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[54] **CONTACT IONIZATION ION SOURCE**

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[63] Continuation of Ser. No. 162,489, July 14, 1971, abandoned.

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **250/423**, 250/425, 313/63

[51] **Int. Cl.** **H01j 39/34**

[58] **Field of Search** 250/423, 424, 425, 427; 313/63

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[57] **ABSTRACT**

An ion source in which an apertured or foraminous electrode having a multiplicity of openings is spaced from one or more active surfaces of an ionisation electrode, the active surfaces comprising a material capable of ionising by contact ionization a substance to be ionized supplied during operation to the active surface or surfaces comprises means for producing during operation a magnetic field which enables a stable plasma to be formed in the space between the active surface or surfaces and the apertured electrode, the field strength of the magnetic field being preferably in the range between 2 and 8 kilogauss.

8 Claims, 2 Drawing Figures

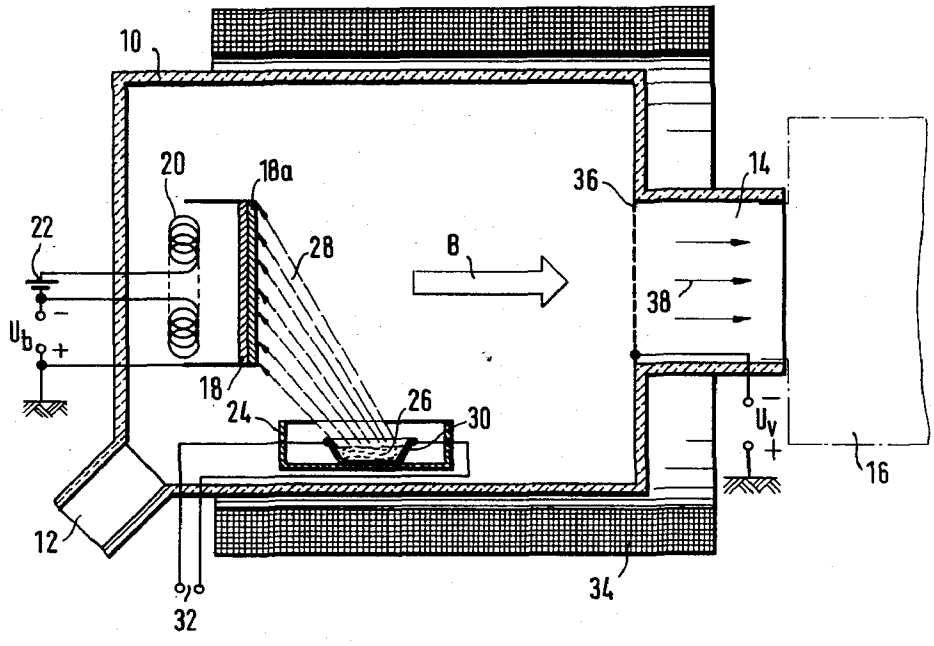


Fig.1

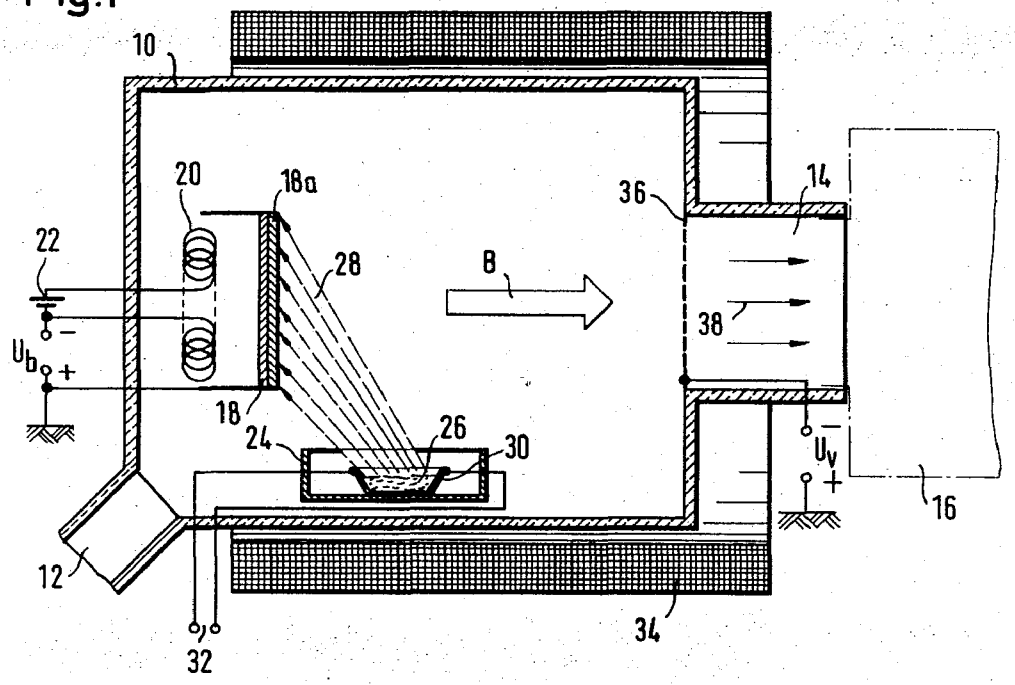
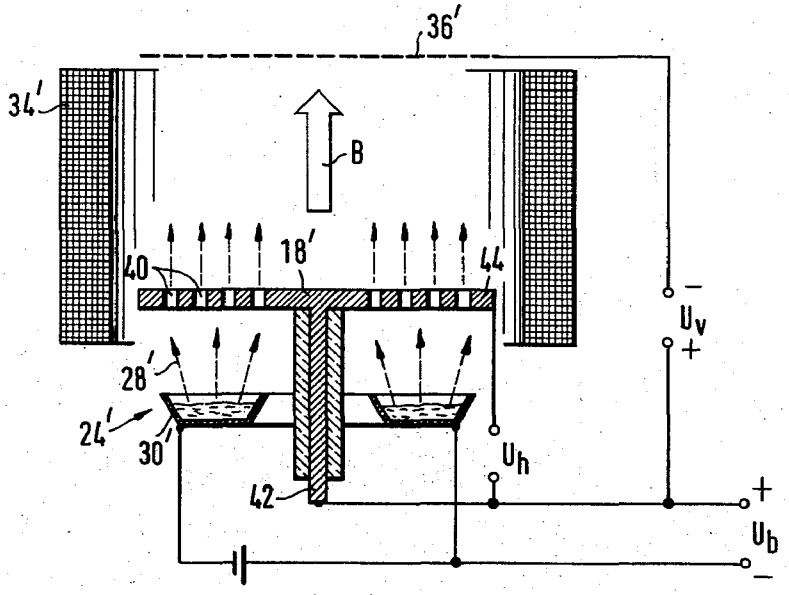


Fig.2



INVENTOR:

BY:

CONTACT IONIZATION ION SOURCE

This is a continuation, of application Ser. No. 162,489, filed July 14, 1971, now abandoned.

The present invention concerns ion sources.

A known form of ion source has a heatable ionisation electrode which has an active surface of a material capable of ionising, by contact ionization, a substance which is to be ionized, a device for supplying atoms of the substance to be ionized to the active surface of the ionization electrode, and an open-structure electrode which can be biased negatively relative to the ionizing electrode and through which the ions produced pass to a consumer (see, for example, "The Review of Scientific Instruments" Vol. 40, No. 8, August 1969, pages 1072 to 1074.

In this known form of ion source, however, the attainable specific ion current strength, which is defined as the ion current strength per unit of active surface of ionization electrode, and the efficiency leave much to be desired, since in operation, a space charge is formed in front of the ionization electrode and impedes the supply of ions, and consequently the ions formed have to be extracted from the source by comparatively high electric fields.

According to one aspect of the present invention there is provided an ion source in which an open-structured electrode having a multiplicity of openings is spaced from one or more active surfaces of an ionization electrode, the active surfaces being formed of a material capable of ionizing by contact ionization a substance to be ionized supplied during operation to the active surface or surfaces, and means are provided for producing during operation a magnetic field which enables a stable plasma to be formed in the space between the active surface or surfaces and the open-structured electrode.

According to another aspect of the present invention there is provided an ion source having an ionization electrode with one or more active surfaces formed of a material capable of ionizing by contact ionization a substance to be ionized supplied thereto during operation, a grid electrode spaced from the said active surface or surfaces, and means for producing during operation a magnetic field which enables a stable plasma to be formed in the space between the active surface or surfaces and the grid electrode.

The strength of the magnetic field is preferably greater than 1.5 or 2 kilogauss and less than 5 or 8 kilogauss. For reasons of economy, efforts should be made to manage with the lowest possible magnetic field strengths.

The distance between the active surface of the ionization electrode and the open-structured electrode, which may, for example, be in the form of a grid grating, lattice, or some other open network, amounts to at least 20 times the Debye length (6.9 T/n, where T is the temperature in degrees Kelvin and n is the number of particles per cubic centimetre in the plasma). In practice, the distance selected will be at least 10 centimetres, and preferably it lies in the range between about 20 and 30 centimetres. A larger distance is inexpedient on account of the magnetic field.

The voltage between the ionization electrode and the open-structure electrode need be only relatively low, for example 10 to 20 volts, since it merely serves to hold back the electrons of the plasma. The high energy required in the known ion sources for drawing off the ions from the space charge is not needed in the present ion source.

A preferred field of application of the ion source according to the invention is in devices for isotope separation operating on the principle of a mass spectrometer. Such isotope separating devices, compared with isotope separating devices operating on other principles, are characterised by a very high separation factor. Hitherto, it has not been possible to achieve satisfactory mass throughput with such devices since ion sources having the necessary performance were not available. The ion sources usually employed, in which the evaporated or gaseous substance to be ionized is ionized by electric discharge or electron discharge or electron bombardment, in fact supply only comparatively small ion currents for a comparatively large energy consumption.

Examples of embodiments of the invention will now be described with reference to the accompanying drawings, in which:

FIG. **1** shows a greatly simplified axial section of an ion source according to a first embodiment of the invention;

FIG. **2** shows a greatly simplified axial section of an ion source according to a second embodiment of the invention.

An ion source is shown in FIG. **1** arranged in a vacuum vessel **10** having a connecting piece **12** leading to a vacuum pump system of conventional type. The vacuum vessel **10** also has a second connecting piece **14** through which the ions produced are passed to a consumer **16,** which may be an isotope-separating device operating on the principle of a mass spectrometer. (Such isotope separating devices are known; see for example the publication by Smith, Parkins and Forrester in the periodical "The Physical Review," Second Series, Vol. 72, No. 11, Dec. 1, 1947, pages 989 to 1002.)

Mounted in the vacuum vessel **10** is an ionization electrode **18** in the form, for example, of a circular plane plate which can be heated by electron bombardment. The electrons are produced by an incandescent cathode **20** connected to a heating voltage source **22,** and are shot at the back of the plate by a negative accelerating voltage U_b of, for example, several hundred volts relative to the ionization electrode **18.**

The vacuum vessel **10** also comprises an evaporator device **24,** which contains a supply of a substance **26** which is to be ionized and supplies a vapour beam **28** of particles of the substance **26** to an active surface **18***a* of the ionization electrode **18.** The evaporator device may, as shown, comprise an evaporator boat **30** provided with electrical connections and heated by direct passage of current.

The vacuum vessel **10** is surrounded by a cylindrical magnet coil **34** which produces a constant magnetic field B having a field strength of preferably 2 and 8 kilogauss extending substantially at right-angles to the active surface **18***a* of the ionization electrode **18** and to an open-structure electrode **36** arranged at a distance from and parallel to the ionization electrode.

The open-structure electrode consists, for example, of a tungsten wire net, and is biased in operation negative relative to the ionization electrode **18** by a bias voltage U_v.

The ionization electrode **18** consists, at least on its active surface **18***a*, of a material which is capable of ionizing the substance **26** by contact ionization. This

means that the ionization voltage of the atoms to be ionized must be comparable with the exit voltage of the material on the active surface **18***a*. For ionizing alkali metals and alkaline-earth metals, and also uranium and the like, therefore, it is possible to use an electrode of tungsten, rhenium or tantalum, for example. If certain varieties of ceramics which are conductive in the hot state are used for the ionization electrode **18** or its active surface **18***a*, elements having higher ionization potentials may be ionized. Beryllium oxide, zirconium oxide and/or thorium oxide ceramics are examples of such ceramics.

In operation, the ionization electrode **18** is heated to the working temperature, for example 2,500°K, by electron bombardment, and the evaporator device **24** is put into operation so that the beam **28** containing atoms of the substance to be ionized is directed on to the active front surface **18***a* of the electrode **18.** The atoms impinging on the surface **18***a* are ionized by contact ionization upon evaporating again from the surface **18***a*, and, with the electrons thermally emitted by the electrode **18,** form a stable plasma held together by the axial magnetic field B. The ions emerging from the plasma pass through the open-structure electrode **36,** which is negatively biased relative to the ionization electrode **18,** to the connection **14** and to the consumer **16.** The negative voltage on the open-structure electrode **36** need be only comparatively low, for example 10 to 20 volts, since the only purpose of this voltage is to hold back the electrons of the plasma. The ions passing through the electrode **36** as indicated by the arrows **38** can then be accelerated and separated in a manner known in the art.

The embodiment shown in FIG. **2** operates on the same principle as the embodiment described with reference to FIG. **1.** Corresponding parts have therefore been provided with the same reference numerals to which a prime is added. For the sake of simplicity, the vacuum vessel is not shown.

The device for supplying the atoms to be ionized again comprises an evaporator device **24'** with an evaporator boat **30'** which, however, has the form of a ring or part of a ring and is positioned at the side of the ionization electrode **18'** facing away from the electrode **36'**. The ionization electrode **18'** has openings **40** through which the vapour **28'** of the substance to be ionized passes, the vapour being ionized by contact with walls of the openings **40.**

As in FIG. **1,** the ionization electrode **18'** may be heated by electron bombardment, in which case the boat **30'** can act as cathode, or it may be heated by direct passage of current, a central electrode **42** and a peripheral electrode **44** being provided for this purpose.

The diameter of the ionization electrode **18** or **18'** is preferably at least 50 millimetres. The distance between the electrodes **18** and **36** or **18'** and **36'** is preferably at least 100 millimetres, advantageously it lies between about 200 and 300 millimetres.

The ionization electrode and evaporator device may also consist of a heatable hollow body which contains a supply of the substance to be ionized and evaporated and has openings corresponding to the openings **40** from which the evaporated material escapes, the vapour being ionized on the walls.

The examples described herein may be modified in a large variety of ways, without going beyond the scope of the invention. It is, however, essential that there be in front of the active surface of the ionization electrode a magnetic field of a strength such that a stable plasma can be maintained which is composed of the ions produced and the thermally emitted electrons. If the ionizing substance is already in gaseous or vapour form, an evaporator device is obviously not necessary.

In a further embodiment example, the open-structure electrode has the form of a perforated cylinder surrounding the plasma, the ions escaping in the radial direction through the cylindrical electrode to the consumer. In this case, a somewhat higher voltage, for example, about −200 to −300 volts, needs to be applied to the open-structure electrode than in the embodiments described hereinbefore.

What we claim is:

1. An ion source for use in an evacuated vessel, said source comprising:

means for supplying a gaseous or vaporized ionizable material in said evacuated vessel;

an ionization electrode having at least one active surface of substantial area formed of a material capable of ionizing said ionizable material by contact therewith;

means for heating said ionization electrode;

an open-structured electrode having a multiplicity of openings therein and spaced from said active surface or surfaces by space free of intervening field-affecting structures;

means for producing and maintaining, in the space between said active surface or surfaces and said open-structured electrode, a magnetic field of a character favoring the formation in said space of a stable plasma, and

means for applying to said open-structured electrode an electro-negative potential barely sufficient to repel electrons issuing from said plasma and to favor movement through said electrode of ions issuing from said plasma.

2. An ion source as defined in claim **1,** in which said open-structured electrode is a grid electrode, in which, further, said electro-negative potential is such as to provide an average field strength between 0.3 and 2 volts per centimeter in the space between surface or surfaces and said open-structured electrode, and in which the axis of said magnetic field is essentially perpendicular to said active surface or surfaces.

3. An ion source as defined in claim **1,** in which said open-structured electrode is a grid electrode, and said surface or surfaces and said open-structured electrode are so disposed that the field in the space therebetween is essentially unidirectional and essentially aligned in the direction of said magnetic field.

4. An ion source as defined in claim **1,** in which said ionizable material is a vaporized material and in which evaporator means are provided within said vessel for vaporizing said ionizable material.

5. An ion source as defined in claim **4,** in which said evaporator means is disposed immediately adjacent said space between said active surface or surfaces and said open-structured electrode.

6. An ion source as defined in claim **4,** in which said ionization electrode is traversed by openings whose wall surfaces consist of said material capable of ionizing said ionizable material by contact therewith and in which, further, said evaporator means is disposed on the opposite side of said ionization electrode from said open-structured electrode and adapted to produce

vapor for ionization in said openings or at said active surface beyond said openings.

7. An ion source as defined in claim 1, in which said material capable of ionizing said ionizable material by contact therewith is a substance selected from the group consisting of tungsten, rhenium, tantalum and ceramic materials that are electrically conductive at the operating temperature of said ionization electrode.

8. Apparatus for separation of ionizable isotopes adapted for operation on the principle of a mass spectrometer in an evacuated vessel, which apparatus includes:

an ion source comprising an ionization electrode having at least one active surface formed of a material capable of ionizing said isotopes by contact therewith;

means for introducing said isotopes in gaseous or vapor form in the space adjacent to said ionization electrode;

means for heating said ionization electrode;

an open-structured electrode having a multiplicity of openings therein and spaced from said active surface or surfaces by space free of intervening structures;

means for producing and maintaining, in the space between said active surface or surfaces and said open-structured electrode, a magnetic field of a character favoring the formation in said space of a stable plasma, and

means for applying to said open-structured electrode an electro-negative potential barely sufficient to repel electrons issuing from said plasma and to favor movement through said electrode of ions issuing from said plasma.

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