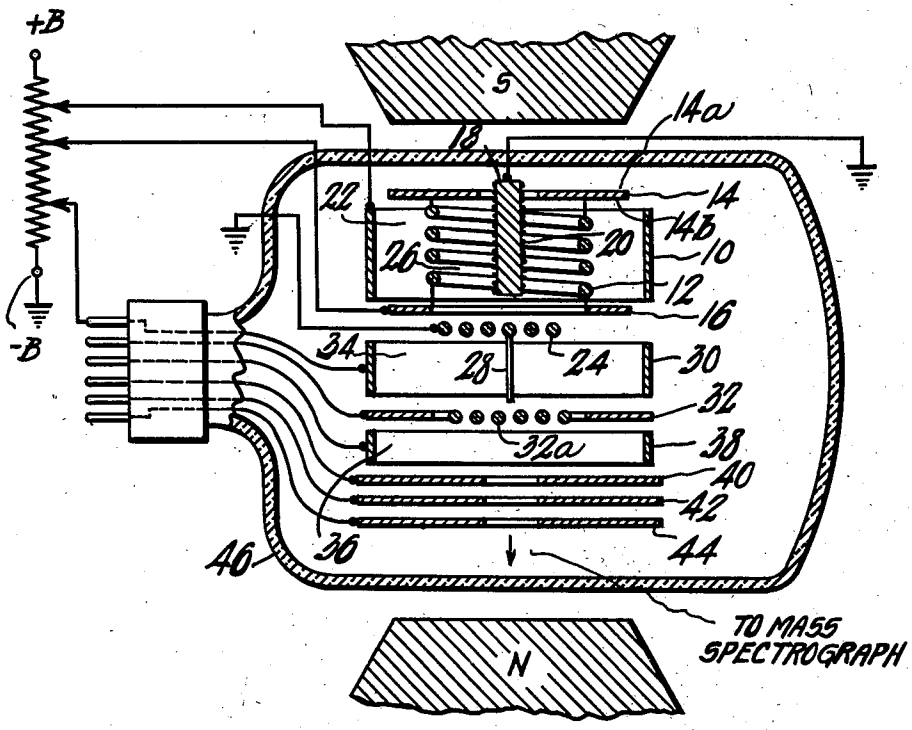
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PARTICLE SOURCE

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PARTICLE SOURCE

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1

The present invention relates to charged or neutral particle sources.

In conventional ion sources, the particles are ionized by electron bombardment in a space which is only partially evacuated. The ions are then drawn by electric fields, as by an ion gun, through a communicating aperture into another space external to the first, in which second space they are to be analyzed.

These systems have certain disadvantages among which may be mentioned the fact that continuous pumping is usually necessary to prevent the pressure from rising too high and that the equipment is generally bulky and difficult of construction. Furthermore, it is particularly inconvenient to ionize solid state materials.

It is an object of the present invention to provide an improved charged particle source.

It is a further object of the invention to provide a source of ions which is more flexible in use and which readily produces ions of solid state substances.

A further object of the invention is to produce an ion source in a high vacuum without the necessity for continuous pumping.

Another object of the invention is to produce positive or uncharged particles at the election of an operator, for analysis in a mass spectrograph or other instrument.

These and other objects, advantages, and novel features of the invention will be more apparent from the following description when taken in connection with the accompanying drawing in which the sole figure represents an ion source which is suited for use in conjunction with a mass spectrograph.

In accordance with the invention and to provide means for analyzing solid specimens, there is provided means first for producing ions from the residual gas in the system by bombardment by trapped electrons. Thence these gas ions are caused to bombard the solid specimen, thereby releasing other ions and neutral particles therefrom. The neutral particles (that is uncharged molecules or fragments thereof) may be subjected to trapped electron bombardment and are ionized. All of the ions thence are projected into a conventional ion analyzing space. The electron trapping structures for producing ions are disclosed in applicant's copending U. S. application, Serial No. 93,324, filed May 14, 1949. Briefly, in such structures, electrons are drawn by cold emission from one of two electrodes and biased to suitable potentials bounding a trapping space subjected to an axial magnetic field. Residual

2

gas in the space is ionized, and some of the ions thence are swept out of the trapping space by suitably applied negative accelerating potentials.

In a preferred embodiment of the invention, the first trapping space is an annular region surrounding an axially disposed solid specimen. Ions from the specimen thence are projected axially through a second trapping space where the neutral particles from the specimen are ionized, and finally all of the ions are further projected axially and accelerated into the ion analyzing region of the spectrometer.

Referring now more particularly to the sole figure, a cylindrical electrode 10 is connected as an anode to a B+ supply.

A cathode electrode is connected on a lower potential point on the B+ supply and comprises a cylindrically wound grip 12 and a portion 14*b* of top plate 14 and bottom end plates 14 and 16 (at the top and bottom respectively as viewed in the figure). A central electrode 18 is connected to a conventional ground, to which the negative terminal of the B+ supply is connected. The electrode 18 has on its surface a sample 20 to be analyzed in a mass spectrograph or the like. The cathode, including portion 14*a* of the upper end plate 14 and the lower plate 16 together with the apertured electrode 12 and the anode 10 define an electron trapping space 22. The electron trapping space 22 is substantially toroidal. The grid 12, together with a portion 14*a* of the upper end plate 14 and with a grid structure 24, defines an auxiliary space 26 surrounded by the electron trapping space. The grid 24 has connected to it a central electrode 28 which is surrounded by cylindrical electrode 30 connected at some suitable point on the B+ supply lower in potential than the connection of the cathode 12. The electrodes 24 and 28 are grounded. Electrodes 24 and 28 together with cylindrical electrode 30 define a space 34 which may be a second electron trapping space. This second space has a lower electrode 32, a portion 32*a* of which is grid-like in construction as shown. A cylindrical space 36 is defined by the electrode 32, a cylindrical electrode 38, and an apertured electrode 40. Electrodes 42 and 44 are also apertured or have slits. A magnetic field is provided as schematically indicated by the magnetic pole pieces designated N and S. All of the electrodes thus far described are enclosed within an envelope 46, and the pole pieces N, S, or other means for producing a magnetic field may be located outside the envelope if desired. The envelope is preferably highly evacuated and sealed.

In operation, the electrode **10** acts as an anode and the other electrode comprising electrodes **12**, **14***b* and **16** together acts as a cathode concave to the anode and surrounded by it. The space **22** so defined is thus an electron trapping space. With a suitable magnetic field applied, the trapped electrons circulate circumferentially within this space. Even though the envelope **46** is highly evacuated, there remain occasional gas particles in the electron trapping space. These particles are eventually struck by one or more circulating electrons, and the gas particles are ionized, producing positive and negative particles. The negative particles are trapped in the electron trapping space, as explained in my co-pending application, Serial No. 93,324, filed May 14, 1949, entitled "Improvement in Gas Rectifier Tube Employing Magnetic Field." In fact, the form of the electron trapping space and the electrode structure may conform to that taught in my said co-pending application, except that an auxiliary space such as **26** surrounds or is surrounded by the electron trapping space and by the cathode, and except that the two spaces communicate through one or more apertures or openings in the cathode electrode, in this instance through the openings between the grid wires of grid **12**.

Other co-pending applications of mine which disclose trapping spaces and their utilization are application Serial No. 150,530, filed March 18, 1950, entitled "Discharge Tube Voltage Transformer"; application Serial No. 67,796, filed December 29, 1948, entitled "Improvement in Direct Current Transformer"; and application Serial No. 57,463, filed October 30, 1948, entitled "Electrical Generators."

These positive particles or positive ions created in the trapping region **22** are drawn by the electric field toward the grid **12**. Most of them pass through the grid openings through which the electron trapping space **22** and the auxiliary space **26** communicate. Grid **12** is at a higher potential than electrode **18** which has the coating of the sample **20**. Accordingly, the positively charged particles find themselves in a field that impels them toward the sample **20**. The sample **20** is therefore bombarded by the positively charged particles. The bombardment causes the release from the solid sample **20** of three types of particles—positively charged, negatively charged, or neutral particles. Of course, the order of the electrodes inside to outside, could be reversed, with the positive ion permeable cathode intermediate the anode and cathode. However, the present arrangement is preferred because the ions from the sample are thus readily concentrated in the line of the axis.

First directing attention to the case in which it is desired to analyze the positively charged particles or ions. These positively charged particles are drawn toward and through grid **24** into the secondary space **34**. Thence by suitable relative potentials on grid **32***a* and electrodes **38**, **40**, **42**, and **44**, the openings in the latter electrodes may be made to act as a lens system in which the positively charged particles are focused by the fields resulting from the increasingly negative potentials to pass out of the aperture in the last one **44** and into a mass spectrograph.

Second, directing attention to the case in which it is desired to analyze the neutral particles from sample **20**. The neutral particles from space **26** enter the secondary trapping space **34** by diffusion, as electrode **30** is made sufficiently positive with respect to grid **24** and electrode **28** so

that the space **34** is an electron trapping space, in accordance with the principles hereinbefore mentioned. At least some of these diffused neutral particles are struck by the trapped electrons in space **34**, resulting in ionization and secondary positive particles. These secondary positive particles are drawn into the space **36** by suitable potential (negative with respect to electrode **28**) applied to the grid **32***a* and may be focused by a conventional electrode system suitable for the purpose. The electrode focusing system illustrated includes electrodes **38**, **40**, **42**, and **44**. Electrode **38** is a cylindrical focusing ring. Electrodes **40**, **42**, and **44** may be the customary slit-type focusing electrodes. By analysis of the positive particles drawn from space **34** arising from bombardment of the neutral particles diffused from space **26** into space **34**, the neutral particles from the sample **20** may be indirectly analyzed.

It will be apparent that there is disclosed herein an improved and superior means for producing charged or neutral particles. The said means comprise an electron trapping space and an auxiliary space surrounded by the trapping space and having openings communicating with said trapping space. Either positively charged or neutral particles from the sample bombarded by the positively charged particles drawn through the communicating openings may be selected for analysis in a secondary space. If neutral particles are to be analyzed, the secondary space by application of suitable potentials to the various electrods may be a second electron trapping space, at the election of the operator causing the potentials to be applied by switches or the like. The flexibility of operation is highly useful, since it saves construction of an alternative arrangement, and particles from samples, such as the sample **20**, are readily and easily analyzed. Furthermore, continuous pumping of the envelope **46** is not required. The envelope **46** may be highly evacuated. Even with extremely high evacuation and extremely low pressure, the circulating electrons in the trapping space **22** produce a plentiful supply of charged particles by electron collision with stray free gas particles. These collisions are plentiful because of the number of times the electrons circulate in the trapping space and notwithstanding the long mean free path between gas molecules.

It will be apparent that I have disclosed a novel, improved charged or neutral particle source, flexible in use, and which does not require continuous pumping.

What is claimed is:

1. In a charged particle source, the combination comprising an anode and a cathode surrounded thereby and concave thereto, said anode and cathode defining therebetween an electron trapping space, said cathode defining and surrounding an auxiliary space and having one or more openings through which said two spaces directly communicate, and a central electrode in said auxiliary space and a coating thereon of a sample to be analyzed.

2. In a charged particle source, the combination comprising a first electrode, an anode electrode, and a cathode electrode, substantially coaxially arranged, said first electrode and said cathode electrode defining therebetween a first space and said cathode and anode electrodes defining therebetween a second trapping space, said cathode electrode having openings through which said spaces directly communicate, said cathode electrode being positioned intermediate said first

electrode and said anode electrode, and a further group of electrodes defining a secondary space situated axially spaced from said first space, said group of electrodes having an opening through which said first and secondary spaces communicate.

3. In a charged particle source, the combination comprising an anode and a cathode surrounded thereby and concave thereto, said anode and cathode defining therebetween an electron trapping space, said cathode defining and surrounding an auxiliary space and having one or more openings through which said two spaces directly communicate, and a further group of electrodes defining a secondary space situated axially spaced from said auxiliary space, said group of electrodes having an opening through which said auxiliary and said secondary spaces communicate, said group of electrodes comprising an electrode of separation through which said secondary and auxiliary spaces directly communicate, a substantially cylindrical anode, an electrode central to said secondary space and to said cylindrical anode, and another electrode which with said electrode of separation and said central electrode define a concave cathode surrounded by said cylindrical anode, said group of electrodes defining a toroidal secondary electron trapping space.

4. In a charged particle source, the combination comprising an anode and a cathode surrounded thereby and concave thereto, said anode and cathode defining therebetween an electron trapping space, said cathode defining and surrounding an auxiliary space and having one or more openings through which said two spaces directly communicate, said electron trapping space being substantially toroidal, a secondary group of electrodes defining a secondary electron trapping space also substantially toroidal and having an electrode of separation between said auxiliary space and said secondary electron trapping space through which said latter two spaces communicate.

5. The combination claimed in claim 4, further comprising a group of focusing electrodes for focusing positively charged particles originating in said secondary electron trapping space.

6. In a charged particle source, the combination comprising a first electrode, an anode electrode, and a cathode electrode, substantially coaxially arranged, said first electrode and said cathode electrode defining therebetween a first space and said cathode and anode electrodes defining therebetween a second electron trapping space, said cathode electrode having openings through which said spaces directly communicate, said cathode electrode being positioned intermediate said first electrode and said anode electrode, and a group of further electrodes defining a secondary electron trapping space situated axially spaced from said first space, said group of further electrodes having an opening through which said first and secondary spaces communicate.

7. The combination claimed in claim 6, said group of electrodes comprising an electrode of separation through which said first and secondary spaces directly communicate a substantially cylindrical second anode, a second cathode concave to and substantially coaxial with said second anode and including said electrode of separation one of said second cathode and second anode being surrounded by the other.

8. The combination claimed in claim 6, said further group of electrodes comprising electrodes arranged to focus positively charged particles originating in said secondary electron trapping space.

9. The combination claimed in claim 6, further comprising means to provide a magnetic field having magnetic vectors substantially axially directed throughout both said trapping spaces.

10. The combination claimed in claim 1, further comprising means to produce a magnetic field having magnetic vectors substantially axially directed throughout said trapping space.

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