April 7, 1970 EISUKE MITANI 3,505,518

ION SOURCE FOR MASS SPECTROMETERS

Filed Dec. 27, 1966 3 Sheets-Sheet 1

FIG. 1
PRIOR ART

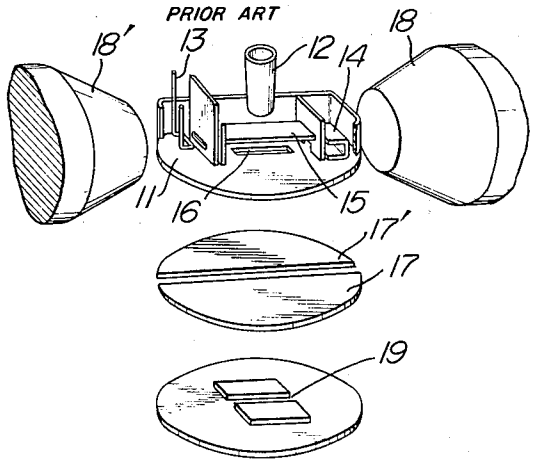


FIG. 3

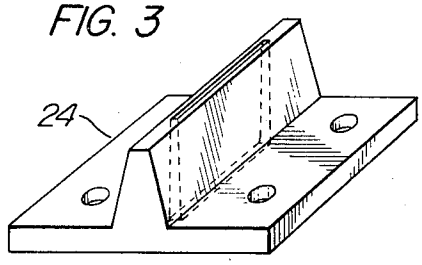
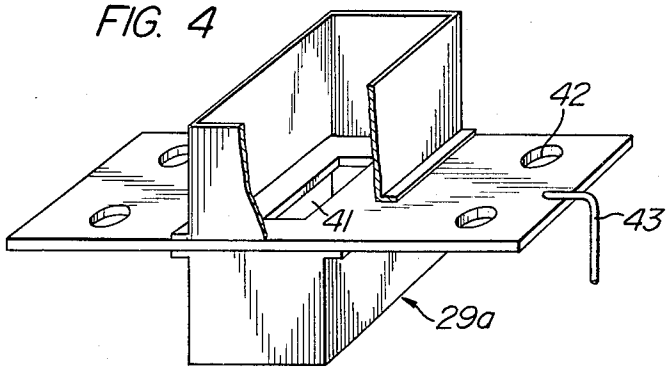


FIG. 4



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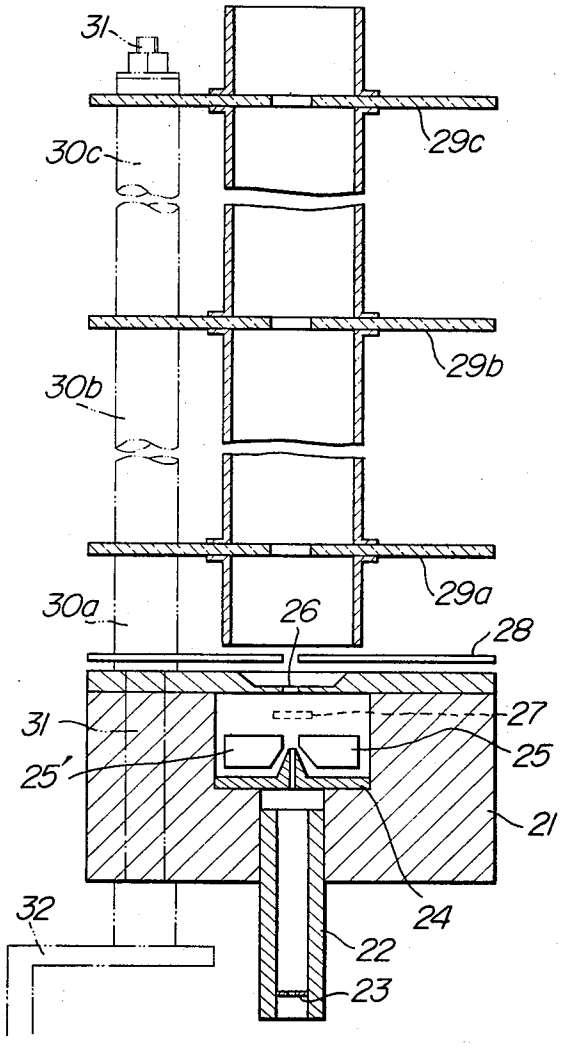
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FIG. 2



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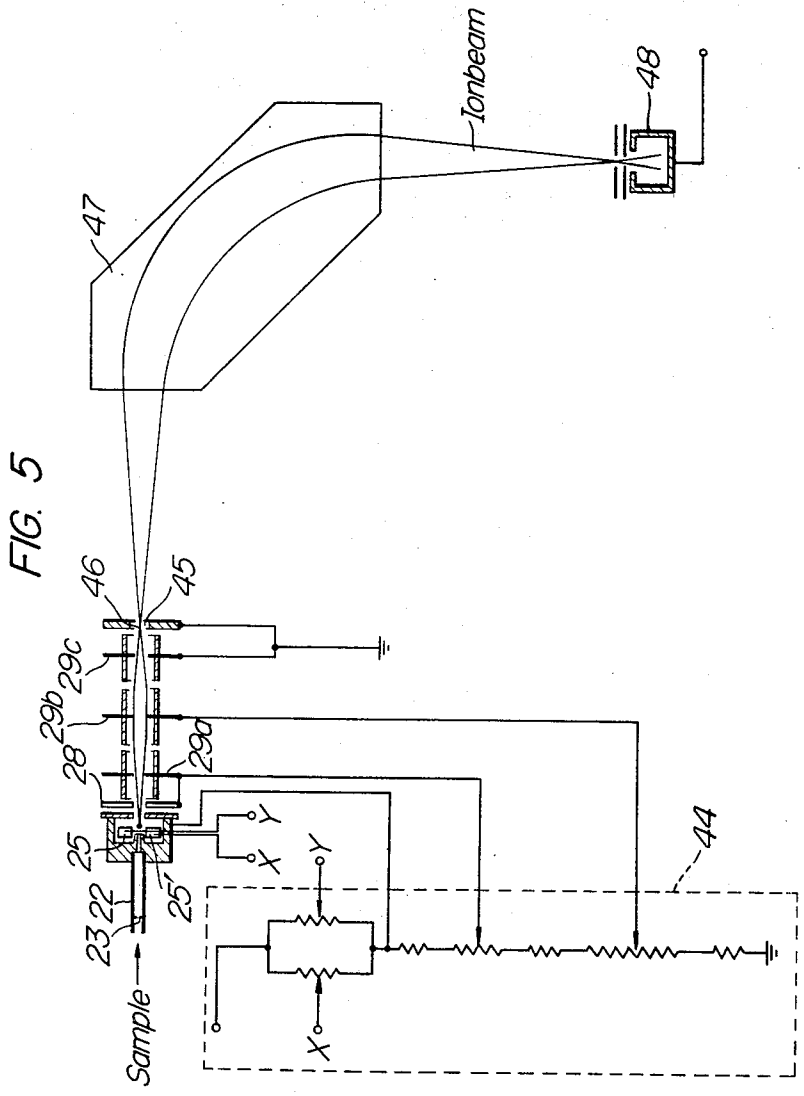
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FIG. 5



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3,505,518

ION SOURCES FOR MASS SPECTROMETERS

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Filed Dec. 27, 1966, Ser. No. 604,702
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Int. Cl. H01j *39/34;* B01d *59/44*
U.S. Cl. 250—41.9 4 Claims

ABSTRACT OF THE DISCLOSURE

An ion source wherein a nozzle is provided and so sized as to regulate the directionality of flow of sample gas after having passed through a gas leak for thereby establishing a unidirectional sample flow of higher density in an ionization chamber, the high density sample flow portion being then ionized by electron bombardment, the ionized high density sample portion being regarded as an object so that a condenser lens system focuses a converged image of the object on an ion source exit slit.

This invention relates to improvements in the structure of ion source means employed in mass spectrometry and the like, and more particularly to improvements in the efficiency of utilization of ions produced by such ion source means.

The primary object of the present invention is to provide an ion source means of electron bombardment type which operates at an improved efficiency over prior art ion source means of this type for thereby obtaining an improved efficiency of ionization of sample gas supplied to the ion source as well as an improved efficiency of utilization of ions produced by the ion source, and minimizing the contamination of the sample in the ion source by shortening the time during which the produced ions remain in the ionization chamber.

In accordance with the present invention, there is provided an ion source of the type in which the same principle as used in prior art ion sources of Nier type is employed for ionizing a sample gas by electron bombardment characterized by the provision of a gas leak disposed in a sample gas inlet pipe, a nozzle having a small aperture disposed downstream of said gas leak and so connected to the discharge end of said sample gas inlet pipe that the sample gas admitted into an ionization chamber can have a relatively high density in said ionization chamber, means for directing an electron beam towards said high density sample gas portion for ionizing the sample gas under the state of relatively high density, and an electrostatic condenser lens system for focusing said sample ions on an ion source exit slit in a manner as if an object disposed at the position at which said sample ions are produced at high density were focused in the form of a converged image on said ion source exit slit.

Other objects, advantages and features of the present invention will become apparent from the following description with reference to the accompanying drawings, in which:

FIG. 1 is a schematic perspective view showing the internal structure of a prior ion source of the Nier type;

FIG. 2 is a longitudinal sectional view of an ion source embodying the present invention;

FIG. 3 is an enlarged perspective view of one form of a sample gas inlet nozzle employed in the ion source according to the present invention;

FIG. 4 is an enlarged perspective view of one form of an electrostatic electrode employed in the ion source according to the present invention; and

FIG. 5 is a diagrammatic view showing one form of a mass spectrometer having incorporated therein the ion source according to the present invention.

Referring first to FIG. 1, one typical form of prior art electron-bombardment ion source commonly called the Nier type ion source will be described so that improvements effected by the present invention can be more clearly understood. FIG. 1 is a perspective view showing the internal structure of such prior art ion source which includes an ionization chamber **11**, a sample gas inlet pipe **12**, a filament **13** for producing an electron beam for the ionization of the sample gas, an electron trap **14**, a repeller **15**, an ionization chamber exit slit **16**, electrodes **17** and **17'** called the half plates for controlling the direction of travel of the ion beam, collimation magnets **18** and **18'**, and an ion source exit slit **19**.

The prior art ion source having such a structure has many defects in view of its poor rate of ionization of a sample gas and further the poor rate of utilizability of ions produced thereby. More precisely, since the sample gas is directly admitted into ionization chamber **11** by way of the inlet pipe **12**, pressure in the ionization chamber **11** becomes uniform and the ionizing region extends over the entire electron beam path. As a result, the rate of ionization with respect to the quantity of admitted gas becomes quite low and only a very small proportion of sample gas can be repelled outwardly from the exit slit **16** in its ionized state. Further the focusing action of the electrostatic lens system in the succeeding stage affects the ion beam emitted from the ion source in such a manner that a considerable quantity of ion is intercepted at the ion source slit **19** with the result that the rate of the quantity of actually utilizable ions to the quantity of whole ions produced is extremely low or commonly in the order of 1:1,000 to 1:10,000. The use of such ion source in a mass spectrometer and the like will inevitably result in a remarkably low sensitivity of the mass spectrometer and like devices. It is thus the present status that an electron multiplier or like means is disposed in the ion collector section to improve the sensitivity of the ion collector section for thereby compensating for the low sensitivity as described above.

Mass spectrometers find their application as a means for the elucidation of the structure of high molecular compounds. However, when the mass spectrometer is employed for the handling of ions of high molecular weight, there arise some problems, including mass discrimination and contamination of samples in the ion source.

The improvements effected by the present invention to eliminate the defects and problems involved in the prior art electron-bombardment ion sources will now be described with reference to FIGS. 2 to 5.

FIG. 2 is a longitudinal sectional view of an embodiment of the ion source according to the present invention. In the ion source of the invention, a sample gas is led, as in the case of prior art ion sources, through a sample gas inlet pipe **22** of relatively large inside diameter and through a gas leak **23** in the pipe **22** to the upstream side

of a nozzle 24. The nozzle 24 is disposed adjacent to the discharge end of the sample gas inlet pipe 22 and has a fine slit-like aperture opening towards the upstream side of a pair of repellers 25 and 25' so that the sample gas is admitted in the form of a narrow-width stream through the nozzle 24 into the ionizing space of an ionization chamber 21. The nozzle 24 is so sized that, of all the sample molecules flowing through the gas inlet pipe 22 into the nozzle 24, those molecules directly flowing into the ionization chamber 21 without impinging against and being reflected by the nozzle inner wall can advance in the form of a straight line stream to leave the ionization chamber 21 through a chamber exit slit 26. By virtue of the above arrangement, the sample gas led out of the nozzle 24 can be concentrated near the downstream side of the repellers 25 and 25' to have a remarkably higher density than heretofore. A beam of electrons 27 is directed to this high density portion of the sample gas to ionize the same. The ions produced in the above-described manner are highly concentrated and are repelled by the electrostatic field established by the repellers 25 and 25' to be forced out of the ionization chamber 21 through the slit 26. Electrostatic condenser lenses 29*a*, 29*b* and 29*c* are disposed on the downstream side of the ionization chamber 21 and are secured to the ionization chamber 21 by a plurality of support rods 31 through spacers 30*a*, 30*b* and 30*c* of electrically insulating material. Between the lens electrodes and the exit slit 26 of the ionization chamber 21, there is disposed a shielding electrode 28 which acts to provide a shield against the electrostatic field established by the lens electrodes 29*a*, 29*b* and 29*c*. The entirety of the ion source including the above members is fixedly mounted on a support base 32.

In the invention, the width and length of the slit-like aperture of the nozzle 24 are so selected as to not impair the smooth streamline flow of the sample gas after having passed through the gas leak 23. The gas leak 23 is provided so that the gas stream flowing from a sample reservoir (not shown) into the ionization chamber 21 can be rendered in the form of a molecular stream for thereby providing ease of maintenance of such stream shape. If such gas leak 23 were not provided and the sample gas should be directly admitted through the nozzle 24 into the ionization chamber 21, flow control of the sample gas would become extremely difficult and other difficulties including a wide inflow velocity distribution of sample gas would arise. The nozzle 24 employed in the embodiment of the invention is schematically shown in perspective fashion in FIG. 3.

The electrostatic condenser lens system described above consists of the repellers 25 and 25', ionization chamber exit slit 26, shielding electrode 28, and cylindrical or two-dimensional electrodes 29*a*, 29*b* and 29*c*, and acts to focus the produced ions on an ion source exit slit disposed on the downstream side of the electrostatic lens system. In the above arrangement, a variable potential may be applied to the nozzle 24 or the ionization chamber exit slit 26 may be adapted to act as an aperture electrode for thereby improving the focusing performance of the electrostatic condenser lens system.

One of the electrostatic lens electrodes employed in the present embodiment is shown in a partly cut-away perspective view in FIG. 4. The lens electrode 29*a* is shown therein as having a slit-like aperture 41 allowing for passage therethrough of the ion beam, a plurality of perforations 42 for receiving therein the support rods 31 of FIG. 2 for fixing the lens electrode in position, and a lead 43 attached thereto.

One application of the ion source of the present invention as incorporated in a conventional mass spectrometer is diagrammatically illustrated in FIG. 5. In FIG. 5 it will be seen that a single D-C power supply 44 is provided so that the voltage is suitably divided for application to the respective electrodes of the electrostatic lens system described above. Terminals X and Y of the D-C power supply 44 are connected to the respective repellers 25 and 25' so as to thereby make the direction control of the ion beam. Further, the shielding electrode 28 and the lens electrode 29*a* are at the same potential. The ion beam forming its intermediate image 46 at an ion source exit slit 45 by the action of the electrostatic lens system having the structure as described above is then subjected to deflection in an analyzing magnetic field 47 and is finally led into an ion collector 48.

It will be appreciated from the foregoing description that, by use of the ion source of the invention having the structure as described above, the time during which the gas remains in the ionization chamber can be remarkably shortened and the rate of gas ionization can be made extremely high owing to the fact that a beam of electrons is directed to that portion of the gas which has a high density. Moreover an increased amount of ions can be led into the analyzing system and thus the efficiency of utilization of produced ions can be remarkably improved by virtue of the fact that the beam of produced ions is focused at the ion source exit slit by the electrostatic lens system. The remarkable reduction in the time during which sample gas or produced ions remains in the ionization chamber of the ion source according to the present invention is advantageous in that contamination of the interior of the ionization chamber, contamination of sample gas, and recombination of produced ions can be obviated. Test results with the ion source of the invention having such a structure proved that the magnetic field employed therewith need not have such a high intensity as that convenitonally employed with the prior ion source of Nier type, and therefore an ion beam with a minimum degree of mass discrimination can be supplied to the analyzing section.

What is claimed is:

1. In an ion source of the type in which a sample gas is admitted into an ionization chamber through a sample gas inlet pipe and is then ionized by electron bombardment, the invention being characterized by the inlet pipe including a gas leak restricting the passage of the gas and a nozzle having a small aperture disposed downstream of said gas leak and connected to the discharge end of said sample gas inlet pipe so that the sample gas admitted into said ionization chamber forms a relatively high density stream of given size forming a first object in said ionization chamber, means for directing an electron beam towards said high density sample gas portion for ionizing the sample gas under the state of relatively high density, an ion source exit slit and an electrostatic condenser lens system for focusing said sample ions to form a second object at said ion source exit slit to correspond to said first object disposed at the position at which said sample ions are produced at high density within said ionization chamber.

2. The combination defined in claim 1 wherein said ionzation chamber includes wall means enclosing an ionization space, a chamber exit slit formed in one portion of said wall means and repeller electrodes positioned in said ionization space adjacent said nozzle, said nozzle having a fine slit-like aperture in alignment with said chamber exit slit so that sample gas admitted in the form of a narrow width stream into the ionization space can advance in the form of a straight line stream toward said chamber slit without contact with said wall means.

3. The combination defined in claim 2, wherein said electrostatic condenser lens system includes a plurality of aligned electrostatic condenser lenses disposed on the downstream side of said ionization chamber along the path of ions emitted therefrom and voltage source means connected to said condenser lenses for focusing said ions to form a converged image at said ion source exit slit formed in the last electrostatic condenser lens along said ion path.

4. The combination defined in claim 3, wherein an electrostatic shield is positioned adjacent said chamber

exit slit between said chamber and said electrostatic condenser lenses to shield said ionization space from the outside electrostatic forces.

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U.S. Cl. X.R.

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