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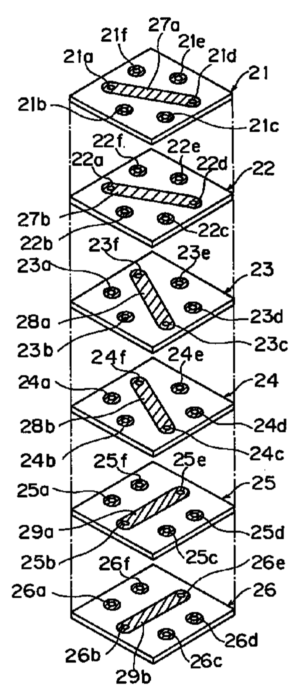
(54) NON-RECIPROCAL CIRCUIT ELEMENT FOR MICROWAVE

(57) Aimed at providing a microwave non-reciprocal circuit element which is further miniature and of low losses without causing conductor losses in center electrodes following miniaturization.

The microwave non-reciprocal circuit element according to the present invention comprises a plurality of center electrodes which are arranged to intersect with each other in a state electrically insulated from each other, and a microwave magnetic or dielectric body which is arranged on an intersecting portion of the plurality of center electrodes, and the respective center electrodes are formed by a plurality of conductors 55, 56 and 57 which are stacked through the microwave magnetic or dielectric body.

FIG. 4



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Description

Technical Field

The present invention relates to a non-reciprocal circuit element which is employed in the microwave band, and relates to a microwave non-reciprocal circuit element which is employed for a circulator or an isolator, for example.

Background Technique

In recent years, miniaturization and generalization of a high-frequency device progress in mobile communication or the like, and miniaturization and cost reduction are strongly required in a non-reciprocal circuit element employed therefor.

As the aforementioned non-reciprocal circuit element, there is an element structured by a plurality of center electrodes which are arranged to intersect with each other in an electrically insulated state and microwave magnetic bodies which are arranged on upper and lower portions of the plurality of center electrodes so that a dc magnetic field is applied by permanent magnets to a portion where the aforementioned plurality of center electrodes intersect with each other, i.e., the so-called lumped element type non-reciprocal circuit element, such as a lumped element type circulator or isolator, for example.

Fig. 1 is an exploded perspective view for illustrating a first example of a conventional microwave non-reciprocal circuit element. This microwave non-reciprocal circuit element has a structure formed by stacking rectangular dielectric substrates 1 to 3. Ports 1a to 1f, 2a to 2f and 3a to 3f are formed on upper surfaces of the respective dielectric substrates 1 to 3 respectively. The respective ports 1a to 3f are structured by forming conductive films to be electrically connected to through hole electrodes which are arranged to enclose centers of the respective dielectric substrates 1 to 3 respectively.

In the dielectric substrate 1, a center electrode 4 is formed to connect the port 1a with the port 1d. Similarly, center electrodes 5 and 6 are formed also on the upper surfaces of the dielectric substrates 2 and 3. The center electrodes 4 to 6 are structured to extend in different directions in the state stacking the dielectric substrates 1 to 3, i.e., to intersect in a state electrically insulated from each other through the dielectric substrates.

The aforementioned microwave non-reciprocal circuit element is structured by stacking the dielectric substrates 1 to 3 in the illustrated state.

Fig. 2 is an exploded perspective view for illustrating a second example of a conventional microwave non-reciprocal circuit element.

In the microwave non-reciprocal circuit element of the second example, ports 7a to 7f ... 9a to 9f are formed on upper surfaces of dielectric substrate 7 to 9 similarly to the first example, and center electrodes 10 to 12 are similarly formed. However, the center electrodes 10 to 12 have such structures that longitudinally extending pairs of conductors 10a and 10b to 12a and 12b are coupled with each other on both ends respectively, as shown in the figure. As to other structures, this element is structured similarly to the microwave non-reciprocal circuit element shown in Fig. 1.

Fig. 3 is an exploded perspective view for illustrating a third example of a conventional microwave non-reciprocal circuit element. In the microwave non-reciprocal circuit element of the third example, a center electrode 14a consisting of metal foil, such as Cu foil, for example, is arranged on a discoidal microwave magnetic body 13a.

The center electrode 14a is so shaped as to pass through a center of an upper surface of the microwave magnetic body 13a, extend in the diametral direction, and further reach side surfaces of the microwave magnetic body 13a. Then, an insulating film 15a consisting of an insulating material is arranged on the aforementioned center electrode 14a, and another center electrode 14b is arranged thereon to intersect with the center electrode 14a. Further, an insulating film 15b, a center electrode 14c and an insulating film 15c are successively arranged on the aforementioned center electrode 14b, and a microwave magnetic body 13b is stacked and fixed. Thereafter permanent magnets are arranged on upper and lower portions so that a dc magnetic field is applied to the structural body which is held by the microwave magnetic bodies 13a and 13b.

In a microwave non-reciprocal circuit element, widths of center electrodes are preferably broad since conductor losses are reduced as the widths of the center electrodes are increased. Following miniaturization of the non-reciprocal circuit element, however, the widths of the center electrodes must also be inevitably narrowed. In the conventional microwave non-reciprocal circuit elements described with reference to Figs. 1 to 3, therefore, widths of the center electrodes 4 to 6, 10 to 12 and 14a to 14c must be narrowed when further miniaturization is promoted, and hence there have been such problems that conductor losses are increased and the amounts of attenuation in transmission directions are increased.

In a method of manufacturing the microwave non-reciprocal circuit element described with reference to Fig. 3, on the other hand, the respective center electrodes 14a to 14c consisting of metal foil have been assembled by manually stacking the same alternately with the insulating films 15a to 15c. Due to miniaturization of the microwave non-reciprocal circuit element, however, the lengths of the aforementioned center electrodes 14a to 14c are now being reduced to about several mm, and manual assembly is now being extremely difficult. Consequently, imperfect assembly such as relative misregistration between the center electrodes 14a to 14c is caused when a miniature microwave non-reciprocal circuit element is structured, and it has been difficult to obtain a microwave non-reciprocal circuit element which is excellent in reliability.

Since the element has been manually assembled as described above, further, there has also been such a problem that imperfect assembly is frequently caused to increase the manufacturing cost.

In addition, a relatively large number of components are required as hereinabove described, while limitation is now being caused in cost reduction of the individual components, and cost reduction for the microwave non-reciprocal circuit element is now being made difficult.

Object of the Invention

An object of the present invention is to provide a microwave non-reciprocal circuit element which is further miniature and brought into a low loss state, without causing conductor losses in center electrodes following miniaturization.

Disclosure of the Invention

According to a wide aspect of the present invention, provided is a microwave non-reciprocal circuit element comprising a plurality of center electrodes which are arranged to intersect with each other in a state electrically insulated from each other, and a microwave magnetic or dielectric body which is arranged on an intersecting portion of the said plurality of center electrodes, and each of the said center electrodes is structured by a plurality of conductors stacked through the microwave magnetic or dielectric body.

According to the present invention, each of the plurality of center electrodes which are made to intersect with each other in the microwave non-reciprocal circuit element in the state electrically insulated from each other is structured by a plurality of conductors which are stacked through the microwave magnetic or dielectric body. Therefore, conductor losses in the center electrodes can be reduced by increasing the number of the conductors since each center electrode is structured by the aforementioned plurality of conductors. Also when miniaturization of the microwave non-reciprocal circuit element is attempted, therefore, reduction of conductor losses can be prevented by simply increasing the number of stacking, whereby it is possible to provide a microwave non-reciprocal circuit element which is further miniature and of low losses as compared with the conventional microwave non-reciprocal circuit elements.

In a certain specific aspect of the present invention, the plurality of conductors structuring the said each center electrode may be embedded in the microwave magnetic or dielectric body so that the respective center electrodes are successively arranged in the direction of thickness in the microwave magnetic or dielectric body, as to the plurality of conductors structuring the aforementioned center electrodes. Alternatively, the plurality of conductors structured by the said each center electrode may be embedded in the microwave magnetic or dielectric body so that the conductors structuring one center electrode and the plurality of conductors structuring the remaining center electrodes are stacked at random in the microwave magnetic or dielectric body in the direction of thickness.

In the aforementioned specific aspect of the present invention, the aforementioned center electrodes are embedded in the microwave magnetic or dielectric body, further successively stacked in the microwave magnetic or dielectric body in the direction of thickness, or the plurality of conductors structuring the aforementioned center electrodes are stacked at random in the microwave magnetic or dielectric body in the direction of thickness. In either of the aforementioned cases, the plurality of conductors structuring the center electrodes are embedded in the microwave magnetic or dielectric body, whereby not only miniaturization and loss reduction can be attained but environment resistance of the microwave non-reciprocal circuit element can be improved by structuring one center electrode by a plurality of conductors.

According to another specific aspect of the present invention, the microwave non-reciprocal circuit element has first to third center electrode portions which consist of the said plurality of conductors and are successively arranged in the direction of thickness, and at least one conductor structuring the said first center electrode portion is arranged on an outer side of the third center electrode portion in the direction of thickness while at least one conductor structuring the third center electrode portion is arranged on an outer side of the first center electrode portion in the direction of thickness. The distance between at least one conductor which is arranged on the outer side of the said third center electrode portion and the conductor of the third center electrode portion which is adjacent to the conductor in the direction of thickness, and the distance between at least one conductor which is arranged on the outer side of the said first center electrode portion and the first center electrode portion which is adjacent to the conductor in the direction of thickness are rendered larger than the distances between other adjacent conductors.

In the structure of arranging at least single conductors which are positioned on the outer sides in the direction of thickness among the plurality of conductors structuring the first and third center electrode portions on opposite sides, i.e., the outer side of the third or first center electrode portion in the direction of thickness, as hereinabove described, it is possible to compensate for shortage of distributed capacitances by the conductors arranged in the aforementioned manner and the conductor of the third or first center electrode portion which is adjacent to the said conductors. Thus, it is possible to increase the distributed capacitances across the first and third center electrode portions, and to make the distributed capacitance across the first and third center electrode portions equal to the distributed capacitance across the first center electrode portion and the second center electrode portion and the distributed capacitance across the second center electrode portion and the third electrode portion. Consequently, I.L. characteristics, isolation identification and return loss characteristics can be uniformalized, and it is possible to cope with improvement in performance of the non-reciprocal circuit element. Further, it is possible to take matched capacitances by the distributed capacitances across the respective center electrode portions. Thus, it is possible to omit a circuit element for matching which has been separately added in general and to cope with miniaturization and weight reduction of the non-reciprocal circuit element, while it is also possible to attain reduction of the cost for the non-reciprocal circuit element.

Further, the conductors structuring the respective center electrode portions are brought into multilayer structures, whereby resistances of the center electrodes can be reduced, thereby improving the Q values. Thus, the Q values can be increased, thereby reducing insertion losses.

According to the present invention, as hereinabove described, it is possible to remarkably contribute to miniaturization, generalization and improvement in performance of a high-frequency device such as a mobile communication device.

Brief Description of the Drawings

Fig. 1 is an exploded perspective view for illustrating a first example of a conventional microwave non-reciprocal circuit element.

Fig. 2 is an exploded perspective view for illustrating a second example of a conventional microwave non-reciprocal circuit element.

Fig. 3 is an exploded perspective view for illustrating a third example of a conventional microwave non-reciprocal circuit element.

Fig. 4 is an exploded perspective view for illustrating a first embodiment.

Fig. 5 is an exploded perspective view showing a modification of a microwave non-reciprocal circuit element according to the first embodiment.

Fig. 6 is an exploded perspective view showing a second modification of the microwave non-reciprocal circuit element according to the first embodiment.

Fig. 7 is an exploded perspective view showing a third modification of a microwave non-reciprocal circuit element according to a second embodiment.

Fig. 8 is an exploded perspective view for illustrating a microwave non-reciprocal circuit element according to the second embodiment.

Fig. 9 is a perspective view showing a magnetic green sheet employed in a third embodiment.

Figs. 10A, 10B, 10C are respective perspective views showing magnetic green sheets and conductors printed on the sheets in the third embodiment.

Fig. 11 is an exploded perspective view for illustrating magnetic green sheets stacked in the third embodiment.

Fig. 12 is a perspective view showing a laminate prepared in the third embodiment.

Fig. 13 is an exploded perspective view of a laminate chip punched in the fork of a disc.

Fig. 14 is a perspective view for illustrating the microwave non-reciprocal circuit element obtained by the third embodiment.

Fig. 15 is an exploded perspective view for illustrating a microwave non-reciprocal circuit element according to a fourth embodiment of the present invention.

Fig. 16 is a partially fragmented sectional view showing a portion where conductors overlap with each other in the microwave non-reciprocal circuit element shown in Fig. 15.

Fig. 17 is a partially fragmented sectional view for illustrating a modification of the microwave non-reciprocal circuit element according to the fourth embodiment, which is a diagram corresponding to Fig. 16.

Fig. 18 is a diagram for illustrating an equivalent circuit of a general isolator.

Fig. 19 is an exploded perspective view for illustrating an electrode arrangement structure of a microwave non-reciprocal circuit element according to a fifth embodiment of the present invention.

Fig. 20 is a partially fragmented sectional view for illustrating an isolator according to the fifth embodiment of the present invention.

Fig. 21 is a perspective view for illustrating the isolator according to the fifth embodiment of the present invention.

Fig. 22 is a partially fragmented sectional view for illustrating a modification of the isolator according to the fifth embodiment of the present invention.

Best Mode for Carrying out the Invention

Embodiments of the microwave non-reciprocal circuit element according to the present invention are now described, to clarify the details of the present invention.

First Embodiment

Fig. 4 is an exploded perspective view for illustrating a microwave non-reciprocal circuit element according to a first embodiment of the present invention. The microwave non-reciprocal circuit element according to the first embodiment is structured by stacking a plurality of rectangular dielectric substrate 21 to 26, and fixing the same to each other by adhesives or the like. As to the dielectric substrates 21 to 26, those consisting of an arbitrary dielectric material such as barium titanate dielectric ceramics, for example, can be employed.

On upper surfaces of the dielectric substrates 21 to 26, hexadic ports 21a to 21f ... 26a to 26f which are arranged around centers of the upper surfaces to be connected to through hole electrodes are formed respectively. With reference to the dielectric substrate 21, for example, a conductor 27a structuring a center electrode is formed on its upper surface to connect the ports 21a and 21d with each other among the aforementioned ports. Similarly, a conductor 27b is formed also on the upper surface of the dielectric substrate 22, to connect the port 22a with the port 22d. The conductors 27a and

27b can be formed by applying conductive paste and baking the same, or by a proper conductive film forming method, respectively.

According to this embodiment, the aforementioned conductors 27a and 27b are electrically connected with each other on both ends via through hole electrodes, thereby forming one center electrode.

Similarly, conductors 28a and 28b which are formed on the upper surfaces of the dielectric substrates 23 and 24 form one center electrode, and conductors 29a and 29b which are formed on the upper surfaces of the dielectric substrates 25 and 26 form another center electrode.

In the microwave non-reciprocal circuit element according to this embodiment, the respective center electrodes are formed by the plurality of conductors 27a and 27b to 29a and 29b which are stacked along the direction of thickness, as described above. Also when the widths of the respective conductors 27a to 29b are narrowed following miniaturization of the microwave non-reciprocal circuit element, therefore, conductor losses can be reduced since one center electrode is formed by a plurality of stacked conductors. Thus, it is possible to obtain a microwave non-reciprocal circuit element which is of low losses and miniature.

Figs. 5 to 7 are respective exploded perspective views showing modifications of the microwave non-reciprocal circuit element according to the first embodiment. These modifications are similar to the first embodiment except that center electrode portions are changed, and hence similar portions are denoted by similar reference numerals, to omit description thereof.

In the modification shown in Fig. 5, conductors 27a to 29b are structured to have pairs of electrode portions which are formed to extend through slits 30, as shown in the figure. Thus, it is possible to attain further reduction of conductor losses.

In the modification shown in Fig. 6, on the other hand, conductors 27a and 27b structuring a first center electrode are formed on dielectric substrates 21 and 24. Similarly, conductors 28a and 28b structuring a second center electrode are formed on dielectric substrates 22 and 25. Further, conductors 29a and 29b structuring a third center electrode are formed on dielectric substrates 23 and 26. Thus, the conductors structuring the respective center electrodes may be arranged at random in the direction of thickness in the finally stacked state.

In the modification shown in Fig. 7, respective conductors 27a to 29b are formed on single sides of virtual straight lines connecting centers of pairs of ports which are coupled by the conductors. Representatively describing the conductors 27a and 27b, for example, the conductor 27a is formed on one side of the aforementioned virtual straight line, while the conductor 27b is formed on the other side of the aforementioned virtual straight line. Therefore, the conductors 27a and 27b are arranged not to overlap with each other in the direction of thickness in a stacked state. The conductors stacked on the remaining center electrodes are also arranged not to overlap with each other in the direction of thickness similarly.

Second Embodiment

Fig. 8 is an exploded perspective view for illustrating a microwave non-reciprocal circuit element according to a second embodiment of the present invention. In the microwave non-reciprocal circuit element according to this embodiment, dielectric substrates 31 to 33 are stacked. As to these dielectric substrates 31 to 33, those consisting of a material which is similar to the first embodiment can be employed.

On upper surfaces of the dielectric substrates 31 to 33, hexadic ports 31a to 31f ... 33a to 33f which are arranged around centers at regular intervals are formed by applying conductive films to be electrically connected to through hole electrodes respectively. Further, a conductor 34 is formed to connect the ports 31a and 31d with each other, while a conductor 35 is formed to connect the ports 32c and 32f with each other and a conductor 36 is formed to connect the ports 33b and 33e with each other similarly.

As to the remaining ports, on the other hand, conductors 40a to 40d, 41a to 41d and 42a to 42d are formed to be electrically connected to the respective ports and through hole electrodes 37a to 37d, 38a to 38d and 39a to 39d which are formed on positions close to center sides of the upper surfaces of the dielectric substrates 31 and 33 respectively.

The aforementioned conductors 40a to 42d are formed to partially overlap with any of the conductors 34 to 36 which are stacked with each other through the dielectric substrates 31 to 33, respectively. Further, the same are electrically connected to center electrodes which are stacked to overlap with each other by the through hole electrodes.

For example, the conductors 40b and 40d are formed to extend in the same direction as the conductor 35 on the dielectric substrate 32, while the conductors 42b and 42d are also formed to extend in the same direction as the conductor 35 similarly. Further, these conductors 40b, 40d, 42b and 42d are electrically connected with the conductor 35. In the stacked state, therefore, not only the aforementioned conductor 35 but the aforementioned conductors 40b, 40d, 42b and 42d are connected between a pair of ports, whereby one center electrode is structured by a plurality of stacked conductors, similarly to the first embodiment. Thus, conductor losses can be reduced also when miniaturization so progresses that the widths of the respective conductors must inevitably be narrowed similarly to the first embodiment, whereby it is possible to obtain a microwave non-reciprocal circuit element which is of low losses and miniature.

As obvious from the second embodiment, the plurality of conductors for structuring the center electrodes in the present invention may simply extend in the same directions so far as the same are conductors which are arranged to connect pairs of ports with each other, and it is not necessary that all of the respective conductors directly electrically connect pairs of ports with each other.

Third Embodiment

As a third embodiment, the following concrete experimental example is described.

Magnetic powder mainly composed of yttrium oxide (Y_2O_3) and iron oxide (Fe_2O_3) was dispersed in an organic solvent with a polyvinyl alcohol binder, to prepare a magnetic slurry. The prepared magnetic slurry was employed to mold a magnetic green sheet having a uniform thickness of several 10 μm by a doctor blade coater, and the sheet was punched to have a rectangular shape of 40 mm x 20 mm.

A magnetic green sheet 51 having a rectangular plane shape shown in Fig. 9 was prepared in the aforementioned manner. Conductor paste prepared by mixing palladium powder and platinum powder with an organic solvent was printed on an upper surface of the aforementioned magnetic green sheet 51 by screen printing, to prepare magnetic green sheets 52 to 54 shown in Figs. 10(a) to (c). On the magnetic green sheets 52 to 54, conductors 55 to 57 of elongated rectangular shapes are formed by printing conductive paste in the aforementioned manner respectively. These conductors 55 to 46 are formed to deviate from each other by about 120° about centers of the respective green sheets 52 to 54.

Then, as shown in Fig. 11, a laminate was obtained by stacking a plurality of magnetic green sheets 52 prepared in the aforementioned manner, also stacking plural magnetic green sheets 53 and 54 similarly, further stacking these, stacking a plurality of blank magnetic green sheets 51 having no conductors printed on upper and lower portions, and compression-bonding theses green sheets in the direction of thickness. Fig. 12 shows this laminate.

As obvious from Fig. 12, a plurality of conductors 55 to 57 are stacked in the laminate 58 through magnetic layers as shown in the figure. The plurality of conductors 55 to 57 finally structure center electrodes respectively.

Then, the aforementioned laminate 58 was punched into the form of a disc having a diameter of about 10 mm about a portion where the conductors 55 to 57 intersected with each other, to obtain a discoidal unfired laminate chip. Fig. 13 shows an exploded perspective view of the discoidal laminate chip obtained in this manner. As obvious from Fig. 13, the conductors 55 to 57 are stacked in a state electrically insulated from each other through the magnetic layers respectively in the aforementioned discoidal laminate chip. In Fig. 13, reference numerals for the initially prepared magnetic green sheets are applied to the magnetic layers which were punched into the form of discs respectively.

Then, the discoidal laminate chip prepared in the aforementioned manner was fired by maintaining the same at a temperature of 1300°C to 1500°C for 5 to 15 hours, to obtain a sintered body. Fig. 14 shows the obtained sintered body in a perspective view. In the sintered body 60, a plurality of conductors 55 to 57 are stacked in the interior in plural through sintered body layers respectively. An outer peripheral side surface 60a of the sintered body 60 obtained in the aforementioned manner was polished to reliably expose both ends of the conductors 55 to 57 on the side surface, and forming external electrodes electrically connected to the respective conductors were formed. formation of the external electrodes were carried out by applying conductive paste containing a glass frit and baking the same. A microwave non-reciprocal circuit element according to the third embodiment was obtained in the aforementioned manner.

In the microwave non-reciprocal circuit element according to this embodiment, one center electrode is formed by the aforementioned plurality of conductors 55, while one center electrode is similarly formed by the plurality of conductors 56 and one center electrode is formed by the plurality of conductors 57 similarly.

Then, earth electrodes were formed on upper and lower surfaces of the sintered body 60 of the non-reciprocal circuit element obtained in the aforementioned manner, or earth electrodes consisting of metal plates were brought into contact with the same, and respective single ends of the aforementioned three center electrodes were electrically connected and grounded. Further, permanent magnets were brought into contact with upper and lower portions of the sintered body, and a dc magnetic field was applied to the center electrodes by the permanent magnets. Further, the aforementioned permanent magnets were held by metal yokes to form a magnetic closed magnetic circuit, for structuring a non-reciprocal circuit device. An impedance matching capacitor which is connected to this type of non-reciprocal circuit device may be provided in the aforementioned sintered body, or in the exterior of the sintered body.

In the microwave non-reciprocal circuit element according to this embodiment, the center electrodes are formed by the plurality of conductors 55 to 57 respectively as described above, whereby conductor losses can be reduced also when miniaturization of the, microwave non-reciprocal circuit element progresses similarly to the first embodiment. Therefore, it is possible to obtain a microwave non-reciprocal circuit element which is of low losses and miniature. In addition, stacking can be made by ceramic stacking · integral firing techniques as described above, whereby the number of components can be reduced as compared with a conventional method of manufacturing a microwave non-reciprocal circuit element employing metal foil. Further, it is also possible to omit a complicated manual operation. In addition, the conductors are formed by a printing step, whereby thinner conductors can be readily structured. Thus, it is possible to readily obtain a further miniaturized microwave non-reciprocal circuit element.

While magnetic sheets molded by a doctor blade coater were employed in the third embodiment, dielectric sheets may be employed in place of the magnetic sheets.

While the conductors were formed on the green sheets by screen printing in the aforementioned manufacturing method, another printing method such as gravure printing may be employed.

Further, preparation of the magnetic or dielectric sheets is not restricted to the doctor blade coater, but may alternatively be carried out by another method such as extrusion molding.

Further, previously molded green sheets may not be employed but the aforementioned laminate may be formed by repeating steps of printing paste containing a dielectric substance or a magnetic substance on support films of polyester or the like, drying the same and thereafter printing conductive paste.

While the plurality of conductors forming one center electrode were stacked in the direction of thickness and the plurality of conductors forming another center electrode were then stacked in the direction of thickness in the third embodiment, further, conductors forming different center electrodes may be stacked at random in the direction of thickness also in the third embodiment, similarly to the modification of the first embodiment.

Further, the plane shapes of the conductors 55 to 57 forming the center electrodes can also be modified in various manners, similarly to the modifications of the first embodiment.

Fourth Embodiment

While the plurality of conductors for structuring the respective center electrodes have been stacked in the directions of thickness through magnetic or dielectric layers in the aforementioned first to third embodiments, a plurality of conductors may be formed on the same height positions so that the plurality of conductors which are formed on the same height positions are further stacked in the direction of thickness through dielectric or magnetic layers in the microwave non-reciprocal circuit element. Fig. 15 shows such an example in an exploded perspective view.

In a microwave non-reciprocal circuit element according to a fourth embodiment, a pair of conductors 71a and 71b are formed in parallel with each other on a sheet 72 consisting of a dielectric material or an insulator material, as obvious from Fig. 15. A first center electrode portion 77 consisting of a plurality of conductors 71a and 71b is formed by stacking three such sheets 72. Similarly, a second center electrode portion 78 is formed by stacking a plurality of sheets 74 consisting of a dielectric material or an insulator material provided with pairs of conductors 73a and 73b. Further, a third electrode portion 79 is formed by stacking a plurality of sheets 76 consisting of a dielectric material or an insulator material provided with pairs of conductors 75a and 75b. The aforementioned first to third center electrode portions 77 to 79 are made to intersect with each other, to form center electrodes so that mutual conductors form angles of 120 degrees in a stacked state. 80 and 81 denote ferrites.

Fig. 16 is a partially fragmented sectional view of the microwave non-reciprocal circuit element according to the fourth embodiment. This sectional portion illustratively shows only a portion where the aforementioned conductors 71a, 73a and 75a overlap with each other in the direction of thickness.

Preferably, insulating layers 82 and 83 may be interposed between the first and third center electrode portions 77 to 79 in the microwave non-reciprocal circuit element according to the fourth embodiment, as shown in Fig. 17.

Also in the microwave non-reciprocal circuit element according to the fourth embodiment shown in Figs. 15 and 16 and the microwave non-reciprocal circuit element according to the modification shown in Fig. 17, one center electrode is formed by a plurality of conductors overlapping with each other in the direction of thickness similarly to the cases of the first to third embodiments, whereby conductor losses in the center electrodes can be reduced similarly to the cases of the first to third embodiments. Further, the Q values of the center electrodes can be improved since electrical resistances of the respective center electrodes can be reduced.

Fifth Embodiment

While conductor losses can be reduced since the center electrodes are formed by the plurality of conductors which are stacked in the direction of thickness as hereinabove described in the aforementioned first to fourth embodiments, it is possible to further improve electric characteristics of a non-reciprocal element more preferably, by devising arrangement of conductors structuring first to third center electrode portions, as in a fifth embodiment described in the following.

Fig. 18 shows a basic equivalent circuit of a general lumped element type isolator. This isolator 101 is formed by arranging three central conductors L1 to L3 on a ferrite 102 in an electrically insulated state to intersect at angles of 120 degrees, and applying a dc magnetic field Hex in the axial direction of the ferrite 102. First ends of the aforementioned respective central conductors L1 to L3 are connected to the ground, while matching capacitive elements C1 to C3 are connected to second ends. Further, a terminal resistor R3 is connected to a terminal P3 of one center electrode L3 among the aforementioned respective central conductors L1 to L3. The aforementioned isolator 101 has a function of transmitting a signal from a terminal P1 to a terminal P2, and absorbing a wave approaching from the terminal P2 by the terminal resistor R3 for inhibiting transmission to the terminal P1, thereby preventing an unnecessary wave from entering a power amplifier or the like.

Referring to the non-reciprocal circuit element according to the fourth embodiment indicated by the equivalent circuit of Fig. 18, for example, there is such a problem that distributed capacitances across the first to third center electrode portions are not equal to each other. Namely, the first center electrode portion 77 and the third center electrode portion 79 are structured on upper and lower portions of the second center electrode portion 78 in the structures shown in Fig. 15 and Fig. 16. Therefore, a distributed capacitance across the second center electrode portion 78 and the first center electrode portion 77 and a distributed capacitance across the second center electrode portion 78 and the third center electrode portion 79 are equal to each other. However, there is such a problem that a distributed capacitance across the first and third center electrode portions 77 and 79 is reduced, dissimilarly to the distributed capacitances across the aforementioned second center electrode portion 78 and the outer center electrode portions 77 and 79. In other words, a distributed capacitance C3-1 across the terminal P1 and the terminal P3 shown in Fig. 18 is reduced as compared with distributed capacitances C1-2 and C2-3.

In order to compensate for the shortage of the aforementioned distributed capacitance C3, it is conceivable to increase matched capacitances of the matching capacitive elements C1 and C3 which are connected to the terminals P1 and P3. When the capacitances of the matching capacitive elements C1 and C3 are increased, however, the operation balance is so deteriorated that dispersion is caused in insertion loss characteristics and isolation characteristics across the respective terminals P1 to P3, return loss characteristics and uniform electric characteristics cannot be obtained.

A lumped element type isolator according to the fifth embodiment solves the aforementioned problems, and hence the same shows further preferable mode of the present invention.

Referring to Figs. 19 to 21, 105 is an isolator characterizing this embodiment, and this is structured by arranging first to third center electrode portions 106 to 108 described later so that the same intersect with each other at intervals of 120 degrees, arranging ferrites 109 and 110 on upper and lower portions thereof, and integrally forming the ferrites 109 and 110 and the aforementioned respective center electrode portions 106 to 108.

Earth plates 111a and 111b are arranged on outer surfaces of the aforementioned respective ferrites 109 and 110, and these earth plates 111a and 111b are connected to outer peripheral surfaces of the aforementioned isolator 105 through earth electrodes 112a to 112c which are formed at intervals of 120 degrees along the circumferential direction thereof.

Further, input/output terminal electrodes 113a to 113c are formed between the respective earth electrodes 112a to 112c on the outer peripheral surfaces of the aforementioned isolator 105, and a terminal resistor which is not shown is connected to one terminal electrode 113c among the same. When the aforementioned input/output terminal electrode 113c is connected to an external circuit without connecting this terminal resistor, this embodiment functions as a circulator.

First end portions of the aforementioned first to third center electrode portions 106 to 108 are connected to the aforementioned earth electrodes 112a to 112c respectively, while second end portions are connected to the aforementioned input/output terminal electrodes 113a to 113c respectively.

The aforementioned isolator 5 is stored in a magnetic yoke forming a magnetic closed circuit which is not shown, and is structured by applying a bias dc magnetic field to axial cores of the aforementioned ferrites 109 and 110 by permanent magnets which are arranged in the yoke.

The aforementioned first to third center electrode portions 106 to 108 are formed by pattern-forming triple conductors 114a to 114c, 115a to 115c and 116a to 116c on insulating sheets 117 respectively, and alternately stacking the same while opposing the same to each other, and are in such a structure that the second center electrode portion 107 is held by the first and third center electrode portions 106 and 108.

As shown in Figs. 19 and 20, the conductor 114a which is positioned on an outer side of the aforementioned first center electrode portion 106 is arranged adjacently to an outer side of a lower portion of the third center electrode poriton 108, while the conductor 116c which is positioned on an outer side of the third center electrode portion 108 is arranged adjacently to the outer side, i.e. an upper portion of the aforementioned first center electrode portion 108. The conductor 114a of the aforementioned first center electrode portion 106 is connected to the aforementioned terminal electrode 113a and the earth electrode 112a with the aforementioned conductors 114b and 114c, while the conductor 116c of the aforementioned third center electrode portion 108 is connected to the aforementioned terminal electrode 113c and the earth electrode 112c with the conductors 116a and 116b.

Further, an insulating sheet 118 is interposed between the aforementioned conductor 114a and the third center electrode portion 108, while an insulating sheet 118 is interposed between the aforementioned conductor 116c and the first center electrode portion 106. Thus, distances T between the aforementioned respective conductors 114a and 116c and the center electrode portions 108 and 106 are substantially twice a distance t between the conductors of the central portions respectively.

Description is now made on action/effect of this embodiment.

According to this embodiment, the conductors 114a and 116c which are positioned on the outer sides of the first and third center electrode portions 106 and 108 are replaced and arranged to be adjacent to outer sides of the opposite side center electrode portions 108 and 106 respectively while the distance T therebetween is widened to about twice the distance t between the conductors of the central portion, whereby sufficient distributed capacitances can be attained by these conductors 114a and 116c and the third and first center electrode portions 108 and 106 which are adjacent thereto, and hence values equivalent to the distributed capacitances across the second center electrode portion 107 and the first and third center electrode portions 106 and 108 adjacent thereto. Consequently, the balance of operations between the respective center electrode portions 106 to 108 can be improved, insertion loss characteristics, isolation characteristics and return loss characteristics can be uniformalized, and it is possible to cope with improvement in performance.

According to this embodiment, matched capacitances of center electrodes can be taken by the distributed capacitances across the aforementioned respective center electrode portions 106 to 108 while distributed capacitances can be taken across the respective conductors 114a and 116c and the earth plates 111a and 111b of the ferrites 109 and 110, whereby it is possible to attain matched capacitances in the aforementioned ferrites 109 and 110. Consequently, a conventional matching circuit element which has been separately added can be made unnecessary, it is possible to cope with miniaturization and weight reduction due to capability of reducing the number of components, while it is possible to contribute to cost reduction. Alternatively, this embodiment may be combined with a matching circuit element.

According to this embodiment, further, the conductors 114a to 114c, 115a to 115c and 116a to 116c of the respective center electrode portions 106 to 108 are stacked into multilayer structures, whereby Q values of the center electrode portion can be improved, and insertion losses can be thereby reduced. Further, it is also possible to employ a technique of cofiring the aforementioned respective center electrodes, the matched capacitances etc. in the ferrites, and the aforementioned respective electric characteristics can be further improved in this case.

As obvious from Fig. 21, further, it is preferable to make the triple conductors of different height positions forming the center electrode portions not to overlap with each other in the direction of thickness, for stabilization of the characteristics.

While each center electrode portion has been formed by three layer center electrodes in the aforementioned embodiment, the present invention is not restricted to this but the same may be formed by two or at least four layer center electrodes.

Fig. 22 shows a modification of the aforementioned embodiment, and in this figure, reference numerals identical to those in Fig. 19 denote the same or corresponding portions. This modification is such an example that each of center electrode portions 106 to 108 is formed by four layer center electrodes, and an effect similar to that of the aforementioned embodiment is attained also in this case by replacing and arranging center electrodes on outer sides of the firs and third center electrode portions 106 and 108 respectively.

While each of the aforementioned embodiments has been applied to a case of bringing an isolator into a discoidal shape, a shape of a rectangular parallelopiped or a polygon is also available with no particular restriction. Further, while the aforementioned embodiments have been described with reference to isolators, the present invention is also applicable to a circulator as a matter of course, and is also applicable to other microwave high-frequency components.

Claims

1. A microwave non-reciprocal circuit element comprising:

   a plurality of center electrodes being arranged to intersect with each other in a state being electrically insulated from each other; and

   a microwave magnetic or dielectric body being arranged on an intersecting portion of said plurality of center electrodes,

   said each center electrode being formed by a plurality of conductors being stacked with each other through the microwave magnetic or dielectric body.

2. The microwave non-reciprocal circuit element in accordance with claim 1, wherein the plurality of conductors forming said each center electrode are embedded in the microwave magnetic or dielectric body, the respective center electrodes being successively arranged in the direction of thickness in said microwave magnetic or dielectric body.

3. The microwave non-reciprocal circuit element in accordance with claim 1, wherein the plurality of conductors forming said each center electrode are embedded in the microwave magnetic or dielectric body, a plurality of conductors forming one center electrode and a plurality of conductors forming another center electrode being stacked at random in the direction of thickness in the microwave magnetic or dielectric body.

4. The microwave non-reciprocal circuit element in accordance with claim 1, having first to third center electrode portions consisting of said plurality of conductors and being successively arranged in the direction of thickness,

   at least one conductor forming said first center electrode portion is arranged on an outer side of the third center electrode portion in the direction of thickness, and at least one conductor forming the third center electrode poriton is arranged on an outer side of the first center electrode portion in the direction of thickness, and

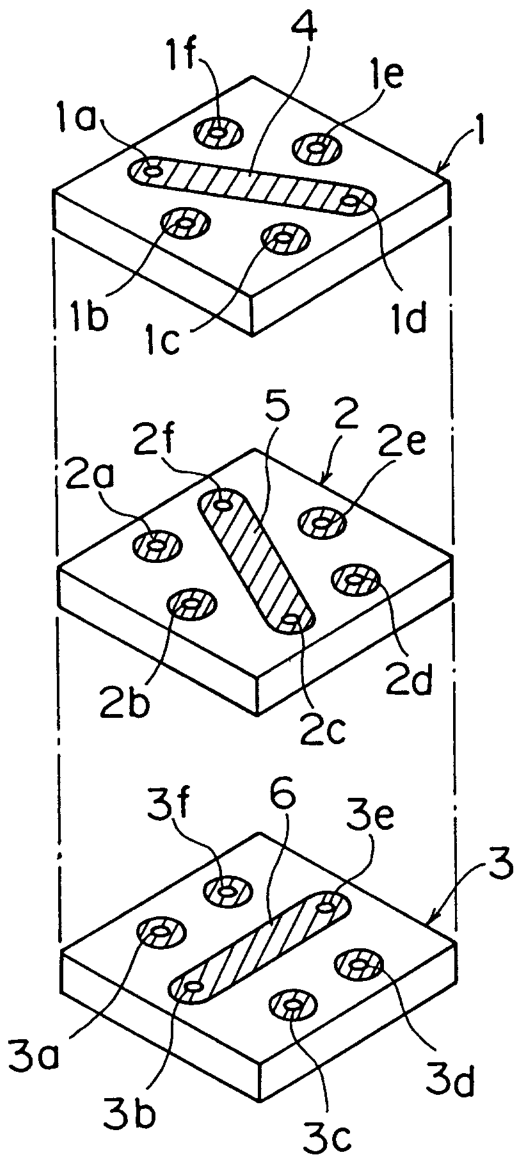
   the distances between at least one conductor arranged on the outer side of said third center electrode portion and at least one conductor arranged on the outer side of the first center electrode portion, and the conductor of the third or first center electrode portion being adjacent in the direction of thickness is made larger than the distance between other adjacent conductors.

5. The microwave non-reciprocal circuit element in accordance with claim 4, wherein the distance between at least one conductor arranged on the outer side of said third center electrode portion and at least one conductor arranged on the outer side of the first center electrode portion, and the conductor of the third or first center electrode portion being adjacent in the direction of thickness is made about twice the distance between other adjacent conductors.

6. The microwave non-reciprocal circuit element in accordance with claim 4 or 5, wherein said first to third center electrode portions are so arranged that the conductors thereof intersect with each other at angles of 120 degrees.

7. The microwave non-reciprocal circuit element in accordance with any of claims 1 to 5, wherein a pair of said conductors are formed on the same height position.

F I G. 1



F I G. 2

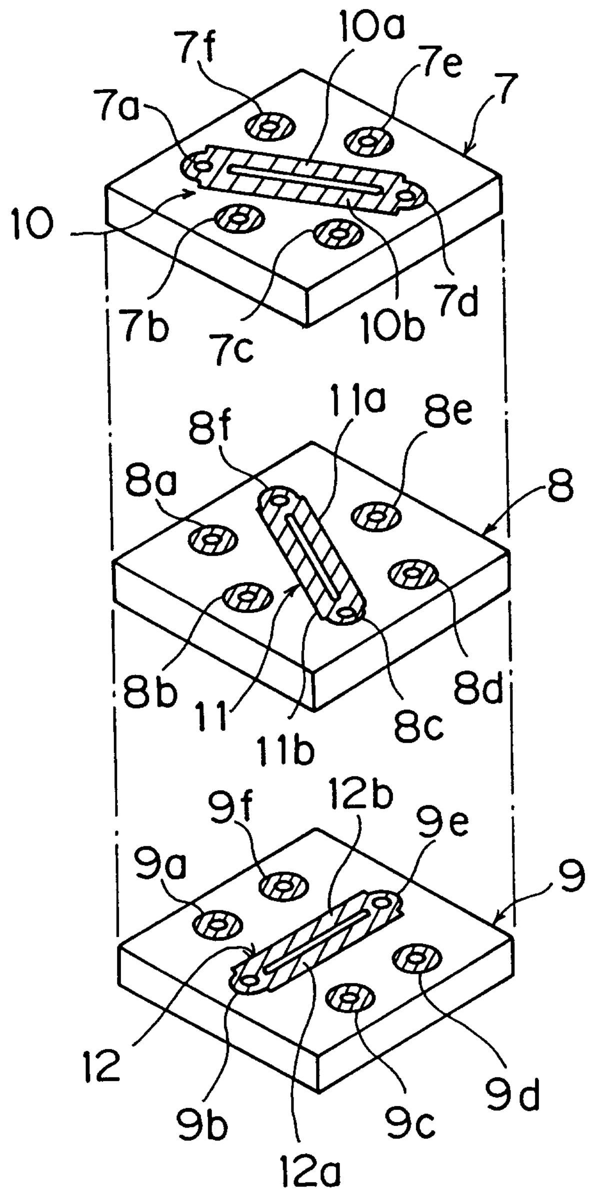

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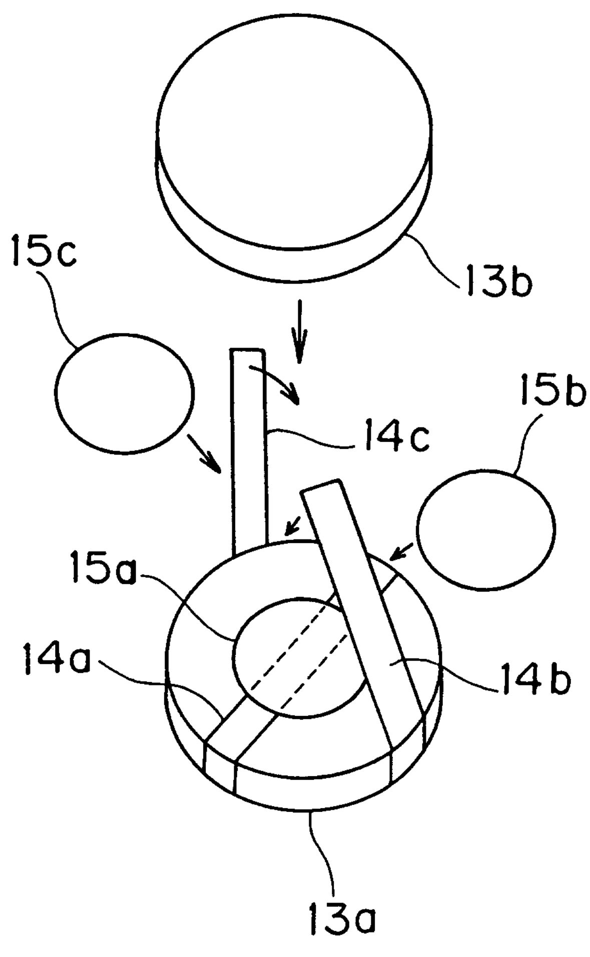
FIG. 3



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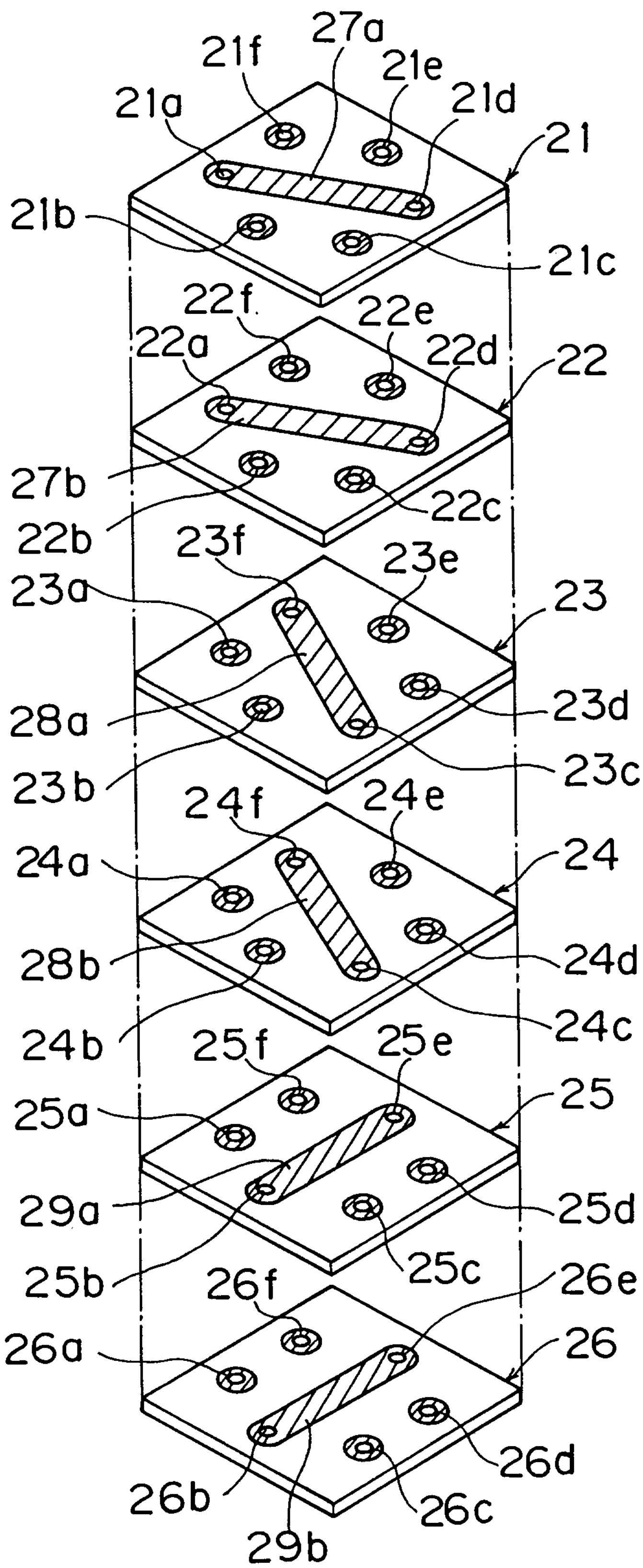
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F I G. 5

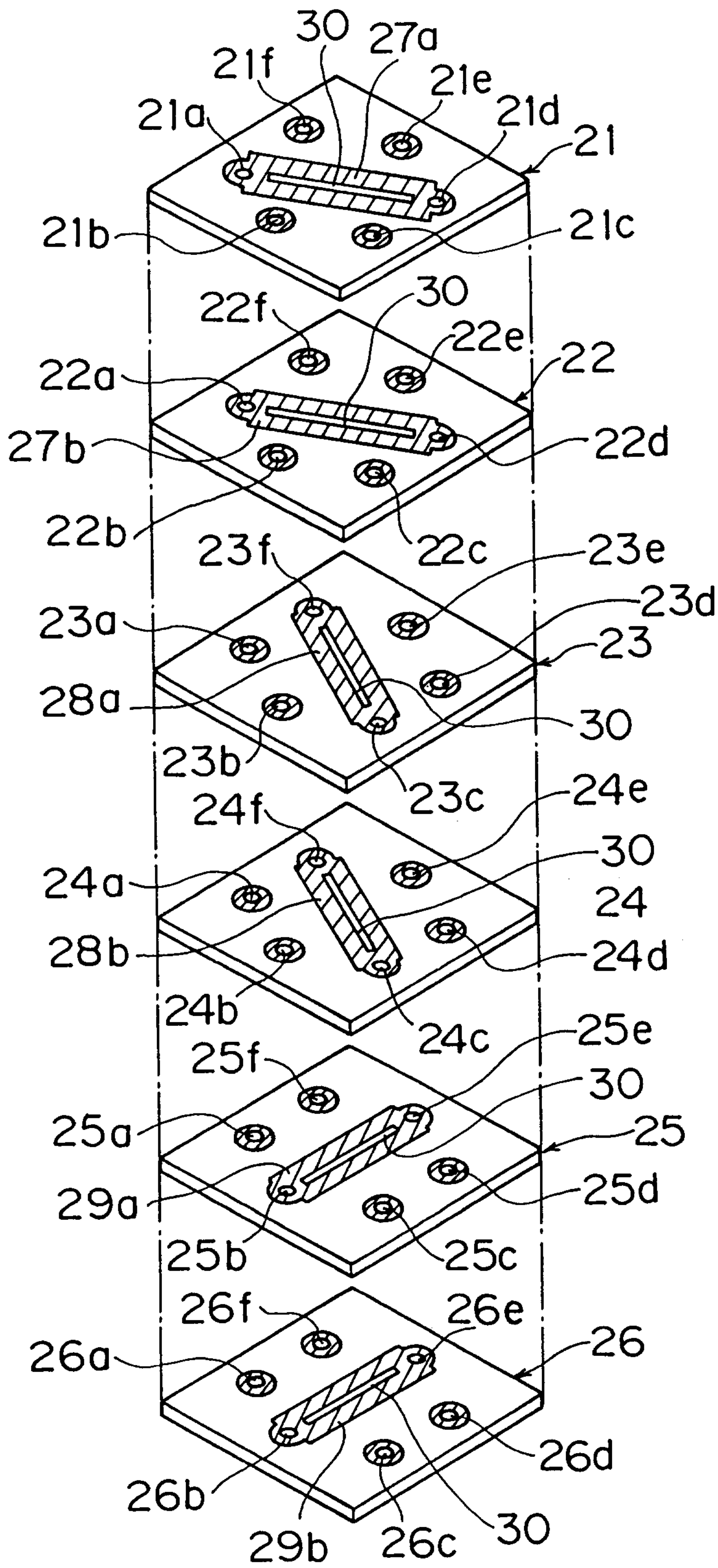
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FIG. 6

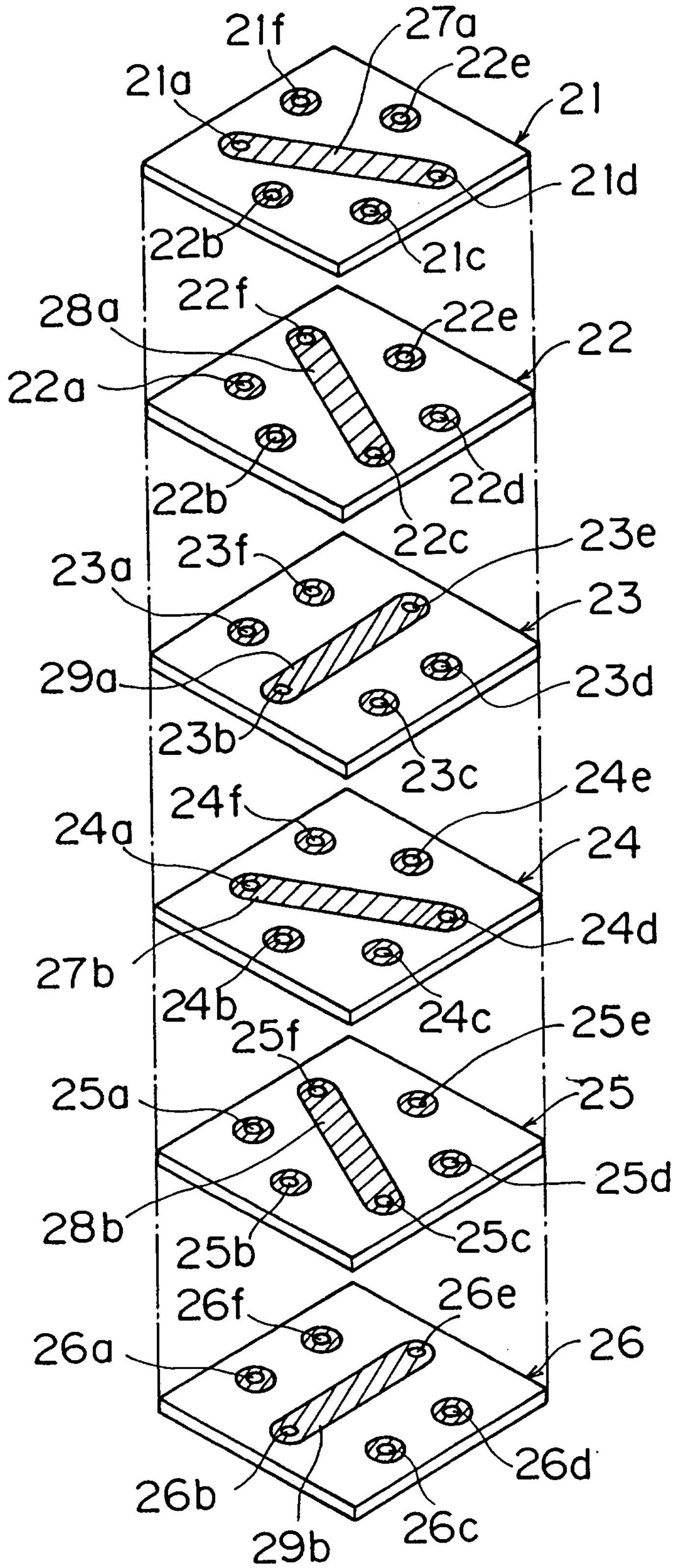
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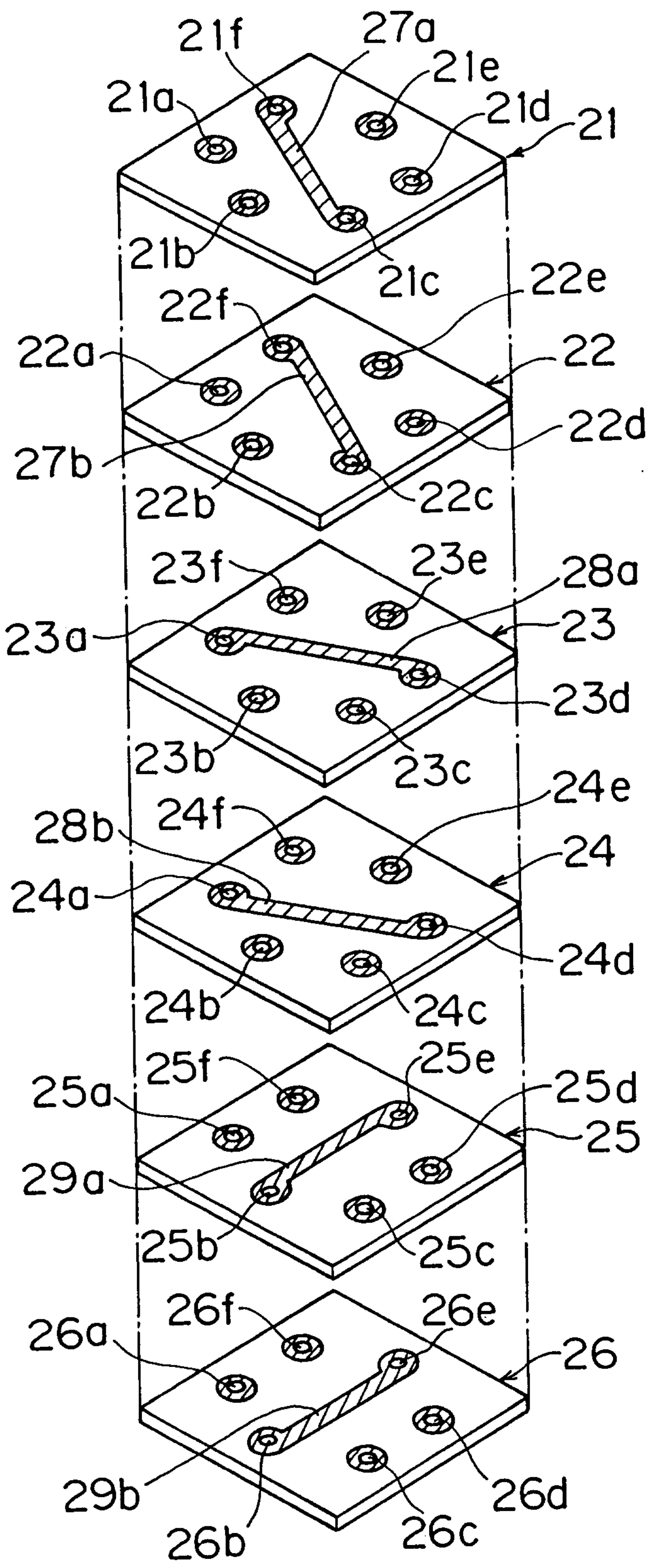
FIG. 7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F I G. 8

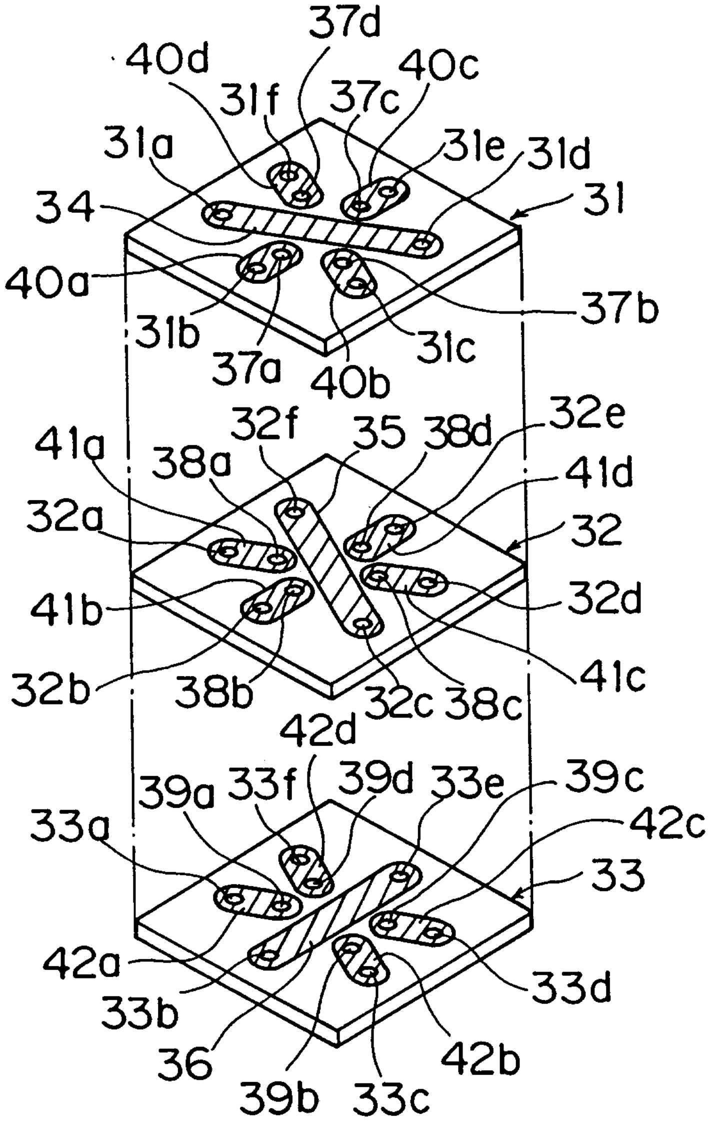
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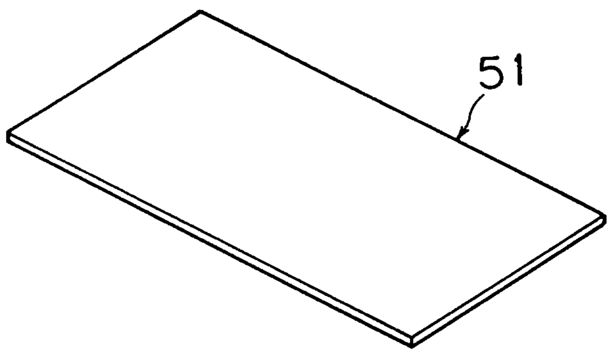
FIG. 9



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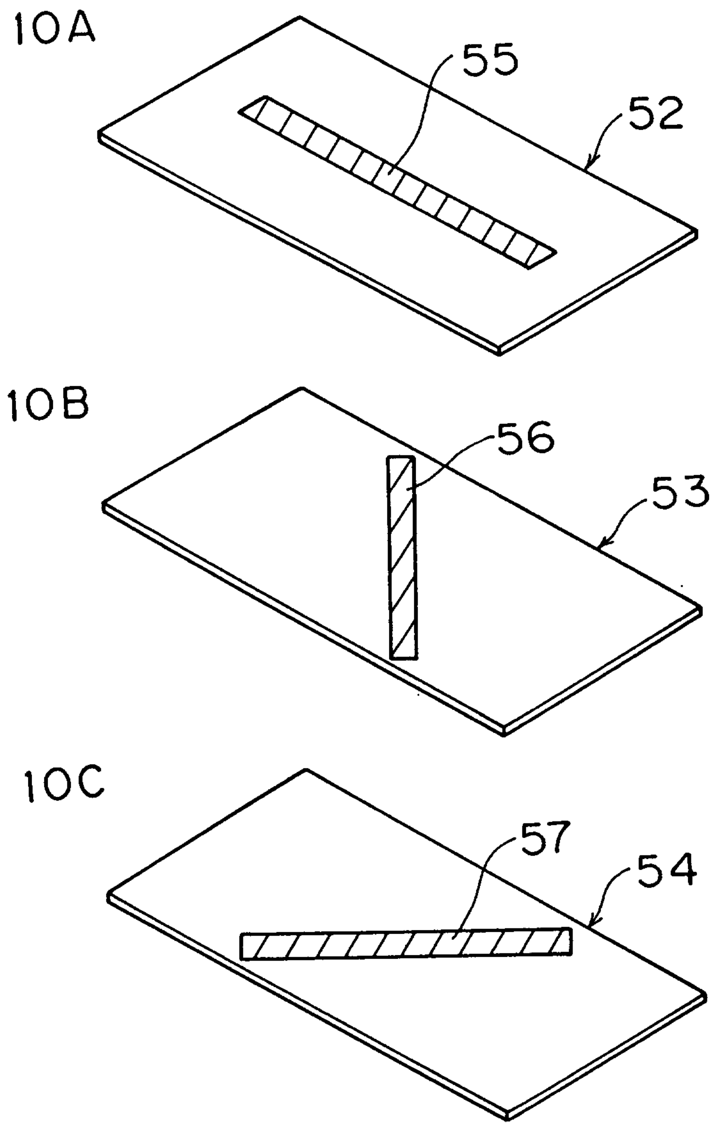


FIG. 11

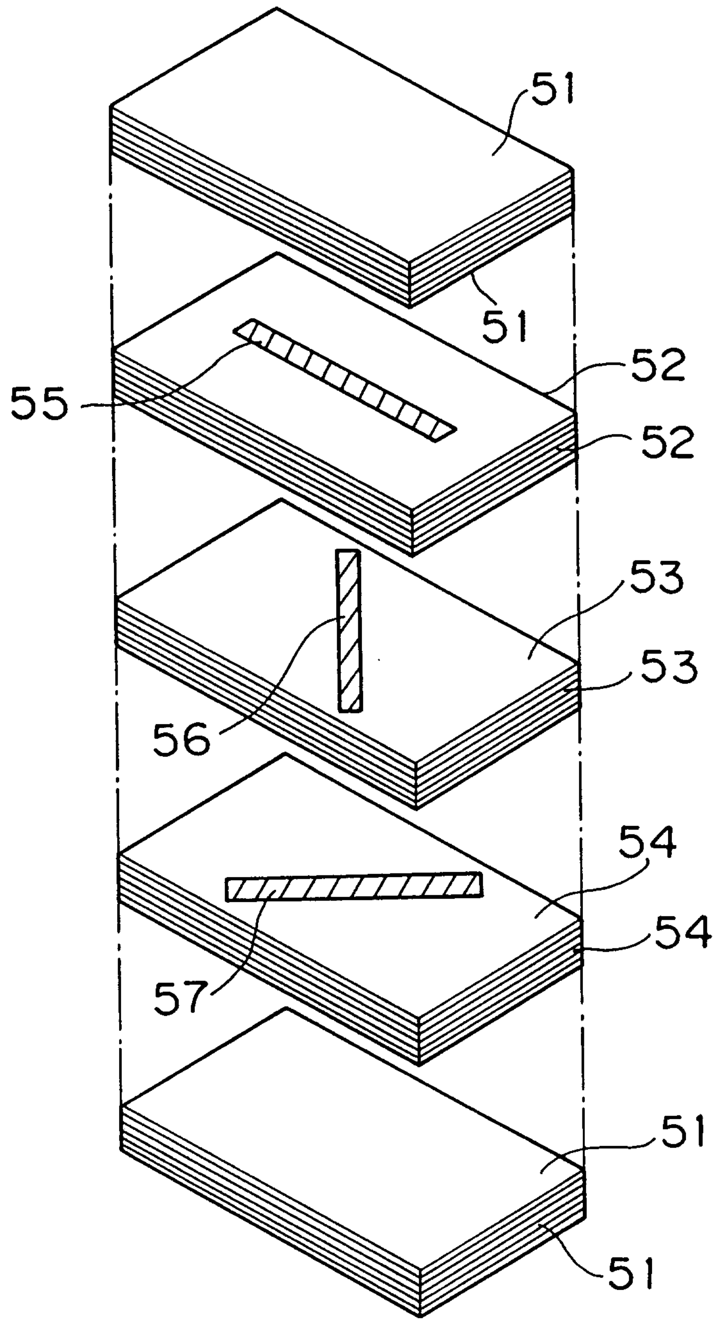


FIG. 12

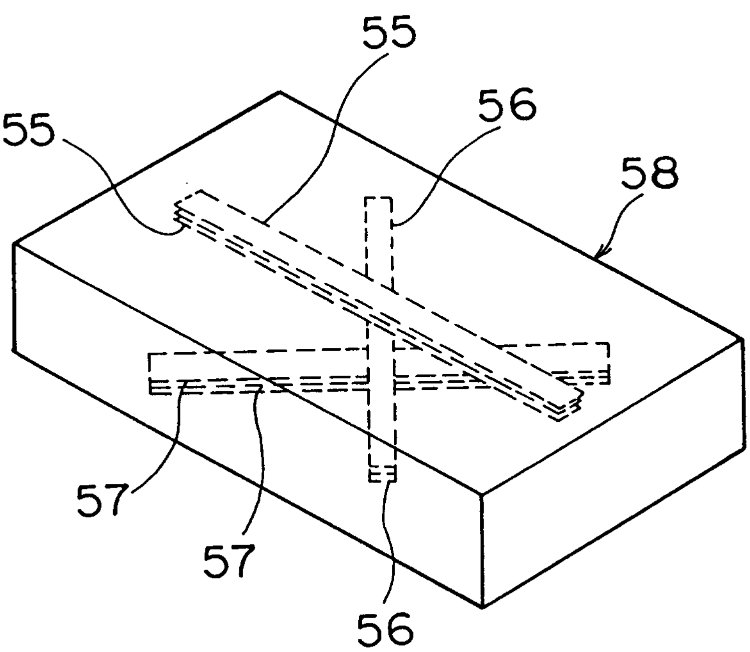
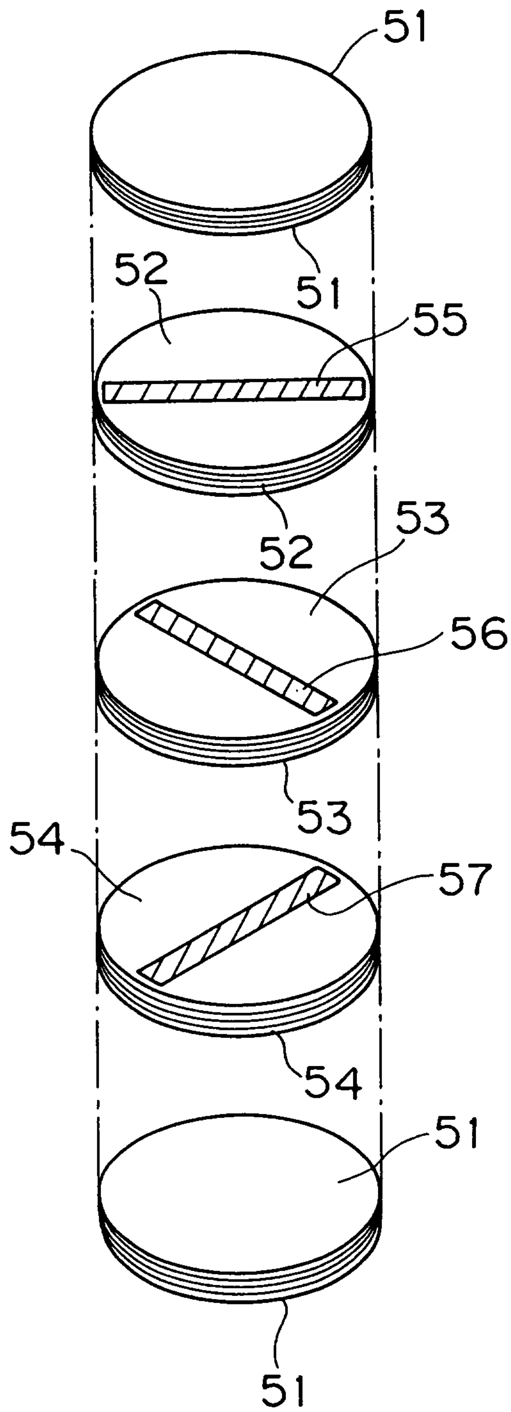


FIG. 13



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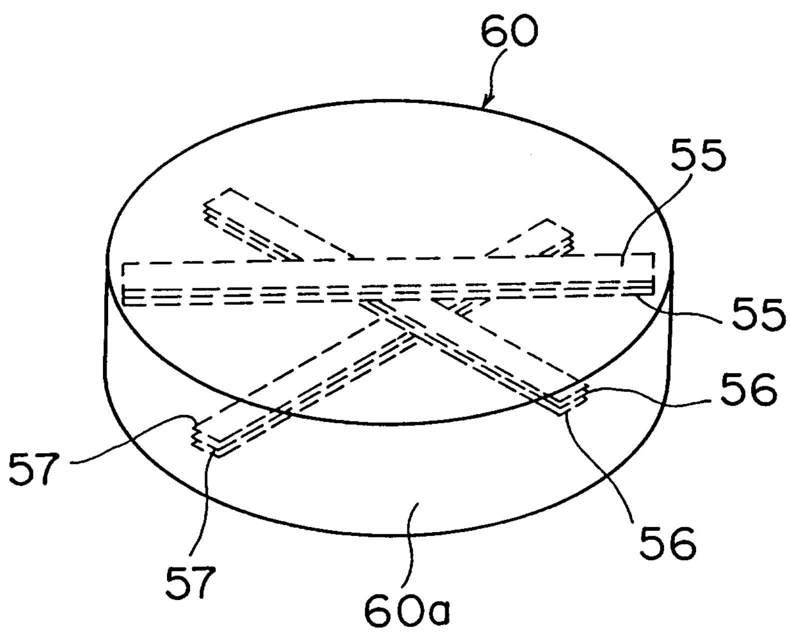

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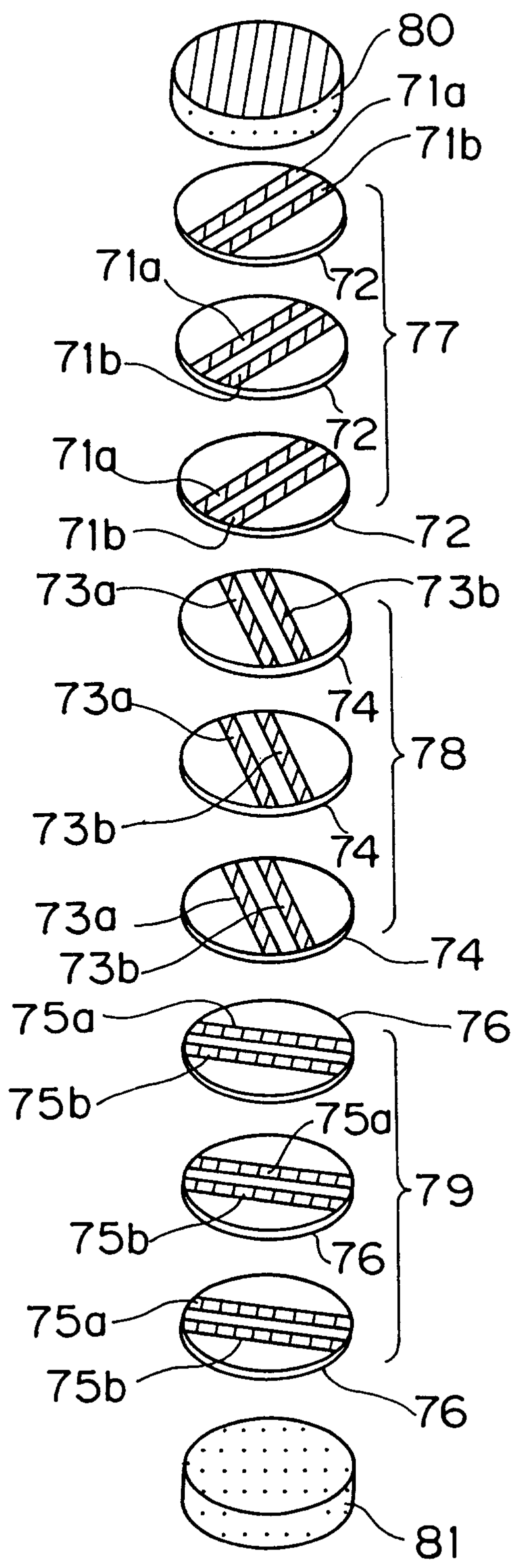
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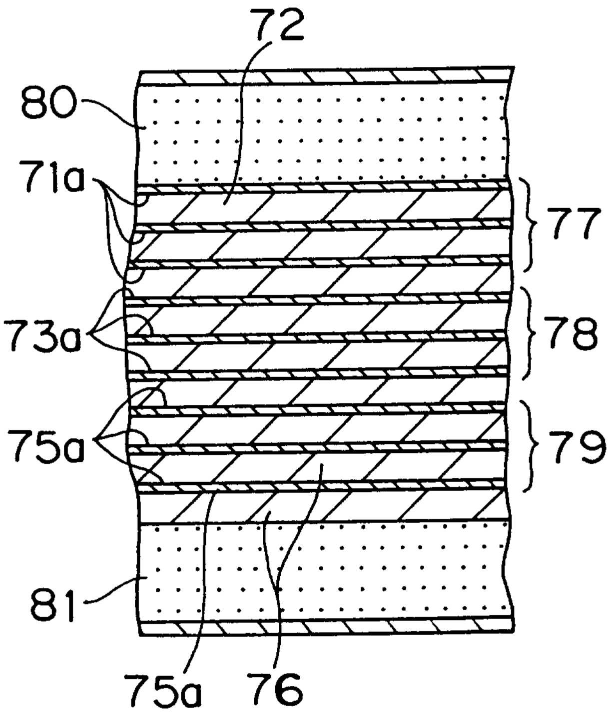

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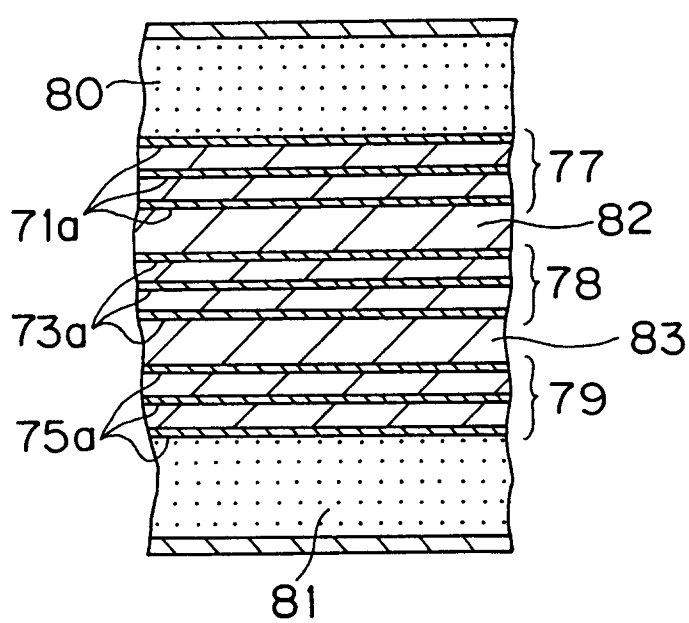
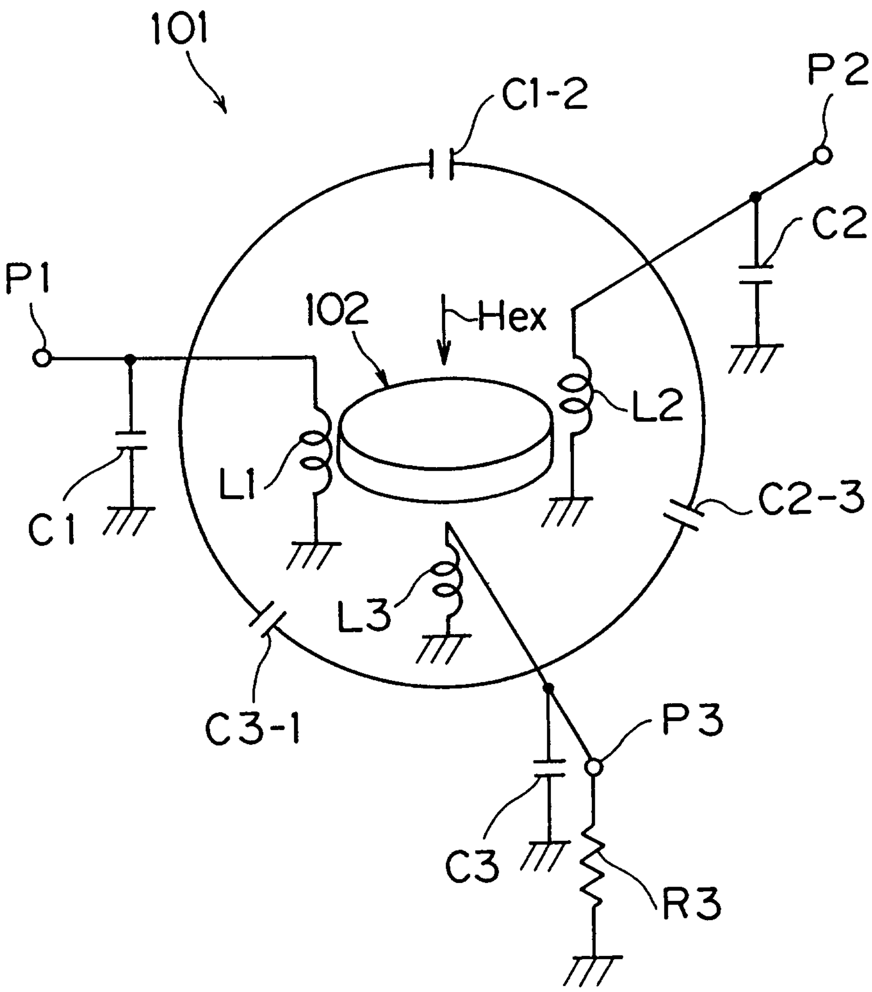


FIG. 18



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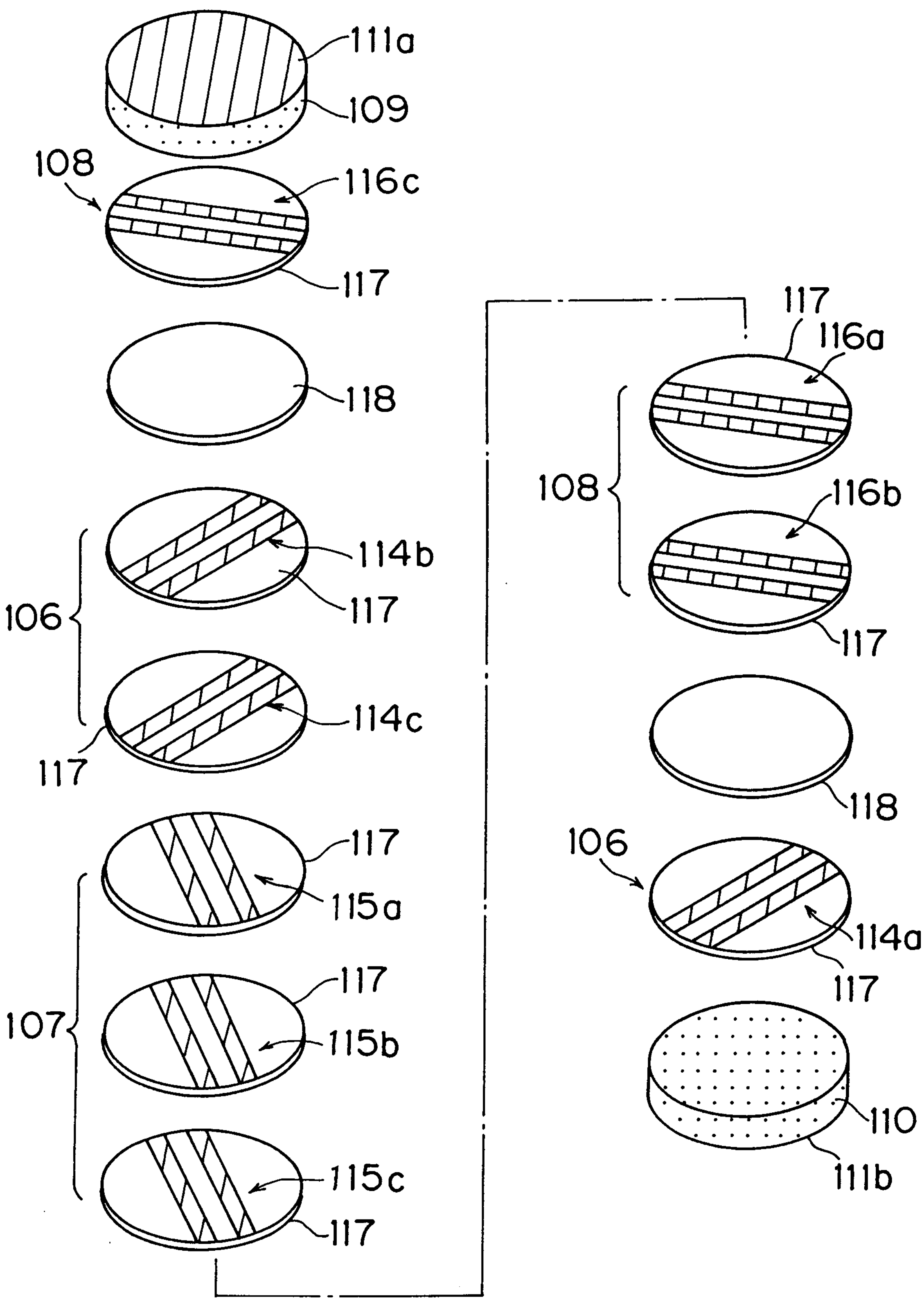
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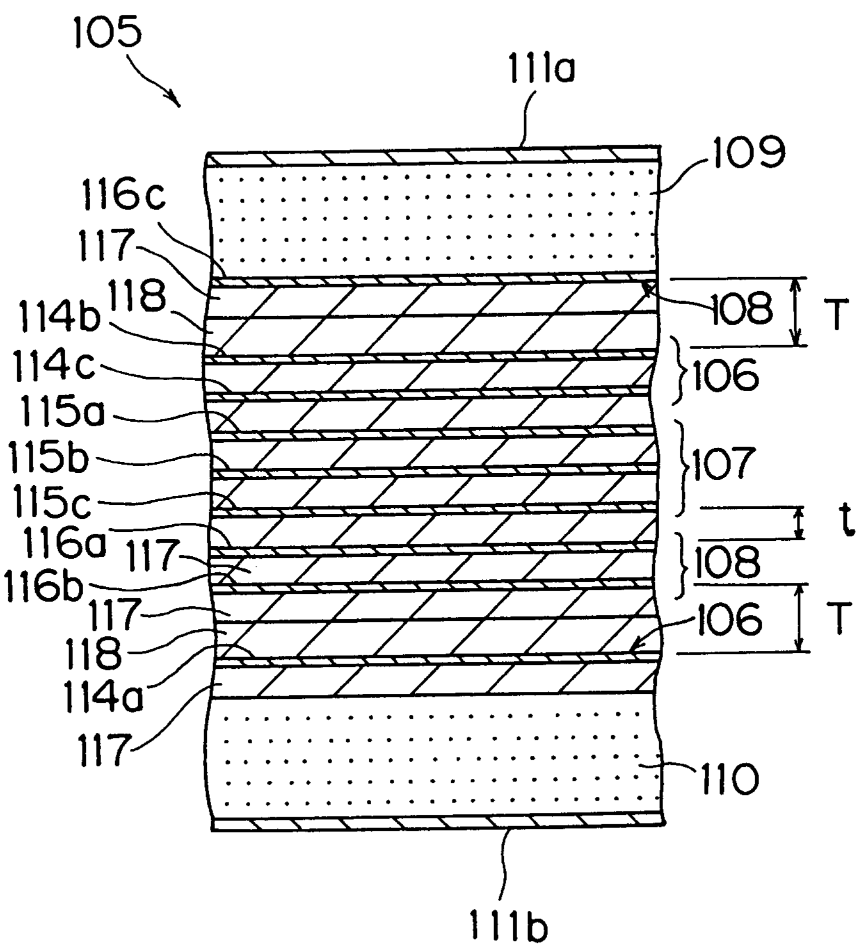
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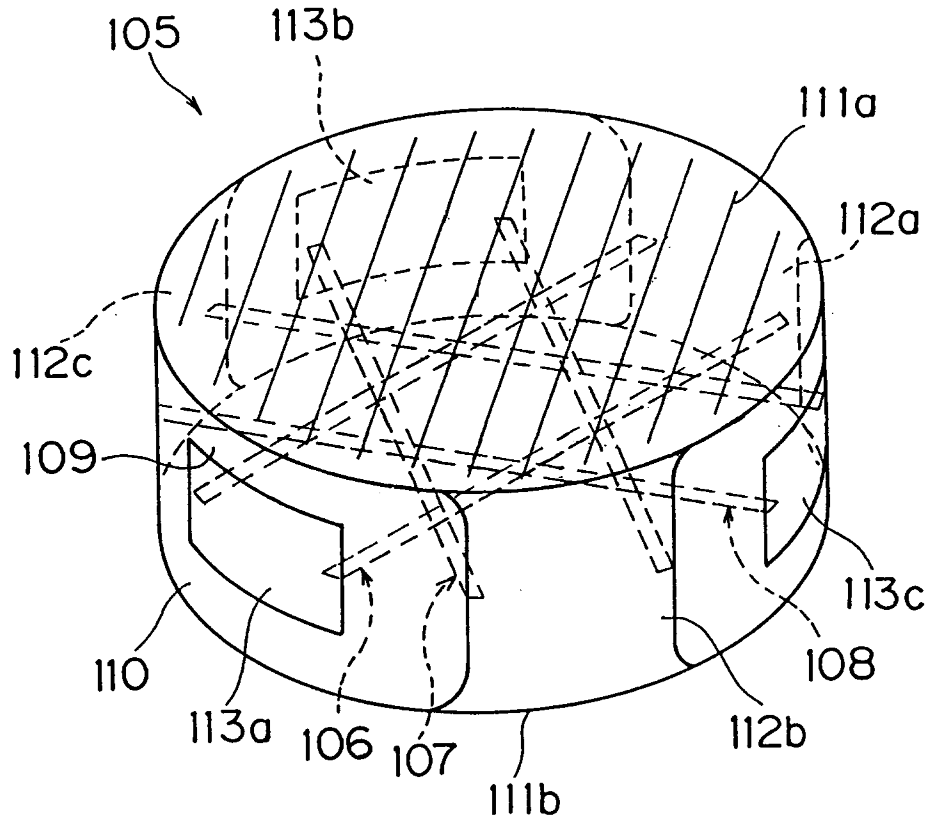
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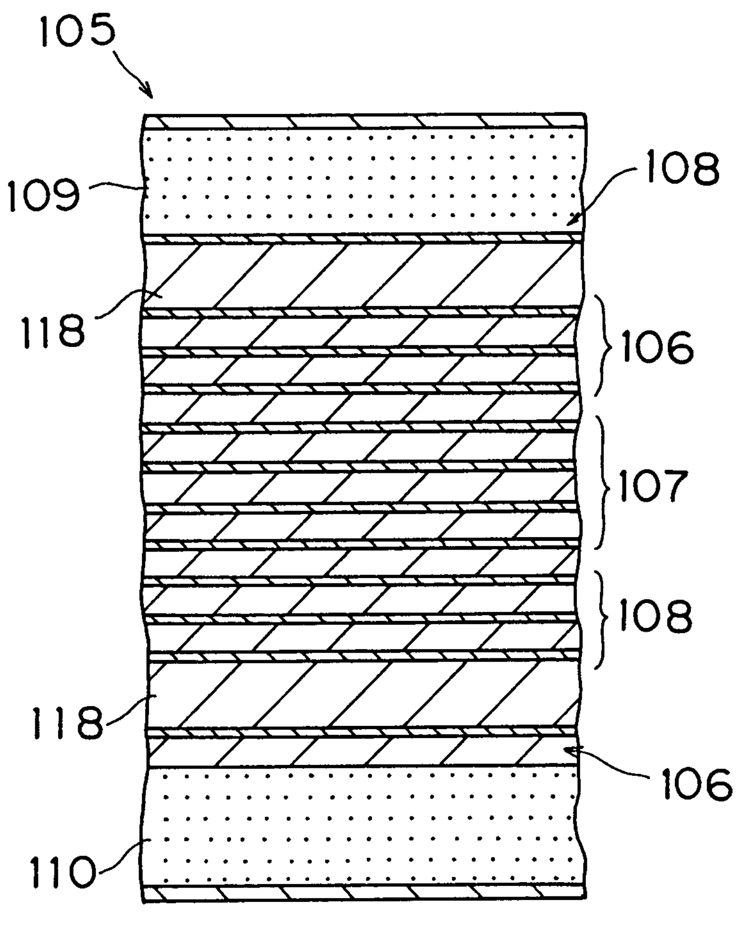

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP94/01623

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl6 H01P1/383, H01P11/00

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)

Int. Cl5 H01P1/383, H01P1/36, H01P11/00

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

Jitsuyo Shinan Koho 1926 - 1994
Kokai Jitsuyo Shinan Koho 1971 - 1994

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

WPI, WPI/L

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, A, 4-345201 (TDK Corp.), December 1, 1992 (01. 12. 92), Fig. 1, (Family: none)	1, 2 3
X Y	JP, A, 57-26912 (Hitachi Metals, Ltd.), February 13, 1982 (13. 02. 82), Fig. 5, (Family: none)	1, 2, 7 3
A	JP, A, 5-299904 (Murata Mfg. Co., Ltd.), November 12, 1993 (12. 11. 93), Full descriptions, all drawings & GB, A, 2266412 & DE, A, 4312455	1-7
A	JP, A, 5-304404 (Murata Mfg. Co., Ltd.), November 16, 1993 (16. 11. 93), Full descriptions, all drawings & GB, A, 2266412 & DE, A, 4312455	1-7
EX	JP, A, 6-291514 (Murata Mfg. Co., Ltd.), October 18, 1994 (18. 10. 94), Full descriptions, all drawings, (Family: none)	1-3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"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
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Date of the actual completion of the international search	Date of mailing of the international search report
December 14, 1994 (14. 12. 94)	January 10, 1995 (10. 01. 95)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP94/01623

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, A, 57-61314 (Hitachi Metals, Ltd.), April 13, 1982 (13. 04. 82), Fig. 5, (Family: none)	1, 2, 7 3

Form PCT/ISA/210 (continuation of second sheet) (July 1992)