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Specification

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I. Title of Invention: (Chinese/English)

STACKED STRUCTURE OF A SPIRAL INDUCTOR

II. Abstract of Chinese Language:

A spiral inductor, comprising a first metal layer, a second metal layer, a first set of dielectric vias, and a second set of dielectric vias. The first metal layer comprises a first, second and third segments, and the layout direction of the third segment is different from the layout direction of the first and second segments. The second metal layer comprises a fourth, fifth and sixth segments, and the sixth segment is connected to the fifth segment and the layout direction of the sixth segment is different from the layout direction of the fourth and fifth segments. The first set of dielectric vias connects the first and fourth segments, and all three form a first shunt winding. The second set of dielectric vias connects the second and fifth segments, and all three form a second shunt winding. The third and sixth segments form a crossover area.

III. Abstract of English language:

A stacked structure of a spiral inductor includes a first metal layer, a second metal layer, a first set of via, and a second set of via. The first metal layer includes a first segment, a second segment, and a third segment, wherein the layout direction of the third segment is different from the layout direction of the first and second segments. The second metal layer includes a fourth segment, a fifth segment, and a sixth segment connected to the fifth segment, wherein the layout direction of the sixth segment is

different from the layout direction of the fourth and fifth segments. The first set of via connects the first and fourth segments, and they construct a first shunt winding. The second set of via connects the second and fifth segments, and they construct a second shunt winding. The third and sixth segments construct a crossover region.

IV. Designated representative diagram:

(1) The designated representative diagram of this case is: Fig. (1).

(2) Brief description of the symbols of the components of this representative diagram:

100、200	Spiral inductor
M11 ~ M16、M21 ~ M26	Metal layer
110、210	First set of dielectric vias
120、220	Second set of dielectric vias
S11 ~ S16、S21 ~ S26	Segment
130、230	First shunt winding
140、240	Second shunt winding
150、250	Crossover area

V. If there is a chemical formula in this case, please reveal the chemical formula that best characterizes the invention.

None

VI. Specification:

[Technical field of the invention]

The present invention relates to a stacked structure of spiral inductors, in particular a stacked structure in which the metal layers in the crossover area are used as shunt windings to improve the quality factor.

[Prior art]

With the development of IC manufacturing in the direction of system on a chip (SoC), passive components such as integrated inductor or integrated transformer have been widely integrated into high frequency integrated circuits. Since ICs are generally manufactured with a silicon substrate, the substrate loss and metal loss of an integrated inductor/integrated transformer will determine its quality factor, especially that the metal loss is the main factor that directly affects the inductor characteristics.

Commonly used inductors comprise symmetric spiral inductors and asymmetric spiral inductors. In most cases, the top layer (or top two layers) of metal is used as the winding of the inductor, and the next layer of metal and dielectric via is used as the crossover. The disadvantage of this type of inductor is that its parasitic resistance will be limited by the single layer of metal, the conductivity of the crossover, the number of dielectric vias, and the dielectric via resistance. To increase the quality factor of the inductor, it is necessary to increase the wire width of the winding, but this will consume more wafer area. Therefore, it has been proposed to use the structure of multi-layer metal in parallel, so that the inductor can obtain lower series resistance than the traditional single-layer inductor in the same area, in order to improve the quality factor, as revealed in the previous case such as U.S. Patent No. 20080074229 and U.S. Patent No. 6664882. However, in both single-layer and multi-layer metal structures, the

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crossover of the inductor uses a different metal layer than the inductor winding itself, which does not optimize the quality factor of the inductor.

[Summary of the invention]

One of the objectives of the present invention is to provide a stacked structure of a spiral inductor to solve the problems of the prior art.

The examples of the present invention discloses a stacked structure of a spiral inductor comprising a first metal layer, a second metal layer, a first set of dielectric vias, and a second set of dielectric vias. The first metal layer comprises a first segment, a second segment, and a third segment, the third segment being connected to the first segment, and the layout direction of the third segment being different from the layout direction of the first segment and the layout direction of the second segment. The second metal layer is laid out below the first metal layer and comprises a fourth segment, a fifth segment, and a sixth segment, the sixth segment being connected to the fifth segment, and the layout direction of the sixth segment being different from the layout direction of the fourth segment and the layout direction of the fifth segment. The first set of dielectric vias connects the first segment to the fourth segment. The second set of dielectric vias connects the second segment to the fifth segment. Wherein, the first segment, the fourth segment and the first set of dielectric vias form a first shunt winding of the spiral inductor, the second segment, the fifth segment and the second set of dielectric vias form a second shunt winding of the spiral inductor, and the third segment and the sixth segment form a first crossover area. This spiral inductor is a symmetric spiral inductor.

The examples of the present invention further discloses a stacked structure of a spiral inductor comprising a first metal layer, a second metal layer, a first set of

dielectric vias, and a second set of dielectric vias. The first metal layer comprises a first segment, a second segment, and a third segment, the third segment being connected to the first segment and the second segment and laid out between the first segment and the second segment. The second metal layer comprises a fourth segment, a fifth segment, and a sixth segment, with the sixth segment being laid out between the fourth segment and the fifth segment. The first set of dielectric vias connects the first segment to the fourth segment. The second set of dielectric vias connects the second segment to the fifth segment. Wherein, the first segment and the fourth segment form a first shunt winding of the spiral inductor, the second segment and the fifth segment form a second shunt winding of the spiral inductor, and the third segment and the sixth segment form a crossover area. This spiral inductor is an asymmetric spiral inductor.

[Embodiments]

In the following examples, at least three types of crossover structures for spiral inductors with multi-layer stacked metal are proposed for symmetric spiral inductors (refer to examples of Figs. 1 to 8) and asymmetric spiral inductors (refer to examples of Figs. 9 to 14), and are mainly divided into L-shape crossover, interdigitated crossover, and trench-shape crossover, which may optimize the quality factor of spiral inductors with multi-layer stacked metal. Wherein, L-shape crossover, interdigitated crossover and trench-shape crossover are defined by the present invention and are used for the purpose of name differentiation only. In addition, the present invention proposes a stacked guard ring to improve the noise blocking capability.

Referring to Fig. 1, Fig. 1 (comprising Fig. 1A and Fig. 1B) is a schematic diagram of an example of a stacked structure of a spiral inductor of the present invention. Wherein, Fig. 1A shows the L-shaped crossover, while Fig. 1B shows the interdigitated crossover. In this example, the L-shaped crossover shown in Fig. 1A and the interdigitated crossover shown in Fig. 1B are applied to a symmetric spiral inductor. As shown in Fig. 1A, the stacked structure of the spiral inductor 100 comprises six metal layers M16 to M11, a first set of dielectric vias 110, and a second set of dielectric vias 120. Metal layers M16 to M14 comprise segments S11, S12, and S13, wherein the segment S13 is connected to segment S11 and laid out between the segment S11 and the segment S12. The metal layers M13 to M11 are laid out below the metal layers M16 to M14, which comprise the segments S14, S15, and S16, wherein the segment S16 is connected to the segment S15 and laid out between the segment S14 and the segment S15. The first set of dielectric vias 110 is connected to the segment S11 and the segment S14, and the second set of dielectric vias 120 is connected to the segment S12 and the segment S15. In this example, the segments S11 of the metal layers M16 to M14, the segments S14 of the metal layers M13 to M11, and the first set of dielectric vias 110 form a first parallel winding (shunt winding) 130 of a spiral inductor 100, and the segments S12 of the metal layers M16 to M14, the segments S15 of the metal layers M13 to M11, and the second set of dielectric vias 120 form a second shunt winding 140 of the spiral inductor 100, and the segments S13 of the metal layer M16 to M14 and the segments S16 of the metal layer M13 to M11 form a crossover area 150.

As shown in Fig. 1B, the stacked structure of the spiral inductor 200 comprises six metal layers M26 to M21, a first set of dielectric vias 210, and a second set of

dielectric vias 220. The metal layers M26, M24, and M22 comprise segments S21, S22, and S23, wherein the segment S23 is connected to the segment S21 and is laid out between the segment S21 and the segment S22. The metal layers M25, M23, and M21 comprise segments S24, S25, and S26, wherein the segment S26 is connected to the segment S25 and is laid out between the segment S24 and the segment S25. The first set of dielectric vias 210 is connected to the segment S21 and the segment S24, while the second set of dielectric vias 220 is connected to the segment S22 and the segment S25. In this example, the segment S21 of the metal layers M26, M24, and M22, the segment S24 of the metal layers M25, M23, and M21, and the first set of dielectric vias 210 form a first parallel winding (shunt winding) 230, the segment S22 of the metal layers M26, M24 and M22, the segment S25 of the metal layers M25, M23 and M21 and the second set of dielectric vias 220 form a second shunt winding 240 of the spiral inductor 200, and the segment S23 of the metal layers M26, M24, and M22 and the segment S26 of the metal layers M25, M23, and M21 form a crossover area 250.

Please note that in the above examples, six metal layers are used as an example, instead of a limitation of the present invention and the number of metal layers is not limited.

Please refer to Fig. 2, Fig. 3, and Fig. 4, wherein Fig. 2 is an upper view of an example of a symmetric spiral inductor 300, Fig. 3 is a longitudinal section of the symmetric spiral inductor 300 shown in Fig. 2 using the stacked structure of Fig. 1A, and Fig. 4 is a longitudinal section of the symmetric spiral inductor 300 shown in Fig. 2 using the stacked structure of Fig. 1B. As shown in Fig. 2, the symmetric spiral inductor 300 comprises a first shunt winding 330 and a second shunt winding 340, and the area labeled A1 in the figure represents the crossover area. Fig. 3 shows a longitudinal section of the symmetric spiral inductor 300 along the dashed line of YY'

in Fig. 2, which adopts a stacked structure of Fig. 1A. As shown in Fig. 3, the stacked structure of the symmetric spiral inductor 300 comprises five metal layers M36 to M32, a first set of dielectric vias 310, and a second set of dielectric vias 320. In this example, the segment S31 of the metal layer M36, the segment S34 of the metal layers M35 to M32, and the first set of dielectric vias 310 form a first shunt winding line 330 of the spiral inductor 300, the segment S32 of the metal layer M36, the segment S35 of the metal layers M35 to M32, and the second set of dielectric vias 320 form a second shunt winding 340 of the spiral inductor 300, and the segment S33 of the metal layer M36 and the segment S36 of the metal layers M35 to M32 form a crossover area 350 (comprising a first part 350A and a second part 350B). As can be seen from Figs. 2 and 3, the layout direction of the segment S33 (forming the first part 350A of the crossover area 350) is different from the layout direction of the segments S31 and S32, and the layout direction of the segment S36 (forming the second part 350B of the crossover area 350) is also different from the layout direction of the segments S34 and S35.

In addition, the metal layer M36 also comprises a first guard ring segment S37, which is arranged outside of the segment S31 and/or the segment S32; the metal layers M35 to M32 also comprises a second guard ring segment S38, which is arranged outside of the segment S34 and/or the segment S35; and the stacked structure also comprises a third set of dielectric vias 360 connecting the first guard ring segment S37 and the second guard ring segment S38. The first guard ring segment S37, the second guard ring segment S38, and the third set of dielectric vias 360 form a stacked guard ring to improve the noise blocking capability.

Note that in this example, since the thickness of the metal layer M36 is greater than the thickness of the metal layers M35 to M32, the first part 350A of the crossover area 350 is realized by using a single layer of metal (i.e., the segment S33 of the metal

layer M36), while the second part 350B of the crossover area 350 is realized by using multiple layers of stacked metal (i.e., the segment S36 of the metal layers M35 to M32), and the metal layers M35 to M32 are laid out below the metal layer M36 for symmetry of inductor.

Fig. 4 shows a longitudinal section of the symmetric spiral inductor 300 along the dashed line of YY' in Fig. 2, which adopts a stacked structure of Fig. 1B. As shown in Fig. 4, the stacked structure of the symmetric spiral inductor 300 comprises six metal layers M46 to M41, a first set of dielectric vias 410, and a second set of dielectric vias 420. In this example, the segment S41 of metal layers M46, M44, and M42, a segment S44 of the metal layers M45, M43, and M41, and the first set of dielectric vias 410 form a first shunt winding 330 of the spiral inductor 300, and the segment S42 of the metal layers M46, M44, and M42, the segment S45 of the metal layers M45, M43, and M41, and the second set of dielectric vias 420 form a second shunt winding 340 of the spiral inductor 300, and the segment S43 of the metal layers M46, M44, and M42 and the segment S46 of the metal layers M45, M43, and M41 form a crossover area 450 (comprising the first part 450A and the second part 450B). As can be seen from Figs. 2 and 4, the layout direction of the segment S43 (which forms the first part 450A of the spanning area 450) is different from the layout direction of the segments S41 and S42, and the layout direction of the segment S46 (which forms the second part 450B of the spanning area 450) is different from the layout direction of the segments S44 and S45.

In addition, the metal layers M46, M44, M42 also comprise a first guard ring segment S47, located outside of the segment S41 and/or the segment S42; the metal layers M45, M43, M41 also comprise a second guard ring segment S48, located outside of the segment S44 and/or the segment S45; and the stacked structure also comprises a third set of dielectric vias 460, connecting the first guard ring segment S47

and the second guard ring segment S48. The first guard ring segment S47, the second guard ring segment S48, and the third set of dielectric vias 460 form a stacked guard ring to improve the noise blocking capability.

Note that in this example, since the thicknesses of the metal layers M46, M44, and M42 are equal to the thicknesses of the metal layers M45, M43, and M41, the first part 450A of the crossover area 450 is realized by using a multi-layer stacked metal (i.e., the segment S43 of the metal layers M46, M44, and M42), the second part 450B of the crossover area 450 is also realized by using a multi-layer stacked metal (i.e., the segment S46 of the metal layers M45, M43, and M41), and the metal layers M46, M44, and M42 and the metal layers M45, M43, and M41 are interlaced in order to achieve symmetry of inductor.

From the illustrations in Fig. 3 and Fig. 4 above, it can be understood that the line layout of the spiral inductor of the present invention can improve the symmetry of the inductors according to the thickness of the metal layer. For example, when the thickness of metal layers in an integrated circuit varies, an "L-shaped crossover structure" (i.e., the crossover structure shown in Fig. 1A or Fig. 3) can be used for circuit layout to achieve better symmetry of inductor. In addition, when the thickness of each metal layer in an integrated circuit is the same, "interdigitated crossover structure" (i.e., the crossover structure shown in Fig. 1B or Fig. 4) can be used for circuit layout to obtain better symmetry of inductor.

From the above examples, it can be seen that the metal layer in the stacked structure of the spiral inductor disclosed in the present invention is also used as the winding of the inductor to optimize the quality factor of the inductor. In this way, the parasitic resistance of the spiral inductor will no longer be limited by the conductivity of the crossover, the number of dielectric vias, and the resistance of the dielectric vias.

Referring to Fig. 5 to Fig. 6, Fig. 5 is an upper view of an example of a symmetric spiral inductor 500 combining series winding and shunt winding, and Fig. 6 (comprising Fig. 6A and Fig. 6B) is a schematic diagram of the first inductor 510 (Fig. 6A) and the second inductor 610 (Fig. 6B) of the symmetric spiral inductor 500 shown in Fig. 5. The symmetric spiral inductor 500 is a multi-layer stacked spiral inductor combining the first inductor 510 (i.e., series winding) and the second inductor 610 (i.e., shunt winding) to increase the series inductance for the same area, resulting in increased wafer area utilization. As shown in Fig. 6A, the first inductor 510 is a conventional single-layer symmetric spiral inductor with metal layer MT1 as the coil winding and metal layer MT2 as the crossover area, wherein the connection points A and B of the first series winding 520 and the second series winding 530 are the centertap of the first inductor 510. If disconnected, the connections A and B may be connected down to the centertap of the second inductor 610 (i.e., the connection points A' and B' of the first shunt winding 620 and the second shunt winding 630). The second inductor 610 of Fig. 6B can be realized by using the stacked structure of Fig. 1A (i.e., L-shaped crossover structure) or the stacked structure of Fig. 1B (i.e., interdigitated crossover structure), wherein the metal layers MT3, MT4, MT5, and MT6 are used as the coil winding and the crossover area, and the metal layers MT1, MT2, MT3, MT4, MT5, and MT6 are parallel to each other.

Please refer to Fig. 7, which shows the longitudinal section of the symmetric spiral inductor 500 along the dotted line of KK' in Fig. 5, which adopts the stacked structure of Fig. 1A. As shown in Fig. 7, the symmetric spiral inductor 500 comprises a first inductor 510 and a second inductor 610. In this example, the first inductor 510 uses the metal layer MT1 as the coil winding (comprising the first series winding 520 and the second series winding 530) and the metal layer MT2 as the crossover area; while the second inductor 610 uses the L-shaped crossover structure of Fig. 1A, wherein the

metal layers MT3 and MT4 correspond to the metal layers M16 to M14 of Fig. 1A, and the metal layers MT5 and MT6 correspond to the metal layers M13 to M11 of Fig. 1A.

Please refer to Fig. 8. The symmetric spiral inductor 500 in Fig. 8 follows the longitudinal section of the dotted line of KK' in Fig. 5, which adopts the stacked structure of Fig. 1B. As shown in Fig. 8, the symmetric spiral inductor 500 comprises a first inductor 510 and a second inductor 610. In this example, the second inductor 610 adopts the interdigitated crossover structure of Fig. 1B, wherein the metal layers MT3 and MT5 correspond to the metal layers M26, M24, and M22 of Fig. 1B, and the metal layers MT4 and MT6 correspond to the metal layers M25, M23, and M21 of Fig. 1B.

Referring to Fig. 9, Fig. 9 (comprising Fig. 9A, Fig. 9B, Fig. 9C, and Fig. 9D) is a schematic diagram of another example of the stacked structure of a spiral inductor of the present invention. Among them, Figs. 9A and 9B show the trench-shape crossover structure, while Figs. 9C and 9D show the interdigitated crossover structure. In this example, the spiral structure shown in Fig. 9A, Fig. 9B, Fig. 9C, and Fig. 9D is applied to an asymmetric spiral inductor. As shown in Fig. 9A, the stacked structure of the spiral inductor 900A comprises six metal layers M96A to M91A, a first set of dielectric vias 910A, and a second set of dielectric vias 920A. The metal layers M96A to M94A comprise segments S91A, S92A, and S93A, wherein the segment S93A is connected to the segment S91A and the segment S92A and is laid out between the segment S91A and the segment S92A. The metal layers M93A to M91A comprise segments S94A, S95A, and S96A, wherein the segment S96A is laid out between the segment S94A and the segment S95A. The first set of dielectric vias 910A is connected to the segment S91A and the segment S94A, and the second set of dielectric vias 920A is connected to the segment S92A and the segment S95A. Among them, the segment S91A of the

metal layers M96A to M94A and the segment S94A of the metal layers M93A to M91A form a first shunt winding of spiral inductor 900A, the segment S92A of the metal layers M96A to M94A and the segment S95A of the metal layers M93A to M91A form a second shunt winding of the spiral inductor 900A, and the segment S93A and the segment S96A form a crossover area 950A. The stacked structure of the spiral inductor 900B in Fig. 9B is similar to the stacked structure of the spiral inductor 900A in Fig. 9A, with the difference that the stacked structure of the spiral inductor 900B is an inversion of the stacked structure of the spiral inductor 900A. In other words, in Fig. 9A, the metal layers M96A to M94A are arranged above the metal layers M93A to M91A, while in Fig. 9B, the metal layers M93B to M91B are arranged below the metal layers M96B to M94B.

As shown in Figure 9C, the stacked structure of the spiral inductor 900C comprises six metal layers M96 to M91C, a first set of dielectric vias 910C, and a second set of dielectric vias 920C. The metal layers M96C, M94C, M92C comprise segments S91C, S92C, and S93C, wherein the segment S93C is connected to the segment S91C and the segment S92C and is laid out between the segment S91C and the segment S92C. The metal layers M95C, M93C, and M91C comprise the segments S94C, S95C, and S96C, wherein the segment S96C is laid out between the segment S94C and the segment S95C. The first set of dielectric vias 910C is connected to the segment S91C and the segment S94C, and the second set of dielectric vias 920C is connected to the segment S92C and the segment S95C. In particular, the segments S91C of the metal layers M96C, M94C, and M92C and the segments S94C of the metal layers M95C, M93C, and M91C form a first shunt winding of the spiral inductor 900C, the segments S92C of the metal layer and the segments S95C of the metal layers M95C, M93C, and M91C form a second shunt winding of the spiral inductor 900C, and the segments S93C of the metal layers M96C, M94C, and M92C and the segments S96C

of the metal layers M95C, M93C, and M91C form a crossover area 950C. The stacked structure of the spiral inductor 900D in Fig. 9D is similar to the stacked structure of the spiral inductor 900C in Fig. 9C, with the difference that the stacked structure of the spiral inductor 900D is an inversion of the stacked structure of the spiral inductor 900C.

Fig. 10 shows an upper view of an example of an asymmetric spiral inductor 1000, while Fig. 11 (comprising Figs. 11A and 11B) shows a first shunt winding 1100 (Fig. 11A) and a second shunt winding 1200 (Fig. 11B) of the asymmetric spiral inductor 1000 shown in Fig. 10.

Please refer to Fig. 12, which shows the cross section of the asymmetric spiral inductor 1000 along the dotted line of CC' in Fig. 10, which adopts the stacked structure of Fig. 9A. As shown in Fig. 12, the stacked structure of the asymmetric spiral inductor 1000 comprises five metal layers M126 to M122, a first set of dielectric vias 1210, and a second set of dielectric vias 1220. In this example, the segment S121 of the metal layer M126, the segments S124 of the metal layers M125 to M122, and the first set of dielectric vias 1210 form the first shunt winding 1100 of the spiral inductor 1000, the segment S122 of the metal layer M126, the segments S125 of the metal layers M125 to M122, and the second set of dielectric vias 1220 form the second shunt winding 1200 of the spiral inductor 1000, and the segment S123 of the metal layer M126 and the segments S126 of the metal layers M125 to M122 form a crossover area 1250 (comprising the first part 1250A and the second part 1250B).

Note that in this example, since the thickness of metal layer M126 is greater than the thickness of the metal layers M125 to M122, the first part 1250A of the crossover area 1250 is realized by using a single layer of metal (i.e., the segment S123 of the metal layer M126), while the second part 1250B of the crossover area 1250 is realized by using multiple layers of stacked metal (i.e., the segments S126 of the metal layers M125 to M122), and the metal layers M125 to M122 are laid out below the metal layer M36 for symmetry of inductor.

Please refer to Fig. 13, which shows the cross-section of the asymmetric spiral inductor 1000 along the dashed line of CC' in Fig. 10, which adopts the stacked structure in Fig. 9B. The stacked structure in Fig. 13 is similar to the stacked structure in Fig. 12, with the difference being that the stacked structure in Fig. 13 is an inversion of the stacked structure in Fig. 12.

Please refer to Fig. 14, which shows the cross section of the asymmetric spiral inductor 1000 along the dotted line of CC' in Fig. 10, which adopts the stacked structure in Fig. 9C. As shown in Fig. 14, the stacked structure of the asymmetric spiral inductor 1000 comprises six metal layers M146 to M141, a first set of dielectric vias 1410, and a second set of dielectric vias 1420. In this example, the segments S141 of the metal layers M146, M144, and M142, the segments S144 of the metal layers M145, M143, and M141, and the first set of dielectric vias 1410 form the first shunt winding 1100 of the asymmetric spiral inductor 1000, the segments S142 of the metal layers M146, M144, and M142, the segments S145 of the metal layers M145, M143, and M141, and the second set of dielectric vias 1420 form the second shunt winding 1200 of the spiral inductor 1000, and the segments S143 of the metal layers M146, M144, and M142 and the segment S146 of the metal layers M145, M143 and M141 form a crossover area 1450 (comprising the first part 1450A and the second part 1450B).

Note that in this example, since the thicknesses of the metal layers M146, M144, and M142 are equal to the thicknesses of the metal layers M145, M143, and M141, the first part 1450A of the crossover area 1450 is realized by using a multi-layer stacked metal (i.e., the segment S143 of the metal layers M146, M144, and M142), the second part 1450B of the crossover area 1450 is also realized by using a multi-layer stacked metal (i.e., the segment S146 of the metal layers M145, M143, and M141), and the metal layers M146, M144, and M142 and the metal layers M145, M143, and M141 are interlaced in order to achieve symmetry of inductor. Of course, the stacked structure of Fig. 9D also may be used to achieve this. Since the stacked structure thereof is only the inversion of Fig. 14, for the sake of simplicity, we will not repeat it here.

Of course, the aforementioned stacked protection rings also may be used to improve the noise blocking capacity. Furthermore, in the above examples, the shapes of the first shunt winding and the second shunt winding are rectangular and octagonal, but this is not a limitation of the present invention.

The above described examples are intended to illustrate the technical features of the present invention only and are not intended to limit the scope of the present invention. As can be seen from the above, the present invention provides a stacked structure of spiral inductor, wherein the metal layers in the crossover area are used as shunt windings to optimize the quality factor of the spiral inductor with multiple layers of metal stacking. Furthermore, the stacked structure of the spiral inductor disclosed herein has a wide range of applications and can be applied to symmetric spiral inductors as well as asymmetric spiral inductors. For different thicknesses of metal layers, different crossover structures are proposed to achieve symmetry of inductor. In

addition, the present invention proposes a stacked guard ring to improve the noise blocking capability.

The above is only a preferred set of examples of the present invention, and all variations and modifications made in accordance with the claims shall fall within the scope of the present invention.

[Brief description of drawings]

Fig. 1 (comprising Fig. 1A and Fig. 1B) is a schematic diagram of an example of the stacked structure of a spiral inductor of the present invention.

Fig. 2 shows an upper view of an example of a symmetric spiral inductor.

Fig. 3 shows the longitudinal section of the symmetric spiral inductor shown in Fig. 2 using the stacked structure in Fig. 1A.

Fig. 4 shows a longitudinal section of the symmetric spiral inductor shown in Fig. 2 using the stacked structure in Fig. 1B.

Fig. 5 shows an upper view of an example of a symmetric spiral inductor combining a series winding and a shunt winding.

Fig. 6 (comprising Fig. 6A and Fig. 6B) shows a schematic diagram of the series winding and the shunt winding of the symmetric spiral inductor shown in Fig. 5.

Fig. 7 shows the cross section of the symmetric spiral inductor shown in Fig. 5 using the stacked structure of Fig. 1A.

Fig. 8 shows the cross section of the symmetric spiral inductor shown in Fig. 5 using the stacked structure of Fig. 1B.

Fig. 9 (comprising Fig. 9A, Fig. 9B, Fig. 9C and Fig. 9D) shows a schematic diagram of another example of the stacked structure of a spiral inductor of the present invention.

Fig. 10 shows an upper view of an example of an asymmetric spiral inductor.

Fig. 11 (comprising Fig. 11A and Fig. 11B) shows the first shunt winding and the second shunt winding of the asymmetric spiral inductor shown in Fig. 10.

Fig. 12 shows the cross section of the asymmetric spiral inductor shown in Fig. 10 using the stacked structure of Fig. 9A.

Fig. 13 shows the cross section of the asymmetric spiral inductor shown in Fig. 10 using the stacked structure of Fig. 9B.

Fig. 14 shows the cross section of the asymmetric spiral inductor shown in Fig. 10 using the stacked structure of Fig. 9C.

[Description of the symbols for the main components]

100、200、900A、900B、900C、900D	Spiral inductor
M16～M11、M26～M21、M36～M32、M46～M41、 MT1～MT6、M96A～M91A、M96B～M91B、 M96C～M91C、M96D～M91D、M126～M122、 M136～M132、M146～M141	Metal layer
110、210、310、410、910A、910B、 910C、910D、1210、1410	First set of dielectric vias
120、220、320、420、920A、920B、 920C、920D、1220、1420	Second set of dielectric vias
360、460	Third set of dielectric vias

S11 ~ S16、S21 ~ S26、S31 ~ S36、S41 ~ S46、 S91A ~ S96A、S91B ~ S96B、S91C ~ S96C、 S91D ~ S96D、S121 ~ S126、S141 ~ S146	Segment
S37、S47	First guard ring segment
S38、S48	Second guard ring segment
130、230、330、620、930A、 930B、930C、930D、1100	First shunt winding
140、240、340、630、940A、 940B、940C、940D、1200	Second shunt winding
150、250、350、450、950A、950B、 950C、950D、1250、1350、1450	Crossover area
A1	Area
350A、450A、1250A、1450A	First part
350B、450B、1250B、1450B	Second part
300、500	Symmetric spiral inductor
YY'、KK'、CC'	Dotted line
510	First inductor
610	Second inductor
A、B、A'、B'	Connection point
520	First series winding
530	Second series winding
1000	Asymmetric spiral inductor

VII. Claims:

1. A stacked structure of a spiral inductor, comprising:
 - a first metal layer, comprising:
 - a first segment;
 - a second segment; and
 - a third segment, connected to the first segment, a layout direction of the third segment being different from a layout direction of the second segment;
 - a second metal layer, laid out below the first metal layer, comprising:
 - a fourth segment;
 - a fifth segment; and
 - a sixth segment, connected to the fifth segment, a layout direction of the sixth segment being different from a layout direction of the fourth segment;
 - a first set of dielectric vias, connecting the first segment to the fourth segment; and
 - a second set of dielectric vias, connecting the second segment to the fifth segment;wherein, the first segment, the fourth segment and the first set of dielectric vias form a first parallel winding (shunt winding); the second segment, the fifth segment and the second set of dielectric vias form a second shunt winding; and the third segment and the sixth segment form a crossover area.
2. The stacked structure of a spiral inductor according to Claim 1, wherein the third segment is laid out between the first segment and the second segment, and the sixth segment is laid out between the fourth segment and the fifth segment.

3. The stacked structure of a spiral inductor according to Claim 1, wherein the thickness of the first metal layer is greater than the thickness of the second metal layer.
4. The stacked structure of a spiral inductor according to Claim 3, wherein the spiral inductor further comprises a third metal layer laid out below the second metal layer, with the structure of the third metal layer being the same as the structure of the second metal layer, and the thickness of the first metal layer being greater than the thickness of the third metal layer.
5. The stacked structure of a spiral inductor according to Claim 1, wherein the thickness of the first metal layer is equal to the thickness of the second metal layer.
6. The stacked structure of a spiral inductor according to Claim 1, wherein the spiral inductor further comprises:
 - a third metal layer laid out below the second metal layer, with the structure of the third metal layer being the same as the structure of the first metal layer; and
 - a fourth metal layer laid out below the third metal layer, with the structure of the fourth metal layer being the same as the structure of the second metal layer;wherein, a seventh segment of the third metal layer, an eighth segment of the fourth segment, the third segment and the sixth segment form the crossover area, and the third segment, the sixth segment, the seventh segment and the eighth segment form an interdigitated crossover structure.

7. The stacked structure of a spiral inductor according to Claim 1, wherein:
the first metal layer further comprises a first guard ring segment, arranged outside of the first segment or the second segment;
the second metal layer further comprises a second guard ring segment, arranged outside of the fourth segment or the fifth segment; and
the stacked structure further comprises a third set of dielectric vias, connecting the first guard ring segment and the second guard ring segment, and the first guard ring segment, the second guard ring segment and the third set of dielectric vias form a stacked guard ring.
8. The stacked structure of a spiral inductor according to Claim 1, wherein the spiral inductor is a symmetric spiral inductor.
9. The stacked structure of a spiral inductor according to Claim 1, wherein the first shunt winding and the second shunt winding are substantially in the shape of a rectangle, an octagon or a circle.
10. A stacked structure of a spiral inductor, comprising:
a first metal layer, comprising:
a first segment;
a second segment; and
a third segment, connected to the first segment and the second segment and laid out between the first segment and the second segment;
a second metal layer, comprising:
a fourth segment;
a fifth segment; and
a sixth segment, laid out between the fourth segment and the fifth segment;

a first set of dielectric vias, connecting the first segment to the fourth segment; and
a second set of dielectric vias, connecting the second segment to the fifth segment;
wherein, the first segment and the fourth segment form a first shunt winding, the
second segment and the fifth segment form a second shunt winding of the
spiral inductor, and the third segment and the sixth segment form a crossover
area.

11. The stacked structure of a spiral inductor according to Claim 10, wherein the second metal layer is laid out above the first metal layer.
12. The stacked structure of a spiral inductor according to Claim 10, wherein the first metal layer is laid out above the second metal layer.
13. The stacked structure of a spiral inductor according to Claim 10, wherein the thickness of the first metal layer is greater than the thickness of the second metal layer.
14. The stacked structure of a spiral inductor according to Claim 13, wherein the spiral inductor further comprises a third metal layer, with the structure of the third metal layer being the same as the structure of the second metal layer, the third metal layer and the second metal layer being laid out above or below the first metal layer, and the thickness of the first metal layer being greater than the thickness of the third metal layer.

15. The stacked structure of a spiral inductor according to Claim 10, wherein the thickness of the first metal layer is equal to the thickness of the second metal layer.
16. The stacked structure of a spiral inductor according to Claim 10, wherein the spiral inductor further comprises:
- a third metal layer, with the structure of the third metal layer being the same as the structure of the first metal layer; and
 - a fourth metal layer, with the structure of the fourth metal layer being the same as the structure of the second metal layer;
- wherein, a seventh segment of the third metal layer, an eighth segment of the fourth segment, the third segment and the sixth segment form the crossover area, and the third segment, the sixth segment, the seventh segment and the eighth segment form an interdigitated crossover structure.
17. The stacked structure of a spiral inductor according to Claim 16, wherein the second metal layer is laid out below the first metal layer, the third metal layer is laid below the second metal layer, and the fourth metal layer is laid out below the third metal layer.
18. The stacked structure of a spiral inductor according to Claim 16, wherein the first metal layer is laid out below the second metal layer, the fourth metal layer is laid below the first metal layer, and the third metal layer is laid out below the fourth metal layer.

19. The stacked structure of a spiral inductor according to Claim 10, wherein:
the first metal layer further comprises a first guard ring segment, arranged outside of the first segment or the second segment;
the second metal layer further comprises a second guard ring segment, arranged outside of the fourth segment or the fifth segment; and
the stacked structure further comprises a third set of dielectric vias, connecting the first guard ring segment and the second guard ring segment, and the first guard ring segment, the second guard ring segment and the third set of dielectric vias form a stacked guard ring.
20. The stacked structure of a spiral inductor according to Claim 10, wherein the spiral inductor is an asymmetric spiral inductor.
21. The stacked structure of a spiral inductor according to Claim 10, wherein the first shunt winding and the second shunt winding are in the shape of a rectangle, an octagon or a circle.

VIII. Drawings:

KEA-577

USA

Priority Document for

USA Appl. No. 12/773,012

中華民國經濟部智慧財產局

INTELLECTUAL PROPERTY OFFICE
MINISTRY OF ECONOMIC AFFAIRS
REPUBLIC OF CHINA

茲證明所附文件，係本局存檔中原申請案的副本，正確無訛，
申請資料如下：

This is to certify that annexed is a true copy from the records of this
Office of the application as originally filed which is identified hereunder:

請 日：西元 2009 年 05 月 19 日
Application Date May 19, 2009

請 案 號：098116543
Application No.

請 人：瑞昱半導體股份有限公司
Applicant(s)

發明人 / 創作人：黃凱易、簡育生、葉達勳
Inventor(s)

局 長
Director General

王美花

西元 2009 年 06 月 06 日
Jun 6, 2009

發明專利說明書

(本說明書格式、順序，請勿任意更動，※記號部分請勿填寫)

※ 申請案號：

※ 申請日：

※IPC 分類：

一、發明名稱：(中文/英文)

螺旋電感之堆疊結構/STACKED STRUCTURE OF A SPIRAL
INDUCTOR

二、中文發明摘要：

螺旋電感堆疊結構包含第一、第二金屬層及第一組、第二組介電窗。第一金屬層包含第一、第二、第三線段，第三線段之佈局方向不同於第一、第二線段之佈局方向。第二金屬層包含第四、第五、第六線段，第六線段連接第五線段且第六線段之佈局方向不同於第四、第五線段之佈局方向。第一組介電窗連接第一、第四線段，且三者係構成第一並聯繞線。第二組介電窗連接第二、第五線段，且三者係構成第二並聯繞線。第三、第六線段構成跨線區域。

三、英文發明摘要：

A stacked structure of a spiral inductor includes a first metal layer, a second metal layer, a first set of via, and a second set of via. The first metal layer includes a first segment, a second segment, and a third segment, wherein the layout direction of the third segment is different from the layout direction of the first and second segments. The second

metal layer includes a fourth segment, a fifth segment, and a sixth segment connected to the fifth segment, wherein the layout direction of the sixth segment is different from the layout direction of the fourth and fifth segments. The first set of via connects the first and fourth segments, and they construct a first shunt winding. The second set of via connects the second and fifth segments, and they construct a second shunt winding. The third and sixth segments construct a crossover region.

四、指定代表圖：

(一)本案指定代表圖為：第（ 1 ）圖。

(二)本代表圖之元件符號簡單說明：

100、200	螺旋電感
M11～M16、M21～M26	金屬層
110、210	第一組介電窗
120、220	第二組介電窗
S11～S16、S21～S26	線段
130、230	第一並聯繞線
140、240	第二並聯繞線
150、250	跨線區域

五、本案若有化學式時，請揭示最能顯示發明特徵的化學式：

無

六、發明說明：

【發明所屬之技術領域】

本發明有關一種螺旋電感之堆疊結構，尤指一種利用跨線區域的金屬層來當作並聯繞線以提升品質因數(quality factor)的堆疊結構。

【先前技術】

隨著 IC 製造朝系統單晶片 (system on chip, SoC) 方向發展，積體電感 (integrated inductor) 或積體變壓器 (integrated transformer) 等被動元件已被廣泛整合製作在高頻積體電路中。由於 IC 製造一般採用矽基底的結構，積體電感/積體變壓器的基底損耗 (substrate loss) 以及金屬損耗 (metal loss) 將決定其品質因數 (quality factor) 的好壞，尤其以金屬損耗為最直接影響電感特性的主因。

目前常見的積體電感包含對稱型螺旋電感以及非對稱型螺旋電感，多採用最上層 (或最上兩層) 金屬來作為電感的繞線，並使用下一層金屬以及介電窗 (via) 來作為跨線 (crossover)。此種電感的缺點是其寄生電阻將受限於此單層金屬、跨線的導電度、介電窗的數量以及介電窗的電阻值。若要提高電感的品質因數，勢必得增加繞線的線寬，但此作法將消耗更多的晶片面積。因此，有人提出利用多層金屬並聯的架構，使得電感在相同面積下，比傳統單層電感得到更低的串聯電阻，藉以提升品質因數，諸如前案美國專利第 20080074229 號、美國專利第 6664882 號所揭示者。然而，無論是

單層金屬架構或者是多層金屬並聯的架構，電感的跨線部份皆是使用到不同於電感繞線本身的金屬層，並無法使電感的品質因數達到最佳化。

【發明內容】

本發明的目的之一在於提供一種螺旋電感之堆疊結構，以解決先前技術中之問題。

本發明之實施例揭露了一種螺旋電感之堆疊結構，包含有一第一金屬層、一第二金屬層、一第一組介電窗以及一第二組介電窗。第一金屬層包含一第一線段、一第二線段以及一第三線段，第三線段連接至第一線段，且第三線段之佈局方向不同於該第一線段之佈局方向與該第二線段之佈局方向。第二金屬層佈局於第一金屬層之下，其包含有一第四線段、一第五線段以及一第六線段，第六線段連接至第五線段，且該第六線段之佈局方向不同於該第四線段之佈局方向與該第五線段之佈局方向。第一組介電窗連接第一線段以及第四線段。第二組介電窗連接第二線段以及第五線段。其中，第一線段、第四線段以及第一組介電窗係構成螺旋電感之一第一並聯繞線，第二線段、第五線段以及第二組介電窗係構成螺旋電感之一第二並聯繞線，以及第三線段與第六線段係構成一第一跨線區域。此螺旋電感係為一對稱型螺旋電感。

本發明之實施例另揭露了一種螺旋電感之堆疊結構，包含有一第

一金屬層、一第二金屬層、一第一組介電窗以及一第二組介電窗。第一金屬層包含一第一線段、一第二線段以及一第三線段，第三線段連接至第一線段與第二線段且佈局於第一線段以及第二線段之間。第二金屬層包含有一第四線段、一第五線段以及一第六線段，第六線段佈局於第四線段與第五線段之間。第一組介電窗連接第一線段以及第四線段。第二組介電窗連接第二線段以及第五線段。其中，第一線段與第四線段係構成螺旋電感之一第一並聯繞線，第二線段與第五線段係構成螺旋電感之一第二並聯繞線，以及第三線段與第六線段係構成一跨線區域。此螺旋電感係為一非對稱型螺旋電感。

【實施方式】

於以下實施例中，係針對對稱型（symmetric）螺旋電感（請參考第 1 圖至第 8 圖之實施例）以及非對稱型（asymmetric）螺旋電感（請參考第 9 圖至第 14 圖之實施例），提出至少三種多層金屬堆疊的螺旋電感之跨線結構，主要係分為 L 型跨線結構（L-shape Crossover）、指間交錯型跨線結構（Interdigitated Crossover）以及溝渠式跨線結構（Trench-shape Crossover），可使多層金屬堆疊的螺旋電感得到最佳化的品質因數。其中，「L 型跨線結構」、「指間交錯型跨線結構」以及「溝渠式跨線結構」等用語係本發明所定義之，僅作為名稱區隔之用。另外，本發明提出堆疊式防護環（stacked guard ring）來增加雜訊的阻隔能力。

請參考第 1 圖，第 1 圖（包含有圖 1A 及圖 1B）為本發明一螺旋電感之堆疊結構之一實施例的示意圖。其中，圖 1A 係表示 L 型跨線結構，而圖 1B 係表示指間交錯型跨線結構。於本實施例中，圖 1A 所示之 L 型跨線結構以及圖 1B 所示之指間交錯型跨線結構皆係應用於一對稱型螺旋電感中。如圖 1A 所示，螺旋電感 100 之堆疊結構係包含六個金屬層 M16~M11、一第一組介電窗（via）110 以及一第二組介電窗 120。金屬層 M16~M14 包含線段 S11、S12 以及 S13，其中線段 S13 係連接至線段 S11 且佈局於線段 S11 以及線段 S12 之間。金屬層 M13~M11 係佈局於金屬層 M16~M14 之下，其包含線段 S14、S15 以及 S16，其中線段 S16 係連接至線段 S15 且佈局於線段 S14 與線段 S15 之間。第一組介電窗 110 係連接線段 S11 以及線段 S14，而第二組介電窗 120 係連接線段 S12 以及線段 S15。於本實施例中，金屬層 M16~M14 之線段 S11、金屬層 M13~M11 之線段 S14 以及第一組介電窗 110 係構成螺旋電感 100 之一第一並聯繞線（shunt winding）130，金屬層 M16~M14 之線段 S12、金屬層 M13~M11 之線段 S15 以及第二組介電窗 120 係構成螺旋電感 100 之一第二並聯繞線 140，且金屬層 M16~M14 之線段 S13 與金屬層 M13~M11 之線段 S16 係構成一跨線（crossover）區域 150。

如圖 1B 所示，螺旋電感 200 之堆疊結構係包含六個金屬層 M26~M21、一第一組介電窗 210 以及一第二組介電窗 220。金屬層 M26、M24、M22 包含線段 S21、S22 以及 S23，其中線段 S23 係連

接至線段 S21 且佈局於線段 S21 以及線段 S22 之間。金屬層 M25、M23、M21 包含線段 S24、S25 以及 S26，其中線段 S26 係連接至線段 S25 且佈局於線段 S24 與線段 S25 之間。第一組介電窗 210 係連接線段 S21 以及線段 S24，而第二組介電窗 220 係連接線段 S22 以及線段 S25。於本實施例中，金屬層 M26、M24、M22 之線段 S21、金屬層 M25、M23、M21 之線段 S24 以及第一組介電窗 210 係構成螺旋電感 200 之一第一並聯繞線 (shunt winding) 230，金屬層 M26、M24、M22 之線段 S22、金屬層 M25、M23、M21 之線段 S25 以及第二組介電窗 220 係構成螺旋電感 200 之一第二並聯繞線 240，且金屬層 M26、M24、M22 之線段 S23 與金屬層 M25、M23、M21 之線段 S26 係構成一跨線區域 250。

請注意，於上述之實施例中，係以六個金屬層為例，然此並非本發明之限制條件，金屬層的個數並不侷限。

請參考第 2 圖、第 3 圖以及第 4 圖，其中第 2 圖為一對稱型螺旋電感 300 之一範例的上視圖，第 3 圖為第 2 圖所示之對稱型螺旋電感 300 採用圖 1A 的堆疊結構之縱剖面圖，而第 4 圖為第 2 圖所示之對稱型螺旋電感 300 採用圖 1B 的堆疊結構之縱剖面圖。如第 2 圖所示，對稱型螺旋電感 300 包含一第一並聯繞線 330 以及一第二並聯繞線 340，而圖中標示 A1 的區域則代表跨線區域。第 3 圖係為對稱型螺旋電感 300 沿著第 2 圖中 YY' 虛線之縱剖面，其係採用 1A 的堆疊結構。如第 3 圖所示，對稱型螺旋電感 300 之堆疊結構係包

含五個金屬層 M36~M32、一第一組介電窗 310 以及一第二組介電窗 320。於本實施例中，金屬層 M36 之線段 S31、金屬層 M35~M32 之線段 S34 以及第一組介電窗 310 係構成螺旋電感 300 之第一並聯繞線 330，金屬層 M36 之線段 S32、金屬層 M35~M32 之線段 S35 以及第二組介電窗 320 係構成螺旋電感 300 之第二並聯繞線 340，且金屬層 M36 之線段 S33 與金屬層 M35~M32 之線段 S36 係構成一跨線區域 350（包含有第一部分 350A 以及第二部分 350B）。由第 2 圖與第 3 圖可得知，線段 S33（構成跨線區域 350 之第一部分 350A）的佈局方向係不同於線段 S31、線段 S32 的佈局方向，且線段 S36（構成跨線區域 350 之第二部分 350B）的佈局方向亦不同於線段 S34、線段 S35 的佈局方向。

另外，金屬層 M36 另包含第一防護環線段 S37，設置於線段 S31 及/或線段 S32 之外側；金屬層 M35~M32 另包含第二防護環線段 S38，設置於線段 S34 及/或線段 S35 之外側；且該堆疊結構另包含一第三組介電窗 360，連接第一防護環線段 S37 以及第二防護環線段 S38。其中，第一防護環線段 S37、第二防護環線段 S38 以及第三組介電窗 360 係構成一堆疊式防護環（stacked guard ring），來增加雜訊的阻隔能力。

請注意，於本實施例中，由於金屬層 M36 之厚度係大於金屬層 M35~M32 之厚度，所以跨線區域 350 的第一部分 350A 係採用單層金屬（亦即金屬層 M36 之線段 S33）來實現，而跨線區域 350 之

第二部分 350B 係採用多層堆疊金屬（亦即金屬層 M35~M32 之線段 S36）來實現，且金屬層 M35~M32 皆佈局於金屬層 M36 之下，以求電感的對稱性。

第 4 圖係為對稱型螺旋電感 300 沿著第 2 圖中 YY' 虛線之縱剖面，其係採用 1B 的堆疊結構。如第 4 圖所示，對稱型螺旋電感 300 之堆疊結構係包含六個金屬層 M46~M41、一第一組介電窗 410 以及一第二組介電窗 420。於本實施例中，金屬層 M46、M44、M42 之線段 S41、金屬層 M45、M43、M41 之線段 S44 以及第一組介電窗 410 係構成螺旋電感 300 之第一並聯繞線 330，金屬層 M46、M44、M42 之線段 S42、金屬層 M45、M43、M41 之線段 S45 以及第二組介電窗 420 係構成螺旋電感 300 之第二並聯繞線 340，且金屬層 M46、M44、M42 之線段 S43 與金屬層 M45、M43、M41 之線段 S46 係構成一跨線區域 450（包含有第一部分 450A 以及第二部分 450B）。由第 2 圖與第 4 圖可得知，線段 S43（構成跨線區域 450 之第一部分 450A）的佈局方向係不同於線段 S41、線段 S42 的佈局方向，且線段 S46（構成跨線區域 450 之第二部分 450B）的佈局方向係不同於線段 S44、線段 S45 的佈局方向。

另外，金屬層 M46、M44、M42 另包含一第一防護環線段 S47，設置於線段 S41 及/或線段 S42 之外側；金屬層 M45、M43、M41 另包含一第二防護環線段 S48，設置於線段 S44 及/或線段 S45 之外側；且該堆疊結構另包含一第三組介電窗 460，連接第一防護環線

段 S47 以及第二防護環線段 S48。其中，第一防護環線段 S47、第二防護環線段 S48 以及第三組介電窗 460 係構成一堆疊式防護環，來增加雜訊的阻隔能力。

請注意，於本實施例中，由於金屬層 M46、M44、M42 之厚度係等於金屬層 M45、M43、M41 之厚度，所以跨線區域 450 的第一部分 450A 係採用多層堆疊金屬（亦即金屬層 M46、M44、M42 之線段 S43）來實現，而跨線區域 450 之第二部分 450B 亦採用多層堆疊金屬（亦即金屬層 M45、M43、M41 之線段 S46）來實現，且金屬層 M46、M44、M42 與金屬層 M45、M43、M41 係相間設置（interlaced），以求電感的對稱性。

由上述第 3 圖及第 4 圖之相關說明可了解，本發明之螺旋電感之線路佈局方式可依據金屬層的厚度，來增加電感的對稱性。例如，當積體電路中之金屬層厚度有不同時，可採用「L 型跨線結構」（即圖 1A 或第 3 圖所示之跨線結構）進行線路的佈局，以獲得較佳之電感對稱性。另外，當積體電路中之每一金屬層的厚度皆相同時，可採用「指間交錯型跨線結構」（即圖 1B 或第 4 圖所示之跨線結構）進行線路的佈局，以獲得較佳之電感對稱性。

由上述之實施例可得知，本發明所揭露之螺旋電感的堆疊結構，其跨線區域的金屬層亦用來作為電感的繞線，以使電感的品質因數達到最佳化。如此一來，螺旋電感的寄生電阻將不再受限於跨線的

導電度、介電窗的數量以及介電窗的電阻值。

請參考第 5 圖至第 6 圖，第 5 圖為結合串聯繞線以及並聯繞線之一對稱型螺旋電感 500 之一範例的上視圖，第 6 圖（包含有圖 6A 以及圖 6B）為第 5 圖所示之對稱型螺旋電感 500 之第一電感 510（圖 6A）以及第二電感 610（圖 6B）的示意圖。對稱型螺旋電感 500 係為結合第一電感 510（亦即串聯繞線）以及第二電感 610（亦即並聯繞線）的多層堆疊螺旋電感，可在相同的面積下增加串聯電感值，使得晶片面積利用率增加。如圖 6A 所示，第一電感 510 係為傳統的單層對稱型螺旋電感，以金屬層 MT1 當作線圈繞線，以金屬層 MT2 當作跨線區域，其中第一串聯繞線 520 以及第二串聯繞線 530 的連接處 A、B 係為第一電感 510 的中心抽頭（center tap），將連接處 A、B 斷開，可往下連接至第二電感 610 的中心抽頭（亦即第一並聯繞線 620 以及第二並聯繞線 630 的連接處 A'、B'）。而圖 6B 之第二電感 610 則可採用圖 1A 的堆疊結構（亦即 L 型跨線結構）或者圖 1B 的堆疊結構（亦即指間交錯型跨線結構）來實現，其係以金屬層 MT3、MT4、MT5、MT6 來當作線圈繞線以及跨線區域，其中金屬層 MT1、MT2、MT3、MT4、MT5、MT6 係彼此上下平行。

請參考第 7 圖，第 7 圖為對稱型螺旋電感 500 沿著第 5 圖中 KK' 虛線之縱剖面，其係採用圖 1A 的堆疊結構。如第 7 圖所示，對稱型螺旋電感 500 包含第一電感 510 以及第二電感 610。於本實施例中，第一電感 510 係以金屬層 MT1 當作線圈繞線（包含第一串聯繞

線 520 以及第二串聯繞線 530)，以金屬層 MT2 當作跨線區域；而第二電感 610 則採用圖 1A 的 L 型跨線結構，其中金屬層 MT3、MT4 係可對應至圖 1A 的金屬層 M16～M14，而金屬層 MT5、MT6 係可對應至圖 1A 的金屬層 M13～M11。

請參考第 8 圖，第 8 圖對稱型螺旋電感 500 沿著第 5 圖中 KK' 虛線之縱剖面，其係採用圖 1B 的堆疊結構。如第 8 圖所示，對稱型螺旋電感 500 包含第一電感 510 以及第二電感 610。於本實施例中，第二電感 610 則採用圖 1B 的指間交錯型跨線結構，其中金屬層 MT3、MT5 係可對應至圖 1B 的金屬層 M26、M24、M22，而金屬層 MT4、MT6 係可對應至圖 1B 的金屬層 M25、M23、M21。

請參考第 9 圖，第 9 圖（包含有圖 9A、圖 9B、圖 9C 以及圖 9D）為本發明一螺旋電感之堆疊結構之另一實施例的示意圖。其中，圖 9A、9B 係表示溝渠式跨線結構，而圖 9C、9D 係表示指間交錯型跨線結構。於本實施例中，圖 9A、圖 9B、圖 9C 以及圖 9D 所示之跨線結構皆係應用於一非對稱型螺旋電感。如圖 9A 所示，螺旋電感 900A 之堆疊結構係包含六個金屬層 M96A～M91A、一第一組介電窗 910A 以及一第二組介電窗 920A。金屬層層 M96A～M94A 包含線段 S91A、S92A、S93A，其中線段 S93A 連接至線段 S91A 與線段 S92A 且佈局於線段 S91A 以及線段 S92A 之間。金屬層 M93A～M91A 包含線段 S94A、S95A、S96A，其中線段 S96A 佈局於線段 S94A 以及線段 S95A 之間。第一組介電窗 910A 係連接線段 S91A

以及線段 S94A，第二組介電窗 920A 係連接線段 S92A 以及線段 S95A。其中，金屬層 M96A~M94A 之線段 S91A 以及金屬層 M93A~M91A 之線段 S94A 係構成螺旋電感 900A 之一第一並聯繞線 930A，金屬層 M96A~M94A 之線段 S92A 以及金屬層 M93A~M91A 之線段 S95A 係構成螺旋電感 900A 之一第二並聯繞線 940A，以及線段 S93A 與線段 S96A 係構成一跨線區域 950A。而圖 9B 之螺旋電感 900B 之堆疊結構係與圖 9A 之螺旋電感 900A 之堆疊結構類似，兩者不同之處在於螺旋電感 900B 之堆疊結構係為螺旋電感 900A 之堆疊結構的倒置。換言之，於圖 9A 中，金屬層 M96A~M94A 係佈局於金屬層 M93A~M91A 之上方，而於圖 9B 中，金屬層 M93B~M91B 係佈局於金屬層 M96B~M94B 之下方。

如圖 9C 所示，螺旋電感 900C 之堆疊結構係包含六個金屬層 M96~M91C、一第一組介電窗 910C 以及一第二組介電窗 920C。金屬層層 M96C、M94C、M92C 包含線段 S91C、S92C、S93C，其中線段 S93C 連接至線段 S91C 與線段 S92C 且佈局於線段 S91C 以及線段 S92C 之間。金屬層層 M95C、M93C、M91C 包含線段 S94C、S95C、S96C，其中線段 S96C 佈局於線段 S94C 以及線段 S95C 之間。第一組介電窗 910C 係連接線段 S91C 以及線段 S94C，第二組介電窗 920C 係連接線段 S92C 以及線段 S95C。其中，金屬層 M96C、M94C、M92C 之線段 S91C 與金屬層 M95C、M93C、M91C 之線段 S94C 係構成螺旋電感 900C 之一第一並聯繞線 930C，金屬層金線段 S92C 與金屬層 M95C、M93C、M91C 之線段 S95C 係構成螺旋電感 900C

之一第二並聯繞線 940C，以及金屬層 M96C、M94C、M92C 之線段 S93C 與金屬層 M95C、M93C、M91C 之線段 S96C 係構成一跨線區域 950C。而圖 9D 之螺旋電感 900D 之堆疊結構係與圖 9C 之螺旋電感 900C 之堆疊結構類似，兩者不同之處在於螺旋電感 900D 之堆疊結構係為螺旋電感 900C 之堆疊結構的倒置。

請參考第 10 圖以及第 11 圖，第 10 圖為一非對稱型螺旋電感 1000 之一範例的上視圖，而第 11 圖（包含有圖 11A 以及圖 11B）則為第 10 圖所示之非對稱型螺旋電感 1000 之第一並聯繞線 1100（圖 11A）以及第二並聯繞線 1200（圖 11B）的示意圖。

請參考第 12 圖，第 12 圖為非對稱型螺旋電感 1000 沿著第 10 圖中 CC' 虛線之橫剖面，其係採用圖 9A 的堆疊結構。如第 12 圖所示，非對稱型螺旋電感 1000 之堆疊結構係包含五個金屬層 M126~M122、一第一組介電窗 1210 以及一第二組介電窗 1220。於本實施例中，金屬層 M126 之線段 S121、金屬層 M125~M122 之線段 S124 以及第一組介電窗 1210 係構成螺旋電感 1000 之第一並聯繞線 1100，金屬層 M126 之線段 S122、金屬層 M125~M122 之線段 S125 以及第二組介電窗 1220 係構成螺旋電感 1000 之第二並聯繞線 1200，且金屬層 M126 之線段 S123 與金屬層 M125~M122 之線段 S126 係構成一跨線區域 1250（包含有第一部分 1250A 以及第二部分 1250B）。

請注意，於本實施例中，由於金屬層 M126 之厚度係大於金屬層 M125～M122 之厚度，所以跨線區域 1250 的第一部分 1250A 係採用單層金屬（亦即金屬層 M126 之線段 S123）來實現，而跨線區域 1250 之第二部分 1250B 係採用多層堆疊金屬（亦即金屬層 M125～M122 之線段 S126）來實現，且金屬層 M125～M122 皆佈局於金屬層 M36 之下，以求電感的對稱性。

請參考第 13 圖，第 13 圖為非對稱型螺旋電感 1000 沿著第 10 圖中 CC' 虛線之橫剖面，其係採用圖 9B 的堆疊結構。第 13 圖與第 12 圖之堆疊結構類似，兩者不同之處在於第 13 圖之堆疊結構係為第 12 圖之堆疊結構的倒置。

請參考第 14 圖，第 14 圖為非對稱型螺旋電感 1000 沿著第 10 圖中 CC' 虛線之橫剖面，其係採用圖 9C 的堆疊結構。如第 14 圖所示，非對稱型螺旋電感 1000 之堆疊結構係包含六個金屬層 M146～M141、一第一組介電窗 1410 以及一第二組介電窗 1420。於本實施例中，金屬層 M146、M144、M142 之線段 S141、金屬層 M145、M143、M141 之線段 S144 以及第一組介電窗 1410 係構成非對稱型螺旋電感 1000 之第一並聯繞線 1100，金屬層 M146、M144、M142 之線段 S142、金屬層 M145、M143、M141 之線段 S145 以及第二組介電窗 1420 係構成螺旋電感 1000 之第二並聯繞線 1200，且金屬層 M146、M144、M142 之線段 S143 與金屬層 M145、M143、M141 之線段 S146 係構成一跨線區域 1450（包含有第一部分 1450A 以及

第二部分 1450B)。

請注意，於本實施例中，由於金屬層 M146、M144、M142 之厚度係等於金屬層 M145、M143、M141 之厚度，所以跨線區域 1450 的第一部分 1450A 係採用多層堆疊金屬（亦即金屬層 M146、M144、M142 之線段 S143）來實現，而跨線區域 1450 之第二部分 1450B 亦採用多層堆疊金屬（亦即金屬層 M145、M143、M141 之線段 S146）來實現，且金屬層 M146、M144、M142 與金屬層 M145、M143、M141 係相間設置，以求電感的對稱性。當然，亦可採用圖 9D 之堆疊結構來實現，由於其堆疊結構僅為第 14 圖之倒置，為簡潔起見，於此不再贅述。

當然，亦可採用前述之堆疊式防護環來增加雜訊的阻隔能力。此外，於上述之實施例中，第一並聯繞線與第二並聯繞線之形狀係以矩形以及八角形（octagon）為例，然此並非本發明之限制條件，本發明所揭露之螺旋電感之堆疊結構可適用於各種形狀。

以上所述的實施例僅用來說明本發明之技術特徵，並非用來侷限本發明之範疇。由上可知，本發明提供一種螺旋電感之堆疊結構，其係利用跨線區域的金屬層來當作並聯繞線，可使多層金屬堆疊的螺旋電感得到最佳化的品質因數。再者，本發明所揭露之螺旋電感之堆疊結構之應用範圍廣泛，其係可應用於對稱型螺旋電感以及非對稱型螺旋電感。且針對不同厚度的金屬層，亦提出不同的跨線結

構，以求電感的對稱性。另外，本發明提出堆疊式防護環（stacked guard ring）來增加雜訊的阻隔能力。

以上所述僅為本發明之較佳實施例，凡依本發明申請專利範圍所做之均等變化與修飾，皆應屬本發明之涵蓋範圍。

【圖式簡單說明】

第 1 圖（包含有圖 1A 及圖 1B）為本發明一螺旋電感之堆疊結構之一實施例的示意圖。

第 2 圖為一對稱型螺旋電感之一範例的上視圖。

第 3 圖為第 2 圖所示之對稱型螺旋電感採用圖 1A 的堆疊結構之縱剖面圖。

第 4 圖為第 2 圖所示之對稱型螺旋電感採用圖 1B 的堆疊結構之縱剖面圖。

第 5 圖為結合串聯繞線以及並聯繞線之一對稱型螺旋電感之一範例的上視圖。

第 6 圖（包含有圖 6A 以及圖 6B）為第 5 圖所示之對稱型螺旋電感之串聯繞線以及並聯繞線的示意圖。

第 7 圖為第 5 圖所示之對稱型螺旋電感採用圖 1A 的堆疊結構之橫剖面圖。

第 8 圖為第 5 圖所示之對稱型螺旋電感採用圖 1B 的堆疊結構之橫剖面圖。

第 9 圖（包含有圖 9A、圖 9B、圖 9C 以及圖 9D）為本發明一螺旋電感之堆疊結構之另一實施例的示意圖。

第 10 圖為一非對稱型螺旋電感之一範例的上視圖。

第 11 圖（包含有圖 11A 以及圖 11B）為第 10 圖所示之非對稱型螺旋電感之第一並聯繞線以及第二並聯繞線的示意圖。

第 12 圖為第 10 圖所示之非對稱型螺旋電感採用圖 9A 的堆疊結構之橫剖面圖。

第 13 圖為第 10 圖所示之非對稱型螺旋電感採用圖 9B 的堆疊結構之橫剖面圖。

第 14 圖為第 10 圖所示之非對稱型螺旋電感採用圖 9C 的堆疊結構之橫剖面圖。

【主要元件符號說明】

100、200、900A、900B、900C、900D	螺旋電感
M16~M11、M26~M21、M36~M32、M46~M41、 MT1~MT6、M96A~M91A、M96B~M91B、 M96C~M91C、M96D~M91D、M126~M122、 M136~M132、M146~M141	金屬層
110、210、310、410、910A、910B、 910C、910D、1210、1410	第一組介電窗
120、220、320、420、920A、920B、 920C、920D、1220、1420	第二組介電窗
360、460	第三組介電窗

S11~S16、S21~S26、S31~S36、S41~S46、	
S91A~S96A、S91B~S96B、S91C~S96C、	
S91D~S96D、S121~S126、S141~S146	線段
S37、S47	第一防護環線段
S38、S48	第二防護環線段
130、230、330、620、930A、	
930B、930C、930D、1100	第一並聯繞線
140、240、340、630、940A、	
940B、940C、940D、1200	第二並聯繞線
150、250、350、450、950A、950B、	
950C、950D、1250、1350、1450	跨線區域
A1	區域
350A、450A、1250A、1450A	第一部分
350B、450B、1250B、1450B	第二部分
300、500	對稱型螺旋電感
YY'、KK'、CC'	虛線
510	第一電感
610	第二電感
A、B、A'、B'	連接處
520	第一串聯繞線
530	第二串聯繞線
1000	非對稱型螺旋電感

七、申請專利範圍：

1. 一種螺旋電感之堆疊結構，包含有：

一第一金屬層，包含有：

一第一線段；

一第二線段；以及

一第三線段，連接至該第一線段，該第三線段之佈局方向不同於該第一線段之佈局方向與該第二線段之佈局方向；

一第二金屬層，佈局於該第一金屬層之下，該第二金屬層包含有：

一第四線段；

一第五線段；以及

一第六線段，連接至該第五線段，該第六線段之佈局方向不同於該第四線段之佈局方向與該第五線段之佈局方向；

一第一組介電窗 (via)，連接該第一線段以及該第四線段；以及

一第二組介電窗，連接該第二線段以及該第五線段；

其中，該第一線段、該第四線段以及該第一組介電窗係構成第一並聯繞線 (shunt winding)；該第二線段、該第五線段以及該第二組介電窗係構成第二並聯繞線；以及該第三線段與該第六線段係構成一跨線 (crossover) 區域。

2. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該第三線段係佈局於該第一線段與該第二線段之間，以及該第六線段係佈局於該第四線段與該第五線段之間。

3. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該第一金屬層之厚度係大於該第二金屬層之厚度。
4. 如申請專利範圍第 3 項所述之螺旋電感之堆疊結構，其中該螺旋電感更包含一第三金屬層佈局於該第二金屬層下方，該第三金屬層之結構係與該第二金屬層之結構相同，且該第一金屬層之厚度係大於該第三金屬層之厚度。
5. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該第一金屬層之厚度係等於該第二金屬層之厚度。
6. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該螺旋電感更包含：
一第三金屬層佈局於該第二金屬層下方，且該第三金屬層之結構係與該第一金屬層之結構相同；以及
一第四金屬層佈局於該第三金屬層下方，且該第四金屬層之結構係與該第二金屬層之結構相同；
其中，該第三金屬層之一第七線段、該第四金屬層之一第八線段、該第三線段與該第六線段係構成該跨線區域；且該第三線段、該第六線段、該第七線段與該第八線段係構成一指間交錯型跨線結構。

7. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中：

該第一金屬層另包含一第一防護環線段，設置於該第一線段或該第二線段之外側；

該第二金屬層另包含一第二防護環線段，設置於該第四線段或該第五線段之外側；以及

該堆疊結構另包含一第三組介電窗，連接該第一防護環線段以及該第二防護環線段，且該第一防護環線段、該第二防護環線段以及該第三組介電窗係構成一堆疊式防護環 (guard ring)。

8. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該螺旋電感係為一對稱型螺旋電感。

9. 如申請專利範圍第 1 項所述之螺旋電感之堆疊結構，其中該第一並聯繞線與該第二並聯繞線之形狀實質上為一矩形、一八角形 (octagon) 或者一圓形。

10. 一種螺旋電感之堆疊結構，包含有：

一第一金屬層，包含有：

一第一線段；

一第二線段；以及

一第三線段，連接至該第一線段與該第二線段且佈局於該第一線段以及該第二線段之間；

一第二金屬層，包含有：

一第四線段；
一第五線段；以及
一第六線段，佈局於該第四線段與該第五線段之間；
一第一組介電窗，連接該第一線段以及該第四線段；以及
一第二組介電窗，連接該第二線段以及該第五線段；
其中，該第一線段與該第四線段係構成一第一並聯繞線，該第二線段與該第五線段係構成該螺旋電感之一第二並聯繞線，以及該第三區段與該第六線段係構成一跨線區域。

11. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該第二金屬層係佈局於該第一金屬層之上方。
12. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該第一金屬層係佈局於該第二金屬層之上方。
13. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該第一金屬層之厚度係大於該第二金屬層之厚度。
14. 如申請專利範圍第 13 項所述之螺旋電感之堆疊結構，其中該螺旋電感佈局於更包含一第三金屬層，該第三金屬層之結構係與該第二金屬層之結構相同，該第三金屬層與該第二金屬層均佈局於該第一金屬層之上或之下，且該第一金屬層之厚度係大於該第三金屬層之厚度。

15. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該第一金屬層之厚度係等於該第二金屬層之厚度。

16. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該螺旋電感更包含：

一第三金屬層，且該第三金屬層之結構係與該第一金屬層之結構相同；以及

一第四金屬層，且該第四金屬層之結構係與該第二金屬層之結構相同；

其中，該第三金屬層之一第七線段、該第四金屬層之一第八線段、該第三線段與該第六線段係構成該跨線區域；且該第三線段、該第六線段、該第七線段與該第八線段係構成一指間交錯型跨線結構。

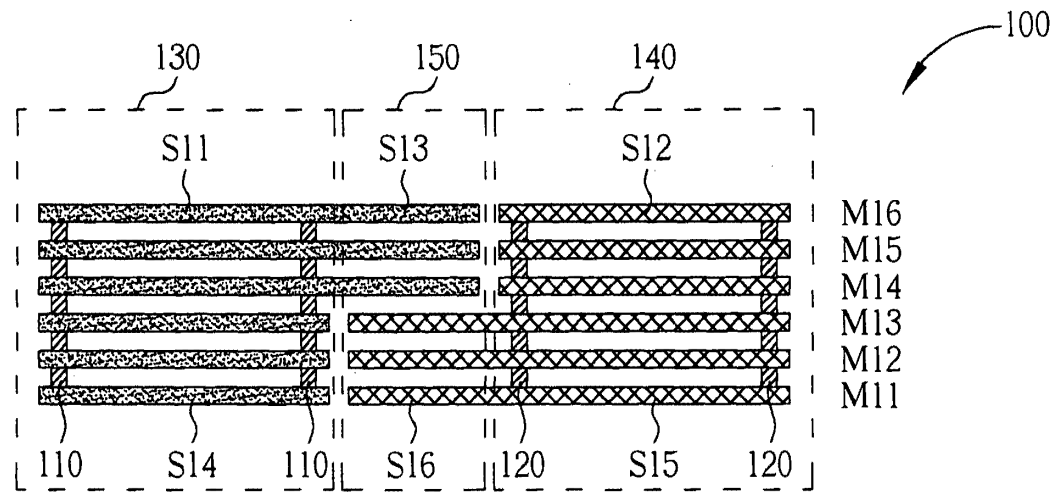
17. 如申請專利範圍第 16 項所述之螺旋電感之堆疊結構，其中該第二金屬層係佈局於該第一金屬層之下，該第三金屬層係佈局於該第二金屬層之下，以及該第四金屬層係佈局於該第三金屬層之下。

18. 如申請專利範圍第 16 項所述之螺旋電感之堆疊結構，其中該第一金屬層係佈局於該第二金屬層之下，該第四金屬層係佈局於該第一金屬層之下，以及該第三金屬層係佈局於該第四金屬層之

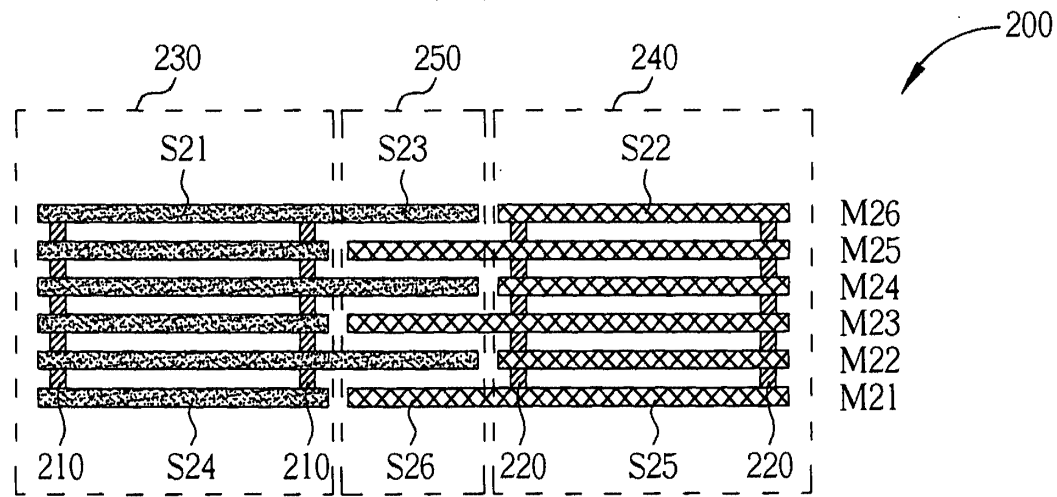
下。

19. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中：
- 該第一金屬層另包含一第一防護環線段，設置於該第一線段或該第二線段之外側；
- 該第二金屬層另包含一第二防護環線段，設置於該第四線段或該第五線段之外側；以及
- 該堆疊結構另包含一第三組介電窗，連接該第一防護環線段以及該第二防護環線段，且該第一防護環線段、該第二防護環線段以及該第三組介電窗係構成一堆疊式防護環。
20. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該螺旋電感係為一非對稱型螺旋電感。
21. 如申請專利範圍第 10 項所述之螺旋電感之堆疊結構，其中該第一並聯繞線與該第二並聯繞線之形狀係為一矩形、一八角形或者一圓形。

八、圖式：



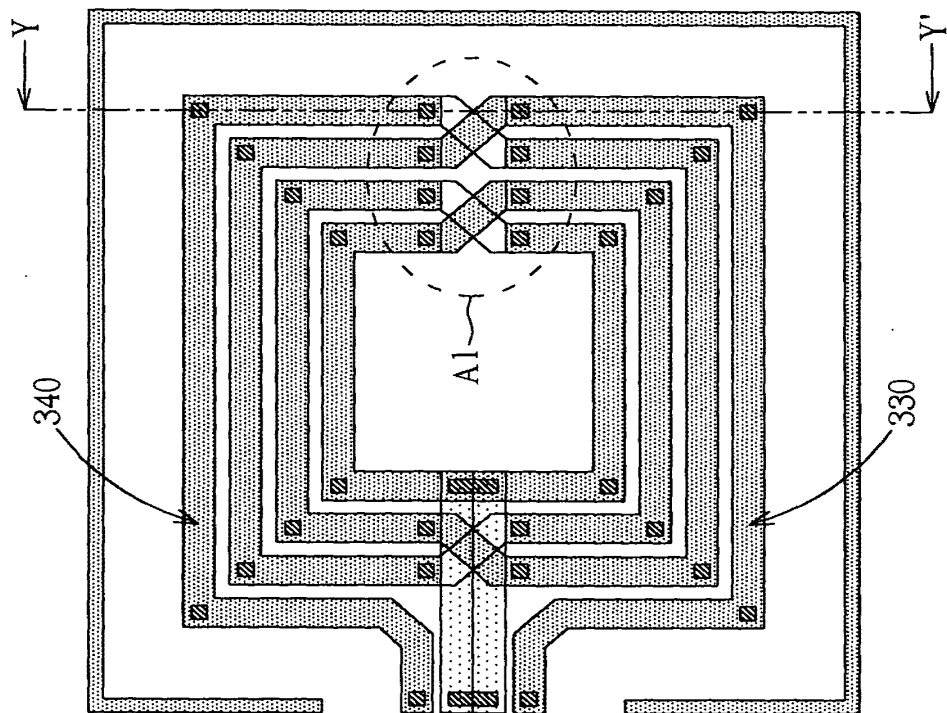
(1A)



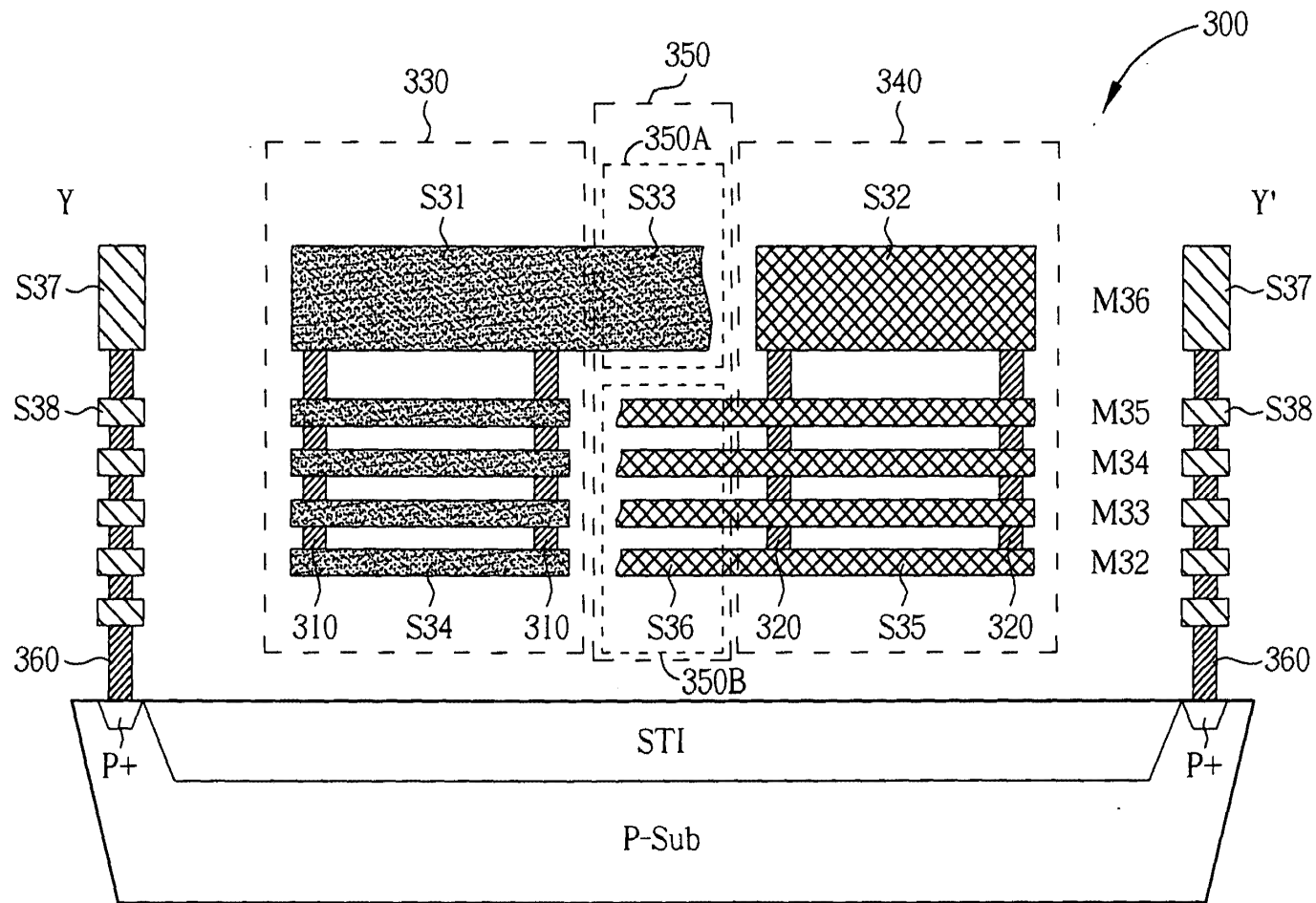
(1B)

第1圖

300

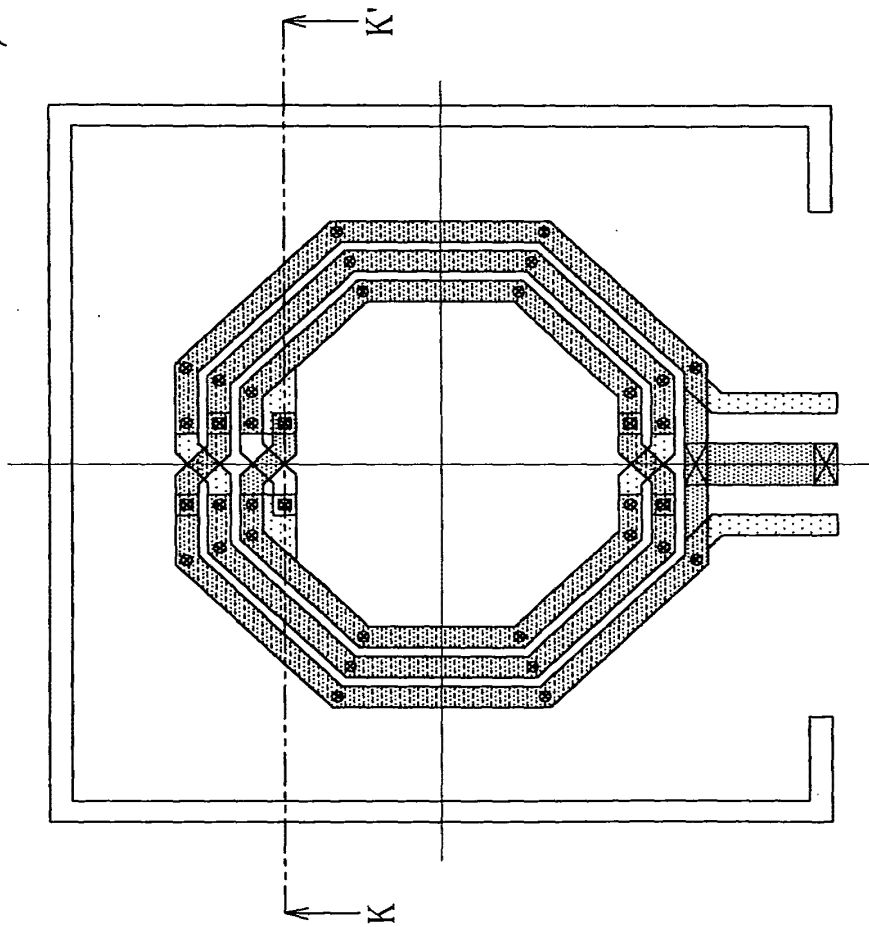


第2圖

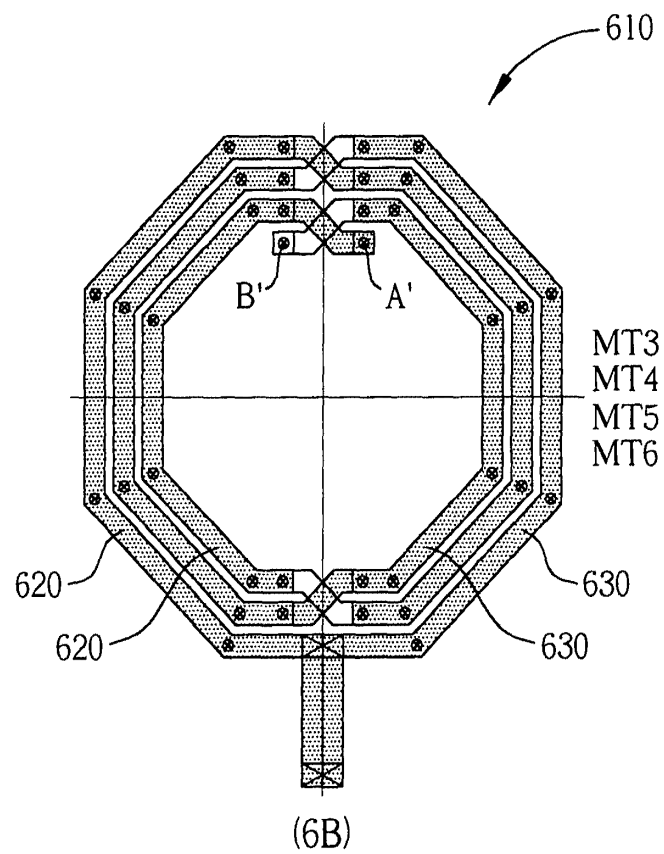
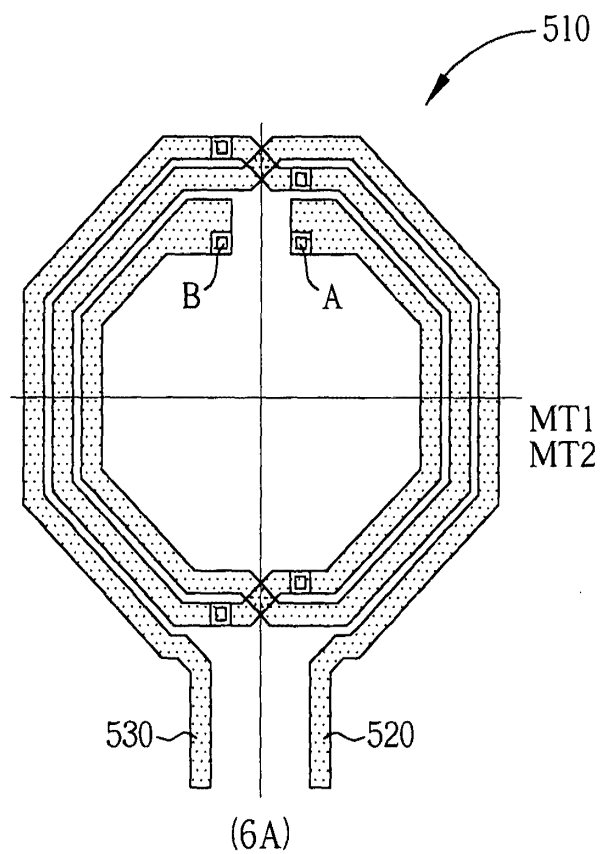


第3圖

500

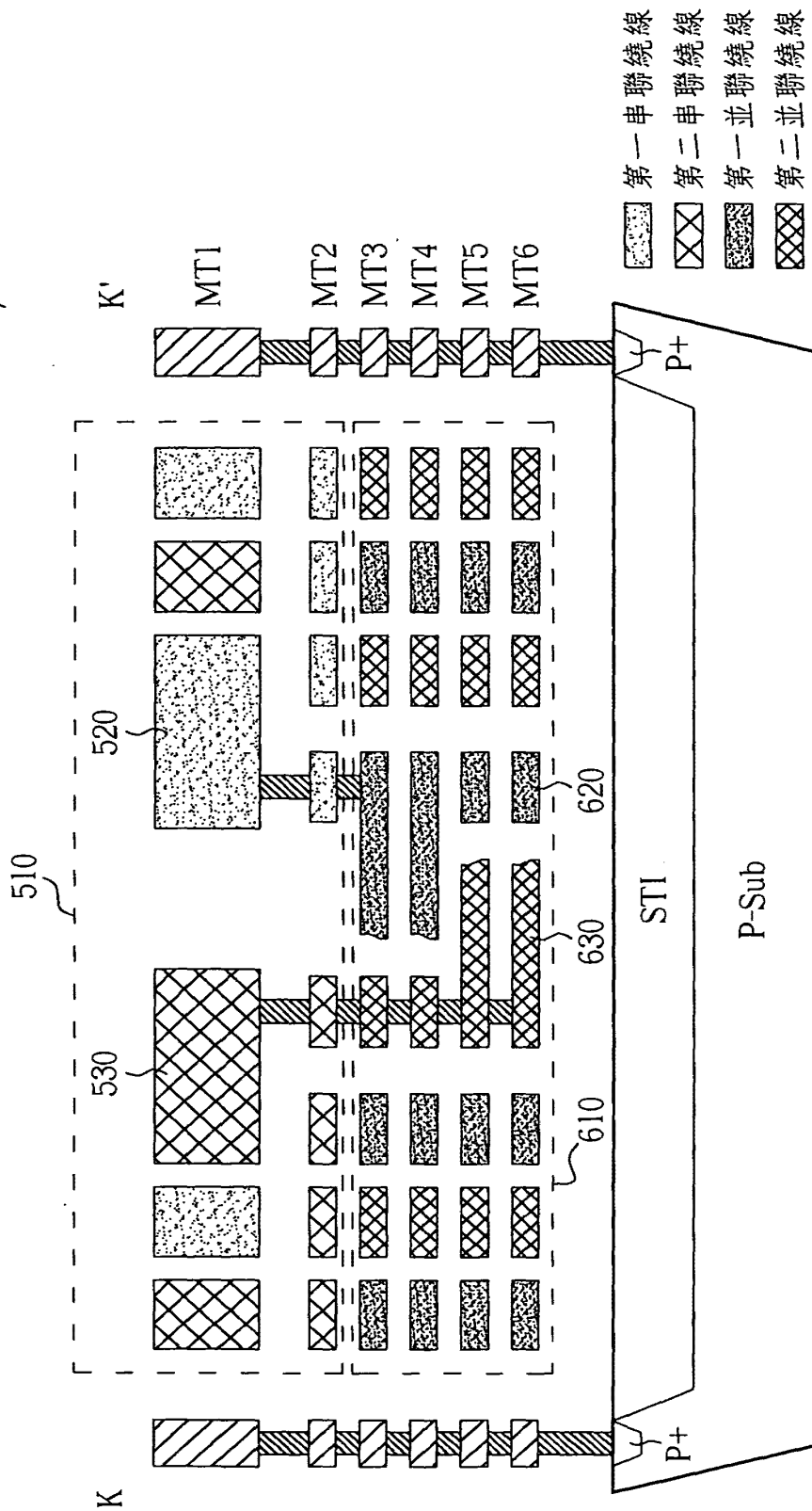


第5圖



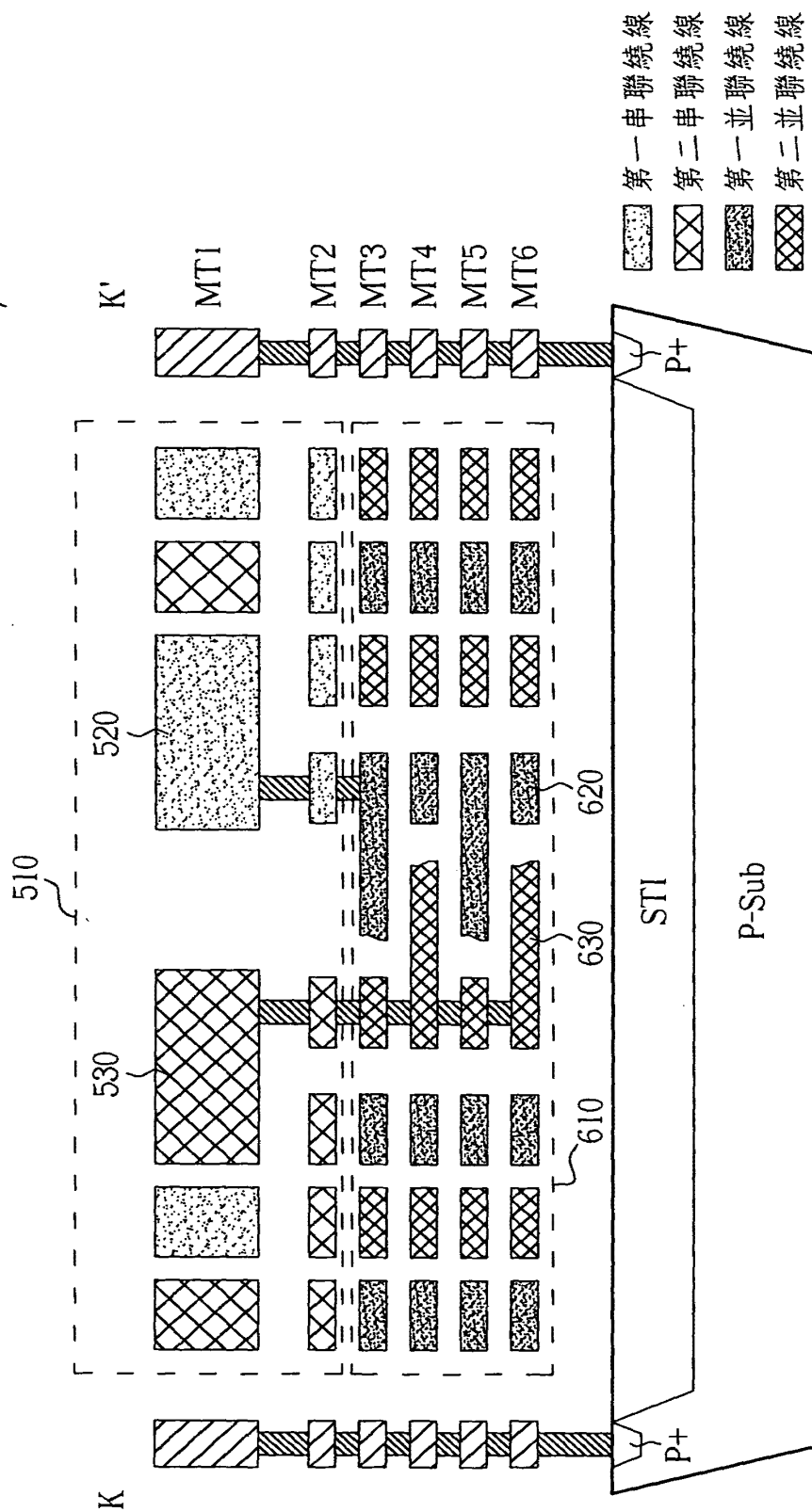
第6圖

500

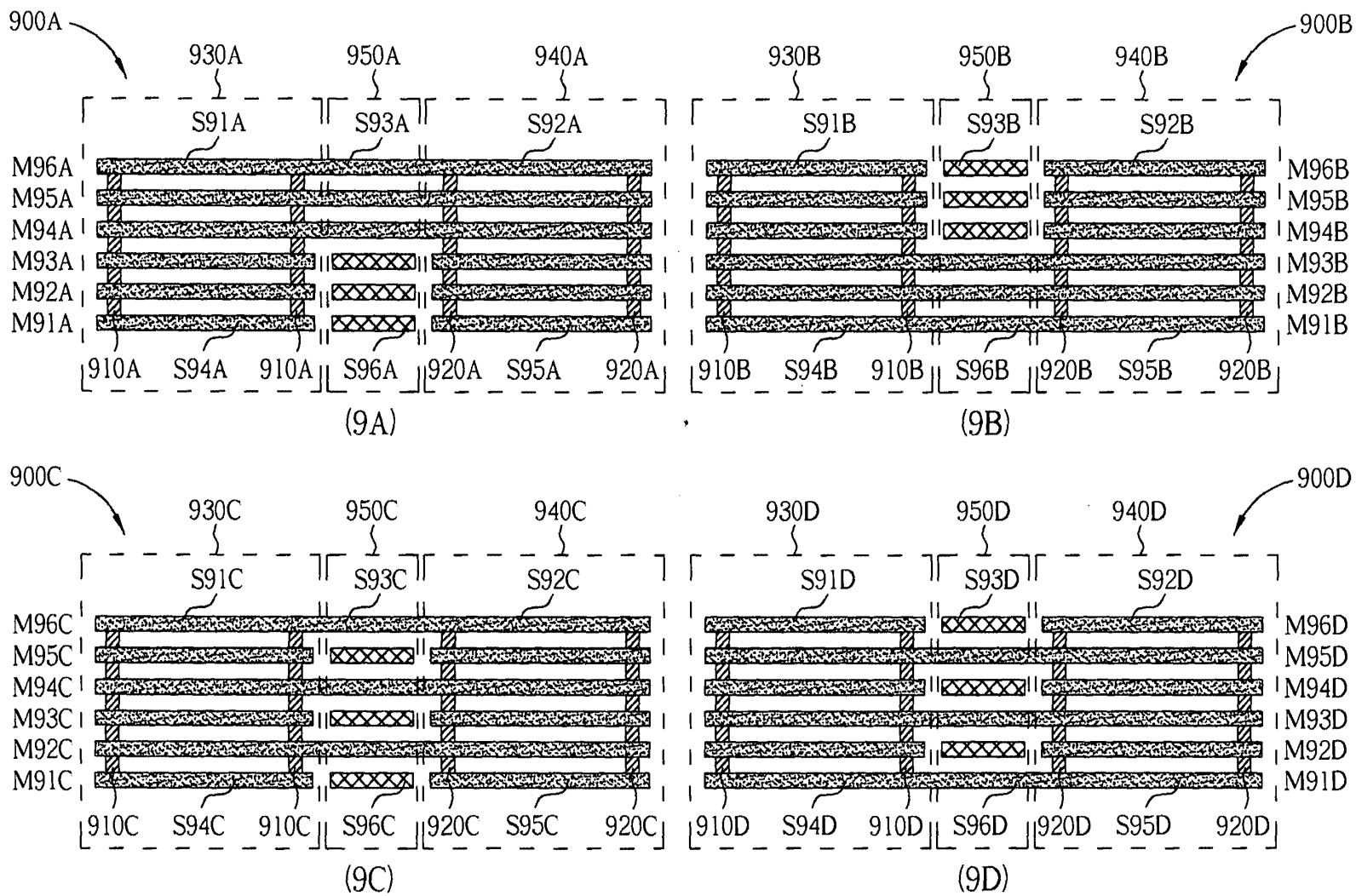


第7圖

500

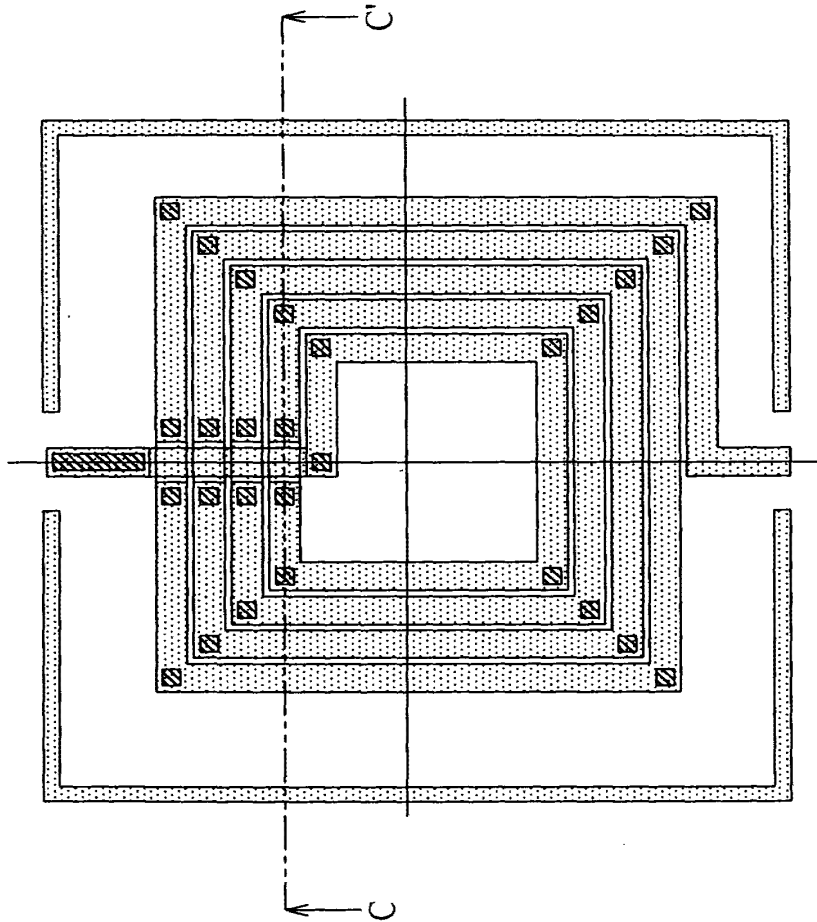


第8圖



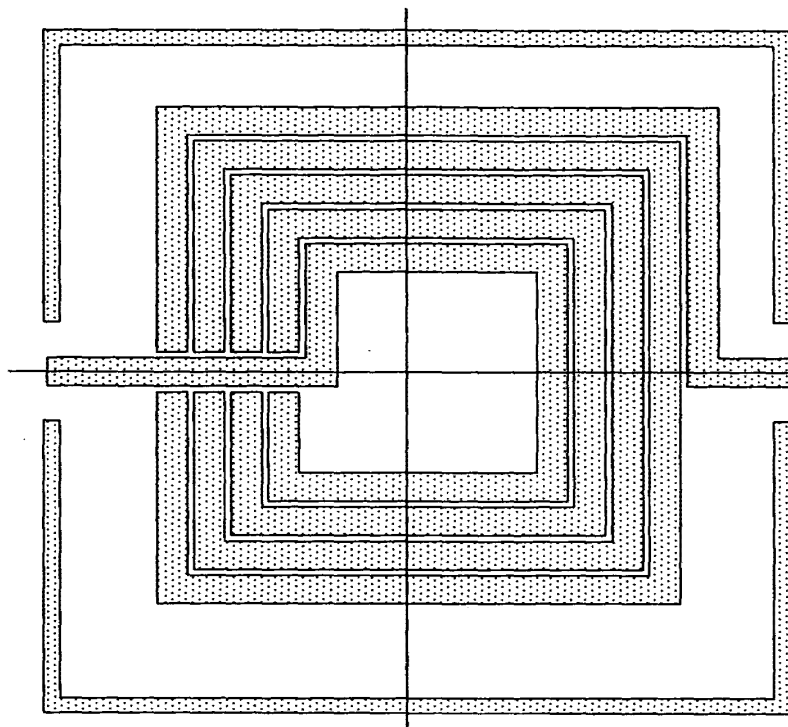
第9圖

1000



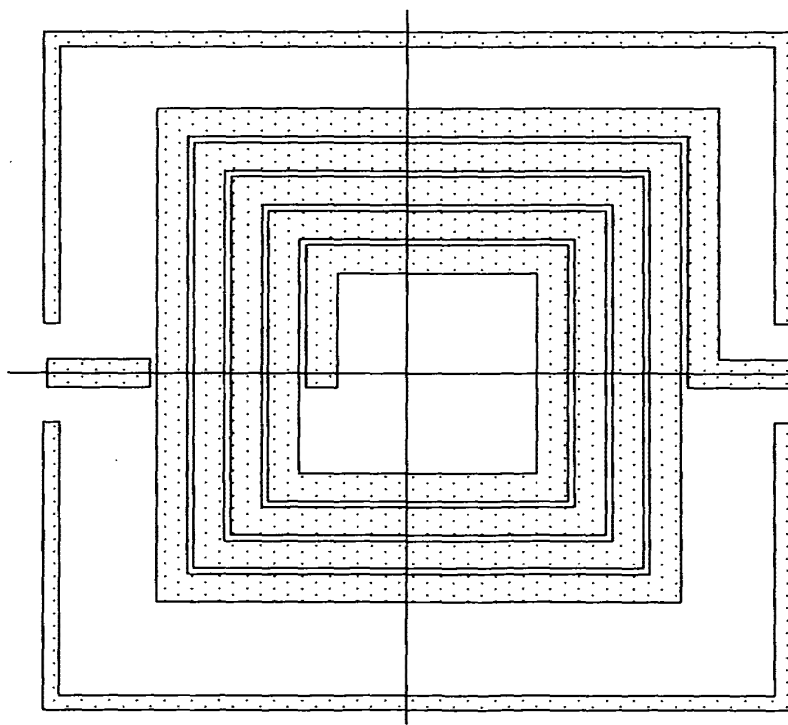
第10圖

1200



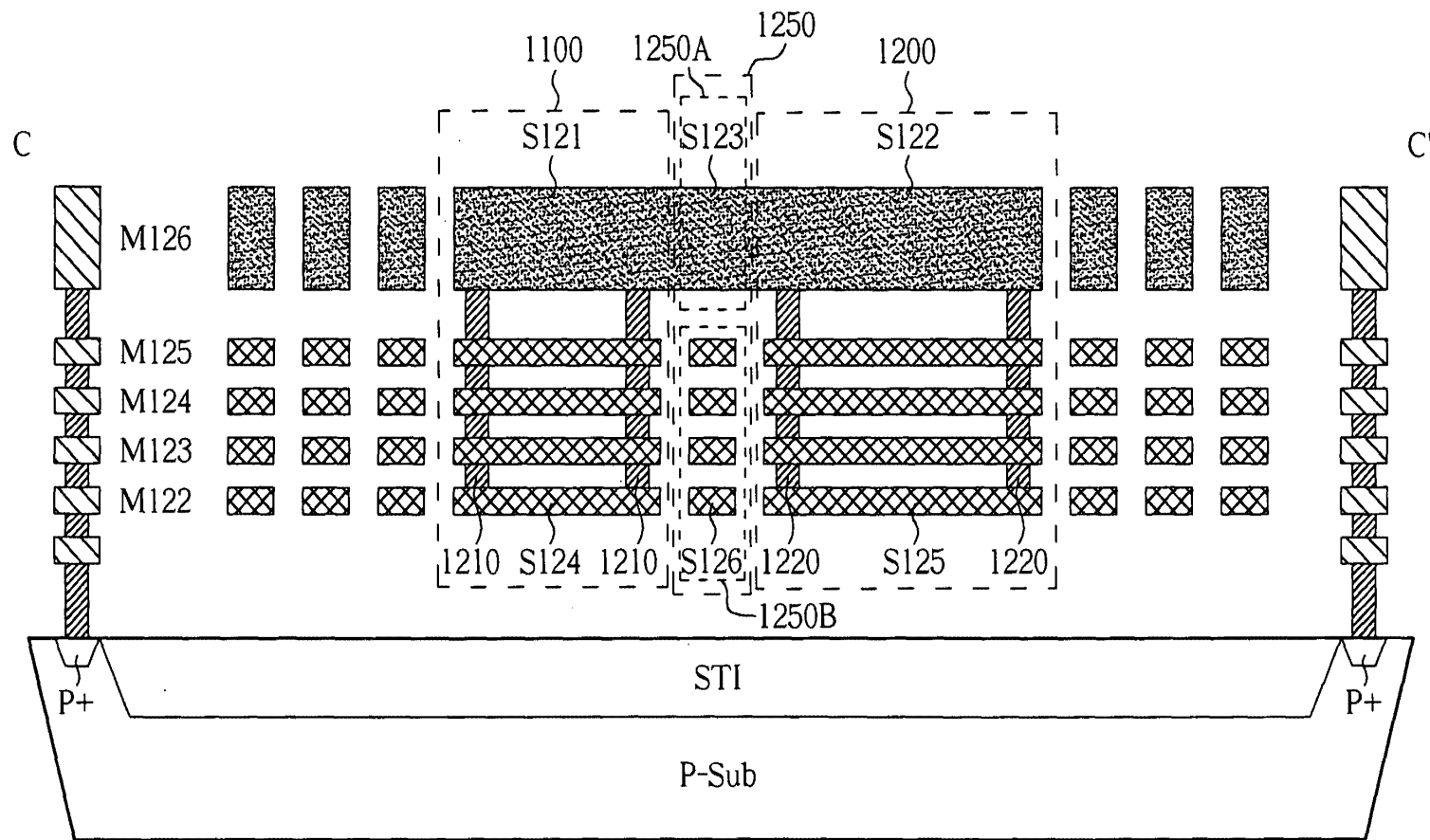
(11B)

1100



(11A)

第11圖



第12圖

