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(54) **Work surface treatment method and work surface treatment apparatus**

Verfahren und Vorrichtung zu Oberflächenbehandlung

Procédé et dispositif de traitement de surfaces

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a method and an apparatus for effecting treatment on a surface of an object, i.e., a work and more particularly for effecting treatment such as film deposition, etching or quality modification by exposing a work to be treated to a plasma and implanting ions in the plasma into the work.

Description of the Background Art

[0002] PSII (Plasma Source Ion Implantation) has been known as a technology for surface treatment of an object, and an example of an apparatus for the same is shown in Fig. 6.

[0003] This apparatus has a grounded vacuum container 1. An exhaust device 11 and a treatment gas supply unit 3 are provided for the container 1. The treatment gas supply unit 3 includes a mass-flow controller, a gas source and others, which are not shown in the figure. An electrode 2 also serving as a holder for supporting a work S, i.e., an object to be treated is arranged in the container 1. The electrode 2 is connected to a DC high-voltage source 22 through an on-off switch 21. A filament 4 which is supplied with an electric power and thereby is heated for emitting electrons is arranged in the container 1. The filament 4 is connected to a filament power source 41 and a discharge bias power source 42.

[0004] For effecting surface treatment on the work S by this apparatus, the work S is transported into the vacuum container 1 by an unillustrated work transporting device, and is held by the holder 2. Then, a treatment gas such as nitrogen gas is supplied into the container 1 from the gas supply unit 3 while keeping a predetermined degree of vacuum in the container 1 at the order of 10^{-4} by operating the exhaust device 11. Also, the filament power source 41 energizes and thereby heats the filament 4 to emit electrons, and the discharge bias power source 42 applies a bias voltage to the filament 4 to accelerate the emitted electrons. Thereby, the treatment gas which is introduced as described above is ionized to form plasma P. During this, the electrode 2 is supplied with a negative high-voltage pulse from the power source 22 through the on-off switch 21. Thereby, the surface of the work S is exposed to the plasma P, and the positive ions in the plasma P are accelerated toward the work S and are implanted into the surface of the work S so that treatment such as modification of quality is effected on the surface of the work S.

[0005] According to the above apparatus and method for the surface treatment, predetermined treatment can be effected relatively uniformly on the surface of the work having a complicated three-dimensional structure.

[0006] However, the apparatus and method for the

surface treatment in the prior art suffer from the following problems. For example, a work, such as an object used in semiconductor device, may have different kinds of portions, i.e., a portion which is covered with an electrically insulating material or is in a floated potential, and a portion which is made of an electrically conductive material, such as an electrically conductive circuit, and it may be desired to effect the treatment only on the above conductive portion. In the processing for this treatment, a pulse voltage is not applied to the insulated portion or the portion carrying the floated potential (both of which will be generally termed as the "insulated portion"), and the positive ions are not ideally implanted into the insulated portion. However, due to the weight of ions, the ions cannot rapidly change their course at the vicinity of the surface of the insulated portion during an on-period of the pulse voltage so that the ions collide with and are implanted into the surface of the insulated portion at and around its end. Generally, when ions are implanted into a work surface with a high energy from about several kilovolts to hundreds of kilovolts, a large amount of secondary ions are emitted from the work surface. If the work surface partially has an insulated portion, positive electric charges are rapidly accumulated at the surface of the insulated portion due to the positive ions, which are implanted into the other portion, i.e., the conductive portion and the end of the insulated portion, and emitted secondary electrons. As a result, an electric field formed by the positive charges causes irregularities in the ion implantation distribution at the conductive portion, and discharge occurs between the surface of the insulated portion and the surface of the conductive portion supplied with the negative high-voltage pulse so that the surface of these portions may be destroyed.

[0007] The prior right document EP-A-0 821 077, related to the same applicant and inventors as the present invention and stak of the art according to Art. 54(3) EPC, discloses method and an apparatus for coating an object with a carbon film. A workpiece supported by a work support electrode in a vacuum container is subjected to an amplitude-modulated, preferably pulse-modulated RF plasma. The basic RF power before modulation is between about 10 and about 100 MHz. The modulation frequency is between 1/100000 and 1/10, preferably between 1/10000 and 1/1000. Pulsed negative DC power is superimposed to the amplitude-modulated RF plasma.

[0008] A further prior right document according to Art. 54(3) EPC is EP-A-0 793 254. This document discloses a plasma processing method and apparatus, where a VHF plasma of preferably 30-100 MHz is applied to a workpiece supported by a work support in a vacuum container. The basic high frequency may be modulated by on/off control or level modulation. The modulation "on" time is 5 - 50 μ s, the "off" time is 10 - 200 μ s and a period of 20 - 250 μ s is used. The work support electrode is biased with a positive pulsed voltage.

SUMMARY OF THE INVENTION

[0009] An object of the invention is to provide a method for surface treatment, in which predetermined surface treatment can be effected on a work portion made of an electrically conductive material without damaging the work even if the work has a surface portion made of an electrically insulating material or carrying a floated potential as well as an apparatus for implementing the method.

[0010] Another object of the invention is to provide a method for surface treatment, in which predetermined surface treatment can be effected uniformly on a work portion made of an electrically conductive material even if the work has a surface portion made of an electrically insulating material or carrying a floated potential as well as an apparatus for implementing the method.

[0011] The invention provides a work surface treatment method comprising the steps of supporting a work by a work support electrode arranged in a vacuum container; supplying a treatment gas corresponding to intended treatment of the work into said container; forming plasma from the gas by applying in a vacuum an amplitude-modulated high-frequency power to an electrode electrically insulated from said work support electrode, said amplitude-modulated high-frequency power being prepared by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency; and applying a positive pulse voltage to said work support electrode to effect the treatment on the surface of said work supported by said work support electrode, wherein said amplitude modulation is pulse modulation, and the timing of each rising of said positive pulse voltage is determined between an intermediate time in the on-period of said pulse-modulated high-frequency power and a time in the subsequent off-period, and the timing of each falling of the positive pulse voltage is determined between a time in the off-period of said pulse-modulated high-frequency power and an intermediate time in the subsequent on-period.

[0012] The invention also provides a work surface treatment apparatus comprising a vacuum container; a work support electrode arranged in said vacuum container; an electrode electrically insulated from said work support electrode; an exhaust device; a treatment gas supply device; a high-frequency power supply device for supplying an amplitude-modulated high-frequency power to the electrode electrically insulated from said work support electrode, a signal generator for preparing said amplitude-modulated high-frequency power by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency; a pulse voltage application device for applying a positive pulse voltage to said work support elec-

trode, and a control unit for controlling said high-frequency power supply device as to supplying a pulse-modulated high-frequency power and controlling said pulse voltage application device as to start application of the positive pulse at a time between an intermediate time in each on-period of said pulse-modulated high-frequency power supplied by said high-frequency power supplying device and a time in the subsequent off-period, and stops the application of said positive pulse voltage at a time between a time in the off-period of said pulse-modulated high-frequency power supplied by said high-frequency power supplying device and an intermediate time in the subsequent on-period.

[0013] The pulse modulation can be performed by on/off of supply of the electric power, or by a modulation in a pulse form.

[0014] Variation with time occurs in density of the negative ions in the plasma while the plasma is being formed from the gas by supplying the pulse-modulated high-frequency power. This variation will now be described below with reference to Fig. 1. According to the research and study by the inventors, negative ions present in the plasma, which remains after cutoff of the pulse-modulated high-frequency power, start to increase in quantity, although this depends on a magnitude and others of the pulse-modulated high-frequency power. In this illustrated example, the increase of the negative ions reaches a peak after about 40 μ sec from cut-off of the pulse-modulated high-frequency power, and the negative ions will disappear within about 200 μ sec after the cut-off of the power. Therefore, the negative ions in the remaining plasma can be implanted into the work surface in such a manner that the pulse-modulated high-frequency power is supplied to the treatment gas for forming the plasma from the treatment gas, and the positive voltage is applied to the electrode supporting the work during a period containing a period that a large amount of negative ions are present after the cut-off of the power. This is owing to the fact that the negative ions are accelerated toward the work support electrode by a potential difference between the work support electrode and the plasma formed by application of the positive voltage.

[0015] The work may partially have an insulated portion (a portion made of an electrically insulating material or a portion in a floated potential) at its surface. In this case, the negative ions are implanted into an end of the insulated portion. However, charges of the implanted negative ions and charges of the emitted secondary electrons cancel each other so that accumulation of the charges at the work surface can be suppressed to a practically allowable extent. Thereby, it is possible to suppress the irregular surface treatment which may be caused by accumulation of charges as well as damages on the object which may be caused by discharging at the vicinity of the work surface.

[0016] The foregoing and other objects, features, aspects and advantages of the present invention will be-

come more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 shows a density of negative ions in plasma formed by supply of a pulse-modulated high-frequency power;

Fig. 2 schematically shows a structure of an example of a work surface treatment apparatus according to the invention;

Fig. 3 shows at (A) an example of timing of supply of a pulse-modulated high-frequency power to an electrode 7 during work surface treatment by the apparatus shown in Fig. 2, shows at (B) an example of timing of application of a positive pulse voltage to an electrode 2, and shows at (C) an example of timing of application of a negative pulse to the electrode 2;

Fig. 4 shows at (A) a specific example of timing of supply of the pulse-modulated high-frequency power to the electrode 7 during work surface treatment by the apparatus in Fig. 2, and shows at (B) a specific example of the timing of supply of the positive pulse voltage to the electrode 2;

Fig. 5 shows an example of a relationship between the positive pulse voltage and the adhesion strength of a film formed by the method of the invention; and

Fig. 6 shows a schematic structure of an example of a work surface treatment apparatus in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] A work surface treatment method which will be described below comprises the steps of supporting a work by a work support electrode arranged in a vacuum container; supplying a treatment gas corresponding to intended treatment of the work into the container; forming plasma from the gas by applying in a vacuum an amplitude-modulated high-frequency power to an electrode electrically insulated from said work support electrode, said amplitude-modulated high-frequency power being prepared by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency; and applying a positive pulse voltage to said work support electrode to effect the treatment on the surface of said work supported by said work support electrode.

[0019] A work surface treatment apparatus which will be described below comprises a vacuum container; a

work support electrode arranged in the vacuum container; an electrode electrically insulated from the work support electrode; an exhaust device; a treatment gas supply device; a high-frequency power supply device for supplying an amplitude-modulated high-frequency power to the electrode electrically insulated from said work support electrode, said amplitude-modulated high-frequency power being prepared by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency; and a pulse voltage application device for applying a positive pulse voltage to said work support electrode.

[0020] A preferred embodiment of the invention will now be described below with reference to the drawings.

[0021] Fig. 2 shows a schematic structure of an example of a work surface treatment apparatus according to the invention. This apparatus has a vacuum container 1 additionally provided with an exhaust device 11. Electrodes 2 and 7 opposed to each other are arranged in the container 1. The electrode 2 serves also as a work support holder, and is connected to a DC power source 22 through a low-pass filter 20 and an on-off switch 21. In Fig. 2, the power source 23 and on-off switch 23S will be described later more in detail. A heater h is provided at the electrode 2. The electrode 7 is a high-frequency electrode and is connected to a signal generator 73 which can generate an arbitrary waveform through a matching box 71 and a high-frequency power source 72. A control unit CONT is connected to the switch 21 and the high-frequency power source 72, and controls timing of supply of a pulse-modulated high-frequency power and application of a positive pulse voltage, which will be described later.

[0022] Further, a treatment gas supply unit 3 is provided for the container 1. The gas supply unit 3 includes one or more gas sources 331, 332, ... of treatment gases which are connected to the container 1 through mass-flow controllers 311, 312, ... and electromagnetic valves 321, 322, ..., respectively.

[0023] For effecting predetermined surface treatment on the work S by this apparatus, the work S is transported into the container 1 and is held by the holder 2. Then, the exhaust device 11 operates to attain and keep a predetermined degree of vacuum in the container 1. Also, a treatment gas is supplied into the container 1 from the gas supply unit 3, and the high-frequency power is supplied from the signal generator 73 to the electrode 7 through the high-frequency power source 72 and the matching box 71. The high-frequency power thus supplied is prepared by pulse modulation which is effected on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of the predetermined frequency of the basic high-frequency power. Also, a positive voltage of a predetermined magnitude is applied to the electrode 2 from the

power source 22 through the on-off switch 21. The supply of the pulse-modulated high-frequency power to the electrode 7 and the application of the positive voltage to the electrode 2 are controlled to start and stop repetitively at constant periods.

[0024] The basic high-frequency power before modulation for producing the amplitude-modulated high-frequency power may have a sinusoidal waveform, a square waveform, a saw-tooth-like waveform, a triangular waveform or others.

[0025] By the following reason, the embodiment uses the basic high-frequency power having the frequency in the range from 10 MHz to 200 MHz. If it were lower than 10 MHz, it would be difficult to trap or confine efficiently the plasma. If it were larger than 200 MHz, it would be difficult for electrons to follow sufficiently the frequency, and it would be difficult to produce efficiently the plasma.

[0026] By the following reason, the embodiment employs the frequency for the amplitude modulation in the range from 1/1000 to 1/10 of the frequency of the basic high-frequency power. If it were smaller than 1/1000, it would be difficult to obtain an effect by the modulation. If it were larger than 1/10, the amplitude modulation would result in a state similar to a state achieved by double supply of the basic high-frequency power rather than a state achieved by effecting the amplitude modulation on the basic high-frequency power.

[0027] A duty ratio (on-time / on-time and off-time) of the pulse modulation of the high-frequency power can be in a range from about 0.1% to about 50%.

[0028] The timing at which the modulated high-frequency power is supplied to the electrode 7 and the positive pulse voltage is applied to the electrode 2 are determined as follows. The timing of rising of the positive pulse voltage applied to the electrode 2 (application start timing or on-timing) is determined between an intermediate time (e.g., a half point) in the on-period of supply of the pulse-modulated high-frequency power to the electrode 7 and a certain time in the subsequent off-period. The timing of falling of the positive pulse voltage applied to the electrode 2 (application stop timing or off-timing) is determined between a certain time in the off-period of supply of the pulse-modulated high-frequency power to the electrode 7 and an intermediate time (e.g., a half point) in the subsequent on-period. More preferably, it is determined between the time in the off-period of supply of the pulse-modulated high-frequency power supply to the electrode 7 and the end of this off-period.

[0029] Further, the period for which the positive pulse voltage is applied to the electrode 2 preferably includes a period during which negative ions are present after cut-off of the pulse-modulated high-frequency power to the electrode 7, and further preferably includes a portion or the whole of the period during which many negative ions are present. The foregoing timing in connection with application of the positive pulse voltage is an example of the timing determined within the period including at least a portion of the period during which many

negative ions are present. In contrast to this example, it is not impossible to apply the positive pulse voltage during the whole period of the treatment. However, if the on-period of application of the positive pulse voltage is excessively larger, a power supply cost wastefully and therefore unpreferably increases.

[0030] From the foregoing, it can be understood that the application of the positive pulse voltage is preferably performed at least for a period starting before and ending after the point of time when the quantity of the negative ions reaches the peak during the off-period of the pulse-modulated high-frequency power.

[0031] A specific example is as follows. As shown at (A) and (B) in Fig. 3, the supply of the high-frequency power to the electrode 7 stops at the same timing as the start of application of the positive voltage to the electrode 2, and the application of the positive voltage to the electrode 2 stops during the off-period of supply of the high-frequency power to the electrode 7.

[0032] Thereby, treatment depending on the kind of the treatment gas is effected on the surface of the work surface S.

[0033] According to the work surface treatment method and apparatus described above, the negative ions in the plasma increase in quantity after the stop of supply of the pulse-modulated high-frequency power to the electrode 7. However, the positive voltage is applied to the work support electrode 2 during the period containing the above period so that the increased negative ions in the plasma can be implanted into the work surface S. This is owing to the fact that the negative ions are accelerated toward the electrode 2 by the potential difference between the electrode 2 and the plasma P during the period of the application of the positive voltage to the electrode 2. The work S may partially have an insulated portion (a portion made of an electrically insulating material or a portion in a floated potential) at its surface. In this case, the negative ions are also implanted into a portion of the insulated portion. However, charges of the implanted negative ions and charges of the emitted secondary electrons cancel each other so that accumulation of the charges at the work surface S can be suppressed to a practically allowable extent. Thereby, it is possible to suppress the irregular surface treatment of the work S which may be caused by accumulation of the charges as well as damages of the work S which may be caused by discharging at the vicinity of the work surface S.

[0034] The positive pulse voltage applied to the electrode 2 is in a range from 50 V to 300 kV. If it were lower than 50 V, the ions implanted into the work would have an excessively low energy so that the ion implantation would not achieve an intended effect. If it were higher than 300 kV, the discharge current would excessively increase so that the thermal damage applied to the work would impractically increase. The magnitude of the positive pulse voltage is appropriately determined within the above range in accordance with the specific treatment

to be effected. when the ions are to be implanted into a portion at a small depth from the surface of the work, the positive pulse voltage is set in a range from 50 volts to several kilovolts. If the ions are to be implanted into a comparatively deep portion, the voltage is set in a range from several kilovolts to 300 kilovolts.

[0035] As another example for implementing the method of the invention by the apparatus shown in Fig. 2, such a manner may be employed that the plasma is formed from the treatment gas by supplying the pulse-modulated high-frequency power to the electrode 7 similarly to the foregoing embodiment, and the positive pulse voltage is applied to the electrode 2 at the predetermined timing. Also, the negative pulse voltage is applied to the electrode 2 from the DC power source 23 through the switch 23S (see Fig. 2) during an off-period of application of the positive pulse voltage to the electrode 2. The switch 23S is controlled by the control unit CONT. The DC power source 23 for applying the negative pulse voltage may commonly use a portion of the DC power source 22 for applying the positive pulse voltage.

[0036] The period for applying the negative pulse voltage to the electrode 2 may be the same as a portion or the whole of the off-period of application of the positive pulse voltage to the electrode 2. For example, as shown at (C) in Fig. 3, the negative pulse voltage is applied from the DC power source 23 during the same period as the on period of supply of the pulse-modulated high-frequency power to the electrode 7. This improves the speed of treating the work S. Even when the negative pulse voltage is applied in the above manner, accumulation of the positive charges at the surface of the insulated portion can be suppressed to an allowable extent by applying the positive pulse voltage during a period other than the above.

[0037] As exemplified in Fig. 4, the application of the positive pulse voltage to the electrode 2 from the power source 22 may be performed during a period containing a period within the off-period of supply of the high-frequency power to the electrode 7 and particularly during a period in which the quantity of negative ions is large (preferably, a period starting before and ending after the peak of the quantity of the negative ions).

[0038] As an example of the work surface treatment apparatus of the preferred embodiment of the invention, description has been given on the treatment apparatus of the capacity-coupling type in which the electrode 7 electrically insulated from the work support electrode 2 supplied with the modulated high-frequency power is arranged in the vacuum container 1 (see Fig. 2). However, such a treatment apparatus of an induction-coupling type may be employed that an electrode electrically insulated from the work support electrode supplied with the modulated high-frequency power is wound around the vacuum container.

[0039] According to the invention, when a high-frequency power is supplied, a magnetic field may be

formed, thereby a helicon wave plasma can be formed.

[0040] According to the invention, when the treatment gas is a deposition gas, a film can be deposited on the work. Also, etching can be performed with an etching gas, and modification of a surface quality can be performed with a surface quality modification gas.

[0041] A specific example will now be described below. In this example, the apparatus in Fig. 2 was used. The pulse-modulated high-frequency power and the positive pulse voltage were supplied to the electrodes 7 and 2 in accordance with patterns shown at (A) and (B) in Fig. 4, respectively. According to the pattern of supply of the pulse-modulated high-frequency power shown at (A) in Fig. 4, the on-time was 1.25 μ sec, the off-time was 23.75 μ sec and the duty ratio was 5 %. As shown at (B) in Fig. 4, the positive pulse voltage rose after 8 μ sec from cut-off of the pulse-modulated high-frequency power, and fell down elapsing of 10 μ sec after the rising. A work was made of stainless steel but had a portion electrically insulated by plastics. By the treatment, a titanium nitride film was deposited on a surface of the portion made of the stainless steel of the work.

Specifications of the Apparatus

[0042]

Size of high-frequency electrode 7: 270 mm in diameter
Size of work support electrode 2: 300 mm in diameter
Distance between electrodes: 30 mm

Conditions for Deposition

[0043]

Work S: a work made of stainless steel and having a portion made of plastics

(The portion of stainless steel had a length of 150 mm, a width of 16 mm and a thickness of 10 mm.)

Pulse-modulated high-frequency power:

Basic high-frequency power:
frequency: 13.56 MHz
200 W

Pulse modulation frequency: 40 kHz
Duty ratio: 5 %

Positive pulse voltage: 5 kV

frequency: 40 kHz
on-time: 10 μ sec
off-time: 15 μ sec

Deposition gas:

TiCl₄ 16 sccm (tank temperature: 50 °C)
N₂ 10 sccm

Deposition pressure: 0.1 Torr

Deposition time: 5 minutes

[0044] Any discharge scratch or damage was not found at the surface of the titanium nitride film obtained in this above example.

[0045] A pulling jig or member having a columnar form of 8 mm in diameter was adhered by adhesive onto the surface of the titanium nitride film deposited in this above example, and a force required for separating the pulling jig from the surface was measured for evaluating the film adhesion strength. As a result, it was found that the film adhesion strength was 20 times or more larger than that of a titanium nitride film formed by a conventional plasma CVD method. It can be consider that the high film adhesion strength was achieved owing to implantation of the negative ions in the plasma into the work S in addition to the effect by the conventional plasma CVD.

[0046] Fig. 5 shows relative values of the film adhesion strength with various magnitudes of the positive pulse voltage applied to the electrode 2 from 100 V to 1000 kV. It can be seen from Fig. 5 that the film adhesion strength increases with the positive pulse voltage.

[0047] Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the present invention being limited only by the terms of the appended claims.

Claims

1. A work surface treatment method comprising:

the step of supporting a work (S) by a work support electrode (2) arranged in a vacuum container (1);

the step of supplying a treatment gas corresponding to intended treatment of the work (S) into said container (1);

the step of forming plasma (P) from said gas by applying in a vacuum an amplitude-modulated high-frequency power to an electrode (7) electrically insulated from said work support electrode (2), said amplitude-modulated high-frequency power being prepared by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency; and

the step of applying a positive pulse voltage to said work support electrode (2) to effect the

treatment on the surface of said work (S) supported by said work support electrode (2), wherein

said amplitude modulation is pulse modulation, and the timing of each rising of said positive pulse voltage is determined between an intermediate time in the on-period of said pulse-modulated high-frequency power and a time in the subsequent off-period, and the timing of each falling of the positive pulse voltage is determined between a time in the off-period of said pulse-modulated high-frequency power and an intermediate time in the subsequent on-period.

2. The work surface treatment method according to claim 1, wherein said positive pulse voltage is in a range from 50 V to 300 kV.

3. The work surface treatment method according to claim 1 or 2, wherein a negative pulse voltage is applied to the work support electrode (2) during the off-period of application of said positive pulse voltage.

4. The work surface treatment method according to any of claims 1 - 3, wherein said work (S) has a surface portion made of an electrically insulating material or carrying a floated potential.

5. A work surface treatment apparatus comprising:

a vacuum container (1);

a work support electrode (2) arranged in said vacuum container (1);

an electrode (7) electrically insulated from said work support electrode (2);

an exhaust device (11);

a treatment gas supply device (3);

a high-frequency power supply device (72) for supplying an amplitude-modulated high-frequency power to the electrode (7) electrically insulated from said work support electrode (2);

a signal generator (73) for preparing said amplitude-modulated high-frequency power by effecting amplitude modulation on a basic high-frequency power having a predetermined frequency in a range from 10 MHz to 200 MHz with a modulation frequency in a range from 1/1000 to 1/10 of said predetermined frequency;

a pulse voltage application device (21, 22) for applying a positive pulse voltage to said work support electrode (2);

a control unit (CONT) for controlling said high-frequency power supply device (72) as to supplying a pulse-modulated high-frequency power and for controlling said pulse voltage application device (21, 22) as to start application of

the positive pulse at a time between an intermediate time in each on-period of said pulse-modulated high-frequency power supplied by said high-frequency power supplying device (72) and a time in the subsequent off-period, and stops the application of said positive pulse voltage at a time between a time in the off-period of said pulse-modulated high-frequency power supplied by said high-frequency power supplying device (72) and an intermediate time in the subsequent on-period.

6. The work surface treatment apparatus according to claim 5, wherein said pulse voltage application device (21, 22) applies the positive pulse voltage in a range from 50 V to 300 kV.
7. The work surface treatment apparatus according to claim 5 or 6, wherein said apparatus further comprises a pulse voltage application device (23, 23S) for applying a negative pulse voltage during a period that said work support electrode (2) is not supplied with the positive pulse voltage.

Patentansprüche

1. Arbeitsflächenbearbeitungsverfahren, das beinhaltet

- den Schritt des Haltens/Stützens einer Arbeitsfläche (S) mittels einer Arbeitsträgerelektrode (2), die in einem Vakuumgehäuse angeordnet ist;
- den Schritt der Zuführung eines Bearbeitungsgases in das besagte Gehäuse (1) entsprechend der beabsichtigten Bearbeitung der Arbeitsfläche (S);
- den Schritt der Bildung von Plasma (P) aus besagtem Gas durch Aufbringung einer amplitudenmodulierten Hochfrequenzleistung in einem Vakuum auf eine Elektrode (7), die von besagter Arbeitsträgerelektrode (2) elektrisch isoliert ist, wobei besagte amplitudenmodulierte Hochfrequenzleistung durch die Durchführung einer Amplitudenmodulation einer Grundfrequenzleistung erzeugt wird, die eine vorfestgelegte Frequenz im Bereich von 10 MHz bis 200 MHz mit einer Modulationsfrequenz im Bereich von 1/1000 bis 1/10 der besagten vorbestimmten Frequenz hat, und
- den Schritt der Aufbringung einer positiven Impulsspannung auf besagte Arbeitsträgerelektrode (2), um die Bearbeitung auf der Oberfläche der besagten Arbeitsfläche (S), unterstützt durch besagte Arbeitsträgerelektrode (2), durchzuführen, wobei
- besagte Amplitudenmodulation eine Impuls-

modulation ist und das Timing eines jeden Anstiegs der besagten positiven Impulsspannung zwischen einer Zwischenzeit des Inbetriebszeitraums der besagten impulsmodulierten Hochfrequenzleistung und einer Zeit in dem darauffolgenden Zeitraum der Außerbetriebnahme vorfestgelegt ist, und das Timing eines jeden Abfalls der positiven Impulsspannung zwischen einer Zeit des Zeitraums der Außerbetriebnahme der besagten impulsmodulierten Hochfrequenzleistung und einer Zwischenzeit des darauffolgenden Inbetriebszeitraums festgelegt ist.

2. Arbeitsflächenbearbeitungsverfahren gemäß Anspruch 1, wobei besagte positive Impulsspannung im Bereich von 50 V bis 300 kV liegt.
3. Arbeitsflächenbearbeitungsverfahren gemäß Anspruch 1 oder 2, wobei eine negative Impulsspannung während des Zeitraums der Außerbetriebnahme des Aufbringens der besagten positiven Impulsspannung auf die Arbeitsträgerelektrode (2) aufgebracht wird.
4. Arbeitsflächenbearbeitungsverfahren gemäß irgendeiner der Ansprüche 1 - 3, wobei besagte Arbeitsfläche (S) einen Oberflächenteil beinhaltet, der aus einem elektrischen Isolationsmaterial gefertigt ist oder ein gleitendes Potential trägt.
5. Arbeitsflächenbearbeitungsgerät, das beinhaltet: ein Vakuumgehäuse (1), eine Arbeitsträgerelektrode (2), die in besagtem Vakuumgehäuse (1) angeordnet ist, eine Elektrode (7), die von besagter Arbeitsträgerelektrode (2) elektrisch isoliert ist, eine Abgasvorrichtung (11), eine Bearbeitungsgaszuführungsvorrichtung (3), eine Hochfrequenzleistungszuführungsvorrichtung (72) zur Zuführung einer amplitudenmodulierten Hochfrequenzleistung zur Elektrode (7), die von besagter Arbeitsträgerelektrode (2) elektrisch isoliert ist, einen Signalgenerator (73) zur Erzeugung der besagten amplitudenmodulierten Hochfrequenzleistung mittels Durchführung einer Amplitudenmodulation auf einer Grundhochfrequenzleistung, die eine vorfestgelegte Frequenz in einem Bereich von 10 MHz bis 200 MHz mit einer Modulationsfrequenz in einem Bereich von 1/1000 bis 1/10 der besagten vorfestgelegten Frequenz hat, eine Impulsspannungsaufbringungsvorrichtung (21, 22) zur Aufbringung einer positiven Impulsspannung auf besagte Arbeitsträgerelektrode (2), ein Steuergerät (CONT) zur Steuerung der besagten Hochfrequenzleistungszuführungsvorrichtung (72), um so eine impulsmodulierte Hochfrequenzleistung aufzubringen und um besagte Impulsspannungsaufbringungsvorrichtung (21, 22) zu steuern, um so mit der Aufbringung des

positiven Impulses zu einer Zeit zwischen einer Zwischenzeit innerhalb eines jeden Inbetriebszeitraums der besagten impulsmodulierten Hochfrequenzleistung, die von der besagten Hochfrequenzleistungs-Zuführungsvorrichtung (72) zugeführt wurde, und einer Zeit im nachfolgenden Außerbetriebszeitraum zu beginnen, und die die Aufbringung der besagten positiven Impulsspannung zu einer Zeit zwischen einer Außerbetriebszeit der besagten impulsmodulierten Hochfrequenzleistung, zugeführt von besagter Hochfrequenzleistungszuführungsvorrichtung (72), und einer Zwischenzeit im nachfolgenden Inbetriebszeitraum stoppt.

6. Die Arbeitsflächenbearbeitungsvorrichtung gemäß Anspruch 5, wobei besagte Impulsspannungsaufbringungsvorrichtung (21, 22) die positive Impulsspannung in einem Bereich von 50 V bis 300 kV aufbringt.
7. Die Arbeitsflächenbearbeitungsvorrichtung gemäß Anspruch 5 oder 6, wobei besagte Vorrichtung weiterhin eine Impulsspannungsaufbringungsvorrichtung (23, 23S) zur Aufbringung einer negativen Impulsspannung während eines Zeitraums beinhaltet, in dem der besagten Arbeitsträgerelektrode (2) die positive Impulsspannung nicht zugeführt wird.

Revendications

1. Procédé de traitement de surface d'une pièce, comprenant :

l'étape qui consiste à faire supporter la pièce (S) par une électrode porte-pièce (2) disposée dans un récipient sous vide (1) ;
 l'étape qui consiste à délivrer dans ledit récipient (1) un gaz de traitement correspondant au traitement prévu de la pièce (S) ;
 l'étape qui consiste à former un plasma (P) à partir dudit gaz par application dans un vide d'une énergie haute fréquence modulée en amplitude à une électrode (7) isolée électriquement vis-à-vis de ladite électrode porte-pièce (2), ladite énergie haute fréquence modulée en amplitude étant générée par l'exécution d'une modulation d'amplitude sur une énergie haute fréquence de base ayant une fréquence prédéterminée dans une plage de 10 MHz à 200 MHz à l'aide d'une fréquence de modulation dans une plage de 1/1000 à 1/10 de ladite fréquence prédéterminée ; et
 l'étape qui consiste à appliquer une tension d'impulsion positive à ladite électrode porte-pièce (2) pour exécuter le traitement sur la surface de ladite pièce (S) supportée par ladite

électrode porte-pièce (2), dans lequel ladite modulation d'amplitude est une modulation par impulsions, et le temps de chaque montée de ladite tension d'impulsion positive est déterminé entre un temps intermédiaire au cours de la période active de ladite énergie haute fréquence modulée par impulsions et un temps au cours de la période inactive suivante, tandis que le temps de chaque descente de la tension d'impulsion positive est déterminé entre un temps au cours de la période inactive de ladite énergie haute fréquence modulée par impulsions et un temps intermédiaire au cours de la période active suivante.

2. Procédé de traitement de surface d'une pièce, selon la revendication 1, dans lequel ladite tension d'impulsion positive se situe dans une plage de 50 V à 300 kV.

3. Procédé de traitement de surface d'une pièce, selon la revendication 1 ou 2, dans lequel une tension d'impulsion négative est appliquée à l'électrode porte-pièce (2) au cours de la période d'arrêt de l'application de ladite tension d'impulsion positive.

4. Procédé de traitement de surface d'une pièce, selon l'une quelconque des revendications 1 à 3, dans lequel ladite pièce (S) présente une partie de surface formée d'un matériau électriquement isolant ou porteuse d'un potentiel flottant.

5. Appareil de traitement de surface d'une pièce, comprenant :

un récipient sous vide (1) ;
 une électrode porte-pièce (2) disposée dans ledit récipient sous vide (1) ;
 une électrode (7) isolée électriquement de ladite électrode porte-pièce (2) ;
 un dispositif d'évacuation (11) ;
 un dispositif de fourniture de gaz de traitement (3) ;
 un dispositif de fourniture d'énergie haute fréquence (72) destiné à fournir une énergie haute fréquence modulée en amplitude à l'électrode (7) isolée électriquement de ladite électrode porte-pièce (2) ;
 un générateur de signal (73) destiné à générer ladite énergie haute fréquence modulée en amplitude en exécutant une modulation d'amplitude sur une énergie haute fréquence de base ayant une fréquence prédéterminée dans une plage de 10 MHz à 200 MHz à l'aide d'une fréquence de modulation dans une plage de 1/1000 à 1/10 de ladite fréquence prédéterminée ;

un dispositif d'application de tension d'impulsion (21, 22) destiné à appliquer une tension d'impulsion positive à ladite électrode porte-pièce (2) ;

une unité de commande (CONT) destinée à commander ledit dispositif de fourniture d'énergie haute fréquence (72) afin qu'il fournisse une énergie haute fréquence modulée par impulsions, et ledit dispositif d'application de tension d'impulsion (21, 22) afin qu'il commence à appliquer l'impulsion positive à un moment situé entre un temps intermédiaire au cours de chaque période active de ladite énergie haute fréquence modulée par impulsions fournie par ledit dispositif de fourniture d'énergie haute fréquence (72) et un moment au cours de la période inactive suivante, et qu'il arrête d'appliquer ladite tension d'impulsion positive à un moment situé entre un temps au cours de la période inactive de ladite énergie haute fréquence modulée par impulsions fournie par ledit dispositif de fourniture d'énergie haute fréquence (72) et un temps intermédiaire au cours de la période active suivante.

6. Appareil de traitement de surface d'une pièce, selon la revendication 5, dans lequel ledit dispositif d'application de tension d'impulsion (21, 22) applique la tension d'impulsion positive dans une plage de 50 V à 300 kV.

7. Appareil de traitement de surface d'une pièce, selon la revendication 5 ou 6, dans lequel ledit appareil comprend également un dispositif d'application de tension d'impulsion (23, 23S) destiné à appliquer une tension d'impulsion négative au cours d'une période pendant laquelle ladite électrode porte-pièce (2) n'est pas alimentée en tension d'impulsion positive.

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Fig.1

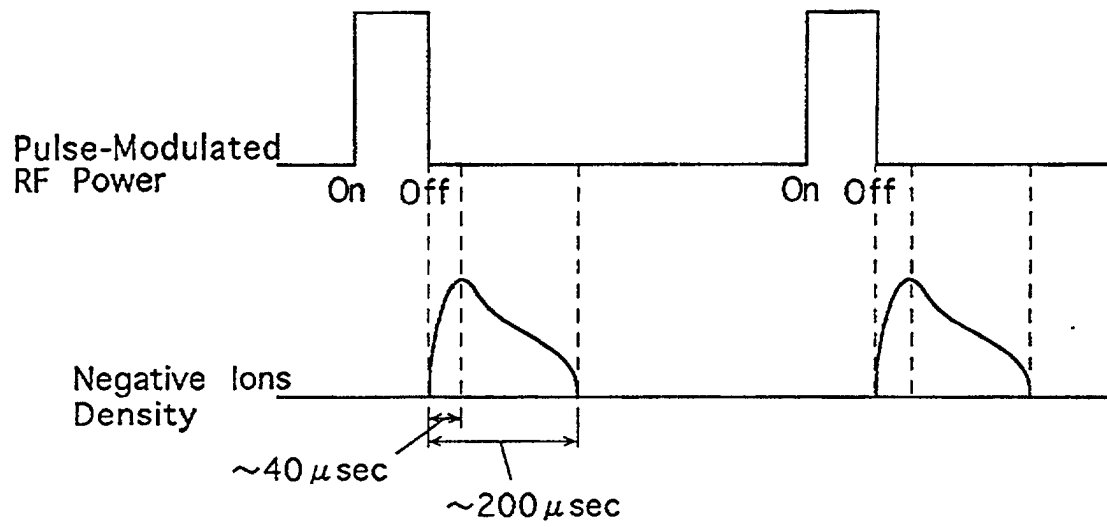


Fig. 2

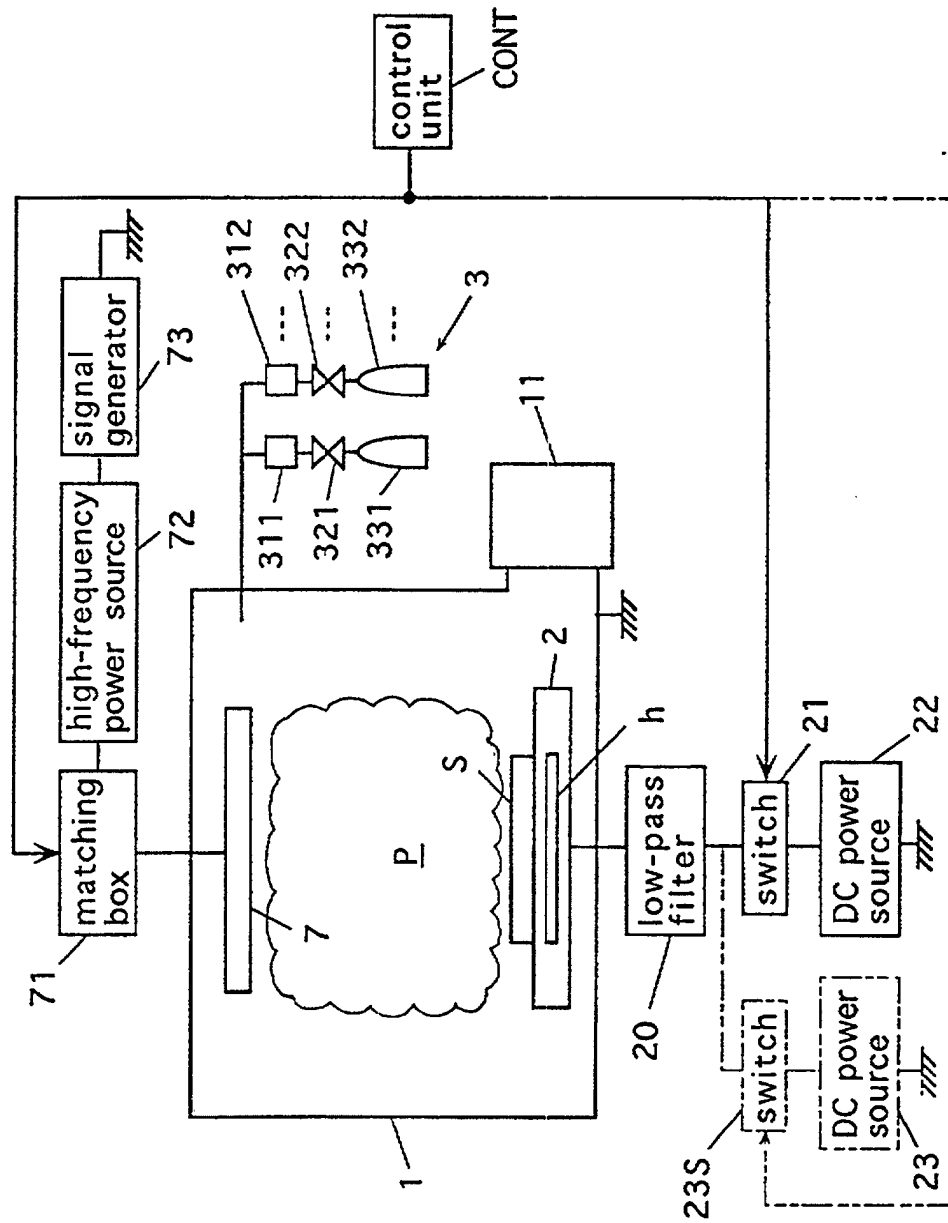


Fig.3

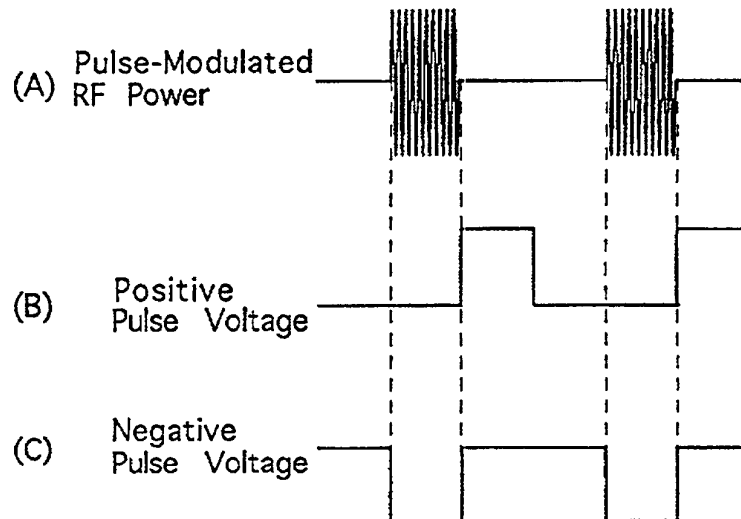


Fig.4

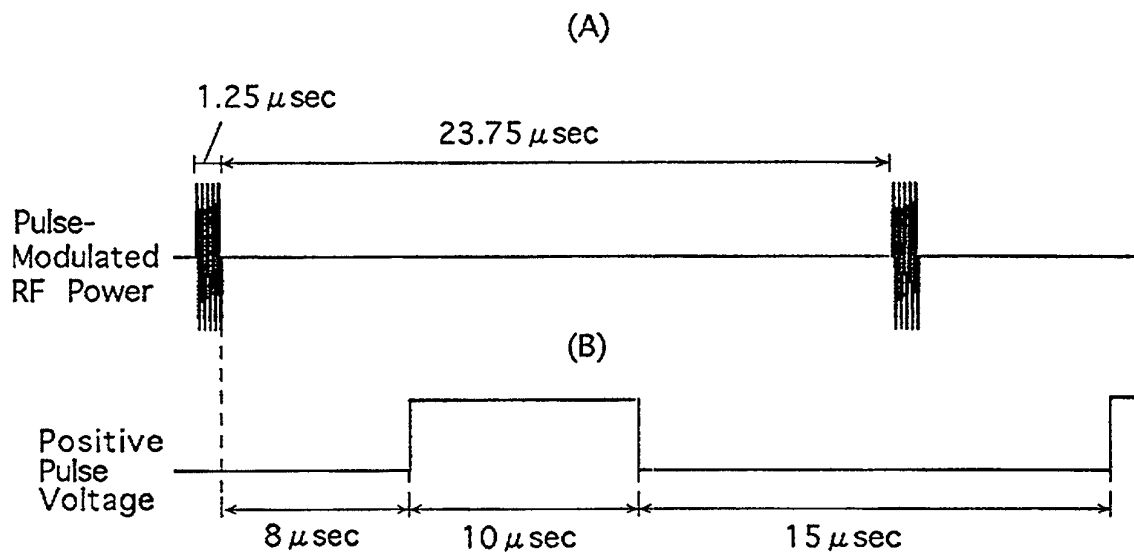


Fig.5

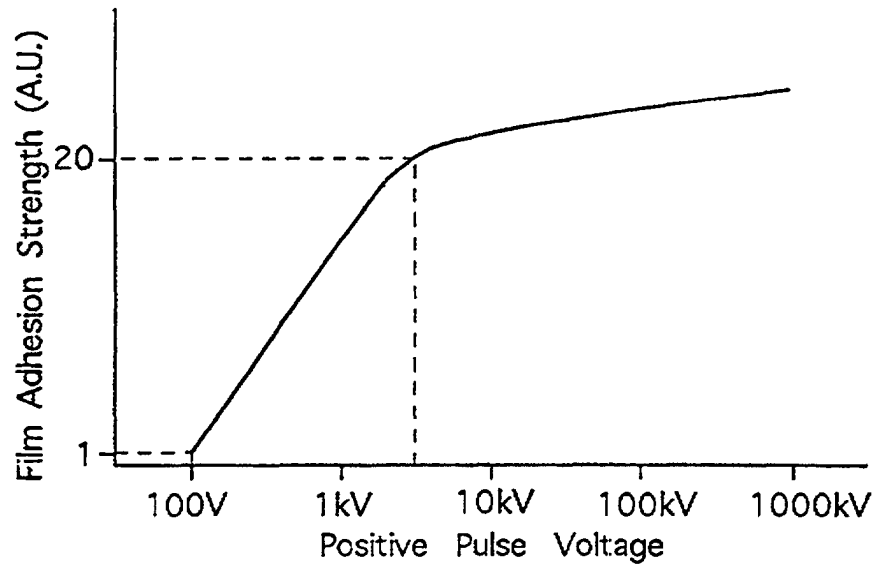


Fig.6(PRIORART)

