PATENT SPECIFICATION (11) 1 576 474

(21) Application No. 2050/77 (22) Filed 19 Jan. 1977 (19)
(31) Convention Application No. 650 531
(32) Filed 19 Jan. 1976 in
(33) United States of America (US)
(44) Complete Specification published 8 Oct. 1980
(51) INT. CL.[3] H01J 47/02
(52) Index at acceptance
H1D 17D 38 8G 9G 9L 9Y

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(54) ION DETECTION ELECTRODE ARRANGEMENT

(71) We, HNU SYSTEMS INC., a corporation organised under the Laws of the Commonwealth of Massachusetts, United States of America, of 383 Elliot Street, Newton Upper Falls, Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the detection of ionized gaseous species.

In accordance with a first aspect of the present invention, there is provided apparatus for detecting ionized gaseous species, comprising: a radiation source for ionizing said species; a collector electrode having a configuration defining an annulus extending across the path of radiant energy emission from the radiation source; a second electrode biased to a polarity opposite to that of said collector electrode and comprising an elongate member having a distal end positioned centrally of the collector electrode and directly exposed in the path of said radiant energy emission, whereby molecular fragments consisting of ions and any free electrons produced by the radiant energy in the gas are exposed to a biasing potential difference between said collector electrode and said second electrode and whereby those said molecular fragments of polarity determined by said bias are collected at said collector electrode, current detector means being connected to said collector electrode for providing an indication of the resultant current flow therethrough; and a shield opaque to radiant energy emission from said source positioned intermediate said source and said collector electrode, the shield having an aperture therethrough aligned with the axis of the collector electrode annuls, the aperture being defined by a surface spaced from said axis by a lesser radial distance than the collector electrode annulus, and the arrangement being such that, while the second electrode is exposed to direct radiant energy through said aperture from said source, the shield is effective to substantially completely prevent impingement of said direct radiant energy on said collector electrode.

In a second and alternative aspect of this invention, there is provided a method of detecting ionized gaseous species, the method comprising: ionizing said species by directing radiant energy from a radiation source into the gas in the region of a collector electrode having a configuration defining an annulus extending across the path of radiant energy emission from the radiation source and a second electrode biased to a polarity opposite to that of said collector electrode and comprising an elongate member having a distal end positioned centrally of the collector electrode and directly exposed in the path of said radiant energy emission, whereby molecular fragments consisting of ions and any free electrons produced by the radiant energy in the gas are exposed to a biasing potential difference between said collector electrode and said second electrode, while shielding the collector electrode to substantially completely prevent impingement thereon of direct radiant energy from said source by means of a shield opaque to said radiant energy emission which shield is positioned intermediate said source and said collector electrode and has an aperture therethrough aligned with the axis of the collector electrode annulus which aperture is defined by a surface spaced from said axis by a lesser radial distance than the collector electrode annulus; and providing an indication of the resultant current flow through the collector electrode resulting from those said molecular fragments of polarity determined by said bias collected thereat by means of a current detector means connected to said collector electrode.

In preferred embodiments, the radiation shield is rigid and comprises an electrically non-conductive and chemically inert material such as fluorinated hydrocarbon organic plastics material or a ceramic insulating material.

In preferred arrangements, the shield comprises a metallic electrostatic shielding material. The metallic electrostatic shielding material may be formed as a coating on organic plastics material.

In the preferred arrangement, both the collector electrode and the shield apertures are coaxial about the second electrode. The collector electrode is preferably a continuous ring and is supported in a spaced relationship relative to the radiant energy shield. The shield suitably extends a limited distance parallel to the axis within and spaced from the collector electrode and partially overlying the inner side of the collector electrode. The second electrode suitably extends to a position closely adjacent the radiation source, and in one embodiment it is tubular in configuration and adapted for conveying samples therethrough to a position adjacent the radiant energy source, the exit ports from the second electrode tube being on the sides thereof, its end being closed.

The invention is hereinafter more particularly described by way of example only with reference to the accompanying drawings, in which:—

Fig. 1 is a side elevational view, partly in section, of one embodiment of apparatus in accordance with the present invention;

Fig. 2 is an enlarged elevational view, partly in section, of part of the apparatus shown in Fig. 1 but rotated through 90° about the longitudinal axis of the apparatus;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is a side elevation, in section, of a modified embodiment of apparatus in accordance with the present invention and adapted for use in chromatographic applications; and

Fig. 5 is a schematic diagram of the detection circuit of the apparatus.

In Fig. 1 there is illustrated an embodiment of apparatus in accordance with this invention in the form of a hand-held sensor of a trace gas analyzer. The sensor comprises a body 10 having a cable 12 extending therefrom to the analyzer, comprising the instrument power source, controls and readout.

Within body 10, a recessed housing 14 contains a radiation source 16, here a low pressure Krypton filled lamp for producing monochromatic vacuum ultraviolet radiation (1236 A°, having an energy level of 10.oeV). Lamp 16 has its cathode 18 in contact with electrical connector 20 and its anode 22 in contact with another electrical connector (not shown), both connectors connected by suitable cables (not shown) to the power source. Lamp 16 has a circular ultraviolet transmitting window 24 of magnesium fluoride, exposed to a cylindrical photoionization chamber 26 thereadjacent. A glass capillary 28 is provided in the lamp 16 to collimate the radiant energy emission therefrom.

Photoionization chamber 26 is formed in a recess, coaxial of lamp 16, in electrode support 30. A cover 32 extends across chamber 26 at the end thereof opposite lamp 16. A gas inlet 34 extends through cover 32 to chamber 26, coaxially thereof. An open protective screen 36 which allows the passage of gas is mounted between support 30 and cover 32 extending across inlet 34. A gas passage 38 extends through support 30 to a fan 40 in housing 14, the fan 40 being arranged to draw gas from inlet 34, through chamber 26 and passage 38, and to exhaust the gas through outlet 42.

As best shown in Figs. 2 and 3, support 30 houses and supports detection electrodes 44 and 46 in chamber 26. Electrodes 44, 46 are of gold plated brass material. The electrodes 44, 46 are supported in insulated fittings 48 the exterior metal jackets of which are connected by wires 50 to grounding connections 52. The electrodes 44, 26 are connected by wires 54 to terminal jacks 56 adapted for connection to the power source (not shown) which biases electrode 44, suitably to +180V. As shown in the drawings the connection of the electrodes 44, 46 and jacks 56 are made in exterior recesses 58 in support 30; the recesses 58 are closed by an outer annular member 60.

Electrode 44 comprises an elongate member extending inwardly from support 30 and bent in chamber 26 to place its distal end closely adjacent window 24 (spaced 0.020 inches therefrom in the preferred embodiment) coaxially of the axis along which radiant energy is emitted from lamp 16 i.e., coaxially of capillary 28 and window 24. Electrode 44 has a diameter of 0.062 inches in this preferred arrangement.

Electrode 46 in the preferred arrangement comprises a continuous annular ring of rectangular cross-section having an inner diameter of 0.375 inches, a material thickness of 0.032 inches, and a height, parallel to the axis of lamp 16, of 0.093 inches. Electrode 46 is coaxial of electrode 44 and the axis of radiant energy emnssion of lamp 16, lying in a plane transverse, i.e., normal, to the axis and parallel to the plane of window 24.

Support 30 is made of material opaque to radiation from lamp 16, e.g., a fluorinated hydrocarbon sold under the trademark "Kel-F" by Westlake Plastics Company of Lenni, Pennsylvania, in the illustrated embodiment. Adjacent lamp 16, support 30 has a portion 62 extending radially inwardly between the lamp 16 and electrode 46 to provide a radiation shield preventing exposure of electrode 46 to direct energy emission from lamp 16. Shield 62 defines a circular aperture coaxial of the energy axis of lamp 16, having an annular surface 64, parallel to the axis of lamp 16, with a smaller diameter (0.250 inches in the preferred arrangement) than the inner diameter of the electrode 46. The surface 64 has a height or axial extent of 0.080 inches in the preferred arrangement. Facing electrode 46, shield 62 is provided with an annular recess 66. A shielding lip 68 is also defined. The outer diameter of lip 68 is 0.320 inches in the preferred arrangement. Electrode 46 is suspended in recess 66, 0.020 inches above the bottom thereof in the preferred arrangement, and by virtue of their respective diameters electrode 46 is spaced from shielding lip 68 and from the outer wall of recess 66, as well. In an axial direction electrode 46 extends above lip 68 a distance of 0.053 inches in the preferred arrangement.

With the electrodes 44, 46 thus arranged, the electrode 44 is directly exposed to radiant energy from lamp 16 at its point of maximum intensity. The electrode 46, however, though also positioned close to lamp 16, is shielded from exposure to radiant energy by shield 62 and its shielding lip 68. In the illustrated embodiments, the cone angle formed between the cone including the inner edges 70, 72 of electrode 46 and lip 68 which are axially remote from window 24 and the axis of the radiation source is about 50°. The angle thus formed substantially shields the electrode 46 from energy emitted through the window 24. With the lip 68 present as shown, electrode 46 will be seen to be shielded both from direct and indirect impingement of energy emitted by lamp 16.

As is also best illustrated in Figs. 2 and 3, interposed between radiation shield 62 and lamp 16, adhesively affixed to shield 62, is an annular electrostatic shield 74. Electrostatic shield 74, in the illustrated embodiment, comprises aluminized organic plastics material (Mylar—Registered Trade Mark), with the plastics interposed between the aluminium layer and lamp 16 for insulation purposes. Alternatively, a low flux ferromagnetic material, e.g., that sold under the trademark "Shieldmu" by Russell Industries, Inc., of Lynbrook, New York, may be employed. Electrostatic shield 74 has an inner diameter equal to that of radiation shield 62 and extends outwardly, under electrode 46, beyond window 24 and preferably to the extent of the diameter of photoionization chamber 26.

Fig. 4 illustrates a modification of the photoionization apparatus described above adapted for use in conjunction with a gas chromatograph and with functionally similar parts correspondingly numbered with a prime designation. The major differences of the modified apparatus are in the construction of one of the electrodes, and the gas inlet. The inlet 34^1 is in a tube 35^1 adapted for connection to the outlet from a chromatograph (not shown). Tube 35^1 extends from inlet 34^1 and bends to locate its passage 37^1 therewithin coaxially of lamp 16^1. A heater 75 is mounted in the apparatus to control the temperature thereof. Mounted to a fitting 39^1 on tube 35^1, coaxially of lamp 16^1 is an electrode 44^1 comprising hypodermic stock having a passage therein 45^1. Electrode 44^1 extends to adjacent window 24^1 of lamp 16^1 to thus convey minute samples directly to the point of maximum energy radiation. To minimize contamination of window 24^1 exit ports 76^1 are provided on the side rather than the end of electrode 44^1. Gas exhausts from chamber 26^1 through passage 38^1 to outlet 42^1 without the need of a fan. Electrode 44^1 is connected by connector 57^1 to the power source (not shown) which biases the electrode 44^1, suitably to +300 V. The configuration and spacing of the other electrode 46^1, radiation shield 62^1, its shielding lip 68^1, and the electrostatic shield 74^1 are the same as in the previously described embodiment.

Fig. 5 schematically depicts the detection circuit employed with either of the embodiments shown in Figs. 1 to 3 or 4. A power source 77 is connected to the electrodes 44 (44^1) and 46 (46^1) to provide a biasing potential difference therebetween to which molecular fragments consisting of ions and any free electrons produced by the radiant energy in the gas will be exposed. The electrode 46 (46^1), which is shielded from the direct radiation energy emission from the radiation source, is connected to the power source 77 via a current flow amplifier 78 and a signal processor 80 which acts as a current detector means and which may comprise a meter, as shown, or may be of the digital type. The electrode 46 (46^1) thus acts as the collector electrode.

We have found that the configuration of an annular collector electrode shielded from the radiation source with an axial second electrode permits both electrodes to be spaced closely adjacent the radiation source. This we have found to contribute significantly increased sensitivity and linearity compared to parallel plate electrodes. The shielding has also been found by us to significantly reduce the effect of background noise and spurious currents which might arise by direct impingement of the radiant energy emission on the collector electrode.

The lip 68 is particularly useful in minimizing the effects of background noise when low level measurements are being made, e.g. 1 to 10 ppm. For higher level measurements, however, the range of linearity may be extended significantly by reducing the height of the lip 68 or eliminating it altogether, if the effects of the resultant increase in background noise can be tolerated. Of course, the collector electrode 46 (46[1]) must still be shielded from direct radiant energy emission in this modified configuration of apparatus.

The close spacing of the electrodes relative to each other also favourably affect sensitivity and linearity; however, too close spacing may result in an unacceptable increase in noise.

WHAT WE CLAIM IS:—

1. Apparatus for detecting ionized gaseous species, comprising: a radiation source for ionizing said species; a collector electrode having a configuration defining an annulus extending across the path of radiant energy emission from the radiation source; a second electrode biased to a polarity opposite to that of said collector electrode and comprising an elongate member having a distal end positioned centrally of the collector electrode and directly exposed in the path of said radiant energy emission, whereby molecular fragments consisting of ions and any free electrons produced by the radiant energy in the gas are exposed to a biasing potential difference between said collector electrode and said second electrode and whereby those said molecular fragments of polarity determined by said bias are collected at said collector electrode, current detector means being connected to said collector electrode for providing an indication of the resultant current flow therethrough; and a shield opaque to radiant energy emission from said source positioned intermediate said source and said collector electrode, the shield having an aperture therethrough aligned with the axis of the collector electrode annulus, the aperture being defined by a surface spaced from said axis by a lesser radial distance than the collector electrode annulus, and the arrangement being such that, while the second electrode is exposed to direct radiant energy through said aperture from said source, the shield is effective to substantially completely prevent impingement of said direct radiant energy on said collector electrode.

2. Apparatus according to Claim 1, wherein the shield comprises organic plastics material.

3. Apparatus according to Claim 1, wherein the shield comprises metallic electrostatic shielding material.

4. Apparatus according to Claim 3, wherein the metallic shielding material extends radially outwardly of said axis from said surface to a position at a greater radial distance from said axis than said collector electrode annulus.

5. Apparatus according to Claim 4, wherein both said electrodes are located in a generally cylindrical chamber, and wherein said metallic shielding material extends radially outwardly of said axis to a position adjacent the edge of said chamber.

6. Apparatus according to any one of Claims 3 to 5, wherein the shield further comprises organic plastics material positioned intermediate the collector electrode and the metallic electrostatic shielding material.

7. Apparatus according to Claim 3, wherein the metallic electrostatic shielding material comprises a coating formed on organic plastics material.

8. Apparatus according to any of Claims 3 to 7, wherein the metallic electrostatic shielding material comprises a low flux ferro-magnetic material.

9. Apparatus according to any one of Claims 3 to 8, wherein the metallic electrostatic shielding material comprises aluminium.

10. Apparatus according to Claim 2 or Claim 6, wherein said organic plastics material comprises a fluorinated hydrocarbon plastics material.

11. Apparatus according to Claim 1, wherein the collector electrode and the shield are spaced apart from each other.

12. Apparatus according to any preceding claim, wherein the distal end portion of the second electrode extends along said axis towards said radiation source terminating at a position spaced closely thereadjacent.

13. Apparatus according to any preceding Claim, wherein the second electrode comprises a tubular member adapted for conveying species to a position adjacent said radiation source, the said second electrode being closed at its end adjacent said source and having exit ports on the sides thereof adjacent said closed end.

14. Apparatus according to any preceding claim, wherein the collector electrode comprises a continuous annulus.

15. Apparatus according to any preceding claim, wherein the shield has a lip which extends within the collector electrode annulus for a distance axially thereof less than the axial extent of the collector electrode.

16. For detecting ionized gaseous species, apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

17. A method of detecting ionized gaseous species, the method comprising: ionizing said species by directing radiant energy from a radiation source into the gas in the region of a collector elec-

trode having a configuration defining an annulus extending across the path of radiant energy emission from the radiant source and a second electrode biased to a polarity opposite to that of said collector electrode and comprising an elongate member having a distal end positioned centrally of the collector electrode and directly exposed in the path of said radiant energy emission, whereby molecular fragments consisting of ions and any free electrons produced by the radiant energy in the gas are exposed to a biasing potential difference between said collector electrode and said second electrode, while shielding the collector electrode to substantially completely prevent impingement thereon of direct radiant energy from said source by means of a shield opaque to said radiant energy emission which shield is positioned intermediate said source and said collector electrode and has an aperture therethrough aligned with the axis of the collector electrode annulus which aperture is defined by a surface spaced from said axis by a lesser radial distance than the collector electrode annulus; and providing an indication of the resultant current flow through the collector electrode resulting from those said molecular fragments of poarity determined by said bias collected thereat by means of a current detector means connected to said collector electrode.

18. A method according to Claim 17, wherein the gaseous species is conveyed to the space between said collector electrode and said second electrode through the said second electrode, which second electrode comprises a tubular member closed at its end adjacent said source and having exit ports on the sides thereof adjacent said closed end.

19. For detecting ionized gaseous species, a method substantially as hereinbefore described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1980.
Published at The Patent Office, 25 Southampton Buildings, London WC2A 1AY,
from which copies may be obtained.

1576474 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG 4

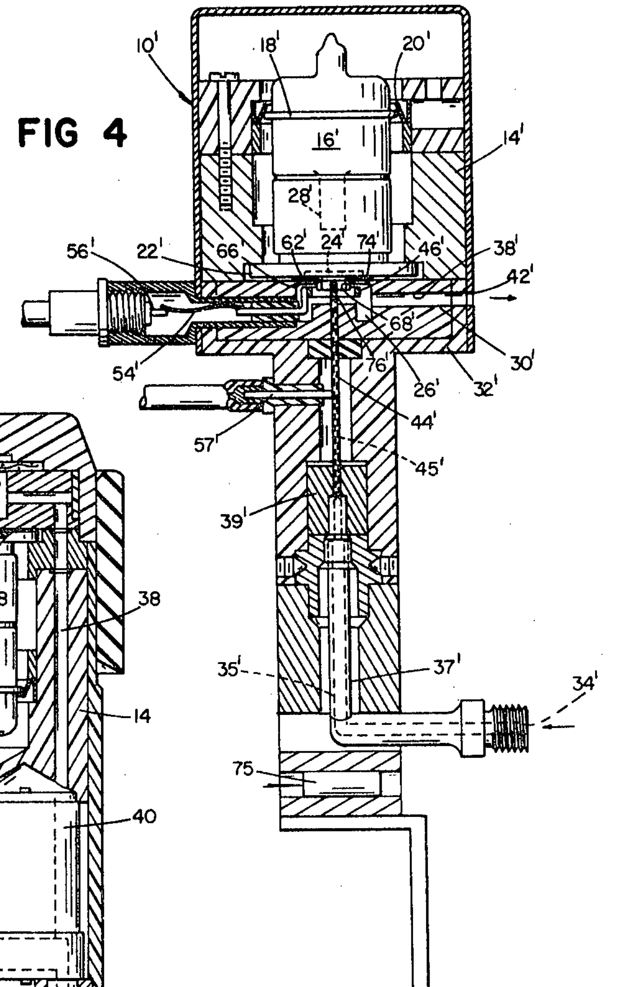


FIG 1

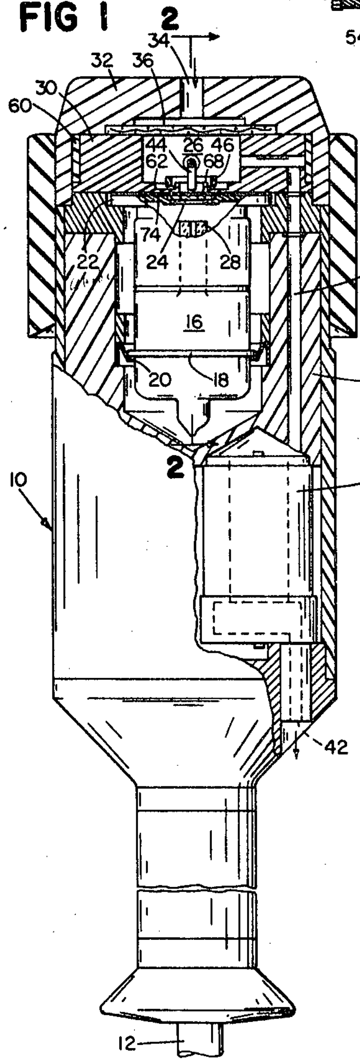
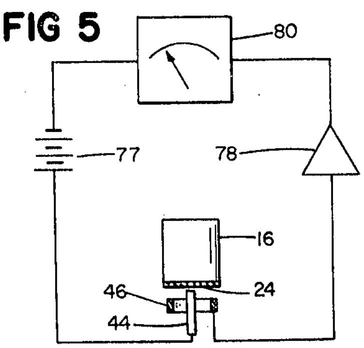


FIG 5



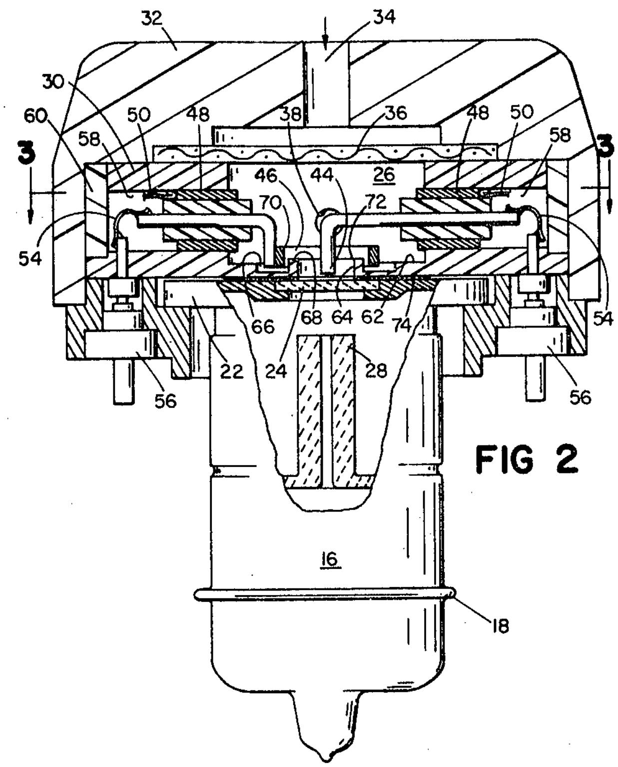

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FIG 2

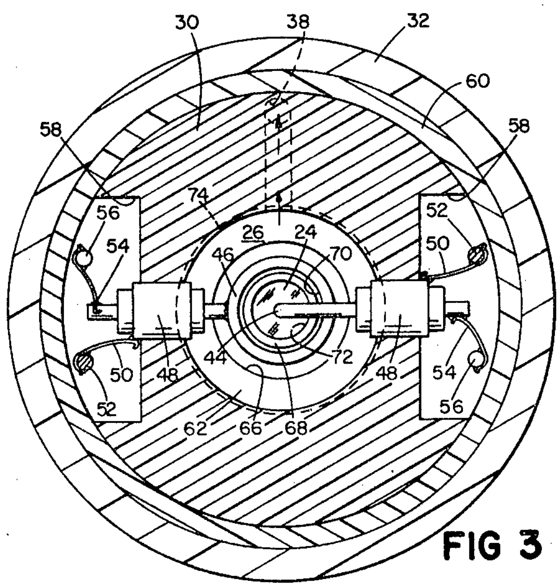
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FIG 3