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(54) **A RADIO FREQUENCY FILTER, A METHOD OF RADIO FREQUENCY FILTERING AND A METHOD OF CONSTRUCTING A RADIO FREQUENCY FILTER**

HOCHFREQUENZFILTER, VERFAHREN ZUR HOCHFREQUENZFILTERUNG UND VERFAHREN ZUR HERSTELLUNG EINES HOCHFREQUENZFILTERS

FILTRE DE FRÉQUENCE RADIO, PROCÉDÉ DE FILTRAGE DE FRÉQUENCE RADIO ET PROCÉDÉ DE CONSTRUCTION DUDIT FILTRE

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Description

Field of the Invention

[0001] The present invention relates to filters for telecommunications, in particular to radio frequency filters.

Description of the Related Art

[0002] Radio frequency filters made up of air-filled cavity resonators are known. It is also known to include posts in the cavity resonators that are loaded with rings of a high dielectric material.

[0003] Technological background is provided by German Patent Publication DE3541585A1 and United States Patent Publication US4166256A.

Summary

[0004] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0005] An example of the present invention is a radio frequency filter comprising at least one resonant chamber that comprises a cavity substantially filled by a granular material and has a lid, the granular material being a dielectric material or magnetic material, in which a layer of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

[0006] The present invention also relates to a method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber that comprises a cavity substantially filled by a granular material and has a lid, the granular material being a dielectric material or magnetic material, in which a layer of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

[0007] The present invention also relates to a method of constructing the radio frequency filter comprising: constructing a lid and constructing a filter body comprising at least one cavity; selecting a granular material, the granular material being a dielectric material or magnetic material; filling said at least one cavity with the selected granular material; applying a layer of compressible material over the granular material; and putting the lid on over the layer of compressible material so as to apply uniform pressure to the granular material.

[0008] Preferred embodiments enable a density and packing of a powder or powder-like dielectric material in a filter cavity to be maintained and controlled. Preferred embodiments provide increased stability, uniformity and density in dielectric powder filled cavities.

[0009] Preferred embodiments enable uniform pressure to be applied to a powder or powder-like dielectric material within a metallic enclosure, specifically the cavity, so as to control the density of the dielectric material. In preferred embodiments, a small part of the cavity or a layer within the cavity is filled with an elastic, compressible and flexible material placed between the powder-filled cavity and the lid which is metallic. The compressible material is preferably of low loss and has low impact on the resonating structure.

[0010] Preferably the lid which may be metallic is shaped and configured to fit the filter body so as to provide a uniform pressure to the granular material without the granular material being squeezed out.

[0011] Preferred embodiments are suitable for use in metrocell base stations and macrocell active antenna arrays.

[0012] Preferred embodiments allow uniform pressure to be applied to the granular material in such a way that its density may be controlled and stabilised. Preferred embodiments allow powders and powder-like materials to be used efficiently in filters and other radio frequency equipment.

[0013] In some preferred embodiments, the at least one chamber houses a respective resonator post and the chamber is substantially filled by the respective resonator post and the granular material.

Brief Description of the Drawings

[0014] An embodiment of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is a cross sectional top view of a combline filter according to a first embodiment,

Figure 2 is a cross sectional end view of a dielectric-filled cavity resonator of the combline filter shown in Figure 1,

Figure 3 is a cross sectional top view of a combline filter according to a second embodiment but in a partly constructed state in which the side lid is not in place, and

Figure 4 is a cross sectional end view of a dielectric-filled cavity resonator of the combline filter according to a third embodiment.

Detailed Description

[0015] The inventors realised that in alternative proposals it was possible to design radio frequency filters having resonant cavities of reduced size compared to air-filled resonant cavities by loading cavities with dielectric or magnetic powder. The powder would fill the cavity practically irrespective of its shape or configuration.

[0016] The inventors realised that whereas it was easy to fill the cavity with the powder through a large aperture in the cavity, this aperture must usually then be closed by a lid. The inventors realised that this was often problematic as it was hard to avoid air spaces (in other words, void areas) with the cavity and hard to ensure an equal packing density of the powder throughout the intended powder volume.

[0017] The inventors realised that it would be useful to provide a way to control the density of the powder within the entire physical space that the powder dielectric material can occupy.

[0018] The inventors realised that it would be useful to control the density of the granular dielectric material by applying a uniform pressure to the material so as to have uniform density within the metal enclosure defining the cavity.

[0019] As shown in Figure 1 and 2, a Combline filter 2 is provided made up of a connected series of resonant cavities each filled with dielectric powder 6, having a dielectric constant for example in the range 2 to 10, in particular 3 to 5, and a low dielectric loss. For example a powder may be of a dielectric constant of 3.8 and a loss tangent of 6×10^{-5}).

[0020] This allows the filter to be smaller in size than if air-filled, for filtering at the same radio frequency. The filter 2 includes a first side wall 8 and a corresponding removable side wall denoted side lid 10, a base plate 12, a top plate 14, and end plates 16 that define the filter. There is also a series of partial inner walls 18 parallel to the end plates 16 that define a series of the resonant cavities 20. Each resonant cavity 20 has an input port (not shown) and an output port (not shown). Within each cavity 20 extending from the base plate 12 is a respective metal post 22.

[0021] As shown in Figure 1 and 2, a small part of each cavity 20 is filled with an elastic flexible and compressible material 24 placed between the powder filled cavity 20 and the side lid 10 which is metal or metallic. That compressible material 24 is low loss and because it is thin has low impact in terms of performance in radio frequency filtering.

Configuration of the side lid with respect to the rest of the filter

[0022] The side lid 10 has a cut-away edge step 11 that runs along all four of its sides so that it has an edge portion 13 of less depth than the main body 15 of the side lid 10.

[0023] A corresponding lip 17 is provided that runs along the corresponding end walls 16, base plate 12 and top plate 14.

[0024] The step 11 and lip 17 are shaped and configured to fit. Specifically, the edge step 11 of the side lid 10 includes a surface 9 against which the inside surface 7 of the lip 17 can slide. Also the lip 17 is configured such that when fastened together in use by screws 19 the edge portion 13 and lip 17 abut.

[0025] In construction, each cavity 20 is filled with the dielectric powder 6 and the compressible material 24, and the side lid is fitted thereto. As the side lid is put into position then fastened, the surface 9 of the side lid 10 slides against the inside surface 7 of the lip 17, so the dielectric powder is prevented from being squeezed out.

[0026] In some similar alternative embodiments (not shown), this feature that the surface of the side lid slides against the inside surface of the lip so the dielectric powder is prevented from being squeezed out, allows dielectric powder to be heaped up then compressed by bringing the side lid into position without loss of powder. In this way extra powder can be added (or removed) so as to readily adjust the density (and hence dielectric properties) of the powder in the filter whilst the compressible material layer 24 acts to keep the density of the powder uniform within the filter.

The compressible material

[0027] In this example the compressible material 24 is Rohacell foam. Rohacell is understood to be a registered trademark associated with Evonik Industries AG. In an otherwise similar alternative example the compressible material is Neoprene.

[0028] In manufacture, the cavities 20 are filled with powder 6 and the compressible material 24 namely the Rohacell foam layer placed over. Doing this may be considered as overfilling the cavities. Upon the side lid 10 being put into place, the Rohacell foam layer is compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6 that fills the cavities 20.

Some details

[0029] Taking the Rohacell material as having a dielectric constant (real relative dielectric permittivity) of 1.067 and a loss tangent of 0.0041, it was calculated that altering the height lr from 2mm to 1 mm, (see Figure2) altered the resonant frequency of a resonant cavity by approximately less than 0.4%. The parameter values assumed were that the resonant cavity had an internal height of 120mm, an internal width of 70mm, a resonator post height of 93mm, and a post cross section diameter of 20.4mm. The dielectric powder was assumed to be fused quartz material having a permittivity of 3.8 and a loss tangent of 6x10-5. These calculations were performed using known High Frequency Structure Simulator (HFSS) software, version 15.0, provided by Ansoft (Http://www.ansys.com/Products/Simulation+Technology/Electromagnetics/HighPerf ormance+Electronic+Design/ANSYS+HFSS). An alteration in the resonant frequency of approximately 0.4% can be readily accommodated by the use a tuning screw (not shown) through the top plate 14 opposite the top of the post 22.

Further Examples

[0030] As shown in Figure 3, a basically similar alternative embodiment is provided, in which the side lid 10" is flat rather than having edge steps. In manufacture, the cavities 20" are filled with powder 6" and the compressible material 24" namely the Rohacell foam layer. Doing this may be considered as overfilling the cavities. Upon the side lid 10" being put into place, the Rohacell foam layer is compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6" that fills the cavities 20".

[0031] As shown in Figure 4, in another basically similar alternative embodiment, in each resonant cavity 20' there is a tuning screw 26 which is located in a hole 28 through the top plate 14 so as to be adjustable in distance from the top of the metal post 22'. Each cavity 20' is filled with the powder 6' then a Rohacell layer 24' is applied and the top plate 14 secured in position. The foam layer 24' is thereby compressed, adjusting the total volume of the foam layer and providing even compression on the powder 6' that fills the cavities 20'. The foam layer 24' has holes 30 cut so as to correspond to the tuning screw positions, and it is through those holes that the tuning screws 26 may penetrate the foam layer 24'.

[0032] The present invention may be embodied in other specific forms without departing from its essential characteristics. For example a granular magnetic material may be used instead of a granular dielectric material.

[0033] The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description.

Claims

1. A radio frequency filter (2) comprising at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid (10), the granular material being a dielectric material or magnetic material, **characterised in that** a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

2. A radio frequency filter according to claim 1, in which the compressible foam material (24) is one of the Rohacell range of foam materials.

3. A radio frequency filter according to claim 1, in which the compressible foam material is Neoprene.

4. A radio frequency filter according to any preceding claim, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

5. A radio frequency filter according to claim 4, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

6. A radio frequency filter according to claim 4 or claim 5, in which the lip (17) is configured such that when the lid is fastened in place the edge portion |(13) and lip (17) abut.

7. A radio filter according to any preceding claim, in which the at least one chamber (20) houses a respective resonator post (22) and the chamber is substantially filled by the respective resonator post (22) and the granular material (6).

8. A method of radio frequency filtering comprising passing a signal for filtering through at least one resonant chamber (20) that comprises a cavity (20) substantially filled by a granular material (6) and has a lid(10), the granular material being a dielectric material or magnetic material, **characterised in that** a layer (24) of compressible foam material is provided between the lid and the granular material so as to apply a uniform pressure to the granular material.

9. A method of radio frequency filtering according to claim 8, in which the compressible foam material is one of the Rohacell range of foam materials.

10. A method of radio frequency filtering according to claim 8, in which the compressible foam material is Neoprene.

11. A method of radio frequency filtering according to any of claims 8 to 10, in which the lid (10) has a cut-away edge step (11) that runs along its sides so that the lid has an edge portion (13) of less depth than its main body (15), the step being configured to fit a corresponding lip (17) that runs along corresponding walls of the filter.

12. A method of radio frequency filtering according to any of claims 8 to 11, in which the edge step (11) of the lid (10) includes a surface (9) against which the inside surface (7) of the lip (17) is slidable.

13. A method of radio frequency filtering according to claim 11 or claim 12, in which the lip (17) is configured such that when the lid is fastened in place the edge portion (13) and lip (17) abut, the lid having been pressed into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of the lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

14. A method of constructing the radio frequency filter according to any of claims 1 to 7 comprising:

   constructing the lid (10) and constructing a filter body (8, 12,14,16,20) comprising at least one cavity(20) ;

selecting the granular material (6), the granular material being a dielectric material or magnetic material;

filling said at least one cavity (20) with the selected granular material; **characterised in** applying the layer (24) of compressible foam material over the granular material; and

putting the lid (10) on over the layer of compressible foam material so as to apply uniform pressure to the granular material.

15. A method of constructing a radio frequency filter according to claim 14, in which the step of bringing the lid (10) into position over the layer of compressible material comprises:

placing the lid on top, and

pressing the lid into position such that a side surface (9) of the lid (10) slides against the inside surface (7) of a lip (17) extending from the filter body, so that the granular dielectric material is prevented from being squeezed out.

16. A method of constructing a radio frequency filter according to claim 14 or claim 15, in which the amount of granular material (6) is adjusted before compression by bringing the lid into position, so as to adjust the density of the granular material in the filter.

Patentansprüche

1. Funkfrequenzfilter (2), umfassend mindestens eine Resonanzkammer (20), die einen Hohlraum (20) umfasst, der im Wesentlichen mit körnigem Material (6) gefüllt ist und einen Deckel (10) aufweist, wobei das körnige Material ein dielektrisches Material oder ein magnetisches Material ist, **dadurch gekennzeichnet, dass** eine Schicht (24) von kompressiblem Schaummaterial bereitgestellt wird zwischen dem Deckel und dem körnigen Material, sodass ein gleichförmiger Druck auf das körnige Material angewendet wird.

2. Funkfrequenzfilter nach Anspruch 1, in welchem das kompressible Schaummaterial (24) eines aus dem Rohacell-Bereich von Schaummaterialien ist.

3. Funkfrequenzfilter nach Anspruch 1, in welchem das kompressible Schaummaterial Neopren ist.

4. Funkfrequenzfilter nach einem beliebigen der vorhergehenden Ansprüche, in welchem der Deckel (10) eine ausgeschnittene Randstufe (11) aufweist, die an seinen Seiten entlangläuft, sodass der Deckel einen Kantenbereich (13) von geringerer Tiefe aufweist als der Hauptkörper (15), wobei die Kante konfiguriert ist zum Anpassen an einen entsprechenden Rand (17), der entlang der entsprechenden Wände des Filters verläuft.

5. Funkfrequenzfilter nach Anspruch 4, in welchem die Randstufe (11) des Deckels (10) eine Oberfläche (9) einschließt, gegen die die Innenfläche (7) des Randes (17) verschiebbar ist.

6. Funkfrequenzfilter nach Anspruch 4 oder Anspruch 5, in welchem der Rand (17) so konfiguriert ist, dass, wenn der Deckel vor Ort befestigt wird, die Randstufe (13) und der Rand (17) aneinanderstoßen.

7. Funkfilter nach einem beliebigen der vorhergehenden Ansprüche, in welchem mindestens eine Kammer (20) einen entsprechenden Resonanzstab (22) unterbringt und wobei die Kammer im Wesentlichen gefüllt ist mit dem entsprechenden Resonanzstab (22) und dem körnigen Material (6).

8. Verfahren zur Funkfrequenzfilterung, umfassend das Weiterleiten eines Signals zum Filtern durch mindestens eine Resonanzkammer (20), die einen Hohlraum (20) umfasst, der im Wesentlich gefüllt ist mit einem körnigen Material (6) und einen Deckel (10) aufweist, wobei das körnige Material ein dielektrisches Material oder ein magnetisches Material ist, **dadurch gekennzeichnet, dass** eine Schicht (24) von kompressiblem Schaummaterial bereitgestellt wird zwischen dem Deckel und dem körnigen Material, sodass ein gleichförmiger Druck auf das körnige Material angewendet wird.

9. Verfahren zur Funkfrequenzfilterung nach Anspruch 8, in welchem das kompressible Schaummaterial eines aus dem Rohacell-Bereich von Schaummaterialien ist.

10. Verfahren zur Funkfrequenzfilterung nach Anspruch 8, in welchem das kompressible Schaummaterial Neopren ist.

11. Verfahren zur Funkfrequenzfilterung nach einem beliebigen der Ansprüche 8 bis 10, in welchem der Deckel (10) eine ausgeschnittene Randstufe (11) aufweist, die an seinen Seiten entlangläuft, sodass der Deckel einen Kantenbereich (13) von geringerer Tiefe aufweist als der Hauptkörper (15), wobei die Kante konfiguriert ist zum Anpassen an einen entsprechenden Rand (17), die entlang der entsprechenden Wände des Filters verläuft.

12. Verfahren zur Funkfrequenzfilterung nach einem beliebigen der Ansprüche 8 bis 11, in welchem die Randstufe (11) des Deckels (10) eine Oberfläche (9) einschließt, gegen die die Innenfläche (7) des Randes (17) verschiebbar ist.

13. Verfahren zur Funkfrequenzfilterung nach Anspruch 11 oder 12, in welchem der Rand (17) so konfiguriert ist, dass, wenn der Deckel vor Ort befestigt wird, der Kantenbereich (13) und der Rand (17) aneinanderstoßen, wobei der Deckel in Position gedrückt wird, sodass eine Gleitfläche (9) des Deckels (10) gegen die Innenfläche (7) des Randes (17) verschiebbar ist, der sich vom Filterkörper aus erstreckt, sodass verhindert wird, dass das körnige dielektrische Material herausgequetscht wird.

14. Verfahren zur Herstellung des Funkfrequenzfilters nach einem beliebigen der Ansprüche 1 bis 7, umfassend:

Herstellen des Deckels (10) und Herstellen des Filterkörpers (8, 12, 14, 16, 20), umfassend mindestens einen Hohlraum (20);
Auswählen des körnigen Materials (6), wobei das körnige Material ein dielektrisches Material oder ein magnetisches Material ist;
Füllen besagten mindestens einen Hohlraums (20) mit dem ausgewählten körnigen Material;
dadurch gekennzeichnet, dass die Schicht (24) kompressiblen Schaummaterials über das körnige Material angewendet wird; und
Legen des Deckels (10) über die Schicht kompressiblen Schaummaterials, um einen gleichförmigen Druck auf das körnige Material anzuwenden.

15. Verfahren zur Herstellung eines Funkfrequenzfilters nach Anspruch 14, in welchem der Schritt des Bringens des Deckels (10) in Position über der Schicht kompressiblen Materials umfasst:

Platzieren des Deckels auf der Oberseite und Drücken des Deckels in Position, sodass eine Seitenfläche (9) des Deckels (10) sich gegen die Innenfläche (7) eines Randes (17) verschiebt, der sich vom Filterkörper aus erstreckt, sodass das körnige dielektrische Material daran gehindert wird, herausgedrückt zu werden.

16. Verfahren zur Herstellung eines Funkfrequenzfilters nach Anspruch 14 oder 15, in welchem die Menge an körnigem Material (6) vor der Kompression eingestellt wird durch Bringen des Deckels in Position, um die Dichte des körnigen Materials im Filter einzustellen.

Revendications

1. Filtre radiofréquence (2) comprenant au moins une chambre de résonance (20) qui comprend une cavité (20) essentiellement remplie d'un matériau granulaire (6) et comporte un couvercle (10), le matériau granulaire étant un matériau diélectrique ou un matériau magnétique, **caractérisé en ce qu'**une couche (24) de mousse compressible est disposée entre le couvercle et le matériau granulaire de façon à appliquer une pression uniforme sur le matériau granulaire.

2. Filtre radiofréquence selon la revendication 1, dans lequel la mousse compressible (24) est une mousse de la gamme de mousses Rohacell.

3. Filtre radiofréquence selon la revendication 1, dans lequel la mousse compressible est du Néoprène.

4. Filtre radiofréquence selon l'une quelconque des revendications précédentes, dans lequel le couvercle (10) a un épaulement découpé au niveau du bord (11) qui s'étend le long de ses côtés de sorte que le couvercle a une partie du bord (13) de profondeur inférieure à celle de son corps principal (15), l'épaulement étant configuré pour s'adapter à une lèvre correspondante (17) qui s'étend le long des parois correspondantes du filtre.

5. Filtre radiofréquence selon la revendication 4, dans lequel l'épaulement du bord (11) du couvercle (10) comporte une surface (9) contre laquelle la surface intérieure (7) de la lèvre (17) peut coulisser.

6. Filtre radiofréquence selon la revendication 4 ou la revendication 5, dans lequel la lèvre (17) est configurée de sorte que lorsque le couvercle est fixé en position la partie du bord (13) et la lèvre (17) sont jointes bout à bout.

7. Filtre radiofréquence selon l'une quelconque des revendications précédentes, dans lequel la ou les chambres (20) contiennent une tige résonnante (22) correspondante et la chambre est essentiellement remplie par la tige résonnante (22) correspondante et le matériau granulaire (6).

8. Procédé de filtrage radiofréquence comprenant le passage d'un signal destiné à être filtré à travers au moins une chambre de résonance (20) qui comprend une cavité (20) essentiellement remplie d'un matériau granulaire (6) et comporte un couvercle (10), le matériau granulaire étant un matériau diélectrique ou un matériau magnétique, **caractérisé en ce qu'**une couche (24) de mousse compressible est disposée entre le couvercle et le matériau granulaire de façon à appliquer une pression uniforme sur le matériau granulaire.

9. Procédé de filtrage radiofréquence selon la revendication 8, dans lequel la mousse compressible est une mousse de la gamme de mousses Rohacell.

10. Procédé de filtrage radiofréquence selon la revendication 8, dans lequel la mousse compressible est du Néoprène.

11. Procédé de filtrage radiofréquence selon l'une quelconque des revendications 8 à 10, dans lequel le couvercle (10) a un épaulement découpé au niveau du bord (11) qui s'étend le long de ses côtés de sorte que le couvercle a une partie du bord (13) de profondeur inférieure à celle de son corps principal (15), l'épaulement étant configuré pour s'adapter à une lèvre correspondante (17) qui s'étend le long des parois correspondantes du filtre.

12. Procédé de filtrage radiofréquence selon l'une quelconque des revendications 8 à 11, dans lequel l'épaulement du bord (11) du couvercle (10) comporte une surface (9) contre laquelle la surface intérieure (7) de la lèvre (17) peut coulisser.

13. Procédé de filtrage radiofréquence selon la revendication 11 ou la revendication 12, dans lequel la lèvre (17) est configurée de sorte que lorsque le couvercle est fixé en position la partie du bord (13) et la lèvre (17) sont jointes bout à bout, le couvercle ayant été enfoncé en position de sorte qu'une surface latérale (9) du couvercle (10) coulisse contre la surface intérieure (7) de la lèvre (17) s'étendant depuis le corps du filtre, de façon à éviter que le matériau granulaire diélectrique ne soit expulsé.

14. Procédé de construction d'un filtre radiofréquence selon l'une quelconque des revendications 1 à 7 comprenant les étapes suivantes :

construire le couvercle (10) et construire un corps de filtre (8, 12, 14, 16, 20) comprenant au moins une cavité (20) ;
sélectionner le matériau granulaire (6), le matériau granulaire étant un matériau diélectrique ou un matériau magnétique ;
remplir ladite ou lesdites cavités (20) avec le matériau granulaire sélectionné ;
caractérisé par l'application de la couche (24) de mousse compressible sur le matériau granulaire ; et
mettre le couvercle (10) par-dessus la couche de mousse compressible de façon à appliquer une pression uniforme sur le matériau granulaire.

15. Procédé de construction d'un filtre radiofréquence selon la revendication 14, dans lequel l'étape de mise en position du couvercle (10) par-dessus la couche de matériau compressible comprend les étapes suivantes :

placer le couvercle sur le dessus, et
enfoncer le couvercle en position de sorte qu'une surface latérale (9) du couvercle (10) coulisse contre la surface intérieure (7) de la lèvre (17) s'étendant depuis le corps du filtre, de façon à éviter que le matériau granulaire diélectrique ne soit expulsé.

16. Procédé de construction d'un filtre radiofréquence selon la revendication 14 ou la revendication 15, dans lequel la quantité de matériau granulaire (6) est ajustée avant compression en mettant le couvercle en position, de façon à ajuster la densité du matériau granulaire dans le filtre.

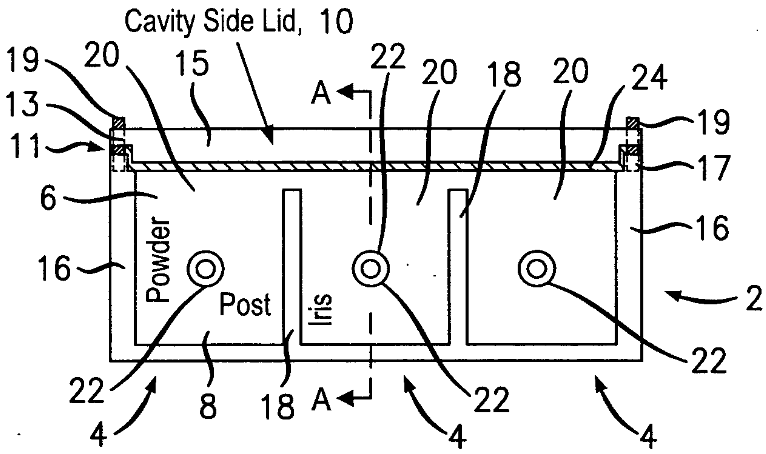

FIG. 1

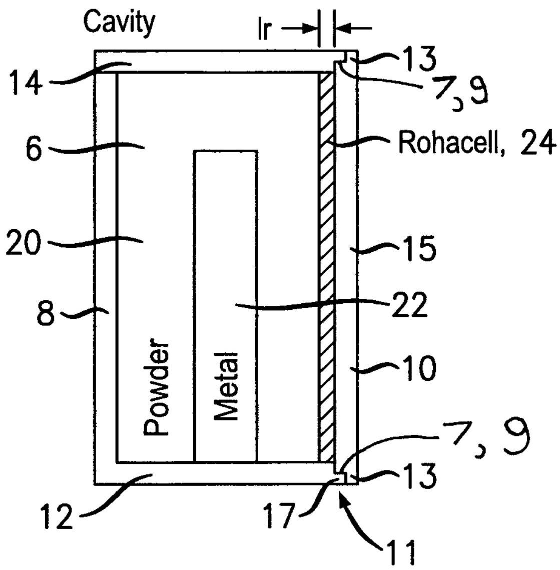

FIG. 2

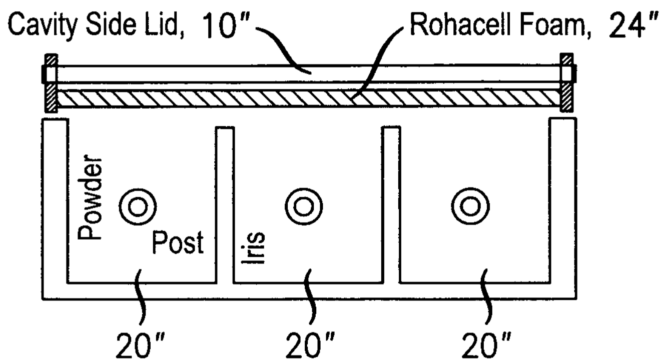

FIG. 3

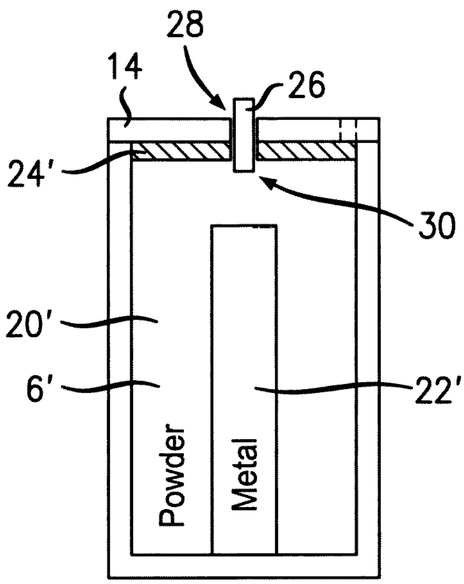

FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 3541585 A1 **[0003]**
- US 4166256 A **[0003]**