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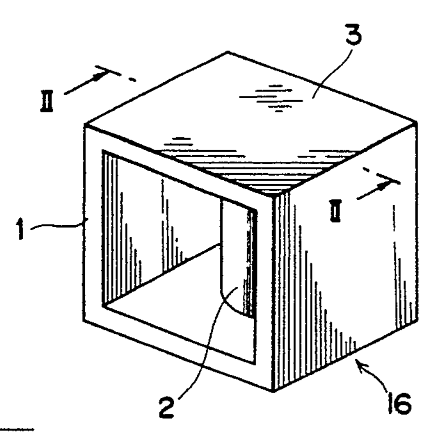
(54) **Dielectric resonator and manufacturing method therefor.**

(57) A dielectric resonator includes a cavity case made of ceramic material and having top and bottom walls and one pair of side walls extending between the top and bottom walls to define a cylindrical cavity, a solid internal dielectric column made of ceramic material and having its opposite ends monolithically connected to the top and bottom walls, and an electric conductive film formed on the surface of the cavity case for carrying a real current.

Fig. 1



EP 0 352 628 A2

DIELECTRIC RESONATOR AND MANUFACTURING METHOD THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a TM mode dielectric resonator in which a solid internal dielectric column is provided inside a cavity case, with both column and cavity case being made of a high frequency ceramic dielectric material. The present invention also relates to a method for manufacturing such a TM mode dielectric resonator.

2. Description of the Prior Art

Conventional dielectric resonators of this type provide an internal dielectric column made from a dielectric ceramic is installed inside a cylindrical cavity case manufactured by bonding ceramic plates with a binder. The top and bottom ends of this internal dielectric column are bonded to the inside wall of the cavity case, and a conductive film which is for the real current path is formed on the inside wall or the outside wall of the cavity case by silver baking or other processes.

A ceramic cavity case is used instead of a metallic cavity case for the following reasons. If an internal dielectric column made of a dielectric ceramic is installed inside a metallic cavity case and bonded to the inside wall of the metallic case with a silver paste applied to the top and bottom ends of the internal dielectric column, the differences in the coefficients of thermal expansion of the metallic case and internal dielectric column result in separation between the inside wall of the metallic case and the top and bottom of the internal dielectric column. Once separation occurs, the resulting joule loss causes the Q factor of the filter to drop, and thus causes problems of instability in the filter characteristics. Therefore, the cavity case is formed from a ceramic material with approximately the same coefficient of thermal expansion as the internal dielectric column. A conductive film is then formed on the surface of the cavity case to carry the real current.

A cross section of a conventional dielectric resonator is shown in Fig. 5, in which the cavity case is formed from a ceramic material. In this dielectric resonator 5, a silver paste is applied to the inside surfaces of ceramic top 6, bottom 7, and sides 8. When this silver paste is baked with top 6, bottom 7, and sides 8 assembled as shown, the silver acts as a binder and members 6, 7, 8 are bonded together to form a square-shaped cavity case 9 while at the same time forming conductive film 10, which forms the real current path, on the inside walls of cavity case 9. In a separate process, a silver paste is also applied to the top and bottom ends of internal dielectric column 11 prepared separately. Internal dielectric column 11 is then placed inside cavity case 9, and by baking the silver paste on both ends of internal dielectric column 11 to conductive film 10 inside cavity case 9, the top and bottom ends of internal dielectric column 11 are affixed to the inside wall of cavity case 9.

However, in processes in which a silver paste is applied to both ends of internal dielectric column 11 and baked to cavity case 9, the end processing of internal dielectric column 11 to which the paste is applied is time consuming, and the baking conditions are strict. Thus, technically it is difficult to expect complete bonding between internal dielectric column 11 and cavity case 9. Also, if the bond between cavity case 9 and internal dielectric column 11 is not complete, incomplete bonded areas will temporarily contact and separate, causing unstable electrical conductivity between internal dielectric column 11, which is the displacement current path, and conductive film 10, which is the real current path. Thus, noise will easily occur and the filter characteristics will not be stable.

Another conventional embodiment is shown in Fig. 6. In this dielectric resonator 15, top 6, bottom 7, and sides 8 are bonded by means of glass glaze 12 to form square cavity case 13. The top and bottom ends of internal dielectric column 11 placed inside cavity case 13 are also bonded to the inside walls of cavity case 13 by means of glass glaze 12 applied to both ends. A silver paste is then applied to the outside walls of cavity case 13 and baked to form conductive film 14.

However, because the dielectric constant of glass glaze 12 is low, and the intrinsic conductivity is low and the Q factor is low, the Q factor of the dielectric resonator 15 also drops due to the effect of the low Q factor glass glaze 12 interposed between internal dielectric column 11 and conductive film 14. Furthermore, due to variations in the thickness of the glass glaze 12 (the dielectric constant of glass glaze 12 is relatively low compared with that of internal dielectric column 11), the bulk dielectric constant of the bond sites of internal dielectric column 11 and cavity case 13 is varied. Thus, the variation in the dielectric constant causes significant errors in the resonance frequency of dielectric resonator 15.

Moreover, in each of the conventional members described above, because the dielectric resonator is formed by bonding top 6, bottom 7, sides

8, and internal dielectric column 11 together by means of a silver paste, glass glaze, or other binder, additional time and processes are required in manufacturing for assembly, thereby increasing manufacturing costs.

SUMMARY OF THE INVENTION

The present invention has been developed with a view to substantially solving the above described disadvantages and has for its essential object to provide an improved dielectric resonator which operates with high stability and high reliability, and with which uniform, constant resonator characteristics can be obtained.

Also, it is an important object of the present invention to provide a method for manufacturing such an improved dielectric resonator to simplify the manufacturing process and also to reduce production costs.

In accomplishing these and other objects, a dielectric resonator according to the present invention comprises: a cavity case made of ceramic material and having top and bottom walls and one pair of side walls extending between the top and bottom walls to define a cylindrical cavity; a solid internal dielectric column made of ceramic material and having its opposite ends monolithically connected to the top and bottom walls; and an electric conductive film formed on the surface of the cavity case for carrying a real current.

Also, according to the present invention, a method for manufacturing a dielectric resonator comprises the steps of: molding a dielectric resonator body which comprises a cavity case made of ceramic material and having top and bottom walls and one pair of side walls extending between the top and bottom walls to define a cylindrical cavity, and a solid internal dielectric column made of ceramic material and having its opposite ends monolithically connected to the top and bottom walls; sintering the molded dielectric resonator body; and depositing an electric conductive film on the surface of the cavity case for carrying a real current.

In a dielectric resonator according to the present invention, the ends of the internal dielectric column are integrally formed with the inside wall of the cavity case without the use of a binder intermediate. Thus, the connecting condition between the internal dielectric column and the cavity case is stable both mechanically and electrically, and therefor, there are no problems with the separation of the bond site or poor bonding. Thus, a resonator with high reliability can be obtained. Specifically, a stable resonance frequency can be obtained because noise is not generated in the output by an unstable bond site as occurred in conventional dielectric resonators bonded by baking a silver paste, and a drop in the Q factor and variations in the resonance frequency do not occur as in conventional dielectric resonators bonded with a glass glaze.

Furthermore, the manufacturing method for a dielectric resonator according to the present invention makes it possible to obtain a dielectric resonator as described above, to simultaneously mold the internal dielectric column and the cavity case by an injection molding or other monolithic molding process. Thus, with the present invention, the number of processes required for manufacturing is decreased by eliminating the cavity case and internal dielectric column assembly processes, resulting in the reduction of manufacturing costs. In addition, the manufacturing method according to the present invention is also suited to mass production by eliminating the assembly process.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description taken in conjunction with a preferred embodiment thereof with reference to the accompanying drawings, throughout which like parts are designated by like reference numerals, and in which:

Fig. 1 is a perspective view of a dielectric resonator according to a preferred embodiment of the present invention;

Fig. 2 is a cross-sectional view taken along a line II-II shown in Fig. 1;

Fig. 3 is a cross-sectional view showing one example of a mold used for injection molding to make the dielectric resonator of Fig. 1;

Fig. 4a is a diagrammatic view of molding apparatus to make the dielectric resonator of Fig. 1;

Fig. 4b is a block diagram showing the steps for manufacturing the dielectric resonator of Fig. 1;

Fig. 5 is a cross-sectional view showing a conventional dielectric resonator; and

Fig. 6 is a cross-sectional view showing another conventional dielectric resonator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figs. 1 and 2, dielectric resonator 16 according to a preferred embodiment of the present invention includes a solid internal dielectric column 2 placed inside a hollow cylindrically-shaped cavity case 1. Cavity case 1 has top and bottom walls to which internal dielectric column 2 is integrally connected, and one pair of side walls. Thus, internal dielectric column 2 can be seen from another side of cavity case 1. A silver paste is baked to the outside surface of cavity case 1 to form conductive film 3. A TM_{010} mode dielectric resonator 16 is thus constructed so that internal dielectric column 2 becomes the displacement current path and conductive film 3 becomes the real current path.

The cavity case 1 and internal dielectric column 2 are formed monolithically from a titanium oxide or other ceramic material with a high dielectric constant. Since a silver paste or glass glaze is not interposed between the top and bottom ends of internal dielectric column 2 and the inside wall of cavity case 1, internal dielectric column 2 can be firmly installed in cavity case 1. In other words, when body is ejected from the mold, cavity case 1 and internal dielectric column 2 are molded monolithically so that internal dielectric column 2 is bonded continuously and homogeneously to cavity case 1.

As shown in Figs. 1 and 2, internal dielectric column 2 is molded as a round column, but it may also be molded as a column with a square or other cross section. Furthermore, as shown in Fig. 2, conductive film 3 is provided only on the outside surface of cavity case 1, but it may also be provided on the inside wall of cavity case 1 or on all surfaces of cavity case 1.

In a dielectric resonator 16 so constructed, the displacement current flowing through internal dielectric column 2 is converted to a real current between internal dielectric column 2 and conductive film 3 and flows to conductive film 3, and the specific electromagnetic vibrations of the TM_{010} mode are trapped inside cavity case 1. Furthermore, by mounting multiple dielectric resonators 16 inside a metallic case (not shown in the figures) and electrically connecting the conductive films 3 of adjacent dielectric resonators 16 by means of a common ground plate (not shown in the figure), a specific electromagnetic coupling occurs between adjacent dielectric resonators 16, and the assembly can be used as a multistage dielectric filter.

A manufacturing method for making dielectric resonators according to the present invention is described next with reference to Figs. 4a and 4b.

Referring to Fig. 3, a molding machine comprises molds 17a and 17b which are used for one-step monolithic molding of cavity case 1 and internal dielectric column 2 by an injection molding process. While only one molding cavity 18 is shown in Fig. 3, a mold 17a, 17b for injection molding with which multiple dielectric resonators can be molded at one time can be made by providing multiple molding cavities 18. Molding cavity 18 is formed in mold 17a, 17b for injection molding to simultaneously mold cavity case 1 and internal dielectric column 2. A parting face PL is provided so as to pass through the center of internal dielectric column 2.

Referring to Fig. 4a, a bulk powder of titanium oxide or other high dielectric constant ceramic material to which an organic binder for molding has been added is then charged from hopper 20 of injection molding machine 19, and the injection plunger inside injection molding machine 19 is driven to inject the molding material into molding cavity 18 of mold 17a, 17b to simultaneously and monolithically mold body 4 of cavity case 1 and internal dielectric column 2. After this, one side of the mold, mold 17a, is moved using air cylinder 21 connected to mold 17a, the movable side of the mold, and molds 17a and 17b are separated and opened from parting face PL to eject the ceramic body 4. An ejected body in which the top and bottom ends of internal dielectric column 2 are monolithically bonded to the inside wall of cavity case 1 is thus obtained.

Referring to Fig. 4b, treatment steps are shown. After the organic binder for molding is removed in degreasing process 22, body 4 is sintered to a hard, dense ceramic molding in sintering process 23. Therefore, cavity case 1 and internal dielectric column 2 have a uniform structure throughout, and the bond site of the two members in particular is a uniform structure stable both mechanically and electrically. After sintering, a silver paste is applied to the outside surface of cavity case 1 by coating machine (not shown) at a silver coating process 24, and this silver paste is baked by oven (not shown) at baking process 25 to form conductive film 3 on the surface of cavity case 1.

In the manufacturing method as described above, the cavity case and internal dielectric column are simultaneously and monolithically molded by an injection molding process, but a similar monolithic molding can also be achieved by compression molding, transfer molding, and other molding processes. Moreover, it is also possible to mold a cylindrical cavity case body and an internal dielectric column body separately, bond by means of press fitting or other method the top and bottom ends of the internal dielectric column to the inside walls of the cavity case while both moldings are still in a body state, and then monolithically sinter the cavity case and internal dielectric column bodies together to form a monolithic dielectric resonator without using a binder to bond the cavity case and internal dielectric column.

According to the present invention, a high reliability dielectric resonator which is stable mechanically and electrically at the bond site between the internal dielectric column and the cavity case can be obtained. Furthermore, such problems of conventional dielectric resonators as the generation of noise due to an unstable bond site between the internal dielectric column and the cavity case, a decrease in the Q factor such as occurs when a binder with a low specific conductivity is used, and variations in the resonance frequency such as occur when a binder with a dielectric constant different from that of the internal dielectric column is used, can be resolved. Furthermore, by manufacturing a dielectric resonator using the method according to the present invention, the cavity case and internal dielectric column can be simultaneously molded as a monolithic structure, the process of assembling the cavity case and internal dielectric column can be eliminated, the production process can be simplified, the production cost of dielectric resonators can be reduced, and dielectric resonators can be easily mass produced.

Although the present invention has been fully described in connection with the preferred embodiment thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. A dielectric resonator comprising:
a cavity case made of ceramic material and having top and bottom walls and one pair of side walls extending between said top and bottom walls to define a cylindrical cavity;
a solid internal dielectric column made of ceramic material and having its opposite ends monolithically connected to said top and bottom walls; and
an electric conductive film formed on the surface of the cavity case for carrying a real current.

2. A method for manufacturing a dielectric resonator comprising the steps of:
molding a dielectric resonator body comprising:
a cavity case made of ceramic material and having top and bottom walls and one pair of side walls extending between said top and bottom walls to define a cylindrical cavity; and
a solid internal dielectric column made of ceramic material and having its opposite ends monolithically connected to said top and bottom walls;
sintering said molded dielectric resonator body; and
depositing an electric conductive film on the surface of the cavity case for carrying a real current.

Fig. 1

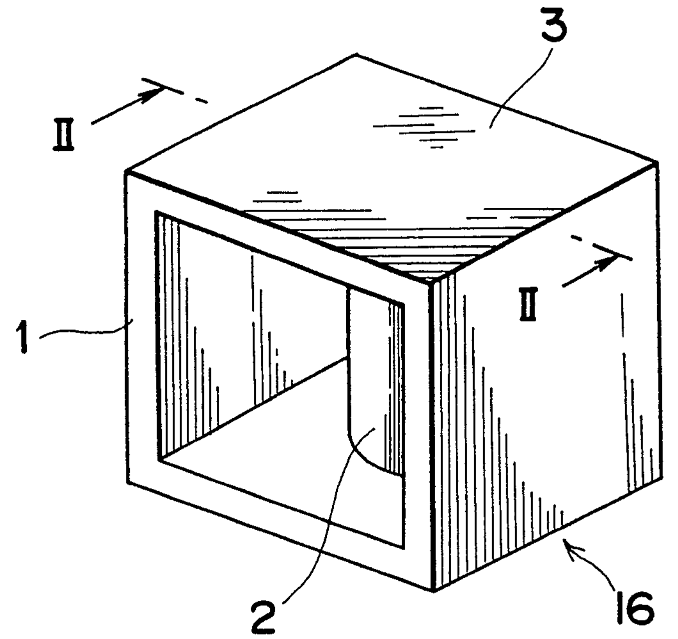


Fig. 2

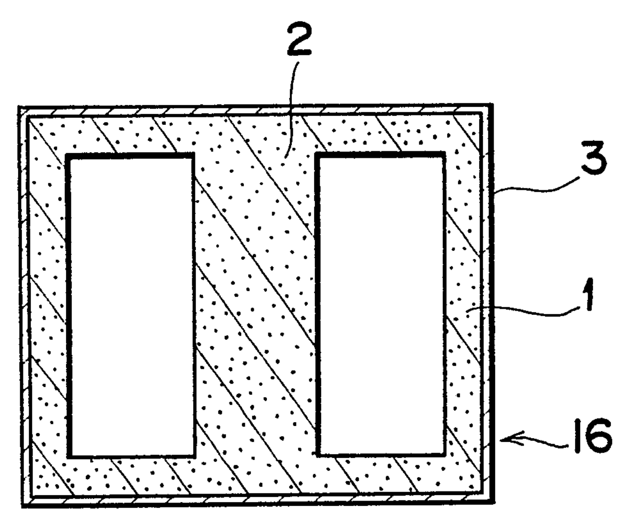


Fig. 3

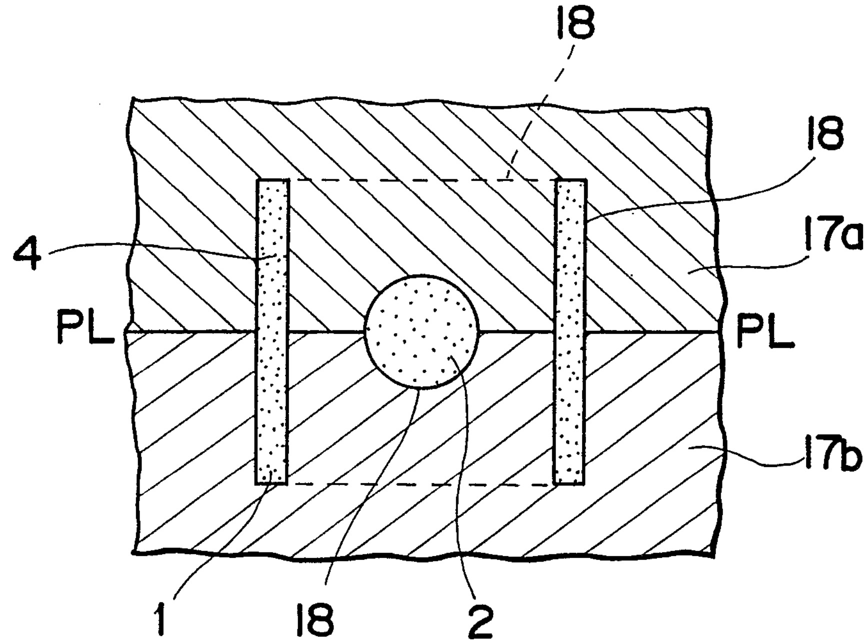


Fig. 4a

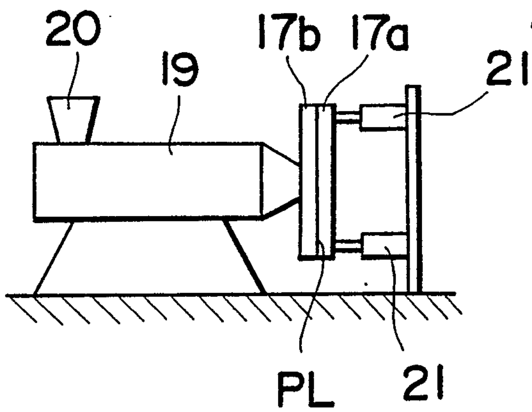


Fig. 4b

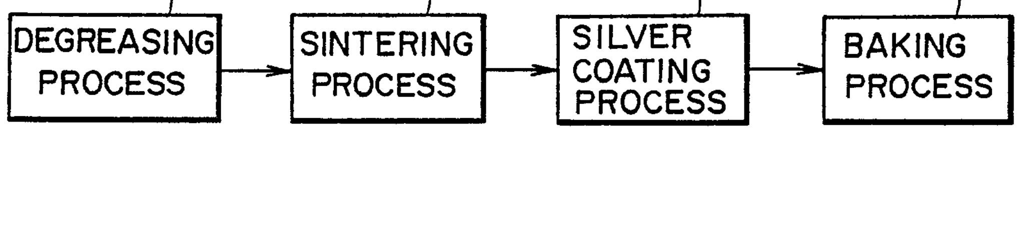


Fig. 5 PRIOR ART

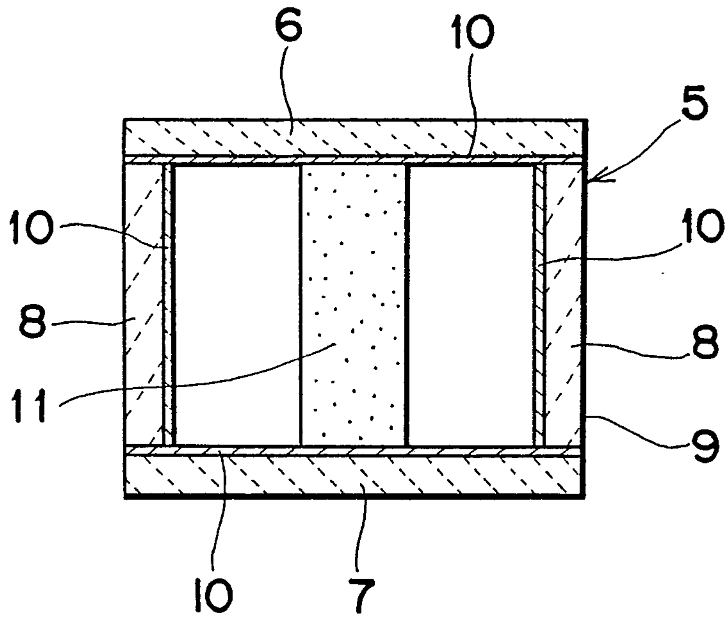


Fig. 6 PRIOR ART