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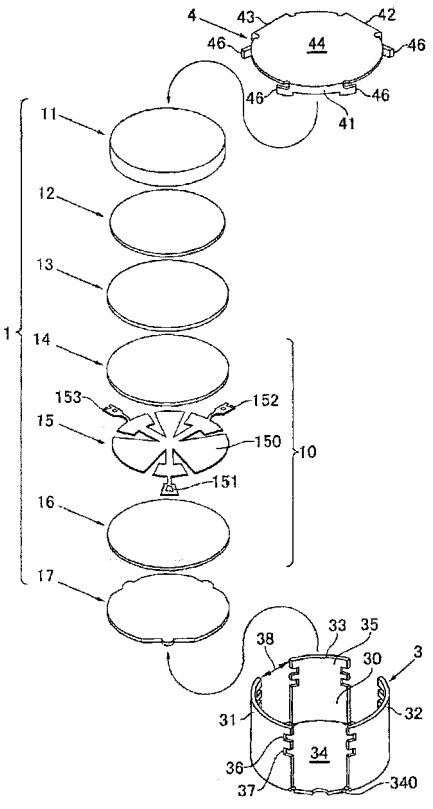
(54) Non-reciprocal circuit device, communication equipment using the same, and method for assembling the non-reciprocal circuit device

(57) A non-reciprocal circuit device includes a holder and a gyromagnetic component assembly (1). The holder includes a casing member (3) and a lid member (4). The casing member (3) has a bottom plate (34) and a plurality of side walls (31-33) spaced apart from each other and rising from a periphery of the bottom plate (34), each side wall (31-33) having a depression (36) in an edge opposed to another side wall in a direction of the periphery. The lid member (4) has a top plate (44) and a plurality of side walls (41-43) spaced apart from each other and hanging from a periphery of the top plate (44), each side wall (41-43) having a projection (46) on an edge opposed to another side wall in a direction of the periphery. The lid member (4) is coupled to the casing member (3) with the projection (46) fitted in the depression (36). The gyromagnetic component assembly (1) is housed in the holder between the top plate (44) and the bottom plate (34). When the projection (46) is fitted in the depression (36), a top plate-side end face (461) of the projection (46) is at least partially pressed against an opposing inner face (361) of the depression (36) while a bottom plate-side end face (462) of the projection (46) is spaced apart from an opposing inner face (362) of the depression (36).

FIG.2



EP 1 848 059 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a non-reciprocal circuit device, a communication equipment using the same, and a method for assembling the non-reciprocal circuit device.

2. Description of the Related Art

[0002] Recently, non-reciprocal circuit devices for mobile communications have been rapidly developed to have higher frequency from 2 GHz to 5 GHz. Generally, direct-current magnetic field to be applied to a gyromagnetic component decreases with increasing frequency, which reduces the size of a gyromagnetic component assembly including a permanent magnet, a magnetic pole plate, and the gyromagnetic component and also simplifies the structure of a holder housing the gyromagnetic component assembly.

[0003] However, there is naturally a limit to such simplification. In non-reciprocal circuit devices of this type, for example, if the gyromagnetic component assembly is housed in a holder formed by mechanically coupling a casing member and a lid member, insufficient coupling strength between the casing member and the lid member immediately results in that the housed gyromagnetic component assembly will be off-balance to decrease the reproducibility of non-reciprocal circuit characteristics.

[0004] Insufficient coupling strength between the casing member and the lid member also presents reliability problems of non-reciprocal circuit devices, such as frequent falling off of the lid member.

[0005] If a complicated fitting mechanism is adopted to ensure sufficient coupling strength between the casing member and the lid member, on the other hand, the complicated fitting mechanism increases the number of processing steps, which leads to higher cost, and also increases the number of assembling steps, which reduces assembling yield.

[0006] Additionally, as the number of assembling steps for the holder increases, the possibility of reducing non-reciprocal circuit characteristics increases accordingly. For example, the gyromagnetic component assembly is usually housed in the casing member prior to the step of assembling the lid member to the casing member. If it takes a long time to assemble the lid member, accordingly, there is a high possibility that the gyromagnetic component assembly housed in the casing member will be displaced during that time to reduce non-reciprocal circuit characteristics. Particularly, considering that the gyromagnetic component assembly has to be reduced in size and weight with increase in frequency, the problem of characteristic degradation due to such displacement is important.

[0007] For a conventional non-reciprocal circuit device of this type, for instance, US Patent No. 6,337,607 B1 discloses a holder whose lid member, which is to be coupled to a casing member, has a saucer-like curved top plate. This curved top plate protrudes into a housing space, making the distance between a bottom plate of the casing member and the curved top plate smaller than the thickness of a gyromagnetic component assembly. With this configuration, when housed in the holder, the gyromagnetic component assembly can be pressed toward the bottom plate of the casing member by springback of the curved top plate.

[0008] However, since the springback effect of the curved top plate disclosed in US Patent No. 6,337,607 B1 is liable to vary, there is a problem with reproducibility and reliability of non-reciprocal circuit characteristics. In addition, since the distance between the bottom plate of the casing member and the curved top plate is not variable, the lid member cannot follow a change in thickness of the gyromagnetic component assembly. In the non-reciprocal circuit device of this type, more specifically, the thickness of the gyromagnetic component assembly may change for different products in accordance with their desired non-reciprocal circuit characteristics. The holder disclosed in US Patent No. 6,337,607 B1 cannot follow such a change in thickness of the gyromagnetic component assembly, and therefore, a variety of holders of different thicknesses are required for different products, leading to higher cost. The curved top plate is also disadvantageous in reducing the height.

[0009] On the other hand, US Patent No. 6,504,445 B1 discloses a holder whose casing member has flare slots, wherein engaging teeth of a lid member engage the flare slots for coupling the casing member and the lid member.

[0010] However, under the actual environment where the non-reciprocal circuit device is subjected to vibration and heat, the holder disclosed in US Patent No. 6,504,445 B1 cannot ensure sufficient coupling strength between them for a long period of time. Moreover, since the engaging teeth of the lid member are fitted in the flare slots of the casing member in a rotary manner, there is an extremely high possibility that the gyromagnetic component assembly inside the casing member will contact the rotating lid member during the assembly of the lid member, causing the problem of displacement.

SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to provide a non-reciprocal circuit device which can improve non-reciprocal circuit characteristics and reliability with a holder for housing a gyromagnetic component assembly provided with a firm mechanical coupling, a communication equipment using the same, and a method for assembling the non-reciprocal circuit device.

[0012] It is another object of the present invention to provide a non-reciprocal circuit device which can reduce

cost with a holder for housing a gyromagnetic component assembly configured to be able to follow a change in thickness of the gyromagnetic component assembly, a communication equipment using the same, and a method for assembling the non-reciprocal circuit device.

[0013] It is still another object of the present invention to provide a non-reciprocal circuit device which can reduce cost while improving assembling yield, a communication equipment using the same, and a method for assembling the non-reciprocal circuit device.

[0014] In order to achieve at least one of the above objects, the present invention provides a non-reciprocal circuit device comprising a holder and a gyromagnetic component assembly.

[0015] The holder includes a casing member and a lid member. The casing member has a bottom plate and a plurality of side walls spaced apart from each other and rising from a periphery of the bottom plate, each side wall having a depression in an edge opposed to another side wall in a direction of the periphery. The lid member has a top plate and a plurality of side walls spaced apart from each other and hanging from a periphery of the top plate, each side wall having a projection on an edge opposed to another side wall in a direction of the periphery. The lid member is coupled to the casing member with the projection fitted in the depression. The gyromagnetic component assembly is housed in the holder between the top plate and the bottom plate.

[0016] One feature of the non-reciprocal circuit device according to the present invention resides in that the holder for housing the gyromagnetic component assembly has an improved structure. In the holder of the non-reciprocal circuit device according to the present invention, more specifically, when the projection is fitted in the depression, a top plate-side end face of the projection is at least partially pressed against an opposing inner face of the depression. With this configuration, sufficient mechanical coupling strength can be ensured between the lid member and the casing member to maintain the gyromagnetic component assembly between the top plate and the bottom plate.

[0017] Moreover, since the top plate-side end face of the projection is at least partially pressed against the opposing inner face of the depression, the contact of the lid member with the casing member can be improved. Thus, when the holder is used as a yoke, the electrical connection between the lid member and the casing member has an improved reliability.

[0018] When the projection is fitted in the depression, on the other hand, a bottom plate-side end face of the projection is spaced apart from an opposing inner face of the depression. From this description, it is apparent that the lid member is pressed by the gyromagnetic component assembly housed in the holder. Here, since the lid member is firmly coupled with the casing member, the gyromagnetic component assembly can be repulsively pressed by using the pressure applied from the gyromagnetic component assembly, thereby eliminating gaps between components constituting the gyromagnetic component assembly to improve the reproducibility of intended non-reciprocal circuit characteristics. Furthermore, applying a pressure to the gyromagnetic component assembly results in stabilizing the position of the gyromagnetic component assembly inside the holder, reducing the variance of characteristics.

[0019] In the non-reciprocal circuit device according to the present invention, each side wall of the casing member may have a plurality of depressions spaced apart in a thickness direction of the non-reciprocal circuit device (along which the side walls rise from the bottom plate). With this configuration, the thickness and capacity of the holder can be adjusted by selecting one of the depressions for fitting of the projection. This means that a single holder is applicable to a variety of gyromagnetic component assemblies of different thicknesses, improving the usability of components.

[0020] In the non-reciprocal circuit device according to the present invention, furthermore, each side wall of the lid member may have a plurality of projections spaced apart in the thickness direction and fitted in the plurality of depressions, respectively. This enhances the coupling strength between the lid member and the casing member of the holder and also keeps constant the pressure from the lid member to the gyromagnetic component assembly to improve non-reciprocal circuit characteristics.

[0021] In a method for assembling the non-reciprocal circuit device according to the present invention, after the lid member is positioned with respect to the casing member, the projection is fitted in the depression for mechanical coupling between the lid member and the casing member.

[0022] This assembling method secures all the advantages of the non-reciprocal circuit device according to the present invention and also avoids the problem that the gyromagnetic component assembly housed in the holder would be displaced during the assembly. Thus, the reproducibility of non-reciprocal circuit characteristics can be improved to prevent the variance among products.

[0023] According to the present invention, as has been described above, a non-reciprocal circuit device, a communication equipment using the same, and a method for assembling the non-reciprocal circuit device have at least one of the following advantages:

(1) Non-reciprocal circuit characteristics and reliability can be improved with a holder for housing a gyromagnetic component assembly provided with a firm mechanical coupling:
(2) Cost can be reduced with a holder for housing a gyromagnetic component assembly configured to be able to follow a change in thickness of the gyromagnetic component assembly; and
(3) Cost can be reduced while improving assembling yield.

[0024] The present invention will be more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

Fig. 1 is a perspective view of a non-reciprocal circuit device according to one embodiment of the present invention;
Fig. 2 is an exploded perspective view showing the internal structure of the non-reciprocal circuit device shown in Fig. 1;
Fig. 3 is a sectional view schematically showing the internal structure of the non-reciprocal circuit device shown in Fig. 1;
Fig. 4 is an enlarged view showing a part of the non-reciprocal circuit device shown in Fig. 1;
Fig. 5 is a perspective view showing another coupling state of the non-reciprocal circuit device shown in Fig. 1;
Fig. 6 is an enlarged view showing a part of the non-reciprocal circuit device shown in Fig. 5;
Fig. 7 is a sectional view schematically showing the internal structure of the non-reciprocal circuit device shown in Fig. 5;
Fig. 8 is a plan view for illustrating a method for assembling a non-reciprocal circuit device according to one embodiment of the present invention;
Fig. 9 is a perspective view for illustrating a step after the step illustrated with Fig. 8;
Fig. 10 is an enlarged front view showing a part of a lid member obtained at the step illustrated with Fig. 9;
Fig. 11 is a plan view for illustrating a step after the steps illustrated with Figs. 8 to 10;
Fig. 12 is a perspective view for illustrating a step after the step illustrated with Fig. 11;
Fig. 13 is a plan view for illustrating a step after the steps illustrated with Figs. 8 to 12;
Fig. 14 is a partially enlarged view for illustrating a step after the step illustrated with Fig. 13;
Fig. 15 is a plan view for illustrating the step illustrated with Fig. 14;
Fig. 16 is a front view for illustrating a step after the step illustrated with Figs. 14 and 15;
Fig. 17 is a plan view for illustrating the step illustrated with Fig. 16;
Fig. 18 is a plan view for illustrating a step after the step illustrated with Figs. 16 and 17;
Fig. 19 is a perspective view of a non-reciprocal circuit device according to another embodiment of the present invention;
Fig. 20 is a perspective view of a lid member for the non-reciprocal circuit, device shown in Fig. 19;
Fig. 21 is an enlarged view showing a part of the non-reciprocal circuit device shown in Fig. 19;
Fig. 22 is an enlarged view showing a part of a non-reciprocal circuit device according to still another embodiment of the present invention;
Fig. 23 is an enlarged view showing a part of a non-reciprocal circuit device according to still another embodiment of the present invention;
Fig. 24 is a sectional view schematically showing the structure of a communication equipment according to one embodiment of the present invention;
Fig. 25 is a sectional view schematically showing the structure of a communication equipment according to another embodiment of the present invention; and
Fig. 26 is a block diagram illustrating a communication equipment according to still another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Figs. 1 to 4 illustrate a non-reciprocal circuit device including a gyromagnetic component assembly 1, for example, such as a distributed parameter type circulator which may be used in mobile communication equipments (e.g., cellular phones and radios) and communication equipments for their base stations. The gyromagnetic component assembly 1 has a permanent magnet 11, a shield 12, an upper magnetic pole plate 13, a gyromagnetic component 10, and a lower magnetic pole plate 17, which are stacked in the mentioned order and integrated together preferably through a conductive adhesive (not shown). Hereinbelow the individual components of the gyromagnetic component assembly 1 will be described in detail.

[0027] The shield 12 may be formed of a conductor plate punched out from a copper plate having a thickness of approximately 0.1 to 0.2 mm and used for strengthening and stabilization of a ground electrode. The shield 12 illustrated in Figs. 1 to 3 has a discoid shape whose diameter is several-ten mm, approximately as large as the lower surface of the permanent magnet 11.

[0028] The permanent magnet 11 has a cylindrical shape whose diameter is several-ten mm and is laid on the shield 12 to apply a magnetic field to the gyromagnetic component 10 beneath the shield 12.

[0029] The upper magnetic pole plate 13 may be formed of a conductor plate punched out from an iron plate having a thickness of approximately 0.1 to 0.3 mm and has a discoid shape whose diameter is several-ten mm. The lower magnetic pole plate 17 may be formed of a conductor plate punched out from an iron plate having a thickness of approximately 0.3 to 1.0 mm and has a discoid shape whose diameter is several-ten mm. The upper magnetic pole plate 13 and the lower magnetic pole plate 17 are used for homogenization and stabilization of a direct-current magnetic field.

[0030] The gyromagnetic component 10 further includes an upper ferrite substrate 14, a central conductor

15 and a lower ferrite substrate 16, which are stacked in the mentioned order and integrated together preferably through a conductive adhesive (not shown).

[0031] The upper ferrite substrate 14 is preferably formed of a soft. magnetic material such as yttrium/iron/garnet (YIG) into a discoid shape having a diameter of several-ten mm and a thickness of approximately 1.0 mm. The lower ferrite substrate 16 is preferably formed of a soft magnetic material such as yttrium/iron/garnet (YIG) into a discoid shape having a diameter of several-ten mm and a thickness of approximately 1.0 mm.

[0032] The central conductor 15 is preferably a conductor plate obtained by processing a copper plate having a thickness of approximately 0.3 to 1.0 mm and has a base body portion 150 and first to third lead terminals 151 to 153 protruding from an outer periphery of the base body portion 150. The base body portion 150 is formed into a circular shape having a diameter of several-ten mm, approximately as large as the plate surface of each of the upper ferrite substrate 14 and the lower ferrite substrate 16. The first to third lead terminals 151 to 153 protruding from the base body portion 150 are each bent in the vicinity of an upper surface edge of the lower ferrite substrate 16.

[0033] One feature of the non-reciprocal circuit device according to the present invention resides in that a holder for holding the gyromagnetic component assembly 1 has an improved structure. Concretely, a holder illustrated in Figs. 1 to 4 includes a casing member 3 and a lid member 4.

[0034] The casing member 3 is an approximately cylindrical bottom-closed member or a container like member which defines within a space 30 for housing the gyromagnetic component assembly 1. Here, the shape of the casing member 3 may vary depending on the shape of the gyromagnetic component assembly 1 to be housed therein, for example, into an approximately rectangular or polygonal tubular shape instead of the illustrated approximately cylindrical shape. In order to function as a yoke with respect to the gyromagnetic component assembly 1 housed in the housing space 30, moreover, the casing member 3 is preferably formed of a magnetic metal material such as iron.

[0035] The casing member 3 will be descried in detail below. The casing member 3 has the housing space 30 defined by a plurality of (e.g., three in the present embodiment) side walls 31 to 33 and a bottom plate 34. The side walls 31 to 33 are spaced apart from each other and rise from the periphery of the bottom plate 34 in a thickness direction H, wherein an open end face 35 is defined by the upper end edges of the side walls 31 to 33.

[0036] The side walls 31 to 33 are each provided with first and second depressions 36, 37 in both side edges opposed to another side wall in a peripheral or lateral direction perpendicular to the thickness direction H.

[0037] The first depression 36 has an opening in the side edge and is preferably in the form of a cut passing through each side wall 31 to 33 from the outer surface to the inner surface. In this cut-out shape, inner faces 361, 362 opposing each other in the thickness direction H each extend perpendicular to the thickness direction H. It should be noted that the first depression 36 is not necessarily required to pass through the side wall but may have a bottom on either of the inner and outer surfaces.

[0038] In addition, the first depression 36 is spaced a distance T1 apart from the open end face 35 in the thickness direction H. That is, on the side of the inner face 361 of the first depression 36, there is secured a strip for the distance T1. Between the adjacent side walls 31 to 33, preferably, each first depression 36 is located at the same level as another opposing first depression 36 with respect to the thickness direction H.

[0039] The second depression 37 may have the same configuration as the first depression 36. To describe it briefly, the second depression 37 has an opening in the side edge and is in the form of a cut passing through each side wall 31 to 33 from the outer surface to the inner surface. In this cut-out shape, inner faces 371, 372 opposing each other in the thickness direction H each extend perpendicular to the thickness direction H.

[0040] In addition, the second depression 37 is spaced a distance T1 apart from the inner face 362 of the first depression 36 in the thickness direction H. That is, on the side of the inner face 371 of the second depression 37, a strip for the distance T1 is secured between the inner faces 371, 362. Between the adjacent side walls 31 to 33, preferably, each second depression 37 is located at the same level as another opposing second depression 37 with respect to the thickness direction H.

[0041] Between the adjacent side walls 31 to 33, the side edges opposing each other in the peripheral direction define an opening 38 through which a part (e.g., the first to third lead terminals 151 to 153) of the gyromagnetic component assembly 1 is to be led out of the housing space 30. In the opening 38, as illustrated in Figs. 1 and 2, the casing member 3 has a coupling protrusion 340 on the side of the bottom plate 34. Preferably, the coupling protrusion 340 is formed by extending the periphery of the bottom plate 34 to protrude outwardly (or radially) from the opening 38. The lower surface of the bottom plate 34 may be used as a mounting surface to be applied to a circuit board.

[0042] Meanwhile, the lid member 4 is an approximately cylindrical bottom-closed member or a container-like member and used as a lid for closing the housing space 30 in combination with the casing member 3. Here, because of its primary purpose, the shape of the lid member 4 may vary depending on the shape of the casing member 3, for example, into an approximately rectangular or polygonal tubular shape instead of the illustrated approximately cylindrical shape. In order to function as a yoke with respect to the gyromagnetic component assembly I along with the casing member 3, moreover, the lid member 4 is preferably formed of a magnetic metal material such as iron.

[0043] The lid member 4 will be descried in detail below. The lid member 4 has a plurality of (e.g., three in the present embodiment) side walls 41 to 43 and a top plate 44. The diameter and profile of the top plate 44 are determined to permit the top plate 44 to fit in the open end face 35 of the casing member 3. In short, the top plate 44 is shaped slightly smaller than the open end face 35. With this configuration, since the top plate 44 can be fitted in the open end face 35, the non-reciprocal circuit device can be reduced in height for the thickness of the top plate 44.

[0044] The side walls 41 to 43, which project from the periphery of the top plate 44 at spaced intervals, are folded outside the open end face 35 to hang down in the thickness direction H. Moreover, the side walls 41 to 43 are each provided with a projection 46 on both side edges opposed to another side wall in the peripheral direction. The projection 46 has end faces 461, 462 opposing each other in the thickness direction H and inclined toward the top plate 44. In other words, the projection 46 has a rising angle (or inclination) with respect to the first depression 36 or the second depression 37.

[0045] Referring to the non-reciprocal circuit device illustrated in Figs. 1 to 3, the lid member 4 is mechanically coupled with the casing member 3 to close the housing space 30 with the top plate 44 by fitting the projections 46 in the first depressions 36. That is, when the lid member 4 is coupled with the casing member 3, the holder provides the closed housing space 30 between the opposing surfaces of the top plate 44 and the bottom plate 34.

[0046] Referring further to Fig. 4, when the projection 46 is fitted in the first depression 36, the top plate 44-side end face 461 of the projection 46 is pressed against the opposing inner face 361 of the first depression 36. On the other hand, there is a gap G between the bottom plate 34-side end face 462 and the opposing inner face 362 of the first depression 36.

[0047] To the gyromagnetic component assembly 1 housed in the housing space 30, the top plate 44 applies a pressure toward the bottom plate 34 (or downward load).

[0048] As described above with reference to Figs. 1 to 4, the lid member 4 and the casing member 3 constituting the holder are coupled such that the end face 461 of the projection 46 and the inner face 361 of the first depression 36 are at least partially pressed against each other. With this configuration, sufficient mechanical coupling strength can be ensured for the holder to maintain the gyromagnetic component assembly 1 within the housing space 30.

[0049] In addition, since the end face 461 of the projection 46 and the opposing inner face 361 of the first depression 36 are pressed against each other, the contact of the lid member 4 with the casing member 3 can be improved. Thus, when the holder is used as a yoke, the electrical connection between the lid member 4 and the casing member 3 has an improved reliability

[0050] When the projection 46 is fitted in the first depression 36, on the other hand, there is the gap G between the end face 462 of the projection 46 and the opposing inner face 362 of the first depression 36. From this description, it is apparent that the top plate 44 of the lid member 4 is pressed by the gyromagnetic component assembly 1 housed in the housing space 30. Here, since the lid member 4 is firmly coupled with the casing member 3, the gyromagnetic component assembly 1 can be reactively (or repulsively) pressed downward by using the pressure applied from the gyromagnetic component assembly 1. Thus, the pressure applied from the top plate 44 toward the bottom plate 34 eliminates gaps between components constituting the gyromagnetic component assembly 1 to improve the reproducibility of intended non-reciprocal circuit characteristics. Furthermore, applying the pressure to the gyromagnetic component assembly 1 results in stabilizing the position of the gyromagnetic component assembly 1 inside the housing space 30, reducing the variance of characteristics.

[0051] When the projection 46 is fitted in the first depression 36, the strip for the distance T1 is left on the side of the inner face 361. With this configuration, the foregoing pressure from the gyromagnetic component assembly 1 can be supported by the strip for the distance T1. This avoids the problem that the first depression 36 would be deformed by the pressure from the lid member 1, thereby enhancing the mechanical coupling strength of the holder.

[0052] Between the adjacent side walls 31 to 33, as set forth above, each first depression 36 is preferably located at the same level as another opposing first depression 36 with respect to the thickness direction H. With this configuration, the pressure from the gyromagnetic component assembly 1 can be uniformly dispersed through a plurality of the first depressions 36, and in turn, a uniform pressure can be applied to the gyromagnetic component assembly 1.

[0053] Although not illustrated in Figs. 1 to 4, the second depression 37 may also be used for fitting with the projection 46 in the same manner as the first depression 36. Therefore, a fitting mechanism with the use of the second depression 37 and its advantages will be further described with reference to Figs.5 to 7. In Figs. 5 to 7, the components similar to those illustrated in Figs. 1 to 4 will be denoted by the same reference symbols.

[0054] Figs. 5 to 7 illustrate a non-reciprocal circuit device whose feature resides in that in the holder, the projection 46 of the lid member 4 is fitted in the second depression 37.

[0055] As set forth above, the second depression 37 is spaced a distance T1 apart from the inner face 362 of the first depression 36 in the thickness direction H. That is, on the side of the inner face 371 of the second depression 37, a strip for the distance T1 is secured between the inner faces 371, 362. With this configuration, the pressure from the gyromagnetic component assembly 1 can be supported by the strip for the distance T1,

which avoids the problem that the second depression 37 would be deformed by the pressure from the lid member 4.

[0056] In the non-reciprocal circuit device illustrated in Figs. 1 to 7, since the first and second depressions 36, 37 are formed in the casing member 3 of the holder, as set forth above, the thickness and capacity of the holding space 30 can be adjusted by selecting one of the first and second depressions 36, 37 for fitting of the projection 46 so as to follow a change in thickness of the gyromagnetic component assembly 1.

[0057] As an embodiment where the gyromagnetic component assembly 1 changes in thickness, for example, the upper magnetic pole plate 13 illustrated in Figs. 2 and 3 is omitted from the non-reciprocal circuit device illustrated in Figs. 5 to 7 to reduce the height of the gyromagnetic component assembly 1 for the upper magnetic pole plate 13. In case of omitting the upper magnetic pole plate 13, the degradation of non-reciprocal circuit characteristics can be avoided by replacing the permanent magnet 11 of the gyromagnetic component assembly 1 with a metal magnet of a conductive magnetic material.

[0058] Also when the permanent magnet 11 is replaced with a ferrite magnet or increased in size so as to apply a stronger magnetic field to the gyromagnetic component 10, the gyromagnetic component assembly 1 changes (increases or decreases) in thickness.

[0059] As set forth above, the thickness of the gyromagnetic component assembly 1 to be used for the non-reciprocal circuit device tends to change for different products in accordance with their desired non-reciprocal circuit characteristics. In this regard, conventional holders cannot follow a change in thickness of the gyromagnetic component assembly 1, and therefore, a variety of holders of different thicknesses are required for different products, which decreases the productivity and leads to higher cost.

[0060] In the non-reciprocal circuit device illustrated in Figs. 1 to 7, on the other hand, the thickness and capacity of the holding space 30 can he adjusted by selecting one of the first and second depressions 36, 37 for fitting of the projection 46 so as to follow a change in thickness of the gyromagnetic component assembly 1. This means that a single holder is applicable to a variety of gyromagnetic component assemblies 1 of different thicknesses, improving the usability of components.

[0061] Moreover, the pressure applied from the lid member 4 to the gyromagnetic component assembly 1 can be adjusted when the thickness and capacity of the holding space 30 is adjusted by selecting one of the first and second depressions 36, 37 for fitting of the projection 46.

[0062] The effects of the non-reciprocal circuit device according to the present invention will be further described from the viewpoint of an assembling method illustrated with Figs. 8 to 18. Figs. 8 to 18 are views for illustrating a method for assembling a non-reciprocal circuit device according to one embodiment of the present invention. In Figs. 8 to 18, the components similar to those illustrated in Figs. 1 to 7 will he denoted by the same reference symbols.

[0063] Prior to assembly of the non-reciprocal circuit device, at first, the lid member 4 (see Figs. 1 to 7) and the casing member 3 (see Figs. 1 to 7) of the holder are manufactured by a process illustrated with Figs. 8 to 10 and a process illustrated with Figs. 11 and 12, respectively.

[0064] In the lid member manufacturing process, after an assembly part, which is the lid member in a developed state as illustrated in Fig. 8, is punched out from a magnetic metal plate such as an iron plate having a thickness of approximately 0.5 to 1.5 mm, the side walls 41 to 43 extending from the top plate 44 are folded to hang down in the thickness direction H, such as by presswork, as illustrated in Figs. 9 and 10. As illustrated in Fig. 10, more specifically, the projection 46 extends upward with their opposing end faces 461, 462 in the thickness direction H being inclined in a tapered manner at a rising angle θ 1 toward the top plate 44. The rising angle θ 1 is preferably set in the range of 5 to 20 degrees and most preferably at approximately 15 degrees.

[0065] In the casing member manufacturing process, on the other hand, after an assembly part, which is the casing member 3 in a developed state as illustrated in Fig. 11, is punched out from a magnetic metal plate such as an iron plate having a thickness of approximately 0.5 to 1.5 mm, the side walls 31 to 33 extending from the bottom plate 34 are folded to rise up in the thickness direction H, such as by presswork, as illustrated in Fig. 12. As illustrated in Fig. 12, more specifically, the first depression 36 extends with their inner faces 361, 362 being in parallel with the peripheral direction perpendicular to the thickness direction H.

[0066] Next, as illustrated in Fig. 13, the lid member 4 and the casing member 3 obtained by the processes illustrated with Figs. 8 to 12 are arranged to oppose the inner surface of the top plate 44 to the inner surface of the bottom plate 34, and then, the top plate 44 is fitted in the open end face 35. Although omitted (indicated by alternate long and short dash lines) from the drawing, the gyromagnetic component assembly 1, which has been described hereinabove with reference to Figs. 1 to 4, is previously housed in the housing space 30 of the casing member 3.

[0067] Then, on the side of the outer periphery of the side walls 31 to 33, the projection 46 is positioned, for example, with respect to the first depression 36 with the top plate 44 being fitted in the open end face 35, as illustrated in Figs. 14 and 15. Moreover, the projection 46 is fitted in the first depression 36 from the side of the outer periphery of the side walls 31 to 33 by applying a pressure F 1 for bending deformation.

[0068] With the projection 46 fitted in the first depression 36, as illustrated with Figs. 14 and 15, the gyromagnetic component assembly 1. housed in the housing

space 30 applies a pressure to the top plate 44 of the lid member 4 in the thickness direction H. As illustrated in Figs. 16 and 17, accordingly, the projection 46 gradually deforms under the pressure, whereby the rising angle θ 1 of the end face 461 illustrated in Fig. 14 decreases to a rising angle θ2 illustrated in Fig. 16. If the end face 461 of the projection 46 are entirely pressed against the opposing inner face 361 of the first depression 36, for example, the rising angle θ2 will be approximately zero. On the other hand, the gap G is left between the bottom plate 34-side end face 462 of the projection 46 and the opposing inner face 362 of the first depression 36.

[0069] As illustrated in Fig. 18, all the projections 46 are fitted in the opposing first depressions 36 in the manner as described above with reference to Figs. 14 to 17, thereby obtaining the non-reciprocal circuit device with the gyromagnetic component assembly 1 housed in the housing space 30 of the holder.

[0070] The non-reciprocal circuit assembling method illustrated with Figs. 8 to 18 can prevent the variance of characteristics. For instance, if the lid member 4 were fitted in the casing member 3 in a rotary manner, as in conventional holders, the gyromagnetic component assembly 1 housed in the casing member 3 would be rotated by friction due to the rotary fitting of the lid member 4, thereby causing a problem of displacement as a cause of decreasing the reproducibility.

[0071] In the assembling method illustrated with Figs. 8 to 18, on the other hand, since the projection 46 of the lid member 4 is fitted in the first depression 36 of the casing member 3 from the side of the outer periphery of the holder, the gyromagnetic component assembly 1 is prevented from being displaced during the assembly. This prevents the variance of characteristics.

[0072] The projection 46 of the lid member 4 is inclined at the rising angle θ1 with respect to the first depression 36. With this configuration, as the deformation under the pressure from the gyromagnetic component assembly 1 progresses to decrease the rising angle from θ1 to θ2, the pressure against the gyromagnetic component assembly 1 reactively (or repulsively) increases to facilitate the control of the pressure (or downward load).

[0073] Since the control of the pressure (or downward load) is facilitated by coupling the lid member 4 with the casing member 3, as described above, the thickness of the gyromagnetic component assembly 1 housed in the housing space 30 can be kept constant, for example, to stabilize the capacitance value. Also, the distance between the permanent magnet 11 and the gyromagnetic component 10 can be kept constant to stabilize the loss value.

[0074] It should be noted that the assembling method described with reference to Figs. 8 to 18 is also applicable to the second depression 37. In addition, the advantages of the present invention described with reference to Figs. 1 to 18 can be likewise demonstrated in a lumped parameter type structure.

[0075] Figs. 19 to 21 illustrate a non-reciprocal circuit device according to another embodiment of the present invention. In Figs. 19 to 21, the components similar to those illustrated in Figs. 1 to 18 will be denoted by the same reference symbols.

[0076] The non-reciprocal circuit device illustrated in Figs. 19 to 20 is characterized in that the lid member 4 of the holder has a plurality of projections, i.e., first and second projections 46, 47.

[0077] The first projection 46 has the same configuration as the projection 46 illustrated in Figs. 1 to 18 and extends upward with their opposing end faces 461, 462 in the thickness direction H being inclined in a tapered manner toward the top plate 44.

[0078] The second projection 47 may have the same configuration as the first projection 46. As will be briefly described below, the second projection extends upward with their opposing end faces 471, 472 in the thickness direction H being inclined toward the top plate 44.

[0079] The first and second projections 46, 47 are spaced a distance T2 apart from each other in the thickness direction H. That is, the first and second projections 46, 47 adjacent each other in the thickness direction H provide a gap for the distance T2 between the end faces 471, 462.

[0080] Referring now to Fig. 21 in respect to the coupling between the lid member 4 and the casing member 3, the distance T2 between the adjacent first and second projections 46, 47 is approximately equal to or slightly larger than the distance T1 between the first and second depressions 36, 37 which are likewise adjacent each other (the distance T1 ≈ the distance T2). With this configuration, since the strip for the distance T1 can be disposed in the gap for the distance T2, the first and second projections 46, 47 can be fitted in the first and second depressions 36, 37, respectively. Therefore, the mechanical coupling strength of the holder can be enhanced by increasing the number of couplings between the lid member 4 and the casing member 3.

[0081] Increasing the number of couplings between the lid member 4 and the casing member 3 also facilitates the control of the pressure from the lid member 4 to the gyromagnetic component assembly 1, thereby improving non-reciprocal circuit characteristics.

[0082] Figs. 22 and 23 are enlarged views each illustrating a part of a non-reciprocal circuit device according to still another embodiment of the present invention. In Figs. 22 and 23, the components similar to those illustrated in Figs. 1 to 21 will be denoted by the same reference symbols.

[0083] Unlike in Fig. 21, the non-reciprocal circuit devices illustrated in Figs. 22 and 23 are characterized in that the distance T2 between the first and second projections 46, 47 adjacent each other in the thickness direction H is smaller than the distance T1 between the first and second depressions 36, 37 also adjacent each other in the thickness direction H (the distance T1 > the distance T2).

[0084] Since the distance T1 is larger than the distance

T2 in Figs. 22 and 23, when only one of the first and second projections 46, 47 is fitted in one of the first and second depressions 36, 37, the position of the top plate 44 in the thickness direction H varies, for example, a distance T3 (the distance T1 - the distance T2) between the case where the first projection 46 is fitted in the first depression 36 (Fig. 22) and the case where the second projection 47 is fitted in the second depression 37 (Fig. 23). This means that the thickness and capacity of the holder can be fine-tuned within the range of the distance T3 and the pressure against the gyromagnetic component assembly 1 can also be controlled depending on the coupling relationships of the first and second projections 46, 47 with the first and second depressions 36, 37.

[0085] Although not illustrated in the drawings, it should be noted that if the first projection 46 is fitted in the second depression 37, the top plate 44 will be located much lower than in Fig. 23. On the other hand, if the second projection 47 is fitted in the first depression 36, the top plate 44 will be located much higher than in Fig. 22 and above the side wall 31. Thus, it is apparent that increasing the number of projections leads to more variation in selecting the male-female fitting position, which allows a more flexible adjustment of the thickness and capacity of the housing space 30.

[0086] The present invention also provides a communication equipment which may be used as a base station, for example, and is characterized in that the non-reciprocal circuit device according to the present invention is employed in its necessary part such as a send unit. Communication equipments using one of the non-reciprocal circuit devices described above with reference to Figs. 1 to 23 will be described below with reference to Figs. 24 to 26. In Figs. 24 to 26, the components similar to those illustrated in Figs. 1 to 23 will be denoted by the same reference symbols.

[0087] First, the communication equipment illustrated in Fig. 24 is an embodiment where the non-reciprocal circuit device 9 described above with reference to Figs. 1 to 4 is surface-mounted on a circuit board 5. More specifically, the circuit board 5 includes a substrate 50 and ground electrodes 51.

[0088] The ground electrodes 51 are disposed on one surface of the substrate 50 around the openings 38. Of the non-reciprocal circuit device 9, the outer surface of the bottom plate of the casing member 3 is firmly fixed to one surface of the circuit board 5 through a conductive adhesive such as solder, and the terminals 151 to 153 of the central conductor 5 led out of the casing member 3 through the openings 38 are electrically connected to the ground electrodes 51 through a conductive adhesive. With this configuration, the communication equipment can be provided with all the advantages of the non-reciprocal circuit device 9 described above with reference to Figs. 1 to 4.

[0089] On the other hand, the communication equipment illustrated in Fig. 25 is an embodiment where the non-reciprocal circuit device 9 described above with reference to Figs. 1 to 4 is fitted in the circuit board 5. More specifically, the circuit board 5 has a holder insertion hole 52 passing through the substrate 50 from one surface to the other, and a step 520 is provided along the periphery of the holder insertion hole 52 on the lower surface side of the substrate 50.

[0090] The non-reciprocal circuit device 9 is mounted on the circuit board 5 as follows. At first, the casing member 3 is guided into the holder insertion hole 52 from the lower surface side of the substrate 50, whereby the coupling protrusions 340 protruding from the openings 38 (see Fig. 1) fit in the step 520. Then, after assembly of the casing member 3 to the substrate 50, the gyromagnetic component assembly is housed in the casing member 3 and the open end face 35 is closed by the lid member 4. Here, the gyromagnetic component assembly housed in the casing member 3 is partially (the lower magnetic pole plate 17 in Fig. 25) led out to the upper surface side of the substrate 50 through the openings, and the substrate 50 is held between the lower magnetic pole plate 17 and the coupling protrusions 340.

[0091] In the embodiment where the non-reciprocal circuit device 9 is mounted as illustrated in Fig. 25, a further reduction in height can be achieved as compared with the embodiment illustrated in Fig. 24, while reducing the assembly cost. In addition, since the gyromagnetic component assembly 1 is subjected to the pressure from the lid member 4 (or downward load), the non-reciprocal circuit device 9 can be firmly fixed to the circuit board 5.

[0092] The communication equipment illustrated in Fig. 26 may be provided in a base station of a mobile communication system and includes a receive circuit unit 6 and a send circuit unit 7 both connected to an antenna 8 for transmission and reception. The receive circuit unit 6 includes a receiving amplifier circuit 61 and a receive circuit 62 for processing received signals. The send circuit unit 7 includes a send circuit 71 for generating audio and video signals and a power amplifier circuit 72. In the above communication equipment, nun-reciprocal circuit devices 91, 92 according to the present invention may be used in the path from the antenna 8 to the receive circuit unit 6 and the send circuit unit 7 or the output stage of the power amplifier circuit. The non-reciprocal circuit device 91 functions as a circulator, while the non-reciprocal circuit device 92 functions as an isolator provided with a terminator resistor R0.

[0093] While the present invention has been particularly shown and described with reference to embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit, scope and teaching of the invention.

Claims

1. A non-reciprocal circuit device comprising a holder and a gyromagnetic component assembly (1),

said holder including a casing member (3) and a lid member (4),
said casing member (3) having a bottom plate (34) and a plurality of side walls (31-33) spaced apart from each other and rising from a periphery of said bottom plate (34), each side wall (31-33) having a depression (36) in an edge opposed to another side wall in a direction of said periphery,
said lid member (4) having a top plate (44) and a plurality of side walls (41-43) spaced apart from each other and hanging from a periphery of said top plate (44), each side wall (41-43) having a projection (46) on an edge opposed to another side wall in a direction of said periphery,
said lid member (4) being coupled to said casing member (3) with said projection (46) fitted in said depression (36),
said gyromagnetic component assembly (1) being housed in said holder between said top plate (44) and said bottom plate (34),
the non-reciprocal circuit device being **characterized in that** when said projection (46) is fitted in said depression (36),a top plate-side end face (461) of said projection (46) is at least partially pressed against an opposing inner face (361) of said depression (36) while a bottom plate-side end face (462) of said projection (46) is spaced apart from an opposing inner face (362) of said depression (36).

2. The non-reciprocal circuit device of claim 1, wherein said gyromagnetic component assembly (1) is pressed by said top plate (44) toward said bottom plate (34).

3. The non-reciprocal circuit device of claim 1 or 2, wherein said projection (46) and said depression (36) have different inclinations.

4. The non-reciprocal circuit device of any one of claims 1 to 3, wherein each side wall (31-33) of said casing member (3) has a plurality of depressions (36, 37) spaced apart in a thickness direction of the non-reciprocal circuit device.

5. The non-reciprocal circuit device of claim 4, wherein each side wall (41-43) of said lid member (4) has a plurality of projections (46, 47) spaced apart in said thickness direction and fitted in said plurality of depressions (36, 37), respectively.

6. The non-reciprocal circuit device of claim 4, wherein each side wall (41-43) of said lid member (4) has a plurality of projections (46, 47) spaced apart in said thickness direction and satisfying T1 > T2,
where T1 represents a distance between adjacent depressions (36, 37) in said thickness direction and T2 represents a distance between adjacent projections (46, 47) in said thickness direction.

7. A communication equipment comprising a send circuit unit (7) with the non-reciprocal circuit device of any one of claims 1 to 6.

8. A method for assembling the non-reciprocal circuit device of any one of claims 1 to 6, comprising the steps of:

positioning said lid member (4) with respect to said casing member (3); and
fitting said projection (46) in said depression (36) for mechanical coupling between said lid member (4) and said casing member (3).

FIG.1

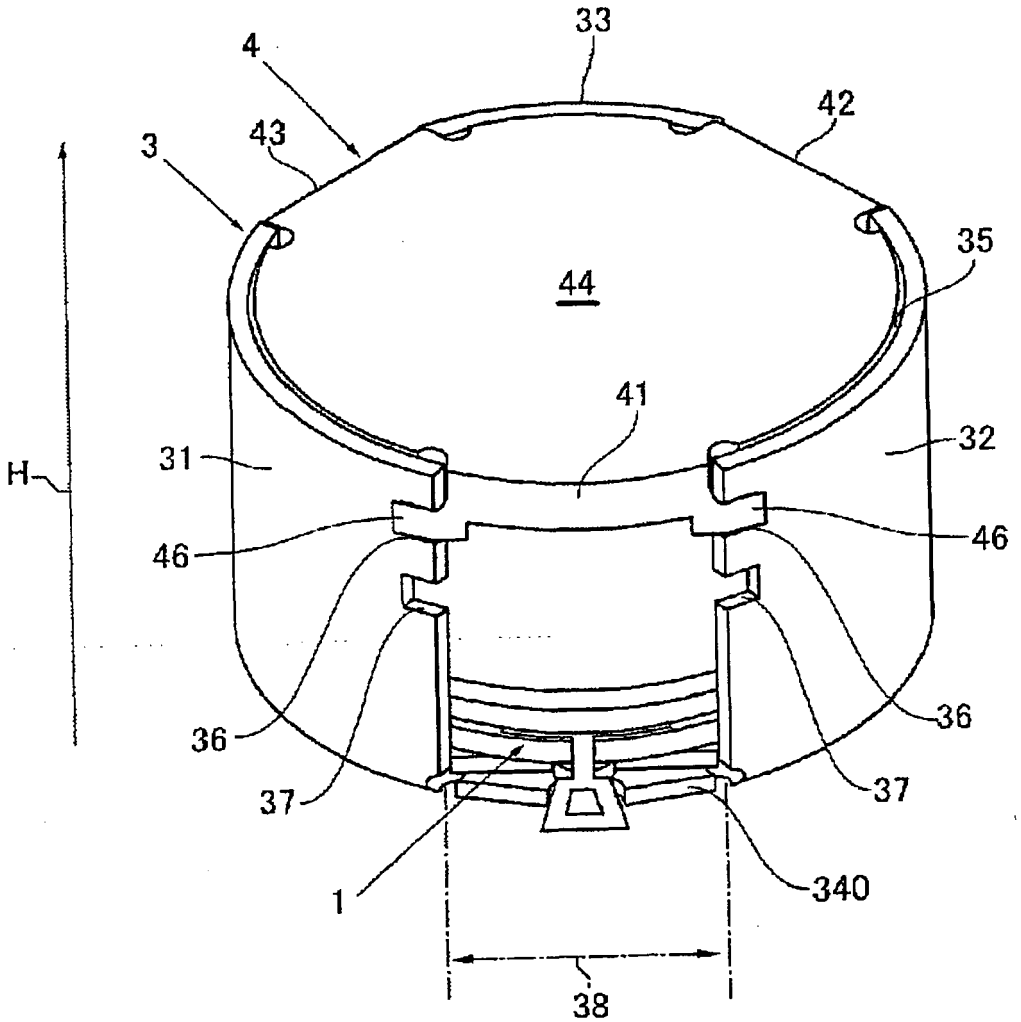


FIG.2

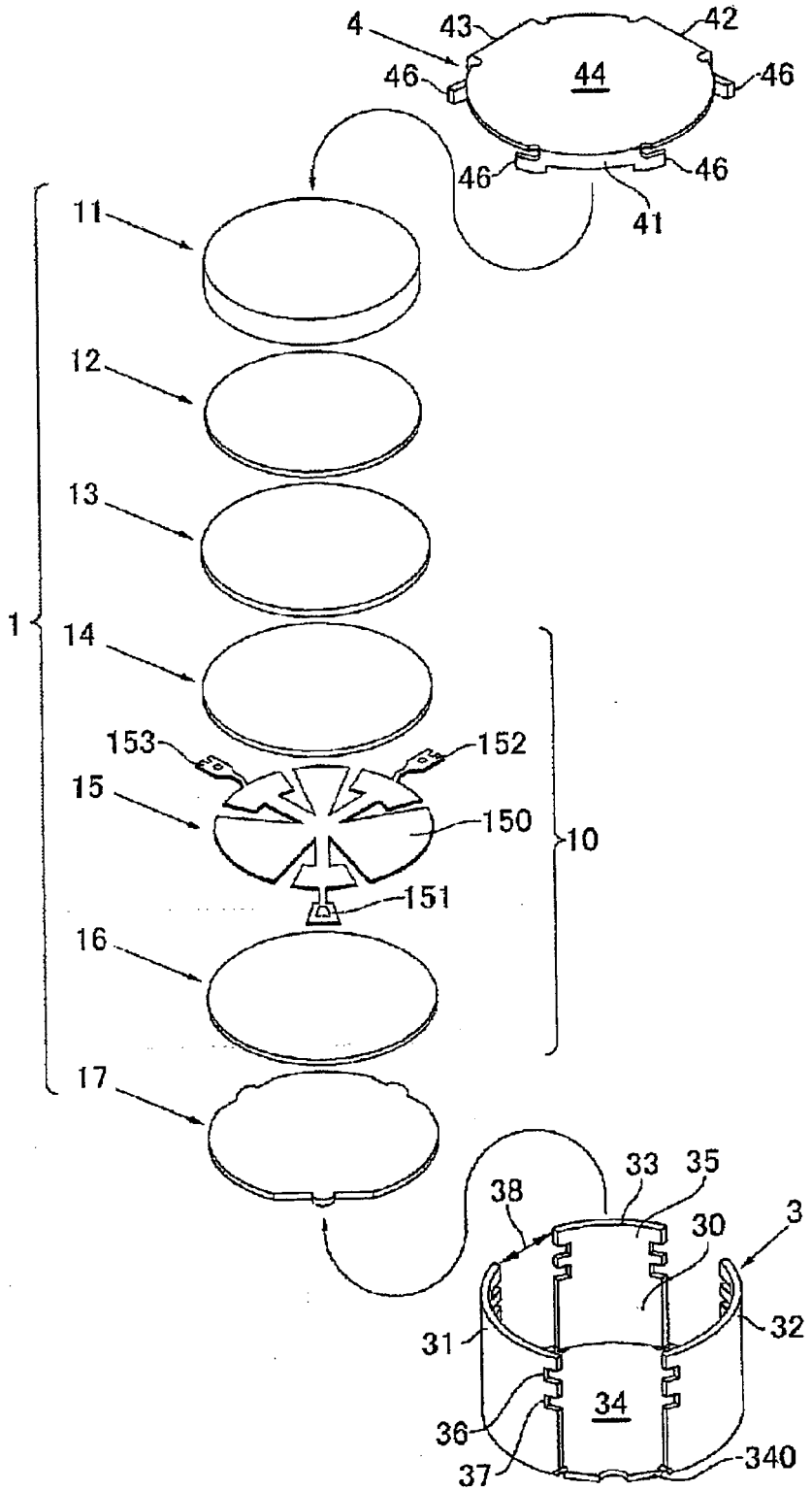

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FIG.3

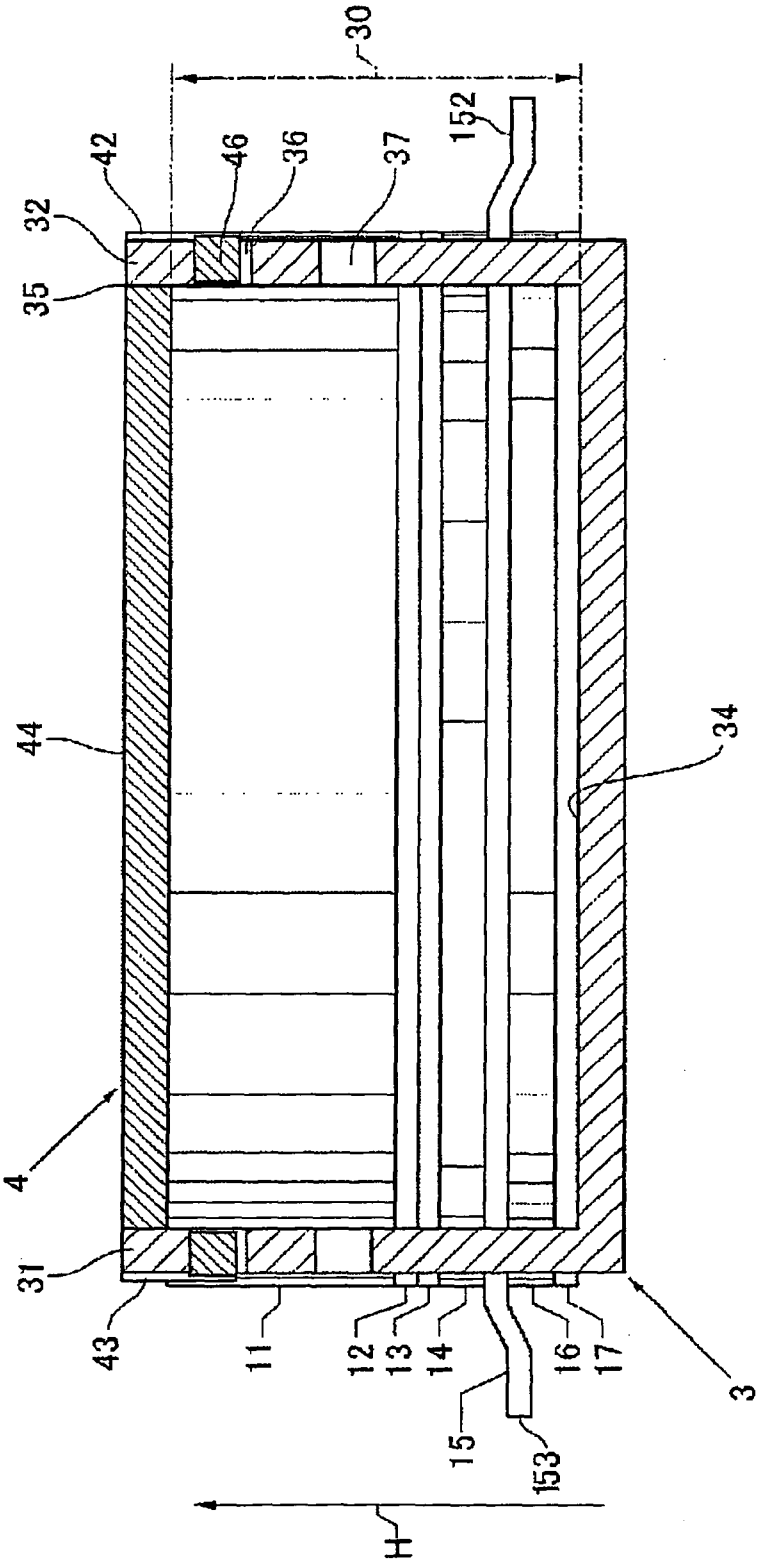

FIG.4

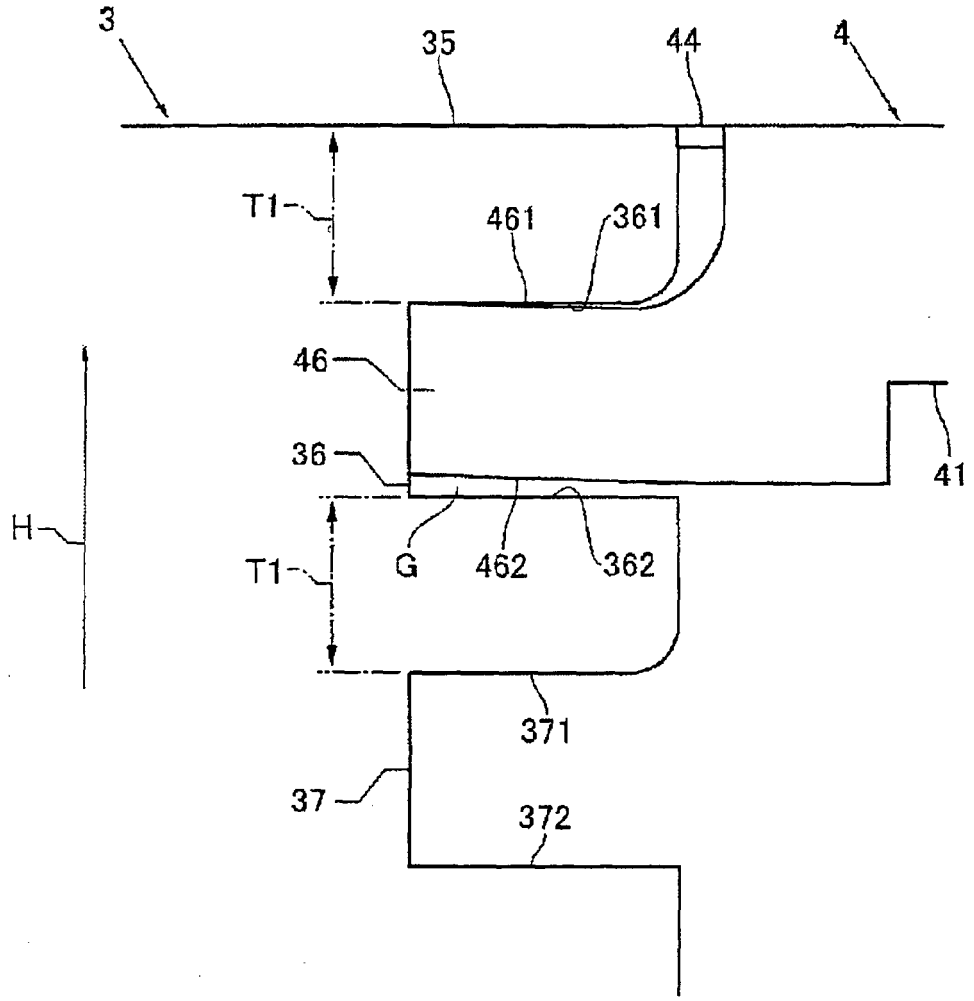

FIG.5

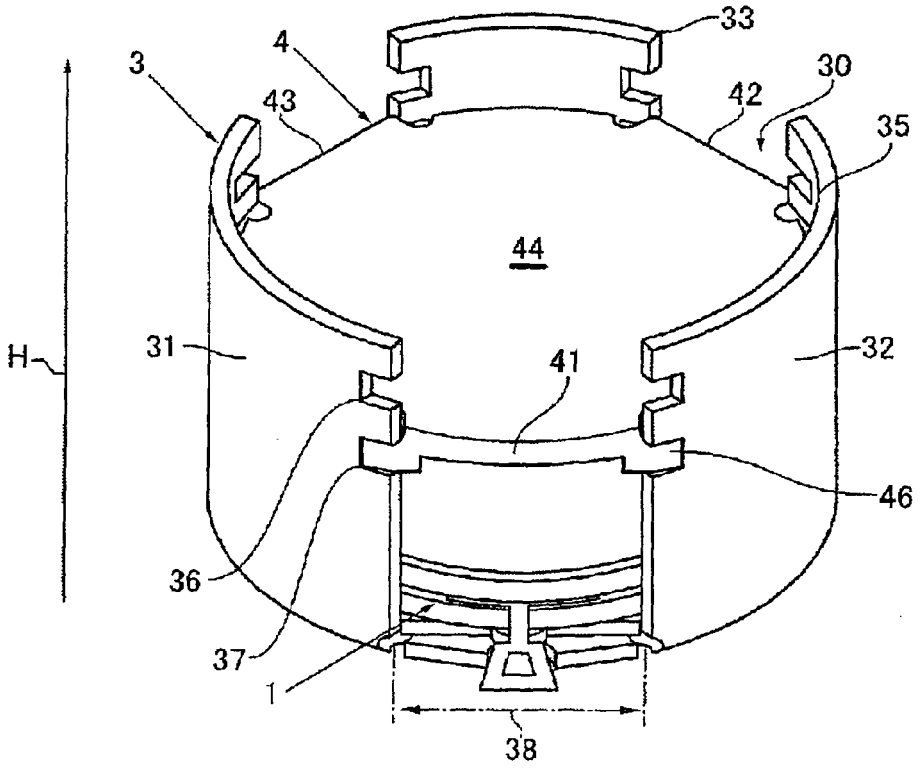
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FIG.6

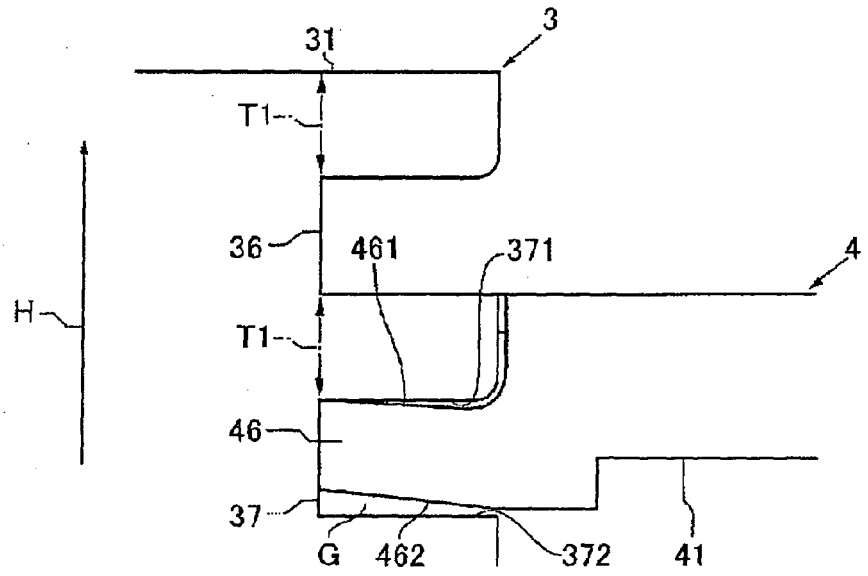
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FIG.7

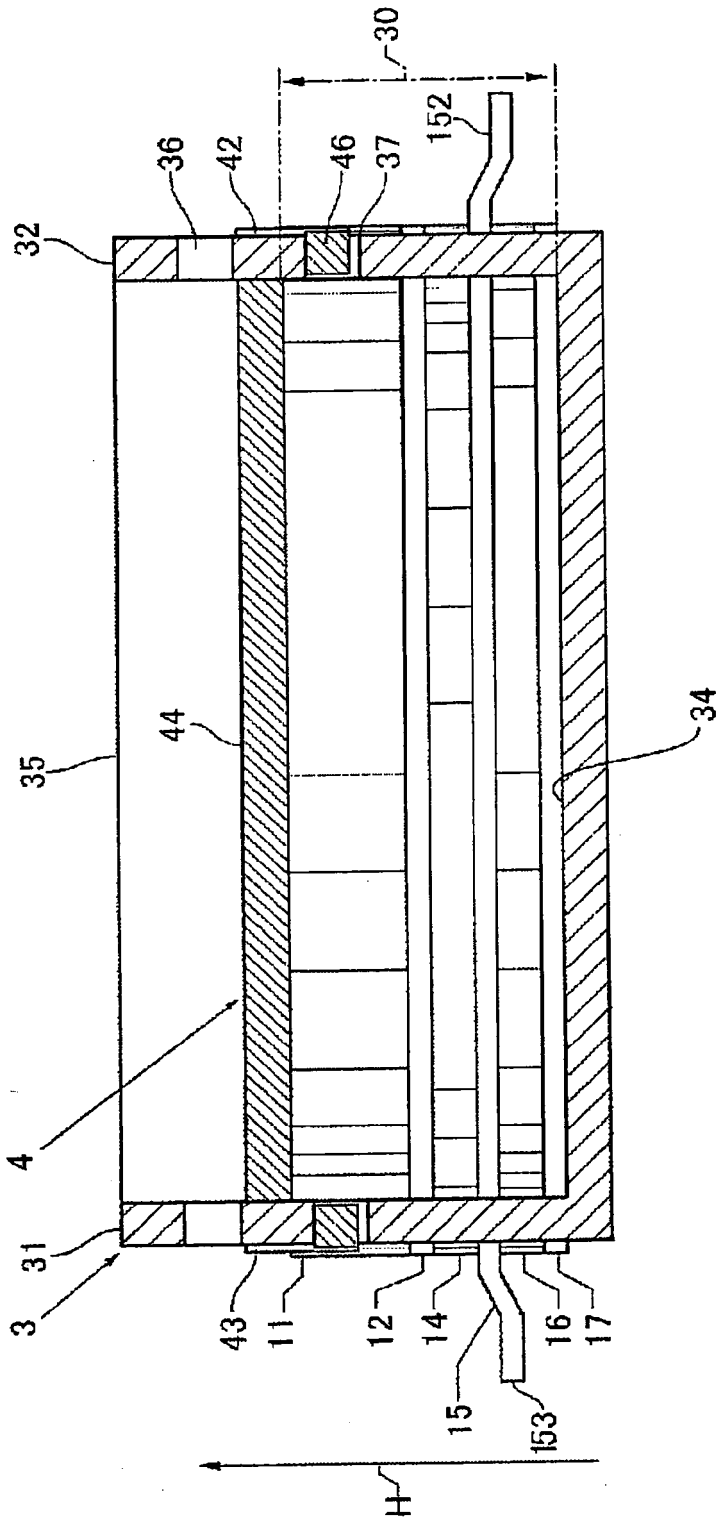

FIG.8

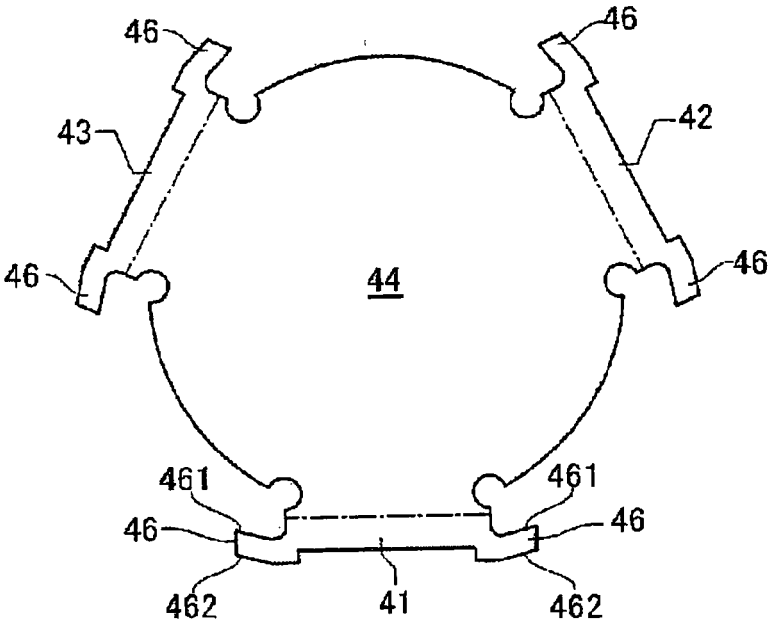
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FIG.9

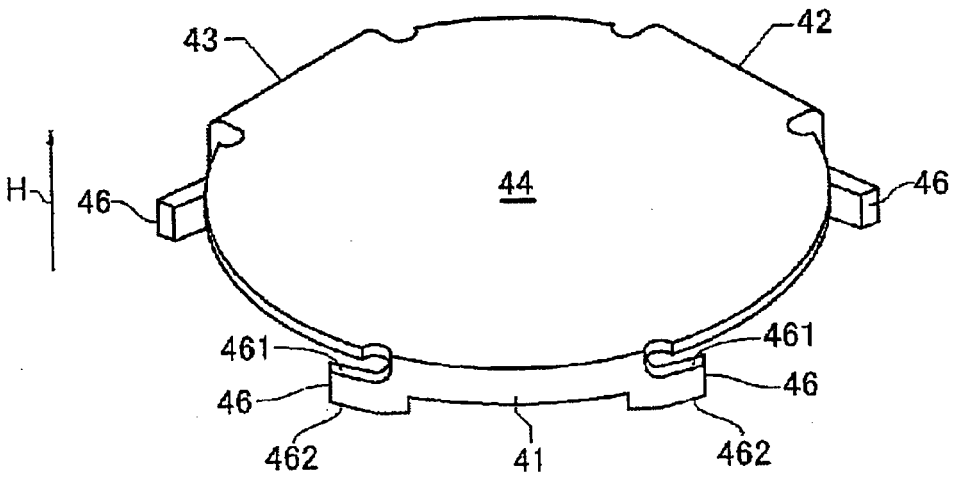
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FIG.10

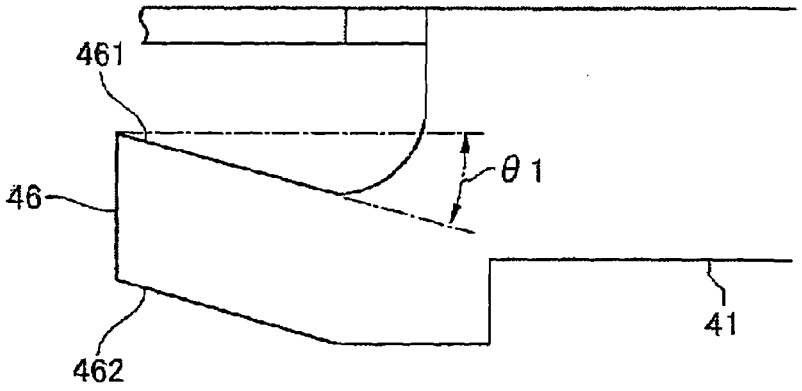

FIG.11

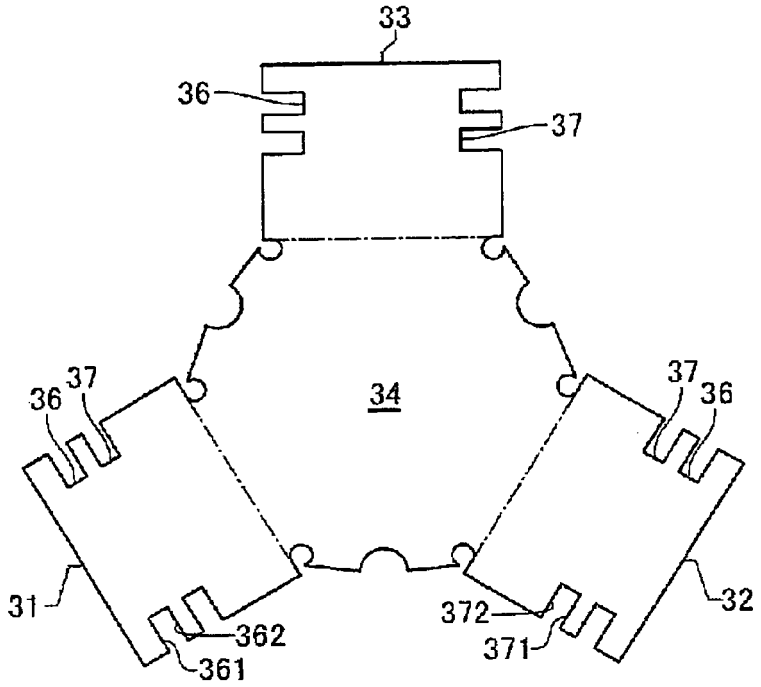
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FIG.12

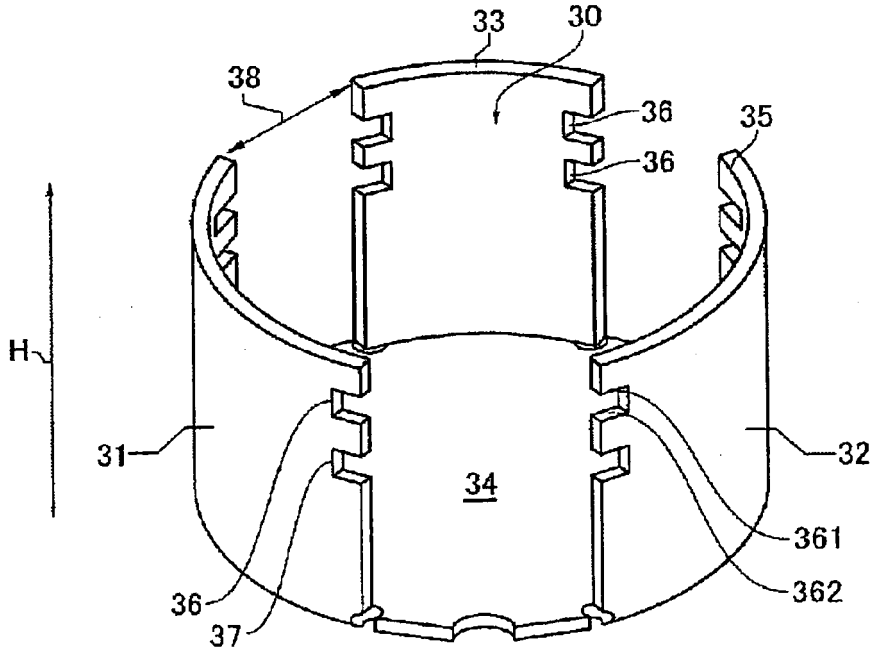
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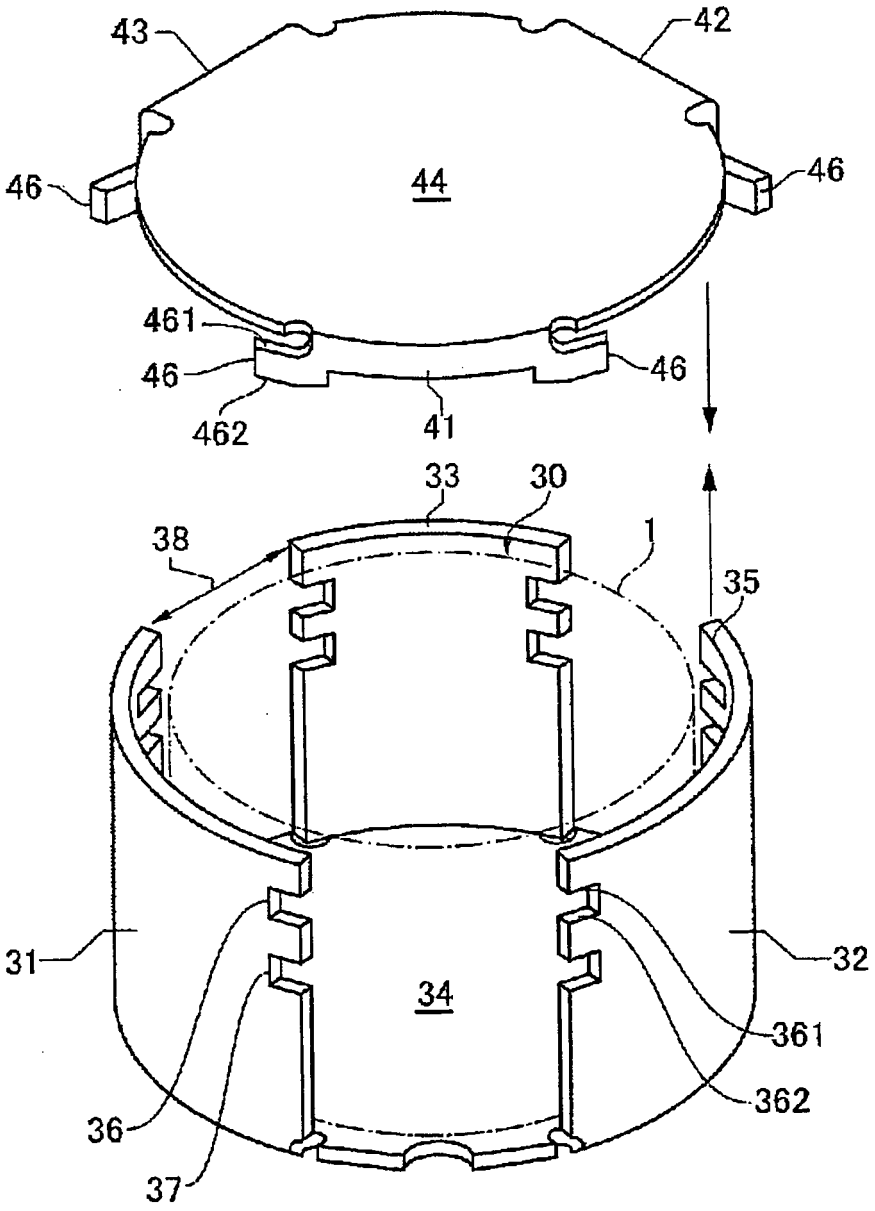
FIG.13



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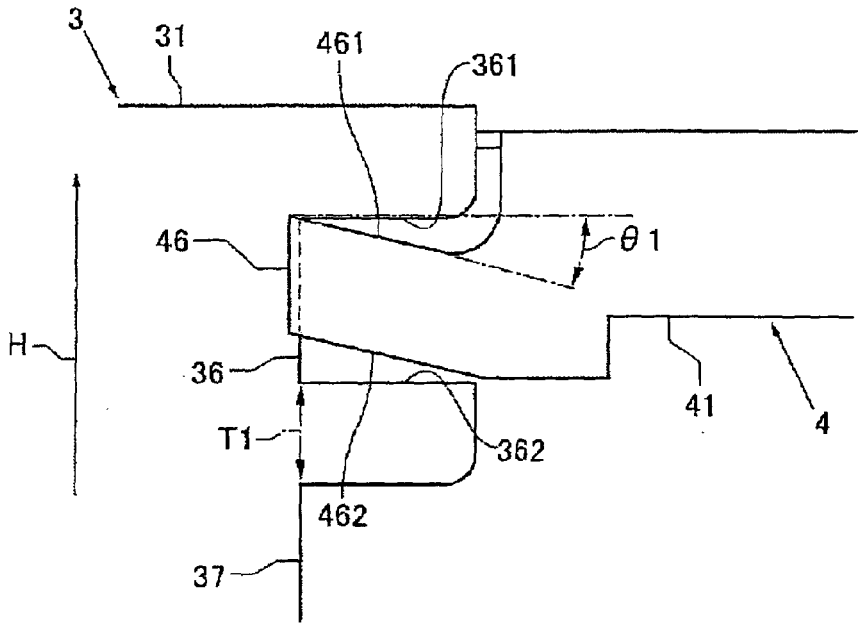
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FIG.15

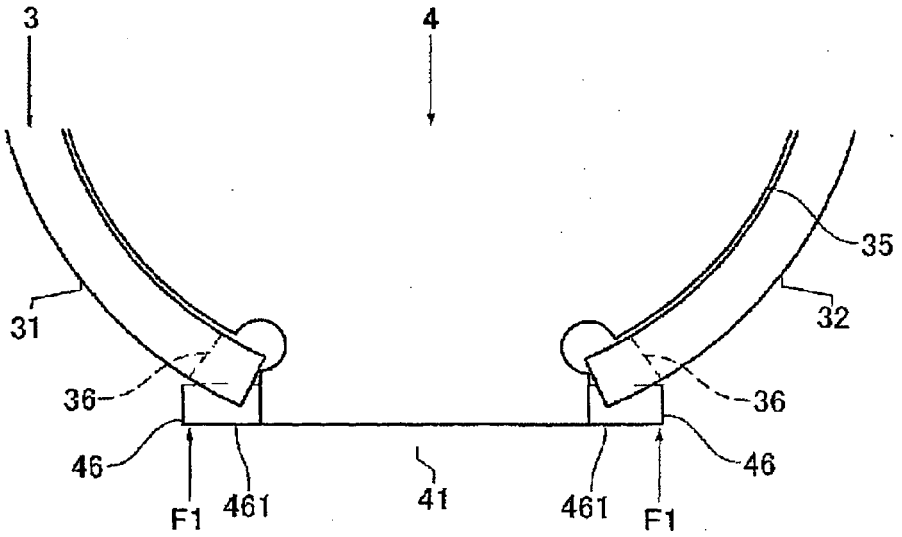
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FIG.16

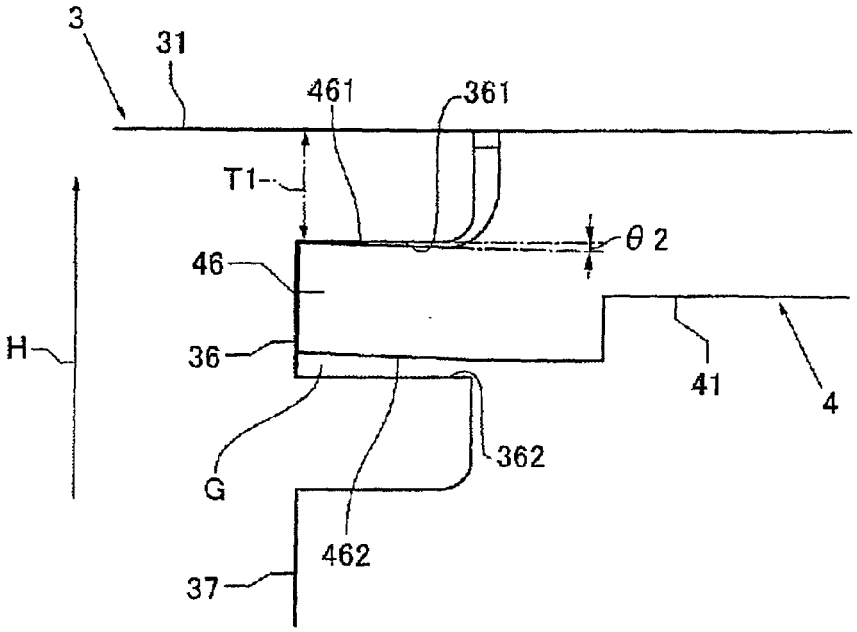


FIG.17

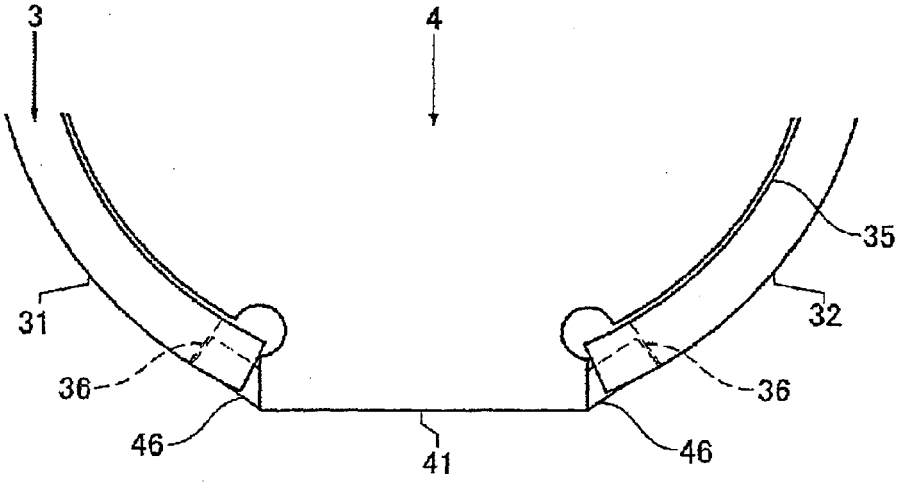
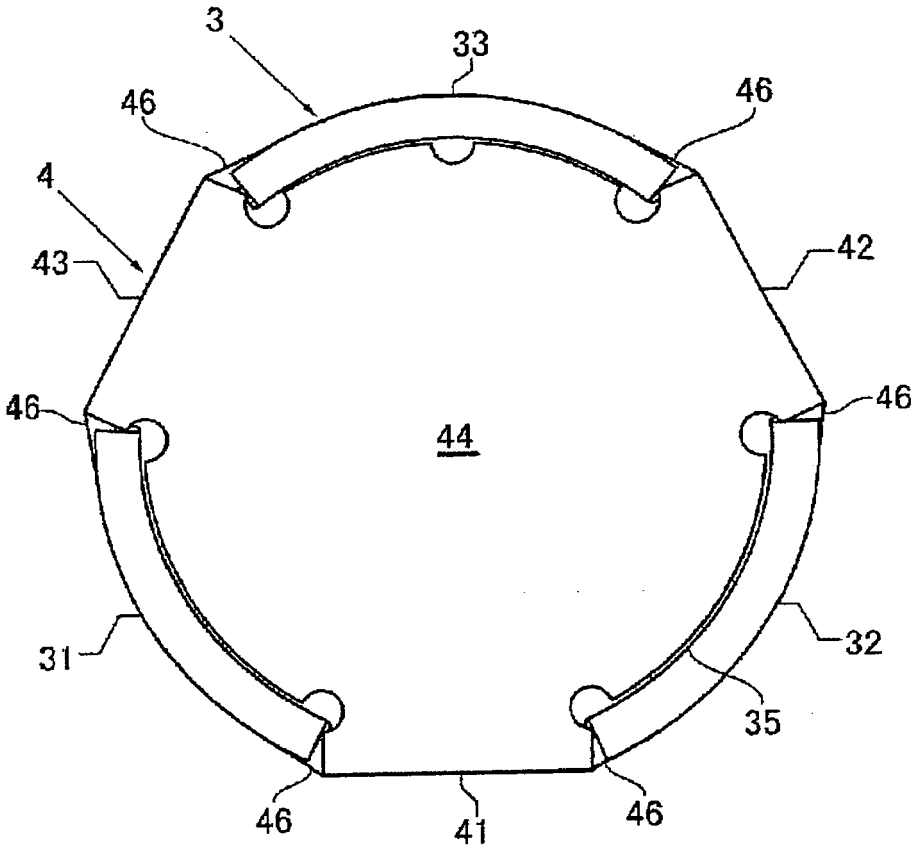


FIG.18



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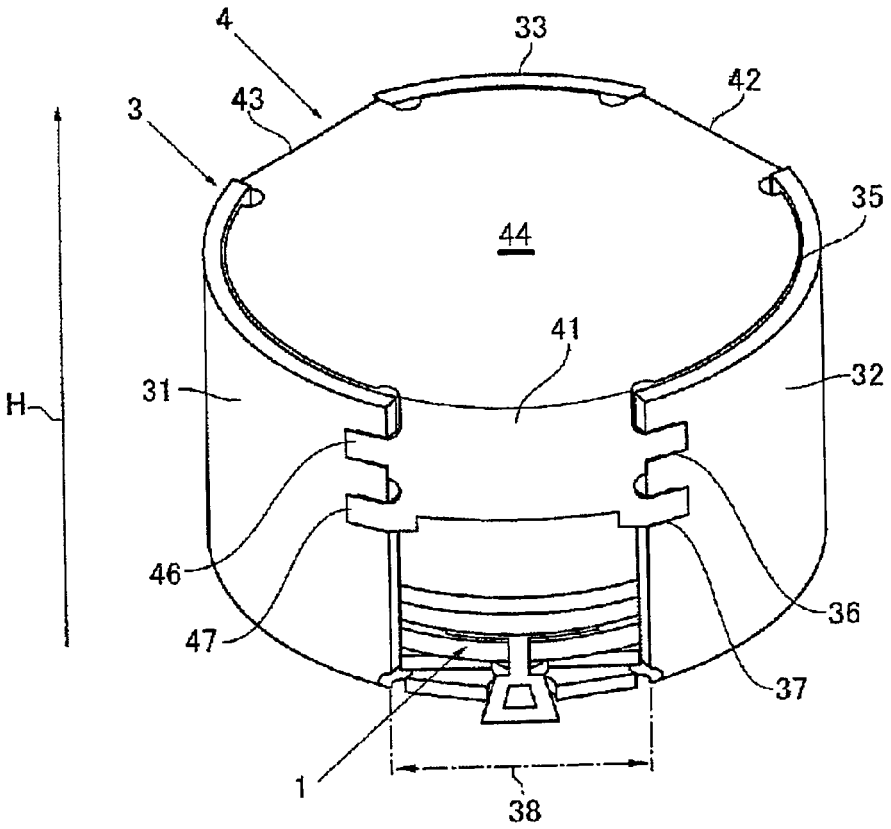
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FIG.20

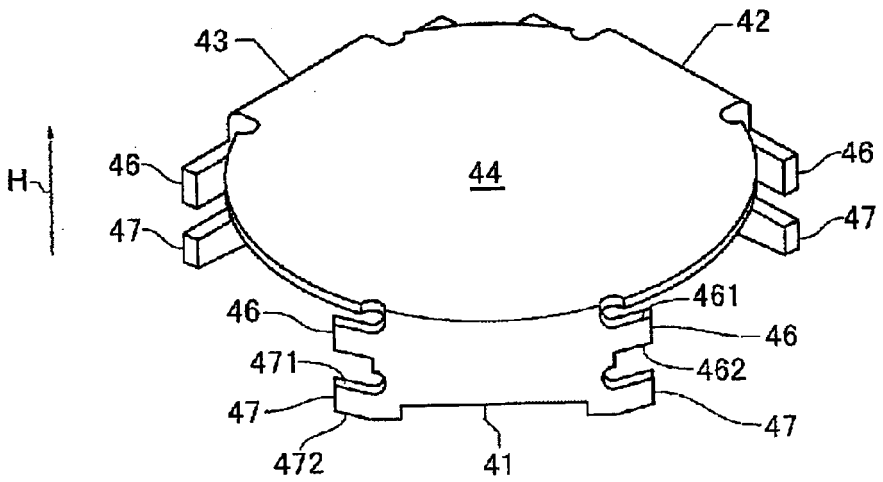
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FIG.21

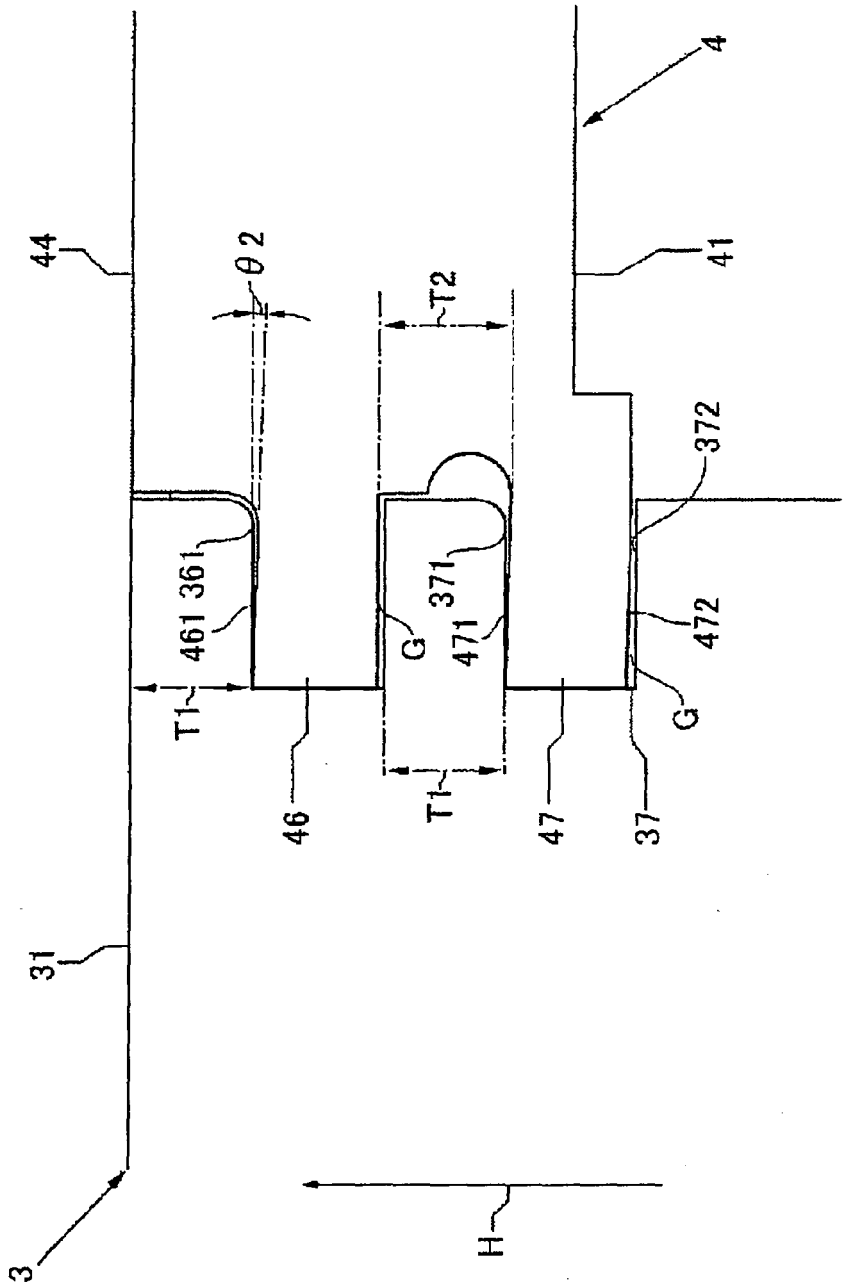

FIG.22

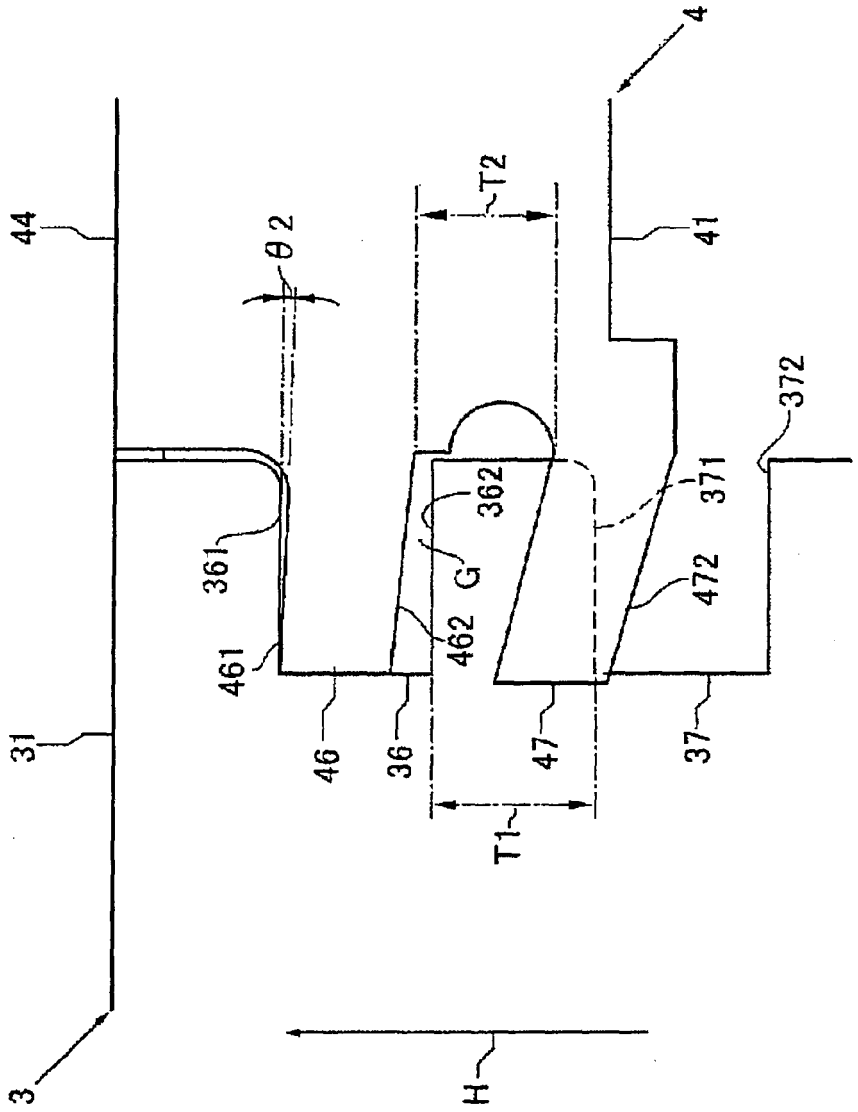

FIG.23

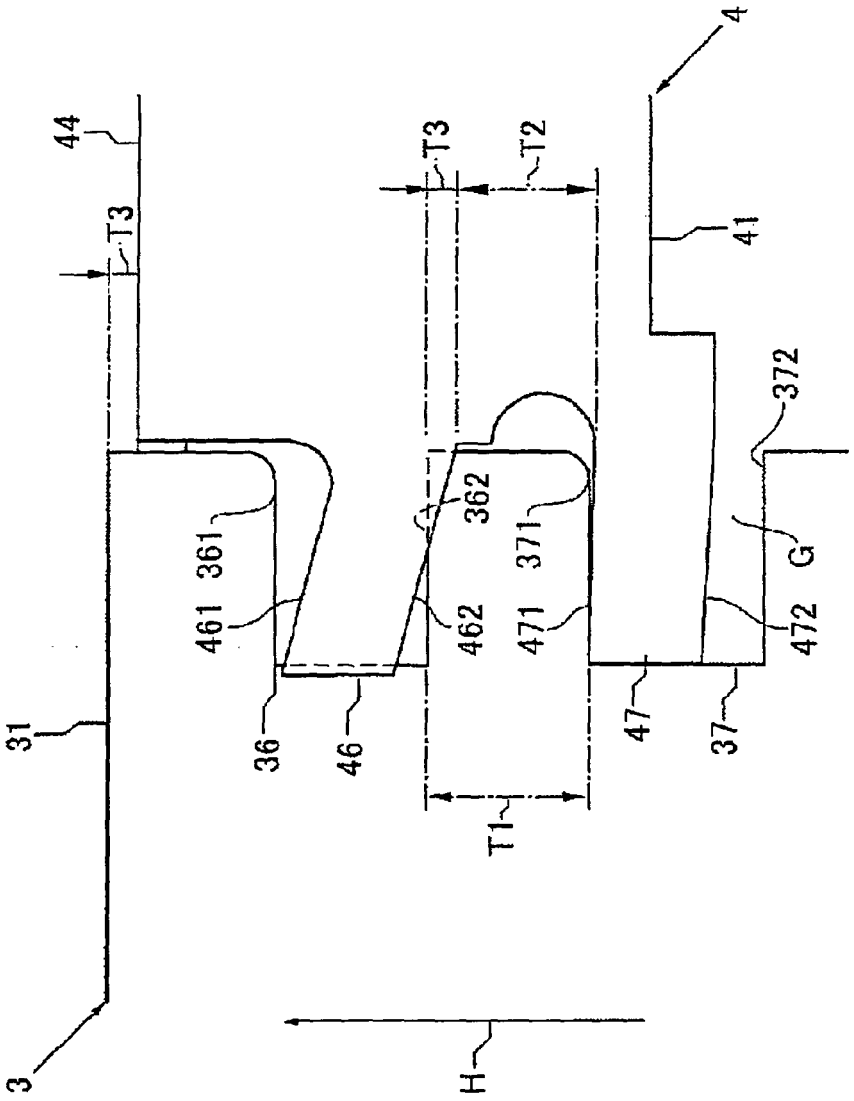
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FIG.24

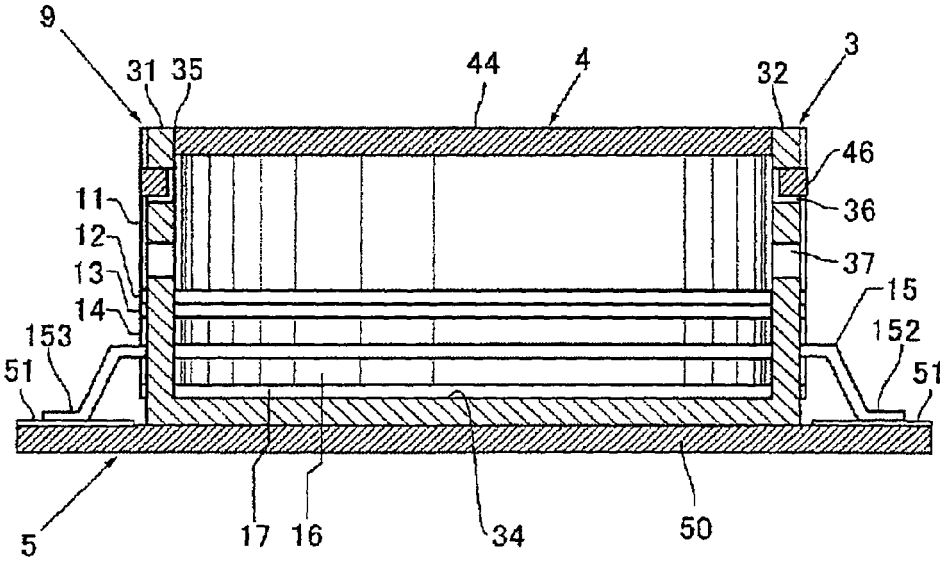
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FIG.25

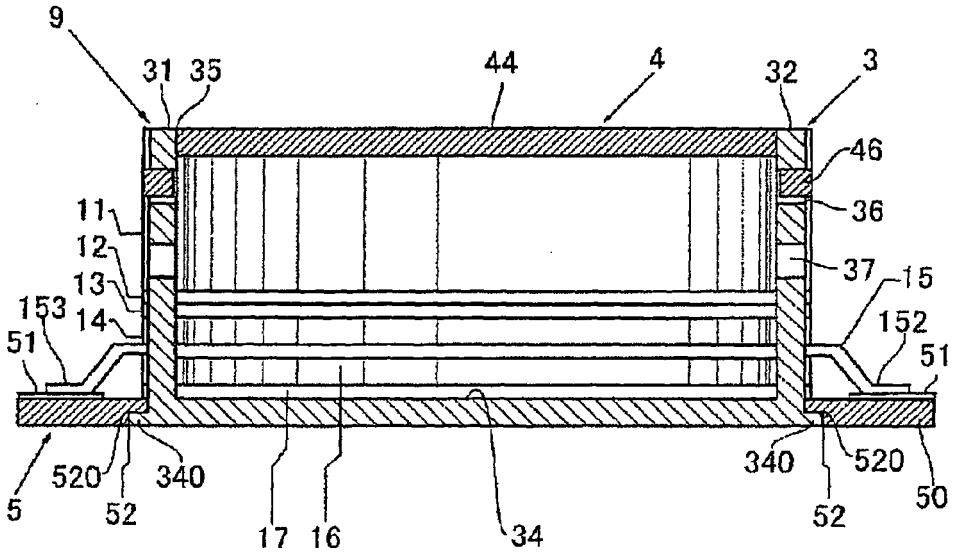
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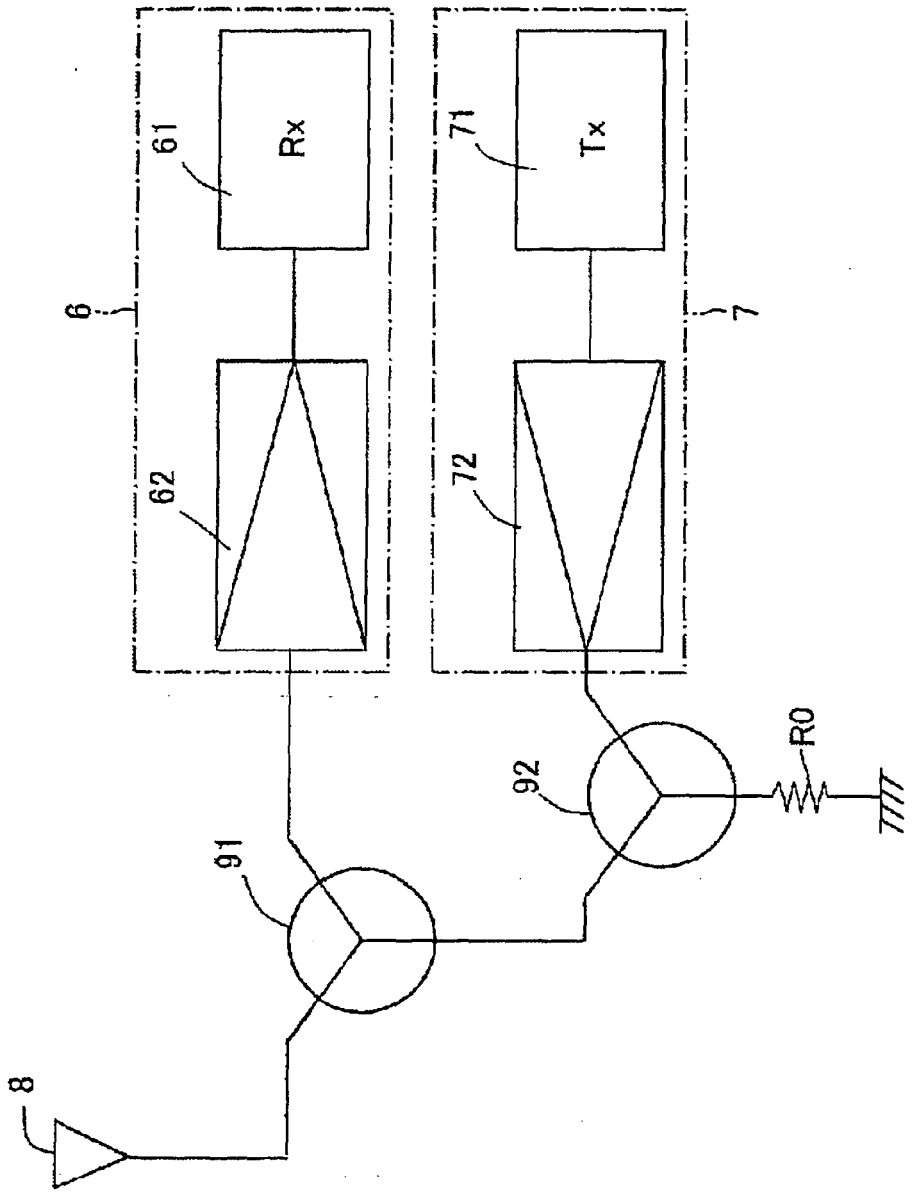
FIG.26



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 25 1617

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,A	US 6 504 445 B1 (KOCHARYAN KAREN [US]) 7 January 2003 (2003-01-07) * column 5, line 17 - column 6, line 12; figures 1,5 *	1	INV. H01P1/387
D,A	US 6 337 607 B1 (GENFAN GERMAN S [US]) 8 January 2002 (2002-01-08) * column 4, lines 43-65; figures 3,4 *	1	
A	JP 2006 101214 A (TDK CORP) 13 April 2006 (2006-04-13) * figures 1-4 *	1	
A	EP 0 957 528 A (MURATA MANUFACTURING CO [JP]) 17 November 1999 (1999-11-17) * paragraphs [0018] - [0023]; figure 1A *	1	

TECHNICAL FIELDS SEARCHED (IPC)

H01P
H05K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 June 2007	Den Otter, Adrianus

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 25 1617

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