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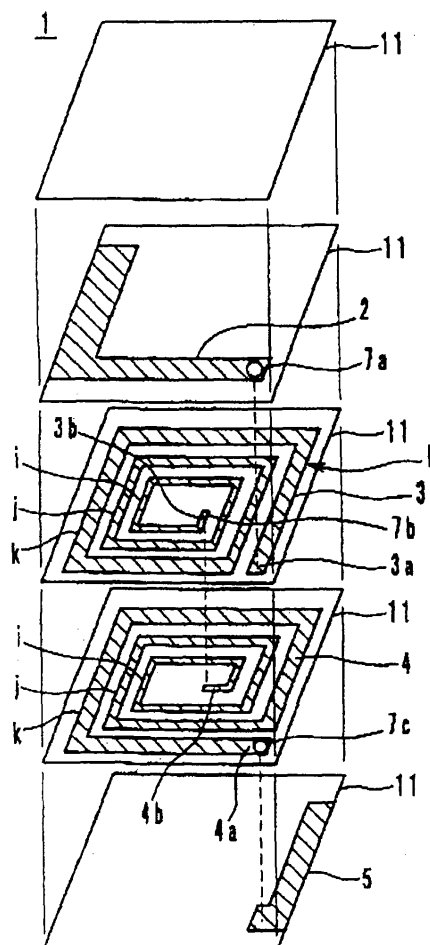
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(54) **Inductor**

(57) There is provided an inductor (1) having a low direct-current resistance and a high Q value. On the surfaces of insulating sheets (11), spiral-shaped coil conductor patterns (3,4) are each formed. Each of the coil conductor patterns (3,4) is set so that the pattern widths of the central portion (j) and the outside portion (k) of the spiral are larger than the pattern width of the inside portion (i) thereof.

FIG. 1



Description**BACKGROUND OF THE INVENTION**5 1. Field of the Invention

[0001] The present invention relates to an inductor, and particularly to an inductor for use in a filter, a resonator, or the like which processes signals in the higher-frequency range.

10 2. Description of the Related Art

[0002] A specific construction example of a conventional inductor of this kind is shown in Fig. 5. An inductor 50 comprises insulating sheets 51 having spiral-shaped coil conductor patterns 53 and 54 formed on the respective surfaces thereof, insulating sheets 51 having lead-out patterns 52 and 55 formed on the respective surfaces thereof, and an insulating cover sheet 51 which has no conductor pattern previously formed on the surface thereof.

[0003] The coil conductor patterns 53 and 54 are electrically connected in series with each other via a via hole 57b provided in the insulating sheet 51, and constitute a coil L. In the coil conductor patterns 53 and 54, respective one ends thereof are electrically connected to the lead-out patterns 52 and 55, respectively, via the respective via holes 57a and 57c provided on the insulating sheet 51.

[0004] After being successively stacked up, the insulating sheets 51 are fired into a one-piece laminated body. On the surface of the laminated body, external input/output electrodes electrically connected to the lead-out patterns 52 and 55, are formed.

[0005] In the conventional inductor 50, each of the spiral-shaped coil conductor patterns 53 and 54 has constant width and thickness at any portion. Also, since each of the coil conductor patterns 53 and 54 has a spiral shape, the line length for one turn of the coil is longer at the outside portion of the spiral than at the inside portion thereof. Consequently, in each of the coil conductor patterns 53 and 54, the direct-current (DC) resistance of the line situated at the outside portion of the spiral is larger than that of the line situated at the inside portion thereof. This results in an increase in the DC resistance of the entire coil conductor patterns 53 and 54. Here, letting the inductance be L, the DC resistance be R, and the resonance frequency be f_0 , the Q value is expressed by $Q = 2\pi f_0 L/R$. Since the conventional inductor 50 has a large DC resistance as described above, the problem arises that the conventional inductor 50 has a low Q value.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide an inductor having a low DC resistance and a high Q value.

[0007] In order to achieve the above-described object, the inductor in accordance with present invention comprises insulating members, and spiral-shaped coil conductor patterns formed on the surfaces of the insulating members, wherein the width of each of the coil conductor patterns is larger at the central portion and the outside portion of the spiral than at the inside portion thereof.

[0008] Since the width of the coil conductor pattern is larger at the central and outside portions of the spiral than at the inside portion thereof, the cross-sectional area of the coil conductor pattern is larger at the central and outside portions of the spiral than at the inside portion thereof. As a consequence, the DC resistance rates (DC resistance per unit length) of the central and outside portions of the spiral are smaller than that of the inside portion of the spiral. This allows the DC resistance of the entire coil conductor pattern to be reduced.

[0009] Furthermore, if the coil conductor pattern has three turns, and the pattern width of the central portion of the spiral is larger than the pattern widths of the inside and outside portions thereof, the cross-sectional area of the coil conductor pattern will increase in the ascending order of the inside, outside, and central portions of the spiral. The DC resistance rate will, therefore, decrease in the descending order of the inside, outside, and central portions of the spiral. This will allow the DC resistance of the entire coil conductor pattern to become low.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

Fig. 1 is an exploded perspective view showing the construction of a first embodiment of an inductor in accordance

with the present invention;

Fig. 2 is a perspective view showing the appearance of the inductor shown in Fig. 1;

Fig. 3 is an exploded perspective view showing the construction of a second embodiment of an inductor in accordance with the present invention;

Fig. 4 is a partly fragmentary sectional view of the spiral portion of a coil conductor pattern;

Fig. 5 is an exploded perspective view showing the construction of a conventional inductor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment]

[0011] In Fig. 1, the specific construction of an inductor in accordance with a first embodiment of the present invention is shown. An inductor 1 comprises insulating sheets 11 having three-turn spiral-shaped coil conductor patterns 3 and 4 formed on the respective surfaces thereof, insulating sheets 11 having lead-out patterns 2 and 5 formed on the respective surfaces, and an insulating cover sheet 11 which has no conductor pattern previously formed on the surface thereof. The insulating sheet 11 is made by kneading dielectric powder or magnetic powder with a binder into a sheet. The patterns 2 through 5 are each constituted of Ag, Pd, Cu, Ni, Au, Ag-Pd, or the like.

[0012] The patterns 2 through 5 are produced, for example, by a method which combines photolithography technique and wet etching technique. Specifically, a conductor layer constituted of Ag and the like is provided over the entire surface of the insulating sheet 11, using a technique such as printing, sputtering, or deposition. Over this conductor layer, a photo-resist layer is formed. Thereafter, the photo-resist layer is covered with a photo mask, and is then exposed to light. Next, the resist layer exposed to light receives development processing, and unnecessary portion of the resist layer is removed. Then, the conductor layer is removed with etching liquid, leaving the portion covered with the resist layer. Thereby, high-accuracy patterns 2 through 5 are formed. Thereafter, the resist layer left is removed.

[0013] In the coil conductor patterns 3 and 4, respective one ends thereof 3a and 4a are each disposed at the outer peripheral edge portions of the insulating sheets 11, the other ends thereof 3b and 4b are each disposed at the central portions of the insulating sheets 11, and the spiral portions are each extending around between the outer peripheral edge portions and the central portions of the spirals. Each of these coil conductor patterns 3 and 4 is arranged so that the pattern widths of the central portion j and the outside portion k of the spiral are larger than that of the inside portion i of the spiral. In the case of the present embodiment, each of the widths of the coil pattern conductor patterns 3 and 4 increases in the ascending order of the inside portion i, the central portion j, and the outside portion k of the spiral. The coil conductor patterns 3 and 4 are electrically connected in series with each other via a via hole 7b provided in the insulating sheet 11, and define a coil L.

[0014] The lead-out pattern 2 is exposed to the left side of the insulating sheet 11 at one end thereof. The lead-out pattern 5 is exposed to the right side of the insulating sheet 11 at one end thereof. The lead-out patterns 2 and 5 are electrically connected to the coil conductor patterns 3 and 4, via holes 7a and 7c provided in the insulating sheet 11, respectively.

[0015] After being successively stacked and pressure bonded, the above-described magnetic sheets 11 are fired into a one-piece laminated body 15 as shown in Fig. 2. At the end portions of the left and the right sides of the laminated body 15, input external electrode 21 and output external electrode 22 are formed, respectively, by means of a coating technique, a transfer technique, a sputtering technique, or the like. As material of the external electrodes 21 and 22, Ag, Ag-Pd, Ni, and Cu or the like is used. The input external electrode 21 is electrically connected to one end of the coil L via the lead-out pattern 2, and the output external electrode 22 is electrically connected to the other end of the coil L via the lead-out pattern 5.

[0016] In the above-described monolithic inductor 1, since the width of each of the coil patterns 3 and 4 is larger at the central portion j and the outside portion k of the spiral than at the inside portion i thereof, the cross-sectional area of each of the coil patterns 3 and 4 is larger at the central portion j and the outside portion k than at the inside portion i. Consequently, the DC resistance rates of the central portion j and the outside portion k of the spiral are smaller than that of the inside portion i of the spiral. This allows the DC resistance of the entire coil conductor patterns 3 and 4 to be lower than the conventional coil conductor patterns having constant widths. This results in an inductor 1 having a high Q value. Moreover, by keeping the width W (see Fig. 4) from the inside portion to the outside portion of the coil conductor pattern the same as the conventional width, the above-described effect can be achieved without decreasing the inductance.

[Second Embodiment]

[0017] In Fig. 3, the specific construction of an inductor in accordance with a second embodiment of the present invention is shown. An inductor 20 uses insulating sheets 21 and 21 having circular-shaped coil conductor patterns 23

and 24 formed on the surfaces thereof, respectively, in place of the insulating sheets 11 and 11 used in the inductor 1 of the first embodiment, and having squared-shaped coil conductor patterns 3 and 4 formed on the surfaces thereof, respectively.

[0018] Each of the coil conductor patterns 23 and 24 has three turns, and the pattern width thereof increases in the ascending order of inside portion i, the outside portion k, and the central portion j of the spiral. Each of the cross-sectional areas of the coil conductor patterns 23 and 24, therefore, increases in the ascending order of inside portion i, the outside portion k, and the central portion j of the spiral. Accordingly, each of the DC resistance rates of the coil conductor patterns 23 and 24 decreases in the descending order of inside portion i, the outside portion k, and the central portion j of the spiral. This results in a reduction in the DC resistance of the entire coil conductor patterns 23 and 24. Here, in order to avoid the repetition of explanation, like portions are identified by the same reference numerals in Fig. 1 and Fig. 3.

[Other Embodiments]

[0019] The present invention is not limited to the above-described embodiments, but various constructions may be adopted within the scope of the present invention as defined in the appended claims. Although, for example, each of the above-described embodiments is manufactured by stacking insulating sheets each having patterns formed on the surfaces thereof and then firing them into a one-piece laminated body, the present invention is not necessarily limited to this one. Alternatively, insulating sheets which have been previously fired may be used. Furthermore, the monolithic inductor may be manufactured by the method as follows:

[0020] First, an insulating layer is formed with paste-like insulating material by a method such as printing, and then paste-like conductive material is applied over the surface of the insulating layer to form a desired conductor pattern. Next, paste-like insulating material is applied over the conductor pattern, and thus an insulating layer in which the conductor pattern is built is formed. In the same manner, by successively repeating such an alternate overlaying of an insulating layer and a conductive layer, an inductor having a monolithic structure is achieved.

[0021] Moreover, the inductor in accordance with the present invention is not limited to one of laminated type, but may be one which has spiral-shaped coil conductor pattern formed on the surface of an insulating substrate made of ceramic or the like. Also, the number of turns of the spiral-shaped coil conductor pattern is not particularly limited to three, but may be two, or more than three.

[0022] Hereinbelow, examples of the inductor 20 having the construction shown in Fig. 3 will now be described. DC resistance values of the inductor 20 were measured by setting R_e (the radii of the coil conductor pattern 23 and 24 (thickness: 0.015 mm)) to 1.9 mm, W (the width from the outside portion k to the inside portion i) to 1 mm, and d (the distance between the inside portion i, the central portion j, and the outside portion k of a spiral) to 0.1 mm (see Fig. 4), and by preparing samples wherein the ratio $i : j : k$ (the ratio of each of the pattern widths of the inside portion i, the central portion j, and the outside portion k) is widely varied as shown in the following Tables 1 and 2. In Table 1, the symbol * denotes the data of the samples departing from the scope of the present invention.

Table 1

Inside portion i	Central portion j	Outside portion K	DC resistance ratio (%) with respect to the case where i:j:k = 1:1:1
1	1.1	1	0.18
1	1.1	1.1	-1.23
1	1.1	1.2	-2.18
1	1.1	1.3	-2.82
1	1.1	1.4	-3.09
1	1.1	1.5	-3.18
1	1.1	1.6	-3.05
1	1.2	1	0.73
1	1.2	1.1	-0.91
1	1.2	1.2	-2.05
1	1.2	1.3	-2.78
1	1.2	1.4	-3.23
1	1.2	1.5	-3.46
1	1.2	1.6	-3.46
1	1.3	1	1.55
1	1.3	1.1	-0.27
1	1.3	1.2	-1.59
1	1.3	1.3	-2.50
1	1.3	1.4	-3.09
1	1.3	1.5	-3.41
1	1.3	1.6	-3.50
1	1.3	1.7	-3.46

Table 2

Inside portion i	Central portion j	Outside portion K	DC resistance ratio (%) with respect to the case where i:j:k = 1:1:1
1	1.4	1.2	-0.91
1	1.4	1.3	-1.96
1	1.4	1.4	-2.68
1	1.4	1.5	-3.14
1	1.4	1.6	-3.37
1	1.4	1.7	-3.41

Table 2 (continued)

Inside portion i	Central portion j	Outside portion K	DC resistance ratio (%) with respect to the case where i: j:k = 1:1:1
1	1.6	1.5	-2.00
1	1.6	1.6	-2.46
1	1.6	1.7	-2.68
1	1.6	1.8	-2.73
1	1.8	1.7	-1.41
1	1.8	1.8	-1.64
1	1.8	1.9	-1.73

[0023] As is apparent from Tables 1 and 2, as each of the pattern widths of the samples increases in the ascending order of the inside portion i, the central portion j, and the outside portion k of the spiral, DC resistance value of the samples decreases by more than two percent with respect to the conventional samples each having the ratio i:j:k = 1:1:1. Furthermore, the samples wherein each of the pattern widths thereof increases in the ascending order of the inside portion i, the outside portion k, and the central portion j of the spiral, also decrease in DC resistance value with respect to the conventional samples which each having the ratio i:j:k = 1:1:1.

[0024] As can be recognized from the foregoing explanation, in accordance with the present invention, since the coil conductor pattern is arranged so that the pattern widths of the central and outside portions of the spiral are larger than that of the inside portion of the spiral, the cross-sectional area of the coil conductor pattern is larger at the central and outside portions of the spiral than at the inside portion thereof. As a consequence, the DC resistance rates of the central and outside portions of the spirals are smaller than that of the inside portion of the spiral. This allows the DC resistance of the entire coil conductor pattern to be reduced, which results in a high Q inductor superior in high-frequency characteristics.

[0025] While the invention has been described in its preferred embodiments, obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

Claims

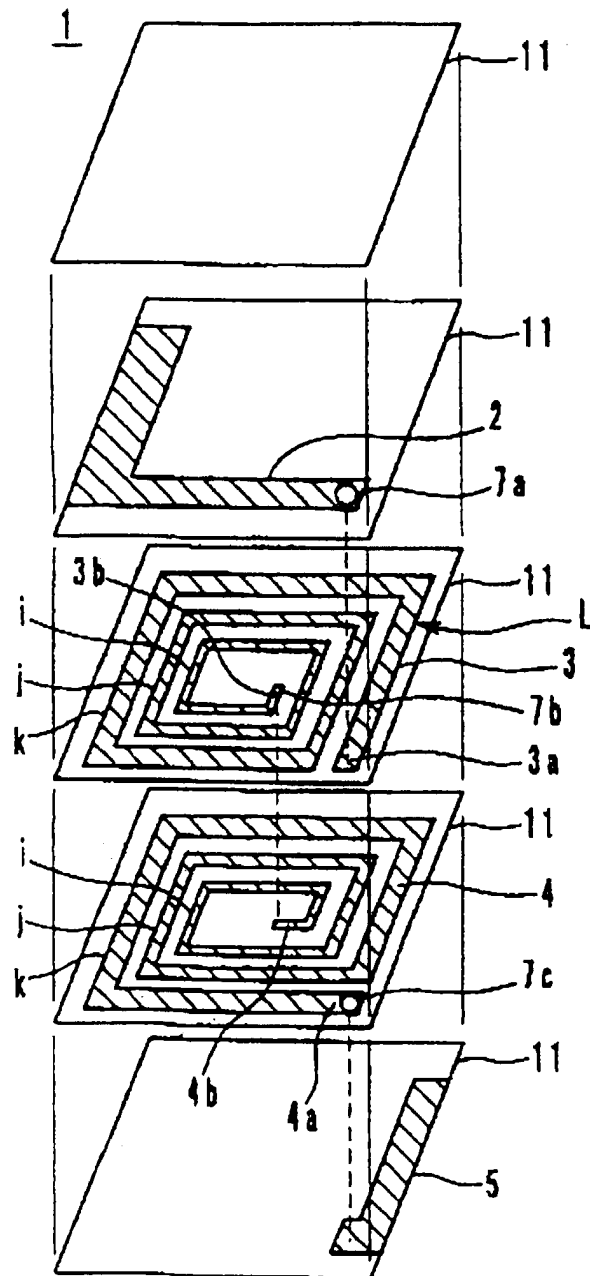
1. An inductor (1/20) comprising:

insulating members (11/21); and
 spiral-shaped coil conductor patterns (3,4/23,24), each of said spiral-shaped coil conductor patterns being formed on the surface of each of said insulating members, wherein:
 the width of each of said coil conductor patterns is larger at the central portion (j) and the outside portion (k) of the spiral than at the inside portion (i) thereof.

2. An inductor (1/20) as claimed in claim 1, wherein:

each of said coil conductor patterns (3,4/23,24) has three turns; and
 the pattern width of the central portion (j) of the spiral is larger than the pattern widths of the inside (i) portion and the outside portion (k) thereof.

FIG. 1



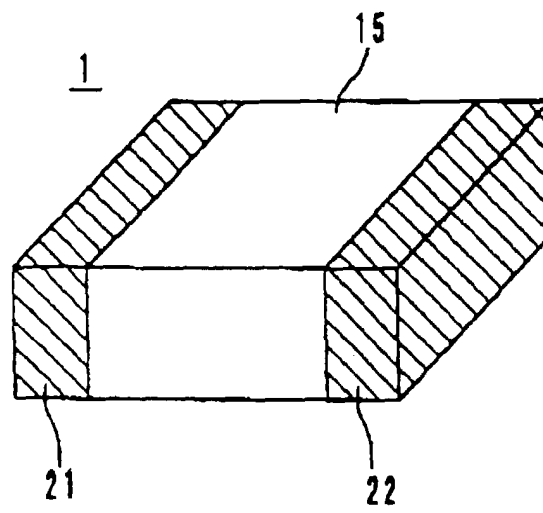


FIG. 2

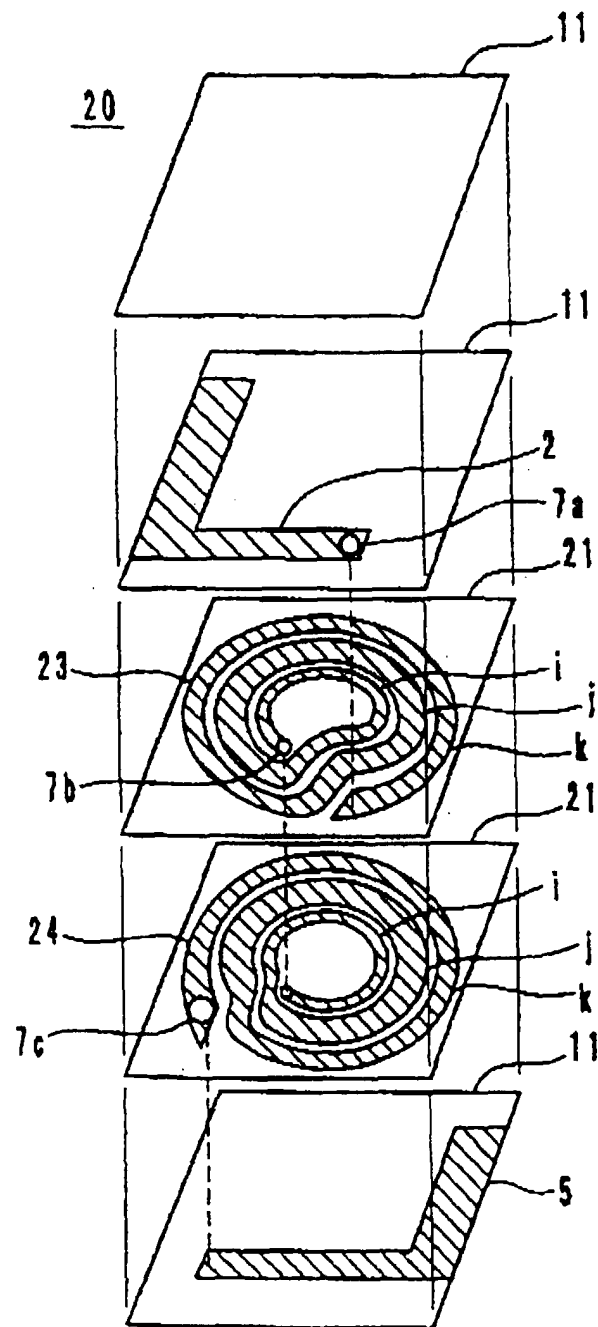


FIG. 3

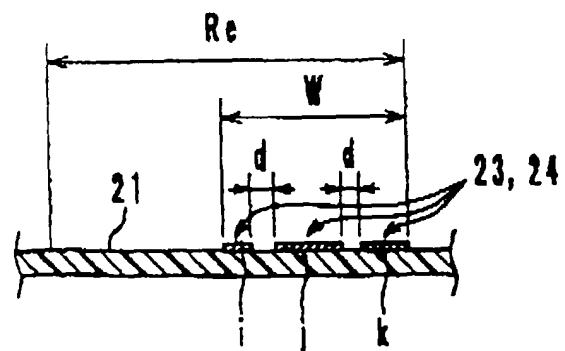


FIG. 4

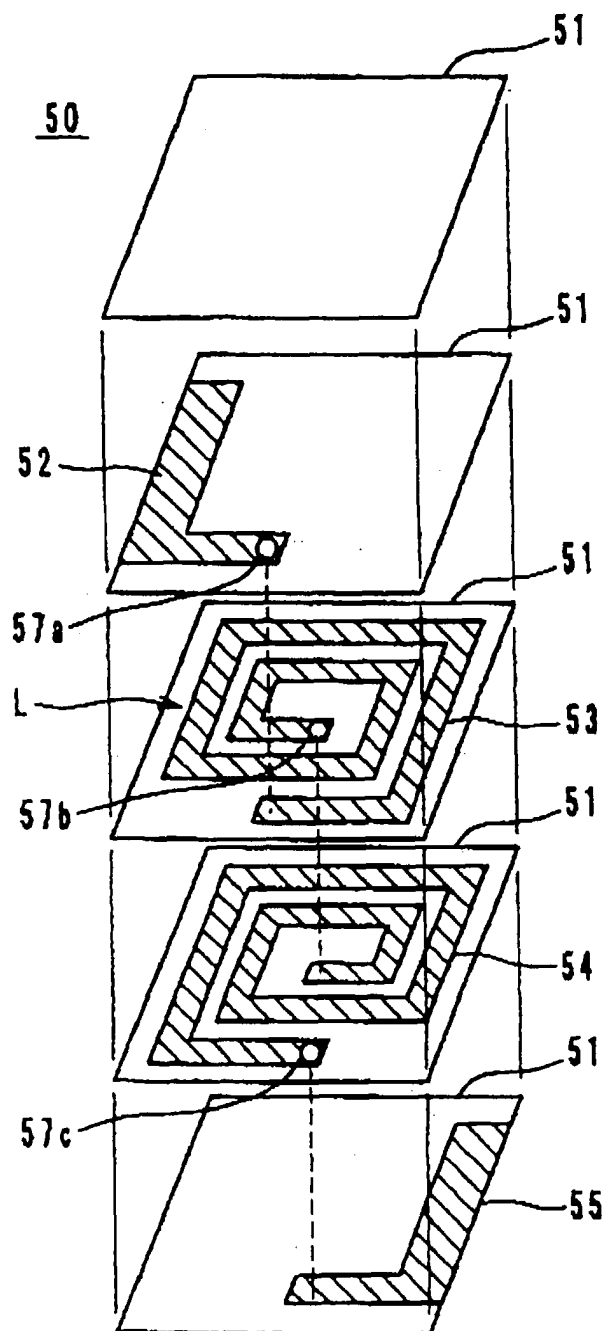


FIG. 5



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 00 40 2546

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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Place of search THE HAGUE		Date of completion of the search 18 December 2000	Examiner Vanhulle, R
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 00 40 2546

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18-12-2000

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