United States Patent

Werner

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[54] ION SOURCE COMPRISING A CONCAVE-SHAPED REPELLER

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[21] Appl. No.: **858,772**

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.**.....**250/41.9 SB,** 313/63, 313/230

[51] **Int. Cl.**.....**H01j 39/36**

[58] **Field of Search**.....250/41.9 SB, 41.9 SA, 41.9 SE; 313/63, 230

[56] **References Cited**

UNITED STATES PATENTS

2,499,289	2/1950	Backus	250/41.9 SB
2,772,362	11/1956	Dietz	250/41.9 SB

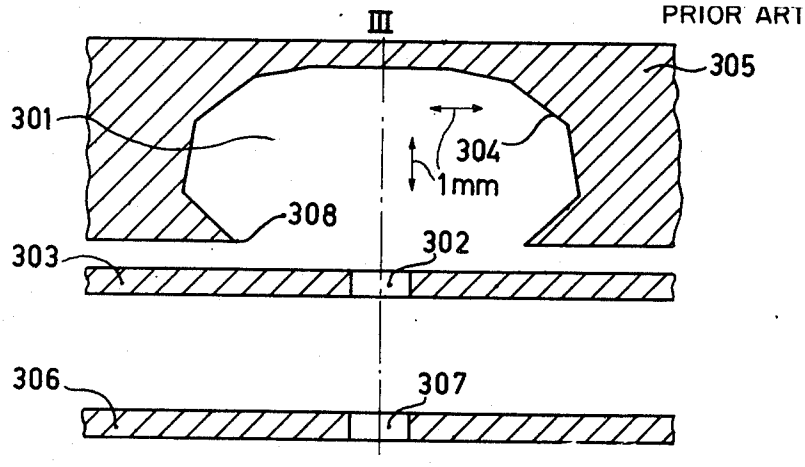
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[57] **ABSTRACT**

An ion source in which gas is ionized by an electron beam in an ionizing space between a narrow extraction gap in an extraction electrode and an inner wall of a repeller electrode; the wall extending substantially parallel to the extraction gap with the open side of the wall facing the gap. The ions are drawn out of the ionizing space through an extraction electrode along electric fields produced by an acclerating electrode. The repeller electrode has a concave-shaped form for making the effective electric field of the ionizing space substantially independent of the accelerating voltage, thereby resulting in high extraction efficiencies.

2 Claims, 10 Drawing Figures



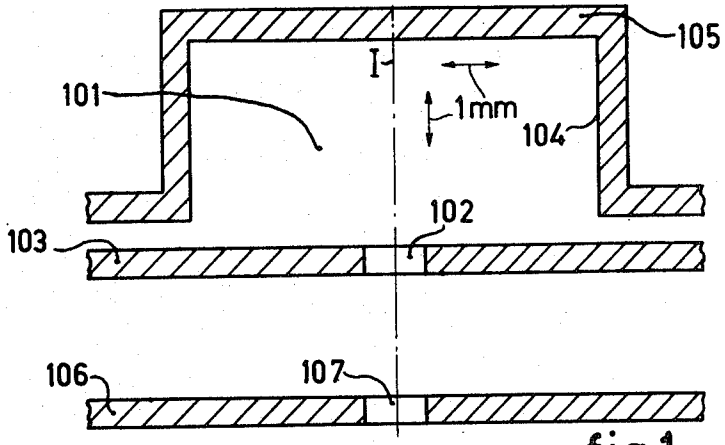


fig.1 PRIOR ART

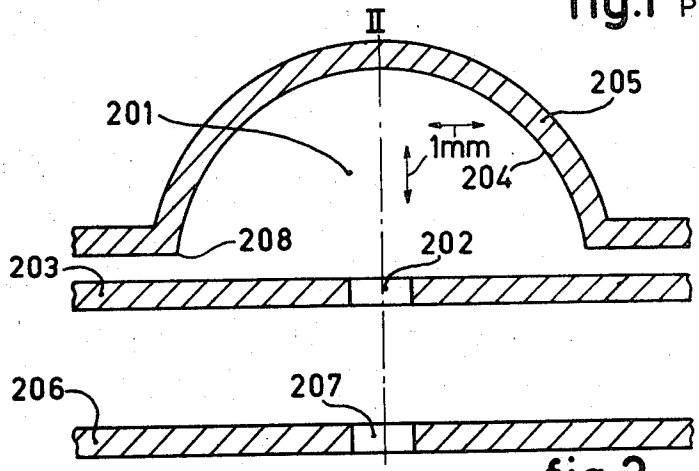


fig.2 PRIOR ART

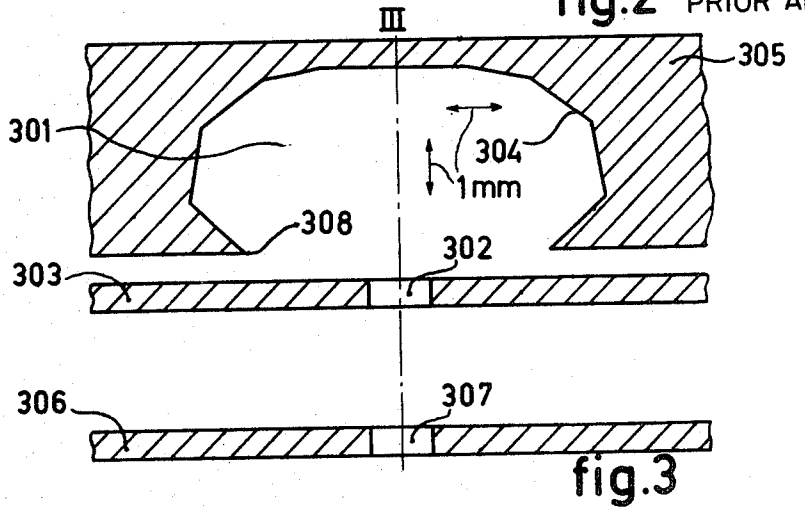


fig.3

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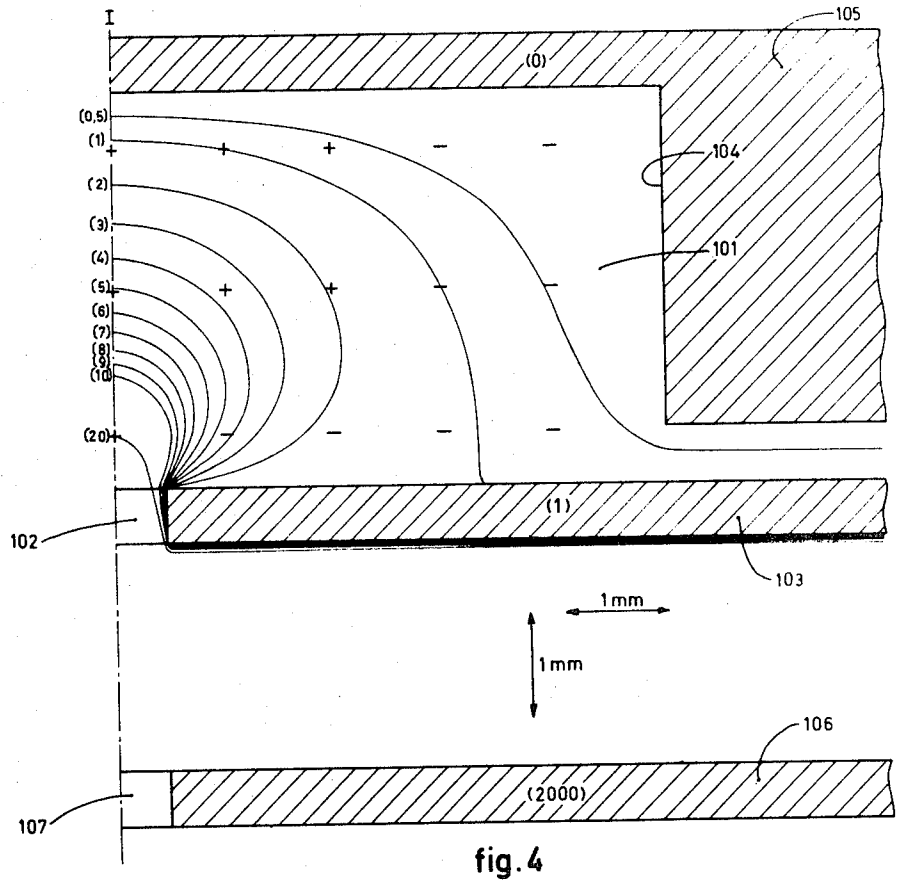


fig. 4

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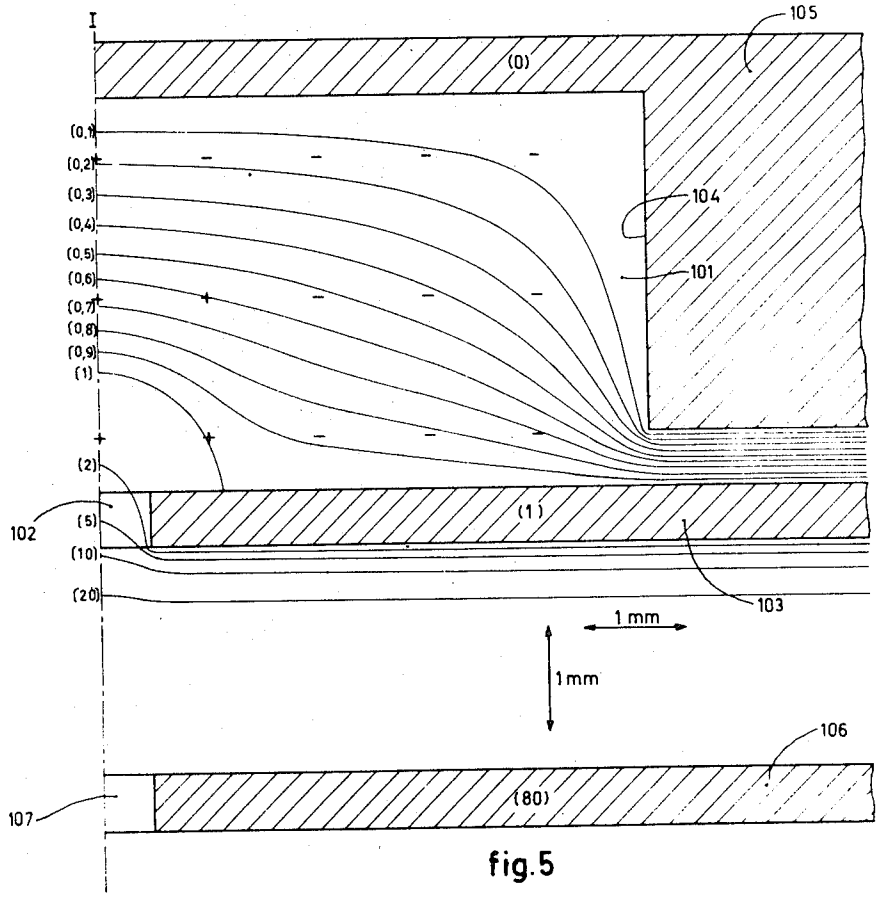


fig.5

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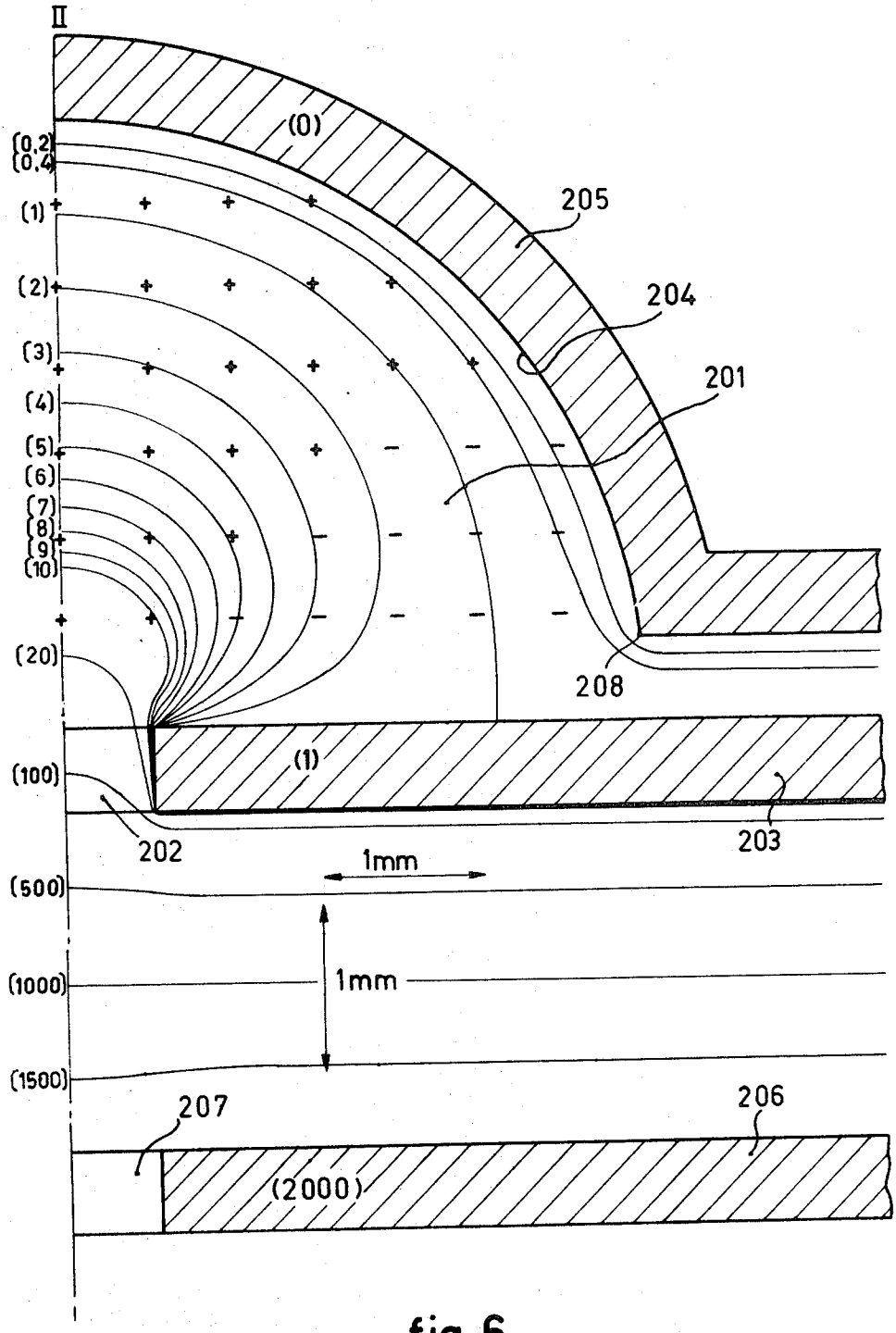


fig.6

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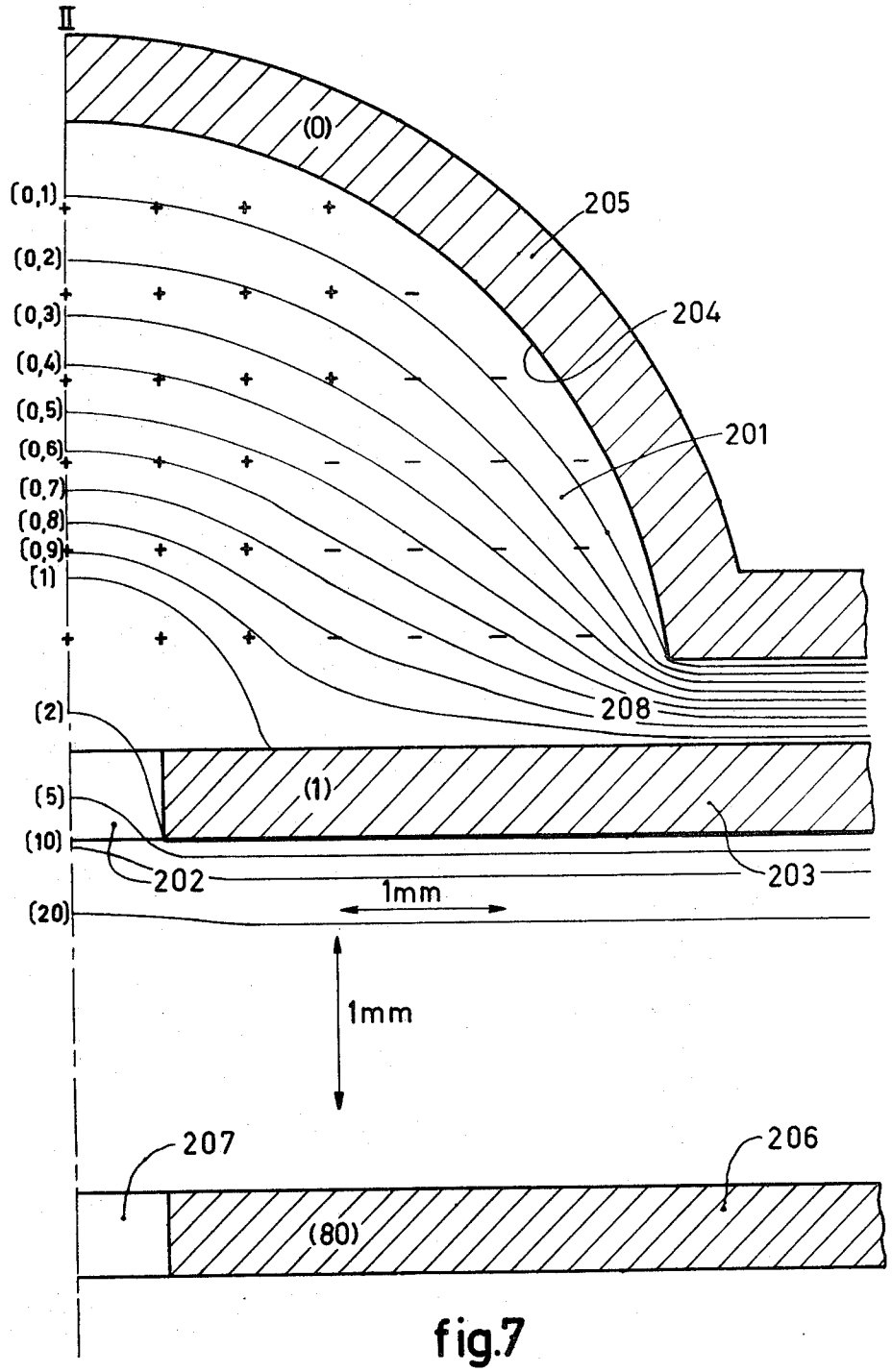


fig.7

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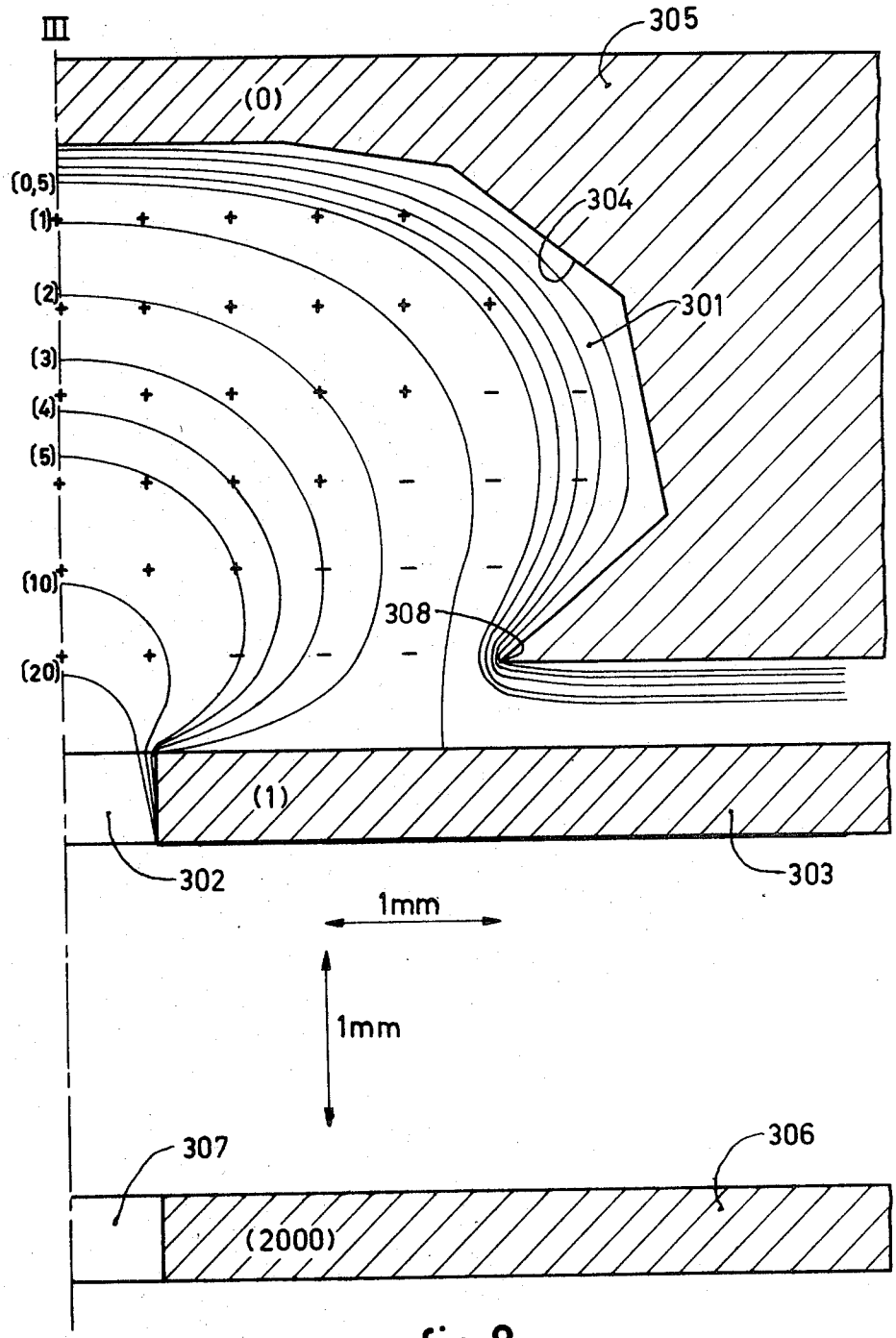


fig.8

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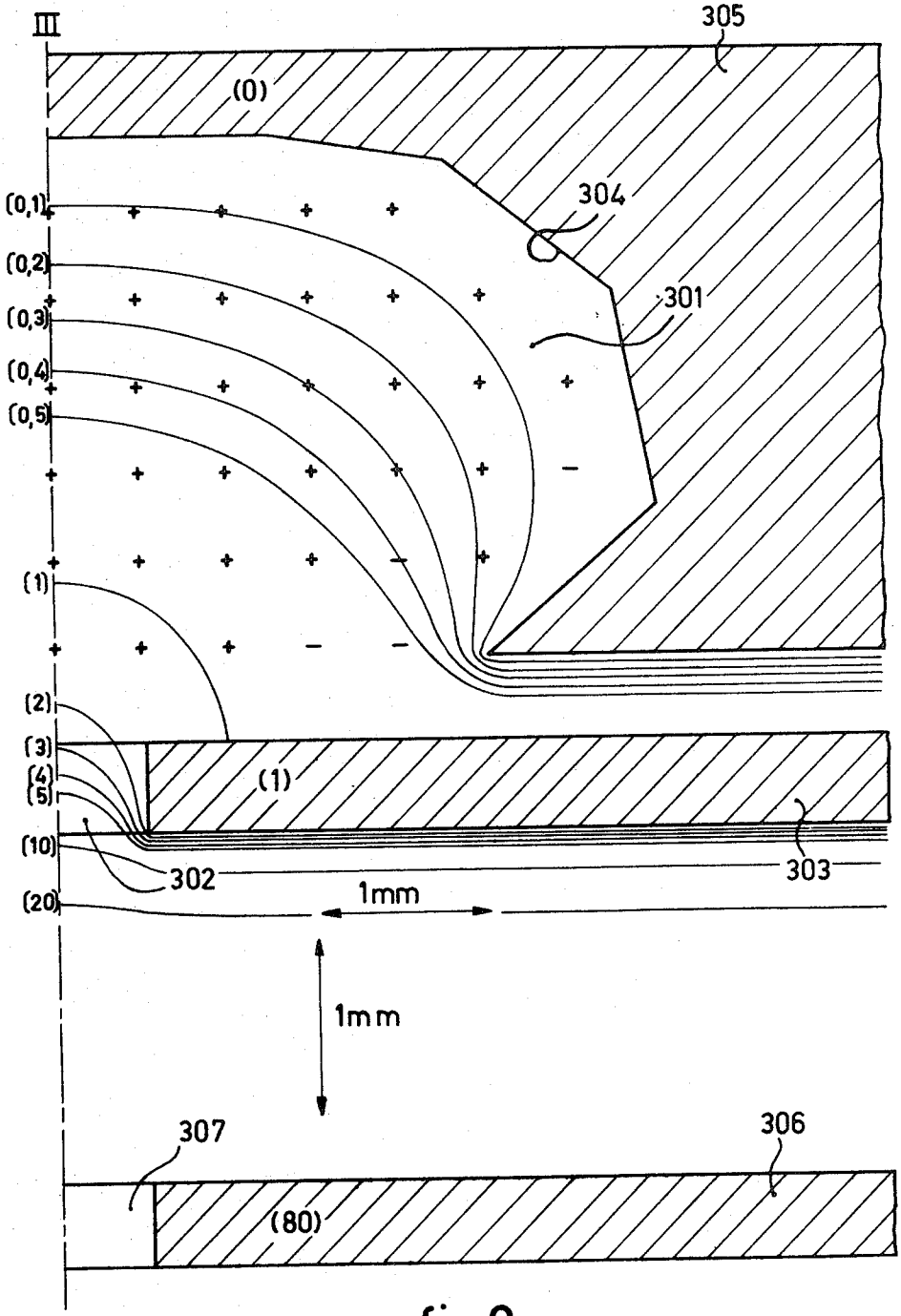


fig.9

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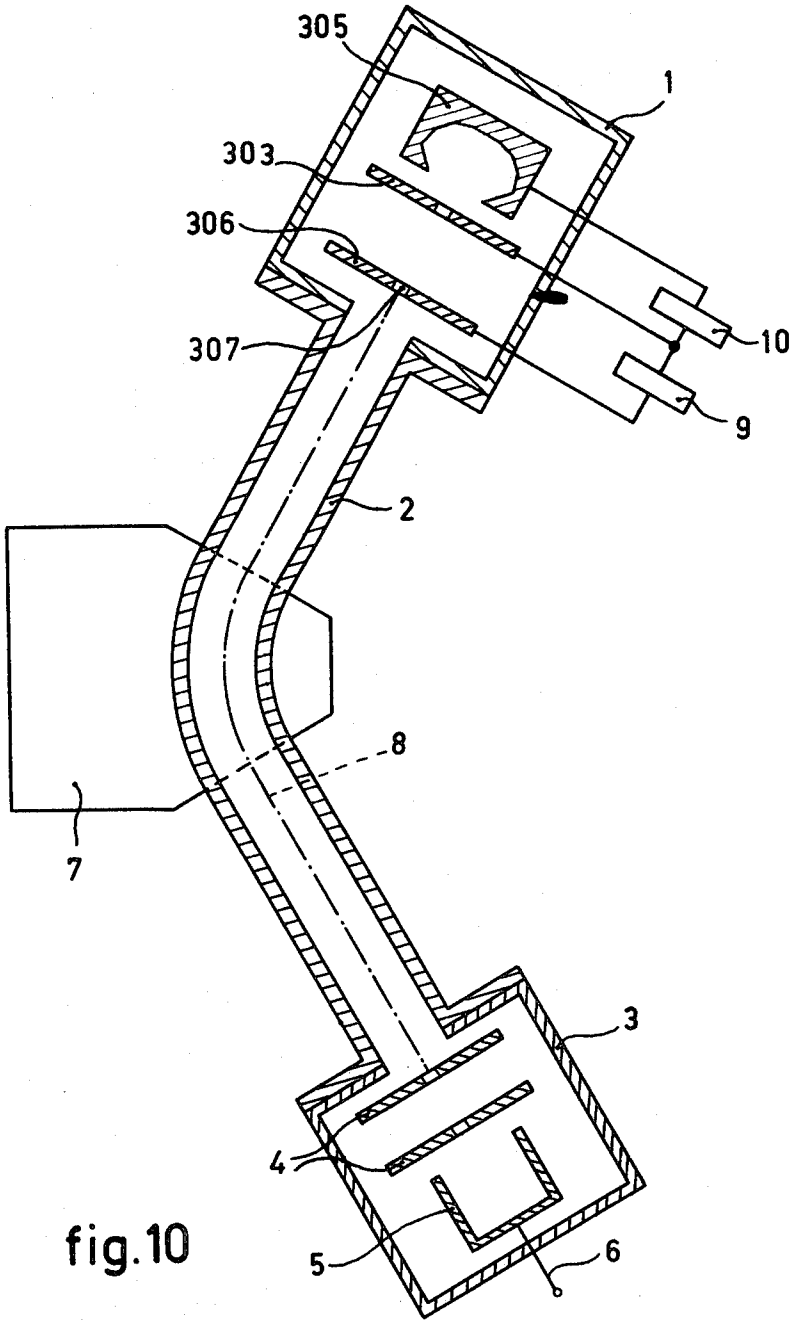


fig.10

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ION SOURCE COMPRISING A CONCAVE-SHAPED REPELLER

The invention relates to an ion source for use in a mass spectrometer in which an ionizing space between a narrow extraction gap in an extraction electrode and an inner wall of a concave-shaped repeller, said wall extending substantially parallel to the extraction gap, and the open side of said repeller facing the extraction gap, a gas is ionized by means of an electron beam extending substantially parallel to the extraction gap and in which the ions formed by means of the electron beam are drawn by an electric field through the extraction gap towards an acceleration electrode having a narrow exit aperture.

The extraction of the ions from the ionizing space is performed in such an ion source by means of the potential field in the ionizing space, which forms the superimposition of the field produced by the extraction voltage which is to denote the voltage of the extraction electrode with respect to the repeller electrode, and of the field due to the voltage of the acceleration electrode, which field is operative in the ionizing space across the extraction gap. An ion emerging from the exit aperture is accelerated by a voltage corresponding to the potential difference between the acceleration electrode and the point in the ionizing space, where the ion is produced. This voltage difference substantially corresponds with the voltage of the acceleration electrode with respect to the repeller electrode and as usual this voltage will be termed the accelerating voltage. The extraction voltage is usually very low, for example, a few volts, because the potential gradient in the ionizing space has to be low in order for the ions emerging from the ion source to be approximately mono-energetic.

In a mass spectrometer comprising such an ion source the substantially mono-energetic ions emerging from the ion source are separated spacially frequently in a sector-shaped magnetic field in accordance with the ratio of mass to charge, while only the ions having a mass-to-charge ratio corresponding to a given track in a magnetic field are recorded in an ion detection device. The ions travel along circular tracks in the magnetic sector field, the radius of said tracks depending upon the mass-to-charge ratio of the ions, upon the velocity of entrance in the magnetic field, or in other words upon the accelerating voltage in the ion source and upon the magnetic field strength. In some types of mass spectrometers of said kind the mass spectrum is recorded on the basis of variation of the magnetic field strength. The accelerating voltage is often of the order of magnitude of a few kilovolts. In other mass spectrometers of said kind recording of the mass spectrum is performed on the basis of variations of the accelerating voltage. In this case the so-called electro-static scanning is concerned. A mass spectrometer of said kind may also be constructed so that the spectrum can be obtained by electro-static or magnetic scanning. In the electro-static scan the accelerating voltage often covers a voltage range from a few kilovolts to a few 10 volts. The light ions are recorded at a high accelerating voltage and the heavy ions at a low accelerating voltage.

There is known an ion source comprising a channel-section repeller electrode, which forms a rectangular gutter.

Furthermore an ion source having a gutter-shaped repeller electrode is known in which the repeller electrode is formed by a curved plate the concave side of which faces the extraction gap, whilst the inner wall of the repeller electrode widens from the bottom of the gutter to the edge.

Said known ion sources only have a satisfactory efficiency at a high ion-accelerating voltage. In a mass spectrometer in which the mass spectrum is recorded on the basis of variations of the ion-accelerating voltage they give rise to considerable differences in sensitivity to light and heavy ions.

The invention has for its object to provide an ion source in which these disadvantages are mitigated for the major part.

According to the invention in an ion source for use in a mass spectrometer in which in an ionizing space between a narrow extraction gap in an extraction electrode and an inner wall of a concave-shaped repeller electrode facing the extraction gap

by its open side, said wall extending substantially parallel to the extraction gap, a gas is ionized by means of an electron beam extending substantially parallel to the extraction gap and in which ions formed by means of the electron beam are drawn with the aid of an electric field through the extraction gap towards an acceleration electrode having a narrow exit aperture, the inner wall of the repeller electrode has near the edge a portion tapering towards the edge.

The configuration of the equipotential lines of the field obtained in the ionizing space of this ion source due to the extraction voltage per se corresponds satisfactorily with the configuration of the field operating across the extraction gap in the ionizing space produced by the voltage of the acceleration electrode, said configuration being such that the lines which are orthogonal to the equipotential lines converge from a large region of the ionizing space towards the extraction gap. The shape of the repeller electrode compels the field due to the extraction voltage to assume a configuration which satisfactorily corresponds with the configuration of the field acting across the extraction gap and produced by the voltage of the acceleration electrode so that the superimposition of these two fields provides a similar configuration. The electric field lines of this superimposition are orthogonal to the equipotential lines of said superimposition so that they converge from a large region of the ionizing space towards the extraction gap practically independently of the value of the extraction voltage with respect to the accelerating voltage. The extraction region, which is to denote the region in the ionizing space from where the ions may emanate and pass the exit gap, is therefore large and substantially independent of the value of the extraction voltage relative to the accelerating voltage.

Surprising results have been obtained in a simple embodiment of the invention in which the sectional area of the inner wall of the repeller electrode at right angles to the direction of the extraction gap, viewed from the latter, forms a concave polygon having obtuse angles. According to a further aspect said sectional area may be a flowing line forming the circumference of such a polygon.

The properties of the ion source are particularly important for mass spectrometers in which the spectrum is recorded on the basis of electro-static scan. The invention particularly relates to a mass spectrometer comprising said ion source and in which between the ion source and an ion detector a magnet is provided for producing a magnetic sector field of constant field strength for the spacial separation between ions of different masses, while means are provided for varying the accelerating voltage independently of the extraction voltage for scanning the mass spectrum of the gas in the ion source. In this mass spectrometer a low accelerating voltage (for example of a few 10 volts) is combined, in the case of electro-static scan, with an extraction voltage which is comparatively high with respect to the former (for example a few volts). This comparatively high extraction voltage relative to the low accelerating voltage is required for overcoming the potential barrier due to the space charge in the ionizing space, which potential barrier is at a maximum for the heaviest ion, which are detected at the very lowest accelerating voltage. A high accelerating voltage (for example of a few kilovolts) at which the light ions are detected is, however, combined with an extraction voltage which is comparatively low with respect thereto (a few volts). The extraction voltage has to remain comparatively low with respect to said high accelerating voltage in order to restrict the energy spread and hence to ensure a satisfactory resolution of the ions. Owing to said properties of the configuration of the equipotential lines in the ionizing space in the ion source the combination of the low accelerating voltage with the extraction voltage of comparatively high value with respect to the former and of the high accelerating voltage with the extraction voltage of low value relative thereto do not give rise to appreciable difference in the extraction efficiency for light ions on the one hand and heavy ions on the other hand.

The invention will be described more fully with reference to the accompanying drawing.

FIG. 1 is a sectional view of a portion inside a vacuum envelope of a known ion source.

FIG. 2 is a sectional view of a portion in a vacuum envelope of a further known ion source.

FIG. 3 is a sectional view of a portion in a vacuum envelope of an ion source embodying the invention.

FIGS. 4 and 5 illustrate the properties of the ion source shown in FIG. 1.

FIGS. 6 and 7 illustrate the properties of the ion source shown in FIG. 2.

FIGS. 8 and 9 illustrate the properties of the ion source shown in FIG. 3.

FIG. 10 shows schematically part of a mass spectrometer in accordance with the invention comprising the ion source of FIG. 3.

The known ion source shown in FIG. 1 comprises an ionizing space **101** located between the extraction gap **102** in the extraction electrode **103** and the rectangular inner wall **104** of the gutter-shaped repeller electrode **105**. In the ionizing space a gas is ionized by means of an electron beam (not shown) travelling in a direction at right angles to the plane of the drawing. Behind the extraction gap the acceleration electrode **106** having an exit aperture **107** is arranged. FIG. 1 is drawn to scale. In the Figure a unit of length corresponding to 1 mm is shown.

The known ion source of FIG. 2 is drawn on the same scale as FIG. 1. The ionizing space **201** is located between the extraction gap **202** in the extraction electrode **203** and the circular inner wall **204** of the gutter-shaped repeller electrode **205**, which wall widens towards the edge **208**. The ion source comprises an acceleration electrode **206**, having an exit aperture **207**.

The ion source according to the invention in FIG. 3 is drawn on the same scale as that of FIGS. 1 and 2. The ionizing space **301** is located between the extraction gap **302** in the extraction electrode **303** and the inner wall **304** of the gutter-shaped repeller electrode **305**, which wall tapers towards the edge **308**. The sectional area of the inner wall **304** is a polygon having obtuse angles. The acceleration electrode **306** has an exit aperture **307**.

In FIG. 4 the part on the right-hand side of the line I of FIG. 1 is shown on an enlarged scale. In the ionizing space **101** in FIG. 4 equipotential lines of the electric field due to an extraction voltage of 1 V and an accelerating voltage of 2,000 V are illustrated. The potentials relative to the repeller at the places of the equipotential lines and at the electrodes are indicated in volts between brackets. FIG. 4 shows furthermore the region in the ionizing space **101**, from which on the basis of calculations in which the influence of the space charge is neglected, ions pass through the exit gap at said voltages with an initial speed zero. The places marked by "+" are associated with the extraction region and the places marked by "—" are located beyond the same. It has been found that the influence of the space charge like the influence of a magnetic field of the order of 100 Gauss is extremely slight. In FIG. 5 the equipotential lines and the extraction region in the same ionizing source are illustrated for an extraction voltage of 1 V and an accelerating voltage of 80 V.

FIGS. 6 and 7 relate to the ion source of FIG. 2 and are otherwise completely similar to FIGS. 4 and 5 so that further explanation may be dispensed with.

FIGS. 8 and 9 relate to the ion source of FIG. 3 and are otherwise completely similar to FIGS. 4 and 5; further explanation is therefore not needed.

A comparison between FIGS. 4, 5 and FIGS. 6, 7 shows that the configuration of the equipotential lines in the known ion sources is highly different at different accelerating voltages, which involves, as will also be seen from a comparison of FIGS. 4, 5 with FIGS. 6, 7 that the extraction region is highly different at different accelerating voltages. These high differences do not appear in an ion source in accordance with the invention. A comparison of FIGS. 8 and 9 shows that the configuration of the equipotential lines does not essentially differ at accelerating voltages differing by a factor **25**. A comparison of FIGS. 8 and 9 shows the stability of the extraction region in the ion source according to the invention. The extraction region indicated in FIGS. 8 and 9 is restricted to the ions of zero initial speed, but the same applies to ions of a thermal initial speed of any direction.

In the mass spectrometer of FIG. 10, reference numeral **1** designates the envelope of the ion source comprising the elements of FIG. 3. The envelope **1** of the ion source is connected through a partially curved tube **2** with an ion detection device, whose diaphragms **4** and ion collector **5** are accommodated inside the envelope **3**. The ion collector **5** is connected through the conductor **6** to a recording device (not shown). In the tube **2** the ions emerging from the exit gap **307** of the ion source are deflected by means of a magnetic sector field of 60° of a strength of 1,820 Gauss produced by the magnet **7** shown schematically. In the sector field the ions trace a circle of a radius proportional to the root of the product of the mass divided by the charge and of the accelerating voltage. At a given accelerating voltage practically only ions of a given ratio between mass and charge cover the track **8**, which terminates at the collector **5** and has a radius of curvature of 5 cms in a magnetic field. The spectrum of the gas in the ion source is obtained by the varying accelerating voltage provided by the voltage source **9**, shown in a block diagram. Between the extraction electrode **303** and the repeller electrode **305** prevails a voltage provided by the voltage source **10** shown in a block diagram. It has been found that in this mass spectrometer the extraction efficiency for light and heavy ions is particularly little different. At a variation of the accelerating voltage from 2,000 V, at which ions of the mass **2** are detected, up to the accelerating voltage of 100 V, at which ions of the mass **40** are detected, the extraction efficiency varies by a factor of less than 25 percent.

I claim:

1. An ion source comprising an envelope containing an ionizable gas, a repeller electrode within said envelope having a reentrant wall portion wherein the reentrant wall portion of said repeller electrode forms a concave polygon having obtuse angles, an extraction electrode within said envelope having a narrow extraction gap spaced from and parallel to the reentrant wall portion of said repeller electrode and forming therewith an ionizing space in which the gas is ionized by an electron beam, and an acceleration electrode spaced from and parallel to said extracting electrode on the side opposite said repeller electrode and having a narrow exit aligned with said gap for providing an electric field within said ionizing space, the reentrant portion of said repeller electrode forming a concave cavity the wall of which tapers inwardly towards the extraction electrode to form an aperture of smaller cross-sectional area than portions further removed from said extraction electrode whereby the configuration of said electric field within said ionizing space is substantially independent of a voltage applied to said acceleration electrode.

2. A mass spectrometer comprising an ion source, said ion source comprising an envelope containing an ionizable gas to be analyzed, a repeller electrode having a reentrant wall portion within said envelope, a substantially flat extraction electrode having a narrow extraction gap positioned spaced from and parallel to the reentrant wall portion of said repeller electrode forming therewith an ionizing space, an electron beam for ionizing said gas, and an acceleration electrode spaced from and parallel to said extracting electrode on the side opposite said repeller electrode and having a narrow exiting aperture aligned for providing an electric field for drawing ions out of said ionizing space, the reentrant portion of said repeller electrode forming a concave cavity, the wall of which tapers inwardly towards the extraction electrode to form an aperture of smaller cross-sectional area than portions further removed from said extraction electrode whereby the configuration of said electric field within said ionizing space is substantially independent of voltages applied to said acceleration electrode, ion detecting means, magnetic means positioned

between said ion source and said ion detecting means for producing a magnetic sector field of constant magnetic strength for the spacial separation between ions of different masses, and means for varying the voltage of the acceleration electrode relative to said repeller electrode independently of the voltage of the extraction electrode relative to said repeller electrode for obtaining the mass spectrum of said gas in said ion source.

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