

[54] ION BEAM INTENSITY MEASURING APPARATUS

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[58] **Field of Search**..... 250/41.9 D, 41.9 ME

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

1,171,700	11/1969	Great Britain	250/41.9 D
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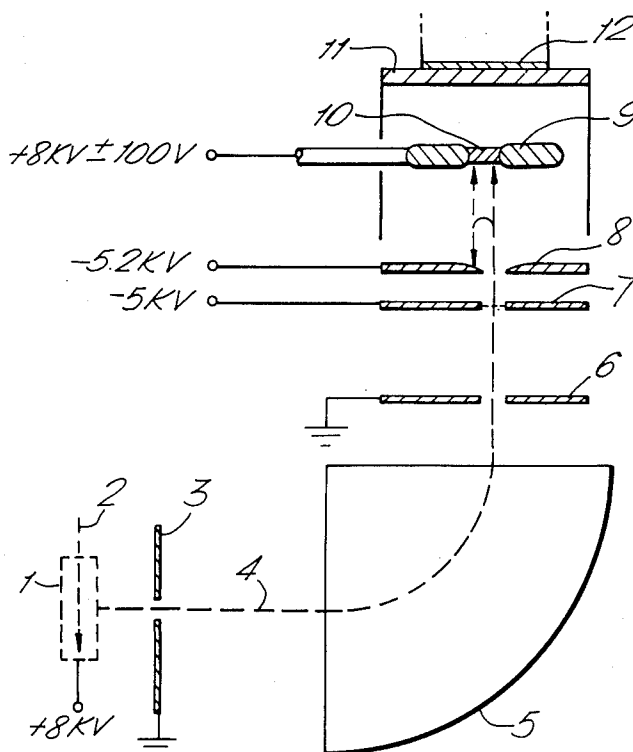
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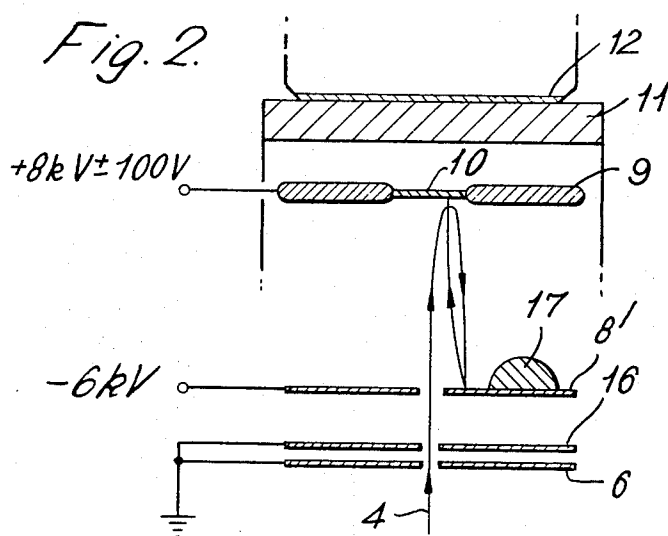
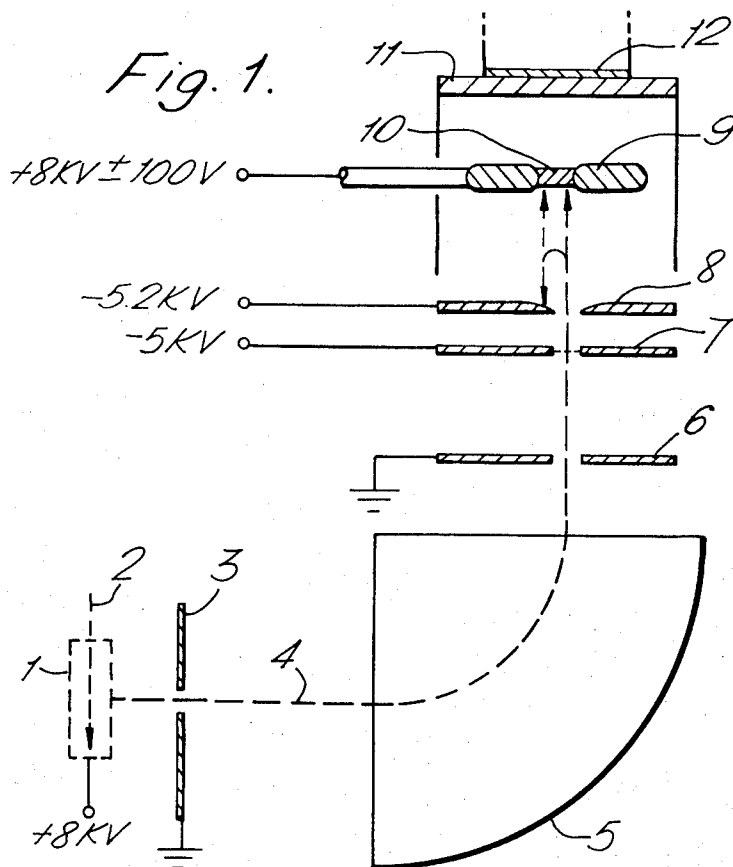
[57] **ABSTRACT**

In a known energy-selective ion measuring apparatus, mainly for mass spectrometers, the ions pass through an apertured electrode towards an electrode to which a variable retarding voltage is applied. The centre of the latter electrode is occupied by a scintillator beyond which is located a photomultiplier. When the retarding voltage equals or exceeds the ion source voltage, all ions are repelled to the apertured electrode to produce secondary electrons which are accelerated to the scintillator to produce an output. When the retarding voltage is less than the source voltage, only ions of lesser energy, such as metastable fragments, are so repelled.

In the present invention the aforesaid apertured electrode, instead of being earthed or earthy, is held at a high voltage opposite in sign to that of the retarding voltage, which increases the sensitivity. Optionally a transverse field is provided by an asymmetrical projection of the apertured electrode, in order to prevent ions being repelled through the aperture, thereby further increasing the sensitivity.

7 Claims, 2 Drawing Figures





ION BEAM INTENSITY MEASURING APPARATUS CROSS-REFERENCE TO RELATED APPLICATION

The known apparatus described above is the subject of copending U.S. Appln. Ser. No. 769,644, filed Oct. 22, 1968, by N. R. Daly and R. E. Powell, now U.S. Pat. No. 3,579,270, issued May 18, 1971.

BACKGROUND OF THE INVENTION

This invention relates to ion beam intensity measuring apparatus and methods suitable for mass spectrometers, and is a modification or improvement of the apparatus described in our British Pat. No. 1,171,700 (U.S. Application Ser. No. 769,644 filed Oct. 22, 1968, now U.S. Pat. No. 3,579,270.).

In the latter specification there is described and claimed ion beam intensity measuring apparatus suitable for use with a mass spectrometer comprising a first apertured electrode for admitting the ion beam, a first retarding electrode located beyond said first apertured electrode to apply a retarding electric field to ions passing through the aperture, a detector for detecting secondary electrons emitted from said first apertured electrode by ions repelled to said first apertured electrode by said field, and a connection for applying a variable potential to said first retarding electrode. The detector is preferably a scintillation detector located centrally in the retarding electrode.

When the retarding electrode voltage equals or exceeds the source accelerating voltage, all ions are repelled to the apertured electrode where secondary electrons are produced which are accelerated to the scintillator and an output is obtained from a photomultiplier located beyond the retarding electrode. When the retarding electrode voltage is less than the source accelerating voltage, only ions of lesser energy, such as those resulting from metastable fragmentations are so repelled and produce secondary electrons. The apparatus thus has one application in determining metastable ion spectra.

A second, apertured, retarding electrode can precede the above-described arrangement, to which a lower voltage is applied, thus setting a lower as well as an upper limit to the ion energy detected and making the apparatus of more general application as an energy range selector.

The present invention provides a modified arrangement of increased sensitivity.

SUMMARY OF THE INVENTION

According to the present invention the apertured electrode preceding the first retarding electrode, and at which the secondary electrons are produced by repelled ions, is provided with a connection whereby it can be maintained at a high potential relative to the apertured input electrode of the measuring apparatus (for example, the resolving slit of a mass spectrometer), said high potential being of opposite polarity to the potential applied to said first retarding electrode.

The effect is firstly, to increase the energy of repelled ions which strike the apertured electrode, thereby increasing the secondary electron coefficient. Secondly, the emitted electrons strike the scintillator with increased energy, thereby increasing the light output.

The apertured electrode at which the electrons are produced may be preceded by a further apertured electrode and may be maintained at a potential which is

slightly negative relative thereto. In such an arrangement the increased potential is effectively provided between the retarding electrode and the further apertured electrode (which may be provided with a gridded aperture to improve the uniformity of the electric field), the electrode at which the electrons are produced also serving to suppress any electrons produced at the further electrode by the incident beam.

According to the present invention there may also be provided between the retarding electrode and the apertured electrode at which the secondary electrons are generated an electric field component whose direction is transverse to the axis of the aperture, whereby the ion paths between said two electrodes are displaced away from said axis and the tendency for ions to be repelled back through the aperture is thereby reduced.

The transverse field component may be provided by an assymmetrically located projecting portion of the apertured electrode, extending towards the retarding electrode, for example a part-cylindrical, eg semi-cylindrical, portion having its axis parallel to the slit which constitutes the aperture. The projecting portion preferably extends beyond the ends of the slit to provide a sensibly uniform transverse field in the slit region.

In the absence of such a transverse field component there is a tendency for a fraction of the ions repelled from the retarding electrode to pass back through the aperture in the preceding electrode, instead of striking it to generate secondary electrons. It will be apparent that the transverse field component would thus reduce the ion losses through the aperture whether or not the apertured electrode was held at the aforementioned high potential.

To enable the nature of the present invention to be more readily understood, attention is directed by way of example, to the accompanying drawings wherein:

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified diagram of a mass spectrometer embodying one form of the invention.

FIG. 2 is a similar diagram embodying a preferred form of the invention.

DESCRIPTION OF AN EMBODIMENT

In FIG. 1 a mass spectrometer comprises a conventional ion source 1 maintained at a high positive potential V_A , in the present example +8 kV. The gaseous sample is ionised by an electron beam 2. Positive ions are accelerated towards an earthed slit 3 from which a beam 4 passes to a magnetic sector 5. The beam leaving sector 5 passes through a slit in an earthed input electrode 6, which forms the resolving slit of the spectrometer in this embodiment. Thereafter it passes through the gridded aperture of an electrode 7 held at -5 kV, and then through the aperture of an electrode 8 held at -5.2 kV towards a retarding electrode 9. The potential of electrode 9 is variable above and below +8 kV.

The centre of electrode 9 is occupied by a scintillator 10 whose surface facing electrode 8 is coated with a thin layer of aluminium. Beyond electrode 9 is a window 11 against which is mounted the photocathode 12 of a photomultiplier tube.

The operation of the present apparatus is similar to that of the apparatus described in the aforementioned specification. If electrode 9 is held at say +7.9 kV, only ions of energy, less than 7.9 keV, e.g., metastable frag-

ment ions, are repelled to electrode 8 and produce secondary electrons thereat, which are accelerated into scintillator 10 and produce an output. If electrode 9 is held at say +8.1 kV, all the ions in the beam are repelled to electrode 8 and the photomultiplier output represents the total beam content.

The distinguishing feature of the present invention is that instead of the electrode at which the electrons are produced being at the same (earth) potential as electrode 6, as described in the aforementioned specification, electrode 8 is held at a high negative potential, in this example -5.2 kV, in order to increase the potential difference between the secondary-electron producing electrode 8 and the retarding electrode 9. As shown, electrode 8 may be preceded by electrode 7 and held slightly, e.g., 200 V, negative thereto. The increased potential difference is then effectively the 13 kV provided between electrodes 7 and 9, and the aperture in the former may include a grid to improve the uniformity of the electric field. Electrode 8 then acts not only to produce the secondary electrons, but also to suppress any secondary electrons produced by the incident beam 4 striking electrode 7.

It can be shown that, as an approximation,

$$S = K \cdot V$$

where S is the secondary electron coefficient at electrode 8 and V is the energy of the ions incident on this electrode.

Also, approximately,

$$L = V \cdot S$$

where L is the light output of scintillator 10 and V is the energy of the electrons incident on the scintillator.

Hence

$$L = K \cdot V^2$$

Since V is proportional to the potential difference between electrodes 9 and 7/8, by taking electrodes 7/8 to a high negative potential instead of to earth, the light output is increased accordingly. An increase in sensitivity by a factor 4 has been achieved thereby. The high potential applied to electrodes 7 and 8 is not critical, and a suitable value is readily found by experiment.

As described in the aforementioned specification, an apertured retarding electrode held at less than +8 kV can be provided between electrodes 6 and 7 to set a lower limit to the energy of ions detected.

DESCRIPTION OF PREFERRED EMBODIMENT

In FIG. 2 the ion beam 4 from the magnetic sector (not shown) of the mass spectrometer again passes through a slit in the earthed electrode 6 which forms the resolving slit of the spectrometer. Beyond electrode 6 is an earthed clean-up electrode 16 having an aperture slit, and beyond that a further electrode 8' having an aperture slit. The latter is the electrode at which ions repelled from the retarding electrode 9 generate secondary electrons as described with reference to FIG. 1. The electrons are accelerated onto the scintillator 10 which occupies the centre of electrode 9 as already described.

In FIG. 2 the electrode 8' comprises a semi-cylindrical portion 17 extending from its surface towards electrode 9. The axis of portion 17 is parallel to the slit in electrode 8'. The electric field lines from electrode 9 concentrate towards portion 17, which is

equivalent to providing a field component directed transversely to the axis of the aperture towards portion 17. The positive ions travelling towards and repelled from electrode 9 are therefore deflected from the axis towards portion 17 as shown, so that they strike electrode 8' away from the slit therein and their tendency to be repelled axially therethrough is reduced. Portion 17 extends beyond the ends of the slit so that the field in the slit region is sensibly uniform.

The (negative) secondary electrons are deflected back in the opposite direction in travelling from electrode 8' to scintillator 10.

The clean-up electrode 16 is not an essential feature of the invention.

The potential on electrode 9 is variable above and below the ion source voltage as hereinbefore described, e.g., it is held at +8 kV $\pm$ 100 V. The potential on electrode 8' is a high negative potential, e.g., -6 kV, in order to enhance the sensitivity of the measuring apparatus as described with reference to FIG. 1. When held at a high negative potential, high or low energy ions can be detected with almost equal efficiency.

A further apertured electrode connected to a positive potential lower than that of electrode 9 can be located between electrode 8' and electrode 16 to set a lower limit to the ion energy detected, as described in the aforementioned specification.

Suitable dimensions in the embodiment of FIG. 2 are:

Separation between electrodes 8' and 9: 1.5 inch

Height of portion 17: 0.1 inch

Diameter of portion 17: 0.2 inch

Distance of portion 17 axis from electrode 8 axis: 0.5 inch

Width of slit in electrode 8': 0.1 inch

Length of slit in electrode 8': 0.4 inch

Length of portion 17: 1.0 inch

It may be noted that if the negative potential applied to electrodes 8 (FIG. 1) or 8' (FIG. 2) is reduced to say -200 V, no sensitivity enhancement is obtained, but the potential acts to suppress any electrons emitted by ions striking electrodes 6 or 16. Variation of this potential can thus be used as a sensitivity control if desired.

I claim:

1. Ion beam intensity measuring apparatus suitable for use with a mass spectrometer comprising an apertured resolving electrode connected to a fixed reference potential, a first apertured electrode located beyond said apertured resolving electrode for admitting the ion beam and capable of emitting secondary electrons from a surface thereof, a first retarding electrode located beyond said first apertured electrode to apply a retarding electric field to ions passing through the aperture, a detector mounted on said first retarding electrode facing said first apertured electrode for detecting secondary electrons emitted from said first apertured electrode by ions repelled to said first apertured electrode by said field, means for applying a variable high potential to said first retarding electrode, and means for applying to said first apertured electrode a high potential which is of opposite polarity to said variable high potential relative to the fixed potential of said apertured resolving electrode.

2. Apparatus as claimed in claim 1 wherein said first apertured electrode is preceded by a further apertured electrode capable of being maintained at a potential which is slightly lower than that of said first apertured electrode.

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3. Apparatus as claimed in claim 1 comprising means located between said first retarding electrode and said first apertured electrode for providing an electric field component whose direction is transverse to the axis of the aperture, whereby the ion paths between said two electrodes are displaced away from said axis and the tendency for ions to be repelled back through the aperture is thereby reduced.

4. Apparatus as claimed in claim 3 wherein said first apertured electrode comprises an assymmetrically located projecting portion which extends towards said first retarding electrode in order to provide said field component.

5. Apparatus as claimed in claim 4 wherein said assymetrical portion comprises a part-cylindrical portion

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having its axis substantially parallel to a slit which constitutes the aperture.

6. Apparatus as claimed in claim 5 wherein said projecting portion extends beyond the end of the slit to provide a sensibly uniform transverse field in the slit region.

7. Apparatus as claimed in claim 1 wherein said means for applying a variable potential and said means for applying a potential comprise means for applying to said first retarding electrode a variable positive potential relative to said apertured resolving electrode, and means for applying to said first apertured electrode a negative potential relative to said apertured resolving electrode.

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