11 and a connection wire 16 electrically interconnects electrodes 9 and 12. When positive and negative voltages are applied to the wires 15, 16 respectively, the electric fields shown by arrows in Figure 6 are generated inside the quartz crystal material. These electric fields produce strains within the quartz crystal material, which strains extend outwardly or inwardly from the centre line of each tine. Thus if an alternating potential is applied between the wires 15, 16 the quartz crystal vibrator would perform symmetrical flexural vibrations. The electric fields have a larger component in the direction of the X-axis than the electric fields produced in the conventional quartz crystal vibrator shown in Figures 1 and 2 and consequently the quartz crystal vibrator of Figure 4 has lower dynamic impedance characteristics.

The quartz crystal vibrator shown in Figure 4 cannot be supported and secured to a conventional support member because of the provision of the wires 15, 16 which must be maintained out of electrical contact.

Figure 7 shows the quartz crystal vibrator 8 secured to a support member 17 made of an electrically insulating material such as a ceramic material. A pair of conductors 18, 19 are provided on the support member 17 in such a way that they are out of electrical contact with one another. The vibrator 8 is supported in such away that the portions 13, 14 of the electrodes 11, 12 are secured to the conductors 19, 18 respectively using solder or conductive adhesive. The electrode 19 is electrically connected to the conductor 18 by a wire 20 and the electrode 10 is electrically connected to the conductor 19 by a wire 21.

The support member 17 may be made by plating one surface of a ceramic plate with gold after which the coated ceramic plate is cut to the desired shape and then sintered. Alternatively, the support member may be made from a thin glass plate on which a metallic film has been deposited, the glass plate subsequently being cut to the desired shape by a chemical etching technique. If the conductors 18, 19 can be electrically insulated completely from one another the support member 17 does not require the recess shown in Figure 7. It is desirable that the rate of expansion of the material of the support member is the same as the rate of expansion of the quartz crystal vibrator. This may be achieved by forming the support member 17 of quartz crystal material cut in the same manner as the quartz crystal vibrator. Thus no strains are generated between the quartz crystal vibrator and the support member within a relatively wide temperature range. This enhances the performance of the quartz crystal vibrator.

Figures 8 and 9 illustrate another method of mounting the quartz crystal vibrator 8. In this embodiment the quartz crystal vibrator is secured to a support member 23 forming part of a casing 22 for the quartz crystal vibrator. Electrodes 24 are provided to enable the quartz crystal vibrator to be electrically connected to external circuitry (not shown). Figure 9 illustrates a method of making the casing 22. The casing comprises a base board 25 and frames 26, 27 each being made of semi-calcined ceramic material. A gold paste 24 is coated on the frame 26 to form the electrodes 24. The base board 25 and the frames 26, 27 are assembled together and then calcined which results in the gold being sintered and the base board and frames being secured together. The quartz crystal vibrator is then mounted on the frame 26. This arrangement is advantageous by virtue of the fact that it requires less labour to mount the quartz crystal vibrator in a timepiece than the arrangement shown in Figure 7.

The quartz crystal vibrators according to the present invention and described above may be used to advantage in wristwatches where superior timekeeping is achieved.

WHAT WE CLAIM IS:—

1. A quartz crystal vibrator of the tuning fork type having a plurality of electrodes thereon and secured to a support member, the support member being made of electrically insulating material and having electrically

conducting portions which are out of electrical contact with one another but each of which is in electrical contact with a respective electrode. 35

2. A quartz crystal vibrator as claimed in claim 1 in which the support member forms part of the casing within which the vibrator is mounted. 40

3. A quartz crystal vibrator as claimed in any preceding claim in which the vibrator comprises a plate of quartz crystal material having a pair of electrodes on each face, each electrode on one face being electrically connected to one of the electrodes on the other face. 45

4. A quartz crystal vibrator as claimed in claim 3 in which each electrode on one face of the vibrator has a portion which is secured to and in electrical contact with a respective electrically conducting portion of the support member. 50

5. A quartz crystal vibrator as claimed in any preceding claim in which said support member is made of quartz crystal material. 55

6. A quartz crystal vibrator substantially as herein described with reference to and as shown in Figures 4 to 9 of the accompanying drawings. 60

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