

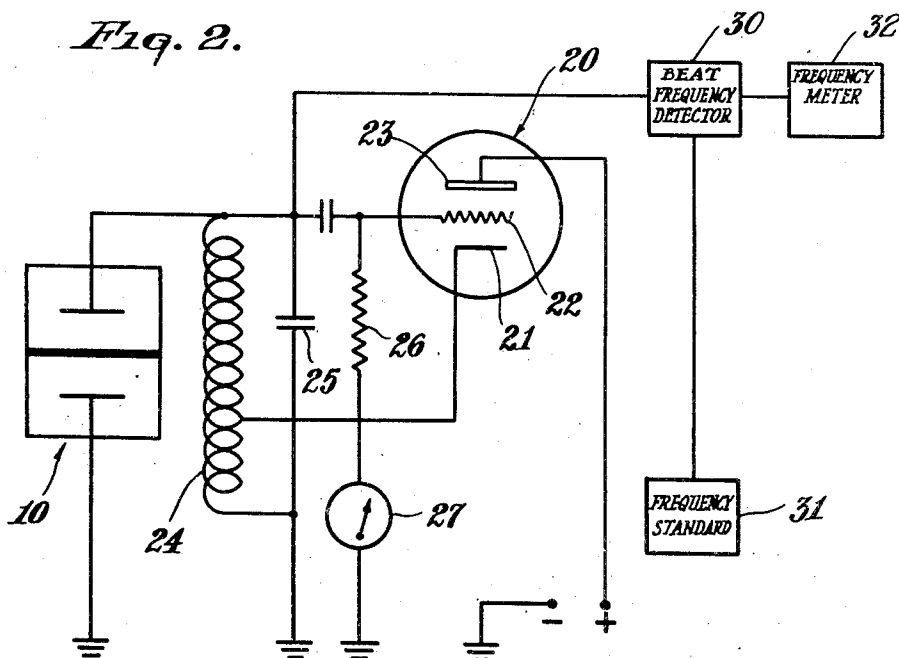
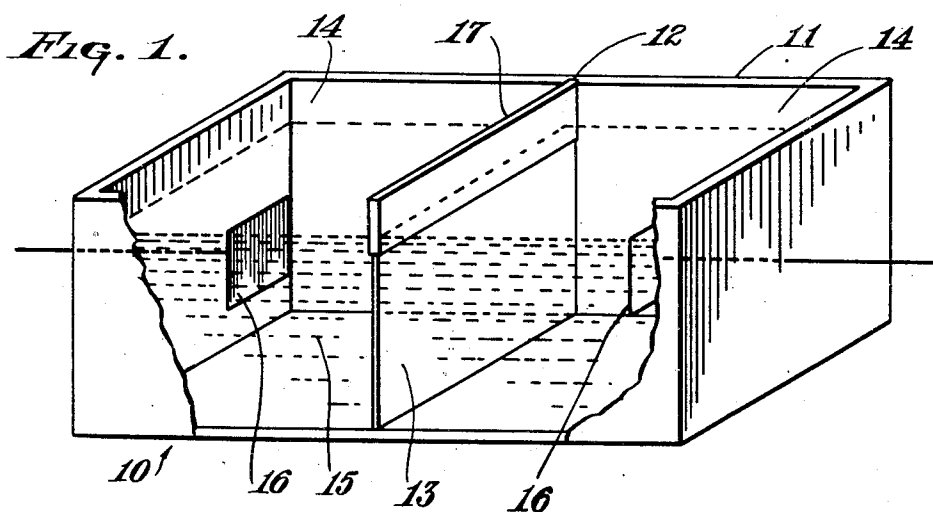
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PIEZOELECTRIC CRYSTAL

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PIEZOELECTRIC CRYSTAL

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My invention relates to piezo-electric devices and to a method for manufacturing the same.

The invention will be described in connection with the manufacture of piezo-electric quartz crystal wafers; however, it should be well understood that the invention is equally applicable for the manufacture of piezo-electric crystals consisting of other materials, for example, of tourmaline, and having a shape other than that of a wafer, for example, having the shape of a bar.

The resonant frequency of a quartz crystal wafer is a function of its physical dimensions and in general in the case of the most generally used types of crystals, for example, of the so-called X-cut, Y-cut, AT-cut and BT-cut, the thickness of the wafer largely determines its resonant frequency. In general the wafer is produced by grinding a rough-cut crystal blank in lapping machines in a series of steps until the thickness of the wafer becomes only slightly greater than the thickness corresponding to the desired frequency value. Subsequently the wafer is manually lapped until it exhibits the desired frequency. In some instances the normal lapping is substituted in whole or in part by a treatment in an etching atmosphere, for example, by exposure to hydrofluoric acid vapors, or in an etching solution, for example, by immersion in a solution of ammonium difluoride until the desired final frequency is attained.

In their subsequent use crystal wafers so processed undergo a substantial change in frequency from the frequency to which the wafer is initially processed. This change in frequency commonly identified as aging, has been found to be greatly influenced by the presence of disordered crystalline material on the surface of the wafer and within the microscopic crystalline peaks protruding from the wafer surfaces. This disordered material and those microscopic crystals at the surface of the wafer which are not permanently secured to the body of the wafer become dislodged to a greater or lesser degree in the subsequent use of the wafer and correspondingly vary the electro-mechanical constants and hence the resonant frequency of the wafer. Since the conditions under which the crystal wafer is to be subsequently operated are not generally known, the course and extent of the resultant frequency change are unpredictable and subject to wide variations.

It is an object of my invention to provide a novel method for manufacturing piezo-electric crystal elements whereby crystals of improved characteristics are produced.

A more specific object of my invention is to provide a method of manufacturing quartz crystal wafers which obviates aging of the wafer produced by changes in the electro-mechanical constants thereof resulting from the presence of disordered crystalline material.

A further object of my invention is to provide

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novel apparatus for processing quartz crystal wafers.

These and further objects of my invention will appear as the specification progresses.

In accordance with my invention the above-noted aging of piezo-electric crystal wafers is substantially entirely precluded or minimized to the point that aging in the subsequent use of the wafer is of a minor character and predictable by subjecting the wafer to combined chemical and physical forces which dissolve and simultaneously disrupt the disordered crystalline material and non-permanently secured microscopic crystals from the wafer surfaces. More particularly, the crystal wafer is immersed in an etching solution which is agitated at a supersonic frequency whereby the wafer surface is chemically etched and the wafer is simultaneously subjected to physical forces derived from the high kinetic energy imparted to the etching solution which disrupt the disordered crystalline material and non-permanently secured microscopic crystals from the wafer surface.

In the preferred form of the invention the etching solution is agitated at a supersonic frequency by the crystal wafer being processed. More particularly, the wafer is made to act as a piston in the etching solution by electrically coupling the wafer to an oscillator preferably operating at the resonant frequency of the wafer. In this preferred arrangement a further advantage is obtained in that by measuring the frequency of the oscillator in well-known manner, the resonant frequency of the wafer becomes known and the supersonic etching of the crystal wafer can be prevented from continuing to a point beyond the desired final frequency of the wafer.

My invention will be described in greater detail with reference to the appended drawing forming part of the specification in which:

Fig. 1 is a perspective view showing an etching container for processing a quartz crystal wafer in accordance with my invention. For clarity of illustration one side of the container has been broken away.

Fig. 2 is a schematic diagram of apparatus for processing a quartz crystal wafer in accordance with the preferred embodiment of my invention.

Referring to the drawing, the apparatus shown in Fig. 1 comprises a rectangular tank 10 of hard rubber, Bakelite or the other electrical insulating material resistant to the etching solution, the side walls 11-11 of which are notched at 12 to receive a crystal wafer 13 which divides the tank into two compartments 14-14. Within each compartment 14 is an etching solution 15 consisting, for example, of a 40% water solution of hydrofluoric acid or a 25% water solution of ammonium difluoride. Each of the etching solutions 15 also serves as an electrode for the crystal wafer by means of which electrical energy is applied to the

crystal wafer for vibrating the same at a supersonic frequency thereby producing supersonic agitation of the etching solution. Electrical connections to the etching solutions are made by electrode plates 16—16, for example, of copper. The crystal wafer 13 is completely immersed in the etching solution and to minimize direct electrical conduction between the compartments the barrier formed by the crystal wafer is preferably supplemented by means of an insulating masking element 17 of hard rubber which barrier extends beyond the surface of the etching solution.

In carrying out the process in accordance with the invention, a crystal wafer 13 is cut to the desired shape and to a thickness greater than the thickness corresponding to the desired resonant frequency. The rough cut wafer may then be machine lapped to a thickness value corresponding to or greater than the thickness at which heretofore the manual processing of the wafer was initiated.

For vibrating the crystal wafer at a supersonic frequency the wafer is coupled to an oscillator, for example, of the type shown in Fig. 2. The oscillator shown comprises a discharge tube 20 having a cathode 21, a control grid 22 and an anode 23 connected in feedback relationship in known manner to an inductance-capacitance tuned circuit 24—25 having a resonant frequency in the supersonic range, i. e., a resonant frequency greater than about 25 kilocycles. A self-regulating operating bias voltage for the tube 20 is provided by means of a grid-leak resistor 26. Ammeter 27 serves as a grid-current indicator during operation of the oscillator. The crystal wafer to be processed is connected across the resonant circuit 24—25 by means of conductors affixed to the electrode plates 16—16 (see Fig. 1).

The cutting of the wafer from the mother crystal and the subsequent lapping thereof produces a substantial amount of disordered crystalline material in microscopic form which remains on the surface of the wafer and/or within the microscopic cavities produced by the crystalline elements protruding from the surface of the crystal. By immersing the wafer in an etching solution agitated at supersonic frequency the wafer is subjected simultaneously to chemical action and to the action of the kinetic energy forces imparted to the solution by the supersonic agitation and it is found that the disordered crystalline material is substantially completely removed as well as those microscopic crystals which are only partially etched out by the chemical action and thus non-permanently secured to the crystal wafer.

In the preferred arrangement of my invention, the constants of the tuned circuit 24—25 are so selected that the resonant frequency of the tuned circuit approximates the resonant frequency of the crystal wafer whereby the crystal wafer vibrates at its resonant frequency and becomes the frequency determining element of the oscillator. Under this condition of treatment relatively little energy is demanded from the oscillator and it is found that an oscillator employing receiving type tubes, for example, of the type 6J5 produce sufficient excitation of the crystal wafer to bring about vigorous agitation of the etching solution. Furthermore, a simple method of continuously checking the degree of etching is provided by means of which the etching of the wafer to a point beyond the desired final frequency is prevented. More particularly, the oscillator may be coupled to a beat-frequency detector 30 and the

frequency of the wafer compared with a signal voltage of the desired frequency derived from a frequency standard 31. The beat frequency produced by detector 30 is applied to a frequency meter 31 and the etching of the wafer is terminated when the resonant frequency of the wafer attains a predetermined value with respect to the frequency of the standard 31 as indicated by the frequency meter 32.

While I have described my invention by means of specific examples and in specific embodiments I do not wish to be limited thereto for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

What I claim is:

1. In the manufacture of piezo-electric elements the steps comprising immersing a crystal element in an etching solution and etching the surface of the element so immersed while simultaneously vibrating the element and agitating said solution at a supersonic frequency.

2. In the manufacture of piezo-electric elements the steps comprising predimensioning a crystal element to a resonant frequency greater than about 25 kilocycles, immersing the predimensioned element in an etching solution, and etching the surface of said element so immersed while simultaneously vibrating the element and agitating said solution at the resonant frequency of the element.

3. The method of manufacturing a piezo-electric element having a predetermined resonant frequency, comprising predimensioning a crystal wafer to a resonant frequency greater than about 25 kilocycles, immersing the predimensioned element in an etching solution, etching the surface of said element so immersed while simultaneously vibrating the element and agitating said solution at the resonant frequency of the element, measuring the resonant frequency of the element, and terminating said etching when the resonant frequency of the element equals the said predetermined resonant frequency.

4. Apparatus for processing piezo-electric elements, comprising a container for an etching solution, means to so position the element in the container that the major surfaces of the element are exposed to the etching solution and the element divides the container into two compartments, and means to electrically connect the etching solution in each of said compartments to a source of electrical potential.

5. Apparatus for processing piezo-electric elements, comprising a container for an etching solution, means to so position the element in the container that the major surfaces of the element are exposed to the etching solution and the element divides the container into two compartments, and means coupled to said element through the etching solution to vibrate the element at a super-sonic frequency.

6. Apparatus for processing piezo-electric elements, comprising a container for an etching solution, means to so position the element in the container that the major surfaces of the element are exposed to the etching solution and the element divides the container into two compartments, means coupled to the element through the etching solution to vibrate the element at the resonant frequency of the element, and means to measure the resonant frequency of the element during the etching thereof.