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DRAWINGS ATTACHED

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(54) METHOD OF MANUFACTURING AN ENERGY TRAPPED TYPE CERAMIC FILTER

(71) We, MURATA MANUFACTURING CO. LTD., of 16 Koaza Nishijin-cho, Oaza Kaiden, Nagaoka-Cho Otokuni-gun, Kyoto-fu, 617, Japan, a Company duly organised under the laws of 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 generally to a method for manufacturing a piezoe-electric ceramic resonator, and more particularly to a method for manufacturing an energy trapped type piezoelectric ceramic resonator which is used as an electric wave filter or an impedance transformer, and also to a manufacturing method suitable for mass production which enables to very efficiently and economically manufacture a ceramic filter being small in size and unchanged in characteristics.

The term "Piezoelectric ceramic" used frequently herein indicates ceramics which are made of fired polycrystalline ceramic materials, and is capable of providing, by operation of electrical polarization, piezoelectric characteristics generally similar to those possessed inherently by certain natural dielectrics i.e., quartz crystal or Rochelle salt or the like.

Among well known piezoelectric ceramics, there have been Barium Titanate and Lead Titanate-Zirconate Ceramics.

There has conventionally been used as an electric wave filter a ceramic resonator composed of such piezoelectric ceramics. However, the conventional ceramic resonators have troubles in casing thereof in its practical use, because of using the vibration of a piezoelectric ceramic plate in radial mode. That is, it is necessary for casing of a ceramic resonator to apply electrically secure connection as well as without damping mechanical vibration of the ceramic resonator. Among conventional methods of mechanical holding and electrical connection of the prior ceramic resonator, there has been a wire-mounting method which comprises providing pin terminals on a base, supporting the ceramic resonator in the air, through lead wires connected between pin terminals and electrodes of the ceramic resonator, and covering all such devices by outer cases, and there has been another type of a metal plate-contacting method which comprises contacting to electrodes of the ceramic resonator such point contacts as formed on the flexible metal plates acting as terminals themselves, and accommodating such all devices within outer cases.

Therefore, these prior ceramic resonators constructed by said conventional methods have the disadvantages that electrical characteristics of the ceramic resonators become worse when stress is put on the mechanical parts thereof, and the mechanical strength of the ceramic resonator becomes unstable when stress is put on the electrical characteristics. This is because these prior ceramic resonators have been constructed by using both electrical connections and mechanical features of the resonators in supporting them in a casing. Such resonators also have further disadvantages in that their size is relatively large because of difficulty in miniaturization thereof and in that their construction is not suitable for mass production.

There has recently been proposed an energy trapped type ceramic resonator as a ceramic resonator not having the above-mentioned disadvantages. An electrical filter using this resonator can be used in place of an electrical filter using said conventional ceramic resonators. The energy trapped type ceramic resonator is to utilize such phenomena that vibrational energies between small electrodes provided partially on both surfaces of a thin piezoelectric ceramic plate may be trapped only between the small electrodes and near them. Since this resonator vibrates only at the electrode area, it is necessary not to damp vibration of such

electrode area. For this reason, this resonator has been manufactured in the prior art by the following steps:

running external-connecting electrodes from resonator electrodes formed on a thin piezoelectric ceramic plate and connecting lead wires to said external connecting electrodes; covering resonator electrodes with spacers made of insulative materials such as synthetic resin so as to form spaces between the resonator electrodes and the spacers and moulding the whole ceramic assembly in a layer of insulative resin or accommodating the whole ceramic assembly within a casing and injecting resin into the casing to surround them. However, the piezoelectric ceramic plate and resonator electrodes formed thereon are very small in size, and it is thus very difficult and troublesome to place the spacers on the resonator electrodes. Accordingly, such conventional methods have not been very efficient.

It is therefore one object of the present invention to improve said conventional method for making energy trapped type ceramic resonators and to provide an improved method for enabling the mass production of such resonators.

It is another object of the present invention to provide a method of manufacturing a ceramic resonator which has very stable characteristics, that is securely mechanically held such that the electrical characteristics thereof will not be affected.

It is a further object of the present invention to provide a ceramic resonator suitable for an electrical filter which is smaller in size and simpler in constrruction than the prior types.

The present invention is accordingly a method of manufacturing an energy trapped type piezoelectric ceramic resonator which comprises covering electrodes of an energy trapped type ceramic resonator formed on a piezoelectric ceramic wafer with a thin layer of a gap-forming material which is solid or semi-solid at normal temperature but can be easily melted by heating: thereafter placing an insulative thermosetting resinous material layer on the surface of the said piezoelectric ceramic wafer and covering the surface of said layer of gap-forming material, said thermosetting resinous material having a composition such that on heating to cure the resin the layer becomes porous, heating the thus covered ceramic wafer to cure the resin and to melt said thin layer of gap-forming material to form gaps between the resonator electrodes and the insulative resinous layer by said molten thin layer of gap-forming material being absorbed into the pores of the insulative resinous layer.

The present invention will be explained in greater detail with reference to the accompanying drawings in which:

Figure 1 is a front surface view of a three terminal electrode-electrical filter using an energy trapped type ceramic resonator with an insulative resinous layer removed;

Figure 2 is a rear surface view of the electrical filter of Figure 1;

Figure 3 is a sectional view of the electrical filter taken along the lines 3—3 of Figures 1 and 2;

Figures 4 to 6 are sectional views of one embodiment of the method of the invention showing each step in the process of manufacturing the filter; and

Figure 7 is a plan view showing a number of ceramic resonators for electrical filters arranged on a holder.

A three terminal type electrical filter will be described with reference to the drawings as one example of this invention.

Figures 1 to 3 are a front view, a rear view, and a sectional view of the three terminal type electrical filter, respectively, in which, reference numeral 1 denotes a piezoelectric ceramic wafer, on one surface of which are formed two split type electrodes 2a and 2b. From each of these electrodes are taken out outer connecting electrodes 3a and 3b, at end portions of which are connected lead wires 4a and 4b. An electrode 5 opposite to said split type electrodes 2a and 2b is provided on the rear surface of said piezoelectric ceramic plate 1, an outer connecting electrode 6 is taken out from said electrode 5 and a lead wire 7 is connected at an end portion of said outer connecting electrode 6.

The piezoelectric ceramic wafer 1 is polarized throughout the whole thereof or at least between the mutually opposite electrodes, so that an energy trapped type resonator in thickness expansion mode is formed between the split electrode 2a and the electrode 5 and between the split electrod 2b and electrode 5, respectively. Further the two energy trapped type resonators formed between the split electrode 2a and the electrode 5 and between the split electrod 2b and the electrode 5 are mechanically coupled by the centre portion of the ceramic wafer 1. The present invention relates to a method of providing a protective layer by covering the resonator electrodes of such an electrical filter with an insulative resinous layer in such a manner so as not to impair vibration of the resonators.

Figure 4 shows a state in the manufacturing method of the present invention wherein the gap-forming material 9 is adhered to electrodes of an electrical filter. The material 9 may be wax, paraffin or the like which is in solid or semi-solid state at normal temperature but is easily softened by heating and tends to melt at a relatively low temperature. The gap-forming material 9 is placed on the resonator electrodes by means

of brush coating, printing or dipping while in the molten condition. Immersing or dipping is more suitable for producing a thin layer on a large number of ceramic wafers all at once. The gap-forming material 9 solidifies in the air in a very short time.

The piezoelectric ceramic wafer 1 provided with gap-forming layers 9 on the electrodes is next provided with a layer 10 of a thermosetting resinous material having a composition such that on heating to cure the resin the layer becomes porous. This step is shown in Figure 5.

During the heating step to cure the resin the gap-forming material such as wax, paraffin or the like forming the thin layers 9 is melted and absorbed into the pores of the insulative resinous outer layer 10 so that gaps 11 are formed as shown in Figure 6. Vibration of electrodes will not be damped due to the presence of these gaps 11, so that a desirable energy trapped type filter is obtained. The layer 10 may be alternatively formed by molding instead of the dipping method. In this case the method may be operated as follows:

The piezoelectric ceramic wafer 1 on which the coated layer 9 of the adhering gap-forming material is provided is placed in a mould. The thermosetting, insulative resinous layer 10 is moulded around the wafer with the gap-forming material thereon. The resinous layer is then heated to effect curing and becomes porous. This simultaneously melts the gap-forming material and the latter becomes absorbed into the pores of the layer of resinous material.

In the energy trapped type resonator, the gaps 11 between electrodes and the insulative resinous layer 10 need only be a few microns in the thickness direction of the wafer. The kinds and quantities of the gap-forming material and the composition of the insulative resin is selected so that said gaps are easily obtained.

The three terminal type electrical filter has been explained above, but, of course, it goes without saying that the present invention can be applicable for the production of a two terminal type electrical filter of the energy trapped type or the production of ceramic filter portions of hybrid microcircuit elements using as a substrate the piezoelectric ceramic wafer provided with energy trapped type electrical filter.

The manufacturing of a single filter has been explained above. However, the present invention can also be used to manufacture a plurality of filters simultaneously by arranging a plurality of filters on a holder i.e. as shown in Figure 7 thereby making possible mass producing of the filters.

It is apparent from the above explanation that the present invention does not require the positioning of spacers as in the prior art. It thus decreases the number of parts used in the method and thus mass production can be carried out more efficiently and economically than the prior manufacturing methods.

Further, in accordance with the present invention, the ceramic resonators manufactured are much smaller in size than the prior resonators because gaps are made on resonator electrodes without spacers.

Further, in accordance with the present invention, lead wires of the ceramic resonator can be attached to outer electrodes by solder or conductive paint and the like, and these attaching surfaces are well fixed by the insulative resinous layer. Therefore, both electrical connection and mechanical holding are secure and firm, and thus ceramic resonators can be obtained which are free from change in characteristics and which are durable.

WHAT WE CLAIM IS:—

1. A method of manufacturing an energy trapped type piezoelectric ceramic resonator which comprises covering electrodes of an energy trapped type ceramic resonator formed on a piezoelectric ceramic wafer with a thin layer of a gap-forming material which is solid or semi-solid at normal temperature but can be easily melted by heating: thereafter placing an insulative thermosetting resinous material layer on the surface of the said piezoelectric ceramic wafer and covering the surface of the said layer of gap-forming material, said thermosetting resinous material having a composition such that on heating to cure the resin the layer becomes porous, heating the thus covered ceramic wafer to cure the resin and to melt said thin layer of gap-forming material to form gaps between the resonator electrodes and the insulative resinous layer by said molten thin layer of gap-forming material being absorbed into the pores of the insulative resinous layer.

2. The method as claimed in Claim 1, wherein said gap forming material is wax.

3. The method as claimed in Claim 1, wherein said gap forming material is paraffin.

4. The method as claimed in Claim 1, wherein the insulative resinous layer is formed by dipping the wafer in a bath of insulative resinous material dissolved in a solvent.

5. The method as claimed in Claim 1, wherein said insulative resinous layer is formed by moulding insulative resinous material around the wafer.

6. A method of manufacturing an energy trapped type ceramic filter as hereinbefore

of brush coating, printing or dipping while in the molten condition. Immersing or dipping is more suitable for producing a thin layer on a large number of ceramic wafers all at once. The gap-forming material 9 solidifies in the air in a very short time.

The piezoelectric ceramic wafer 1 provided with gap-forming layers 9 on the electrodes is next provided with a layer 10 of a thermosetting resinous material having a composition such that on heating to cure the resin the layer becomes porous. This step is shown in Figure 5.

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The three terminal type electrical filter has been explained above, but, of course, it goes without saying that the present invention can be applicable for the production of a two terminal type electrical filter of the energy trapped type or the production of ceramic filter portions of hybrid microcircuit elements using as a substrate the piezoelectric ceramic wafer provided with energy trapped type electrical filter.

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2. The method as claimed in Claim 1, wherein said gap forming material is wax.

3. The method as claimed in Claim 1, wherein said gap forming material is paraffin.

4. The method as claimed in Claim 1, wherein the insulative resinous layer is formed by dipping the wafer in a bath of insulative resinous material dissolved in a solvent.

5. The method as claimed in Claim 1, wherein said insulative resinous layer is formed by moulding insulative resinous material around the wafer.

6. A method of manufacturing an energy trapped type ceramic filter as hereinbefore

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described with reference to and as illustrated in the accompanying drawings.

7. An energy trapped type piezoelectric ceramic resonator made by the method according to any of claims one to six.

REGINALD W. BARKER & CO.,
Patent Agents for the Applicants,
13 Charterhouse Square,
London, E.C.3.

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