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APPARATUS FOR IMPLANTING AN ION ON A TARGET AND METHOD FOR THE SAME

BACKGROUND OF THE INVENTION

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FIELD OF THE INVENTION

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The invention relates to an apparatus and a method for implanting ions on a target, and more particularly relates to the apparatus and the method for preventing impurity ions, which are different from desired ions in at least one of mass number and energy, from being implanted on a target.

DESCRIPTION OF THE RELATED ART

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Fig. 2 shows an example of an ion implantation apparatus of the related art. The ion implantation apparatus includes an ion source 2 having a plasma production chamber 4 for electrostatically extracting ions 8 therefrom, a mass segregation magnet 10 for selectively deriving specific ions (which are specified by a mass number and valence) from the ions 8 extracted from the ion source 2, an acceleration pipe 12 for electrostatically accelerating the ions 8 derived from the mass segregation magnet 10, and a momentum segregation



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magnet 14 for selectively deriving the ions having a specific momentum (which is specified by a mass number and energy) from the ions 8 derived from the acceleration pipe 12. The ion implantation apparatus is constructed so that only the desired ions derived from the momentum segregation magnet 14 are implanted on a target (e.g. substrate such as a semiconductor wafer) 16.

The target 16 is held on a holder 18 at a ground potential. A scanner for scanning ions 8 and others not shown are usually provided between the momentum segregation magnet 14 and the target 16. A path of the ions 8 from the outlet of the ion source 2 to the holder 18 is included in a vacuum chamber. The vacuum chamber is not shown.

The ion source 2 includes the plasma production chamber 4 for generating plasma and an extraction electrode 6 for extracting the ions 8. The plasma production chamber has a positive potential, and then an extraction voltage V_E applied therebetween from a DC extraction electrode 20. The ions 8 are electrostatically generated from the plasma production chamber 4 by the extraction voltage.

The acceleration pipe 12 has a plurality of electrodes 13. The acceleration pipe 12 has a positive potential, and then a voltage V_A is applied between an

inlet and outlet electrode 13 from a DC accelerating power source 22. The ions 8 are electrostatically accelerated by the accelerating voltage V_A so that the ions 8 has target energy.

5 Assuming that the valence of the desired ions is Z_1 , the total energy E_T of the desired ions incident on the target 16 is expressed by the following equation.

[Equation 1]

$$E_T = (V_E + V_A) \times Z_1 \quad [\text{eV}]$$

10 Since the following phenomenon occurs between the outlet of the mass segregation magnet 10 and the inlet of the acceleration pipe 12, impurity ions which are different from the desired ions may be mixed into the desired ions in the ion implantation apparatus.

15 (1) The energy accelerated by the acceleration pipe 12 is changed by charging conversion in which the desired ions collide with a residual gas. For example, when doubly charged ions are converted into singly charged ions by the charging conversion, the energy accelerated by the
20 acceleration pipe 12 becomes half of that in the case of the doubly charged ions, if the Voltage V_A is constant.

25 (2) Where the desired ions are molecular ions, by molecular dissociation, the desired ions change into different ions. For example, when BF_2 ions dissociate into BF ions and F ions, or B ions and F ions, the BF_2

ions no longer are the desired ions.

(3) A part of the ions 8 collides with the member which constitutes an apparatus such as the vacuum chamber so that atoms or molecules of the member are out of the surface of the member by a sputtering to become impurity ions.

(4) A part of the ions 8 collides with the member which constitutes an apparatus such as the vacuum chamber so that atoms or molecules deposited on or implanted in the member during previous operation of the ion implantation apparatus are out of the member surface by sputtering to become impurity ions.

(5) The gas or vapor used to generating plasma in the plasma production chamber 4 of the ion source 2 flows out from the plasma production chamber 4 into a passage of the ions 8, and then the flown gas or vapor is ionized on the passage to the inlet of the acceleration pipe 12, or otherwise the flown gas or vapor reacts with the atoms or molecules generated owing to the phenomena of the above items (3) and (4) thereby to become impurity ions.

In the ion implantation apparatus, it is not preferred that the impurity ions which are different from the desired ions in at least one of mass number and energy are implanted into the target 12 together with the desired ions. Accordingly, a desired implantation characteristic

of the target cannot be obtained.

Therefore, when ion implantation with high purity is required as in the example shown in Fig. 2, the momentum segregation magnet 14 as described above as well as the mass number segregation magnet 10 is provided behind the acceleration pipe 12 in order to derive only the ions having a specific momentum selectively.

The momentum segregation magnet 14 permits the impurity ions generated owing to the phenomena of the above items (1) and (2) to be removed. The impurity ions having a different momentum from that of the desired ions are generated in the phenomena of (1) and (2).

However, in the impurity ions generated by the phenomena of the above items (3) to (5), the impurity ions which satisfy the following Equation 2 cannot be separated and removed from the desired ions by means of the momentum segregation magnet 14. This applies to the case where the left side $\approx$ the right side in Equation 2 (that means, the left side of the Equation 2 is equal or about equal to the right side thereof). Now it is assumed that M_T denotes the mass number of the desired ions, Z_T denotes the valence thereof, M_C denotes the mass number of the impurity ions at issue, and Z_C denotes the valence thereof. V_E and V_A have been already defined.

[Equation 2]

$$M_i \cdot (V_E + V_A) / Z_i = M_c \cdot V_A / Z_c$$

Assuming that B is a magnetic flux density, V_T is an entire acceleration voltage, m is a mass, and q is a charge, the circling radius R of the ions in the momentum segregation magnet 14 is expressed by a following Equation 3. Now, assuming that M is the mass number of the ions and m_p is the mass of a proton, $m = M \cdot m_p$. Further, Z is the valence of the ions and e is an electron weight, $q = Z \cdot e$. In short, Equation 3 implies that the ions with the same $M \cdot V_T / Z$ provides the same circling radius R .

[Equation 3]

$$R = B^{-1} \sqrt{(2mV_T/q)}$$

Therefore, if the above Equation 2 is satisfied, in the momentum segregation magnet 14, the circling radii of the desired ions and impurity ions are equal to each other, both cannot be separated from each other. As a result, even with the momentum segregation magnet 14, the impurity ions as well as the desired ions are implanted into the target 16. This applies to the case where the left side $\cong$ the right side of the Equation 2 (that means, the left side of the Equation 2 is equal or about equal to the right side thereof).

A case where the valence Z_i of the desired ions and the valence Z_c of the impurity ions at issue are equal to each other (i.e. where $Z_i = Z_c$) is typical. For example,

both are singly charged ions. In this case, the above Equation 2 can be represented by the following equation.

[Equation 4]

$$M_I \cdot (V_E + V_A) = M_C \cdot V_A$$

5 If the ion implantation is carried out for the target 16 on the condition of the Equation 4, the desired ions as well as the impurity ions will be implanted into the target 16. This applies to the case where the left side $\cong$ the right side (that means, the left side of the Equation 2 is equal or about equal to the right side thereof).
10 Such implantation is not preferable.

 It can be supposed that the momentum segregation magnet 14 is served as the mass segregation magnet without providing the mass segregation magnet 10. However, in
15 such a case, the above problem becomes more serious. In case the mass segregation magnet 10 is not present, the impurity ions are generated between the outlet (more particularly, outlet of the extraction electrode 6) and the inlet of the acceleration pipe 12 in this wider range
20 than the above range.

SUMMARY OF THE INVENTION

 It is an object of the invention to prevent impurity
25 ions, which are different from desired ions in at least

one of mass number and energy from being implanted into a target together with the desired ions.

The method for implanting the desired ion on the target according to this invention is characterized in that if the relationship of Equation 2 is satisfied or in Equation 2, the left side $\cong$ right side, one of the extraction voltage V_E and the acceleration voltage V_A is increased and the other thereof is decreased while the value of $(V_E + V_A)$ is substantially constant.

The apparatus for implanting the ion on the target according to the invention is characterized in that it includes a control device for increasing one of the extraction voltage V_E and the acceleration voltage V_A and decreasing the other thereof while maintaining the value of $(V_E + V_A)$ substantially constant and satisfying the Equation 2.

When a voltage to be increased or decreased is represented by ΔV , the above Equation 2 after voltage adjustment is converted into the following Equation 5 or Equation 6. Either method of Equation 5 and Equation 6 may be adopted.

[Equation 5]

$$M_I \cdot \{(V_E - \Delta V) + (V_A + \Delta V)\} / Z_I \neq M_C \cdot (V_A + \Delta V) / Z_C$$

[Equation 6]

$$M_I \cdot \{(V_E + \Delta V) + (V_A - \Delta V)\} / Z_I \neq M_C \cdot (V_A - \Delta V) / Z_C$$

In both cases of Equation 5 and Equation 6, the value of the left side and that of the right side are not equal to each other. In this way, as understood from the explanation of the above Equation 3, in the momentum segregation magnet, since the circling radius of the desired ions and that of the noted impurity ions are made different from each other, the impurity ions can be removed by the momentum segregation magnet to derive selectively only the desired ions which are implanted into the target. Namely, it is possible to prevent impurity ions which are different from the desired ions in at least one of their mass number and energy from being implanted into the target together with the desired ions.

Further, when the above voltage is adjusted, since the value of $(V_E + V_A)$ which is a sum of the extraction voltage V_E and the acceleration voltage V_A is kept substantially constant, it is not necessary to vary the total energy of the desired ions on the target. For this reason, the initial ion implanting condition of the desired ions can be maintained.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing an exemplary ion implantation apparatus for implementing the running

method according to this invention; and

Fig. 2 is a schematic view of an exemplary conventional ion implantation apparatus.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a schematic view showing an exemplary ion implantation apparatus for implementing a running method according to this invention. Referring to Fig. 1, with
10 like reference numerals referring to like parts in Fig. 2 showing a prior art, different points of this invention from the prior art will be mainly explained below.

In the ion implantation apparatus, a magnitude of the output voltage produced from each of an extraction
15 power source 20 and an acceleration power source 22 is variable. In the ion implantation, a control device 24 controls the extraction power source 20 and the acceleration power source 22 to increase or decrease the extraction voltage V_e outputted from the extraction power
20 source 20 and the acceleration voltage V_a outputted from the acceleration power source 22.

In this ion implantation apparatus, an explanation will be given of a case where after As ions have been implanted into a target 16 for a long time, desired BF₃
25 ions in place of the As ions are implanted.

Since As ions has been implanted into the target
16 for a long time, a large amount of As atoms or As molecules
has been deposited on or implanted in the member such
as a vacuum chamber which constitutes the ion implantation
5 apparatus.

In case where desired BF_2 ions (mass number of 49)
with total energy of 115 keV are implanted on the
above-condition. The extraction voltage V_E is 40 kV. The
acceleration voltage V_A is 75 kV. As the impurity ions,
10 the As ions (mass number of 75) sputtered owing to the
 BF_2 ions are noted. It is assumed that the valence of
 BF_2 ions and As ions is 1.

In this case, the left side and right side of above
Equation 2 (or Equation 4) are represented by the following
15 Equation 7 and Equation 8.

[Equation 7]

$$\text{The left side} = M_i \cdot (V_E + V_A) = 49 \times (40 + 75) = 5635$$

[Equation 8]

$$\text{The right side} = M_c \cdot V_A = 75 \times 75 = 5625$$

20 Therefore, if any means is not taken, in Equation
2 (or Equation 4), the left side $\approx$ the right side. The
difference between both sides is as very small as about
0.2 %. Owing to this, the momentum segregation magnet
14 cannot separate the As ions with 75 keV from the BF_2
25 ions with 115 keV so that the As ions will be implanted

into the target 16 together with the desired BF_2 ions with 115 keV.

In order to avoid the above situation, the above voltage adjustment will be implemented. For example, the voltage ΔV is set for 10 kV, and the extraction voltage V_E is decreased by 10 kV to be set for 30 kV. The acceleration voltage V_A is increased by 10 kV to be set for 85 kV. This increasing or decreasing method corresponds to the example of Equation 5 described above. Thus, the left side and right side of the above Equation 2 (or Equation 4) can be represented as the following Equation 9 and Equation 10, respectively.

[Equation 9]

$$\text{The left side} = M_I \cdot (V_E + V_A) = 49 \times (30 + 85) = 5635$$

[Equation 10]

$$\text{The right side} = M_C \cdot V_A = 75 \times 85 = 6375$$

As a result, in Equation 2 (or Equation 4), the left side $\approx$ the right side. The difference in the value between both sides is about 12 %. Therefore, the momentum segregation magnet 14 can sufficiently separate the As ions with 85 keV from the desired BF_2 ions with 115 keV. Thus, only the desired BF_2 ions can be selectively implanted into the target 16. Additionally, the total energy of the desired BF_2 ions remains 115 ekeV.

The lower limit of the difference to be given between

the left side value and the right side value in Equation 2 (or Equation 4) depends on a resolution of the momentum segregation magnet 14. Therefore, the limit of the difference may be larger than the resolution of the momentum segregation magnet 14. For example, the lower limit is preferably 5 % or so. The upper limit is not particularly given. As the difference increases, the separation by the momentum segregation can be easily implemented more easily. However, since the difference is not required to be excessively, actually, for example, the upper limit may be 50 %.

In contrast to the above case, as mentioned above, the extraction electrode V_E may be increased by ΔV and the acceleration voltage V_A may be decreased by ΔV . This increasing or decreasing method corresponds to the example of the above Equation 6.

In this embodiment, the voltage adjustment of increasing or decreasing the extraction voltage V_E and the acceleration voltage V_A as described above can be carried out through the control by the control device 24. However, the voltage adjustment may be carried out by the other means such as manual setting without using the control device 24.

Further, also in the case where the mass segregation magnet 10 is not provided and the momentum segregation

magnet 14 is served as the mass segregation magnet, as described above, the method according this invention can be applied to the case. In this case, the impurity ions generated between the outlet of the ion source 2 and the inlet of the acceleration pipe 12 are noted.

As described hitherto, in accordance with this invention, in the momentum segregation magnet, since the circling radius of the desired ions and that of the noted impurity ions are made different from each other, the impurity ions can be removed by the momentum segregation magnet to derive selectively only the desired ions which are implanted into the target. Namely, it is possible to prevent impurity ions which are different from the desired ions in at least one of their mass number and energy from being implanted into the target as well as the desired ions. Further, even when the above voltage adjustment is implemented, since the value of $(V_E + V_A)$ which is a sum of the extraction voltage V_E and the acceleration voltage V_A is kept substantially constant, it is not necessary to vary the total energy of the desired ions incident on the target. For this reason, the initial ion implanting condition by the desired ions can be maintained.

WHAT IS CLAIMED IS:

1. An apparatus for implanting an ion on a target, the apparatus comprising:

5 an ion source for electrostatically extracting ions from the ion source at an extraction voltage of V_E ;

an acceleration device for electrostatically extracting the extracted ion at an acceleration voltage of V_A ;

10 a momentum segregation magnet for selectively deriving desired ions having a specific momentum from the extracted ions so that the desired ions derived from the momentum segregation magnet are implanted on the target; and

15 a control device increasing one of the extraction voltage V_E and the acceleration voltage V_A and decreasing the other of the extraction voltage V_E and the acceleration voltage V_A while keeping the value of $(V_E + V_A)$ substantially constant and satisfying a following equation A as follows:

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$$M_I \cdot (V_E + V_A) / Z_I = M_C \cdot V_A / Z_C$$

2. The ion implantation apparatus according to claim 1, wherein the control device increases one of the extraction voltage V_E and the acceleration voltage V_A by ΔV and decreases the other of the extraction voltage V_E

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and the acceleration voltage V_A by ΔV while satisfying a following equation B as follows:

$$M_I \cdot \{(V_E - \Delta V) + (V_A + \Delta V)\} / Z_I \neq M_C \cdot (V_A + \Delta V) / Z_C$$

5 3. The ion implantation apparatus according to claim 1, wherein the control device increases one of the extraction voltage V_E and the acceleration voltage V_A by ΔV and decreases the other of the extraction voltage V_E and the acceleration voltage V_A by ΔV while satisfying
10 a following equation C as follows:

$$M_I \cdot \{(V_E + \Delta V) + (V_A - \Delta V)\} / Z_I \neq M_C \cdot (V_A - \Delta V) / Z_C$$

4. A method for implanting an ion on a target, comprising the steps of;

15 a) extracting ions electrostatically at an extraction voltage of V_E ;

 b) extracting the extracted ion electrostatically at an acceleration voltage of V_A ;

 c) deriving desired ions having a specific
20 momentum from the extracted ions so that the desired ions are implanted on the target;

 d) increasing one of the extraction voltage V_E and the acceleration voltage V_A and decreasing the other of the extraction voltage V_E and the acceleration voltage
25 V_A while keeping the value of $(V_E + V_A)$ substantially

constant and satisfying a following equation A as follows:

$$M_I \cdot (V_E + V_A) / Z_I = M_C \cdot V_A / Z_C$$

5 5. The method according to claim 4, wherein the
control device increases one of the extraction voltage
 V_E and the acceleration voltage V_A by ΔV and decreases
the other of the extraction voltage V_E and the acceleration
voltage V_A by ΔV while satisfying a following equation
B as follows:

10 $M_I \cdot \{(V_E - \Delta V) + (V_A + \Delta V)\} / Z_I \neq M_C \cdot (V_A + \Delta V) / Z_C$

6. The method according to claim 4, wherein the
control device increases one of the extraction voltage
 V_E and the acceleration voltage V_A by ΔV and decreases
15 the other of the extraction voltage V_E and the acceleration
voltage V_A by ΔV while satisfying a following equation
C as follows:

$$M_I \cdot \{(V_E + \Delta V) + (V_A - \Delta V)\} / Z_I \neq M_C \cdot (V_A - \Delta V) / Z_C$$

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