United States Patent [19]
Reifenschweiler

[11] **3,833,829**
[45] **Sept. 3, 1974**

[54] **ION SOURCE**

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[22] Filed: **Dec. 14, 1972**

[21] Appl. No.: **315,096**

[30] **Foreign Application Priority Data**

Jan. 3, 1972 Netherlands 7200001

[52] **U.S. Cl.** .... **313/360,** 313/61 S, 313/153
[51] **Int. Cl.** **H05h 5/02**
[58] **Field of Search** .... 313/61 R, 61 S, 63, 153

[56] **References Cited**

UNITED STATES PATENTS

3,408,526 10/1968 Elenga .... 313/61 R
3,581,093 5/1971 Carr.................................. 313/61 S

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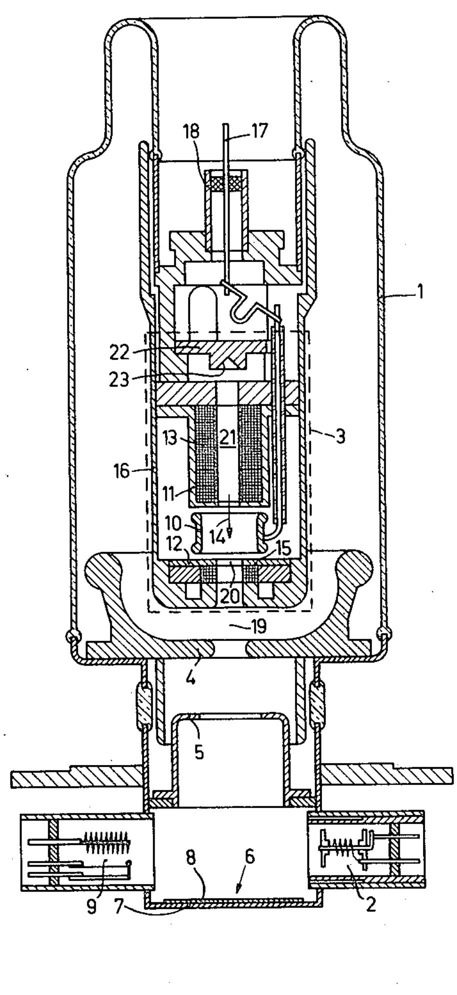
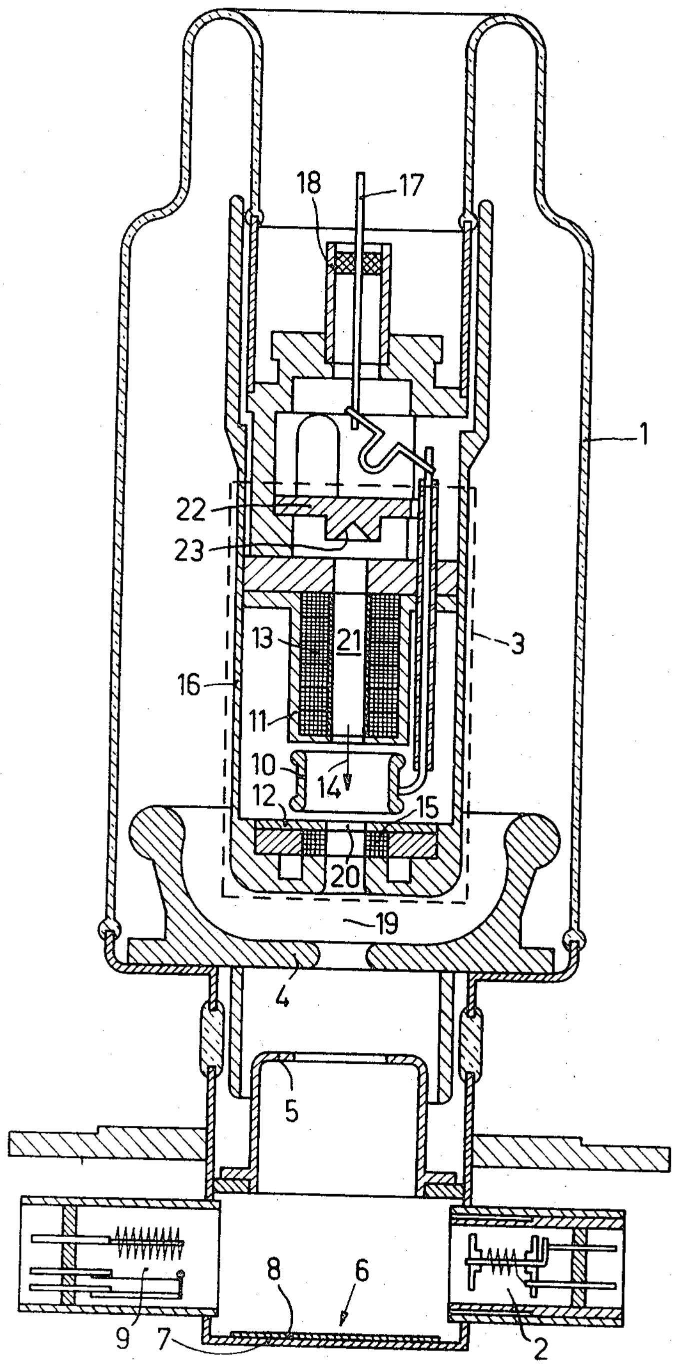
[57] **ABSTRACT**

An ion source having an anode between two cathodes and means for producing an axial magnetic field. Detremental heating of the cathode present opposite to the ion exit aperture by particles which are accelerated in the reverse direction and have a charge which is opposite to that of the extracted ion beam is prevented. For that purpose said cathode and the means for producing an axial magnetic field have an axial aperture. A collector electrode is present for capturing the relevant particles. The ion source is particularly suitable for a sealed neutron generator.

2 Claims, 1 Drawing Figure

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ION SOURCE

The invention relates to an ion source comprising a first cathode, a second cathode having an ion exit aperture, an anode between the two cathodes, and means for producing an axial magnetic field.

Such an ion source is known from the U.S. Pat. No. 3,408,526 and has the advantage that it can operate at a comparatively low gas pressure. This is caused by the fact that the electrons which are formed in the gas discharge between the anode and the two cathodes can move only mainly in the direction of the lines of force of the magnetic field and thus cover a long track before they reach the anode. Also in the case of a comparatively low pressure, this long track results in a large ionization possibility per electron.

A beam of ions is extracted from the ion source by applying a potential difference between an accelerating electrode and the cathode with the ion exit aperture. The accelerated ions then impinge generally upon a target the shape of which is determined by the nature of the device in which the ion source is used. A part of the ions of the ion beam, however, ionizes the gas which is present in the space in which the accelerating field prevails. The resulting formed electrons and negative ions, if the ions supplied by the ion source are positive, and positive ions, if the ion source supplies negative ions, respectively, are accelerated in the reverse direction by the accelerating field. These particles obtain a large energy as a result of the generally high accelerating voltage used, pass the ion exit aperture in the reverse direction and impinge upon the oppositely located cathode. As a result of this, said cathode is considerably heated which is very disadvantageous in connection with cathode material which is sputtered and scattered throughout the ion source. Permanent magnetic material which is used for producing the said axial magnetic field and which, in order to obtain a field which is as strong as possible, should preferably be present in the immediate proximity of the cathode, also cannot withstand said considerably heating.

It is the object of the invention to provide an ion source in which said drawbacks do not occur and for that purpose the invention is characterized in that the first cathode and the means for producing an axial magnetic field comprise an axial aperture and the ion source furthermore comprises a collector electrode on the side of the first cathode remote from the anode. As a result of this, the particles accelerated in the reverse direction can pass the first cathode and then impinge upon the collector electrode which can be arranged and constructed so that the evolved thermal enerby has no detrimental results.

The collector electrode preferably comprises a funnel-like cavity as a result of which the evolved thermal energy is distributed over a large area.

The invention will be described in greater detail with reference to the accompanying drawing of a neutron generator in which the ion source according to the invention is used.

The neutron generator shown is of the sealed type and comprises in an envelope **1** a gas mixture consisting of 50 percent deuterium and 50 percent tritium at a pressure of approximately 5×10^{-3} mm Hg. The gas mixture is supplied and its pressure maintained at the correct value by a pressure control **2**. The pressure control comprises a large quantity of the gas mixture absorbed in finely divided titanium powder, and can supply it by heating.

The mixture of deuterium and tritium is ionized in the ion source **3** and a beam of positive deuterium ions and tritium ions is extracted from the ion source by the accelerating electrode **4**. The ion source is at a positive voltage of 250 kV relative to the accelerating electrode **4**. The formed ion beam passes the screen electrode **5** and impinges upon the target **6**. The target **6** consists of a base plate **7** of a material having a small absorption coefficient and diffusion coefficient for deuterium and tritium (for example, copper) and a reaction layer **8** of a material having a large absorption coefficient for deuterium and tritium. The reaction layer **8** consists of a 5 μm thick layer of titanium.

The target **6** has been provided in the neutron generator without having been saturated with deuterium and tritium and in the first hours of life of the generator it absorbs deuterium and tritium from the ion beam impinging upon the target **6**. The absorbed deuterium and tritium cannot diffuse away to any considerable extent to places in the target **6** which are present at a deeper location than the thickness of the reaction layer **8**, because the base plate **7** has a small absorption coefficient and diffusion coefficient for deuterium and tritium. The result is that the reaction layer **8** is ever more strongly saturated with deuterium and tritium as a result of which the neutron output begins. The neutron output occurs in particular from the reaction between deuterium and tritium. The collision with an energy of 250 keV between a deuterium nucleus and a tritium nucleus supplies a neutron having an energy of 14 MeV and an alpha particle having an energy of 3.6 MeV. It is to be noted that neutrons are formed to a small extent from the reaction between two deuterium nuclei. These neutrons have a much smaller energy. The neutrons having an energy of 14 MeV constitute the effective output of approximately 10^{12} neutrons per second of the generator. After a few hours in operation said neutron output is reached when the saturation of the reaction layer **8** with deuterium and tritium has reached an equilibrium condition.

The accelerating electrode **4** has a negative potential of a few hundred volts relative to the screen electrode **5** and the target **6** to prevent secondary electrons which are formed on the target **6** from being accelerated towards the ion source **3**. The neutron generator furthermore comprises an ionization manometer **9** for checking the gas pressure.

The ion source **3** comprises an anode **10**, a first cathode **11** and a second cathode **12**. The cathodes **11** and **12** have the same potential. The anode **10** has a positive potential of 3 kV relative to the cathodes **11** and **12**. The ion source **3** furthermore comprises a permanent magnet **13** consisting of six permanent magnetic rings which are magnetized so that an axial magnetic field is formed having a main orientation parallel to the arrow **14**. A permanent magnetic ring **15** is magnetized so that said field is intensified in the proximity of the second cathode **12**. The magnetic circuit of which the permanent magnets **13** and **15** form part is closed by the ferromagnetic sleeve **16** bypassing the anode **10**. The anode voltage is supplied *via* the connection **17**. The high voltage which brings the cathodes **11** and **12** at a potential of 250 kV relative to the accelerating electrode **4** is supplied *via* the connection **18**.

Negative ions and electrons which are formed by ionization with the ion beam in the region **19** are accelerated in the direction of the ion source **3.** When said negative particles have reached the ion source, they have a larger energy according as they have been formed closer in the proximity of the accelerating electrode **4** and can thus have an energy of 250 keV. These particles pass the ion exit aperture **20** in the second cathode **12** in the reverse direction but in an ion source according to the invention they do not impinge upon the first cathode **11** as a result of which same would be heated such that the permanent magnet **13** would be damaged and cathode material be sputtered throughout the ion source. As a matter of fact, the first cathode **11** and the permanent magnet **13** comprise an axial aperture **21** through which the particles in question pass after which they impinge upon a collector electrode **22.** The collector electrode **22** is at the same potential as the cathodes **11** and **12** and is mounted in such manner that the evolved heat cannot produce any damage. The collector electrode **22** comprises a funnel-like cavity **23** which serves to distribute the evolved thermal energy over an area which is as large as possible. It is to be noted that only negative particles of large energy can reach the collector electrode **22.** Negative ions and electrons which are formed during the ionization process in the ion source itself cannot reach a potential which is lower than the cathode potential and thus only a small number of them can reach the aperture **21** which forms an equipotential space at cathode potential.

The ion beam which is extracted from the ion source has a current strength of approximately 15 mA. The gas discharge in the ion source **3** results in an anode current of approximately 50 mA. The accelerated ion beam of an energy of 250 keV results in a neutron output of approximately 10^{12} neutrons per second. The neutron generator may be used for scientific purposes such as activation analysis and, as a result of its high neutron output, it is particularly suitable for medical applications such as cancer therapy, "total body" activation analysis and mesurement of the blood circulation.

What is claimed is:

1. An ion source comprising a first cathode, a second cathode having an ion exit aperture, an anode between the two cathodes, and means for producing an axial magnetic field, characterized in that the first cathode and the means for producing an axial magnetic field comprise an axial aperture and that the ion source furthermore comprises a collector electrode on the side of the first cathode remote from the anode.

2. An ion source as claimed in claim **1,** characterized in that the collector electrode comprises a funnel-like cavity.

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