

Sept. 15, 1970

L. C. GUNDERSON ET AL
MICROWAVE CAVITY RESONATOR USING COATED
FUSED SILICA OR GLASS CERAMIC

3,529,267

Filed Oct. 20, 1967

2 Sheets-Sheet 1

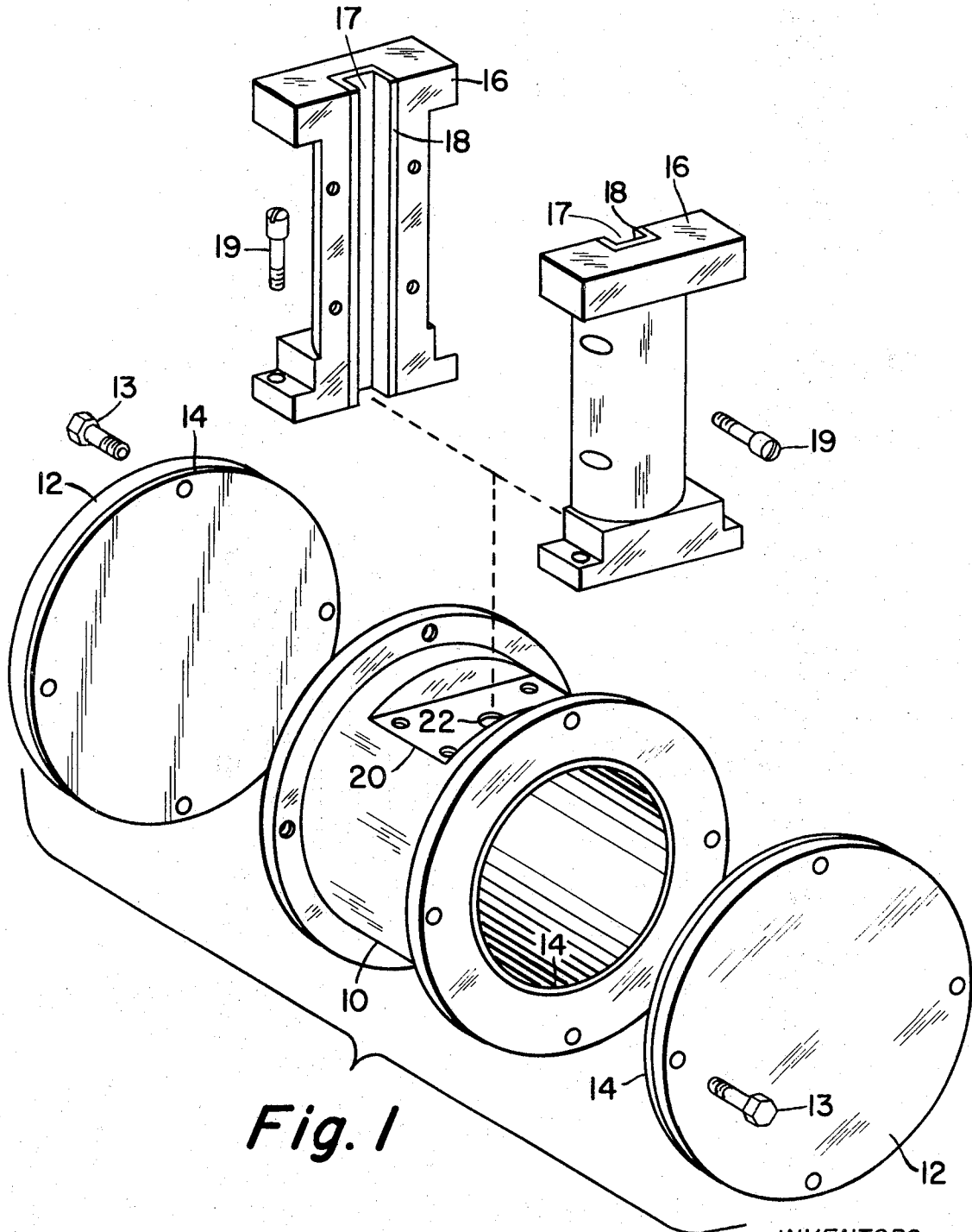


Fig. 1

INVENTORS.
LESLIE C. GUNDERSON
GERHARD K. MEGLA
DAVID M. SMITH

BY *Valter S. Zebrowski*
ATTORNEY

Sept. 15, 1970

L. C. GUNDERSON ET AL
MICROWAVE CAVITY RESONATOR USING COATED
FUSED SILICA OR GLASS CERAMIC

3,529,267

Filed Oct. 20, 1967

2 Sheets-Sheet 2

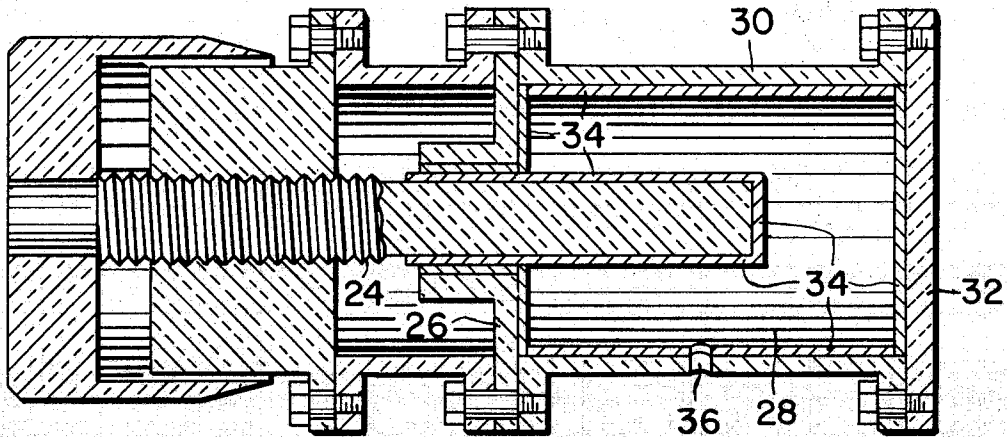


Fig. 2

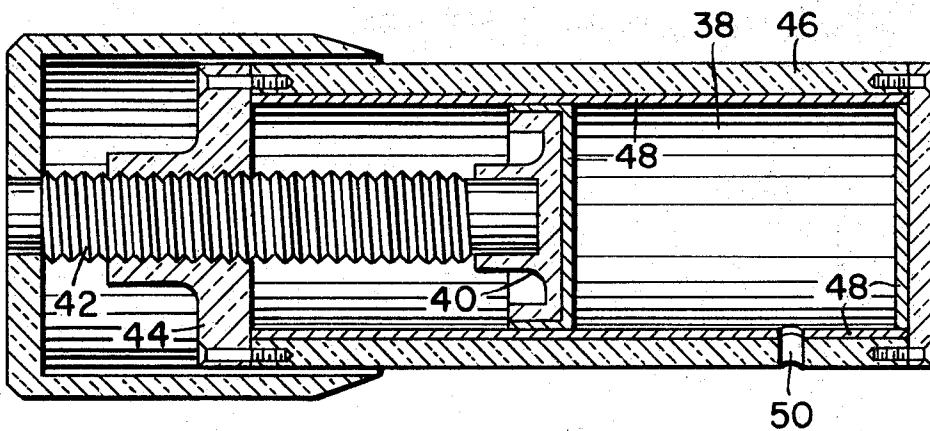


Fig. 3

INVENTORS.

LESLIE C. GUNDERSON
GERHARD K. MEGLA
DAVID M. SMITH

BY

Walter S. Zabrowski

ATTORNEY

1

2

3,529,267

**MICROWAVE CAVITY RESONATOR USING
COATED FUSED SILICA OR GLASS CERAMIC**
Leslie C. Gunderson, Gerhard K. Megla, and David M.
Smith, Raleigh, N.C., assignors to Corning Glass
Works, New York, N.Y., a corporation of New York
Filed Oct. 20, 1967, Ser. No. 676,772
Int. Cl. H01p 7/06

U.S. Cl. 333—83

12 Claims

ABSTRACT OF THE DISCLOSURE

A cylindrical cavity resonator and waveguide constructed from a low expansion fused silica or glass ceramic material and having a high order of frequency and dimensional stability as a function of temperature and time. The high level of stability achieved eliminates the need for frequency compensation which characteristically degrades with age.

BACKGROUND OF THE INVENTION

The resonant frequency of a cavity resonator is a function of the physical dimensions of the cavity. Stability of the resonant frequency is dependent upon the ability of the materials comprising the resonator to maintain dimensional stability. Thermal expansion properties and the tendency to creep with the passage of time are both factors affecting the dimensional stability of materials. Though dimensional changes caused by these factors may be comparatively slight, when resonators are operated in the microwave range even minute dimensional changes can produce serious frequency instability. Consequently, it is desirable to construct resonators from materials having low thermal expansion properties.

An example of one of the lowest expansion materials that has commonly been used in resonator construction is Invar, an alloy of nickel and iron usually containing about 36% nickel with traces of selenium and cobalt. A difficulty encountered with the use of Invar results from the fact that it is quite hard and difficult to machine. Articles made from Invar are ordinarily work hardened and contain high levels of residual stress. This condition promotes creep in the material resulting in gradual dimensional changes as residual stresses seek to redistribute and relieve themselves over a period of time. The tendency of Invar material to creep is reduced somewhat by the process of annealing to permit stress relief, but it is not eliminated entirely. It is difficult to assign an absolute value to the magnitude of creep in Invar since it is generally dependent upon the manner in which the material has been processed and machined but in any case, creep is known to have been one of the major contributors to frequency instability in resonator materials.

To help avoid problems of dimensional instability in resonators constructed of materials such as Invar, a means of providing some degree of automatic frequency stability, commonly called frequency compensation, is often designed into the resonator structure. A common means for achieving frequency compensation in cylindrical cavity resonator involves use of a hollow cylindrical substrate made from relatively low expansion material, and end sections, made from higher expansion material, closing each end of the cylinder to form a resonant cavity. Each cylinder end section takes the shape of two flat discs of different diameters, one mounted coaxially upon the other. The smaller diameter disc, being of slightly less diameter than the inside diameter of the cylindrical cavity, projects into the cavity from one end of the substrate while the larger diameter disc fits securely against the circular rim of the cylinder end.

In the above described resonator configuration, a temperature increase causing the length of the cylinder to expand also caused the thickness of the smaller diameter disc portion of each end plate to expand into the cavity in a manner calculated to maintain the cavity at a constant resonant frequency. Similarly, a decrease in ambient temperature which produces contraction of the cylinder length also produces contraction in the thickness of the end plates tending to maintain the cavity at constant resonant frequency. Since the thicknesses of the smaller diameter discs are usually considerably less than the length of the cylindrical substrate, they must expand or contract to a greater extent per degree of temperature change than does the cylinder length if frequency compensation is to be achieved. Consequently, the end plate material must have a coefficient of thermal expansion of greater magnitude than does the material comprising the cylindrical substrate.

One difficulty in using high expansion materials to obtain frequency compensation is that, ordinarily, the tendency of such materials to creep with time is greater than with lower expansion materials. Also, the difference in radial expansion and contraction of the low expansion cylindrical substrate material and the end-plate materials may produce additional stressing of the materials resulting in geometric distortion of the cavity and a reduction in the ability of the dissimilar resonator materials to compensate for dimensional changes.

Thus, because of their relatively high thermal expansion tendencies, resonators have required frequency compensation in order to obtain a reasonable degree of stability. However, the high degree of creep occurring in frequency compensated resonators reduces the ability of dissimilar resonator component materials to interact with one another to maintain frequency stability over long periods of time. Consequently, operating performance diminished continuously with aging of the resonators materials. Even where the tendency to creep has been minimized by annealing or other means, frequency compensation methods do not ordinarily produce high levels of stability over a wide temperature range. This is because materials having high coefficients of thermal expansion do not ordinarily expand at the same rates per unit of temperature change over a wide range of temperatures.

BRIEF DESCRIPTION OF THE INVENTION

It is an object of the instant invention to provide a cavity resonator with coupling system having a high order of dimensional stability.

It is yet another object of the instant invention to provide a cavity resonator with coupling system having a high order of frequency stability without the necessity of employing frequency compensation.

It is still another object of the instant invention to provide a cavity resonator with coupling system whose quality of frequency stability and performance is substantially unaffected by aging.

It is an additional object of the instant invention to provide a means for electromagnetic coupling to the cavity of a microwave resonator without appreciably decreasing resonator frequency stability thereby.

It is also an object of the instant invention to provide a cavity resonator with coupling system having a high degree of frequency stability over a wide range of ambient temperatures.

Briefly, in accordance with the instant invention, a cavity resonator for electromagnetic energy is provided consisting of a hollow cylindrical substrate and a pair of flat end plates adapted to fit against the ends of the substrate so as to form a cylindrical cavity with closed ends. The substrate, end plates, and means used to fasten the resona-

tor assembly together are constructed of the same low expansion material selected from the group consisting of fused silica or glass-ceramics. A film having high electrical conductivity and a smooth surface finish covers the cavity defining surfaces of the substrate and end plates. An opening defining portion of the cylinder wall and film is provided in order to couple electromagnetic energy between the cavity and points external thereto.

Additional objects, features and advantages of the instant invention will become apparent to those skilled in the art, from the following detailed description and attached drawings on which, by way of example, only the preferred embodiments of the instant invention are illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an exploded view of the cylindrical cavity resonator and waveguide illustrating one embodiment of the instant invention.

FIG. 2 shows a cross sectional view of a tunable coaxial cavity resonator illustrating another embodiment of the instant invention.

FIG. 3 shows a cross sectional view of a cylindrical cavity resonator employing an alternative means of tuning and illustrating another embodiment of the instant invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 a cylindrical cavity resonator composed of a hollow cylindrical substrate 10 and a pair of flat cylinder-end plates 12 is constructed from a single low expansion fused silica or glass-ceramic material. Such materials have considerably lower rates of thermal expansion than conventional resonator materials such as Invar. The approximate compositions of two suitable examples of glass-ceramic materials are listed in column 1 and 2 of the table below. Columns 3 and 4 of the table list the approximate compositions of two suitable fused silica materials. The cylinder-end plates 12 are secured to the substrate 10 by means of threaded fasteners 13 made of the same material as the substrate 10 and the cylinder-end plates 12.

TABLE

	1	2	3	4
SiO ₂	64	64.0	99.5+	93.0
Al ₂ O ₃	22	23.0	-----	-----
Na ₂ O.....	1	0.3	-----	-----
K ₂ O.....	0.2	0.2	-----	-----
Li ₂ O.....	4	4.0	-----	-----
MgO.....	-----	2.0	-----	-----
BaO.....	4	-----	-----	-----
PbO.....	-----	1.5	-----	-----
TiO ₂	2	2.0	-----	7.0
ZrO ₂	2	2.0	-----	-----
As ₂ O ₃	0.8	1.0	-----	-----

The inside surface of the substrate 10 and one face of each of the cylinder end plates 12 defining the resonator cavity are covered by a thin metallized film 14 such as copper, silver, glass frit-silver mixtures, alloys of either copper or silver, or the like in any suitable manner well known in the art. The film 14 should be as highly conductive electrically and have as smooth a surface finish as possible in order to minimize electromagnetic energy losses within the cavity.

Since the metal composition of the film 14 has a much higher thermal expansion characteristic than does the low expansion substrate 10 and end plates 12, the film 14 is made as thin as possible in order to minimize cavity dimension changes due to thermal expansion thereof. Making the thickness of the film 14 as small as possible also increases its ability to adhere to the substrate and end plate materials.

However, the minimum thickness of the film 14 should be at least 3 times the skin depth of electromagnetic energy penetrating the film 14. Skin depth, being a well

known function of the frequency of electromagnetic energy, requires that the minimum permissible thickness of the film 14 be determined for the range of resonant frequencies of the individual cavity.

One example which meets the above criteria is a resonant cavity having a diameter equal to its length of 4 cm. and a silver electroconductive film 2.5 microns thick covering the cavity defining surfaces of a low expansion glass-ceramic resonator. For the resonant cavity of this example, when subjected to electromagnetic energy having a frequency equal to its resonant frequency of 8.4 GHz., a conductive film thickness of 2.5 microns is at least 6 times the skin depth of electromagnetic energy penetration. For a range of operating temperatures from about -50° C. to about 100° C. the expansion and contraction of the conductive film 14 of this example is negligible.

Electromagnetic energy coupling to the resonator cavity of this example is accomplished by means of a waveguide composed of a pair of semi-cylindrical sections 16, having flanged ends for mounting purposes, made of the same material as the substrate 10 and cylinder-end plates 12. Rectangular channels 17 formed lengthwise within the flat surface of both sections 16 are coated with a thin electro-conductive film 18 and form a rectangular waveguide of suitable dimensions when the sections 16 are fastened together and to the substrate 10 by means of suitable threaded fasteners 19 made of the same material as the substrate 10. A flat face 20 formed in the curved outer surface of the substrate 10 provide a suitable surface for mounting of the waveguide sections 16. An opening 22 through the face 20 is positioned to permit electromagnetic energy exchange between the waveguide and the cavity within the substrate 10.

FIGS. 2 and 3 illustrate two examples of means for tuning the cavity of the resonator of the instant invention. FIG. 2 illustrates tuning of a coaxial type resonator by means of an adjustable tuning screw 24 which projects through cylinder-end section 26 into cavity 28. All component parts of the tunable cavity resonator are made of the same low expansion fused silica or glass-ceramic material. All surfaces defining the cavity 28 are covered with a thin metallized film 34 having high electrical conductivity and a smooth surface finish. That portion of the tuning screw 24 adapted to project through the end section 26 into the cavity 28 is likewise coated with a thin metallized film 34. An opening 36 in the cylinder wall 30 provides means for coupling electromagnetic energy between the cavity 28 and external points.

FIG. 3 illustrates tuning of the cavity resonator by means of varying the length of the cavity 38. A circular disc 40 mounted on the end of an adjustable tuning screw 42 is supported by a screw mounting assembly 44 and forms one end of the cavity 38. Adjustment of the tuning screw 42 moves the disc 40 inside the cylindrical substrate 46 and permits varying the length of the cavity 38 as desired. All surfaces forming the cavity 38 are covered with a thin metallizing film 48 having a high electrical conductivity and a smooth surface finish. An opening 50 in the cylinder wall 46 provides means for coupling electromagnetic energy between the cavity 38 and external points. All component parts of the cavity resonator shown in FIG. 3 are made of the same low expansion fused silica or glass ceramic material.

Although the present invention has been described with respect to specific details of certain embodiments thereof, it is not intended that such details be limitations upon the scope of the invention except insofar as set forth in the following claims.

We claim:

1. A cavity resonator for electromagnetic energy comprising
a hollow cylindrical substrate,
a first flat end plate adapted to completely enclose one end of said substrate,

5

- a second flat end plate adapted to completely enclose the other end of said substrate,
 means for fastening said first and second plates to said substrate,
 said substrate, plates, and fastening means being composed of the same low expansion material selected from the group consisting of fused silica and glass-ceramics,
 an electrically conductive film completely covering the surfaces defining said cavity, and
 means for coupling electromagnetic energy between said cavity and points external thereto.
2. The resonator of claim 1 further comprising means for tuning said cavity.
3. The resonator of claim 1 wherein said fastening means comprises threaded fasteners.
4. The resonator of claim 1 wherein said electrically conductive film is selected from the group consisting of copper, silver, glass frit-silver mixtures, copper alloys, and silver alloys.
5. The resonator of claim 1 wherein said coupling means comprises
 an opening defining portion of the cylindrical wall of said substrate,
 a waveguide attached to the outside surface of said portion in such manner as to permit electromagnetic energy exchange between said waveguide and said cavity, and
 means for attaching said waveguide to said substrate, said waveguide and attaching means being made of the same material as said substrate.
6. The resonator of claim 2 wherein said tuning means comprises
 an adjustable tuning screw adapted to project longitudinally into said cavity a selected distance from one end of said substrate,
 means for mounting said tuning screw to said substrate
 said tuning screw and mounting means being made of the same material as said substrate,
 an electrically conductive film covering that portion of said tuning screw adapted to project into said cavity.
7. The resonator of claim 1 wherein the minimum thickness of said electrically conducting film is at least three times the skin depth of the electromagnetic energy penetration.
8. A tunable cavity resonator for electromagnetic energy comprising
 a hollow cylindrical substrate,
 a flat end plate adapted to completely enclose one end of said cavity,
 a cavity tuning assembly adapted to mount to the end of said substrate opposite said flat end plate and to completely enclose said opposite end thereof embodying
 an adjustable tuning screw adapted to project a variable distance into the hollow portion of said

6

- substrate, the longitudinal axis of said tuning screw being the longitudinal axis of said substrate, and
 a circular tuning plate connected to the end of said tuning screw, and adapted to electrically enclose the other end of said cavity,
 means for fastening said cavity tuning assembly and flat end plate to said substrate,
 an electrically conductive film completely covering the cavity defining surfaces, and
 means for coupling electromagnetic energy between said cavity and points external thereto,
 said substrate, flat end plate, cavity tuning assembly, and fastening means being made of the same low expansion material selected from the group consisting of fused silica and glass ceramics.
9. The tunable cavity resonator of claim 8 wherein said fastening means comprises threaded fasteners.
10. The tunable cavity resonator of claim 8 wherein said electrically conductive film is selected from the group consisting of copper, silver, glass frit-silver mixtures, copper alloys and silver alloys.
11. The tunable cavity resonator of claim 8 wherein said coupling means comprises,
 an opening defining portion of the cylindrical wall of said substrate,
 a waveguide attached to the outside surface of said portion in such manner as to permit electromagnetic energy exchange between said waveguide and said cavity, and
 means for attaching said waveguide to said substrate, said waveguide and attaching means being made of the same material as said substrate.
12. The resonator of claim 8 wherein the minimum thickness of said electrically conducting film is at least three times the skin depth of the electromagnetic energy penetration.

References Cited

UNITED STATES PATENTS

3,308,402 3/1967 Grande ----- 333—83

FOREIGN PATENTS

939,451 11/1948 France.

OTHER REFERENCES

Thompson, M. C. et al., "Fabrication Techniques for Ceramic X-Band Cavity Resonators," in The Review of Scientific Instruments, vol. 29, No. 10, October 1958, pp. 865-868.

HERMAN KARL SAALBACH, Primary Examiner

W. H. PUNTER, Assistant Examiner

U.S. Cl. X.R.

333—99