

FARADAY DEVICE

Background of the Invention

Field of the Invention

5 The present invention relates to a Faraday device which is used for measuring a beam current of an ion beam in an ion injector, ion doping apparatus (non-mass separation type ion injector), ion beam irradiation apparatus and the like. More specifically, the present invention relates to a Faraday device
10 for reducing the occurrence of an error in the beam current measurement as the result of entering of ion contained in a plasma, e.g., beam plasma into a Faraday cup. In the present specification, the term "ion" means "positive ion".

15 Description of the Related Art

 A related-art Faraday device is illustrated in Fig. 5. The Faraday device comprises a mask 4, a Faraday cup 12, a suppressor electrode 10, and a positive bias electrode 8. The mask 4 has an aperture 6 for defining an area (configuration)
20 of an ion beam 2 passing through the aperture 6. The Faraday cup 12 receives the ion beam 2 having passed through the aperture 6 and measures the beam current of the ion beam. The suppressor electrode 10 is provided between the Faraday cup 12 and the mask 4 and in the vicinity of the Faraday cup 12. The positive
25 bias electrode 8 is provided between the suppressor electrode

10 and the mask 4.

The mask 4 is usually connected to ground (ground potential part). Positive voltage (with respect to ground) is applied from a positive bias power source 16 to the positive bias electrode 8. Negative voltage (with respect to ground) is applied from a suppressor power source 18 to the suppressor electrode 10. Beam current flowing to the Faraday cup 12 is measured by, for example, a current measuring instrument 14 connected to the Faraday cup 12.

10 The suppressor electrode 10 applied with the negative voltage prevents electrons derived from an upstream part, i.e., the beam line of the ion beam 2, from entering the Faraday cup 12. The suppressor electrode 10 also moves back to the Faraday cup 12 the secondary electrons which are emitted from the Faraday cup 12 when the ion beam 2 is incident on the Faraday cup 12. Such the function prevents such secondary ions from causing an error in the original beam current measurement.

20 The positive bias electrode 8 applied with the positive voltage is provided when an amount of low energy ion, which is not negligible, is contained in the beam line of the ion beam 2. The positive voltage at the positive bias electrode functions to move back the low energy ion upstream. Such the function prevents such low energy ions from causing an error in the original beam current measurement.

25 Around the ion beam 2, due to a collision of the ion beam

2 and a residual gas, electrons and ions are generated to produce a plasma 20a. This plasma is called a beam plasma.

The beam plasma 20a becomes higher in concentration, as a degree of vacuum of the beam line of the ion beam 2 becomes lower (i.e., the gas pressure becomes higher). The degree of vacuum of the ion beam is about 10^{-4} Pa in the normal ion injector. In the ion doping apparatus for directly irradiating the ion beam led out from an ion source on a substrate (i.e., without the mass separator), the degree of vacuum is about 10^{-2} Pa since it is apt to be influenced by the gas flowing out of the ion source. The latter apparatus has a higher concentration of the beam plasma 20a.

In the vicinity of the aperture 6 of the surface of the mask 4, the ion beam 2 collides with the mask 4 to generate secondary electrons, ions and the like, so that a plasma 20b is produced. This plasma 20b is also considerably high in concentration.

Accordingly, even if the positive bias electrode 8 is provided, if the plasma 20 containing the beam plasma 20a and the plasma 20b becomes higher in concentration, it reaches the positive bias electrode 8 as shown in Fig. 5. If the plasma 20 reaches the positive bias electrode 8, the plasma 20 is influenced by the negative voltage of the suppressor electrode 10. An ion 22 of the plasma 20 (one of a great number of ions 22 is typically illustrated in Fig. 5) is drawn out of the plasma

20 toward the Faraday cup 12 by the negative voltage of the suppressor electrode 10, and is incident on the Faraday cup 12.

As a result, a part of the ion 22 of the plasma 20 is
5 measured by the Faraday cup 12, in addition of the beam current of the ion beam 2 to originally be measured, and an error is caused in the beam current measurement.

Summary of the Invention

10 An object of the present invention is to prevent the ions, which are contained in the beam plasma and the plasma generated in the vicinity of the surface of the mask, from entering the Faraday cup, and thereby to reduce an error in the beam current measurement.

15 A Faraday device of the present invention comprises magnets for developing a magnetic field having a direction crossing an aperture of the mask in the vicinity of the aperture.

A beam plasma and a plasma generated in the vicinity of the mask surface as the result of ion beam collision is trapped
20 by the magnetic field, which developed in the vicinity of the aperture of the plasma, and hence does not reach the positive bias electrode. As a result, a chance is reduced that the ions contained in the plasma are drawn out by the negative voltage of the suppressor electrode and are incident on the Faraday
25 cup. Therefore, an error in the beam current measurement is

minimized.

Brief Description of the Drawings

Fig. 1 is a cross sectional view showing a Faraday device
5 according to the present invention;

Fig. 2 is a plan view showing the Faraday device;

Fig. 3 is a cross sectional view showing another
arrangement of magnets used in the Faraday device;

Fig. 4 is an enlarged sectional view showing a structure
10 containing the magnets in the Faraday device of Fig. 1; and

Fig. 5 is a cross sectional view showing a related-art
Faraday device.

Detailed Description of the Invention

15 Fig. 1 is a cross sectional view showing a Faraday device
according to the present invention. Fig. 2 is a plan view
of the Faraday device. Same portions will be designated by
same reference numerals in the related art illustrated in Fig.
5. Description will be given placing emphasis on different
20 portions.

In the Faraday device, a pair of magnets 30, polarities
of which are opposite to each other, are buried in the mask
4. The magnets 30 are disposed across the aperture 6 of the
mask 4. The magnets 30 develop a magnetic field which is
25 distributed across the aperture 6 in the vicinity of the aperture

6 of the mask 4. Lines of magnetic force of the magnetic field are designated by reference numeral 32.

Although it is not always necessary to bury the magnets 30 in the mask 4 as in this embodiment, the buried magnets 30
5 are preferable since there is no chance that the ion beam 2 and the plasma 20 hit the magnets 30 thereby sputtering the magnets 30.

The magnets 30 may be electromagnets. Preferably, the magnets 30 are permanent magnets, which are easy to handle.
10 In this embodiment, those are permanent magnets.

As shown in Fig. 4, each of the magnets 30 is placed such that two magnetic poles (N, S) are vertically arranged (i.e., arranged along a direction in which the ion beam 2 passes through). The reason for this will be described later. The
15 direction of magnetic field lines 32 in this example is opposite to that of the magnetic field lines as shown in Fig. 1.

To avoid the disturbance of the magnetic field developed by the magnets 30, parts and members located near the magnets 30 are preferably made of non-magnetic material. In this
20 embodiment, the mask 4, positive bias electrode 8, suppressor electrode 10 and the Faraday cup 12 are made of non-magnetic materials. In a case where the suppressor electrode 10, the Faraday cup 12 and the like are located far from the mask 4, those may be made of other materials than the non-magnetic
25 material. The non-magnetic materials are, for example,

aluminum, non-magnetic stainless steel, and molybdenum.

In the Faraday device, the beam plasma 20a and the plasma 20b generated in the vicinity of the surface of the mask 4 as the result of ion beam collision, viz., the plasma 20 consisting
5 of those plasmas, is trapped by the magnetic field generated in the vicinity of the aperture 6 of the mask 4. More specifically, the electrons and ions of the plasma 20 make the Larmormotionwhilespirallyrevolvingaroundthemagneticfield
lines 32. In particular, the electrons revolve around them
10 with the small spiral radius. Therefore, the electrons are hard to move across the magnetic field lines 32. When the electrons are trapped, the ions are also electrically attracted by the trapped electrons, so that the ions are hard to move across the magnetic field lines 32. With this mechanism, the
15 plasma 20 is trapped by the magnetic field, and fails to reach the positive bias electrode 8. When the plasma 20 is high in the concentration, an intensity of the magnetic field is increased correspondingly.

More exactly, under the positive voltage of the positive
20 bias electrode 8, a force acts on the electrons of the plasma 20 in the vicinity of the aperture 6 to move the electrons in the plasma 20 to the positive bias electrode 8. In this case, the electron spiral radius is small and its force of revolving around the magnetic field lines 32 is strong. Therefore, if
25 an intensity of the magnetic field is increased to some extent,

the attraction of the electrons to the positive bias electrode 8 is reduced, which is negligible.

Where the plasma 20 is prevented from going to the positive bias electrode 8 by the magnetic force, the positive voltage of the positive bias electrode 8 acts on the plasma 20 to move back the ions in the plasma 20 to a position upstream of the positive bias electrode 8. Accordingly, a chance is reduced that the ions of the plasma 20 are drawn out by the negative voltage of the suppressor electrode 10 and incident on the Faraday cup 12. As a result, an error in the beam current measurement of measuring the ion beam 2 is reduced. Thus, the positive bias electrode 8 functions to reduce the error in the beam current measurement of measuring the ion beam 2 as well as the magnetic field.

Such an effect is more remarkable when the Faraday device is used in a situation where a degree of vacuum of the beam line of the ion beam 2 is low, and the beam plasma 20a, which is high in the concentration, is easy to occur, as in the case of the ion doping apparatus.

While one Faraday device is used in the embodiment mentioned above, a plurality of Faraday devices may be used as shown in Fig. 2 (in this case, the Faraday devices are arranged side by side). In the Fig. 2 case, a plurality of slit-shaped apertures 6 are arranged side by side for one mask 4. The magnets 30 are disposed (buried) in a state that each slit is located

between the two adjacent magnets 30. Reference numeral 32 is magnetic field lines. The Faraday cups 12 are disposed on a position downstream of the array of the apertures 6 (in Fig. 2, only one Faraday cup 12 is typically illustrated). The positive bias electrode 8 and the suppressor electrode 10, in this embodiment, are shaped like plates and used commonly for those Faraday cups 12.

The magnets 30 may be placed as shown in Fig. 3. In Fig. 3, the two magnetic poles (N, S) of each magnet are horizontally arranged (i.e., arranged along a direction perpendicular to the direction in which the ion beam 2 passes through). The arrangement of the magnets in Fig. 1 is more preferable than the arrangement in Fig. 3. The reason for this follows. In the Fig. 1 arrangement of the magnets, the magnetic field lines 32 expand to a position upstream of the mask 4. Accordingly, the plasma 20 is trapped at a position located more apart from the mask 4 in the upstream direction. Therefore, the arrangement of the magnets makes it more difficult for the plasma 20 to move to the positive bias electrode 8.

As seen from the foregoing description, a beam plasma and a plasma generated in the vicinity of the mask surface as the result of ion beam collision is trapped by the magnetic field, which developed in the vicinity of the aperture of the plasma. Hence, the beam plasma and the plasma generated in the vicinity of the mask surface do not reach the positive bias

electrode. Therefore, a chance is reduced that the ions contained in the plasma are drawn out by the negative voltage of the suppressor electrode and are incident on the Faraday cup. Thus, an error in the beam current measurement is
5 minimized.

What is claimed is:

1. A Faraday device comprising:

a mask having an aperture for determining an area of an ion beam passing through said aperture;

5 a Faraday cup for receiving the ion beam passing through said mask;

a suppressor electrode disposed between said Faraday cup and said mask, said suppressor electrode being applied with a negative voltage;

10 a positive bias electrode disposed between said suppressor electrode and said mask, said positive bias electrode being applied with a positive voltage; and

a pair of magnets for developing a magnetic field having a direction crossing said aperture of said mask in the vicinity
15 of said aperture.

2. The Faraday device according to claim 1, wherein said magnets are buried in said mask while said magnets are disposed across the aperture.

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3. The Faraday device according to claim 1, wherein said magnets are electromagnets.

4. The Faraday device according to claim 1, wherein
25 said magnets are permanent magnets.

5. The Faraday device according to claim 1, wherein each of the magnets is arranged such that two magnetic poles are arranged along a direction in which the ion beam passes
5 through.

6. The Faraday device according to claim 1, wherein each of the magnets is arranged such that two magnetic poles are arranged along a direction perpendicular to a direction
10 in which the ion beam passes through.

7. The Faraday device according to claim 1, wherein the aperture has a slit shape.