

COIL, COIL ASSEMBLY, COIL DEVICE, AND SEMICONDUCTOR PROCESS APPARATUS

5 TECHNICAL FIELD

[0001] The present disclosure relates to the field of semiconductor manufacturing, and specifically relates to a coil, a coil assembly, a coil device, and an inductively coupled plasma semiconductor process apparatus for exciting plasma.

10 BACKGROUND

[0002] As an important component for exciting plasma, the coil is suitable for semiconductor process apparatuses for etching, deposition, or the like. Taking an etching semiconductor process apparatus as an example, dry etching refers to a technology of etching by plasma in a semiconductor manufacturing process. With the rapid development of semiconductor component manufacturing processes, requirements on the performance and integration level of components are becoming increasingly stringent, which in turn places higher demands on the uniformity of a semiconductor etching process.

[0003] In a commonly used inductively coupled plasma (ICP) etching apparatus, a radio frequency current flows through a coil in an upper electrode loop to generate an electromagnetic field in a chamber by inductive coupling, and then various reactant gases are introduced into the chamber through a pipeline and excited by the electromagnetic field generated by the coil to form plasma. The plasma then reaches a surface of a silicon wafer inside the chamber through diffusion, electromigration and the like to implement etching.

[0004] With the continuous development of semiconductor manufacturing technology, a diameter of the wafer is becoming larger while the critical dimension (CD) is becoming smaller. Therefore, how to improve the distribution uniformity of plasma has become an urgent problem to be solved.

SUMMARY

[0005] The present disclosure aims to solve at least the problem of uneven plasma distribution in the existing art, and provides a coil, a coil assembly, a coil device, and an inductively coupled plasma semiconductor process apparatus for exciting plasma.

5 [0006] To achieve the object of the present disclosure, according to a first aspect of the present disclosure, there is disclosed a coil for exciting plasma and used in a semiconductor process apparatus, wherein the coil extends on a plane by gyration,

the coil includes a plurality of arched parts and a plurality of connection parts arranged about a gyration center of the coil, and adjacent arched parts are connected by
10 the connection parts;

the coil has a first end and a second end, wherein from the first end to the second end of the coil, the arched parts and the connection parts are sequentially and alternately arranged at intervals, and gyration radii of the arched parts gradually increase;

at least one of the plurality of arched parts includes a first deformable segment, an
15 arc segment and a second deformable segment connected in sequence, wherein the first deformable segment and the second deformable segment are connected to two ends of the arc segment, respectively, a center of a circle where the arc segment is located is the gyration center, and the gyration radius of the arched part is a distance from the arc segment to the gyration center,

20 a maximum distance from the first deformable segment of the arched part to the gyration center is greater than the gyration radius of the arched part; and

a maximum distance from the second deformable segment of the arched part to the gyration center is less than the gyration radius of the arched part.

[0007] Further, on the plane, the first deformable segment protrudes in a direction away
25 from the gyration center relative to the circle where the arc segment is located, and the second deformable segment is retracted inward in a direction approaching the gyration center relative to the circle where the arc segment is located.

[0008] Further, from the first end to the second end of the coil, the first deformable segment and the second deformable segment are alternately arranged at intervals.

30 [0009] Further, the first end and the second end of the coil are both located on a first virtual straight line, and

the first end and the second end of the coil are located on two sides of a second virtual straight line, respectively, wherein the second virtual straight line is perpendicular

to the first virtual straight line, and intersected with the first virtual straight line at the gyration center.

[0010] Further, from the first end to the second end of the coil, two adjacent arched parts are located on two sides of the first virtual straight line, respectively; and

5 the first deformable segment and the second deformable segment on the same arched part are located on two sides of the second virtual straight line, respectively.

[0011] Further, from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals.

10 [0012] Further, the first deformable segment is arched, and vertices of all first deformable segments are located on a third virtual straight line passing through the gyration center; and

 the second deformable segment is arched, and vertices of all second deformable segments are located on a fourth virtual straight line passing through the gyration center.

15 Further, the third virtual straight line is perpendicular to the fourth virtual straight line; or

 an angle formed by the third virtual straight line with the first virtual straight line is in a range of 20° to 40° ; or

 an angle formed by the fourth virtual straight line with the first virtual straight line
20 is in a range of 20° to 40° ; or

 an angle formed by the third virtual straight line with the first virtual straight line is in a range of 50° to 70° ; or

 an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 50° to 70° .

25 [0013] Further, a wafer to be processed has a diameter ϕ , and on the same arched part, the first deformable segment protrudes by a distance $H1$, and

$H1/\phi$ ranges from 0.005 to 0.1; or

$H1/\phi$ ranges from 0.0067 to 0.05.

[0014] Further, a wafer to be processed has a diameter ϕ , and on the same arched part,
30 the second deformable segment is retracted inward by a distance $H2$, and

$H2/\phi$ ranges from 0.005 to 0.1; or

$H2/\phi$ ranges from 0.0067 to 0.05.

[0015] According to a second aspect of the present disclosure, there is further provided a coil for exciting plasma and used in a semiconductor process apparatus, wherein the coil

extends on a plane by gyration, the coil includes a plurality of arched parts and a plurality of connection parts arranged about a gyration center of the coil, and the plurality of arched parts are connected by the connection parts;

each arched part has a deformable segment configured to change a shape of an induced electromagnetic field generated by the coil and surrounded by the arched part, to adjust the distribution of plasma generated by the induced electromagnetic field.

[0016] Further, the coil has a first end and a second end, wherein the arched parts are sequentially distributed from the first end to the second end of the coil, and gyration radii of the arched parts gradually increase.

[0017] Further, the deformable segment includes a first deformable segment and a second deformable segment located on the same arched part;

a maximum distance from the first deformable segment to the gyration center is greater than the gyration radius of the arched part; and

a maximum distance from the second deformable segment to the gyration center is less than the gyration radius of the arched part.

[0018] Further, the arched part further has an arc segment, the first deformable segment and the second deformable segment are connected to two ends of the arc segment, respectively, a center of a circle where the arc segment is located is the gyration center, and the gyration radius of the arched part is a distance from the arc segment to the gyration center.

[0019] Further, the first end and the second end of the coil are both located on a first virtual straight line, and

the first end and the second end of the coil are located on two sides of a second virtual straight line, respectively, wherein the second virtual straight line is perpendicular to the first virtual straight line, and intersected with the first virtual straight line at the gyration center;

from the first end to the second end of the coil, two adjacent arched parts are located on two sides of the first virtual straight line, respectively; and

the first deformable segment and the second deformable segment on the same arched part are located on two sides of the second virtual straight line, respectively.

[0020] Further, the first deformable segment is arched, and vertices of all first deformable segments are located on a third virtual straight line passing through the gyration center; and

the second deformable segment is arched, and vertices of all second deformable

segments are located on a fourth virtual straight line passing through the gyration center.
[0021] Further, the third virtual straight line is perpendicular to the fourth virtual straight line.

[0022] Further, a maximum gyration radius of the coil is smaller than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals.

[0023] Further, an angle formed by the third virtual straight line with the first virtual straight line is in a range of 20° to 40° ; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 50° to 70° .

[0024] Further, a minimum gyration radius of the coil is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of second deformable segments and a plurality of first deformable segments are sequentially and alternately arranged at intervals.

[0025] Further, an angle formed by the third virtual straight line with the first virtual straight line is in a range of 50° to 70° ; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 20° to 40° .

[0026] According to a third aspect of the present disclosure, there is further provided a coil assembly for exciting plasma and used in a semiconductor process apparatus, including a plurality of coils as described above, wherein the plurality of coils are circumferentially and uniformly distributed with the gyration center as a deflection center.

[0027] According to a fourth aspect of the present disclosure, there is further provided a coil device for exciting plasma and used in a semiconductor process apparatus, including at least two coil assemblies as described above, wherein the at least two coil assemblies are disposed spaced apart from inside to outside.

[0028] Further, a maximum gyration radius of coils in an innermost coil assembly is smaller than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals;

a minimum gyration radius of coils in an outermost coil assembly is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of second deformable segments and a plurality of first deformable segments are

sequentially and alternately arranged at intervals.

[0029] Further, the first deformable segment and the second deformable segment are both arched;

vertices of all first deformable segments on the innermost coil assembly are located on a third virtual straight line passing through the gyration center;

vertices of all second deformable segments on the outermost coil assembly are located on a fifth virtual straight line passing through the gyration center; and

the third virtual straight line coincides with the fifth virtual straight line.

[0030] Further, the first deformable segment and the second deformable segment are both arched;

vertices of all second deformable segments on the innermost coil assembly are located on a fourth virtual straight line passing through the gyration center;

vertices of all first deformable segments on the outermost coil assembly are located on a sixth virtual straight line passing through the gyration center; and

the fourth virtual straight line coincides with the sixth virtual straight line.

[0031] According to a fifth aspect of the present disclosure, there is further provided an inductively coupled plasma semiconductor process apparatus, including a process chamber and the coil as described above, or the coil assembly as described above, or the coil device as described above, configured to excite a gas in the process chamber to plasma.

[0032] According to the coil of the present disclosure, by providing the first deformable segment and the second deformable segment on the arched part, and making a maximum distance from the first deformable segment to the gyration center greater than the gyration radius of the arched part; and a maximum distance from the second deformable segment to the gyration center less than the gyration radius of the arched part, it is equivalent to adjust a corresponding region of an area enclosed by the coil in the circumferential direction to counteract an area difference generated on the coil to avoid terminal studs, and thus achieve a more uniform plasma density distribution over a wafer, thereby greatly improving the process uniformity in a radius direction of the wafer as well as the process quality.

BRIEF DESCRIPTION OF DRAWINGS

[0033] FIG. 1 is a schematic structural diagram of an inductively coupled plasma semiconductor process apparatus in the existing art;

[0034] FIG. 2 is a schematic structural diagram of a coil of an upper electrode in the existing art;

[0035] FIG. 3 is a schematic structural diagram of a deformable region of the coil of the upper electrode in the existing art;

5 [0036] FIG. 4 is a schematic quadrant view corresponding to the deformable region of the coil of the upper electrode in the existing art;

[0037] FIG. 5 is a diagram showing etching rates of an inductively coupled plasma semiconductor process apparatus in the existing art;

10 [0038] FIG. 6 is a diagram showing eccentricity data of the inductively coupled plasma semiconductor process apparatus in the existing art;

[0039] FIG. 7 is a schematic structural diagram of a coil according to a first embodiment of the present disclosure;

[0040] FIG. 8 is a schematic structural diagram of a coil assembly according to the first embodiment of the present disclosure;

15 [0041] FIG. 9 is a schematic structural diagram of a coil according to a second embodiment of the present disclosure;

[0042] FIG. 10 is a schematic structural diagram of a coil assembly according to the second embodiment of the present disclosure;

20 [0043] FIG. 11 is a schematic structural diagram of a coil device according to the present disclosure, including a coil assembly according to the first embodiment and a coil assembly according to the second embodiment;

[0044] FIG. 12 is a diagram showing etching rates of an inductively coupled plasma semiconductor process apparatus adopting a coil device according to the present disclosure; and

25 [0045] FIG. 13 is an eccentric diagram of an inductively coupled plasma semiconductor process apparatus adopting a coil device according to the present disclosure.

[0046] List of reference signs:

10, coil; 11, arched part; 12, connection part; 111, first deformable segment; 112, second deformable segment; 113, arc segment; O, gyration center; R, gyration radius; D1, first virtual straight line; D2, second virtual straight line; D3, third virtual straight line; 30 D4, fourth virtual straight line; D5, fifth virtual straight line; and D6, sixth virtual straight line..

DETAIL DESCRIPTION OF EMBODIMENTS

[0047] To make those skilled in the art better understand the technical solutions of the present disclosure, the coil, the coil assembly, the coil device, and the inductively coupled plasma semiconductor process apparatus for exciting plasma provided in the present disclosure will be described in detail below with reference to the accompanying drawings.

[0048] As shown in FIG. 1, an inductively coupled plasma semiconductor process apparatus in the existing art includes a housing 1, a reaction chamber 2, an upper matcher 3, an upper electrode 4, a lower matcher 5, and a lower electrode 6. The upper electrode 4 includes an inner coil 7 and an outer coil 8 electrically connected to the upper matcher 3, respectively. A coil structure typically used in existing common solutions is shown in FIG. 2, where the inner coil 7 and the outer coil 8 form a concentric coil set and are connected in parallel. In the coil structure shown in FIG. 2, the inner coil 7 includes two single coils of 1.5 turns, the outer coil 8 also includes two single coils of 1.5 turns, and a gyration radius of each single coil gradually increases while the coil extends by gyration.

[0049] It has been found that, as shown in FIG. 3, since each single coil is connected to terminal studs 9 at both ends, when the coil extends to a position corresponding to the terminal stud 9 at a preset gyration radius, the coil may be deformed notably near the terminal stud 9 to avoid the terminal stud 9, resulting in a difference with the preset gyration radius. As shown in FIG. 3, $R > r'$ may occur in region A' and region B' (where R is an actual gyration radius of the single coil; and R' is the preset gyration radius).

[0050] As shown in FIGs. 3 and 4, since $R > r'$ in region A' and region B', an area of the region surrounded by the coil in quadrants I, III is larger than an area of the region in quadrants II, IV, so that an inductance at a position corresponding to quadrants I, III as a whole is slightly greater than an inductance at a position corresponding to quadrants II, IV. Since the strength of the inductance is proportional to the plasma density, the plasma density at the position corresponding to quadrants I, III is greater than the plasma density at the position corresponding to quadrants II, IV, leading to a higher etching rate in a region corresponding to quadrants I, III of the wafer than that in a region corresponding to quadrants II, IV (see the etching rate data diagram of an inductively coupled plasma semiconductor process apparatus in the existing art shown in FIG. 5). Due to the relative non-uniform etching rates, as shown in the etching rate eccentric diagram of the existing art in FIG. 6, a special map similar to a butterfly shape will be formed after etching, resulting in an overall etching rate which is not only uneven, but also varies greatly among

sampling points, thereby seriously affecting the process quality. Therefore, how to improve the uniformity of etching and improve the process quality is an urgent problem to be solved in the art.

[0051] To solve the above technical problem, in a first embodiment of the present disclosure as shown in FIG. 7, there is provided a coil for exciting plasma and used in a semiconductor process apparatus for etching, deposition, or the like. The semiconductor process apparatus is, for example, an inductively coupled plasma semiconductor process apparatus, or the like. The coil 10 extends on a plane by gyration. The coil 10 includes a plurality of arched parts 11 and a plurality of connection parts 12 arranged about a gyration center O of the coil 10, and adjacent arched parts 11 are connected by the connection parts 12.

[0052] As shown in FIG. 7, the coil 10 has a first end and a second end, where from the first end to the second end of the coil 10, the arched parts 11 and the connection parts 12 are sequentially and alternately arranged at intervals, and gyration radii R of the arched parts 11 gradually increase.

At least one of the plurality of arched parts 11 includes a first deformable segment 111, an arc segment 113 and a second deformable segment 112 connected in sequence. The first deformable segment 111 and the second deformable segment 112 are connected to two ends of the arc segment 113, respectively, a center of a circle where the arc segment 113 is located is the gyration center O, and the gyration radius R of each arched part 11 is a distance from the arc segment 113 to the gyration center O, a maximum distance from the first deformable segment 111 of the arched part 11 to the gyration center O is greater than the gyration radius R of the arched part 11; and a maximum distance from the second deformable segment 112 of the arched part 11 to the gyration center O is less than the gyration radius R of the arched part 11.

[0053] According to the coil 10 of the present disclosure, by providing the first deformable segment 111 and the second deformable segment 112 on the arched part 11, and making a maximum distance from the first deformable segment 111 to the gyration center O greater than the gyration radius R of the arched part 11, and a maximum distance from the second deformable segment 112 to the gyration center O less than the gyration radius R of the arched part 11, it is equivalent to adjust a corresponding region of an area enclosed by the coil 10 in the circumferential direction to counteract an area difference generated on the coil 10 to avoid terminal studs, and thus achieve a more uniform plasma density distribution over a wafer, thereby greatly improving the process uniformity in a

radius direction of the wafer as well as the process quality.

[0054] The coil 10 of the present disclosure will be described in detail below with reference to the first embodiment:

[0055] As shown in FIG. 7, on a plane where the coil 10 is located, the first end and the second end of the coil 10 are both located on a first virtual straight line D1, while the first end and the second end of the coil 10 are located on two sides of a second virtual straight line D2, respectively. The second virtual straight line D2 is perpendicular to the first virtual straight line D1, and intersected with the first virtual straight line at the gyration center O, dividing the plane into four quadrants as shown in FIG. 7. In the first embodiment, in a process of extending from the first end to the second end, the coil 10 sequentially passes through quadrant II, quadrant III, quadrant IV, quadrant I, quadrant II, and quadrant III, to form a 1.5-turn winding structure. In other words, the coil 10 in the first embodiment is a 1.5-turn winding structure formed by extending by gyration in a counterclockwise direction shown in FIG. 7.

[0056] As shown in FIG. 7, in the first embodiment, a total of three arched parts 11 are provided from the first end to the second end of the coil 10. The first arched part 11 is close to the first end of the coil 10, the third arched part 11 is close to the second end of the coil 10, and the second arched part 11 is located between the first arched part 11 and the third arched part 11. Meanwhile, the first arched part 11 and the third arched part 11 are located in quadrants II and III to the left of the first virtual straight line D1 in FIG. 7, and the second arched part 11 is located in quadrants I and IV to the right of the first virtual straight line D1 in FIG. 7. In other words, from the first end to the second end of the coil 10, two adjacent arched parts 11 are located on two sides of the first virtual straight line D1, respectively.

[0057] In the three arched parts 11 of this embodiment, each arched part 11 includes a first deformable segment 111, an arc segment 113 and a second deformable segment 112 connected in sequence in a counterclockwise direction. Since the three arched parts 11 are sequentially arranged at intervals in the counterclockwise direction, as shown in FIG. 7, the first deformable segment 111 and the second deformable segment 112 are alternately arranged at intervals from the first end to the second end of the coil 10. Moreover, in each of the first arched part 11 and the third arched part 11, the first deformable segment 111 and the arc segment 113 are located in quadrant II, while the second deformable segment 112 is located in quadrant III; and in the second arched part 11, the first deformable segment 111 and the arc segment 113 are located in quadrant IV, while the second

deformable segment 112 is located in quadrant I. In other words, the first deformable segment 111 and the second deformable segment 112 on the same arched part 11 are located on two sides of the second virtual straight line D2, respectively.

[0058] As shown in the first embodiment in FIG. 7, on a plane where the coil 10 is located, the first deformable segments 111 in quadrants II and IV protrude in a direction away from the gyration center O, while the second deformable segments 112 in quadrants I and III are retracted inward in a direction approaching the gyration center O.

[0059] Further, on the same arched part 11, the first deformable segment 111 protrudes by a distance H1, the second deformable segment 112 is retracted inward by a distance H2, a wafer to be processed has a diameter ϕ , $H1/\phi$ ranges from 0.005 to 0.1, and $H2/\phi$ ranges from 0.005 to 0.1. In this embodiment, a wafer to be processed has a diameter ϕ of 300mm, and therefore, H1 may range from 2mm to 24mm, and H2 may range from 2mm to 24mm. A certain compensation effect can be obtained within such ranges, making the process rate (e.g., etching rate) relatively uniform. In an embodiment, H1 ranges from 2mm to 12mm, and H2 ranges from 2mm to 12mm, where a good compensation effect can be obtained within such ranges, making the process rate more uniform.

[0060] Taking the second arched part 11 to the right of the first virtual straight line D1 in FIG. 7 as an example, ideally, the arched part 11 should take a distance from the arc segment 113 to the gyration center O as the gyration radius R thereof and form two sector structures with equal areas in quadrants I and IV in FIG. 7, to ensure a uniform density of the generated plasma. However, in practice, in order to avoid the terminal stud, the connection part 12 connected to an end of the arched part 11 in quadrant IV is actually gradually retracted inward in a clockwise extending direction, which may cause a reduced sector area surrounded by the arched part 11 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant IV, while the connection part 12 connected to an end of the arched part 11 in quadrant I is actually gradually expanded outward in a counterclockwise extending direction, which may cause an increased sector area surrounded by the arched part 11 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant I, resulting in two different sector areas.

[0061] According to the formula $L = \frac{\Psi}{I} = \frac{BS}{I}$ (where L is inductance; Ψ is magnetic flux; I is current passing through the coil 10; B is an electric field intensity, and S is an area enclosed by the coil 10), the inductance L is proportional to the area S of the coil 10.

[0062] Due to the different areas enclosed in quadrants I and IV by the coil 10, the

inductance, and thus the plasma density, are also different, finally leading to inconsistent etching rates and non-uniform etching.

[0063] In the present disclosure, however, by providing the first deformable segment 111 protruding in the direction away from the gyration center O in quadrant IV, the sector area enclosed by the deformed first deformable segment 111 with the arc segment 113, the first virtual straight line D1, and the second virtual straight line D2 in quadrant IV is increased, so that the area change caused by deformation of the corresponding connection part 12 is reduced. Meanwhile, by providing the second deformable segment 112 retracted inward in the direction approaching the gyration center O in quadrant I, the area enclosed by the deformed second deformable segment 112 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant I is reduced, so that the area change caused by deformation of the corresponding connection part 12 is reduced. Similarly, the situation of the coil 10 in quadrant II is the same as that in quadrant IV, and the situation in quadrant III is also the same as that in quadrant I, which are not repeated here.

[0064] It can be seen that by providing the first deformable segment 111 and the second deformable segment 112, the coil 10 of the present disclosure can reduce the area changes of the coil 10 caused by the connection part 12 for avoiding the terminal stud, so that the areas in the quadrants are closer to each other, the plasma density distribution is more uniform, and finally, the overall etching rate is more uniform. In other words, by changing the shape of the coil 10, the plasma densities in quadrants I and III are reduced, while the plasma densities in quadrants II and IV are increased, and with the changes in the plasma density, the etching rates in quadrants I, III are reduced, while the etching rates in quadrants II, IV are increased, and the overall plasma density on the wafer surface is more uniform, so that the "butterfly" map is improved, and the uniformity of the overall wafer etching is improved.

[0065] As shown in FIG. 7, the first deformable segment 111 is arched, and vertices of all first deformable segments 111 are located on a third virtual straight line D3 passing through the gyration center O; and the second deformable segment 112 is arched, and vertices of all second deformable segments 112 are located on a fourth virtual straight line D4 passing through the gyration center O.

[0066] In some embodiments, the third virtual straight line D3 is perpendicular to the fourth virtual straight line D4.

[0067] In some embodiments, to further improve the uniformity of the etching rate, the third virtual straight line D3 forms an angle A with the first virtual straight line D1, where

A satisfies: $20^{\circ} \leq A \leq 40^{\circ}$.

[0068] In some embodiments, to further improve the uniformity of the etching rate, the fourth virtual straight line D4 forms an angle B with the first virtual straight line D1, where B satisfies: $50^{\circ} \leq B \leq 70^{\circ}$.

5 [0069] As shown in FIG. 8, the first embodiment of the present disclosure further discloses a coil assembly for exciting plasma and used in a semiconductor process apparatus, including a plurality of coils 10 circumferentially and uniformly distributed with the gyration center O as a deflection center.

10 [0070] Specifically, as shown in FIG. 8, in the first embodiment, the coil assembly includes two coils 10 with the gyration center O as the deflection center, and a deflection angle between the two coils 10 is 180° . In other words, the two coils 10 form a centrosymmetric structure with the gyration center O as a symmetrical center.

[0071] It can be seen that in the first embodiment shown in FIG. 8, each coil 10 extends on a plane by gyration, each coil 10 includes a plurality of arched parts 11 and a plurality of connection parts 12 arranged about the gyration center O of the coil 10, and the plurality of arched parts 11 are connected by the connection parts 12. A pair of arched parts 11 symmetrical to each other in the two coils 10 form an approximate circle shape, and all the arched parts 11 form a plurality of approximate circles spaced apart from inside to outside.

20 [0072] Each arched part 11 has a deformable segment configured to change a shape of an induced electromagnetic field generated by the coil 10 and surrounded by the arched part 11, to adjust the distribution of plasma generated by the induced electromagnetic field. In other words, in the above embodiments, the shape of the induced electromagnetic field generated by the coil 10 is changed by providing the deformable segment, so that the
25 electromagnetic field change generated by the connection part 12 avoiding the terminal stud can be counteracted, and the plasma distribution generated by the induced electromagnetic field can be adjusted, thereby making the etching rate more uniform.

[0073] As shown in FIG. 8, each coil 10 has a first end and a second end, and from the first end to the second end of the coil 10, the arched parts 11 are sequentially arranged,
30 and gyration radii R of the arched parts 11 gradually increase. Each arched part 11 includes a first deformable segment 111, an arc segment 113 and a second deformable segment 112, and the first deformable segment 111 and the second deformable segment 112 are located on the same arched part 11. A maximum distance from the first deformable segment 111 to the gyration center O is greater than the gyration radius R of the arched

part 11. A maximum distance from the second deformable segment 112 to the gyration center O is less than the gyration radius R of the arched part 11.

[0074] According to the coil 10 of the present disclosure, by providing the first deformable segment 111 and the second deformable segment 112 on the arched part 11, and making a maximum distance from the first deformable segment 111 to the gyration center O greater than the gyration radius R of the arched part 11, and a maximum distance from the second deformable segment 112 to the gyration center O less than the gyration radius R of the arched part 11, it is equivalent to adjust a corresponding region of an area enclosed by the coil 10 in the circumferential direction to counteract an area difference generated on the coil 10 to avoid terminal studs, and thus achieve a more uniform plasma density distribution over a wafer, thereby greatly improving the process uniformity in a radius direction of the wafer as well as the process quality.

[0075] It will be appreciated that the first deformable segment 111, the arc segment 113, and the second deformable segment 112 are sequentially connected, a center of a circle where the arc segment 113 is located is the gyration center O, and the gyration radius R of each arched part 11 is a distance from the arc segment 113 to the gyration center O.

[0076] As shown in FIG. 8, on a plane where the coil 10 is located, there is a first virtual straight line D1 and a second virtual straight line D2 perpendicular to each other, and the first virtual straight line D1 is intersected with the second virtual straight line D2 at the gyration center O to divide the plane into four quadrants. The coil 10 forms a 1.5-turn winding structure by extending by gyration in a counterclockwise direction.

[0077] It should be noted that in the above embodiment, the coil 10 has 1.5 turns, but this is not limiting, and in some other embodiments not shown in the drawings, the coil 10 may have 1 turn, 2 turns, 2.5 turns, and so on.

[0078] As shown in FIG. 8, the first end and the second end of each coil 10 are both located on the first virtual straight line D1, and the first end and the second end of each coil 10 are located on two sides of the second virtual straight line D2, respectively. From the first end to the second end of the coil 10, two adjacent arched parts 11 are located on two sides of the first virtual straight line D1, respectively. The first deformable segment 111 and the second deformable segment 112 are located on the same arched part 11, and the first deformable segment 111 and the second deformable segment 112 on the same arched part 11 are located on two sides of the second virtual straight line D2, respectively.

[0079] The first deformable segment 111 is arched, as shown in FIG. 8, vertices of all first deformable segments 111 in the two coils 10 are fitted into a third virtual straight

line D3 passing through the gyration center O. The second deformable segment 112 is arched, and vertices of all second deformable segments 112 are fitted into a fourth virtual straight line D4 passing through the gyration center O. The third virtual straight line D3 is perpendicular to the fourth virtual straight line D4.

5 [0080] It should be noted that in the first embodiment shown in FIG. 8, the two coils 10 form an inner coil of the upper electrode, so that a maximum gyration radius R of the coil 10 is smaller than a radius of a wafer to be processed, and from the first end to the second end of the coil 10, a plurality of first deformable segments 111 and a plurality of second deformable segments 112 are sequentially and alternately arranged at intervals.

10 [0081] In some embodiments, the third virtual straight line D3 forms an angle A with the first virtual straight line D1, where A satisfies: $20^{\circ} \leq A \leq 40^{\circ}$.

[0082] In some embodiments, the fourth virtual straight line D4 forms an angle B with the first virtual straight line D1, where B satisfies: $50^{\circ} \leq B \leq 70^{\circ}$.

[0083] It should be noted that in the first embodiment, the coil 10 is mounted on an inner
15 coil of the upper electrode. In other words, a maximum area surrounded by the coil 10 is smaller than an area of the wafer, where when the coil 10 is an inner coil, the maximum area surrounded by the coil 10 refers to an area surrounded by an outer peripheral contour of the coil 10. However, this is not intended to be limiting. In the second embodiment shown in FIG. 9, the coil 10 may be an outer coil of the upper electrode. In other words,
20 a minimum area surrounded by the coil 10 is greater than the area of the wafer, where when the coil 10 is an outer coil, the minimum area surrounded by the coil 10 refers to an area surrounded by an inner peripheral contour of the coil 10.

[0084] The following describes the scheme of the present disclosure with reference to a specific second embodiment:

25 [0085] As shown in FIG. 9, in the second embodiment, the coil 10 is substantially the same as that in the first embodiment, except that the first deformable segment 111 and the second deformable segment 112 are disposed at different positions in this embodiment. As shown in FIG. 9, each arched part 11 includes a second deformable segment 112, an arc segment 113 and a first deformable segment 111 connected in sequence in a
30 counterclockwise direction. Therefore, in the second embodiment, the second deformable segment 112 and the arc segment 113 of the first arched part 11, and the second deformable segment 112 and the arc segment 113 of the third arched part 11, are located in quadrant II, and the first deformable segment 111 of the first arched part 11 is located in quadrant III; while the second deformable segment 112 and the arc segment 113 of the

second arched part 11 are located in quadrant IV, and the first deformable segment 111 of the second arched part 11 is located in quadrant I. In other words, in this second embodiment, although the first deformable segment 111 and the second deformable segment 112 on the same arched part 11 are located on two sides of a second virtual straight line D2, respectively, their positions are opposite to those in the first embodiment. [0086] Also taking the second arched part 11 to the right of the first virtual straight line D1 as an example, ideally, the arched part 11 should take a distance from the arc segment 113 to the gyration center O as the gyration radius R thereof and form two sector structures with equal areas in quadrants I and IV to the right of the first virtual straight line D1 in FIG. 9, respectively, to ensure a uniform density of the generated plasma. However, in practice, in order to avoid the terminal stud, the connection part 12 connected to an end of the arched part 11 in quadrant IV is actually gradually retracted inward in a clockwise extending direction, which may cause a reduced sector area surrounded by the arched part 11 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant IV, while the connection part 12 connected to an end of the arched part 11 in quadrant I is actually gradually expanded outward in a counterclockwise extending direction, which may cause an increased sector area surrounded by the arched part 11 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant I, resulting in two different sector areas.

[0087] According to the formula $L = \frac{\Psi}{I} = \frac{BS}{I}$ (where L is inductance; ψ is magnetic flux; I is current passing through the coil 10; B is an electric field intensity, and S is an area enclosed by the coil 10), the inductance L is proportional to the area S of the coil 10.

[0088] Due to the different areas enclosed in quadrants I and IV by the coil 10, the inductance, and thus the plasma density, are also different, finally leading to inconsistent etching rates and non-uniform etching.

[0089] In contrast, according to the coil of the present disclosure, by providing the second deformable segment 112, the arc segment 113 and the first deformable segment 111 connected in sequence in the counterclockwise direction, and making a maximum distance from the first deformable segment 111 to the gyration center O greater than the gyration radius R of the arched part 11, and a maximum distance from the second deformable segment 112 to the gyration center O less than the gyration radius R of the arched part 11, it is equivalent to adjust an area enclosed by the coil 10 to counteract an area difference generated on the coil 10 to avoid terminal studs, and thus achieve a more

uniform plasma density distribution over a wafer, thereby greatly improving the process uniformity in a radius direction of the wafer as well as the process quality.

[0090] It should be emphasized that, in the second embodiment, a minimum area of the coil 10 is greater than the area of the wafer. In other words, the coil 10 in the second embodiment is an outer coil, and when the coil 10 is an outer coil, the minimum area surrounded by the coil 10 refers to an area surrounded by an inner peripheral contour of the coil 10. Therefore, under the condition that the minimum area of the coil 10 is greater than the area of the wafer, the coil 10 is located beyond an orthographic projection of the wafer on the plane. As a result, while disposing the first deformable segment 111 and the second deformable segment 112, not only the influence of the area surrounded by the coil 10, but also a distance between the coil 10 and the edge of the wafer, should be considered.

[0091] According to experimental data, when the wafer to be processed has a diameter of 300mm and the first deformable segment 111 is disposed in quadrant I, the etching rate at a position corresponding to the first deformable segment 111 in quadrant I is reduced compared with the case of a standard coil in the existing art; and if the first deformable segment 111 in quadrant I is changed to the second deformable segment 112, the etching rate at the corresponding position in quadrant I is increased compared with the case of a standard coil in the existing art.

[0092] This is because the first deformable segment 111 is provided protruding in the direction away from the gyration center O in quadrant I, so that the sector area enclosed by the deformed first deformable segment 111 with the arc segment 113, the first virtual straight line D1, and the second virtual straight line D2 in quadrant I is increased. Although the inductance is increased, a distance between an edge of the first deformable segment 111 and an edge of the wafer is increased due to the outward expansion, and the plasma density reaching the wafer surface is actually decreased, thereby reducing the etching rate. Accordingly, if the second deformable segment 112 is provided retracted inward in the direction approaching the gyration center O in quadrant I, the area enclosed by the deformed second deformable segment 112 with the first virtual straight line D1 and the second virtual straight line D2 in quadrant I is reduced. Although the inductance is reduced, a distance between an edge of the second deformable segment 112 and an edge of the wafer is decreased due to the inward compression, and the plasma density reaching the wafer surface is increased, thereby increasing the etching rate.

[0093] In other words, under the condition that the minimum area of the coil 10 (i.e., an area enclosed by an inner peripheral contour of the coil 10) is greater than the area of the

wafer, i.e., when the coil 10 is an outer coil, the etching rate at a corresponding position can be reduced by providing the first deformable segment 111, while the etching rate at a corresponding position can be increased by providing the second deformable segment 112. Therefore, in this embodiment, the first deformable segment 111 is disposed in quadrants I and III, and the second deformable segment 112 is disposed in quadrants II and IV.

[0094] As shown in FIG. 9, in this embodiment, the first deformable segment 111 disposed in quadrant I can reduce the etching rate in quadrant I, and the second deformable segment 112 disposed in quadrant IV can increase the etching rate in quadrant IV. Similarly, the situation of the coil 10 in quadrant II is the same as that in quadrant IV, and the situation in quadrant III is also the same as that in quadrant I, thereby achieving a more uniform overall etching rate.

[0095] It should be further noted that according to experimental data, when the wafer to be processed has a diameter of 300mm and the first deformable segment 111 in quadrant I has $H1=6\text{mm}$ in FIG. 9, the etching rate at a position corresponding to the first deformable segment 111 in quadrant I is reduced compared with the case of a standard coil in the existing art. When $H1=12\text{mm}$, the etching rate at the position corresponding to the first deformable segment 111 in quadrant I is further reduced, but the reduction in the etching rate is slowed. When $H1=15\text{mm}$, the etching rate at the position corresponding to the first deformable segment 111 in quadrant I is increased instead of decreased. In other words, the first deformable segment 111 protrudes away from the gyration center O within a limited range, within which the influence of the distance between the first deformable segment 111 and the wafer on the etching rate is greater than the influence of the area change caused by the first deformable segment 111 on the etching rate; and beyond which, the influence of the area change caused by the first deformable segment 111 on the etching rate is dominant, causing the etching rate to be increased instead of decreased.

[0096] Therefore, in the second embodiment, $H1/\phi$ ranges from 0.0067 to 0.05, and $H2/\phi$ ranges from 0.0067 to 0.05. In this embodiment, a wafer to be processed has a diameter ϕ of 300mm, and therefore, $H1$ may range from 2mm to 30mm, and $H2$ may range from 2mm to 30mm. In an embodiment, $H1$ ranges from 2mm to 15mm, and $H2$ ranges from 2mm to 15mm, where a good compensation effect can be obtained within such ranges, and the etching rate is more uniform.

[0097] As shown in FIG. 9, similar to the first embodiment, in the second embodiment, the first deformable segment 111 is arched, and vertices of all first deformable segments 111 are located on a third virtual straight line D3 passing through the gyration center O;

and the second deformable segment 112 is arched, and vertices of all second deformable segments 112 are located on a fourth virtual straight line D4 passing through the gyration center O.

[0098] In some embodiments, the third virtual straight line D3 is perpendicular to the fourth virtual straight line D4.

[0099] The difference between the second embodiment and the first embodiment is that to further improve the uniformity of the etching rate, in this embodiment, the third virtual straight line D3 forms an angle B with the first virtual straight line D1, where B satisfies: $50^{\circ} \leq B \leq 70^{\circ}$.

[0100] In some embodiments, to further improve the uniformity of the etching rate, the fourth virtual straight line D4 forms an angle A with the first virtual straight line D1, where A satisfies: $20^{\circ} \leq A \leq 40^{\circ}$.

[0101] As shown in the second embodiment in FIG. 10, the present disclosure further discloses a coil assembly which has substantially the same structure as the coil assembly in the first embodiment, except that in this embodiment, the two coils 10 form an outer coil of the upper electrode, so that a minimum gyration radius R of the coil 10 is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil 10, a plurality of second deformable segments 112 and a plurality of first deformable segments 111 are sequentially and alternately arranged at intervals.

[0102] In some embodiments, the third virtual straight line D3 forms an angle B with the first virtual straight line D1, where B satisfies: $50^{\circ} \leq B \leq 70^{\circ}$.

[0103] In some embodiments, the fourth virtual straight line D4 forms an angle A with the first virtual straight line D1, where A satisfies: $20^{\circ} \leq A \leq 40^{\circ}$.

[0104] The present disclosure further discloses a coil device for exciting plasma and used in a semiconductor process apparatus, including at least two coil assemblies as described above, where the at least two coil assemblies are disposed spaced apart from inside to outside.

[0105] Specifically, as shown in FIG. 11, the coil device includes the coil assembly of the first embodiment and the coil assembly of the second embodiment. The coil assembly of the first embodiment is located at an innermost side, i.e., is an inner coil assembly, while the coil assembly of the second embodiment is located at an outermost side, i.e., is an outer coil assembly.

[0106] It will be appreciated that a maximum gyration radius R of coils 10 in the innermost coil assembly is smaller than a radius of a wafer to be processed, and from the

first end to the second end of the coil 10, a plurality of first deformable segments 111 and a plurality of second deformable segments 112 are sequentially and alternately arranged at intervals.

[0107] A minimum gyration radius R of coils 10 in the outermost coil assembly is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil 10, a plurality of second deformable segments 112 and a plurality of first deformable segments 111 are sequentially and alternately arranged at intervals.

[0108] The first deformable segment 111 and the second deformable segment 112 are both arched. Vertices of all first deformable segments 111 on the innermost coil assembly are located on a third virtual straight line D3 passing through the gyration center O. Vertices of all second deformable segments 112 on the outermost coil assembly are located on a fifth virtual straight line D5 passing through the gyration center O. The third virtual straight line D3 coincides with the fifth virtual straight line D5.

[0109] The first deformable segment 111 and the second deformable segment 112 are both arched. Vertices of all second deformable segments 112 on the innermost coil assembly are located on a fourth virtual straight line D4 passing through the gyration center O. Vertices of all first deformable segments 111 on the outermost coil assembly are located on a sixth virtual straight line D6 passing through the gyration center O. The fourth virtual straight line D4 coincides with the sixth virtual straight line D6.

[0110] In other words, as shown in FIG. 11, all first deformable segments 111 in the coil assembly (i.e., the inner coil assembly) of the first embodiment are located in quadrants II and IV, while all second deformable segments 112 in the coil assembly (i.e., the outer coil assembly) of the second embodiment are located in quadrants II and IV. Meanwhile, the first deformable segments 111 in the inner coil assembly correspond to the second deformable segments 112 in the outer coil assembly, and vertices of all the first deformable segments 111 and the second deformable segments 112 in quadrants II and IV are located on the same virtual straight line. Correspondingly, all second deformable segments 112 in the inner coil assembly are located in quadrants I and III, while all first deformable segments 111 in the outer coil assembly are located in quadrants I and III. Meanwhile, the second deformable segments 112 in the inner coil assembly correspond to the first deformable segments 111 in the outer coil assembly, and vertices of all the first deformable segments 111 and the second deformable segments 112 in quadrants I and III are located on the same virtual straight line.

[0111] FIG. 12 is a diagram showing etching rates of an inductively coupled plasma

semiconductor process apparatus adopting a coil device according to the present disclosure, and FIG. 13 is a diagram showing eccentricity data of an inductively coupled plasma semiconductor process apparatus adopting a coil device according to the present disclosure. According to the eccentricity data of FIG. 13, compared with the data in FIG. 6, values in regions corresponding to quadrants I and III are decreased, values in regions corresponding to quadrants II and IV are increased, an overall difference range of etching rates is greatly reduced, the overall uniformity of the wafer is improved, and the butterfly map is also improved.

[0112] As can be seen, according to the coil 10 of the present disclosure, by providing the first deformable segment 111 and the second deformable segment 112 on the arched part 11, and making a maximum distance from the first deformable segment 111 to the gyration center O greater than the gyration radius R of the arched part 11, and a maximum distance from the second deformable segment 112 to the gyration center O less than the gyration radius R of the arched part 11, it is equivalent to adjust an area enclosed by the coil 10 to counteract an area difference generated on the coil 10 to avoid terminal studs, and thus achieve a more uniform plasma density distribution over a wafer, thereby greatly improving the process uniformity in a radius direction of the wafer as well as the process quality.

[0113] The present disclosure further discloses an inductively coupled plasma semiconductor process apparatus, including a process chamber and the coil 10 as described above, or the coil assembly as described above, or the coil device as described above, configured to excite a gas in the process chamber to plasma.

[0114] It will be appreciated that the above implementations are merely exemplary implementations for the purpose of illustrating the principle of the present disclosure, and the present disclosure is not limited thereto. Various modifications and improvements can be made by a person having ordinary skill in the art without departing from the spirit and essence of the present disclosure. Accordingly, all of the modifications and improvements also fall within the protection scope of the present disclosure.

What is claimed is:

1. A coil for exciting plasma and used in a semiconductor process apparatus, wherein the coil extends on a plane by gyration,

5 the coil comprises a plurality of arched parts and a plurality of connection parts arranged about a gyration center of the coil, and adjacent arched parts are connected by the connection parts;

the coil has a first end and a second end, wherein from the first end to the second end of the coil, the arched parts and the connection parts are sequentially and
10 alternately arranged at intervals, and gyration radii of the arched parts gradually increase;

at least one of the plurality of arched parts comprises a first deformable segment, an arc segment and a second deformable segment connected in sequence, wherein the first deformable segment and the second deformable segment are connected to two
15 ends of the arc segment, respectively, a center of a circle where the arc segment is located is the gyration center, and the gyration radius of the arched part is a distance from the arc segment to the gyration center,

a maximum distance from the first deformable segment of the arched part to the gyration center is greater than the gyration radius of the arched part; and

20 a maximum distance from the second deformable segment of the arched part to the gyration center is less than the gyration radius of the arched part.

2. The coil according to claim 1, wherein on the plane, the first deformable segment protrudes in a direction away from the gyration center relative to the circle
25 where the arc segment is located, and the second deformable segment is retracted inward in a direction approaching the gyration center relative to the circle where the arc segment is located.

3. The coil according to claim 1, wherein from the first end to the second end of
30 the coil, the first deformable segment and the second deformable segment are alternately arranged at intervals.

4. The coil according to claim 1, wherein the first end and the second end of the coil are both located on a first virtual straight line, and

the first end and the second end of the coil are located on two sides of a second virtual straight line, respectively, wherein the second virtual straight line is perpendicular to the first virtual straight line, and intersected with the first virtual straight line at the gyration center.

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5. The coil according to claim 4, wherein from the first end to the second end of the coil, two adjacent arched parts are located on two sides of the first virtual straight line, respectively; and

10 the first deformable segment and the second deformable segment on the same arched part are located on two sides of the second virtual straight line, respectively.

6. The coil according to claim 4, wherein from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals.

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7. The coil according to claim 4, wherein the first deformable segment is arched, and vertices of all first deformable segments are located on a third virtual straight line passing through the gyration center; and

20 the second deformable segment is arched, and vertices of all second deformable segments are located on a fourth virtual straight line passing through the gyration center.

8. The coil according to claim 7, wherein the third virtual straight line is perpendicular to the fourth virtual straight line; or

25 an angle formed by the third virtual straight line with the first virtual straight line is in a range of 20° to 40° ; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 20° to 40° ; or

30 an angle formed by the third virtual straight line with the first virtual straight line is in a range of 50° to 70° ; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 50° to 70° .

9. The coil according to claim 2, wherein a wafer to be processed has a diameter

ϕ , and on the same arched part, the first deformable segment protrudes by a distance $H1$, and

$H1/\phi$ ranges from 0.005 to 0.1; or

$H1/\phi$ ranges from 0.0067 to 0.05.

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10. The coil according to claim 2, wherein a wafer to be processed has a diameter ϕ , and on the same arched part, the second deformable segment is retracted inward by a distance $H2$, and

$H2/\phi$ ranges from 0.005 to 0.1; or

10 $H2/\phi$ ranges from 0.0067 to 0.05.

11. A coil for exciting plasma and used in a semiconductor process apparatus, wherein the coil extends on a plane by gyration, the coil comprises a plurality of arched parts and a plurality of connection parts arranged about a gyration center of the coil, and the plurality of arched parts are connected by the connection parts;

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each arched part has a deformable segment configured to change a shape of an induced electromagnetic field generated by the coil and surrounded by the arched part, to adjust the distribution of plasma generated by the induced electromagnetic field.

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12. The coil according to claim 11, wherein the coil has a first end and a second end, the arched parts are sequentially distributed from the first end to the second end of the coil, and gyration radii of the arched parts gradually increase.

13. The coil according to claim 12, wherein the deformable segment comprises a first deformable segment and a second deformable segment located on the same arched part;

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a maximum distance from the first deformable segment to the gyration center is greater than the gyration radius of the arched part; and

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a maximum distance from the second deformable segment to the gyration center is less than the gyration radius of the arched part.

14. The coil according to claim 13, wherein the arched part further has an arc segment, the first deformable segment and the second deformable segment are connected to two ends of the arc segment, respectively, a center of a circle where the

arc segment is located is the gyration center, and the gyration radius of the arched part is a distance from the arc segment to the gyration center.

15. The coil according to claim 13, wherein the first end and the second end of the coil are both located on a first virtual straight line, and

the first end and the second end of the coil are located on two sides of a second virtual straight line, respectively, wherein the second virtual straight line is perpendicular to the first virtual straight line, and intersected with the first virtual straight line at the gyration center;

from the first end to the second end of the coil, two adjacent arched parts are located on two sides of the first virtual straight line, respectively; and

the first deformable segment and the second deformable segment on the same arched part are located on two sides of the second virtual straight line, respectively.

16. The coil according to claim 15, wherein the first deformable segment is arched, and vertices of all first deformable segments are located on a third virtual straight line passing through the gyration center; and

the second deformable segment is arched, and vertices of all second deformable segments are located on a fourth virtual straight line passing through the gyration center.

17. The coil according to claim 16, wherein the third virtual straight line is perpendicular to the fourth virtual straight line.

18. The coil according to claim 16, wherein a maximum gyration radius of the coil is smaller than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals.

19. The coil according to claim 18, wherein an angle formed by the third virtual straight line with the first virtual straight line is in a range of 20° to 40° ; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 50° to 70° .

20. The coil according to claim 16, wherein a minimum gyration radius of the coil is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of second deformable segments and a plurality of first deformable segments are sequentially and alternately arranged at intervals.

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21. The coil according to claim 20, wherein an angle formed by the third virtual straight line with the first virtual straight line is in a range of 50° to 70°; or

an angle formed by the fourth virtual straight line with the first virtual straight line is in a range of 20° to 40°.

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22. A coil assembly for exciting plasma and used in a semiconductor process apparatus, comprising a plurality of coils according to any one of claims 1 to 21, wherein the plurality of coils are circumferentially and uniformly distributed with the gyration center as a deflection center.

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23. A coil device for exciting plasma and used in a semiconductor process apparatus, comprising at least two coil assemblies according to claim 22, wherein the at least two coil assemblies are disposed spaced apart from inside to outside.

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24. The coil device according to claim 23, wherein a maximum gyration radius of coils in an innermost coil assembly is smaller than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of first deformable segments and a plurality of second deformable segments are sequentially and alternately arranged at intervals;

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a minimum gyration radius of coils in an outermost coil assembly is greater than a radius of a wafer to be processed, and from the first end to the second end of the coil, a plurality of second deformable segments and a plurality of first deformable segments are sequentially and alternately arranged at intervals.

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25. The coil device according to claim 24, wherein the first deformable segment and the second deformable segment are both arched;

vertices of all first deformable segments on the innermost coil assembly are located on a third virtual straight line passing through the gyration center;

vertices of all second deformable segments on the outermost coil assembly are

located on a fifth virtual straight line passing through the gyration center; and
the third virtual straight line coincides with the fifth virtual straight line.

5 26. The coil device according to claim 25, wherein the first deformable segment
and the second deformable segment are both arched;
vertices of all second deformable segments on the innermost coil assembly are
located on a fourth virtual straight line passing through the gyration center;
vertices of all first deformable segments on the outermost coil assembly are
located on a sixth virtual straight line passing through the gyration center; and
10 the fourth virtual straight line coincides with the sixth virtual straight line.

27. An inductively coupled plasma semiconductor process apparatus,
comprising a process chamber and the coil according to any one of claims 1 to 21, or
the coil assembly according to claim 22, or the coil device according to any one of
15 claims 23 to 26, configured to excite a gas in the process chamber to plasma.