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PARK et al.

(54) **ION SOURCE, AND MASS ANALYSIS APPARATUS INCLUDING SAME**

(71) Applicant: **KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE**, Daejeon (KR)

(72) Inventors: **Chang Joon PARK**, Daejeon (KR); **Jong Rok AHN**, Daejeon (KR); **Cheolsu HAN**, Suwon-si (KR); **Sang Jung AHN**, Daejeon (KR)

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CPC *H01J 49/147* (2013.01); *H01J 49/067* (2013.01); *H01J 49/16* (2013.01)

(57) **ABSTRACT**

According to one embodiment of the present invention, an ion source includes: an anode tube in which gas flowing in through one side is ionized and discharged to the other side and in which a slit is formed on the outer circumference thereof; a filament which emits thermal electrons toward the slit so as to ionize the gas; and a diffusion-preventing body arranged between the filament and the slit and having at least one hole through which the thermal electrons can pass so as to reduce the diffusion of the thermal electrons flowing into the anode tube.

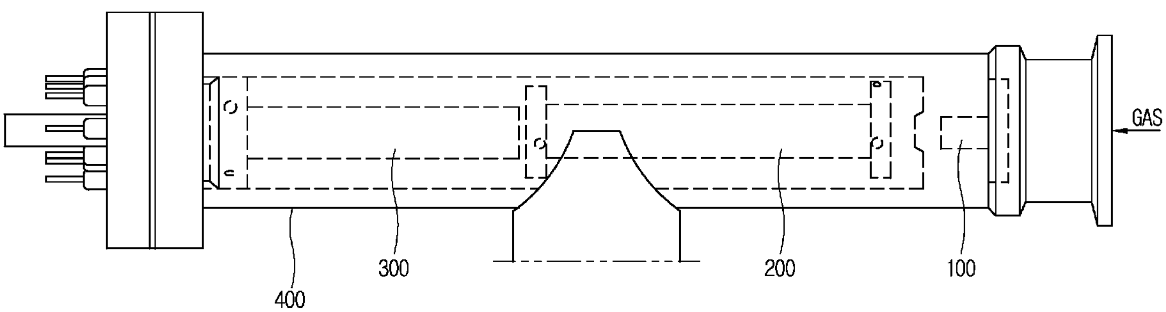


FIG. 1

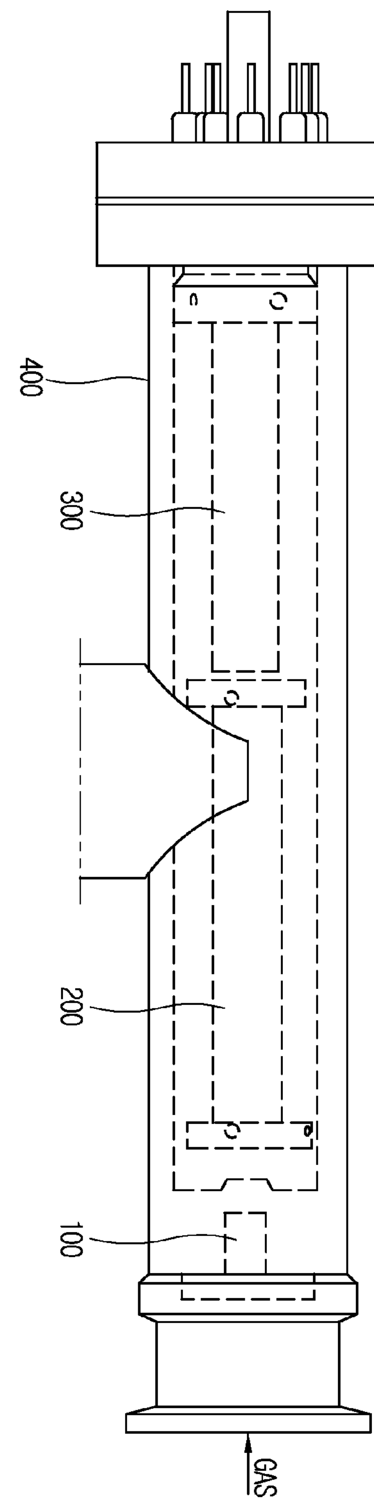


FIG. 2

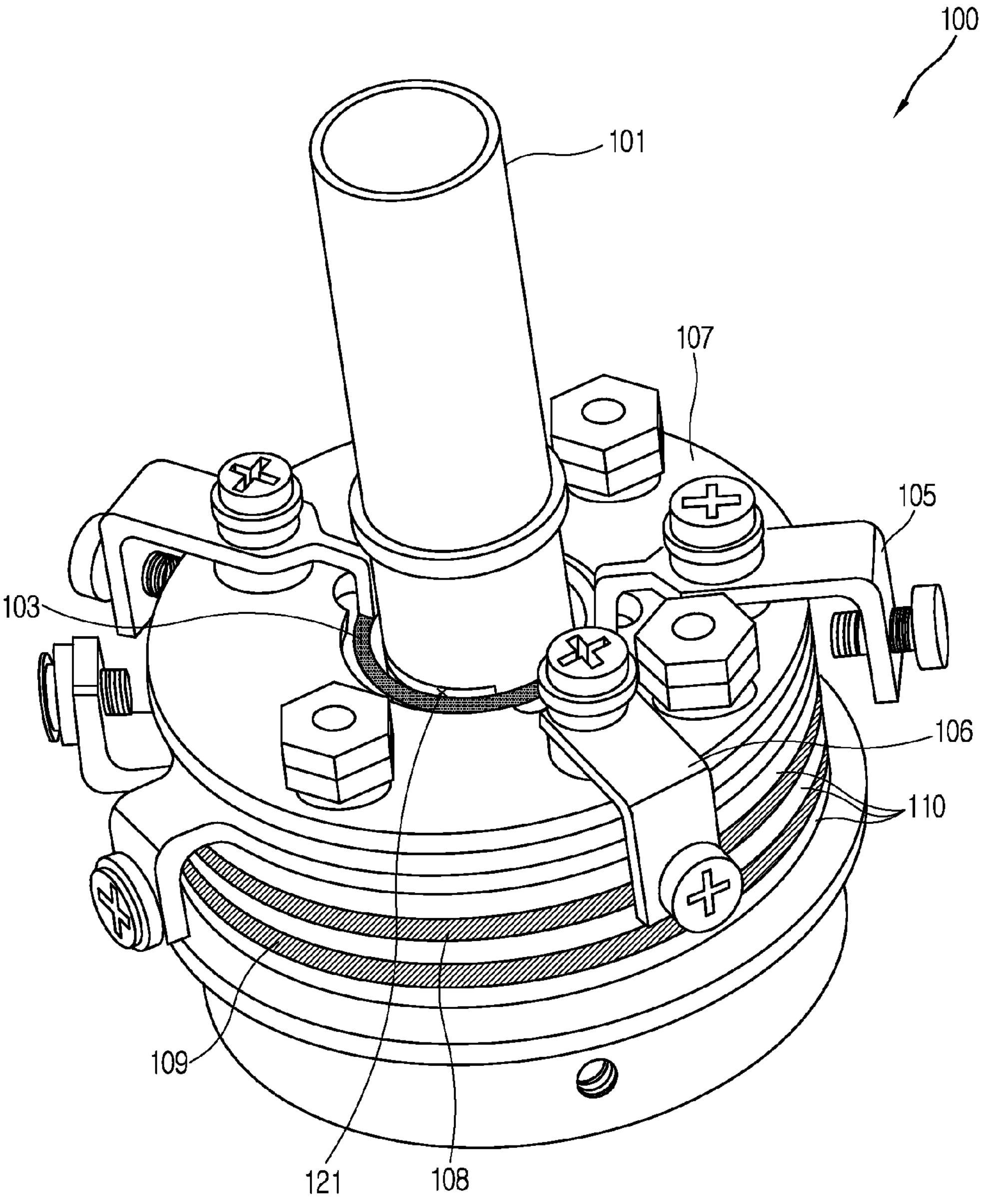


FIG. 3

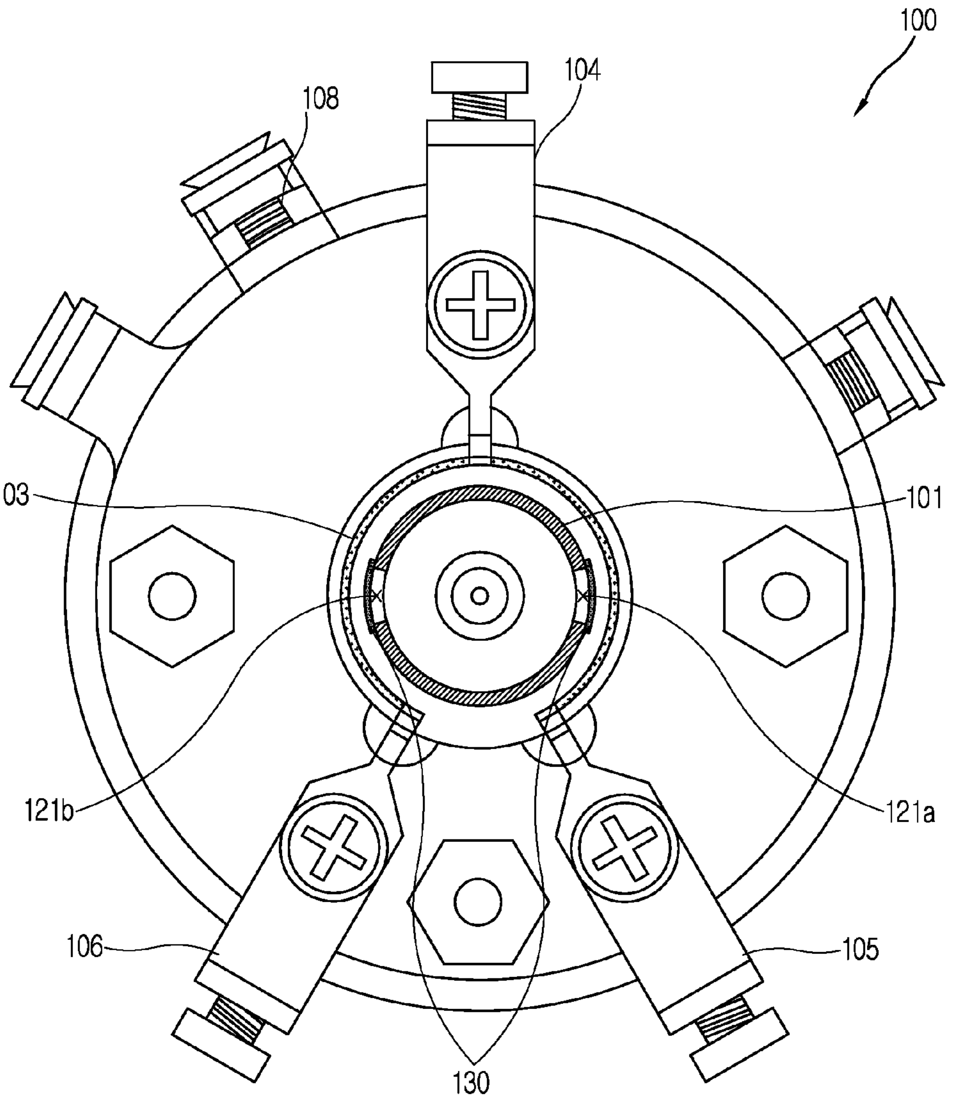


FIG. 4

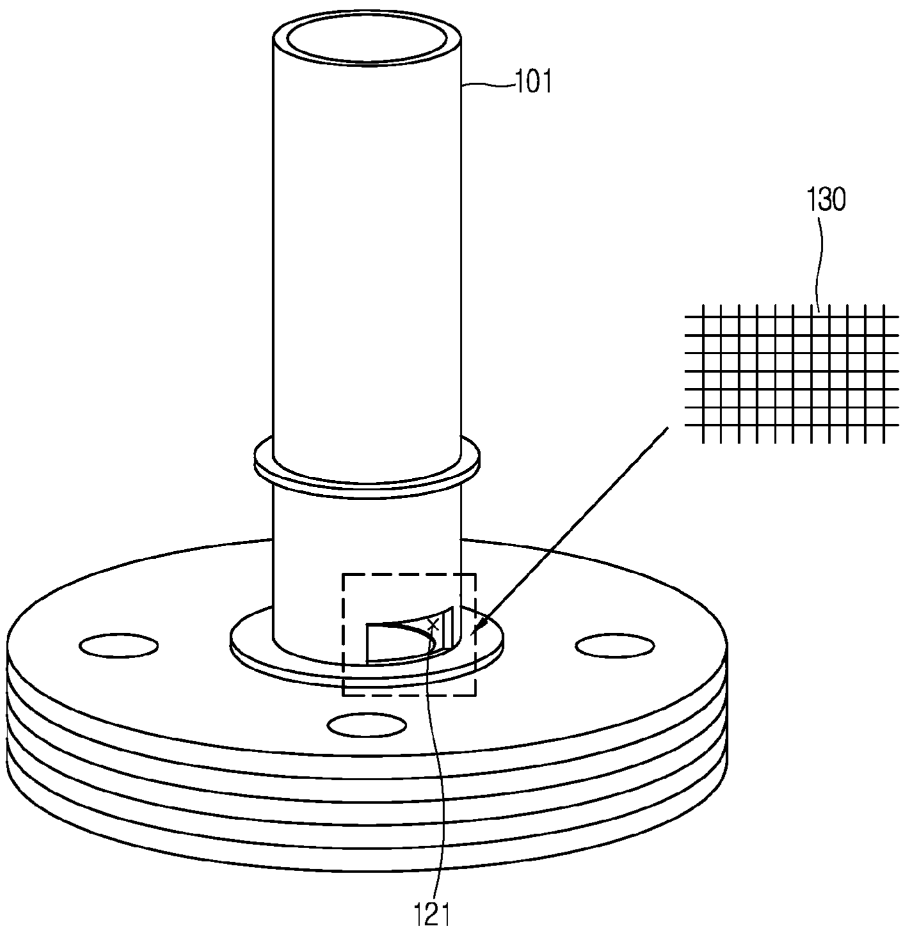


FIG. 5

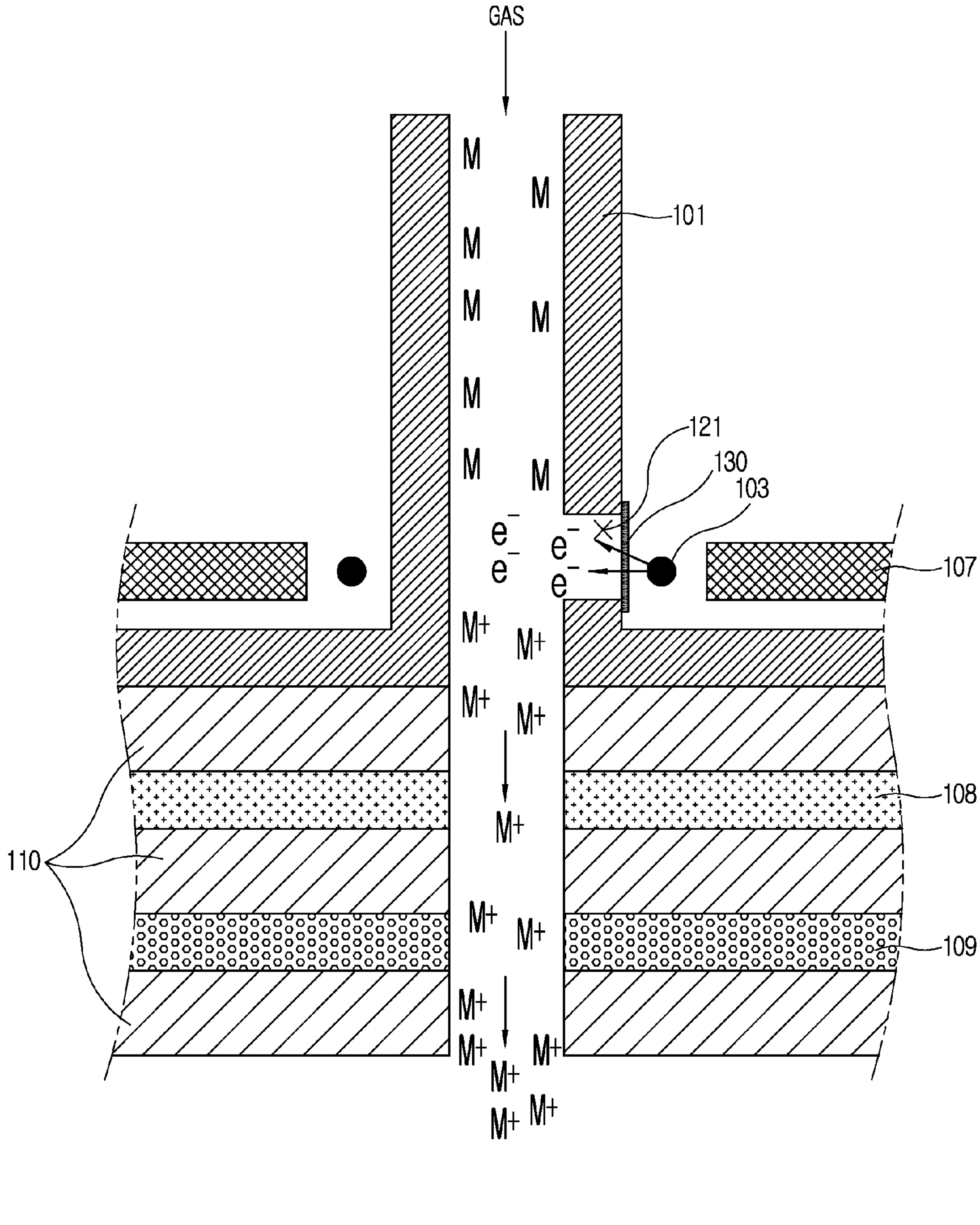
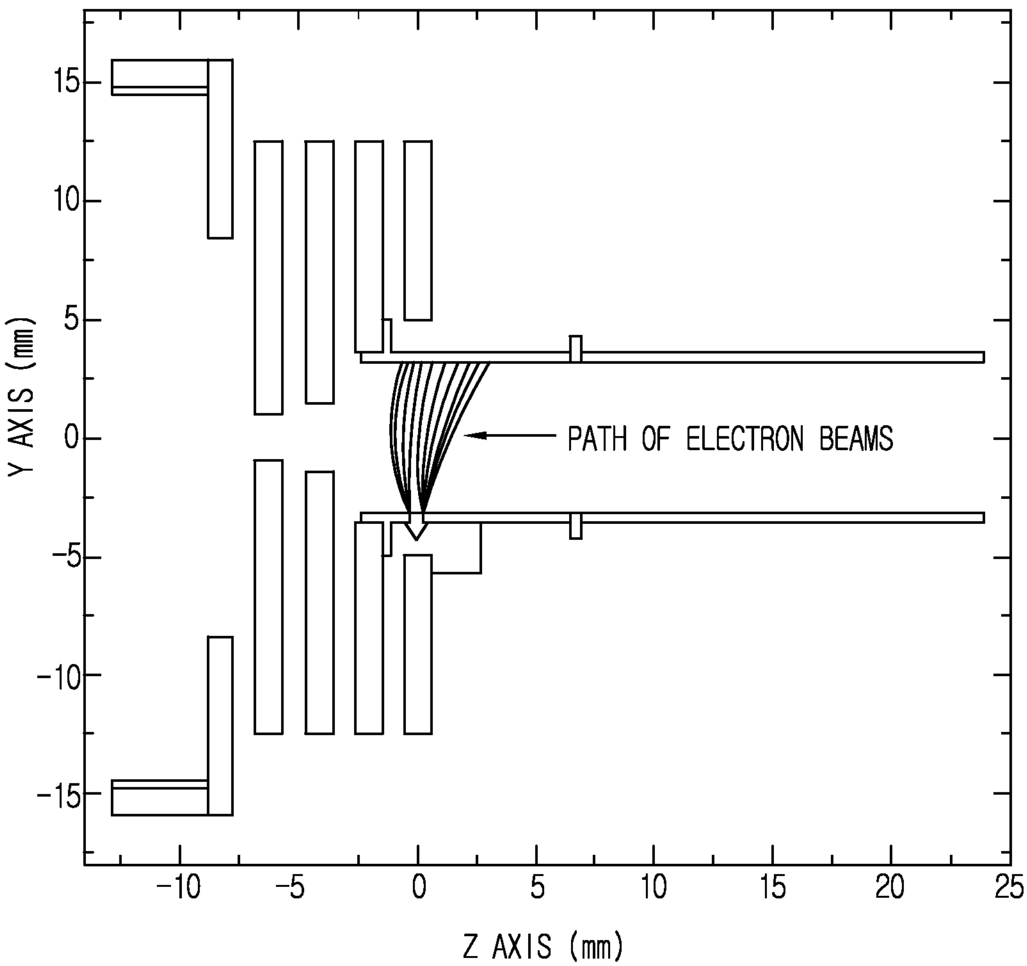
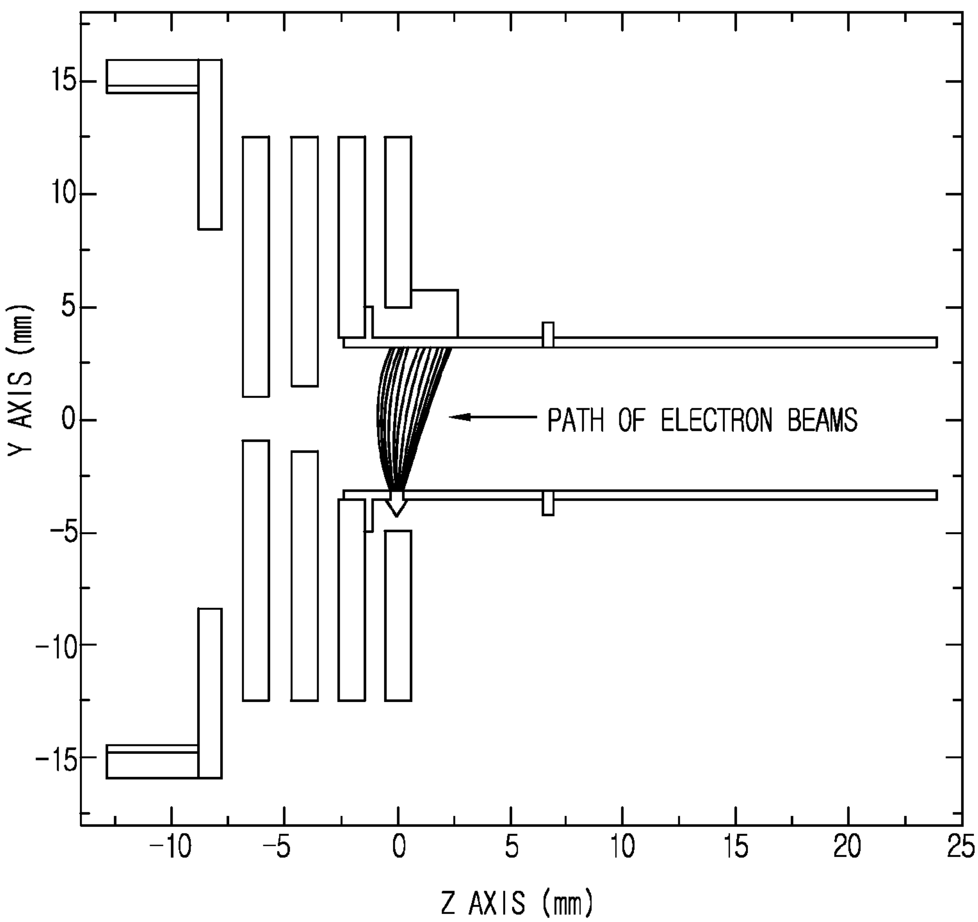

GAS
M
M
M
M
M
M
M
M
M
101
121
130
103
e⁻
e⁻
e⁻
e⁻
e⁻
107
M+
M+
M+
M+
M+
108
110
M+
M+
109
M+
M+
M+
M+
M+
M+

FIG. 6



PATH OF ELECTRON BEAMS
Y AXIS (mm)
Z AXIS (mm)
15
10
5
0
−5
−10
−15
−10
−5
0
5
10
15
20
25

FIG. 7


15
10
5
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−5
−10
−15
Y AXIS (mm)
−10
−5
0
5
10
15
20
25
Z AXIS (mm)
PATH OF ELECTRON BEAMS

FIG. 8

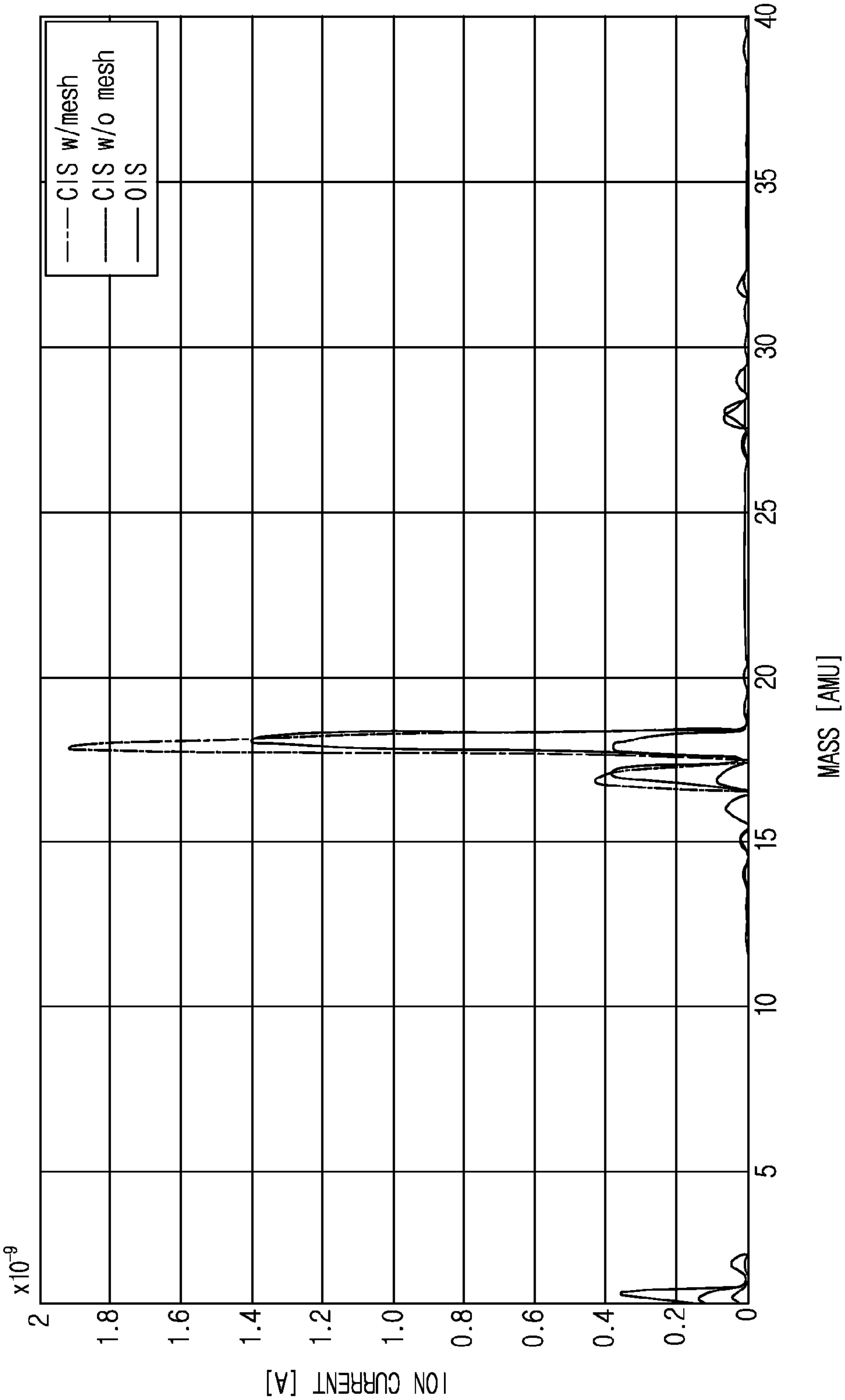
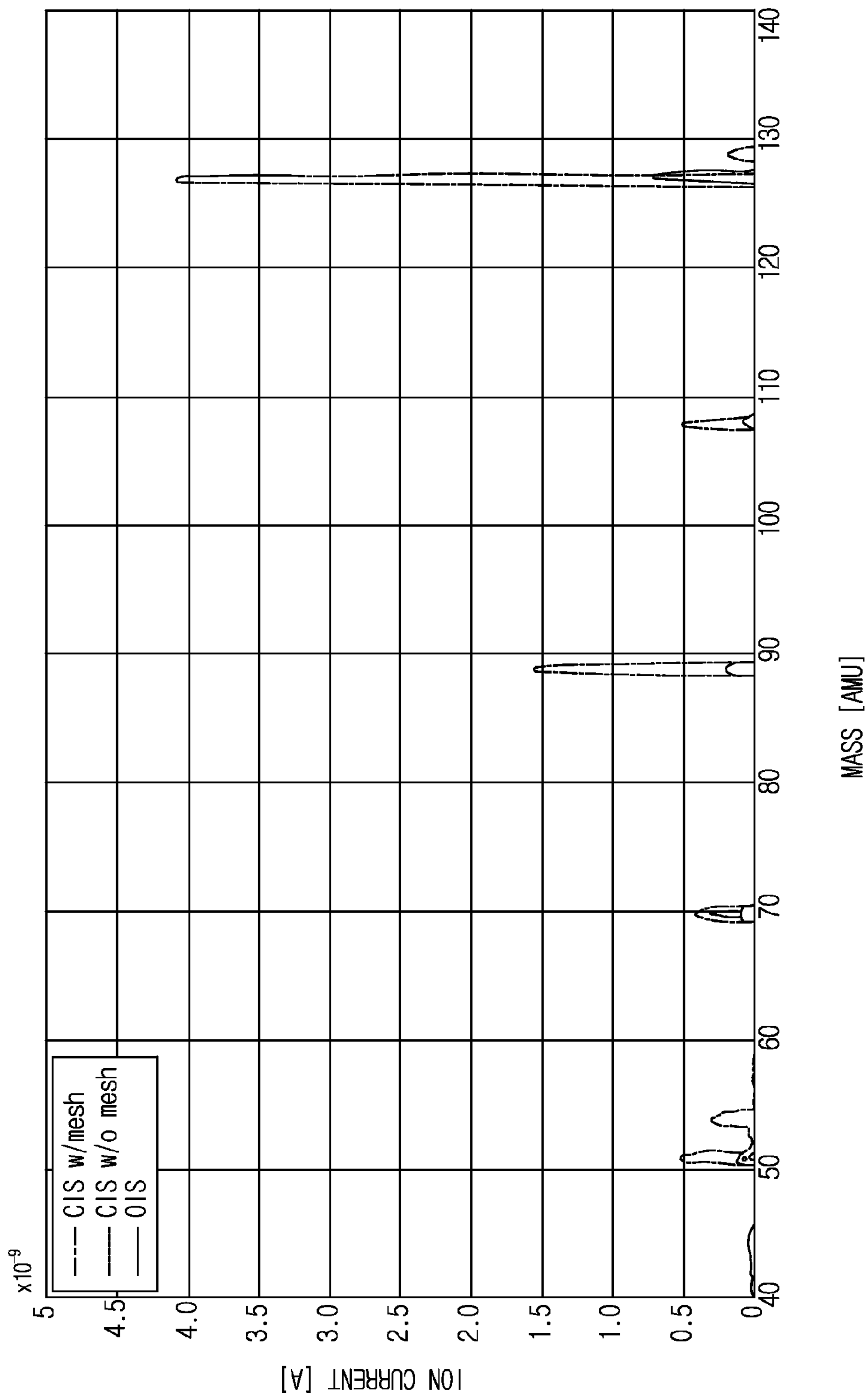

CIS w/mesh
CIS w/o mesh
OIS
x10^-9
ION CURRENT [A]
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2
MASS [AMU]
0
5
10
15
20
25
30
35
40

FIG. 9


CIS w/mesh
CIS w/o mesh
OIS
x10-9
5
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
ION CURRENT [A]
40
50
60
70
80
90
100
110
120
130
140
MASS [AMU]

ION SOURCE, AND MASS ANALYSIS APPARATUS INCLUDING SAME

TECHNICAL FIELD

[0001] The present invention relates to an ion source for ionizing gas molecules, and a mass analysis apparatus including the same.

BACKGROUND ART

[0002] A mass spectrometer is an apparatus for measuring and analyzing a mass of molecules. The mass spectrometer serves to ionize a sample material into ions, and to separate the generated ions in order of a mass to charge ratio. Such a mass spectrometer is composed of an ion source, a mass filter and a detector. The ion source serves to generate ions by ionizing sample gas to be analyzed, and the mass filter serves to filter ions generated from the ion source under a specific condition that only a specific mass of the ions can pass through. The detector serves to collect ions having passed the mass filter and to convert the ions into an electric signal. A result collected from the detector, which displays sample gas information, is provided to a user as an x (mass)-y (signal) plot. A mass peak can be identified using a library search program.

[0003] For an accurate identification of the sample gas, signal intensity should be high enough, and the mass filter should have a very narrow pass band. The sensitivity and mass resolution are the important factors for evaluation of the mass spectrometer performance.

[0004] In a mass spectrometer such as a gas chromatograph mass spectrometer or a residual gas analyzer, an ion source is a core component which greatly influences on sensitivity and resolution of the mass spectrometer. Accordingly, an ion source with improved ionization efficiency may be considered for higher sensitivity of the mass spectrometer.

[0005] Among the various mass spectrometers, a residual gas analyzer is widely used in the fields such as semiconductor devices, flat panel displays, industries related to vacuum and aerospace, etc.

DISCLOSURE OF THE INVENTION

[0006] Therefore, an object of the present invention is to provide an ion source which, with improved ionization efficiency, enables more ions to reach the detector after passing through the mass filter, and thereby enhances sensitivity of the mass spectrometer.

[0007] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is provided an ion source, including: an anode tube configured to ionize gas introduced through one side and to discharge the ionized gas to the other side, and having a slit formed on a circumference thereof; a filament configured to emit thermal electrons toward the slit so as to ionize the gas; and a diffusion-preventing body arranged between the filament and the slit and having at least one hole through which the thermal electrons pass into the anode tube.

[0008] In an embodiment of the present invention, the diffusion-preventing body may be formed of a conductive material, may be formed to have a mesh shape, and may be coupled to an outer circumference of the anode tube.

[0009] In an embodiment of the present invention, the filament may be formed to have a circular arc shape, and a first electrode and a second electrode may be connected to the two ends of the filament. A common electrode may be connected to one point between the first and second electrodes.

[0010] In an embodiment of the present invention, the slit may be positioned to face the filament formed between the first electrode and the common electrode, or the slit may be positioned to face the filament formed between the second electrode and the common electrode.

[0011] In an embodiment of the present invention, the slit may be formed on an outer circumference of the anode tube in plurality in number.

[0012] In an embodiment of the present invention, the ion source may further include a repeller formed at a position spaced from an outer circumference of the filament so that thermal electrons from the filament are emitted toward the slit.

[0013] In an embodiment of the present invention, the ion source may further include a focus lens formed at another side of the anode tube so as to focus gas ions coming from the anode tube.

[0014] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is also provided a mass analysis apparatus, including: the ion source configured to ionize gas introduced thereinto through one side and to discharge the ionized gas to the other side; a mass filter unit configured to filter only a specific mass among gas ions discharged from the ion source; and a detector configured to detect the filtered ions.

[0015] The ion source and the mass spectrometer including the same according to at least one embodiment of the present invention have the following advantages. Owing to the conductive diffusion-preventing body formed on a slit, a voltage inside the anode tube can be distributed uniformly, so that diffusion of electrons passing through the slit can be prevented, and discharge of sample gas to outside through the slit can be reduced. This can increase ionization efficiency and thus enhance sensitivity of the mass spectrometer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a conceptual view illustrating a residual gas analysis apparatus as an example of a mass spectrometer according to an embodiment of the present invention;

[0017] FIG. **2** is a perspective view of an ion source according to an embodiment of the present invention;

[0018] FIG. **3** is a planar view of FIG. **2**;

[0019] FIG. **4** is a conceptual view illustrating an example of a diffusion-preventing body coupled to an anode tube;

[0020] FIG. **5** is a sectional view of FIG. **2**;

[0021] FIG. **6** is a conceptual view illustrating a moving path of thermal electrons of FIG. **5** according to a comparative embodiment;

[0022] FIG. **7** is a conceptual view illustrating a moving path of thermal electrons of FIG. **5** according to a preferred embodiment;

[0023] FIG. **8** is a view illustrating sensitivity of a mass spectrometer in case of measuring residual gas according to a preferred embodiment of the present invention; and

[0024] FIG. **9** is a view illustrating sensitivity of a mass spectrometer in case of measuring SF_6 gas according to a preferred embodiment of the present invention.

MODES FOR CARRYING OUT THE PREFERRED EMBODIMENTS

[0025] Description will now be given in detail of an ion source and a mass analysis apparatus including the same according to the present invention, with reference to the accompanying drawings. For the sake of brief description with reference to the drawings, the same or equivalent components may be provided with the same or similar reference numbers, and description thereof will not be repeated. In general, a suffix such as "module" and "unit" may be used to refer to elements or components. Use of such a suffix herein is merely intended to facilitate description of the specification, and the suffix itself is not intended to give any special meaning or function.

[0026] A singular representation may include a plural representation unless it represents a definitely different meaning from the context.

[0027] FIG. **1** is a conceptual view illustrating a residual gas analysis apparatus as an example of a mass spectrometer according to an embodiment of the present invention.

[0028] The residual gas analysis apparatus may include an ion source **100**, a filter unit **200** and a detector **300**. The ion source **100**, the filter unit **200** and the detector **300** may be mounted in a vacuum chamber **400**.

[0029] The ion source **100** may be configured to have a hollow cylindrical body partially, and may be formed to discharge gas flowing in through one side to the other side after ionization.

[0030] As the ion source **100**, may be used an electron-impact ion source which is ionized by colliding with neutral molecules or atoms, by accelerating thermal electrons generated when an electric current flows on a filament **103** (refer to FIG. **3**). The ion source **100** may be categorized into an open ion source (01S) and a closed ion source (CIS). The present invention relates to a closed ion source (CIS) used to measure gases in a vacuum chamber which is at a relatively high pressure of 10^{-4}~10^{-2} Torr, or used to measure impurity gases of a process chamber.

[0031] Hereinafter, the ion source **100** according to a preferred embodiment of the present invention will be explained in more detail with reference to the attached drawings.

[0032] FIG. **2** is a perspective view of the ion source **100** according to an embodiment of the present invention, FIG. **3** is a planar view of FIG. **2**, FIG. **4** is a conceptual view illustrating an example of a diffusion preventing body coupled to an anode tube **101**, and FIG. **5** is a sectional view of FIG. **2**.

[0033] Referring to FIGS. **2** to **5**, the ion source **100** may include an anode tube **101**, a filament **103**, and a diffusion-preventing body **130** (refer to FIG. **3**). The anode tube **101** may be formed as a cylindrical chamber having a slit. Gas flowing into the anode tube **101** from one side may be ionized in the anode tube **101**, and then may be discharged to the other side. The anode tube **101** is provided with a slit **121** through which thermal electrons are introduced. That is, the anode tube **101**, a type of ionization chamber, is configured to generate positive ions when gas introduced thereinto collides with thermal electrons.

[0034] In this instance, a formula representing an ionization process is as follows.

$$M+e^- \text{->} M^+ +2e^- \text{->} F^+ +N+2e^-$$

[0035] Herein, 'M' denotes sample gas for ionization, 'M^+' denotes ionized radical positive ions, 'F^+' denotes fragment ions, 'N' denotes neutral fragment ions, and 'e^-' denotes electrons.

[0036] The filament **103** serves to emit thermal electrons for ionizing sample gas introduced into the anode tube **101**. The filament **103** may be formed of tungsten, rhenium, etc.

[0037] The filament **103** is formed to have a circular arc shape, and is spaced from an outer circumference of the anode tube **101** by a predetermined interval. A first electrode **105** and a second electrode **106** are connected to two ends of the filament **103**, and a common electrode **104** is connected to one point of the filament **103** where the first electrode **105** and the second electrode **106** have been connected. An electric current may be selectively supplied to either the common electrode **104** with the first electrode **105**, or the common electrode **104** with the second electrode **106**. A controller (not shown) for controlling an operation of the ion source is configured to supply the current to one of the first electrode **105** and the second electrode **106**, by a preset voltage.

[0038] The anode tube **101** receives thermal electrons emitted from the filament **103** through the slit **121**. The anode tube **101** may be provided with a plurality of slits **121***a*, **121***b*.

[0039] For instance, when the anode tube **101** is provided with two slits **121**, the first slit **121***a* may be positioned to face the filament **103** formed between the first electrode **105** and the common electrode **104**, and the second slit **121***b* may be positioned to face the filament **103** formed between the second electrode **106** and the common electrode **104**.

[0040] A repeller **107** (refer to FIG. **2**), configured to push thermal electrons emitted from the filament **103** toward the slit **121**, is formed at a position spaced from an outer circumference of the filament **103**. The repeller **107** may be formed to have a cylindrical shape. Once a voltage higher than a voltage applied to the filament **103** is applied to the anode tube **101**, thermal electrons generated from the filament **103** are attracted to the slit **121** of the anode tube **101** by a voltage difference.

[0041] A focus lens **109** or an extractor **108** may be positioned below the anode tube **101**. The focus lens **109** serves to focus extracted ions and to supply the extracted ions to the filter unit **200** connected thereto. The focus lens **109** may be formed as a lens having a through hole. The extractor **108** is positioned between the focus lens **109** and the anode tube **101**, and extracts ions generated from the anode tube **101** to outside of the anode tube **101**. The extractor **108** may be formed as a lens having a through hole.

[0042] The diffusion-preventing body **130** is formed to reduce an opening ratio of the slit **121**. That is, the diffusion-preventing body **130** is configured to reduce discharging rate of the sample gas to outside through the slit **121**, and to distribute a voltage inside the anode tube **101** uniformly. For this, the diffusion-preventing body **130** is provided with at least one hole through which thermal electrons pass, so as to reduce diffusion of the thermal electrons.

[0043] For instance, the diffusion-preventing body **130** is formed to cover the slit **121**. In this instance, an opening ratio of the slit **121** with the diffusion-preventing body **130** may be about 70%.

[0044] The diffusion-preventing body **130** may be placed between the filament **103** and the slit **121**, or on an inner circumference of the anode tube **101**. The diffusion preventing body **130** may be formed of a conductive material. For instance, the diffusion-preventing body **130** may be formed of a stainless steel material. The diffusion-preventing body **130** is provided with at least one hole through which thermal electrons pass. For instance, the diffusion-preventing body **130** may be formed as a metallic mesh with a plurality of holes. The diffusion-preventing body **130** reduces diffusion of electron beams, including thermal electrons, into the periphery inside the anode tube **101**. The diffusion-preventing body **130** may be coupled to the anode tube **101** so as to cover the slit **121** of the anode tube **101**.

[0045] Hereinafter, the present invention will be explained in more detail with reference to FIGS. **6** and **7**. FIG. **6** is a conceptual view illustrating a moving path of thermal electrons of FIG. **5** according to a comparative embodiment. FIG. **7** is a conceptual view illustrating a moving path of thermal electrons of FIG. **5** according to a preferred embodiment.

[0046] FIG. **6** illustrates a path (trajectory) of electron beams at the ion source **100** without the diffusion-preventing body **130** according to a comparative embodiment, and FIG. **7** illustrates a path of electron beams at the ion source **100** provided with the diffusion-preventing body **130** according to a preferred embodiment of the present invention.

[0047] As shown in FIGS. **6** and **7**, a path of electron beams is less diffused in the preferred embodiment, than in the comparative embodiment. In case of the ion source having two slits according to a comparative embodiment, a voltage inside the anode tube is distributed non-uniformly due to the slits, and a voltage deviation is increased according to a position inside the anode tube. Due to such a non-uniform voltage distribution, thermal electrons introduced into the anode tube are diffused. Further, since gas flowing in the anode tube is discharged out quickly through the slits, ionization efficiency of the introduced gas is reduced.

[0048] The diffusion-preventing body **130** (refer to FIG. **4**) is configured to uniformly distribute voltage inside the anode tube by including at least one hole, thereby preventing diffusion of thermal electrons as shown in FIG. **7**. Further, the diffusion-preventing body **130** prevents diffusion of electrons passing therethrough, and reduces gas flowing out through the slit **121**, by reducing an opening ratio of the slit **121**. Further, the diffusion-preventing body **130** is formed of a conductive material, thereby reducing occurrence of a voltage difference at the two sides of the slit **121**.

[0049] FIG. **8** is a view illustrating sensitivity of a mass spectrometer in case of measuring residual gas according to a preferred embodiment of the present invention, and FIG. **9** is a view illustrating sensitivity of the mass spectrometer in case of measuring SF_6 gas according to a preferred embodiment of the present invention.

[0050] When a vacuum level (degree of vacuum) is 2×10^{-6} Torr after vacuum pumping has started, by opening a needle valve, the vacuum level is adjusted to 5×10^{-6} Torr. Under such a configuration, signal intensities are compared to each other in a condition that the same amount of SF_6 gas is injected at each experiment. FIG. **8** illustrates a signal intensity comparison result when residual gas is measured at a mass range of 1-40 amu, and FIG. **9** illustrates a signal intensity comparison result when SF_6 gas is measured at a mass range of 40-130 amu.

[0051] A red spectrum was obtained using a CIS with the diffusion-preventing body **130**, a blue spectrum using a general CIS without the diffusion-preventing body, and a black spectrum using an OIS. FIG. **8** shows that a CIS with the diffusion-preventing body **130** provides about 4-5 times enhanced signal intensity than that the general CIS. When the CIS is compared with the OIS, the overall signal intensities are almost the same, although each mass peak shows a little different intensity. However, in a condition that SF_6 sample gas is injected from outside (FIG. **9**), the CIS with the diffusion-preventing body **130** provides about 10 times enhanced signal intensity than a general CIS without the diffusion-preventing body and an OIS.

[0052] As the present features may be embodied in several forms without departing from the characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

1. An ion source, comprising:

an anode tube configured to ionize gas introduced thereinto through one side and to discharge the ionized gas to the other side, and having a slit formed on an outer circumference thereof;

a filament configured to emit thermal electrons toward the slit so as to ionize the gas; and

a diffusion-preventing body arranged between the filament and the slit and having at least one hole through which the thermal electrons pass so as to reduce diffusion of the thermal electrons flowing into the anode tube.

2. The ion source of claim **1**, wherein the diffusion-preventing body is formed of a conductive material, is formed to have a mesh shape, and is coupled to an outer circumference of the anode tube.

3. The ion source of claim **1**, wherein the filament is spaced from the slit so as to maintain a predetermined distance from the slit, and is connected to a first electrode and a second electrode, and

wherein the filament is connected to a common electrode on one point between the first and second electrodes.

4. The ion source of claim **3**, wherein the slit is positioned to face the filament formed between the first electrode and the common electrode, or the slit is positioned to face the filament formed between the second electrode and the common electrode.

5. The ion source of claim **1**, wherein the slit is formed on an outer circumference of the anode tube in plurality in number.

6. The ion source of claim **3**, wherein an electric current is selectively applicable to the first electrode or the second electrode.

7. A mass spectrometer, comprising:

the ion source of claim **1** configured to ionize gas introduced thereinto through one side and to discharge the ionized gas to the other side;

a mass filter unit configured to filter ions discharged from the ion source on the basis of a mass; and

a detector configured to detect the filtered ions.

* * * * *