

COIL STRUCTURE FOR GENERATING PLASMA AND SEMICONDUCTOR PROCESS DEVICE

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TECHNICAL FIELD

[0001] The present disclosure relates to the field of semiconductor processing technology, and in particular, to a coil structure in a semiconductor process device for generating plasma, and a semiconductor process device.

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BACKGROUND

[0002] An Inductive Coupled Plasma (ICP) source is a plasma source commonly used for dry etching and thin film deposition in the semiconductor field. The ICP source generates plasma by exciting a gas with a high-frequency electromagnetic field generated by high-frequency current passing through coils, can operate under a relatively low chamber pressure, and has the characteristics of high plasma density and small damage to workpieces. As characteristic scales become smaller and smaller, challenges in processing processes also become more and more serious, and one of important requirements is consistency of the plasma source. For the ICP source, distribution of the coils plays a key role in etching morphology and etching uniformity, so that uniform symmetry of coil current in a radial distribution and an angular distribution needs to be continuously optimized, so as to further improve the capability of plasma processing equipment to manufacture highly integrated devices.

[0003] FIG. 1 is a schematic diagram of an existing coil structure. FIG. 2A is a projection view of the coil structure of FIG. 1 on a radial section thereof. As shown in FIG. 1 and FIG. 2A, the coil structure includes an inner coil group 11 and an outer coil group 12, each of which is formed by two planar coils, the two planar coils are rotationally and symmetrically distributed at 180° with respect to an axial direction of the coil structure, and an orthographic projection of each planar coil on the radial section is in a shape of an involute, and the number of turns of each coil is 1.5. An outer end of the two planar coils of the inner coil group 11 which is located on an outer circle and an outer end of the two

planar coils of the outer coil group 12 which is located on an outer circle are connected in parallel, and are electrically connected to an output terminal of a matcher 13. An inner end of the two planar coils of the inner coil group 11 which is located on an inner circle and an inner end of the two planar coils of the outer coil group 12 which is located on an inner circle are connected in parallel, and are electrically connected to an input terminal of the matcher 13.

[0004] As shown in FIG. 2A, taking a case where a single planar coil is in a shape of an involute and the number of turns of the involute is 1.5 as an example, the involute is not uniformly distributed in a left part and a right part which are on two sides of the dashed line in FIG. 2A in terms of geometric distribution, such that an electromagnetic field is not uniformly distributed in the left part and the right part, and a current in the coil in the left part is different from the current in the coil in the right part. As a result, asymmetrical distribution of free radical and ion density of the plasma is caused during the process, that is, the plasma is not distributed uniformly, which causes non-uniform etching of wafers and adverse effects on etching quality or etching efficiency.

SUMMARY

[0005] The present disclosure aims to solve at least one technical problem in the prior art, and provides a coil structure in a semiconductor process device for generating plasma and a semiconductor process device, which can compensate for a current distribution difference of coils in a radial direction, and improve radial distribution uniformity and angular distribution uniformity of coupling energy generated below the coils, so as to improve distribution uniformity of free radical and ion density of the plasma in a radial direction and overall voltage endurance of the coils, thereby realizing high-power feeding.

[0006] In order to achieve the above objective, the present disclosure provides a coil structure in a semiconductor process device for generating plasma, including at least one coil unit each including M coil groups, M being an integer greater than or equal to 4; the M coil groups have same structures and are connected in parallel with each other; each of the coil groups includes N layers of planar coils parallel to each other, N being an even number greater than or equal to 4; and planar coils corresponding to each layer in the M coil groups are arranged at a same layer in a one-to-one correspondence manner, and the

M planar coils located at the same layer are spaced apart from each other along a circumferential direction of the planar coils and are uniformly distributed; and

the N layers of planar coils in each of the coil groups are disposed at intervals along a direction perpendicular to planes where the planar coils are located, and are sequentially
5 connected in series end to end; and orthographic projections of every two adjacent layers of planar coils on the respective planes where the planar coils are located are mirror-symmetrical with respect to each other.

[0007] Optionally, M is an even number greater than or equal to 4;

input ends of the M coil groups are disposed at a same layer, and are divided into M/2
10 input end groups in the circumferential direction of the planar coils, each of the input end groups includes the input ends of two adjacent coil groups, and a first extension section is connected between the input ends of the two adjacent coil groups for electrically connecting the input ends; and first extension sections in the M/2 input end groups are electrically connected to each other; and

15 output ends of the M coil groups are disposed at a same layer, and are divided into M/2 output end groups in the circumferential direction of the planar coils, each of the output end groups includes the output ends of two adjacent coil groups, and a second extension section is connected between the output ends of the two adjacent coil groups for electrically connecting the output ends; and second extension sections in the M/2 output
20 end groups are electrically connected to each other.

[0008] Optionally, an extension direction of the first extension section is the same as an extension direction of a planar coil in one of the coil groups which is connected to the first extension section; and

an extension direction of the second extension section is the same as an extension
25 direction of a planar coil in one of the coil groups which is connected to the second extension section.

[0009] Optionally, a first connection terminal is disposed at a middle position of the first extension section for being electrically connected to an output terminal of a radio frequency power supply; and a second connection terminal is disposed at a middle position
30 of the second extension section for being electrically connected to an input terminal of the radio frequency power supply.

[0010] Optionally, M/2 first connection terminals are divided into M/4 first terminal groups in the circumferential direction of the planar coils, each of the first terminal groups

includes two adjacent first connection terminals, and a first connecting strip is connected between the two adjacent first connection terminals for electrically connecting the two adjacent first connection terminals; and an input connection terminal is disposed at a middle position of the first connecting strip for being electrically connected to the output terminal of the radio frequency power supply; and

M/2 second connection terminals are divided into M/4 second terminal groups in the circumferential direction of the planar coils, each of the second terminal groups includes two adjacent second connection terminals, and a second connecting strip is connected between the two adjacent second connection terminals for electrically connecting the two adjacent second connection terminals; and an output connection terminal is disposed at a middle position of the second connecting strip for being electrically connected to the input terminal of the radio frequency power supply.

[0011] Optionally, M/4 first connecting strips are uniformly distributed in the circumferential direction of the planar coils, M/4 second connecting strips are uniformly distributed in the circumferential direction of the planar coils, a diameter of a circle where the M/4 first connecting strips are located is the same as a diameter of a circle where the M/4 second connecting strips are located, and the M/4 first connecting strips and the M/4 second connecting strips are staggered from each other in the circumferential direction of the planar coils.

[0012] Optionally, N is equal to 4, and a number of turns of each layer of planar coil is 0.25.

[0013] Optionally, a plurality of coil units are provided, and the coil groups in the plurality of coil units have different sizes and are nested with each other.

[0014] Optionally, two coil units are provided and are a first coil unit and a second coil unit, and an outer diameter of the second coil unit is smaller than an inner diameter of the first coil unit; and

a number of layers of planar coils of each of the coil groups in the first coil unit and a number of layers of planar coils of each of the coil groups in the second coil unit are set based on power fed in the first coil unit and power fed in the second coil unit, respectively.

[0015] As another technical solution, the present disclosure further provides a coil structure, including a first coil structure and a second coil structure which are nested with each other, wherein the first coil structure adopts the above coil structure provided in the present disclosure; and

the second coil structure includes two layers of planar coils that are parallel to each other and are connected in series end to end, and orthographic projections of the two layers of planar coils on planes where the planar coils are located are mirror-symmetrical with respect to each other.

5 [0016] Optionally, a distance between every two adjacent layers of planar coils is less than or equal to 10mm.

[0017] Optionally, a number of the coil groups is greater than or equal to 4 and less than or equal to 64.

10 [0018] Optionally, a height of each planar coil in a direction perpendicular to a plane where of the planar coil is located is greater than or equal to 2mm and less than or equal to 15mm.

[0019] As another technical solution, the present disclosure further provides a semiconductor process device, including a radio frequency power supply, a reaction chamber, and the above coil structure provided in the present disclosure, wherein a dielectric window is provided at a top of the reaction chamber, and the coil structure is disposed above the dielectric window; and the radio frequency power supply is configured to apply radio frequency power to the coil structure.

[0020] The present disclosure has the following beneficial effects.

20 [0021] The coil structure in the semiconductor process device for generating the plasma provided in the present disclosure includes the M coil groups, M being an integer greater than or equal to 4; the M coil groups have the same structures and are connected in parallel with each other; each of the coil groups includes the N layers of planar coils parallel to each other, N being an even number greater than or equal to 4; and the planar coils corresponding to each layer in the M coil groups are arranged at a same layer in a one-to-one correspondence manner, and the M planar coils located at the same layer are spaced apart from each other along the circumferential direction of the planar coils and are uniformly distributed. Therefore, the M coil groups have angular symmetry in the circumferential direction of the planar coils, that is, the M coil groups are symmetrical in the circumferential direction of the planar coils, which can avoid a current distribution difference in the circumferential direction and thus improve angular distribution uniformity of plasma density, thereby improving process uniformity.

30 [0022] Moreover, the N layers of planar coils in each of the coil groups are disposed at intervals along the direction perpendicular to the planes where the planar coils are located,

and are sequentially connected in series end to end; and the orthographic projections of every two adjacent layers of planar coils on the respective planes where the planar coils are located are mirror-symmetrical with respect to each other. By setting every two adjacent layers of planar coils to be mirror-symmetrical with respect to each other, a magnetic field/an electric field generated by one of the two adjacent layers of planar coils and a magnetic field/an electric field generated by the other of the two adjacent layers of planar coils can be mutually compensated, so that the current distribution difference of the coils in the radial direction can be compensated, and the radial distribution uniformity of the coupling energy generated below the coils can be improved, thereby improving the distribution uniformity of the free radical and ion density of the plasma in the radial direction and improving the process uniformity.

[0023] Meanwhile, by disposing an even number of planar coils at four or more layers in each coil group at intervals along the direction perpendicular to the planes where the planar coils are located, a distance between the input end and the output end of the coil group (i.e., a distance between the planar coil at the uppermost layer and the planar coil at the lowermost layer) can be increased. Meanwhile, since a total voltage applied across the input end and the output end of the coil group by the radio frequency power supply is constant, a voltage endured by each layer of planar coil is only $1/N$ of the total voltage, so that overall voltage endurance of the coil group can be improved, and high-power feeding can be realized on the basis of meeting a requirement on the process uniformity.

[0024] Another coil structure provided in the present disclosure combines the above coil structure provided in the present disclosure with two layers of planar coils parallel to each other, and can be applied in a case where inner-circle fed-in power and outer-circle fed-in power are different, that is, the above coil structure provided in the present disclosure can be applied to high-power feeding (greater than 5KW), and the two layers of planar coils parallel to each other can be applied to low-power feeding (less than or equal to 2KW), thereby meeting various process requirements.

[0025] By adopting the above coil structure provided in the present disclosure, the semiconductor process device provided in the present disclosure can compensate for the current distribution difference of the coils in the radial direction, and improve the radial distribution uniformity of the coupling energy generated below the coils, so that radial distribution uniformity and angular distribution uniformity of the free radical and ion

density of the plasma can be improved, and the overall voltage endurance of the coils can also be improved, thereby realizing high-power feeding.

BRIEF DESCRIPTION OF DRAWINGS

- 5 [0026] FIG. 1 is a schematic diagram of an existing coil structure;
[0027] FIG. 2A is a schematic diagram illustrating distribution of an electromagnetic field in the prior art;
[0028] FIG. 2B is a projection view of the coil structure of FIG. 1 in a radial section thereof;
- 10 [0029] FIG. 3A is a schematic structural diagram of two layers of coils;
[0030] FIG. 3B is another schematic structural diagram of two layers of coils;
[0031] FIG. 4A is a schematic diagram of a coil structure according to an embodiment of the present disclosure;
[0032] FIG. 4B is a perspective view of one coil group of a coil structure according to an
- 15 embodiment of the present disclosure;
[0033] FIG. 5 is another perspective view of one coil group of a coil structure according to an embodiment of the present disclosure;
[0034] FIG. 6 is a top view of one coil group of a coil structure according to an embodiment of the present disclosure;
- 20 [0035] FIG. 7 is a side view taken in a direction A1 of FIG. 6;
[0036] FIG. 8 is a side view taken in the direction A2 of FIG. 6;
[0037] FIG. 9A is a perspective view of two coil groups that are different in number of turns;
[0038] FIG. 9B is a perspective view of four coil groups of a coil structure according to
- 25 an embodiment of the present disclosure;
[0039] FIG. 10 is a top view of four coil groups of a coil structure according to an embodiment of the present disclosure;
[0040] FIG. 11 is a side view taken in a direction A1 of FIG. 10;
[0041] FIG. 12 is a side view taken in a direction A2 of FIG. 10;
- 30 [0042] FIG. 13 is a perspective view of sixteen coil groups of a coil structure according to an embodiment of the present disclosure;

[0043] FIG. 14 is a top view of sixteen coil groups of a coil structure according to an embodiment of the present disclosure;

[0044] FIG. 15 is a perspective view of two of the sixteen coil groups of FIG. 13;

[0045] FIG. 16 is a top view of two of the sixteen coil groups of FIG. 13;

5 [0046] FIG. 17 is a top view of sixteen coil groups, first connecting strips, and second connecting strips of a coil structure according to an embodiment of the present disclosure;

[0047] FIG. 18 is another top view of sixteen coil groups, first connecting strips, and second connecting strips of a coil structure according to an embodiment of the present disclosure;

10 [0048] FIG. 19 is a schematic structural diagram of a first coil unit and a second coil unit of a coil structure according to an embodiment of the present disclosure;

[0049] FIG. 20 is a schematic structural diagram of another coil structure according to an embodiment of the present disclosure;

[0050] FIG. 21 is another schematic structural diagram of another coil structure according to an embodiment of the present disclosure; and

15 [0051] FIG. 22 is a schematic structural diagram of a semiconductor process device according to an embodiment of the present disclosure.

DETAIL DESCRIPTION OF EMBODIMENTS

20 [0052] In order to enable those of ordinary skill in the art to better understand the technical solutions of the present disclosure, a coil structure in a semiconductor process device for generating plasma and a semiconductor process device provided in the present disclosure are described in detail below with reference to the drawings.

[0053] An embodiment of the present disclosure provides a coil structure in a
25 semiconductor process device for generating plasma, the semiconductor process device may be configured to perform an etching process on wafers, and the coil structure is used as an upper electrode for exciting a process gas in a reaction chamber to generate the plasma.

[0054] The coil structure includes M coil groups, with M being an integer greater than or
30 equal to 4, and each coil group includes N layers of planar coils parallel to each other, with N being an even number greater than or equal to 4. The N layers of planar coils are disposed at intervals along a direction perpendicular to planes where the planar coils are

located, and are sequentially connected in series end to end. Orthographic projections of every two adjacent layers of planar coils on the respective planes where the planar coils are located are mirror-symmetrical with respect to each other. "Mirror" refers to the fact that, between the two adjacent layers of planar coils, the orthographic projection (hereinafter referred to as a first projection A) of one layer of planar coil on the plane where the one layer of planar coil is located and the orthographic projection (hereinafter referred to as a second projection B) of the other layer of planar coil on the plane where the other layer of planar coil is located are the same in shape and opposite in spiral direction. Specifically, the first projection A and the second projection B have front surfaces and back surfaces which are parallel to the respective planes where the planar coils are located, and a shape of the front surface of one of the first projection A and the second projection B is the same as a shape of the back surface of the other of the first projection A and the second projection B. "Symmetrical" refers to the fact that all parameters of the shape of the front surface of one of the first projection A and the second projection B are completely the same as all parameters of the shape of the back surface of the other of the first projection A and the second projection B.

[0055] By setting every two adjacent layers of planar coils in each coil group to be mirror-symmetrical with respect to each other, a magnetic field/an electric field generated by one of the two adjacent layers of planar coils and a magnetic field/an electric field generated by the other of the two adjacent layers of planar coils can be mutually compensated, so that a current distribution difference of the coils in a radial direction can be compensated, and radial distribution uniformity of coupling energy generated below the coils can be improved, thereby improving distribution uniformity of free radical and ion density of the plasma in the radial direction and improving process uniformity.

[0056] In a comparative embodiment of the embodiments of the present disclosure, referring to FIG. 3A, a coil structure 03 is electrically connected to a radio frequency power supply 1 through a matcher 2, and the radio frequency power supply 1 is configured to apply radio frequency power to the coil structure 03. The coil structure 03 includes a first coil unit 03a located at an outer circle and a second coil unit 03b located at an inner circle, and the first coil unit 03a and the second coil unit 03b have same structures and are just different in size, and are nested with each other. Taking the structure of the first coil unit 03a as an example, the first coil unit 03a includes a first planar coil 031 and a second planar coil 032, which are spaced apart from each other in a vertical direction and are

connected in series with each other; and orthographic projections of the first planar coil 031 and the second planar coil 032 on planes where the first planar coil 031 and the second planar coil 032 are located are mirror-symmetrical with respect to each other. In this way, the current distribution difference of the coils in the radial direction can be compensated and the radial distribution uniformity of the coupling energy generated below the coils can be improved, but for avoiding a failure of the mutual compensation effects of the first planar coil 031 and the second planar coil 032 on the current distribution difference, a vertical distance D1 between the first planar coil 031 and the second planar coil 032 is not allowed to be too large (for example, when the vertical distance D1 is less than or equal to 10mm, the process uniformity is less than or equal to 1%), resulting in relatively low voltage endurance of the coil structure 03 (less than or equal to 4KV). Therefore, the maximum allowable feed-in power of the coil structure 03 is 2KW, such that the coil structure 03 cannot be applied to a high-power feeding process (greater than 5KW).

[0057] Referring to FIG. 3B showing another coil structure 03', as compared to the above coil structure 03, the vertical distance between the first planar coil 031 and the second planar coil 032 in the coil structure 03' is increased to D2, which may be, for example, 30mm. By increasing the vertical distance, the voltage endurance of the coil structure 03' can be increased to be more than 12KV, which enables the coil structure 03' to be applied to the high-power feeding process (greater than 5KW). However, the excessive vertical distance may cause a failure of the mutual compensation effects of the first planar coil 031 and the second planar coil 032 on the current distribution difference, resulting in a deterioration of the process uniformity from 1% to 2.7% and a failure to meet a uniformity requirement (less than or equal to 1.5%) of the process.

[0058] In order to solve the above problem, referring to FIG. 4A, an embodiment of the present disclosure provides a coil structure 3, including at least one coil unit, and each coil unit includes M coil groups, with M being an integer greater than or equal to 4; in a case where a plurality of coil units are provided, the coil groups in the plurality of coil units are different in size and are nested with each other. For example, FIG. 4A shows two coil units, which are a first coil unit 3a and a second coil unit 3b nested with each other, and an outer diameter of the second coil unit 3b is smaller than an inner diameter of the first coil unit 3a. Certainly, the embodiments of the present disclosure are not limited thereto. According to specific needs, only one coil unit may be provided, or three or more coil units may be provided in practical applications.

[0059] The first coil unit 3a and the second coil unit 3b have same structures and are just different in size. Taking the first coil unit 3a as an example, the first coil unit 3a includes M coil groups, and each coil group includes N layers of planar coils parallel to each other, with N being an even number greater than or equal to 4. Taking N=4 as an example, the four layers of planar coils are a first planar coil 31, a second planar coil 32, a third planar coil 33, and a fourth planar coil 34 in sequence from top to bottom. The N layers of planar coils are disposed at intervals along a direction (i.e., a vertical direction in FIG. 4A) perpendicular to planes where the planar coils are located, and are sequentially connected in series end to end, thereby realizing serial connection of the N layers of planar coils. Orthographic projections of every two adjacent layers of planar coils on the respective planes where the planar coils are located are mirror-symmetrical with respect to each other. It should be noted that “square” in FIG. 4A is only used to illustrate the planar coil, and does not represent a specific structure of the planar coil.

[0060] With the coil group including the N layers of planar coils parallel to each other, with N being an even number greater than or equal to 4, that is, the coil group includes an even number of planar coils at four or more layers, as compared with the coil structure 03 shown in FIG. 3A, a vertical distance D5 between an input end and an output end of the coil group, that is, a distance between the first planar coil 31 at the uppermost layer and the fourth planar coil 34 at the lowermost layer, can be increased, for example, the vertical distance D5 is greater than or equal to 30mm. Thus, the voltage endurance between the first planar coil 31 at the uppermost layer and the fourth planar coil 34 at the lowermost layer can be increased to 12KV or more, so that the coil structure coil 3 provided in the embodiment of the present disclosure can be applied to the high-power feeding process (greater than 5KW). Meanwhile, the second planar coil 32 is disposed adjacent to and below the first planar coil 31 at the uppermost layer, and the orthographic projections of the second planar coil 32 and the first planar coil 31 on the planes where the second planar coil 32 and the first planar coil 31 are located are mirror-symmetrical with respect to each other, that is, the same in shape and opposite in spiral direction. In this way, a magnetic field/an electric field generated by the second planar coil 32 and a magnetic field/an electric field generated by the first planar coil 31 can be mutually compensated, that is, distribution of a total magnetic field/a total electric field, which is formed by superposition of the magnetic field/the electric field generated by the second planar coil 32 and the magnetic field/the electric field generated by the first planar coil 31, has mirror

symmetry, so that a current distribution difference of each layer of planar coil in the radial direction can be compensated. Similarly, the third planar coil 33 is disposed adjacent to and above the fourth planar coil 34 at the lowermost layer, and the orthographic projections of the third planar coil 33 and the fourth planar coil 34 on the planes where the third planar coil 33 and the fourth planar coil 34 are located are mirror-symmetrical with respect to each other, so that a magnetic field/an electric field generated by the third planar coil 33 and a magnetic field/an electric field generated by the fourth planar coil 34 can be mutually compensated. In addition, the orthographic projections of the second planar coil 32 and the third planar coil 33 adjacent thereto on the planes where the second planar coil 32 and the third planar coil 33 are located are mirror-symmetrical with respect to each other, so that the magnetic field/the electric field generated by the second planar coil 32 and the magnetic field/the electric field generated by the third planar coil 33 can be mutually compensated. Thus, the current distribution difference of each layer of planar coil in the radial direction can be compensated, and the radial distribution uniformity of the coupling energy generated below the coils can be improved, thereby improving the distribution uniformity of the free radical and ion density of the plasma in the radial direction and improving the process uniformity.

[0061] Based on the above, with an even number of planar coils at four or more layers disposed at intervals in the direction perpendicular to the planes where the planar coils are located, as compared with the coil structure 03 shown in FIG. 3A, the distance D5 between the input end and the output end of the coil group (i.e., the distance between the planar coil at the uppermost layer and the planar coil at the lowermost layer) can be increased, for example, the distance D5 is increased to 30mm or more. Meanwhile, a distance between the first planar coil 31 at the uppermost layer and the second planar coil 32 adjacent thereto and a distance between the fourth planar coil 34 at the lowermost layer and the third planar coil 33 adjacent thereto are both D3, a distance between the second planar coil 32 and the third planar coil 33 adjacent to each other is D4, and the distances D3 and D4 are all less than or equal to 10mm, for example. In this way, it can be ensured that the mutual compensation effects of every two adjacent layers of planar coils on the current distribution difference do not fail, so as to ensure that the process uniformity meets the requirement. Meanwhile, since a total voltage applied across the input end and the output end of the coil group by the radio frequency power supply 1 through the matcher 2 is constant, a voltage endured by each layer of planar coil is only $1/N$ of the total voltage,

so that overall voltage endurance of the coil group can be improved, and high-power feeding can be realized on the basis of meeting the requirement on the process uniformity.

[0062] It should be noted that the number of the layers of planar coils, i.e., a value of N , may be set according to specific needs in practical applications. The higher the power required to be fed is, the larger the distance between the input end and the output end of the coil group (i.e., the distance between the planar coil at the uppermost layer and the planar coil at the lowermost layer) is, the greater the value of N is.

[0063] It should be further noted that the distance between every two adjacent layers of planar coils is not allowed to be too large, so as to ensure that the mutual compensation effects of every two adjacent layers of planar coils on the current distribution difference do not fail; and such distance is not allowed to be too small, so as to avoid ignition between every two adjacent layers of planar coils caused by the too close distance. Optionally, the distance between every two adjacent layers of planar coils is less than or equal to 10mm, such as 5mm or 7mm.

[0064] In some alternative embodiments, a shape of each layer of planar coil is a spiral involute.

[0065] In some alternative embodiments, a height of each layer of planar coil in the direction perpendicular to the plane where the planar coil is located is greater than or equal to 2mm and less than or equal to 15mm.

[0066] In some alternative embodiments, the number of turns of each layer of planar coil may be set according to needed inductance, and the larger the needed inductance is, the more the number of turns is. Specifically, the inductance is proportional to a square of the number of turns. The planar coils at different layers are the same in number of turns. In addition, the number of turns of each layer of planar coil is not allowed to be too large, otherwise the number of the coil groups (i.e., a value of M) is limited due to excessive space occupied in a circumferential direction. Preferably, $N=4$, and the number of turns of each layer of planar coil is 0.25, which makes a total number of turns of the four layers of planar coils to be 1, that is, the four layers of planar coils form one circle in the circumferential direction.

[0067] In one specific embodiment, referring to FIG. 4B, taking the first coil unit 3a as an example, $N=4$ and the number of turns of each layer of planar coil is 2. The four layers of planar coils are a first planar coil 31, a second planar coil 32, a third planar coil 33, and a fourth planar coil 34 in sequence from top to bottom. The four layers of planar coils are

disposed at intervals along the direction perpendicular to the planes where the planar coils are located, and are sequentially connected in series end to end. Specifically, every two adjacent layers of planar coils are connected in series through a connecting column 4 and are electrically connected, and the connecting column 4 is, for example, disposed along the direction perpendicular to the planes where the planar coils are located. An input end 31a and an output end 31b of the coil group are an end at an outer circle of the first planar coil 31 at the uppermost layer and an end at an outer circle of the fourth planar coil 34 at the lowermost layer, respectively. Each of the four layers of planar coils is a spiral involute with the same parameters, and every two adjacent layers of planar coils have opposite spiral directions. Specifically, along the direction perpendicular to the planes where the planar coils are located, when viewed from the top, the spiral direction of the first planar coil 31 is clockwise, the spiral direction of the second planar coil 32 adjacent to the first planar coil 31 is counterclockwise, and the first planar coil 31 and the second planar coil 32 are mirror-symmetrical with respect to each other; the spiral direction of the third planar coil 33 adjacent to the second planar coil 32 is clockwise, that is, the third planar coil 33 is mirror-symmetrical with respect to the second planar coil 32, and also coincides with the first planar coil 31; and the spiral direction of the fourth planar coil 34 adjacent to the third planar coil 33 is counterclockwise, that is, the fourth planar coil 34 is mirror-symmetrical with respect to the third planar coil 33, and also coincides with the second planar coil 32.

[0068] In another specific embodiment, referring to FIG. 5 to FIG. 8, taking the first coil unit 3a as an example, $N=4$ and the number of turns of each layer of planar coil is 0.25. The four layers of planar coils are a first planar coil 31, a second planar coil 32, a third planar coil 33, and a fourth planar coil 34 in sequence from top to bottom. The four layers of planar coils are disposed at intervals along the direction (i.e., a direction Z in FIG. 7) perpendicular to the planes where the planar coils are located, and are sequentially connected in series end to end. Specifically, every two adjacent layers of planar coils are connected in series through a connecting column 4 and are electrically connected, and the connecting column 4 is, for example, disposed along the direction perpendicular to the planes where the planar coils are located. An input end 31a and an output end 31b of the coil group are an end of the first planar coil 31 at the uppermost layer and an end of the fourth planar coil 34 at the lowermost layer, respectively, with the two ends close to each other. Each of the four layers of planar coils is a spiral involute with the same parameters,

and every two adjacent layers of planar coils have opposite spiral directions. Specifically, as shown in FIG. 6, the first planar coil 31 and the second planar coil 32 are symmetrical with respect to a second axis O2 parallel to the planes where the planar coils are located (that is, the spiral direction of the first planar coil 31 is opposite to the spiral direction of the second planar coil 32); the second planar coil 32 and the third planar coil 33 are symmetrical with respect to a first axis O1 parallel to the planes where the planar coils are located (that is, the spiral direction of the second planar coil 32 is opposite to the spiral direction of the third planar coil 33); and the third planar coil 33 and the fourth planar coil 34 are symmetrical with respect to the second axis O2 parallel to the planes where the planar coils are located (that is, the spiral direction of the third planar coil 33 is opposite to the spiral direction of the fourth planar coil 34).

[0069] As shown in FIG. 8, the vertical distance D5 between the input end 31a and the output end 31b of the coil group is equal to the sum of two times of a distance D3, a distance D4, a height H1 of the second planar coil 32, and a height H2 of the third planar coil 33, that is, $D5 = 2 \times D3 + D4 + H1 + H2$. Taking a case where the distance D3 and the distance D4 are both equal to 7mm and the height H1 and the height H2 are both equal to 5mm as an example, the distance D5 is 31mm, which can meet a requirement of a process on the voltage endurance of the coil structure.

[0070] For the coil structure shown in FIG. 1, a shape of the orthographic projection on the radial section has asymmetry in a circumferential direction (i.e., an angular direction). Specifically, as shown in FIG. 2B showing the radial section being divided into four quadrant regions (I, II, III, IV), since a radius of the involute of each planar coil gradually increases as the involute of each planar coil extends from an inner end to an outer end, a part of the coil structure in the first quadrant region I and a part of the coil structure in the third quadrant region III are obviously different from a part of the coil structure in the second quadrant region II and a part of the coil structure in the fourth quadrant region IV, which may cause a current distribution difference of the coil structure in the circumferential direction (i.e., the angular direction), thereby causing non-uniform distribution of an electromagnetic field. During the process, the non-uniform distribution of the electromagnetic field may cause asymmetrical distribution of the free radical and ion density of the plasma, which may cause non-uniform angular distribution of plasma density and finally affect the process uniformity.

[0071] In order to solve the above technical problem, the M coil groups are provided, with M being an integer greater than or equal to 4; the M coil groups have the same structures and are connected in parallel with each other; and the planar coils corresponding to each layer in the M coil groups are arranged at a same layer in a one-to-one correspondence manner, and the M planar coils located at the same layer are spaced apart from each other along a circumferential direction of the planar coils and are uniformly distributed, that is, the M planar coils located at the same layer are arranged at different rotation angles in the circumferential direction. Specifically, taking M=4 as an example, referring to FIG. 9B to FIG. 12, the four coil groups are a first coil group 3a1, a second coil group 3a2, a third coil group 3a3, and a fourth coil group 3a4, respectively, each of the four coil groups includes N (for example, N=4) layers of planar coils parallel to each other; and taking the four layers of planar coils shown in FIG. 5 as an example, among the M coil groups, the M first planar coils 31 are disposed at the same layer, spaced apart from each other along the circumferential direction of the planar coils, and uniformly distributed; the M second planar coils 32 are disposed at the same layer, spaced apart from each other along the circumferential direction of the planar coils, and uniformly distributed; the M third planar coils 33 are disposed at the same layer, spaced apart from each other along the circumferential direction of the planar coils, and uniformly distributed; and the M fourth planar coils 34 are disposed at the same layer, spaced apart from each other along the circumferential direction of the planar coils, and uniformly distributed. In other words, any coil group may coincide with another coil group adjacent thereto after rotating clockwise or counterclockwise by a certain angle along the circumferential direction of the planar coils. For example, FIG. 9B shows four coil groups, and in this case, taking the first coil group 3a1 as an example, the first coil group 3a1 may coincide with another coil group adjacent thereto (e.g., the second coil group 3a2 or the fourth coil group 3a4) after rotating clockwise or counterclockwise by 90° along the circumferential direction of the planar coils. It should be readily understood that, since the M planar coils disposed at the same layer in the M coil groups are distributed on a same circle, a first end and a second end of the M planar coils are respectively located on two concentric circles.

[0072] The M coil groups have the same shapes and can be uniformly distributed along the circumferential direction of the planar coils, and the M planar coils corresponding to each layer of the M coil groups can form an approximate circle together in the circumferential direction of the planar coils. Therefore, the M coil groups have angular

symmetry in the circumferential direction of the planar coils, that is, the M coil groups are symmetrical in the circumferential direction of the planar coils, which can avoid the current distribution difference in the circumferential direction and thus improve angular distribution uniformity of the plasma density, thereby improving the process uniformity.

[0073] It should be noted that, if fewer than four coil groups are provided, for example, the figure (a) in FIG. 9A shows one coil group having a two-layer planar coil structure, the figure (b) in FIG. 9A shows two coil groups each having a two-layer planar coil structure, as can be seen from the figure (a), each layer of the coil group is provided with only one planar coil, and the coil structure is asymmetrical in a circumferential direction (i.e., an angular direction) of the planar coils, so that the current distribution difference still exists; and as can be seen from the figure (b), each layer of each coil group is provided with two planar coils, that is, the number of the planar coils is increased, but since the two planar coils at the same layer are mirror-symmetrical with respect to each other, the coil structure shown in the figure (b) is still asymmetrical in a circumferential direction (i.e., an angular direction) of the planar coils. It is found that, only in a case where four or more coil groups (i.e., $M \geq 4$) are provided and the M planar coils at a same layer are arranged at different rotation angles in the circumferential direction, an approximate circle can be formed to meet a requirement of the process on angular uniformity. In addition, the larger the number of the coil groups is, that is, the larger the value of M is, the better the angular uniformity is, preferably, M=4 or 8 or 16.

[0074] In some other alternative embodiments, referring to FIG. 13 and FIG. 14, M=16, the sixteen coil groups are respectively a first coil group 3a1 to a sixteenth coil group 3a16. It should be noted that the larger the number of the coil groups is, that is, the larger the M value is, the better the angular symmetry of the coil structure formed by the M coil groups is, and the better the angular distribution symmetry of the plasma density is. In some preferred embodiments, the number of the coil groups (i.e., the value of M) is greater than or equal to 2 and less than or equal to 64.

[0075] In some alternative embodiments, the M coil groups may be specifically connected in parallel with each other in the following way: the input end and the output end of each coil group (i.e., the end of the planar coil at the uppermost layer and the end of the planar coil at the lowermost layer, the two ends being close to each other) are electrically connected to an input terminal and an output terminal of the radio frequency power supply 1 through the matcher 2, respectively. Optionally, in order to reduce the number of

connection terminals of the radio frequency power supply 1, M is an even number greater than or equal to 2; the input ends of the M coil groups are disposed at the same layer (all at the uppermost layer or the lowermost layer), and are divided into $M/2$ input end groups (in pairs) in the circumferential direction of the planar coils, each input end group includes the input ends of two adjacent coil groups, and a first extension section is connected between the input ends of the two adjacent coil groups for electrically connecting the input ends; and the first extension sections in the $M/2$ input end groups are electrically connected to each other. Similarly, the output ends of the M coil groups are disposed at the same layer (all at the uppermost layer or the lowermost layer), and are divided into $M/2$ output end groups (in pairs) in the circumferential direction of the planar coils, each output end group includes the output ends of two adjacent coil groups, and a second extension section is connected between the output ends of the two adjacent coil groups for electrically connecting the output ends; and the second extension sections in the $M/2$ output end groups are electrically connected to each other.

[0076] Taking $M=16$ as an example, the input ends of the sixteen coil groups are disposed at the same layer, and are divided into eight input end groups in the circumferential direction of the planar coils, and each input end group includes the input ends of two adjacent coil groups. FIG. 15 and FIG. 16 show the input ends 31a of two adjacent coil groups (3a1, 3a2) from the sixteen coil groups, and the first extension section 5a is connected between the input ends 31a of the two adjacent coil groups (3a1, 3a2) for electrically connecting the input ends 31a; and the first extension section 5a is electrically connected to another adjacent first extension section 5a. Similarly, FIG. 15 and FIG. 16 show the output ends 31b of the two adjacent coil groups (3a1, 3a2) from the sixteen coil groups, and the second extension section 5b is connected between the output ends 31b of the two adjacent coil groups (3a1, 3a2) for electrically connecting the output ends 31b; and the second extension section 5b is electrically connected to another adjacent second extension section 5b. In this way, the sixteen coil groups may be connected in parallel with each other.

[0077] In some alternative embodiments, as shown in FIG. 15, an extension direction of the first extension section 5a is the same as that of the planar coil in one coil group which is connected to the first extension section 5a. For example, as shown in FIG. 15, the extension direction of the first extension section 5a is the same as that of the planar coil (e.g., the planar coil at the uppermost layer) in the first coil group 3a1 which is connected

to the first extension section 5a. An extension direction of the second extension section 5b is the same as that of the planar coil in one coil group which is connected to the second extension section 5b. For example, as shown in FIG. 15, the extension direction of the second extension section 5b is the same as that of the planar coil (e.g., the planar coil at the lowermost layer) in the second coil group 3a2 which is connected to the second extension section 5b.

[0078] In some alternative embodiments, as shown in FIG. 15, a first connection terminal 51a is disposed at a middle position of the first extension section 5a for being electrically connected to the output terminal of the radio frequency power supply 1; and a second connection terminal 51b is disposed at a middle position of the second extension section 5b for being electrically connected to the input terminal of the radio frequency power supply 1. In this way, it can be ensured that total lengths of two adjacent coil groups are the same, which allows a current to flow through the two coil groups along the same paths.

[0079] It should be noted that the M coil groups may be connected in parallel with each other in any other way. For example, the input ends of the M coil groups are directly electrically connected, and the output ends of the M coil groups are directly electrically connected.

[0080] In some alternative embodiments, in order to further reduce the number of the connection terminals of the radio frequency power supply 1, the M/2 first connection terminals 51a are divided into M/4 first terminal groups (in pairs) in the circumferential direction of the planar coils. As shown in FIG. 17, each first terminal group includes two adjacent first connection terminals 51a, and a first connecting strip 6a is connected between the two adjacent first connection terminals 51a for electrically connecting the two adjacent first connection terminals 51a; and an input connection terminal 61a is disposed at a middle position of the first connecting strip 6a for being electrically connected to the output terminal of the radio frequency power supply 1. Similarly, the M/2 second connection terminals 51b are divided into M/4 second terminal groups (in pairs) in the circumferential direction of the planar coils, each second terminal group includes two adjacent second connection terminals 51b, and a second connecting strip 6b is connected between the two adjacent second connection terminals 51b for electrically connecting the two adjacent second connection terminals 51b; and an output connection terminal 61b is disposed at a middle position of the second connecting strip 6b for being electrically connected to the input terminal of the radio frequency power supply 1. Taking

M=16 as an example, the eight first connection terminals 51a are divided into four first terminal groups in the circumferential direction of the planar coils; and the eight second connection terminals 51b are divided into four second terminal groups in the circumferential direction of the planar coils.

5 [0081] In some alternative embodiments, in order to ensure symmetry of the coil structure in a circumferential direction thereof, as shown in FIG. 17, the M/4 first connecting strips 6a are uniformly distributed in the circumferential direction of the planar coils, the M/4 second connecting strips 6b are uniformly distributed in the circumferential direction of the planar coils, a diameter of a circle where the M/4 first connecting strips 6a are located
10 is the same as that of a circle where the M/4 second connecting strips 6b are located, and the M/4 first connecting strips 6a and the M/4 second connecting strips 6b are staggered from each other in the circumferential direction of the planar coils, that is, the M/4 first connecting strips 6a and the M/4 second connecting strips 6b are alternately disposed in the circumferential direction of the planar coils. By making the M/4 first connecting strips
15 6a and the M/4 second connecting strips 6b be staggered from each other in the circumferential direction of the planar coils, line connection layout between the radio frequency power supply and the connecting strips can be designed more conveniently. Certainly, the embodiments of the present disclosure are not limited thereto. For example, as shown in FIG. 18, the M/4 first connecting strips 6a and the M/4 second connecting
20 strips 6b may overlap each other in a one-to-one correspondence manner in the direction perpendicular to the planes where the planar coils are located.

[0082] In some alternative embodiments, the coil structure 3 includes a plurality of coil units, and the coil groups in the plurality of coil units have different sizes and are nested with each other. For example, FIG. 19 shows two coil units, which are a first coil unit 3a
25 and a second coil unit 3b, an outer diameter of the second coil unit 3b is smaller than an inner diameter of the first coil unit 3a, and the first coil unit 3a and the second coil unit 3b are nested with each other.

[0083] Optionally, the number of layers of planar coils of each coil group in the first coil unit 3a is the same as the number of layers of planar coils of each coil group in the second
30 coil unit 3b, such as four layers. However, the embodiments of the present disclosure are not limited thereto. According to a power ratio of the first coil unit 3a to the second coil unit 3b, the number of layers of planar coils of each coil group in the first coil unit 3a may be different from the number of layers of planar coils of each coil group in the second coil

unit 3b. Specifically, the higher the fed-in power is, the larger the number of layers is; conversely, the lower the fed-in power is, the smaller the number of layers is.

[0084] As another technical solution, an embodiment of the present disclosure further provides a coil structure, including a first coil structure and a second coil structure which are nested with each other. Specifically, as shown in FIG. 20, a first coil structure 201 and a second coil structure 202 are both annular and have different sizes, the first coil structure 201 is located at an outer circle, and the second coil structure 202 is located at an inner circle; or, as shown in FIG. 21, the second coil structure 202 is located at the outer circle, and the first coil structure 201 is located at the inner circle.

[0085] The first coil structure 201 adopts the coil structure provided in the above embodiments. The first coil structure 201 is provided with one coil unit including M coil groups, with M being an integer greater than or equal to 4, each coil group includes N layers of planar coils parallel to each other, with N being an even number greater than or equal to 4, and orthographic projections of every two adjacent layers of planar coils on planes where the planar coils are located are mirror-symmetrical with respect to each other. FIG. 20 and FIG. 21 illustrate four layers of planar coils. With each coil group including the N layers of planar coils parallel to each other, with N being an even number greater than or equal to 4, that is, each coil group includes an even number of planar coils at four or more layers, voltage endurance between a planar coil at the uppermost layer and a planar coil at the lowermost layer can be increased to 12KV or more, so that the coil structure provided in the embodiment of the present disclosure can be applied to a high-power feeding process (greater than 5KW) at the inner circle or the outer circle.

[0086] The second coil structure 202 includes two layers of planar coils that are parallel to each other and are connected in series end to end, and orthographic projections of the two layers of planar coils on planes where the planar coils are located are mirror-symmetrical with respect to each other. The two layers of planar coils in the second coil structure 202 adopt, for example, the first planar coil 031 and the second planar coil 032 shown in FIG. 3A. The second coil structure 202 can be applied in a case where the power (less than or equal to 2KW) fed in the outer circle or the inner circle is relatively low.

[0087] The coil structure provided in the embodiment of the present disclosure combines the coil structure provided in the above embodiments with the two layers of planar coils that are parallel to each other and are connected in series end to end, and can be applied in a case where the inner-circle fed-in power and the outer-circle fed-in power are different,

that is, the first coil structure 201 can be applied to high-power feeding (greater than 5KW), and the second coil structure 202 can be applied to low-power feeding (less than or equal to 2KW), thereby meeting various process requirements.

[0088] As another technical solution, an embodiment of the present disclosure further provides a semiconductor process device. For example, as shown in FIG. 22, the semiconductor process device includes a radio frequency power supply 1 for an upper electrode, a matcher 2, a reaction chamber 100, and a coil structure 3; and a dielectric window 101 is provided at a top of the reaction chamber 100, and the coil structure 3 is disposed above the dielectric window 101. The coil structure 3 adopts the coil structure provided in each above embodiment of the present disclosure, for example, the coil structure 3 adopts the coil structure 3 shown in FIG. 4A.

[0089] The radio frequency power supply 1 is configured to apply radio frequency power to the coil structure 3 through the matcher 2, so as to excite a process gas in the reaction chamber 100 to generate plasma. In addition, a base 102 is further disposed in the reaction chamber 100 for bearing a wafer, and is electrically connected to a radio frequency source 103 for a lower electrode. The radio frequency source 103 is configured to apply a radio frequency bias to the base 102, so as to attract the plasma to move towards a surface of the wafer.

[0090] By adopting the above coil structure provided in the present disclosure, the semiconductor process device provided in the present disclosure can compensate for a current distribution difference of the coils in a radial direction, and improve radial distribution uniformity of coupling energy generated below the coils, so that distribution uniformity of free radical and ion density of the plasma in the radial direction can be improved, and overall voltage endurance of the coils can also be improved, thereby realizing high-power feeding.

[0091] It should be understood that the above embodiments are merely exemplary embodiments adopted to illustrate the principle of the present disclosure, and the present disclosure is not limited thereto. Various modifications and improvements can be made by those of ordinary skill in the art without departing from the spirit and essence of the present disclosure, and those modifications and improvements are also considered to fall within the scope of the present disclosure.

What is claimed is:

1. A coil structure in a semiconductor process device for generating plasma, wherein the coil structure comprises at least one coil unit each comprising M coil groups, M being an integer greater than or equal to 4; the M coil groups have same structures and are connected in parallel with each other; each of the coil groups comprises N layers of planar coils parallel to each other, N being an even number greater than or equal to 4; and planar coils corresponding to each layer in the M coil groups are arranged at a same layer in a one-to-one correspondence manner, and M planar coils located at the same layer are spaced apart from each other along a circumferential direction of the planar coils and are uniformly distributed; and

the N layers of planar coils in each of the coil groups are disposed at intervals along a direction perpendicular to planes where the planar coils are located, and are sequentially connected in series end to end; and orthographic projections of every two adjacent layers of planar coils on the respective planes where the planar coils are located are mirror-symmetrical with respect to each other.

2. The coil structure of claim 1, wherein M is an even number greater than or equal to 4;

input ends of the M coil groups are disposed at a same layer, and are divided into M/2 input end groups in the circumferential direction of the planar coils, each of the input end groups comprises input ends of two adjacent coil groups, and a first extension section is connected between the input ends of the two adjacent coil groups for electrically connecting the input ends; and first extension sections in the M/2 input end groups are electrically connected to each other; and

output ends of the M coil groups are disposed at a same layer, and are divided into M/2 output end groups in the circumferential direction of the planar coils, each of the output end groups comprises output ends of two adjacent coil groups, and a second extension section is connected between the output ends of the two adjacent coil groups for electrically connecting the output ends; and second extension sections in the M/2 output end groups are electrically connected to each other.

3. The coil structure of claim 2, wherein an extension direction of the first

extension section is the same as an extension direction of a planar coil in one of the coil groups which is connected to the first extension section; and

an extension direction of the second extension section is the same as an extension direction of a planar coil in one of the coil groups which is connected to the second extension section.

4. The coil structure of claim 2, wherein a first connection terminal is disposed at a middle position of the first extension section for being electrically connected to an output terminal of a radio frequency power supply; and a second connection terminal is disposed at a middle position of the second extension section for being electrically connected to an input terminal of the radio frequency power supply.

5. The coil structure of claim 4, wherein $M/2$ first connection terminals are divided into $M/4$ first terminal groups in the circumferential direction of the planar coils, each of the first terminal groups comprises two adjacent first connection terminals, and a first connecting strip is connected between the two adjacent first connection terminals for electrically connecting the two adjacent first connection terminals; and an input connection terminal is disposed at a middle position of the first connecting strip for being electrically connected to the output terminal of the radio frequency power supply; and

$M/2$ second connection terminals are divided into $M/4$ second terminal groups in the circumferential direction of the planar coils, each of the second terminal groups comprises two adjacent second connection terminals, and a second connecting strip is connected between the two adjacent second connection terminals for electrically connecting the two adjacent second connection terminals; and an output connection terminal is disposed at a middle position of the second connecting strip for being electrically connected to the input terminal of the radio frequency power supply.

6. The coil structure of claim 5, wherein $M/4$ first connecting strips are uniformly distributed in the circumferential direction of the planar coils, $M/4$ second connecting strips are uniformly distributed in the circumferential direction of the planar coils, a diameter of a circle where the $M/4$ first connecting strips are located is the same as a diameter of a circle where the $M/4$ second connecting strips are located,

and the M/4 first connecting strips and the M/4 second connecting strips are staggered from each other in the circumferential direction of the planar coils.

5 7. The coil structure of any one of claims 1 to 6, wherein N is equal to 4, and a number of turns of each layer of planar coil is 0.25.

10 8. The coil structure of any one of claims 1 to 6, wherein a plurality of coil units are provided, and coil groups in the plurality of coil units have different sizes and are nested with each other.

9. The coil structure of claim 8, wherein two coil units are provided and are a first coil unit and a second coil unit, and an outer diameter of the second coil unit is smaller than an inner diameter of the first coil unit; and

15 a number of layers of planar coils of each of the coil groups in the first coil unit and a number of layers of planar coils of each of the coil groups in the second coil unit are set based on power fed in the first coil unit and power fed in the second coil unit, respectively.

20 10. The coil structure of any one of claims 1 to 6, wherein a distance between every two adjacent layers of planar coils is less than or equal to 10mm.

11. The coil structure of any one of claims 1 to 6, wherein a number of the coil groups is greater than or equal to 4 and less than or equal to 64.

25 12. The coil structure of any one of claims 1 to 6, wherein a height of each planar coil in a direction perpendicular to a plane where of the planar coil is located is greater than or equal to 2mm and less than or equal to 15mm.

30 13. A coil structure, comprising a first coil structure and a second coil structure which are nested with each other, wherein the first coil structure adopts the coil structure of any one of claims 1 to 12; and

the second coil structure comprises two layers of planar coils that are parallel to each other and are connected in series end to end, and orthographic projections of the

two layers of planar coils on planes where the planar coils are located are mirror-symmetrical with respect to each other.

14. A semiconductor process device, comprising a radio frequency power supply,
5 a reaction chamber, and the coil structure of any one of claims 1 to 12 or the coil structure of claim 13, wherein a dielectric window is provided at a top of the reaction chamber, and the coil structure is disposed above the dielectric window; and the radio frequency power supply is configured to apply radio frequency power to the coil structure.

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