United States Patent [19]

Komoda

[11] **3,846,663**

[45] **Nov. 5, 1974**

[54] **ELECTRON GUN DEVICE HAVING A FIELD EMISSION CATHODE TIP PROTECTED FROM DESTRUCTION DUE TO ION IMPINGEMENT**

[75] Inventor: **Tsutomu Komoda,** Kodaira, Japan

[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan

[22] Filed: **Sept. 20, 1971**

[21] Appl. No.: **182,041**

[30] **Foreign Application Priority Data**

Sept. 18, 1970 Japan 45-81283

[52] **U.S. Cl.** ..... **315/3,** 250/311, 313/82 R, 313/86, 315/31 R

[51] **Int. Cl.** **H01j 29/02,** H01j 29/52

[58] **Field of Search** ..... 313/82 R, 82 T; 250/310, 250/311; 315/3

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Primary Examiner—Robert Segal

Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

In an electron gun device of the field emission type, a suppression electrode having a potential which is higher than that of the anode is disposed between a cathode tip of needle shape and said anode so that passage through said suppression electrode of ions emitted from said anode by means of electron impingement thereon is prevented, whereby the needle tip of the cathode is protected from destruction due to ion impingement thereon.

2 Claims, 3 Drawing Figures

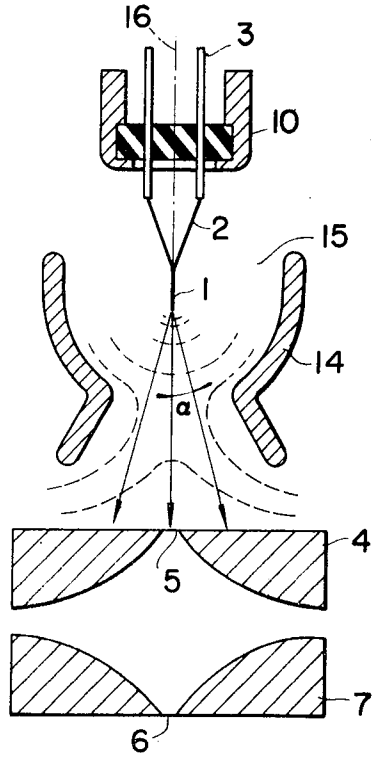


FIG. 1
PRIOR ART

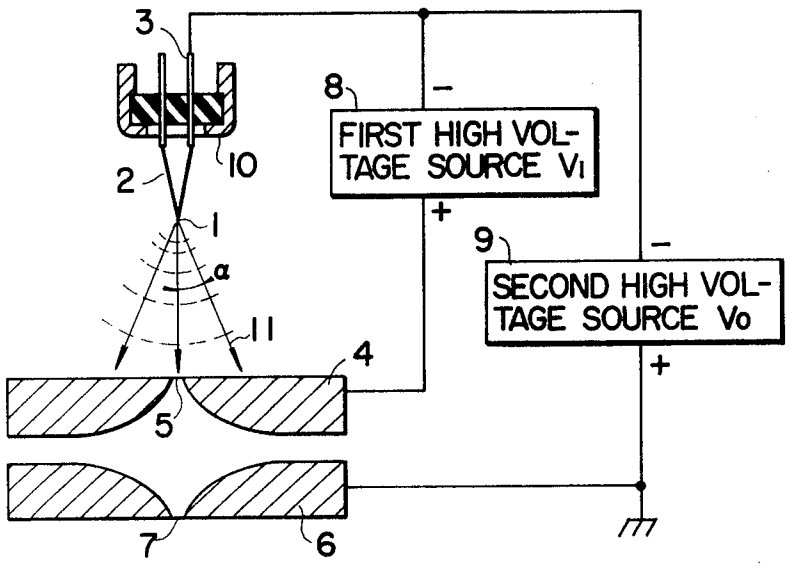


FIG. 2

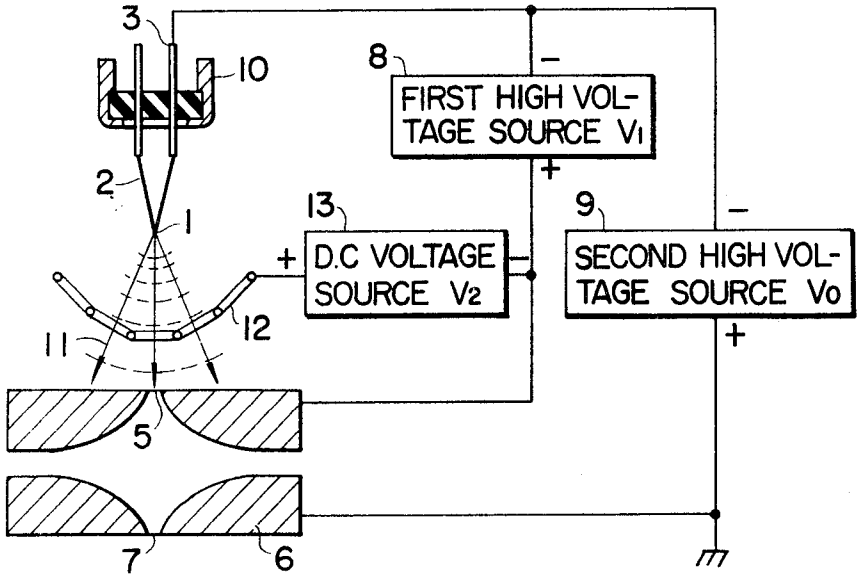
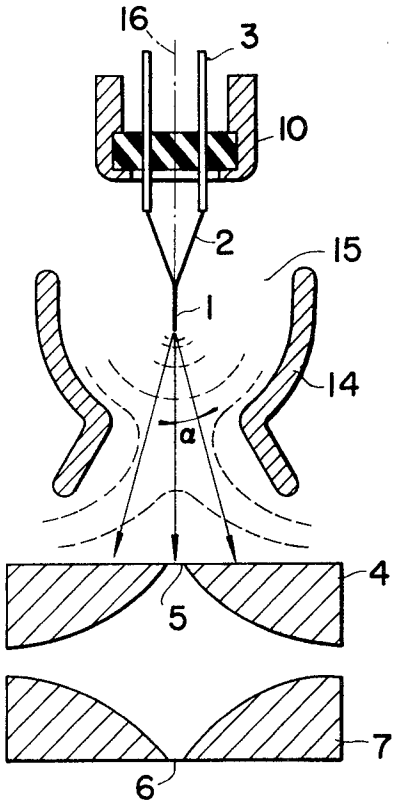


FIG. 3



ELECTRON GUN DEVICE HAVING A FIELD EMISSION CATHODE TIP PROTECTED FROM DESTRUCTION DUE TO ION IMPINGEMENT

BACKGROUND OF THE INVENTION

This invention relates to an electron gun device of the field emission type, which is particularly suitable as a source of an electron beam in an electron microscope, and the like.

As is well known, a conventional electron gun device of the field emission type for an electron microscope has a cathode tip of needle shape, means for heating said tip and an anode for causing electrons to be emitted from said tip by creating an electric field between said tip and said anode.

In such an electron gun device, when it is intended to obtain an electron beam having a current value which is more than 10μ A, the electron beam varies unstably with a frequency which increases rapidly with operation. As a result of this, the tip portion of said cathode is destroyed so that the field emission of electrons therefrom stops.

Since the useful life of the cathode tip in the conventional electron gun device is very short for the reasons described above, it is necessary to exchange said tip frequently. In the electron gun device, ultra high vacuum conditions must be maintained and once this condition is broken for exchange of said tip, it is necessary to evacuate the electron gun device once again. However, this requires complicated procedures and a very long time is required to effect such evacuation.

SUMMARY OF THE INVENTION

An object of the invention is to provide an electron gun device having a very long useful life.

Another object of the invention is to provide an electron gun device having the advantage that the number of times wherein exchange of the cathode tip is required, and thus the number of times wherein evacuation of the microscope is necessary, has been greatly reduced.

A further object of the invention is to provide an electron gun device suitable as the source of an electron beam for use in an electron microscope and the like.

In order to attain the above objects, the electron gun device of this invention is characterized by employment of a suppression electrode disposed between the cathode tip and the anode which will prevent the passage therethrough of ions emitted from said anode as a result of impingement of the electrons thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing a conventional electron gun device; and

FIGS. **2** and **3** are schematic diagrams showing embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **1**, an electron gun of the field emission type for an electron microscope includes a cathode tip **1** of needle shape for electron emission, a tungsten filament **2** of hair-pin shape, terminal electrodes **3**, a first anode **4**, a second anode **6**, the respective anodes being provided with holes **5** and **7** through which an electron beam passes. A first high voltage source **8** is connected between the tip **1** and the first anode **4**. A second high voltage source **9** is connected between the tip **1** and the second anode **6**. The connection point of the second anode **6** and the positive terminal of the voltage source **9** is grounded.

In the conventional electron gun structure, a negative high voltage, for example −30KV, is applied to the cathode tip **1** through the terminal electrodes **3**, and another high voltage of 2–3KV is applied between the tip **1** and the first anode **4** by the source **8** connected therebetween. In the electron gun device of conventional structure, since the intensity of the electric field adjacent to the tip portion of the cathode tip **1** has a very high value due to the potential difference between said tip **1** and the first anode **4**, electrons are caused to emit from said tip **1** from the electric current flowing through the filament **2** so as to heat it and clean its surface. These electrons passing through the hole **5** are focused by the electric field produced between the first and second anodes **4** and **6** which act as an electron lens so that an electron beam having a fine spot of high density is obtained from the hole **7**.

Now, in this case, since an electric field is formed as shown by dotted lines in FIG. **1**, electrons **11** emitted from the tip **1**, as shown in the same figure, are accelerated by the potential difference between the cathode and anode **4** and all electrons except those passing through the hole **5** impinge on the first anode **4**.

Molecules on the surface of the first anode **4** which are struck by these electrons are ionized and these ions are emitted from the surface due to the potential gradient in the interelectrode space and the force of the electron impingement thereon. Emitted ions are accelerated by the potential difference between the electrodes in the opposite direction of the electrons and impinge on the tip portion of the cathode tip **1**. An atomic layer is etched on the surface of said tip portion as a result of this bombardment and its surface condition is varied by means of the ion impingement thereon. As a result of this, the condition of the field emission from the cathode tip **1** is varied so that emission of the electron current thereon becomes unstable.

Generally, the tip portion of the cathode top **1** is very sharp so as to allow electrons to be emitted therefrom by means of electric field effects. For example, a tungsten line, having a diameter of 0.1 – 0.2mm and a radius of curvature at the tip portion formed in needle shape to have the very small value of 500 A., is used as the tip. Therefore, when the ion impingement on the tip exceeds a certain limit, the tip portion of the cathode tip is destroyed so that emission of electrons therefrom stops.

Since the tip **1** is destroyed for reasons described above, it is apparent that the tip can be protected from such destruction by preventing the ion impingement thereon. Thus, the electron gun device of the present invention is designed to have a suppression electrode for preventing the passage therethrough of ions; for example, an electrode **12** of mesh shape having large openings is disposed between the tip **1** and the first anode **4**, as shown in FIG. **2**, and to which a positive high voltage having a voltage value of 10 – 100V higher than that applied to the first anode **4** is applied from a D.C. voltage source **13** whose a positive terminal is connected to said electrode **12**.

As one example, the voltages V0, V1 and V2 of the respective voltage sources **9, 8** and **13** are set at V0 = 30,000V, V1 = 2,500V and V2 = 100V. With such an arrangement, since a positive high voltage having a voltage value of V1 + V2 with respect to the tip is applied to electrode **12,** electrons are emitted from the tip **1** in a manner similar to a conventional electron gun device. The emitted electrons reach the electrode **12,** but since this electrode has very large openings arranged in the form of a mesh, they are not intercepted by it so that a major part of said electrons pass through said electrode **12** and reach the first anode **4.**

All electrons except those passing through the hole **5** impinge on the surface of the first anode **4** and thereby ions are produced therefrom; however, since the electrode **12** has a positive potential with respect to the first anode **4,** the potential gradient between the electrode **12** and the first anode **4** will not accelerate the ions away from the anode surface. In fact, the ions generated by the electron bombardment of the surface of anode **4** will be repelled by the electrode **12,** thereby preventing the ions from reaching the cathode tip. Thus, the tip portion of the cathode tip **1** will not be destroyed with the result that said tip will have a very long and useful life.

In the above embodiment, the mesh electrode **12** is used as a suppression electrode, as described above, but another electrode **14** having a single large opening can be used instead of said mesh electrode, as shown in FIG. **3.** In FIG. **3,** the voltage sources **8, 9** and **13** are omitted, but the relation between the voltages applied to the respective electrodes is similar to that in the aforementioned embodiment.

It is sometimes difficult to produce a uniform potential distribution by means of the mesh electrode **12;** however, since the electrode **14** can be made precisely and has the single large opening **15,** it is possible to produce a uniform potential distribution along an axis **16,** and thus the aberration is made small.

Electrons are emitted from the tip within the limits of an opening angle α of about **30°** therefrom due to the shape of the tip portion. Therefore, if the opening **15** of the electrode **14** is made in such a manner as to have such an opening angle, the emitted electrons will not impinge on this electrode, and therefore will reach the first anode **4.** In a manner similar to the embodiment shown in FIG. **2,** ions produced at the first anode **4** cannot pass through said electrode **14** on account of the potential distribution as shown in dotted lines in FIG. **3.**

As is apparent from the above description, according to the present invention, the top portion of the cathode tip can be protected from destruction due to ion impingement, and therefore the life time of said tip greatly increases. Moreover, this invention can be applied to all electron gun devices of the field emission type having at least a cathode tip of needle shape and an anode for producing the electric field between it and the tip, so as to cause electrons to be emitted from the tip.

What I claim is:

1. In an electron gun device of the field emission type having a cathode tip of needle shape, means for heating said cathode tip to clean it, means for drawing electrons from said cathode tip including an anode opposing said cathode tip and having a hole therein which is of smaller area than the area of the remainder of said anode through which at least part of the electrons from said cathode pass and means for applying a positive electric voltage to said anode with respect to said cathode tip so as to produce an electric field therebetween sufficient to cause electrons to be emitted from said cathode tip toward said anode, the improvement which comprises

suppression electrode means disposed between said cathode tip and said anode for preventing passage therethrough of ions emitted from said anode by means of electron impingement therein, said suppression electrode means including an electrode having an elongated annular configuration symmetrical about a central axis with a middle portion thereof being closer to said central axis than the two end portions thereof, and

means for applying to said suppression electrode means a positive voltage higher than that applied to said anode, whereby said cathode tip can be protected from destruction due to ion impingement thereon.

2. An electron gun device as defined in claim **1,** wherein said suppression electrode has a single large opening having an opening angle of about 30° measured from said cathode tip toward said anode.

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