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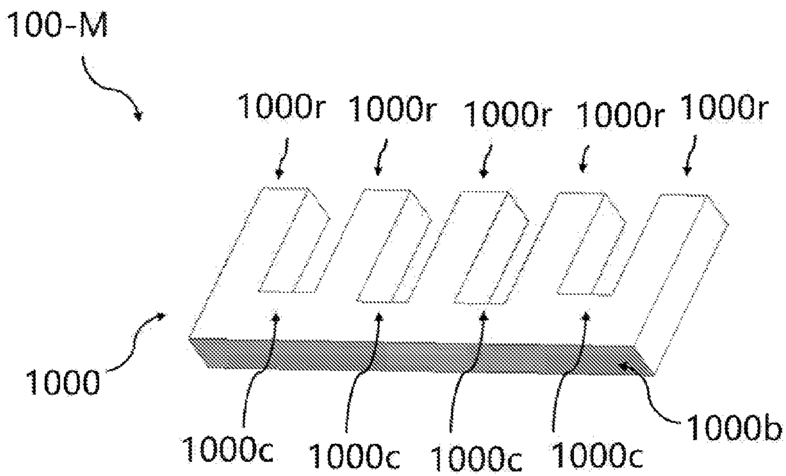

FIG.6

(57) Abstract: The present disclosur relates to a resonator structure for a filter comprising a filter housing defining a closed metal cavity for the resonator structure, the resonator structure comprising a one-piece main body made of a dielectric material, characterized in that, the main body comprising: a plurality of resonator rods extending longitudinally between upper and lower walls of the metal cavity, with at least one longitudinal end surface of each resonator rod being metalized for establishing grounded connection with the metal cavity; and at least one coupling crossbar intersecting with the resonator rods such that the resonator rods are held spaced from one another and coupled by means of the at least one crossbar. Also, the present disclosure relates to a filter comprsing the above-said resonator structure and a radio unit or an antenna filter unit comprisng the above-said filter.

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RESONATOR STRUCTURE, FILTER, RADIO UNIT AND ANTENNA FILTER UNIT

Technical Field

[0001] The present disclosure generally relates to the technical field of communication device, and more particularly, to a resonator structure, a filter comprising such a resonator structure, and a radio unit or an antenna filter unit comprising the filter.

Background

[0002] This section introduces aspects that may facilitate better understanding of the present disclosure. Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] With the development of an advanced radio system, it is required to have a small-sized smart radio with high performance all the time. Highly integrated advanced antenna systems (AAS) with multi-channels and highly integrated macro system with multi-bands have been widely developed recently. In those radio systems, a radio frequency (RF) filter is one important part for selecting a desired frequency and rejecting unwanted frequency spurious of the system.

[0004] Both metal filters and ceramic waveguide (CWG) filters are widely used in those AAS system. Metal filters provide good insertion loss (IL) and power handling ability, with mature material and production technology. Much efforts have been made to minimize the size and weight based on the metal filters, such as by soldering lid, making use of sheet metal, and using semi-solid die casting technology. However, there comes a limitation for the size and weight reduction of the metal filters. Compared with a metal filter, a CWG filter has the advantages of having a small size, easy integration with a radio system by means of surface mounting technology (SMT). The thickness of the radio can be greatly reduced by using CWG filters, and the number of RF connectors is reduced by a simple SMT process. However, CWG filters in a reduced size could not provide satisfactory Q value and insertion loss. For an AAS system, it is still necessary to look for a filter with small size, low weight and improved Q value.

[0005] A transversal magnetic (TM) mode filter comprising a ceramic resonator in a metal housing is under development for a macro radio system. This TM mode filter includes one end grounding solution, two ends grounding solution, and a dual mode solution. As compared with a metal filter, the TM mode filter can greatly reduce the filter size, and at the same time, gain good Q value and reduce filter loss.

[0006] Although the TM mode filter is attractive in performance, it is mainly used in a macro radio system, not in an AAS system. That is because the TM mode filter is quite complex in mechanical design, and its size still cannot be reduced to a level that meets the needs of the AAS system.

[0007] Thus, there is a need to seek for a filter solution for the purpose of providing macro radio systems or radios and AAS systems with high production effectivity, small filter size and improved Q value/reduced filter loss.

Summary

[0008] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0009] One of the objects of the disclosure is to provide a resonator structure for a TM mode filter which allows simplifying the production process, improving assembling efficiency and reducing assembly cost and to provide a radio unit or an antenna filter unit which has a small filter size and improved Q value/reduced filter loss.

[0010] According to a first aspect of the disclosure, there is provided a resonator structure for a filter comprising a filter housing defining a closed metal cavity for the resonator structure, the resonator structure comprising a one-piece main body made of a dielectric material. The main body comprises: a plurality of resonator rods extending longitudinally between upper and lower walls of the metal cavity, with at least one longitudinal end surface of each resonator rod being metalized for establishing grounded connection with the metal cavity; and at least one coupling crossbar intersecting with the resonator rods such that the resonator rods are held spaced from one another and coupled by means of the at least one crossbar.

[0011] In an embodiment of the disclosure, at least one resonator rod has its peripheral surface fully metalized in such a manner that the fully metalized peripheral surface is joined to its metalized longitudinal end surface.

[0012] In an embodiment of the disclosure, at least one resonator rod has its peripheral surface partially metalized in such a manner that at least one metalized area on the partially metalized peripheral surface is joined to its metalized longitudinal end surface.

[0013] In an embodiment of the disclosure, one non-metalized end area is provided on the partially metalized peripheral surface, or two circumferential closed metalized end areas formed on the partially metalized peripheral surface, at least one of which is joined to its metalized longitudinal end surface, is spaced by a circumferential closed non-metalized area.

[0014] In an embodiment of the disclosure, at least one longitudinal end of at least one resonator rod is shaped to have an end cap extended portion which extends substantially perpendicular to the longitudinal direction of the resonator rods.

[0015] In an embodiment of the disclosure, the plurality of resonator rods are arranged in a line.

[0016] In an embodiment of the disclosure, the end cap extended portion is shaped to mainly extend in a direction along and/or perpendicular to the line in which the resonator rods are arranged.

[0017] In an embodiment of the disclosure, two resonator rods that are not adjacent to each other along a predetermined signal transmission path of the filter are coupled inductively or capacitively by a coupling pattern provided on a coupling bridge that extends between the two resonator rods, the coupling bridge being formed by one coupling crossbar extending between the two non-adjacent resonator rods concerned, or by one integral segment that is formed by two or more coupling crossbars and resonator rods therebetween.

[0018] In an embodiment of the disclosure, the coupling pattern is embodied as a metal strip substantially extending along the coupling bridge.

[0019] In an embodiment of the disclosure, at least one end of the metal strip is joined to a metalized peripheral surface of one of the two resonator rods or is provided with a branch arm that is joined to a metalized grounding surface of the coupling crossbar on which the metal strip extends.

[0020] In an embodiment of the disclosure, an end of the metal strip is located in the proximity of and spaced from one of the two resonator rods.

[0021] In an embodiment of the disclosure, the coupling pattern comprises two metal strips extending towards each other, terminating at their first ends and spaced from each other by a gap.

[0022] In an embodiment of the disclosure, a second end that is opposite to the first end on each of the metal strips is joined to a metalized surface of one of the two resonator rods.

[0023] In an embodiment of the disclosure, a second end that is opposite to the first end on each of the metal strips is located in the proximity of a non-metalized surface of one of the two resonator rods.

[0024] In an embodiment of the disclosure, the dielectric material is ceramic or plastic.

[0025] In an embodiment of the disclosure, lower longitudinal end surfaces of all the resonator rods are metalized.

[0026] In an embodiment of the disclosure, the at least one coupling crossbar has its lower side surface metalized and provided in flush with lower metalized longitudinal end surfaces of the plurality of resonator rods that are located in a same plane, thereby providing a metalized base surface which is to be placed in contact with the lower wall of the metal cavity.

[0027] In an embodiment of the disclosure, a lower side surface of the at least one coupling crossbar extends above the lower metalized longitudinal end surfaces of the plurality of resonator rods.

[0028] In an embodiment of the disclosure, the two or more coupling crossbars extend at different heights along the longitudinal direction of the resonator rods.

[0029] In an embodiment of the disclosure, the plurality of resonator rods are held by two or more coupling crossbars such that a projection of the resonator structure onto a horizontal plane is strip-shaped or grid-shaped.

[0030] In an embodiment of the disclosure, the at least one coupling crossbar is joined with the resonator rods together to form a plate-like common base block from an upper side of which the resonator rods protrude, the plate-like common base block having its lower side surface metalized, thereby forming a metalized base surface which serves as a lower wall of the metal cavity.

[0031] In an embodiment of the disclosure, a plurality of first blind holes are provided on the metalized base surface of the plate-like common base block in areas of lower longitudinal ends of the resonator rods for tuning frequency, and/or a plurality of second blind holes are provided on the metalized base surface of the plate-like common base block in positions between the lower longitudinal ends of two adjacent resonator rods for tuning coupling.

[0032] In an embodiment of the disclosure, at least one through slot, which has its walls metalized, is provided in the plate-like common base block, so as to isolate two resonator rods located on opposite sides of the at least one through slot.

[0033] According to a second aspect of the present disclosue, there is provided a filter comprising a filter housing defining a closed metal cavity. At least one resonator structure as mentioned in the above is arranged in the metal cavity, with at least one metalized longitudinal end surface of each resonator rod being placed in grounded connection with the metal cavity.

[0034] In an embodiment of the disclosure, a top or bottom part of the filter housing against which at least one resonator rod abuts with its metalized longitudinal end, is provided with at least one through-hole through which at least a portion of a metalized longitudinal end surface of the at least one resonator rod is exposed.

[0035] In an embodiment of the disclosure, a partition wall is provided between two resonance cavities associated with two adjacent resonator rods of the resonator structure, and a coupling window is provided in the partition wall for coupling the two adjacent resonator rods.

[0036] In an embodiment of the disclosure, the filter housing is made of metal, or made of non-metal material with at least its inner walls being metalized.

[0037] According to a third aspect of the present disclosure, there is provided a filter comprising a filter housing defining a closed metal cavity. The filter comprises a resonator structure as mentioned in the above, the resonator structure being arranged such that its resonator rods extend into the metal cavity, and the metalized base surface of its plate-like common base block serves as a lower wall of the metal cavity.

[0038] In an embodiment of the disclosure, a partition wall is provided between two resonance cavities associated with two adjacent resonator rods of the resonator structure, having its lower end welded to the upper side of the plate-like common base block of the resonator structure.

[0039] In an embodiment of the disclosure, a coupling window is provided on the partition wall.

[0040] In an embodiment of the disclosure, the resonator structure is configured as a lid part of the filter housing, and the filter housing comprises a chassis part to which the lid part is attached so as to obtain the closed metal cavity, wherein the chassis part is made of metal or made of non-metal material with at least its inner walls being metalized.

[0041] According to a fourth aspect of the disclosure, there is provided a radio unit or an antenna filter unit, comprising at least one filter as mentioned in the above.

[0042] According to the present disclosure, the resonator structure is embodied as a one piece block which is made of dielectric material with only part of its surfaces being metalized. Therefore, instead of installing separate ceramic resonators one by one in the filter housing, the resonator structures can be designed, produced and installed as a whole, which therefore greatly reduces the complexity in assembling. Also, it allows to include different types of resonator rods in one and the same resonator structure, for example, by having some resonators rods with two longitudinal metalized ends (i.e. two-ends grounded type), some resonator rods with only one longitudinal metalized end (i.e. one-end grounded type), and/or some resonator rods with fully or partially metalized peripheral surfaces joined to their longitudinal metalized ends (i.e. peripheral surface metalized type that is based on two-ends or one-end grounded type). TM mode resonators of the two-ends grounded type and the one-end grounded type can have improve Q values, and the TEM mode resonators of peripheral surface metalized type can function to reject the spurious of the TM resonators used in one filter.

[0043] The resonator structure of the present disclosure also allows introducing two kinds of coupling structures in design: inductivity coupling between two adjacent resonator rods along the signal transmission path of the filter through the coupling crossbar; and inductivity and capacitive coupling between two non-adjacent resonator rods through a coupling pattern provided on the coupling crossbars. It therefore allows flexibly adapting to the design of filters and increasing its diversity. Additionally, the resonator structure of the present disclosure enables tuning the filter produced by laser through the through-holes on the filter housing, without the need of installing tuning screws. This may facilitate reducing the filter size, improving the production effectivity and making it possible to apply surface mounting technology in an easy manner.

[0044] In view of the above, the resonator structure of the present disclosure has the advantages of providing a filter with a high Q value, reduced filter loss, reduced filter size and reduced assembly cost and producing a highly integrated and energy effective radio unit or antenna filter unit with the size being significantly reduced. It is also easy to be mass produced and to be integrated with other functional component by the surface mounting technology.

Brief Description of the Drawings

[0045] These and other objects, features and advantages of the disclosure will become apparent from the following detailed description of illustrative embodiments thereof, which are to be read in connection with the accompanying drawings.

[0046] FIG.1 shows a schemetic view of an existing TM filter comprising a ceramic resonator housed in a metal cavity.

[0047] FIG.2 shows a schematic view of an existing band pass filter.

[0048] FIG.3 shows an exploded view of the band pass filter as shown in FIG.2

[0049] FIG.4 shows a sectional view of the band pass filter as shown in FIG.2.

[0050] FIG.5 shows a perspective view of a filter according to a first embodiment of the present disclosure, with the upper lid part being removed for better illustration.

[0051] FIG.6 shows a perspective view of a first example of the resonator structure according to the present disclosure for the filter as shown in FIG.5.

[0052] FIG.7 shows another perspective view of the resonator structure according to the present disclosure as shown in FIG.6.

[0053] FIG.8 shows a sectional view of the filter according to the first embodiment of the present disclosure, which is taken along the A-A line shown in FIG.5

[0054] FIG.9 shows a schematic view of a second example of the resonator structure according to the present disclosure.

[0055] FIG.10 shows a schematic view of a variant of the resonator structure according to the present disclosure as shown in FIG.9.

[0056] FIG.11 shows a sectional view of a third example of the resonator structure according to the present disclosure.

[0057] FIG.12 shows a sectional view of a fourth example of the resonator structure according to the present disclosure.

[0058] FIG.13 shows a sectional view of a filter according to a second embodiment of the present disclosure, with the fourth example of the resonator structure being arranged in the metal cavity.

[0059] FIG.14 shows a perspective view of a fifth example of the resonator structure according to the present disclosure.

[0060] FIG.15 shows a perspective view of a variant of the resonator structure according to the present disclosure as shown in FIG.14.

[0061] FIG.16 shows a sectional view of a sixth example of the resonator structure according to the present disclosure.

[0062] FIG.17 shows a perspective view of a filter according to a third embodiment of the present disclosure, with its front side plate being removed for better illustration.

[0063] FIG.18 shows a perspective view of a seventh example of the resonator structure according to the present disclosure, which is housed in the filter as shown in FIG. 17.

[0064] FIG.19 shows a perspective view of an eighth example of the resonator structure according to the present disclosure.

[0065] FIG. 20 shows a schematic view of a filter according to a fourth embodiment of the present disclosure, which comprises a one-piece resonator structure having two resonator rods coupled to each other by a coupling crossbar.

[0066] FIG.21A and FIG.21B show the E field and the H field created in the filter according to the fourth embodiment of the present disclosure.

[0067] FIG.22A to FIG.22I show coupling structures between non-adjacent resonator rods in one resonator structure according to the present disclosure.

[0068] FIG.23 shows a perspective view of a filter according to a fifth embodiment of the present disclosure.

[0069] FIG.24 shows the S parameter curve of the filter as shown in FIG.23.

[0070] FIG.25 shows a perspective view of a filter according to the present disclosure, comprising a filter housing having an opened chassis part and a side lid part, with its side lid part being removed for explaining how to place the resonator structure into its chassis part before attaching the side lid part to the chassis part.

[0071] FIG. 26 shows a perspective view of a filter according to the present disclosure, which comprises a tubular hollow chassis part and two end lid parts that are attached to the chassis part after the resonator structure is inserted into the chassis part.

[0072] FIG. 27 shows a perspective view of a filter according to the present disclosure, which comprises through holes on the upper part of the filter housing against which the resonator rods abut with their upper metalized ends.

[0073] FIG. 28 shows a perspective view of a resonator structure according to a ninth example of the present disclosure, which can function as a lid part of the filter housing.

[0074] FIG.29 shows a perspective view of the resonator structure of FIG. 28 in an upside-down position.

[0075] FIG.30 shows a perspective view of a chassis part of the filter housing to be joined with the resonator structure of FIG.28.

[0076] FIG.31 shows a perspective view of a filter according to a sixth embodiment of the present disclosure, which is obtained by attaching the resonator structure of FIG.28 as a lid part to the chassis part shown in FIG.30.

Detailed Description

[0077] The embodiments of the present disclosure are described in detail with reference to the accompanying drawings. It should be understood that these embodiments are discussed only for the purpose of enabling those skilled in the art to better understand and thus implement the present disclosure, rather than suggesting any limitations on the scope of the present disclosure. Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present disclosure should be or are in any single embodiment of the disclosure. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present disclosure. Furthermore, the described features, advantages, and characteristics of the disclosure may be combined in any suitable manner in one or more embodiments. Those skilled in the relevant art will recognize that the disclosure may be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the disclosure.

[0078] Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

[0079] FIG. 1 shows a conventional TM filter 1' comprising a filter housing 11' and a ceramic resonator 12' housed in the filter housing 11'. The filter housing 11' comprises a chassis part 110' with an opening and a lid part 111' attached to the chassis part and covering the opening. The chassis part 110' and the lid part 111' each are made of metal. The resonator 12' stands uptight, with its upper end and lower end abutting against an inner wall of the lid part 111' and a bottom wall of the chassis part 110' respectively. So, one or more support elements are needed to guarantee a good connection in products lifetime, which brings difficulty in both design and production. For this type of TM filter, a tuning screw 112' is required to insert through a hole on the lid part 111' for tuning frequency. It is difficult to mass produce this type of TM filter, especially when the filter comprises lots of resonators.

[0080] FIG. 2 shows a schematic view of a conventional band pass filter 1'', which comprises five resonators 12'' standing upright in their resonance cavities defined by a filter housing 11'' comprised of a metal chassis part 110'' and a metal lid part 111'' and partition walls 110w'' provided between two adjacent resonators 12'', as shown in FIG. 3 and FIG. 4. Three of the resonators 12'' in the middle are ceramic resonators and two of the resonators 12'' on both left and right ends are metal resonators. The ceramic resonators are placed one by one into the chassis part 110'' of the filter 1'', and after the lid part 111'' is attached to the chassis part 110'' by fastening elements 112c (for example, screws), each ceramic resonator abuts against the bottom of the chassis part 110'' and the inner wall of the lid part 111'' and is placed in grounded connection with the metal cavity defined by the filter housing. The two metal resonators are fastened to blind holes provided in bosses 110b'' formed on the bottom of the chassis part and supported thereby in their resonance cavities. Coupling between two adjacent resonance cavities is realized by a coupling window provided in the partition wall 110w'' extending therebetween. An input connector 13I'' and an output connector 13O'' are provided at an input end and an output end of the filter 1'' respectively and coupled to an input resonator and an output resonator along a predetermined signal transmission path in the filter respectively. A tuning screw 112'' is also provided for each resonator. From FIG.3, it can be seen that, it involves many steps to install all the resonators in a desired manner in the filter housing, and after the lid part 111'' is attached to the chassis part 110'', it is not easy to guarantee that all the resonators are kept in place all the time. For example, when one of the resonators is displaced unintentionally or does not occupy its installation position any more, the performance of the whole filter will get worse or even cannot function properly.

[0081] For providing a method of assembling a plurality of resonators into a filter housing in an easy manner and ensuring stability and durability of the filter assembled, the present disclosure provides a resonator structure and a filter with such a resonator structure.

[0082] FIG. 5 shows a filter 1-1 according to the first embodiment of the present disclosure. The filter 1-1 comprises a filter housing 11 and resonators 12 provided in the filter housing. The filter housing 11 is comprised of a metal chassis part 110 with an opening 1101 and a metal lid part (not shown) attached to the chassis 110 to cover the opening after the resonators 12 are placed into the chassis part through the opening, such that an inner-side surface of the filter housing defines a closed metal cavity for housing resonators. FIG.5 shows the chassis part is open without being covered by the lid part for the purpose of clearly illustrating the installation of the resonators inside the chassis.

[0083] The filter 1-1 as shown in FIG.5 comprises three resonator structures 100-I, 100-M, 100-O according to the present disclosure. The three resonator structures are placed in three sub-cavities defined by partition walls 110w extending vertically in the chassis part 110. An input resonator structure 100-I is arranged in an input sub-cavity associated with an input connector (not shown). An intermediate resonator structure 100-M is arranged in an intermediate sub-cavity. And an output resonator structure 100-O is arranged in an output sub-cavity associated with an output connector (not shown). A signal transmission path extends along a line in which the resonators in the input resonator structure 100-I are arranged, then goes to the intermediate resonator structure 100-M by way of a coupling through a first coupling window 13-L formed in a left end of the partition wall 100w. Similarly, the signal transmission path goes to the output resonator structure 100-O by means of a coupling through a second coupling window 13-R formed in a right end of the partition wall 100w. At the end of the signal transmission path, a signal comes out via the output connector.

[0084] **A TM mode resonator structures of two-ends grounded type**

[0085] **A first example of the resonator structure**

[0086] For better illustration of the resonator structure according to the present disclosure, just the intermediate resonator structure 100-M is taken as an example. FIG. 6 and FIG. 7 show the intermediate resonator structure 100-M as a first example of the resonator structure according to the present disclosure. The resonator structure 100-M according to a first example of the present disclosure comprises a one-piece main body 1000 made of a dielectric material. The main body 1000 comprises a plurality of resonator rods 1000r extending longitudinally and at least one coupling crossbar 1000c intersecting with the resonator rods such that the resonator rods are held spaced from one another and coupled in a desired manner by means of the at least one coupling crossbar.

[0087] In the example shown in FIG. 6, five resonator rods 1000r, each of which is embodied in the form of a cuboid column, are alligned in a line, and four coupling crossbars 1000c extending between two adjacent resonator rods are in flush with the resonator rods on two lateral sides and a bottom side, such that the one-piece main body 1000 is substantially in the form of a comb comprising all the teeth portions extending from a common base portion. From FIG.6 and FIG.7, it can be seen that, the tip end of the teeth portions of the comb-shaped main body is metalized and the bottom side surface of the common base portion of the comb-shaped main body is metalized such that a flat metalized base surface is provided, which can be used as a installation base surface by means of which the main body can be placed into the chassis part 110 and fixedly connected to an inner surface on the bottom of the chassis part, for example, by welding, without the need of installing resonators one by one.

[0088] FIG.8 shows a sectional view of the filter 1-1 of FIG.5, which sectional view is taken along the line A-A indicative of a central plane of the resonator structure 100-M. It can be seen that, both the upper end and the lower end of each resonator rod 1000r are metalized and abut against the inner wall of the lid part 111 and the bottom wall of the chassis part 110 respectively and thus are placed in grounded connection with the closed metal cavity 11c defined by the filter housing 11. All the resonator rods 1000r function as TM mode center resonators 12 in the filter 1-1.

[0089] **A second example of the resonator structure**

[0090] FIG. 9 and FIG. 10 show a second example of the resonator structure according to the present disclosure. Different from the first example of the resonator structure, the second example of the resonator structure 100-M2 further comprises end cap extended portions 1000e integrally formed on the upper ends of the resonator rods 1000r. The end cap extended portions 1000e each extend substantially perpendicular to the longitudinal direction of the resonator rods 1000r and have their upper surfaces metalized. Therefore, the end cap extended portions 1000e allow providing enlarged end surfaces to be placed in contact and also in grounded connection with the inner top wall of the metal cavity 11c.

[0091] As shown in FIG. 9, the end cap extended portions 1000e are embodied as flat pads having substantially the same size. The flat pads extend both along and perpendicular to the line in which the resonator rods 1000r are aligned. It can be understood that the end cap extended portions 1000e may be configured to have different sizes or shapes or orientations. For instance, as shown in FIG. 10, some end cap extended portions 1000e are shaped as elongate pads each having a main extension length extending along or perpendicular to the line in which the resonator rods are arranged. Or rather, the end cap extended portions are formed by bending tip ends of teeth portions of the comb-like main body of the resonator structure 100-M2 along or perpendicular to the extension direction of the common base portion of the comb-like main body.

[0092] It can be understood that the end cap extended portions of the resonator rods in one and the same resonator structure can be configured identically or differently in terms of shape, size or orientations. For example, as a variant, all the end cap extended portions of the resonator rods are configured as elongate pads extending in one and the same direction along the line in which the resonator rods are aligned. All the variants of the end cap extended portions can be easily obtained during the sintering-pressing of dielectric material for the main body of the resonator structure.

[0093] **A third example of the resonator structure**

[0094] FIG. 11 shows a third example of the resonator structure 100-M3 according to the present disclosure. Different from the first example of the resonator structure 100-M in which the coupling crossbars 1000c have their lower side surfaces metalized and provided in flush with lower metalized longitudinal end surfaces of the resonator rods 1000r that are located in a same plane, the third example of the resonator structure 100-M3 comprises coupling crossbars 1000c having lower side surfaces extend above the lower metalized longitudinal end surfaces 1000r-ls of the resonator rods 1000r. In the example shown in FIG. 11, both the upper and lower side surfaces of the coupling crossbars are not metalized. And the coupling crossbars 1000c are shown to extend at different heights along the longitudinal direction of the resonator rods 1000r and/or have different thicknesses along the longitudinal direction of the resonator rods 1000r.

[0095] **A TM mode resonator structure of a one-end grounded type**

[0096] **A fourth example of the resonator structure**

[0097] FIG.12 shows a fourth example of the resonator structure according to the present disclosure. As compared with the first example of the resonator structure 100-M, the fourth example of the resonator structure 100-M4 differs in that the upper end surfaces of the resonator rods 1000r are naked without being covered with a metal layer. Or rather, only the bottom surface 1000b of the common base portion of the comb-like main body of the resonator structure 100-M4 is metalized for the purpose of establishing grounded connection with the closed metal cavity 11c defined by the filter housing 11. For example, as shown in FIG. 13, the resonator structure 100-M4 according to the fourth example of the present disclosure is placed on the bottom of the metal cavity 11c defined by the filter housing of the filter 1-2 according to the second embodiment of the present disclosure, with its metalized bottom surface 1000b abutting against and being fixedly connected to the bottom of the metal cavity 11c. The upper ends of the resonator rods 1000r are spaced from the top of the metal cavity by a certain interval. Therefore, capacitive couplings are formed between the top of the metal cavity and the non-metalized upper end surface of the resonator rods 1000r.

[0098] **A fifth example of the resonator structure**

[0099] FIG. 14 and FIG. 15 show a fifth example of the resonator structure 100-M5 according to the present disclosure. The fifth example of the resonator structure can be regarded as a variant of the fourth example of the resonator structure and differs therefrom in the provision of the end cap extended portions 1000e integrally formed on ends of the resonator rods 1000r. And it enables providing enlarged end surfaces to form capacitive coupling with the inner top wall of the metal cavity 11c defined by the filter housing 11.

[00100] As compared with the second example of the resonator structure 100-M2, the fifth example of the resonator structure 100-M5 differs only in that the upper end surfaces of the end cap extended portions 1000e of the resonator rods 1000r are naked without being covered with a metal layer.

[00101] It can be understood that the end cap extended portions 1000e of the resonator rods 1000r in one and the same resonator structure can be configured identically or differently in terms of shape, size or orientations. For example, as a variant, all the end cap extended portions 1000e of the resonator rods are configured as elongate pads extending in one and the same direction along the line in which the resonator rods are aligned.

[00102] **A sixth example of the resonator structure**

[00103] FIG. 16 shows a sixth example of the resonator structure 100-M6 according to the present disclosure. As compared with the third example of the resonator structure 100-M3 shown in FIG. 11, the sixth example of the resonator structure 100-M6 differs in that it has the upper end surfaces of its resonator rods 1000r naked without being covered with a metal layer. As shown in FIG. 16, both the upper and lower side surfaces of the coupling crossbars 1000c are not metalized. And the coupling crossbars are shown to extend at different heights along the longitudinal direction of the resonator rods and/or have different thicknesses along the longitudinal direction of the resonator rods.

[00104] **A resonator structure of peripheral surface metalized type that is based on two-ends or one-end grounded type**

[00105] **A seventh example of the resonator structure**

[00106] FIG. 17 shows a filter 1-3 according to the third embodiment of the present disclosure, with its side plate being removed for better illustration of a resonator structure 100-M7 according to the seventh example of the present disclosure. The resonator structure according to the seventh example is developed based on the first through the sixth examples of the resonator structures mentioned in the above. Specifically, the resonator rods 1000r of the resonator structure 100-M7 according to the seventh example differs from those of the resonator structures according to the first through the sixth examples in that its resonator rods 1000r each have their peripheral surfaces fully or partially metalized in such a manner that at least one metalized area 1000fm, 1000pm is provided on the peripheral surface of one resonator rod and joined to one or two metalized longitudinal end surfaces of the resonator rod concerned. The metalized area on the peripheral surface of the resonator rod 1000r can function to create a TEM mode and reject the spurious that exists in a TM mode resonator.

[00107] FIG. 18 shows a resonator structure 100-M7 according to the seventh example of the present disclosure. As clearly shown in FIG. 18, the resonator rod 1000r1 has its peripheral surface fully metalized in such a manner that the fully metalized peripheral surface 1000fm is joined to its metalized longitudinal end surfaces. In an alternative embodiment, the upper end of the resonator rod 1000r1, which is configured to abut against the upper wall of the metal cavity 11c, may be designed naked, namely without being metalized.

[00108] As a variant of the resonator rod 1000r1, the resonator rod 1000r2 has its peripheral surface partially metalized in such a manner that one upper metalized area 1000pm is formed on the peripheral surface and joined to the upper metalized longitudinal end surface. The lower border line of the upper metalized area 1000pm is spaced from the bottom metalized surface 1000b of the common base portion of the comb-like main body of the resonator structure 100-M7 such that a capacitive coupling is formed between the upper metalized area 1000pm and the bottom

metalized surface 1000b of the common base portion of the comb-like main body 1000.

[00109] As another variant, the resonator rod 1000r3 has its peripheral surface partially metalized in such a manner that one lower metalized area 1000pm is formed on the peripheral surface and joined to the bottom metalized surface 1000b of the common base portion of the comb-like main body 1000 of the resonator structure 100-M7 (namely, to the lower metalized longitudinal end surface of the resonator rod concerned). The upper border line of the lower metalized area 1000pm is spaced from the upper metalized longitudinal end surface of the resonator rod 1000r3 concerned such that one non-metalized end area is provided on the upper end of the peripheral surface of the resonator rod 1000r3 concerned.

[00110] As a variant of the resonator rod 1000r3, the resonator rod 1000r5 has the non-metalized end area provided on a circumferential surface of an end cap extended portion 1000e in the form of a flat pad. The upper end of the resonator rod 1000r3 or the resonator rod 1000r5, which is configured to abut against the upper inner wall of the metal cavity, may be designed naked without a metal covering thereon. Alternatively, the resonator rod 1000r3 or the resonator rod 1000r5 may be designed to have its upper end naked and to be placed in the metal cavity with a gap between its upper end and the upper wall of the metal cavity 11c.

[00111] As another variant of the resonator rod 1000r3, the resonator rod 1000r4 has its peripheral surface partially metalized such that two circumferential closed metalized end areas 1000pm formed on the peripheral surface, at least one of which is joined to its metalized longitudinal end surface, is spaced by a circumferential closed non-metalized area. The upper end of the resonator rod 1000r4, which is configured to abut against the upper inner wall of the metal cavity, may or may not be metalized.

[00112] **An eighth example of the resonator structure**

[00113] FIG. 19 shows an eighth example of the resonator structure 100-M8 in which the projection of the resonator structure onto a horizontal plane is grid-shaped rather than strip-shaped as shown in FIG. 6-FIG.7, FIG. 9-FIG. 12 and FIG.14-FIG.18. In the example shown in FIG. 19, the resonator rods 1000r are held by the coupling crossbars 1000c in a 2×3 array. The coupling crossbars 1000c each extend between two adjacent resonator rods 1000r. Some coupling crossbars may be joined to each other on their end areas. And one coupling crossbar extends at a height different from other coupling crossbars that lie substantially in a same plane.

[00114] Although it is shown in FIG. 19 that the resonator rods 1000r are held in a 2×3 array, it can be understood that the resonator rods 1000r may be arranged in a different array, totally depending on cases, and the number of coupling crossbars 1000c for the array of the resonator rods may vary from case to case, depending on specific design requirement for signal couplings between resonator rods. For example, the projection of the resonator structure onto a horizonal plane may change to be E shaped or H shaped, with the resonator rods being arranged in a 2×3 array still.

[00115] **Coupling between two adjacent resonator rods**

[00116] FIG. 20 shows schematically an example of a resonator structure 100 of a filter 1-4 according to the fourth embodiment of the present disclosure, which resonator structure is in the form of a one-piece block made of dielectric material and comprising two resonator rods 1000r and a coupling crossbar 1000c intersecting with the resonator rods and holding them spaced from one another. The resonator structure 100 is placed in a closed metal cavity 11c. The coupling crossbar 1000c is joined with the resonator rods 1000r on each end, thereby forming a common base portion of the whole resonator structure. The bottom surface 1000b of the common base portion is metalized and placed in grounded connection with the bottom wall of the metal cavity. The resonator rods 1000 extend from the common base portion on its upper side and abut against the inner upper wall of the metal cavity. A partition wall 100w is provided in the metal cavity 11c, dividing the metal cavity 11c into two sub-cavities

each of which has a resonator rod 1000r placed therein as a central resonator. In the partition wall 100w, a coupling window 100wc is provided, through which the coupling crossbar 1000c extends and the resonator rods 1000r are coupled with each other.

[00117] FIG. 21A and FIG. 21B show the E field and the H field generated by the two resonator rods 1000r in the two sub-cavities for realizing RF function of the filter 1-4.

[00118] Although it is shown in FIG. 20 that a partition wall 100w provided with a coupling window 100wc is provided in the metal cavity, it can be understood that the partition wall is not compulsory. For example, as shown in FIG. 23, a filter 1-5 according to the fifth embodiment of the present disclosure comprises a resonator structure 100 according to the present disclosure, without any partition walls provided. The resonator structure 100 is substantially E shaped and comprises three resonator rods 1000r aligned and held by two coupling crossbars 1000c. The resonator structure is placed in a metal cavity 11c defined by a filter housing of the filter 1-5. Upper metalized ends of the resonator rods 1000r and the lower metalized base surface 1000b defined by the lower metalized end surfaces of the resonator rods 1000r and the lower surfaces of the coupling crossbars 1000c abut against the upper wall and the lower wall of the metal cavity 11c, and connected thereto to form a grounding connection with the metal cavity. An input connector 13I is coupled to one resonator rod on the left end, and an output connector 13O is coupled to one resonator rod on the right end. The filter 1-5 as shown in FIG. 23 is a simple filter with 3 poles. The S parameter curve of the filter 1-5 can be seen in FIG. 24.

[00119] **Coupling between two non-adjacent resonator rods**

[00120] In a resonator structure according to the present disclosure which contains more than two resonator rods, there are necessarily two resonator rods that are not adjacent to each other along a predetermined signal transmission path of the filter. For the sake of better illustration, these two resonator rods can be called “non-adjacent resonator rods”.

[00121] According to the present disclosure, the non-adjacent resonator rods can be coupled inductively or capacitively by a coupling pattern provided on a coupling bridge that extends between the two non-adjacent resonator rods. The coupling bridge can be embodied in the form of one coupling crossbar extending all the way and intersecting with the resonator rod(s) between the two non-adjacent resonator rods concerned, or in the form of one integral segment that is formed by two or more coupling crossbars and resonator rods therebetween.

[00122] As can be seen from the first through the eighth examples of the resonator structure according to the present disclosure, due to the provision of the coupling crossbar(s), any two non-adjacent resonator rods in one resonator structure can be considered as joined by means of one coupling bridge formed by the combination of one or more coupling crossbars and resonator rod(s) therebetween.

[00123] **Inductivity coupling between two non-adjacent resonator rods**

[00124] Referring to FIG.22A, one coupling crossbar 1000c, which acts as a coupling bridge between two non-adjacent resonator rods 1000r-l, 1000r-r, is provided, having, on its naked lateral side, a support surface on which a coupling pattern embodied in the form of a metal strip 1000cp is provided. The coupling pattern 1000cp extends substantially along the support surface of the coupling crossbar 1000c. In the embodiment shown in FIG.22A, each end of the metal strip is joined to a metalized peripheral surface of one resonator rod of two non-adjacent resonator rods, thereby achieving inductivity coupling between the two non-adjacent resonator rods 1000r-l, 1000r-r.

[00125] FIG. 22B shows another example of the coupling pattern configured for achieving inductivity coupling between two non-adjacent resonator rods. In the embodiment shown in FIG. 22B, one end of the metal strip 1000cp is joined to a metalized peripheral surface of one resonator rod 1000r-l of the two non-adjacent resonator rods. The other end of the metal strip 1000cp is provided with a branch arm 1000cp-a that is joined to a metalized grounding surface of the coupling crossbar. The

metalized grounding surface of the coupling crossbar is joined with the lower metalized longitudinal end surfaces of the two resonator rods into a whole metalized base surface 1000b. Therefore, an inductivity coupling between the two non-adjacent resonator rods is formed by means of both the metal strip 1000cp and the metalized base surface 1000b.

[00126] FIG.22C shows how to achieve an inductivity coupling between two non-adjacent resonator rods 1000r-l, 1000r-r without metalized peripheral surfaces. As can be seen from FIG.22C, all the resonator rods share a common metalized base surface 1000b. The coupling pattern is embodied in a metal strip 1000cp comprising a main extension portion extending along the coupling crossbar and two branch arms 1000cp-a extending from two ends of the main extension portion and joined to the common metalized base surface 1000b. Each end of the main extension portion extends into an area of one resonator rod. That is to say, the branch arms 1000cp-a each are located on a lateral side surface of one resonator rod of the two non-adjacent resonator rods concerned. Therefore, an inductivity coupling between the two non-adjacent resonator rods is formed by means of both the metal strip and the metalized base surface 1000b.

[00127] **Capacitive coupling between two non-adjacent resonator rods**

[00128] FIG.22D shows an example of obtaining a capacitive coupling between two non-adjacent resonator rods. As can be seen from FIG. 22D, the coupling pattern is embodied in the form of a metal strip 1000cp with one end being joined to a metalized peripheral surface of one resonator rod 1000r-l and the other end being spaced from a metalized area on the peripheral surface of the other resonator rod 1000r-r by a gap. Therefore, a capacitive coupling between the two non-adjacent resonator rods is formed as a result of the metal strip.

[00129] FIG. 22E shows another example of realizing a capacitive coupling between two non-adjacent resonator rods. As can be seen from FIG. 22E, the coupling pattern is embodied as a metal strip 1000cp with one end being joined to a metalized

peripheral surface of one resonator rod 1000r-l and the other end being located in the proximity of and spaced from the other resonator rod 1000r-r. For enhancing the capacitive coupling, the end of the metal strip 1000cp that is spaced from the resonator rod can be provided with a butt 1000cp-b extending perpendicular to the main extension of the metal strip.

[00130] FIG. 22F shows a variant of the coupling pattern extending between metalized areas on the peripheral surfaces of two non-adjacent resonator rods. The coupling pattern is embodied as a metal strip 1000cp with both ends being spaced from metalized areas on the resonator rods 1000r-l, 1000r-r. Each end of the metal strip may be provided with a butt 1000cp-b extending perpendicular to the main extension of the metal strip such that the capacitive coupling between the two non-adjacent resonator rods can be strengthened by the enlarged end surfaces provided by the butts.

[00131] FIG. 22G shows a coupling structure in which the coupling pattern which is embodied in the form of a metal strip 1000cp provided with a butt 1000cp-b on each end, extends between the left resonator rod 1000r-l and the right resonator rods 1000r-r that are non-adjacent to each other and have no metalized area on their peripheral surfaces. The butt 1000cp-b on the left end of the metal strip 1000cp is located in the projection of the left resonator rod 1000r-l onto the horizontal plane, and the butt 1000cp-b on the right end of the metal strip 1000cp is spaced from the right resonator rod 1000r-r.

[00132] FIG. 22H shows a coupling structure in which the coupling pattern comprises two metal strips 1000cp extending towards each other, terminating at their first ends 1000cp-1 and spaced from each other by a gap, and a second end 1000cp-2 that is opposite to the first end on each of the metal strips 1000cp is joined to a fully metalized peripheral surface of one of two non-adjacent resonator rods 1000r-l, 1000r-r. The first ends 1000cp-1 are embodied in the form of butts, so as to enlarge the capacitive coupling therebetween.

[00133] FIG.22I shows a coupling structure in which the coupling pattern comprises two metal strips 1000cp extending towards each other, terminating at their first ends 1000cp-1 and spaced from each other by a gap, and a second end 1000cp-2 that is opposite to the first end on each of the metal strips is located in the proximity of a non-metalized surface of one of the two non-adjacent resonator rods 1000r-l, 1000r-r. The first ends 1000cp-1 are embodied in the form of butts, so as to enlarge the capacitive coupling therebetween

[00134] **Installation of the resonator structure into the filter housing**

[00135] As mentioned in the above, the filter housing defines a closed metal cavity for housing at least one resonator structure according to the present disclosure. The filter housing can be embodied as a two-part component or three-part component, any part of which is made of metal or made of dielectric material with its inner wall being metalized. Depending on the specific design of the filter housing, the installation method for installing the resonator structure into the filter housing may vary from case to case.

[00136] Referring back to FIG.8, the filter housing 11 is composed of a lid part 111 and a chassis part 110 with an opening onto which the lid part is attached such that the lid part 111 and the chassis part 110 are joined together as a whole and a closed metal cavity 11c is formed with the resonator structure being located in place. That is to say, before attaching the lid part 111 to the opening of the chassis part 110, the at least one resonator structure is put into the recess defined by the chassis part 110 and connected to the bottom of the recess by welding. After attaching the lid part 111 to cover the opening of the chassis part, the resonator rods may abut against the inner wall of the lid part with their upper ends and connected thereto by welding, or may be spaced from the inner wall of the lid part, with their upper end surfaces being either naked or metalized.

[00137] Referring to FIG. 25, the filter housing 11 can be embodied as another type of a two-part component comprising a chassis part 110 provided with a side opening.

Through the side opening, the resonator structure 100 is put into a recess defined by the chassis part, with its upper end and its lower end abutting against the upper and lower inner walls of the chassis part and being connected thereto by means of welding. As can be seen from FIG.25, the resonator structure 100 is assembled well into the chassis part 110, before attaching a side lid part (not shown) to the side opening of the chassis part. Although it is shown that all the upper ends of the resonator rods of the resonator structure abut against the upper inner wall of the chassis part, it can be understood that, it is possible that some or all the resonator rods 1000r are spaced from the upper inner wall of the chassis part, as long as the lower end of the resonator structure is fixedly connected to the lower inner wall of the chassis part, for example, by having the metalized base surface 1000b of the common base portion of the resonator structure welded to the lower inner wall of the chassis part.

[00138] It is shown in FIG. 26 that the filter housing 11 is embodied as a three-part component, comprising a tubular chassis part 110 with two end openings and two end lid parts (not shown) configured for closing the two end openings. This configuration enables inserting at least one resonator structure 100 through either end opening into a cavity defined by the hollow tubular part and optionally partition wall(s) 100w provided in the hollow tubular chassis part 110. In the embodiment shown in FIG. 26, two resonator structures according to the present disclosure can be inserted into two sub-cavities separated by a partition wall 100w extending along the longitudinal direction of the hollow tubular chassis part.

[00139] **Holes for tuning frequency**

[00140] No matter whether the filter housing is embodied as a two-part component or a three-part component or a component having more than three parts, at least one end of the resonator structure 100 abuts against a top or bottom portion of the filter housing. The top or bottom part of the filter housing against which at least one resonator rod abuts with its metalized longitudinal end, is provided with at least one

through-hole through which at least a portion of a metalized longitudinal end surface of the at least one resonator rod installed in the filter housing is exposed. Specifically referring to FIG. 27, through-holes 1100h are provided on the lid part 111 of the filter housing 11 and located in regions corresponding to the upper metalized ends of the resonator rods of the resonator structures according to the present disclosure. Thereby, the metal layers on the metalized end surface of the resonator rods, which are accessible through the through-holes 1100h, can be removed by applying laser, for example, during mass production, such that the frequency of the filter can be tuned according to practical needs.

[00141] Although it is shown in FIG. 27 that only the lid part 111 is provided with through-holes 1100h for frequency tuning, it can be understood that, the bottom of the chassis part 110, against which the resonator structure 100 abut with one metalized end, may also be provided with through-holes in regions corresponding to the lower metalized end surfaces of the resonator rods.

[00142] Although it is described that the filter housing of the filter shown in FIG. 5, FIG.13, FIG.20 and FIG. 23 is made of a metal chassis part and a metal lid part which are joined together as a whole for example, by welding at their abutting surfaces, it can be understood that, the filter housing can have its lid part and/or chassis part made of nonmetal material (for example, dielectric materials, such as plastic or ceramic), with both the lid part and chassis part being metalized on their inner side surfaces so as to jointly define a closed metal cavity. In this case, the outer side surfaces of the lid part and/or the chassis part may be or may not be metalized.

[00143] **Resonator structure having double functions**

[00144] Different from the resonator structures according to the first through eighth example of the present disclosure which are assembled into the filter housing as a separate member, the resonator structure according to the ninth example of the present disclosure, which enables providing several resonators in the filter during one-step assembling process, can serve as a part of the filter housing as well.

[00145] Specifically, referring to FIG.28, different from the resonator structure according to the eighth example of the present disclosure in which the coupling cross bars form a grid-shaped block with the resonator rods (as shown in FIG.19), the resonator structure 100-1 according to the ninth example of the present disclosure have its coupling cross bar(s) joined with the resonator rods (specifically, in the area of the lower ends of the resonator rods) together to form a plate-like common base block 100-10 from the upper side of which the resonator rods 1000r protrude. The plate-like common base block has its lower side surface metalized, thereby forming a metalized base surface which may serve as a lower wall of the metal cavity (instead of being connected to the lower wall of the metal cavity). That is to say, the plate-like common base block 100-10 of the resonator structure 100-1 functions both as a coupling structure for the resonator rods thereon and as a lid part of the filter housing.

[00146] As shown in FIG. 28 and FIG. 29, the circumferential surface of the plate-like common base block 100-10 is also metalized such that when the resonator structure 100-1 is attached, as a lid part, to the chassis part 110 (as shown in FIG.30) of the filter housing 11, a closed metal cavity can be formed. The chassis part 110 of the filter housing 11 may be made of metal or made of non-metal materials with at least its inner wall being metalized.

[00147] The resonator rods 1000r may have its upper end naked (as shown in FIG. 28) or have its upper end metalized, and optionally have its peripheral surface partially or fully metalized. In the embodiment as shown in FIG.28 though FIG.31, on the metalized base surface of the plate-like common base block, a plurality of first blind holes 100-101a are provided in areas of the lower longitudinal ends of the resonator rods such that the frequency associated may be tuned for example by removing a portion of the metal layer from walls of the first blind holes. Additionally, or optionally, a plurality of second blind holes 100-101b are provided on the metalized base surface of the plate-like common base block in positions between the lower longitudinal ends of two adjacent resonator rods, such that the coupling

therebetween may be tuned by removing a portion of the metal layer from walls of the second blind holes.

[00148] At least one through slot 100-102 which has its walls metalized, is provided in the plate-like common base block of the resonator structure, so as to isolate two resonator rods located on opposite sides of the at least one through slot from each other, such that a signal transmission path may be achieved as desired in the filter 1-6. FIG. 29 shows an upside-down view of the resonator structure of FIG.28. It seems as if the resonator rods hung from the plate-like common base block and protrude into the sub-cavities which are separated by partition walls 100w standing upright in the chassis part 110 as shown in FIG. 30. FIG. 30 shows the chassis part 110 upside-down to illustrate the partition walls 100w therein clearly. Coupling windows 100wc are provided in some partition walls for realizing the coupling between resonator rods in a desired manner. When the lid part and the chassis part are joined together, the partition walls are welded to the upper side of the plate-like common base block such that, the through slots 100-102 are blocked on the upper side of the plate-like common base block to keep the metal cavity of the filter housing closed.

[00149] FIG.31 shows the filter 1-6 according to the sixth embodiment of the present disclosure, which is obtained, simply by attaching the resonator structure 100-1 as the lid part to the chassis part 110, without the need of providing a separate cover or lid to be joined with the chassis part to enclose the resonators therein. The filter 1-6 according to the sixth embodiment of the present disclosure allows reducing the number of components of the final product and assembling in one step, thereby improving assembling efficiency with reduced production cost.

[00150] Although it is shown in FIG. 28 that the resonator rods are spaced from each other by strips of metal coating which are configured for facilitating connecting the partition walls to the plate-like common base block by welding, it can be understood that, inductive or capacitive couplings as illustrated with respect to FIG.22A-FIG.22I

may adaptively apply to non-adjacent resonator rods along the predetermined signal transmission path of the filter 1-6.

[00151] According the present disclosure, an antenna filter unit or a radio can be made with at least one filter as said in the above.

[00152] Also, although it is shown in FIG. 5 that all the resonator structures in the filter housing are resonator structures of the first example according to the present disclosure which have resonator rods aligned in a line, it can be understood that, according to the present disclosure, resonator structures in different configurations can be used in a single filter in a desired manner as well. Resonator rods configured in different shapes, sizes, orientations or metallized in different manners may also be used in one resonator structure.

[00153] Additionally, ceramic or plastic can be selected as the dielectric material for the one-piece resonator structure according to the present disclosure. Resonator structures made of ceramic enable obtaining a filter with improved Q value and reduced size. The total weight of the filter can be greatly reduced if plastic is chosen for the main body of the resonator structure according to the present disclosure. As for a resonator structure made of ceramic, it is preferable that part of its surface is metalized according to practical needs. While as for a resonator structure made of plastic, it is preferable that all its surface is metalized so as to reduce the filter loss as much as possible.

[00154] The plastic material for the resonator structure or the filter housing may be selected from the group consisting of PE (Polyethylene), PP (Polypropylene), PVC (Polyvinyl Chloride), PET (Polyethylene Terephthalate), PS (Polystyrene), PA (Polyamide), PPS (Polyphenylenesulfide), PC (Polycarbonates) or PI (Polyimide Film). For example, the plastic material can be in the form of LCP (liquid crystal polymer).

[00155] The metal material for the metallization process can be selected from the group consisting of silver, copper, aluminum, gold, iron, manganese, titanium, chromium or the like.

[00156] According to the present disclosure, the resonant structure makes it possible to obtain a small sized filter, a radio unit or an antenna filter unit, with low loss and improved Q value. The filter of the present disclosure may be mounted, for example, by surface mounting technology (for example, soldering through metalized surface or metalized signal pad or signal pin), so that a radio unit or an antenna filter unit can be easily made as compact as possible according to practical needs. Thus, the production efficiency can be greatly improved. The resonator structure of the present disclosure enables integration of high degree and also fully making use of the space available with reduced cost. Moreover, since the whole structure is simpler than traditional solutions in terms of production and assembling, the production efficiency (especially assembling efficiency) will be improved a lot.

[00157] In the description of the present disclosure, it should be understood that the orientation or position relationship indicated by the terms “upper”, “lower”, “top”, “bottom”, “inward”, “outward”, “horizontal”, “vertical” and so on is based on the orientation or position relationship when the filter is placed in a position as shown, for example, in FIG.5, only for the convenience of describing the invention and simplifying the description, rather than indicating or implying that the filter or element must have a specific orientation, or must be constructed and operated in a specific orientation. The terms “inner”/ “inner side” and “outer”/ “outer side” refer to the sides of the chassis part or the lid part with respect to the interior of the filter. All these terms should not be interpreted as limitative for the inventions revealed in the present disclosure.

[00158] For all kinds of the resonator structures of the present disclosure, the metallization process involved is not limited to plating. For example, hot stamping, printing, coating, or adhesives or the like can be used as well.

[00159] Although it is shown in FIG.5 through FIG.18, the coupling crossbar is in a bar shape, it can be easily understood that the coupling crossbar can be designed in any regular or irregular shapes (including a flat plate-shape, a rod-like shape or a bar shape), and two or more coupling crossbars that are joined together may also be considered as one coupling crossbar.

[00160] References in the present disclosure to “an embodiment”, “another embodiment” and so on, indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to implement such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[00161] It should be understood that, the term “and/or” includes any and all combinations of one or more of the associated listed terms.

[00162] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the present disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof. The terms “connect”, “connects”, “connecting” and/or “connected” used herein cover the direct and/or indirect connection between two elements.

[00163] The present disclosure includes any novel feature or combination of features disclosed herein either explicitly or any generalization thereof. Various modifications

and adaptations to the foregoing exemplary embodiments of this disclosure may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. However, any and all modifications will still fall within the scope of the non-Limiting and exemplary embodiments of this disclosure.

Claims

What is claimed is:

1.A resonator structure (100I, 100M, 100O) for a filter (1-1, 1-2, 1-3, 1-4, 1-5) comprising a filter housing (11) defining a closed metal cavity (11c) for the resonator structure, the resonator structure comprising a one-piece main body (1000) made of a dielectric material, characterized in that,

the main body comprises:

a plurality of resonator rods (1000r) extending longitudinally between upper and lower walls of the metal cavity, with at least one longitudinal end surface of each resonator rod being metalized for establishing grounded connection with the metal cavity; and

at least one coupling crossbar (1000c) intersecting with the resonator rods such that the resonator rods are held spaced from one another and coupled by means of the at least one crossbar.

2. The resonator structure according to claim 1, characterized in that, at least one resonator rod (1000r1) has its peripheral surface fully metalized in such a manner that the fully metalized peripheral surface is joined to its metalized longitudinal end surface.

3.The resonator structure according to claim 1, characterized in that, at least one resonator rod (1000r2, 1000r3, 1000r4, 1000r5) has its peripheral surface partially metalized in such a manner that at least one metalized area on the partially metalized peripheral surface is joined to its metalized longitudinal end surface.

4. The resonator structure according to claim 3, characterized in that, one non-metalized end area is provided on the partially metalized peripheral surface, or two circumferential closed metalized end areas (1000pm) formed on the partially metalized peripheral surface, at least one of which is joined to its metalized longitudinal end surface, is spaced by a circumferential closed non-metalized area.

5. The resonator structure according to any one of claims 1-4, characterized in that, at least one longitudinal end of at least one resonator rod (1000r) is shaped to have an end cap extended portion (1000e) which extends substantially perpendicular to the longitudinal direction of the resonator rods.

6. The resonator structure according to according to claim 5, characterized in that, the plurality of resonator rods (1000r) are arranged in a line.

7.The resonator structure according to claim 6, characterized in that, the end cap extended portion (1000e) is shaped to mainly extend in a direction along and/or perpendicular to the line in which the resonator rods are arranged.

8.The resonator structure according to any one of claims 1-7, characterized in that, two resonator rods that are not adjacent to each other along a predetermined signal transmission path of the filter are coupled inductively or capacitively by a coupling pattern provided on a coupling bridge that extends between the two resonator rods, the coupling bridge being formed by one coupling crossbar extending between the two non-adjacent resonator rods concerned, or by one integral segment that is formed by two or more coupling crossbars and resonator rods therebetween.

9.The resonator structure according to claim 8, characterized in that, the coupling pattern is embodied as a metal strip (1000cp) substantially extending along the coupling bridge.

10.The resonator structure according to claim 9, characterized in that, at least one end of the metal strip (1000cp) is joined to a metalized peripheral surface of one of the two resonator rods or is provided with a branch arm (1000cp-a) that is joined to a metalized grounding surface of the coupling crossbar on which the metal strip extends.

11.The resonator structure according to claim 9, characterized in that, an end of the metal strip is located in the proximity of and spaced from one of the two resonator rods.

12.The resonator structure according to claim 8, characterized in that, the coupling pattern comprises two metal strips (1000cp) extending towards each other, terminating at their first ends (1000cp-1) and spaced from each other by a gap.

13.The resonator structure according to claim 12, characterized in that, a second end (1000cp-2) that is opposite to the first end on each of the metal strips (1000cp) is joined to a metalized surface of one of the two resonator rods.

14.The resonator structure according to claim 12, characterized in that, a second end (1000cp-2) that is opposite to the first end (1000cp-1) on each of the metal strips (1000cp) is located in the proximity of a non-metalized surface of one of the two resonator rods.

15.The resonator structure according to any one of claims 1-14, characterized in that, the dielectric material is ceramic or plastic.

16.The resonator structure according to any one of claims 1-15, characterized in that, lower longitudinal end surfaces of all the resonator rods are metalized.

17.The resonator structure according to claim 16, characterized in that, the at least one coupling crossbar has its lower side surface metalized and provided in flush with lower metalized longitudinal end surfaces of the plurality of resonator rods that are located in a same plane, thereby providing a metalized base surface (1000b) which is to be placed in contact with the lower wall of the metal cavity.

18. The resonator structure according to claim 16, characterized in that, a lower side surface of the at least one coupling crossbar extends above the lower metalized longitudinal end surfaces of the plurality of resonator rods.

19. The resonator structure according to claim 18, characterized in that, the two or more coupling crossbars extend at different heights along the longitudinal direction of the resonator rods.

20. The resonator structure according to any one of claims 1-19, characterized in that, the plurality of resonator rods are held by two or more coupling crossbars such that a projection of the resonator structure onto a horizontal plane is strip-shaped or grid-shaped.

21. The resonator structure (100-1) according to claim 16, characterized in that, the at least one coupling crossbar is joined with the resonator rods (1000r) together to form a plate-like common base block (100-10) from an upper side of which the resonator rods protrude, the plate-like common base block having its lower side surface metalized, thereby forming a metalized base surface (1000b) which serves as a lower wall of the metal cavity.

22. The resonator structure according to claim 21, characterized in that, a plurality of first blind holes (100-101a) are provided on the metalized base surface of the plate-like common base block in areas of lower longitudinal ends of the resonator rods for tuning frequency, and/or a plurality of second blind holes (100-101b) are provided on the metalized base surface of the plate-like common base block in positions between the lower longitudinal ends of two adjacent resonator rods for tuning coupling.

23. The resonator structure according to claim 21 or 22, characterized in that, at least one through slot (100-102), which has its walls metalized, is provided in the plate-like common base block, so as to isolate two resonator rods located on opposite sides of the at least one through slot.

24. A filter (1-1, 1-2, 1-3, 1-4, 1-5), comprising a filter housing (11) defining a closed metal cavity (11c), characterized in that, at least one resonator structure (100-M, 100-M1, 100-M2, 100-M3, 100-M4, 100-M5, 100-M6, 100-M7, 100-M8, 100) according to any one of claims 1-20 is arranged in the metal cavity, with at least one metalized longitudinal end surface of each resonator rod being placed in grounded connection with the metal cavity.

25.The filter according to claim 24, characterized in that, a top or bottom part of the filter housing (11) against which at least one resonator rod abuts with its metalized longitudinal end, is provided with at least one through-hole (1100h) through which at least a portion of a metalized longitudinal end surface of the at least one resonator rod is exposed.

26. The filter according to any one of claims 24 or 25, characterized in that, a partition wall (100w) is provided between two resonance cavities associated with two adjacent resonator rods of the resonator structure, and a coupling window (100wc) is provided in the partition wall for coupling the two adjacent resonator rods.

27. The filter according to any one of claims 24-26, characterized in that, the filter housing (11) is made of metal, or made of non-metal material with at least its inner walls being metalized.

28.A filter (1-6), comprising a filter housing (11) defining a closed metal cavity (11c), characterized in that, the filter comprises a resonator structure (100-1) according to any one of claims 21-23, the resonator structure being arranged such that its resonator rods extend into the metal cavity, and the metalized base surface of its plate-like common base block serves as a lower wall of the metal cavity.

29. The filter according to claim 28, characterized in that, a partition wall (100w) is provided between two resonance cavities associated with two adjacent resonator rods of the resonator structure, having its lower end welded to the upper side of the plate-like common base block of the resonator structure.

30. The filter according to claim 29, characterized in that, a coupling window is provided on the partition wall.

31. The filter according to any one of claims 28-30, characterized in that, the resonator structure is configured as a lid part of the filter housing, and the filter housing (11) comprises a chassis part to which the lid part is attached so as to obtain the closed metal cavity, wherein the chassis part is made of metal or made of non-metal material with at least its inner walls being metalized.

32. A radio unit or an antenna filter unit, characterized by comprising at least one filter according to any one of claims 24-31.

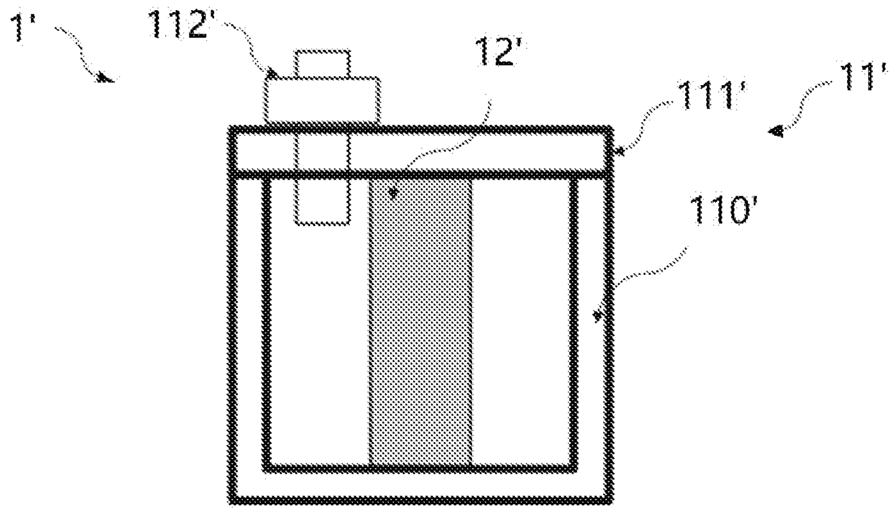

FIG.1

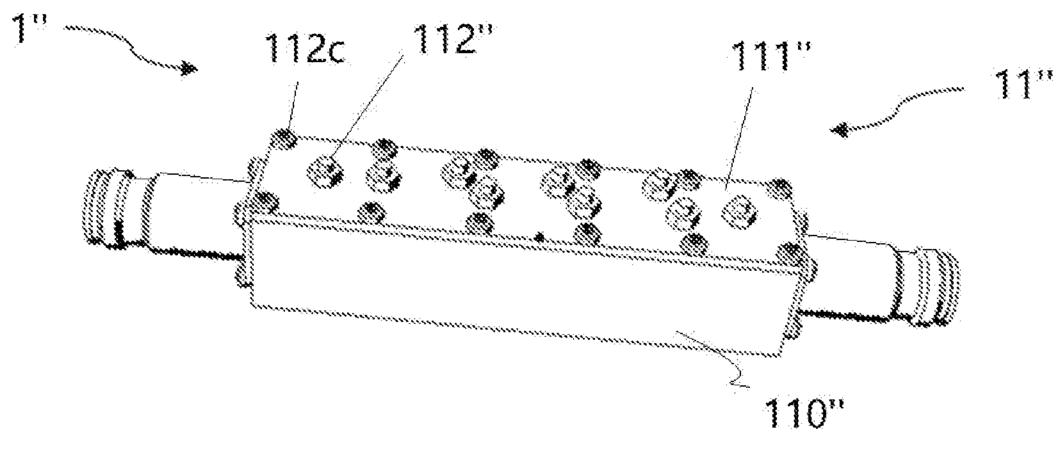

FIG.2

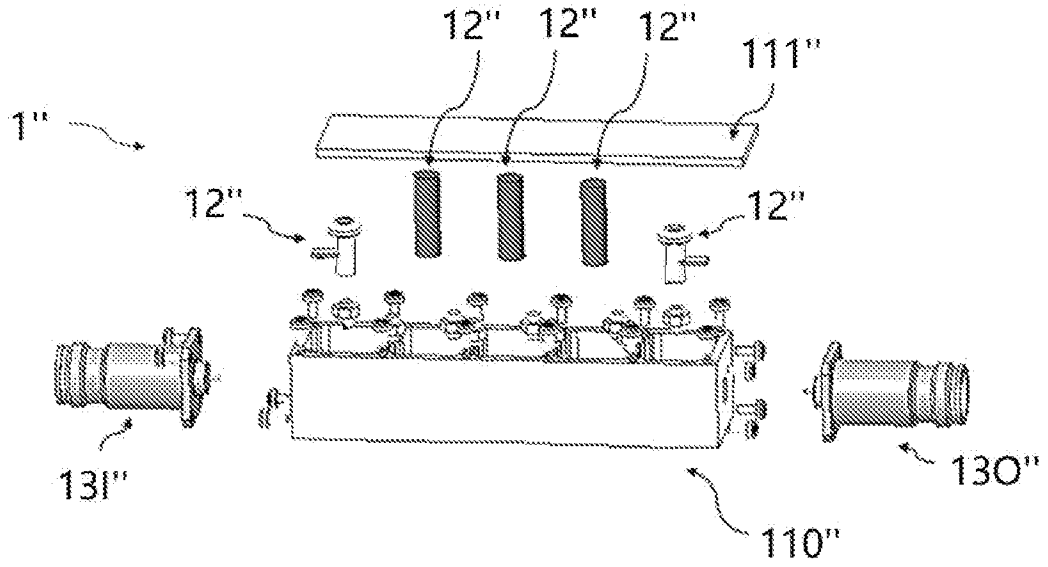
12''
12''
12''
111''
1''
12''
12''
13I''
13O''
110''

FIG.3

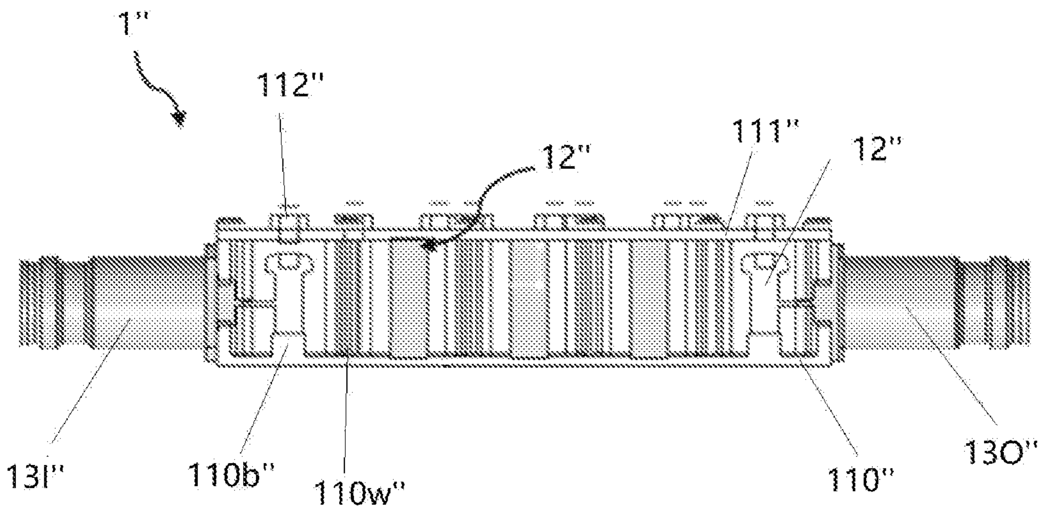
1''
112''
12''
111''
12''
13I''
110b''
110w''
110''
13O''

FIG.4

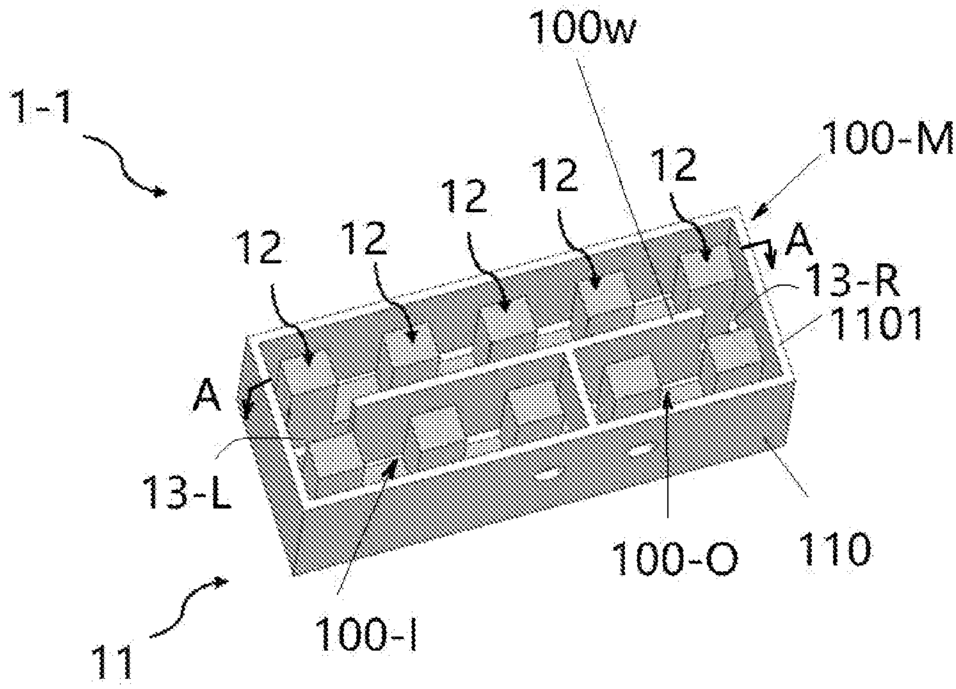
100w
1-1
100-M
12
12
12
12
12
12
A
13-R
1101
A
13-L
100-O
110
11
100-I

FIG.5

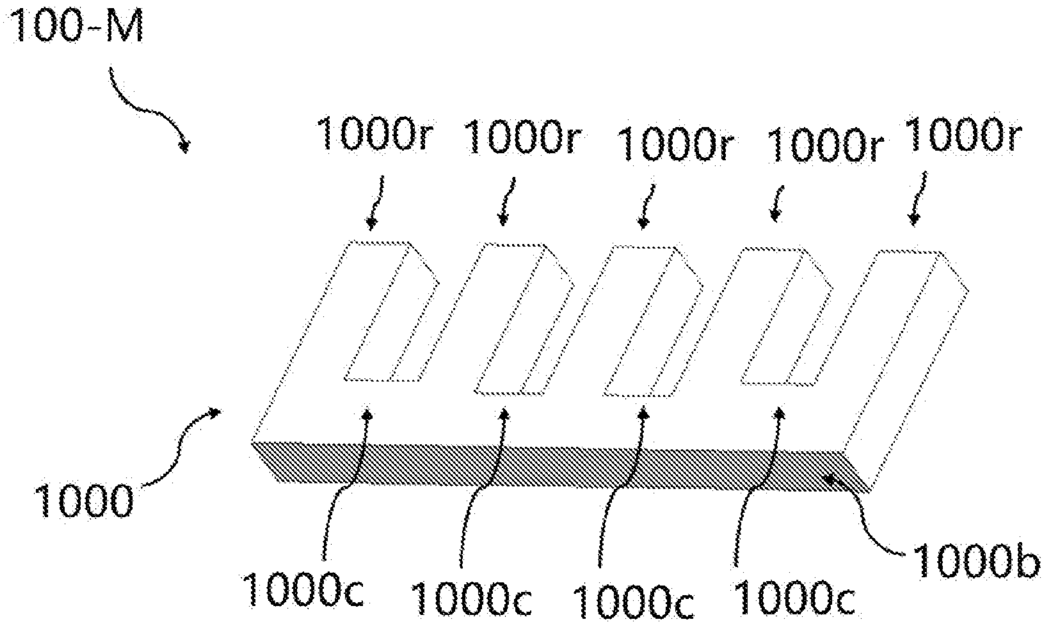
100-M
1000r
1000r
1000r
1000r
1000r
1000
1000c
1000c
1000c
1000c
1000b

FIG.6

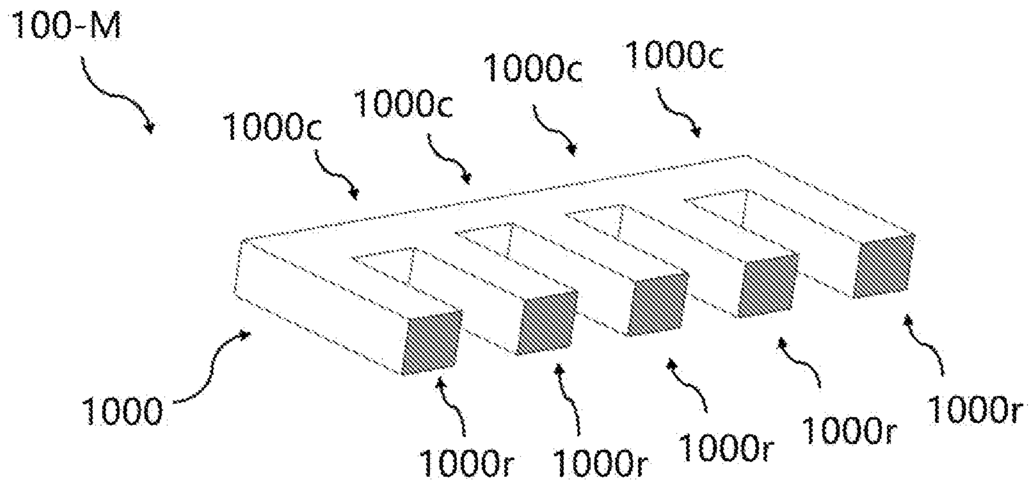
100-M
1000c
1000c
1000c
1000c
1000
1000r
1000r
1000r
1000r
1000r

FIG.7

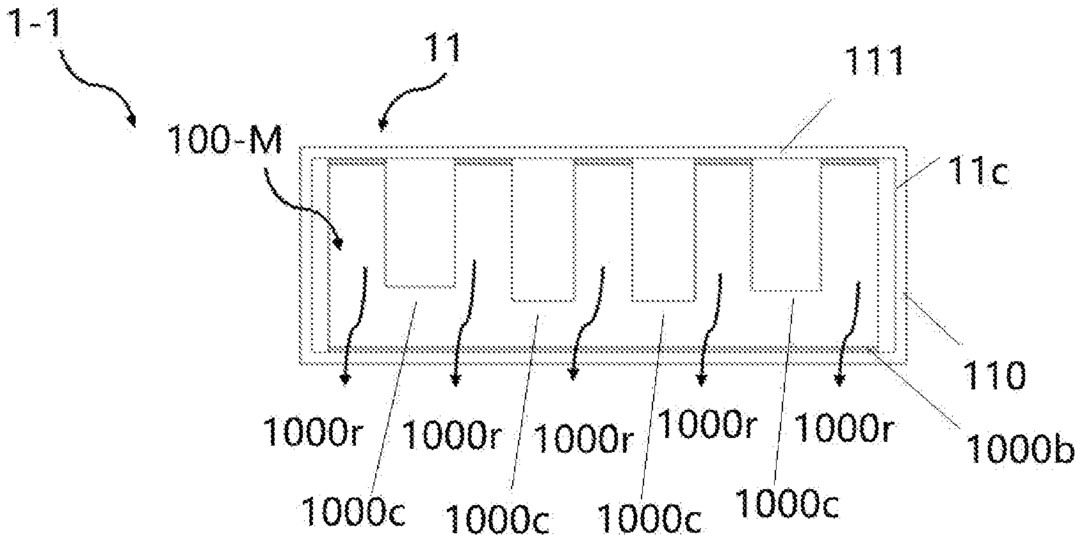
1-1
11
111
100-M
11c
110
1000r
1000r
1000r
1000r
1000r
1000b
1000c
1000c
1000c
1000c

FIG.8

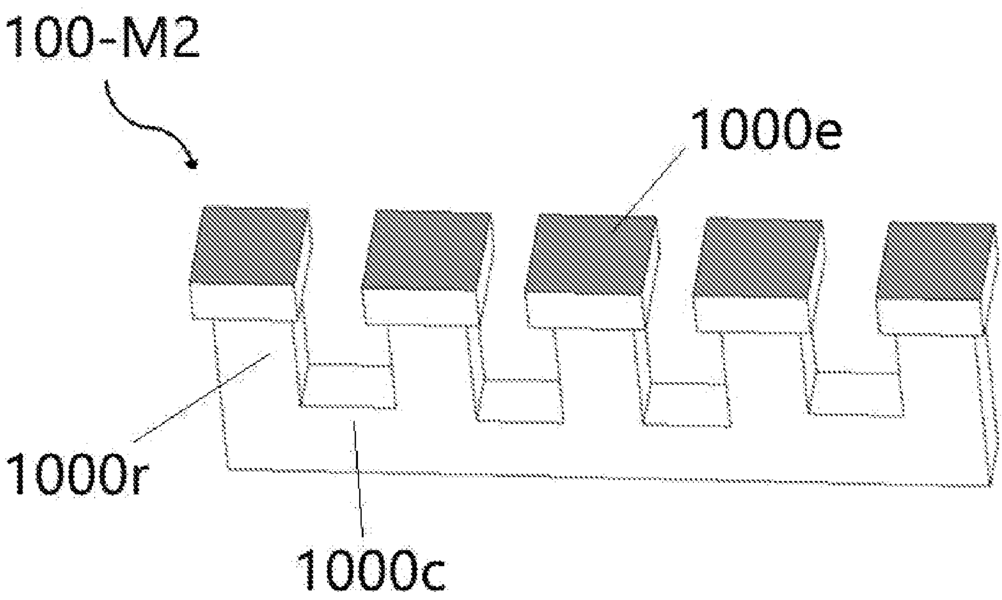

FIG.9

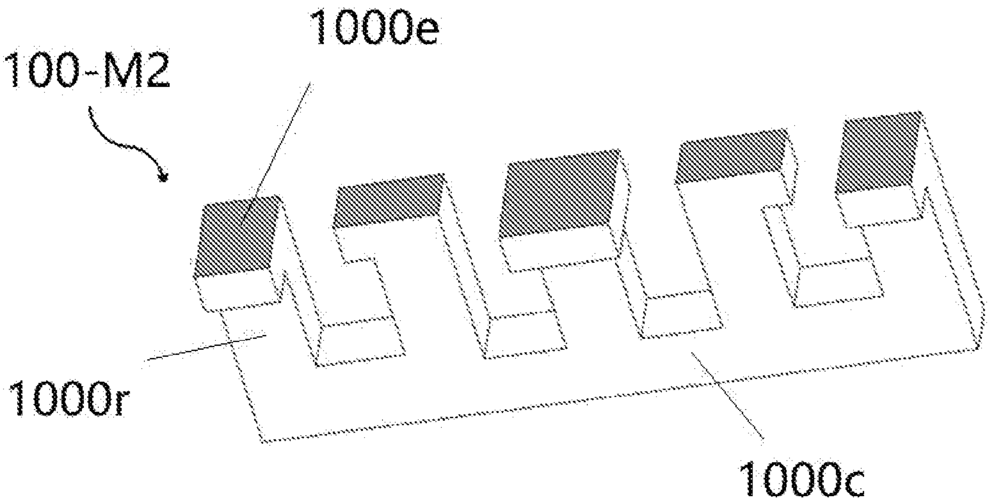

FIG.10

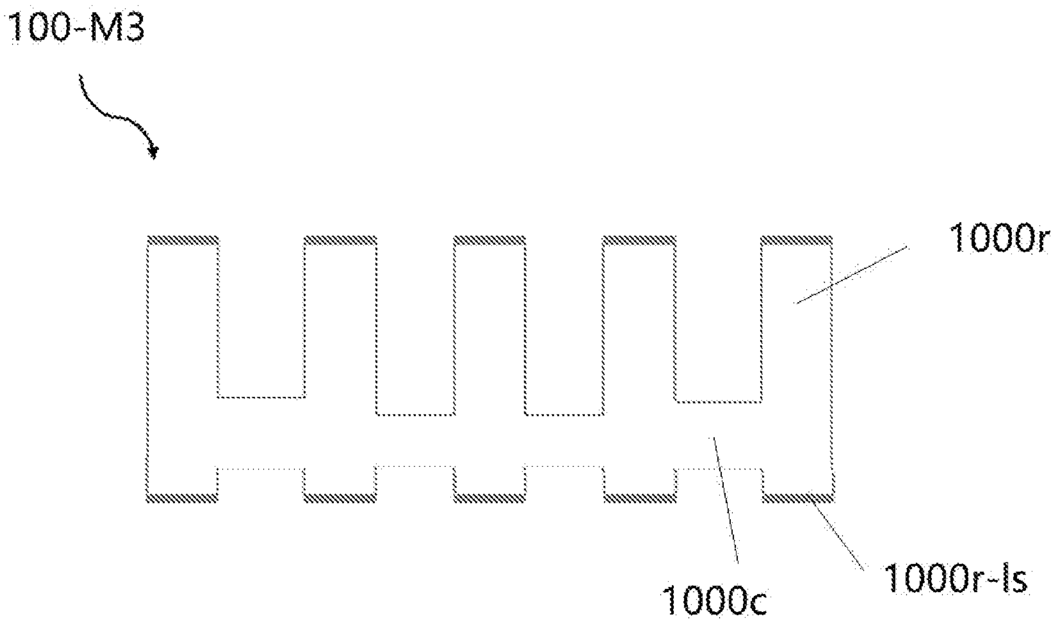

FIG.11

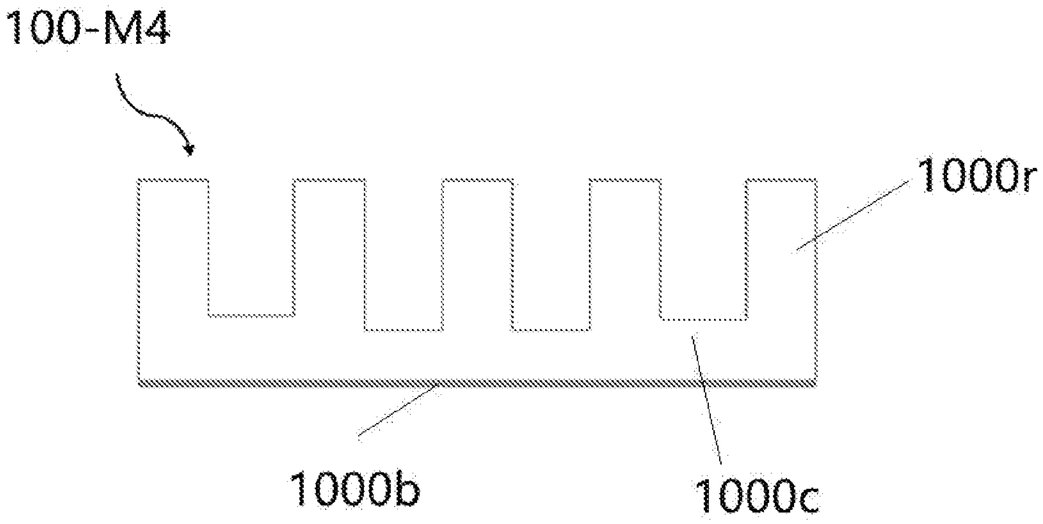

FIG.12

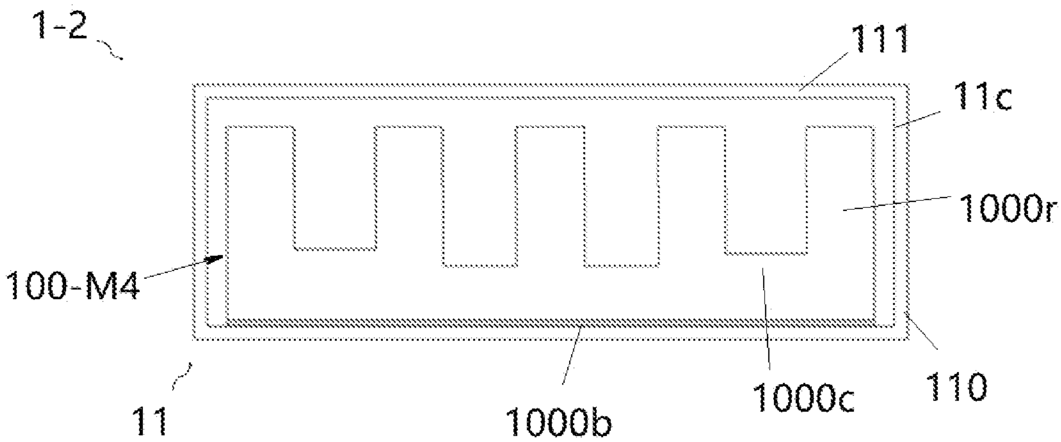
1-2
111
11c
1000r
100-M4
11
1000b
1000c
110

FIG.13

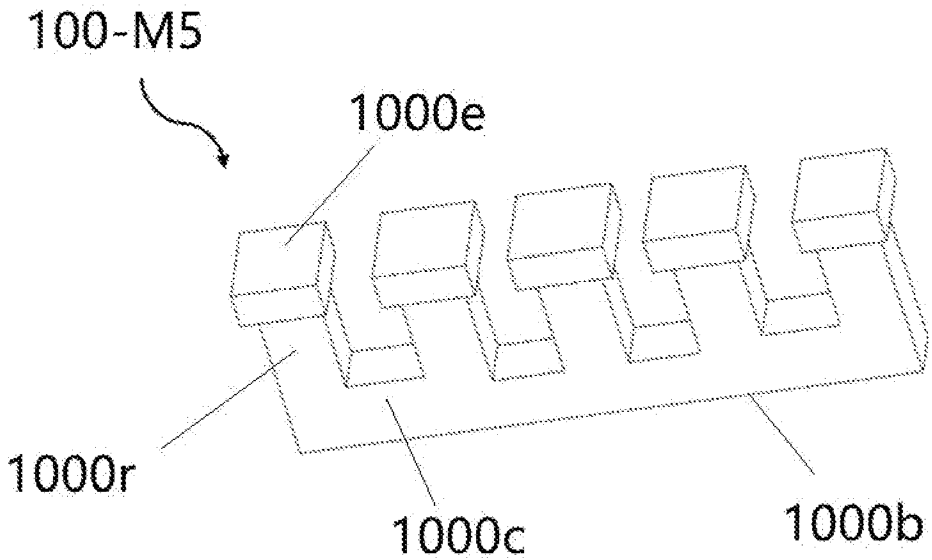
100-M5
1000e
1000r
1000c
1000b

FIG.14

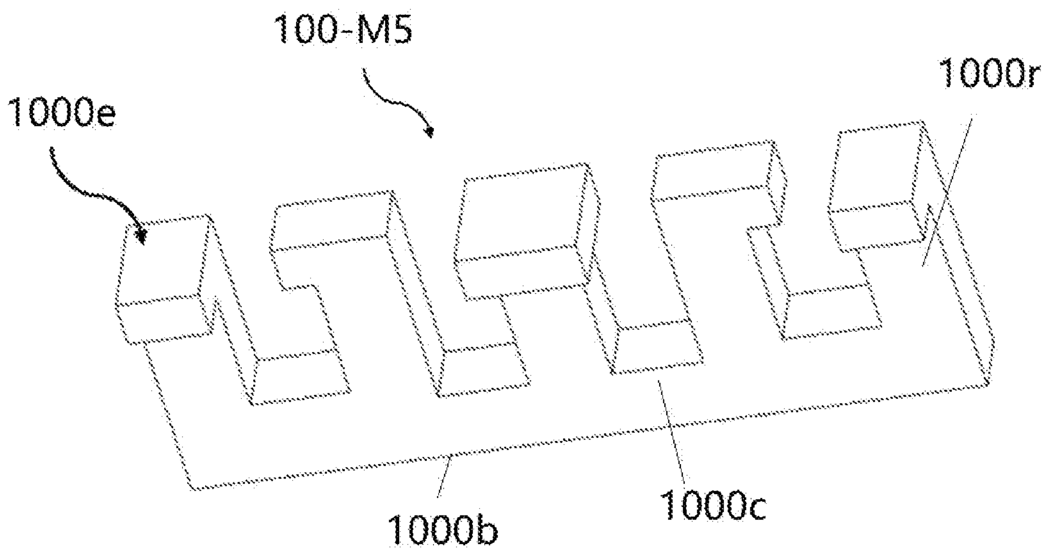
100-M5
1000e
1000r
1000b
1000c

FIG.15

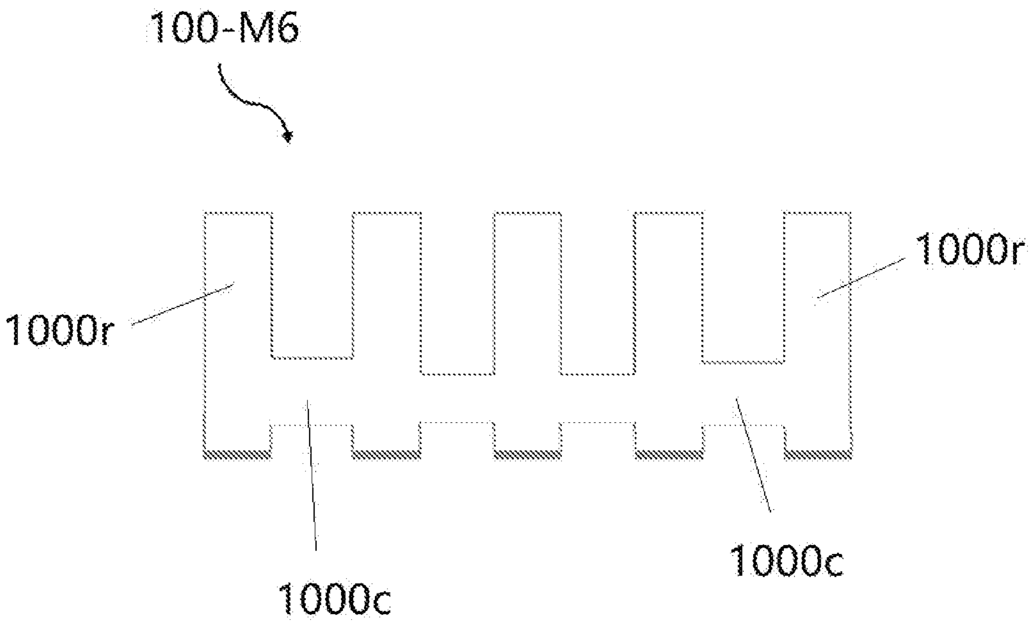
100-M6
1000r
1000r
1000c
1000c

FIG.16

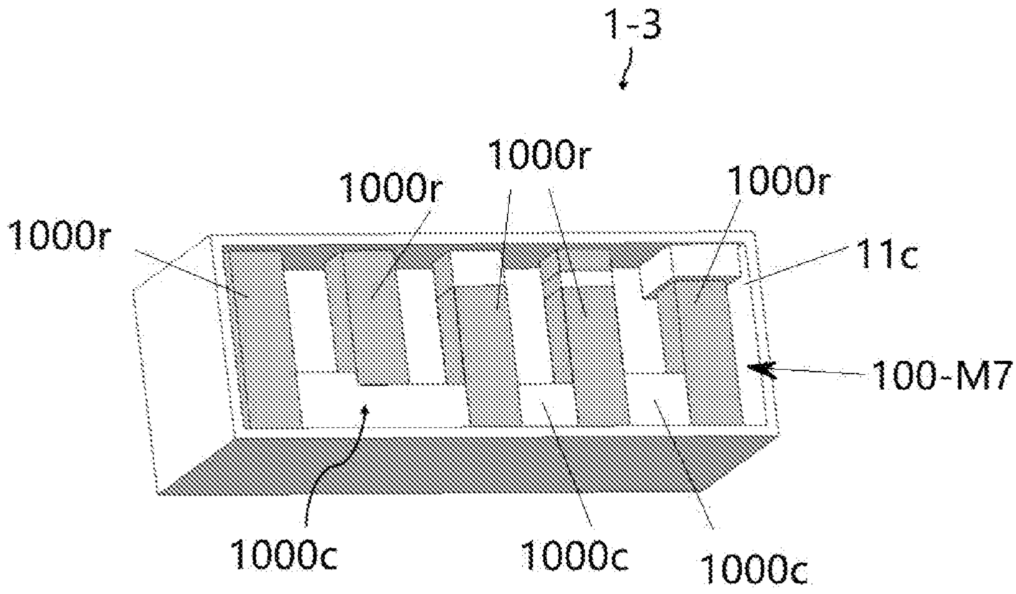
1-3
1000r
1000r
1000r
1000r
11c
100-M7
1000c
1000c
1000c

FIG.17

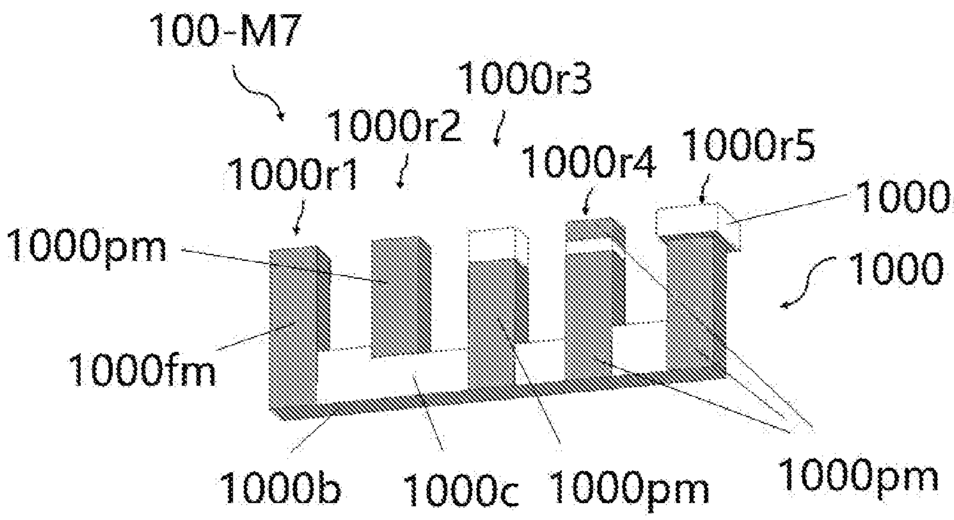
100-M7
1000r3
1000r2
1000r4
1000r5
1000r1
1000e
1000pm
1000
1000fm
1000b
1000c
1000pm
1000pm

FIG.18

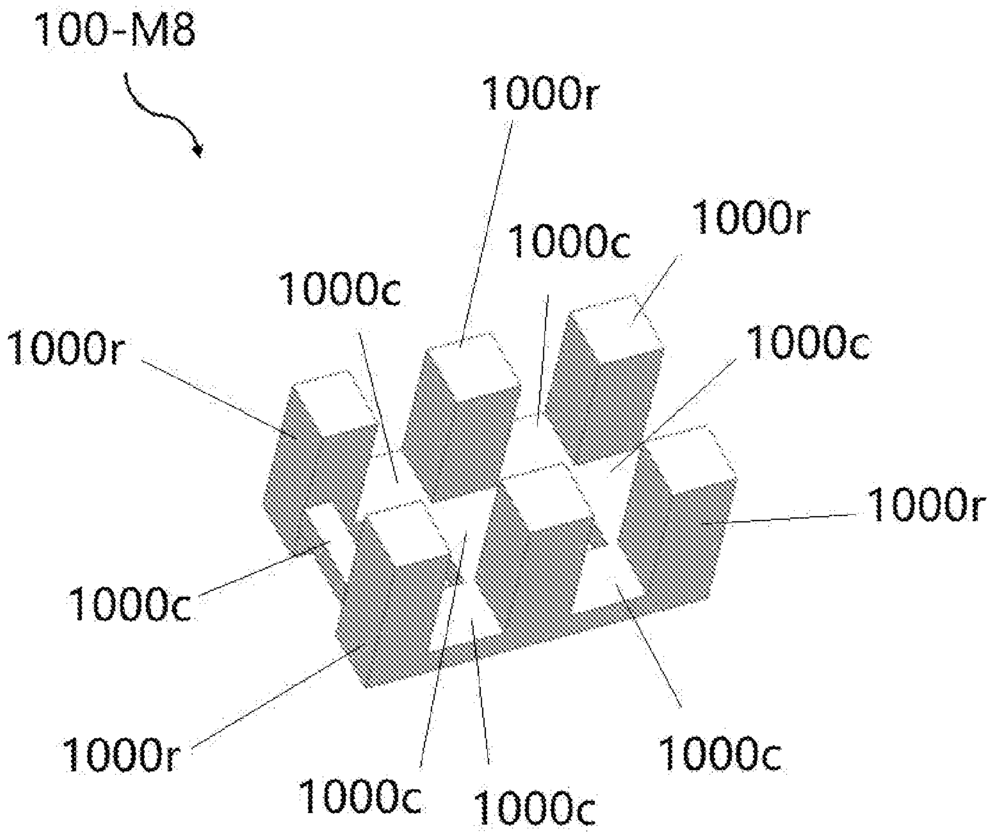
100-M8
1000r
1000c
1000r
1000c
1000r
1000c
1000r
1000c
1000r
1000c
1000c
1000c

FIG.19

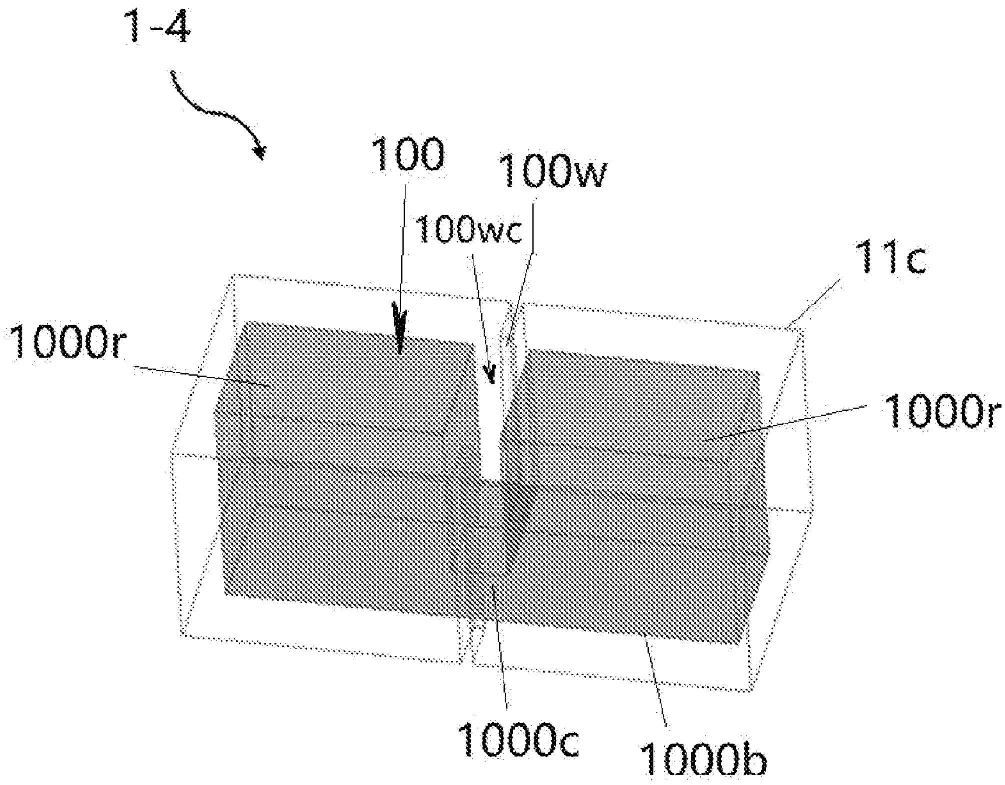

FIG.20

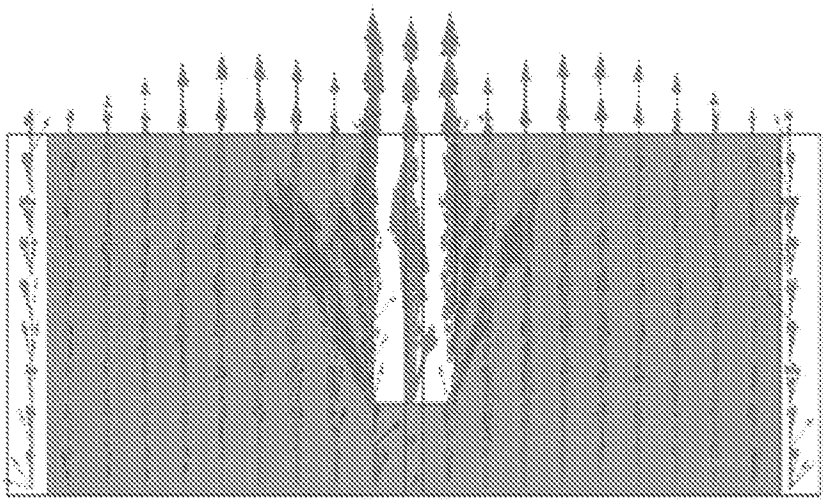

FIG.21A

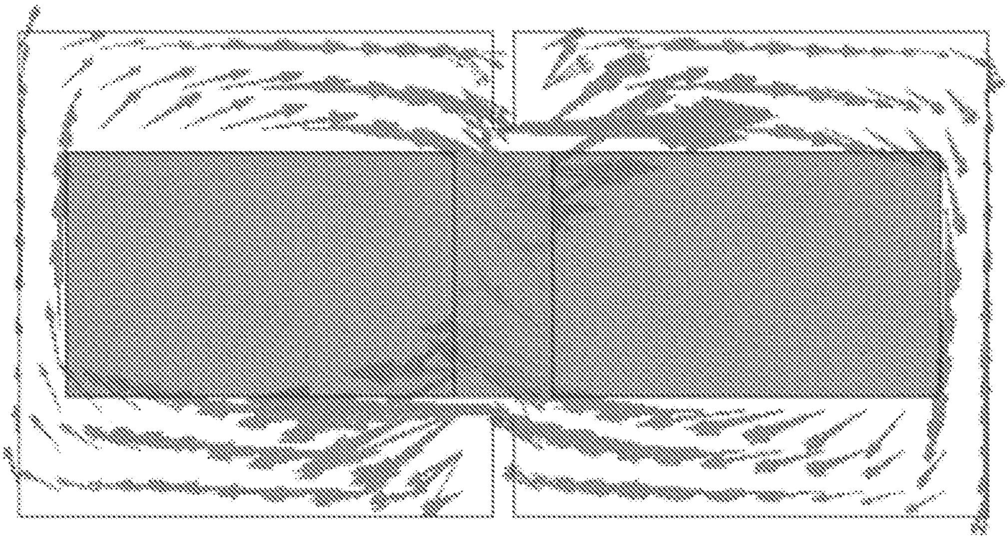

FIG.21B

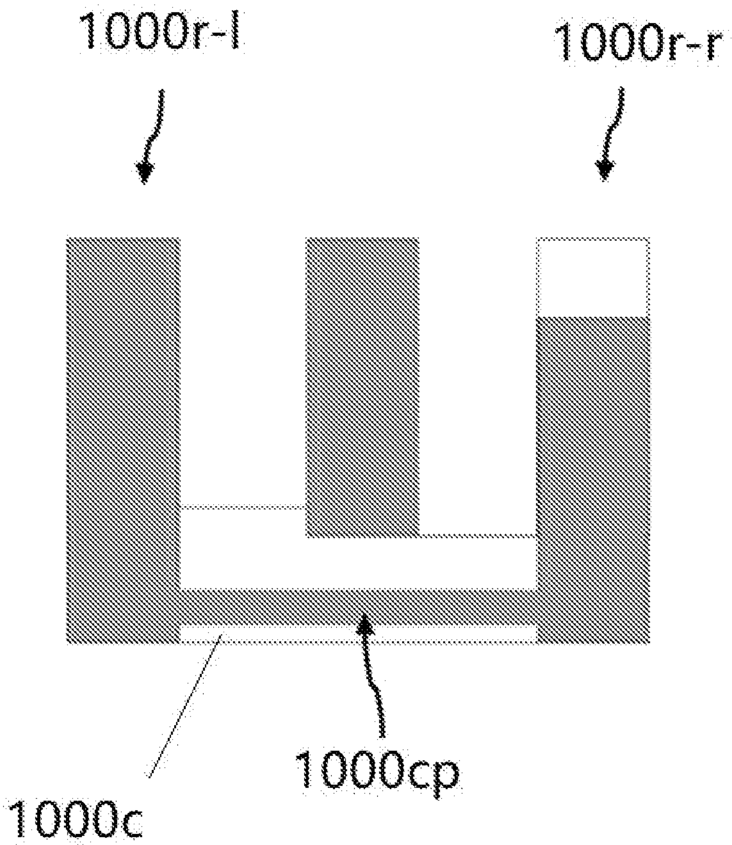

FIG.22A

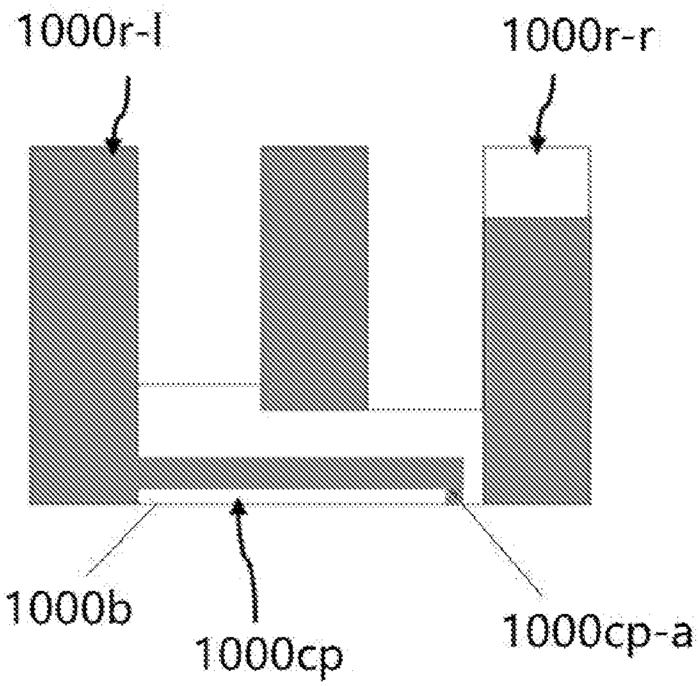

FIG.22B

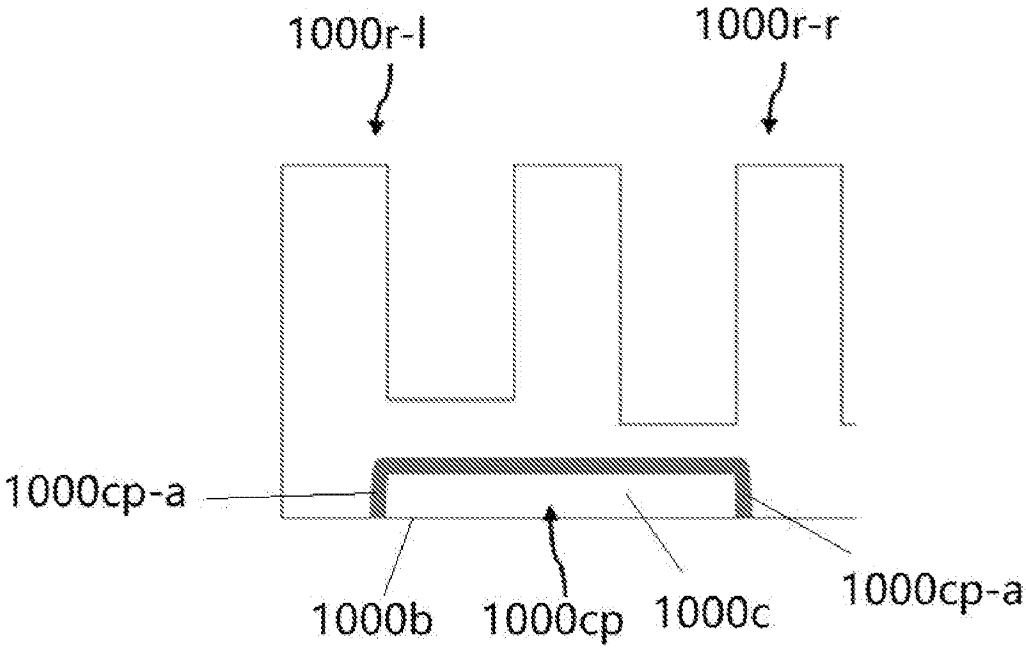

FIG.22C

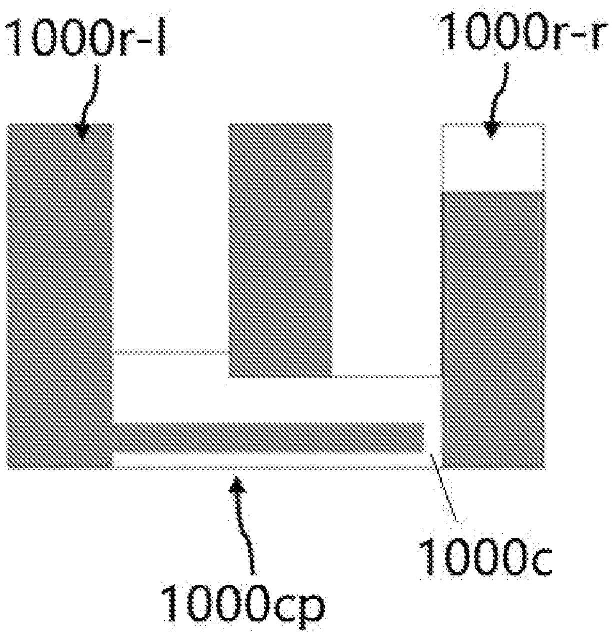

FIG.22D

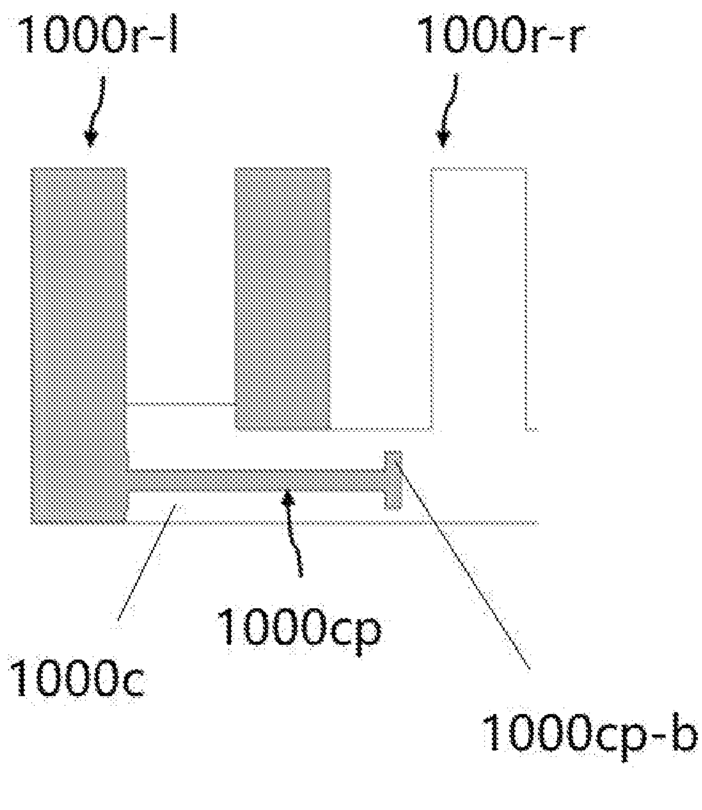

FIG.22E

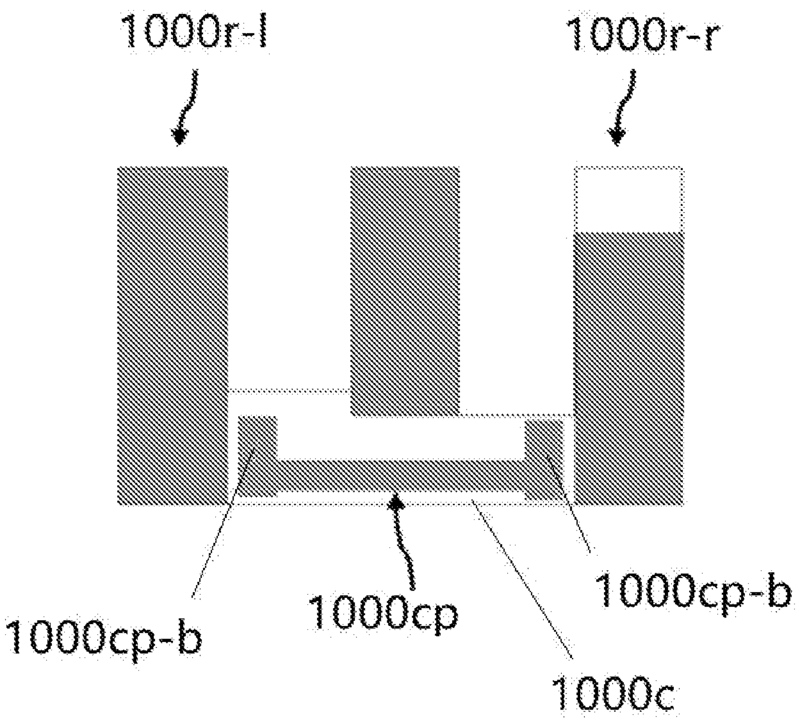

FIG.22F

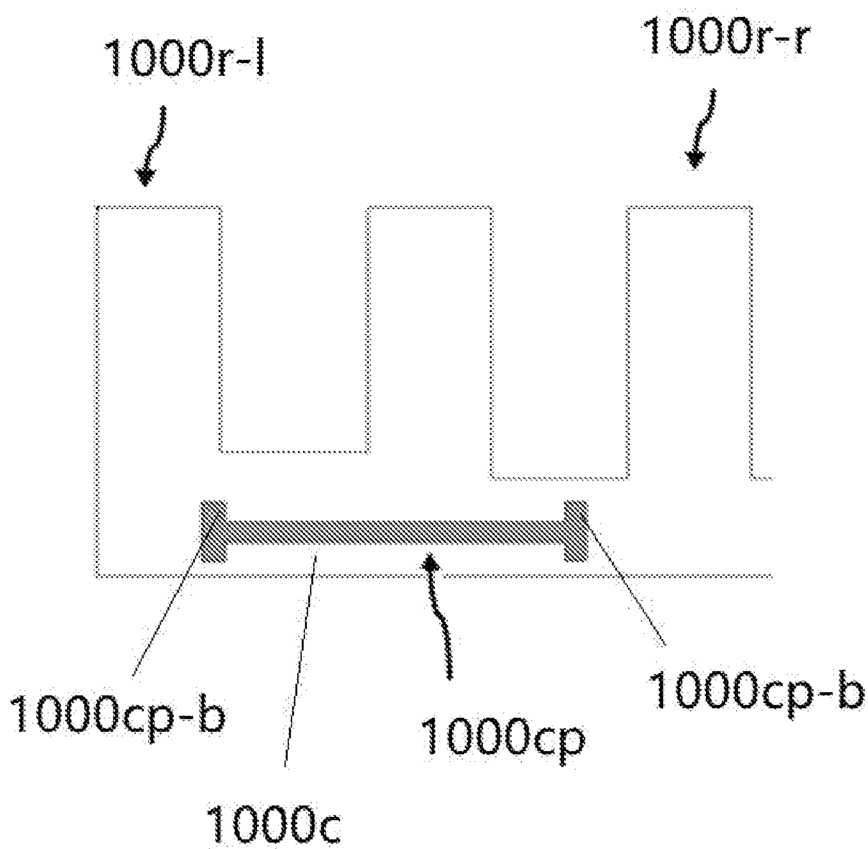

FIG.22G

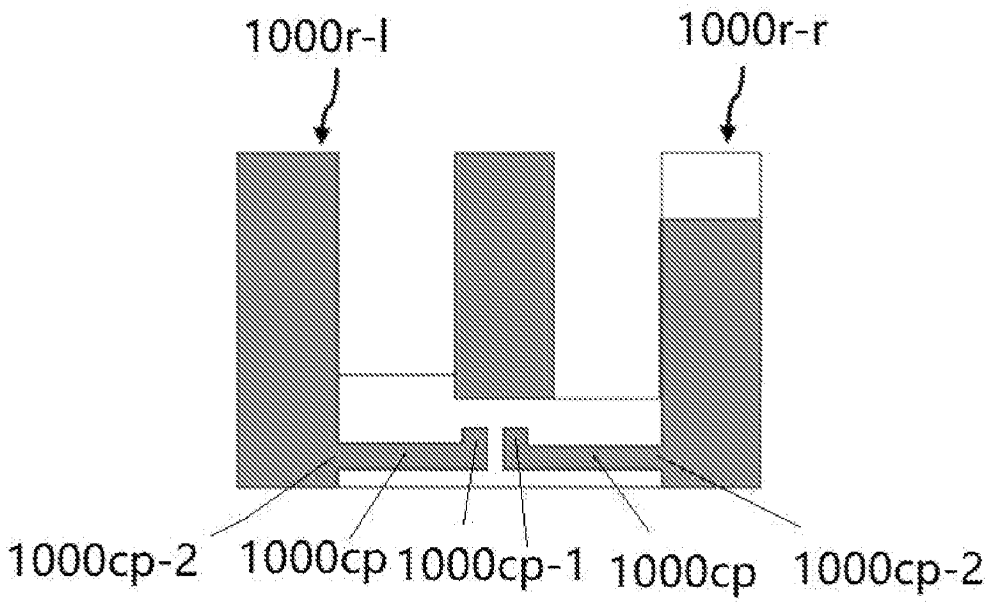

FIG.22H

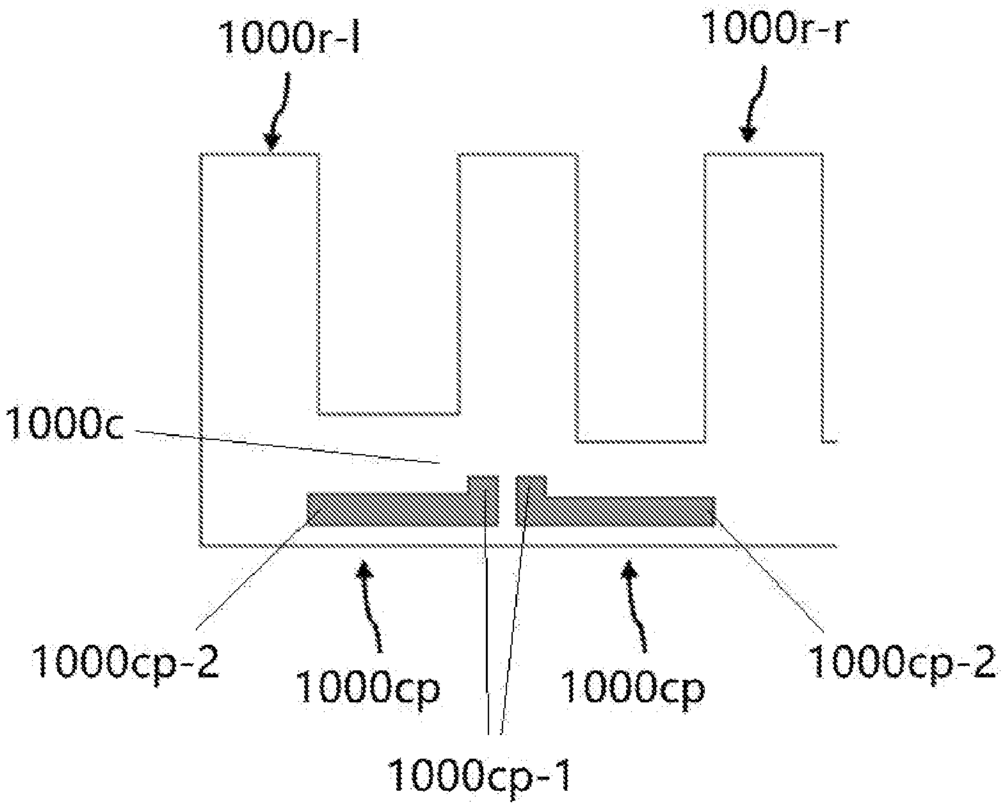

FIG.22I

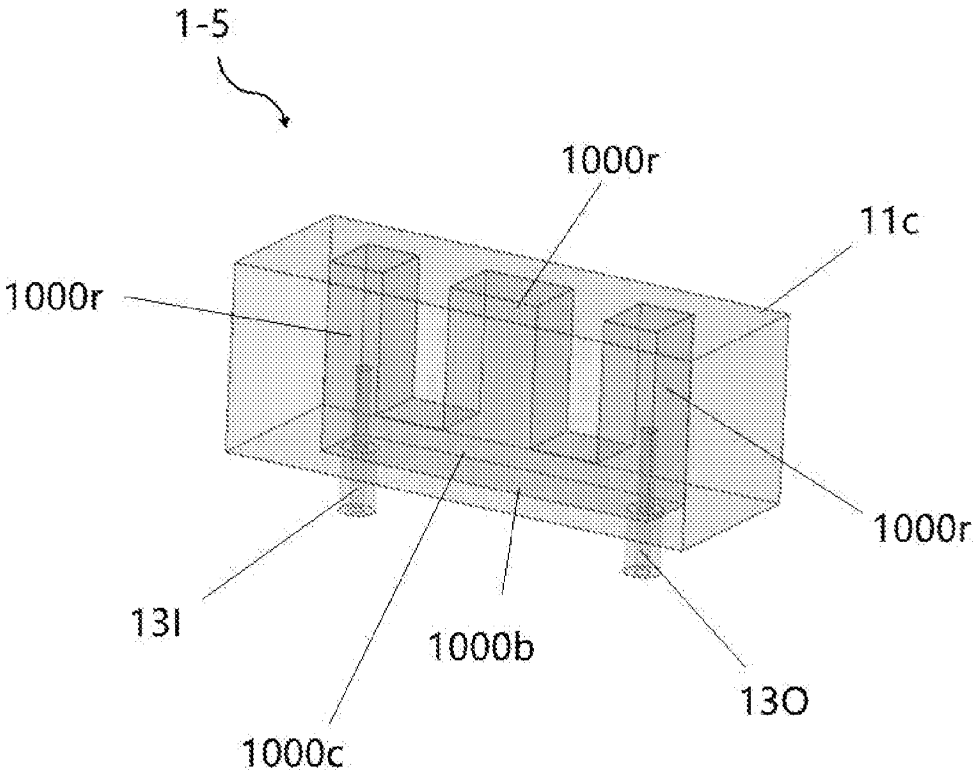
1-5
1000r
11c
1000r
1000r
13I
1000b
13O
1000c

FIG.23

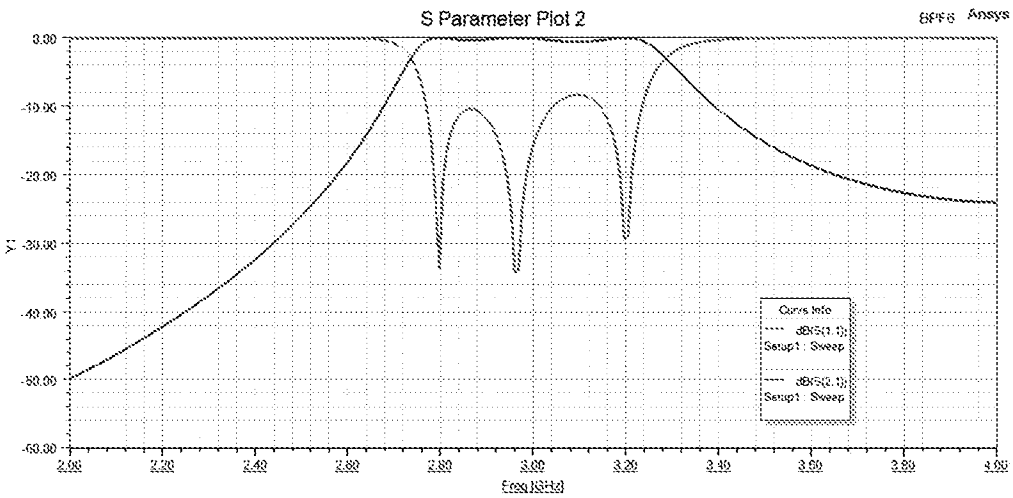
S Parameter Plot 2
Ansys
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
Y1
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
Freq [GHz]
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(2,1))
Setup1 : Sweep

FIG.24

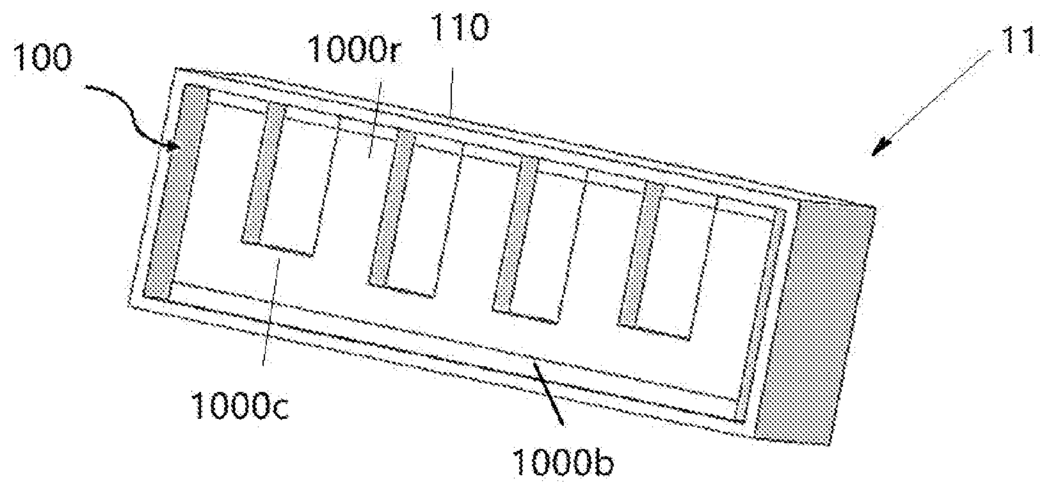

FIG.25

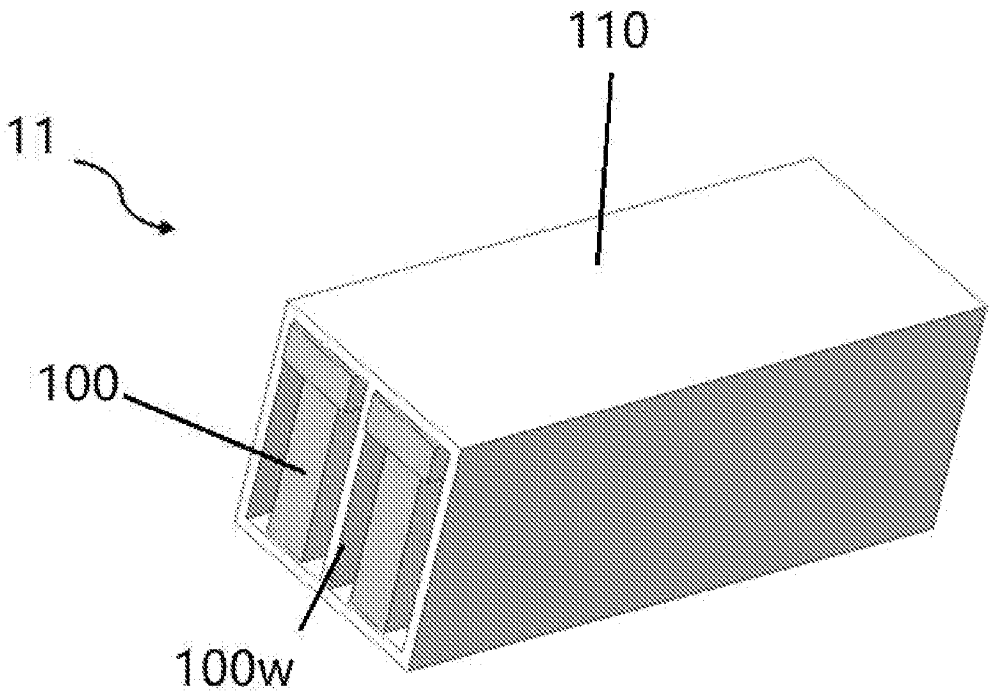

FIG.26

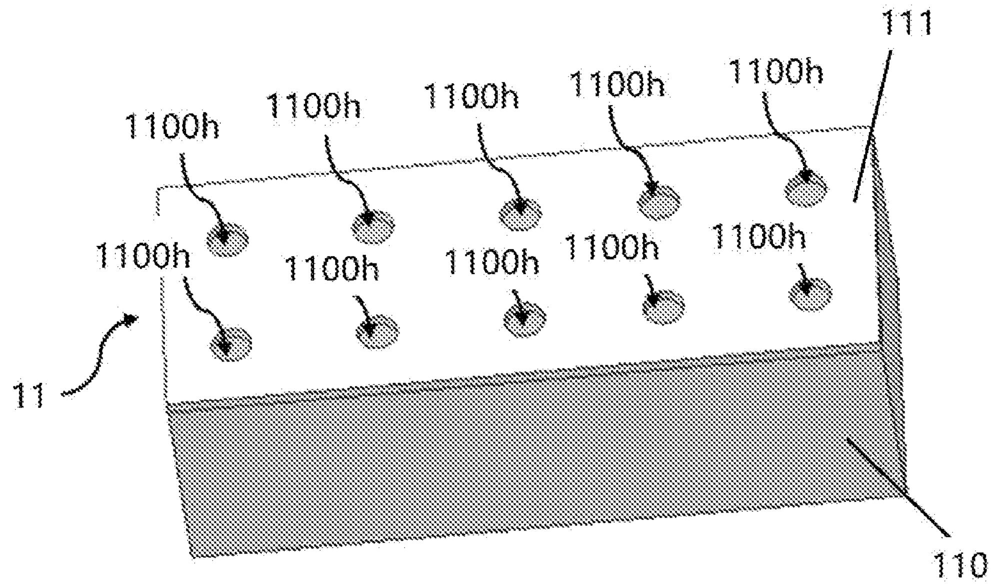
111
1100h
1100h
1100h
1100h
1100h
1100h
1100h
1100h
1100h
1100h
11
110

FIG.27

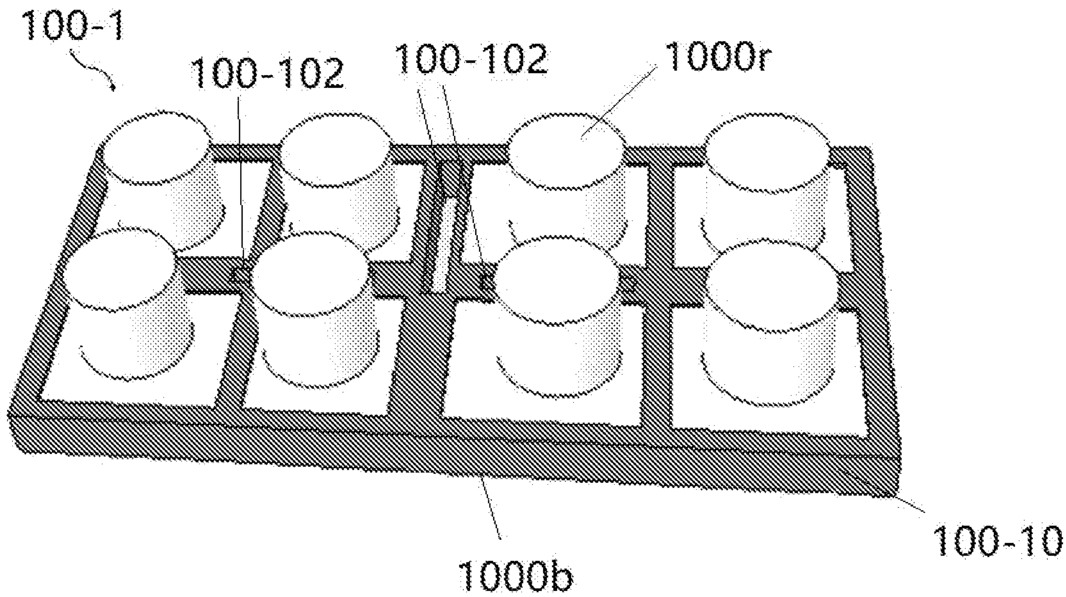
100-1
100-102
100-102
1000r
1000b
100-10

FIG.28

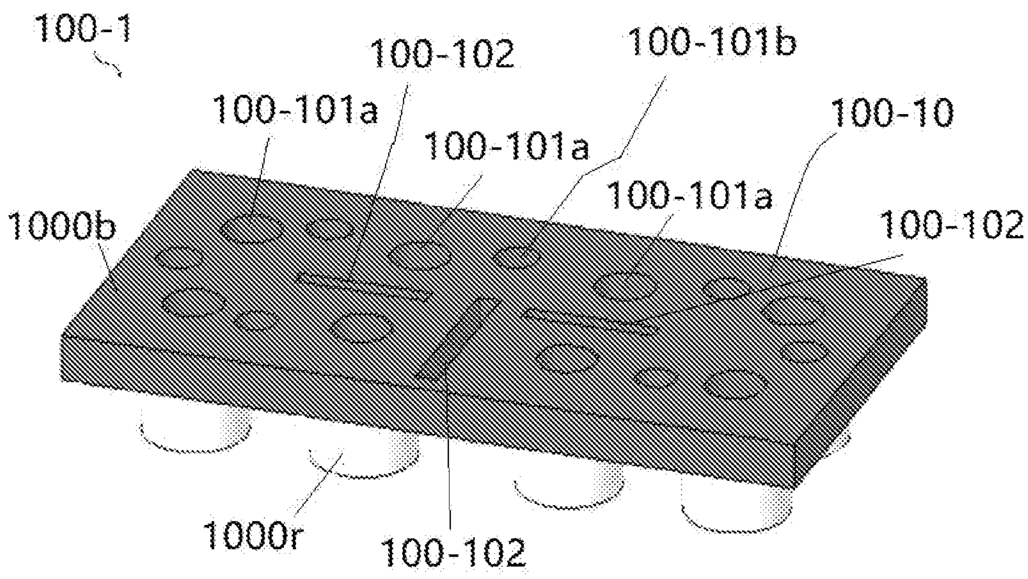
100-1
100-102
100-101b
100-101a
100-101a
100-10
100-101a
1000b
100-102
1000r
100-102

FIG.29

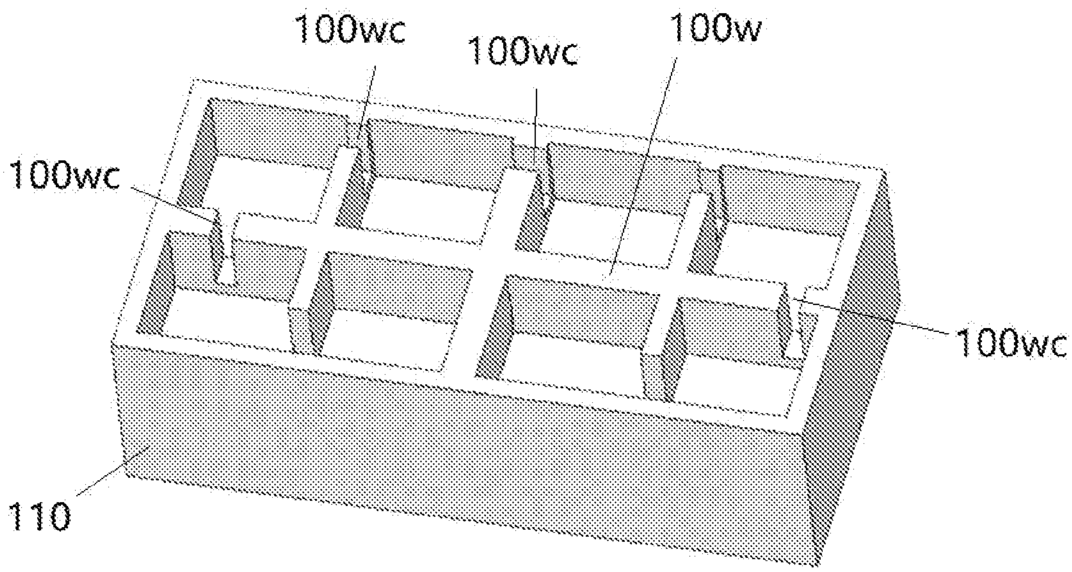
100wc
100wc
100w
100wc
100wc
110

FIG.30

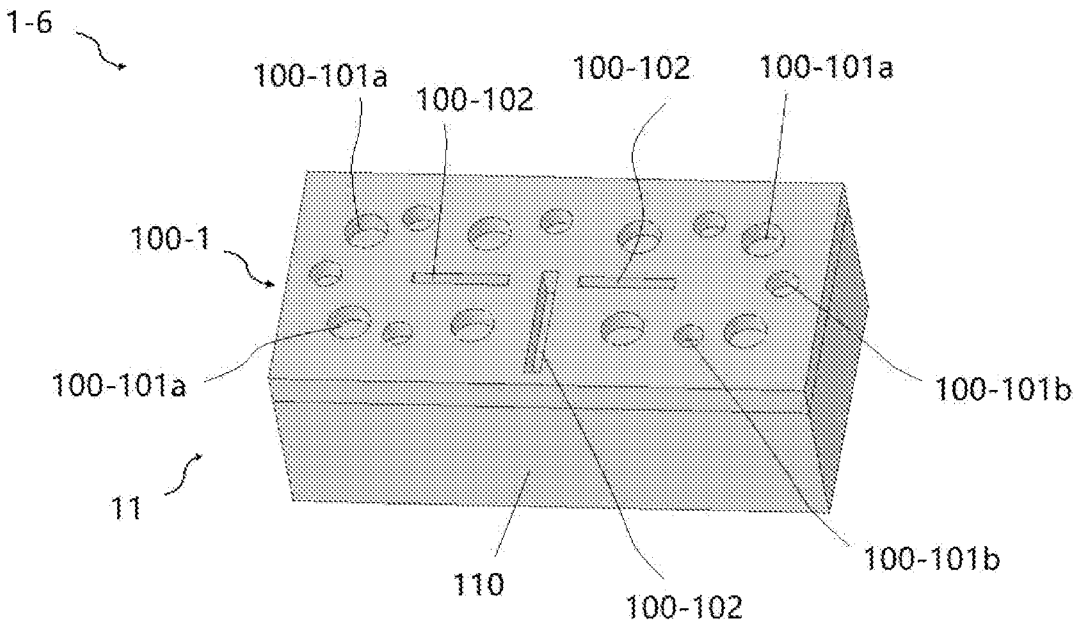
1-6
100-101a
100-102
100-102
100-101a
100-1
100-101a
100-101b
11
110
100-102
100-101b

FIG.31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/097089

A. CLASSIFICATION OF SUBJECT MATTER

H01P 1/207(2006.01)i; H03H 1/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H01P; H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN, CNABS, CNTXT, WOTXT, USTXT, CNKI, IEEE: resonator, filter, metal, antenna, comb-like, integrated forming, housing, transversal magnetic mode

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022190455 A1 (NOKIA SOLUTIONS AND NETWORKS OY) 16 June 2022 (2022-06-16) description, paragraphs [0047]-[0088] and figures 1-14B	1-32
A	CN 103022627 A (ZTE CORP.) 03 April 2013 (2013-04-03) the whole document	1-32
A	CN 109950672 A (HONGKONG FINGU DEV CO., LTD.) 28 June 2019 (2019-06-28) the whole document	1-32
A	CN 109643834 A (COMMSCOPE CO ITAL CO., LTD.) 16 April 2019 (2019-04-16) the whole document	1-32
A	US 2022336937 A1 (KUNSHAN LIXUN RF TECHNOLOGY CO., LTD.) 20 October 2022 (2022-10-20) the whole document	1-32

☐ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 August 2024	**12 August 2024**

Name and mailing address of the ISA/CN	Authorized officer
CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**WU,Qing** Telephone No. **(+86) 010-53961436**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/097089

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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