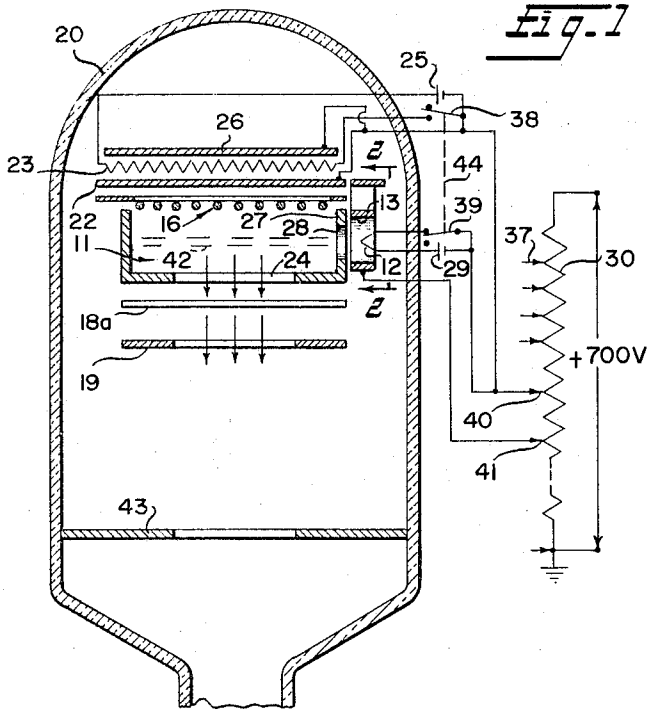
Jan. 3, 1967 J. L. PETERS 3,296,481

ION SOURCE HAVING BOTH DEFLECTION AND REPELLER ELECTRODES FOR DIRECTING AN ELECTRON STREAM

Filed May 13, 1964

Fig. 1



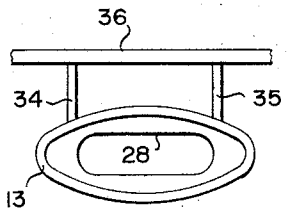
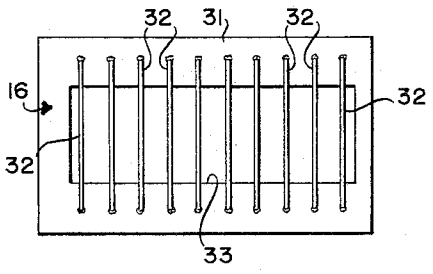


Fig. 2

Fig. 4



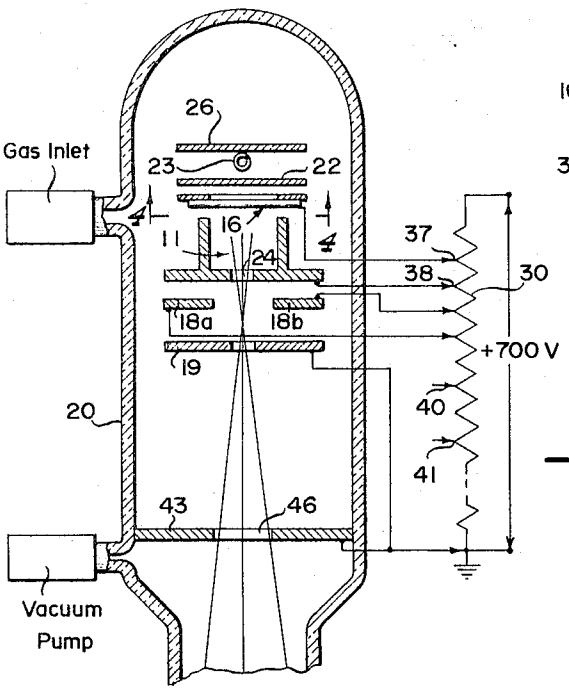


Fig. 3

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ION SOURCE HAVING BOTH DEFLECTION AND REPELLER ELECTRODES FOR DIRECTING AN ELECTRON STREAM

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The present invention relates to ion sources and, more particularly, to means for producing a positive ion beam.

In apparatus such as analytical mass spectrometers and mass spectrometer leak detectors, for example, a source of positive ions and a means for focusing and accelerating the ions are employed to produce a positive ion beam. One type of widely used ion source comprises a box-like ion chamber that contains molecules of gas, means for producing and directing a beam of electrons into the chamber, an ion outlet at the bottom of the chamber, and a grid positioned at the top of the chamber for repelling ions toward the ion outlet. The production of usable ions and, consequently, the current in an ion beam that is formed from the ions leaving the ion outlet depends upon the number of electrons and focusing or controlling of the electrons within the ion chamber.

It is a primary object of the present invention to provide improved means for producing a positive ion beam with increased current.

Another object is to provide an improved ion source for increasing the usable positive ions that are produced in the ion chamber of the ion source.

Still another object is to provide improved means for focusing or controlling an electron beam in an ion chamber of an ion source for increasing the usable positive ions which are produced in the chamber.

A further object is to provide improved means for preventing contamination in an ion source so that a maximum amount of usable ions can be produced.

The foregoing objects as well as other objects and advantages of the inventtion are achieved by an ion source, as is described above, to which is added a deflection electrode that is positioned adjacent the ion repelling grid on the far side of the grid from the bottom of the ion chamber. The focusing electrode and the grid are operated at different voltages to optimize the trajectories of the electrons in the ionization chamber thereby increasing the number of positive ions that are produced in the chamber. An internal heater is positioned in back of the focusing electrode. Means are provided for turning the heater off when the filament of the means for producing and directing a beam of electrons into the chamber is switched on and vice versa, thereby preventing contamination.

In the drawings,

FIG. 1 is a sectional view, partly schematic of an ion beam producing means that is provided in accordance with the present invention;

FIG. 2 is an end view, taken from the line 2—2 in FIG. 1, of the focusing electrode that surrounds the filament of the electron stream producing means;

FIG. 3 is a sectional view, which is taken at right angles with the view shown in FIG. 1, of the ion beam producing means; and

FIG. 4 is an enlarged plan view, taken from the line 4—4 in FIG. 3, of the repeller electrode.

Referring to FIGS. 1 and 3, there is shown a positive ion beam producing means comprising an ion chamber **11** that contains molecules of gas, means including a filament **12** and focusing electrode **13**, shown in FIG. 1, for producing and directing a beam of electrons into the chamber **11** for producing positive ions, a repeller electrode **16** positioned at the top of the chamber for repelling

positive ions toward the bottom of the chamber, and the combination of focusing electrodes **18***a* and **18***b* and an accelerating electrode **19** positioned below the ionization chamber for focusing and accelerating an ion beam that is formed from the ions which pass out of the ion chamber. In accordance with important features of the invention, a deflection electrode **22** is positioned in back of the repeller electrode **16** on the far side of the electrode **16** from the bottom of the ionization chamber and a heater **23** is positioned in back of the deflection electrode **22**.

The heater **23** is a coil or zig zag heater winding which is insulated from the electrode **22**. A heat shield **26**, made from polished metal, is positioned in back of the heater **23** for reflecting heat back into the ion source. The heater **23** is energized by a voltage supply **25** which may be either a D.C. supply as is indicated in FIG. 1 or an A.C. supply. The electrode **22**, which is a plate made from non-magnetic metal like all of the parts of the ion source, distributes the heat produced by heater **23**.

Suitable insulator means, not shown, are employed to support the various elements of the ion beam producing means in insulated relationship with each other within a vacuum envelope **20** that is made from either non-conducting material or from metal. A vacuum pump, which is identified in FIG. 3, is connected to the envelope **20** for drawing gas from the gas inlet, which is identified in FIG. 3, through the ion chamber **11**.

The ionization chamber **11** is a rectangularly shaped box-like electrode. It is open at the top and is closed at the bottom except for a rectangularly shaped slit **24** which forms an ion outlet from the chamber. One of the narrow side walls **27** of the chamber **11** contains a rectangularly shaped slit **28** for passing a beam of electrons into the ionization chamber.

The beam of electrons which passes into the ionization chamber **11** is produced by the filament **12** and the focusing electrode **13**. The filament **12** is a rectangularly shaped strip of tungsten, for example, which is approximately twice as wide as filaments heretofore employed in ion sources. The increased surface area of the wider filament directs more electrons into the ionization chamber **11** to produce more usable positive ions to produce a larger current in the positive ion beam, compared with filaments which have been used in the art heretofore. The filament **12** is energized by a voltage supply **29** shown in FIG. 1. A D.C. voltage supply is shown, but instead an A.C. supply could be used.

The focusing electrode **13** is shaped to form an electron stream that has a rectangular cross section A suitable design for this focusing electrode is shown and described in an article entitled "Mass Spectrometer Leak Detector With Improved Sensitivity," by John L. Peters, on page 1094 of the Review of Scientific Instruments, vol. 30, No. 12, December 1959, for example. The focusing electrode **13** is supported mechanically by struts **34** and **35** which extend from a flat plate **36** that is supported within the tube envelope **20** by suitable insulator means, not shown.

As is shown both in FIG. 1 and in FIG. 3, the various electrodes of the ion source are connected respectively to a plurality of adjustable taps (represented by the arrowheads) along a resistor **30**. The resistor **30** is connected across the output terminals of a regulated D.C. voltage supply, not shown. One end of the resistor is connected to ground, for example, the other end of the resistor being at a positive voltage of 700 volts (for example) with respect to ground.

The repeller electrode or grid **16** comprises a metal plate or frame **31** and fine wires **32** which are stretched across a rectangularly shaped aperture **33**. The wire

portions are accurately positioned and firmly anchored to the frame **31** by welding, for example. The repeller electrode **16** is biased by connecting it to the adjustable tap **37** so that electrode **16** is approximately ten volts more positive than the voltage of the ion chamber **11**. The chamber **11** is connected to the resistor **30** by an adjustable tap **38**. As an example, the repeller electrode **16** contains approximately ten wires **32** from .005 inch to .010 inch in diameter, made from Nichrome V, which are spot welded at each end to the frame **31** and are spaced evenly apart by approximately .060 inch. In constructing the electrode **16** the wires **32** are straightened, stress relieved and then held straight under slight tension when welded.

Beyond the repeller electrode **16** on the far side of the repeller from the bottom of the ion chamber **11**, the second focusing electrode **22** is supported in insulated relationship with respect to the repeller electrode. The deflection electrode **22** is a flat metal plate that is insulated both from electrode **16** and from the first focusing electrode **13** so that operating voltages of these electrodes can be adjusted separately for obtaining optimum trajectories of the electrons in the ion chamber **11** for producing a maximum number of positive ions. The deflection electrode **22**, the heat shield **26** and the filament **12** all are connected to adjustable tap **40** which is approximately 50 to 100 volts more positive than the potential of the focus electrode **13** at tap **41**. The distance from the second deflection electrode **22** to the repeller electrode **16** is chosen so that the electrode **22** can be operated at filament potential. This eliminates the need for another control and another adjustment. This distance is determined experimentally and is 0.100 inch, for example, in an operative embodiment of this invention.

The heater element **23** behind the focusing electrode **22** indirectly heats the electrode **22** and the whole ion source. About 20 watts of power, for example, is supplied to the element **23** by the power supply **25** through the switch **38**. About 20 watts of power also supplied to the filament **12** by the power supply **29** through the switch **39**.

In accordance with one of the features of this invention, the switches **29** and **38** are ganged, as is illustrated by the dashed line **44** in FIG. 1, so that the heater **23** is turned off when the filament **12** is switched on, and vice versa. This provides approximately constant ion source temperature and sufficient heat at all times to prevent contamination of the ion source regardless of whether or not the filament **12** is on or is off. External heater elements, not shown, also are mounted on the tube envelope at positions where contamination otherwise would occur. The temperature of the housing in the ion source region is maintained at from 80 degrees to 90 degrees centigrade, for example. By heating the ion source, as is described above, contamination is prevented and the spectrometer tube, in which the ion source is used, for example, will retain its sensitivity and optimum performance for a considerable length of time.

By using the two heaters (filament **12** and coil **23**) alternately, a maximum usable amount of heat is put into the ion source at all times. In prior art ion sources the heat for decontaminating the ion source is produced both by a hot repeller and by the filament of the electron beam producing means. Therefore, the watts of power supplied to the repeller added to the watts of power supplied to the filament must be the maximum allowable. In this prior art ion source when the filament is off (which is most of the time, nights, etc.), maximum heat to avoid contamination is not being used.

In operation, when the filament **12** is energized by closing the switch **39** there is produced a beam of electrons **42** having a rectangular cross section. The beam is shaped and accelerated by the focusing electrode **13** and by the accelerating electrode formed by the boundary of slit **28**. As the electron beam **42** crosses the ion chamber **11**, it collides with molecules of gas which come into the chamber from the gas inlet, FIG. 3, to produce positive ions.

Within the chamber **11** there is a tendancy for the electrons to penetrate the repeller electrode **32** to be partly collected and partly deflected back into the ion chamber **11**. By providing a focusing electrode **22** behind the repeller electrode **16** and by adjusting the tap **40** to which electrode **22** is connected, the trajectories of the electron stream within the ion chamber **11** are controlled for achieving an optimum rate of ion production and an ion beam having maximum current.

The positive ions produced in the ion chamber **11** are repelled toward the bottom of the chamber by the repeller electrode **16**. The positive ions are formed into a beam having a rectangular cross section which passes through the rectangularly shaped slit **24** at the bottom of the ion chamber through the focusing electrodes **18***a* and **18***b*, and through the accelerating electrode **19**. The ion beam is wedge-shaped and comes to a line focus in the vicinity of the accelerating electrode **19**. Below the accelerating electrode **19** the ion beam passes through a rectangularly shaped slit **46** in an iron baffle **43** which is provided for intercepting stray ions. The baffle **43** is made from metal and is connected to ground as is illustrated in FIG. 3.

The improved ion source, as is described above, produces an order of magnitude increase in positive ion current with a corresponding increase in sensitivity of a mass spectrometer using this improved source. Optimum performance is maintained by avoiding contamination by alternately heating the source by the internal heater **23** and by the filament **12** as is described above.

Since changes could be made both in the illustrated embodiments of the invention and in the above description, and different words of description might be used without departing from the scope and spirit of the invention, it is understood that the invention is limited solely by the accompanyng claims.

What is claimed is:

1. An ion source comprising an ion chamber, means including a filament and first focusing electrode for producing and directing a stream of electrons into said chamber, an ion outlet on one side of said chamber, a grid positioned on the opposite side of said chamber for repelling ions toward said one side, and a deflection electrode positioned on the far side of said grid from said one side of said chamber and substantially parallel to said grid for controlling the trajectories of electrons in said chamber to increase the amount of positive ions which are produced in said chamber, said deflection electrode imposing operative field forces in said chamber through the interposed grid.

2. The ion source as is set forth in claim **1**, in which said deflection electrode is physically separated from said grid.

3. The ion source as is set forth in claim **2**, further including means for supplying different voltages to said deflection electrode and said grid.

4. The ion source as is set forth in claim **1**, further including a heater positioned behind said deflection electrode, and means for energizing said heater and said filament alternately for maintaining an approximately uniform temperature in the ion source for preventing contamination.

5. An ion source comprising an ionizing chamber, means including a filament and an electron focus electrode positioned laterally of said chamber for producing and directing an electron stream into said chamber to produce positive ions, an opening in the bottom of said chamber for passing ions out of said chamber, a repeller electrode positioned at the top of said chamber, said repeller electrode comprising a plurality of spaced conductive elements between which electrons can escape from said chamber, and a deflection electrode positioned above said repeller electrode, spaced physically therefrom in

substantially parallel relation, and operative therethrough for controlling the trajectories of the electron stream in said chamber.

6. An ion source as is set forth in claim 5, further including a heater positioned behind said deflection electrode, and means for energizing said heater and said filament alternately for maintaining an approximately uniform temperature in the ion source for preventing contamination.

7. An ion source comprising an ion chamber having a bottom wall and upwardly extending side walls, an aperture in one of said side walls, means for producing and directing a stream of electrons through said aperture into said chamber, an aperture in said bottom wall, a grid positioned at the top of said ion chamber for repelling ions through the aperture in the bottom wall of said chamber, a deflection electrode positioned adjacent said grid on the far side of said grid from the bottom wall of said chamber, said deflection electrode being physically spaced from said grid and in parallel relation thereto, and operative therethrough for controlling the trajectories of the electron stream in said chamber.

8. The ion source as is set forth in claim 7, further including adjustable means for supplying voltages to said repeller electrode and to said deflection electrode to control the trajectories of the electron stream in said chamber for optimizing the production of positive ions in said chamber.

9. The ion source as is set forth in claim 7, further including a heater positioned behind said deflection electrode for indirectly heating said second focus electrode and said ion source, and means including a switch for energizing said heater.

10. The ion source as is set forth in claim 7, wherein said grid comprises a metal frame having a plurality of spaced wire portions stretched across said frame in at least one plane and firmly anchored to said frame.

11. The ion source as set forth in claim 7, said means for producing electrons comprising a filament having a width substantially equal to the height of the electron beam aperture in the side wall of the ion chamber.

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