

[54] FIELD EMISSION ELECTRON GUN

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[58] Field of Search..... 315/29, 30, 31

[56] **References Cited**

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[57] ABSTRACT

In an electron gun device of the field emission type having a cathode tip, and first and second anodes connected to responsive voltage sources, a control electrode connected to a control voltage source is disposed in the neighborhood of the cathode tip so as to control the electron beam emitted from the cathode tip whereby a stable electron beam can be obtained.

5 Claims, 3 Drawing Figures

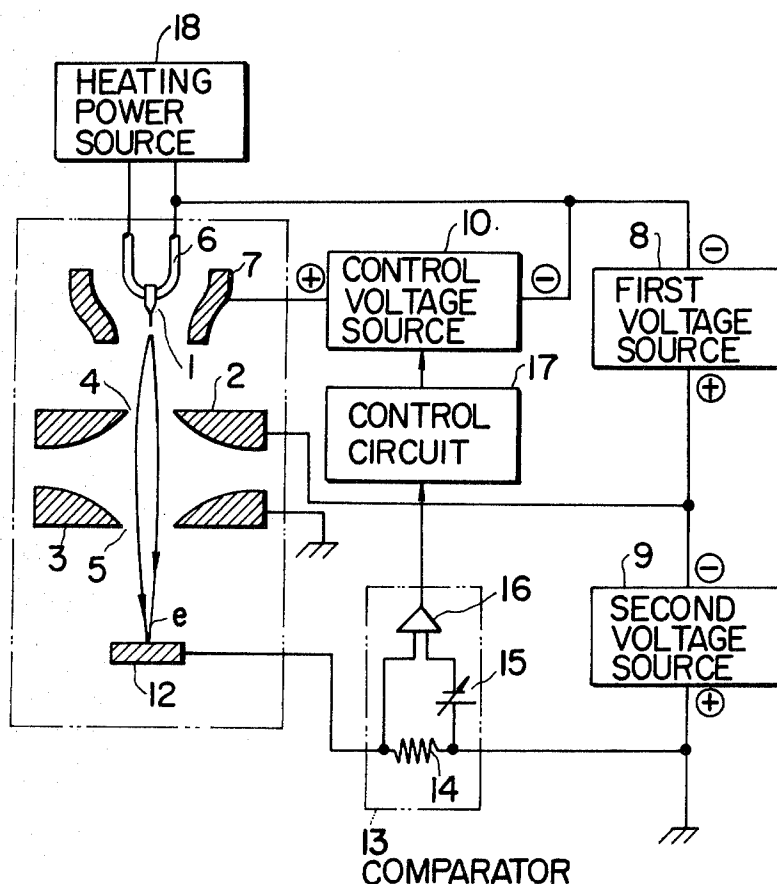


FIG. 1

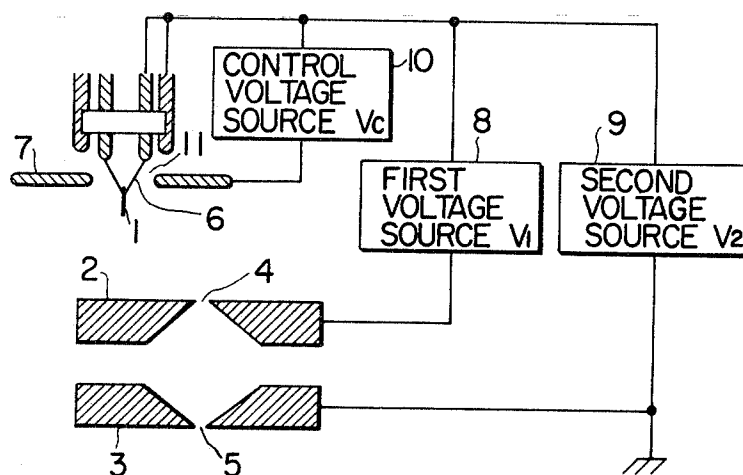
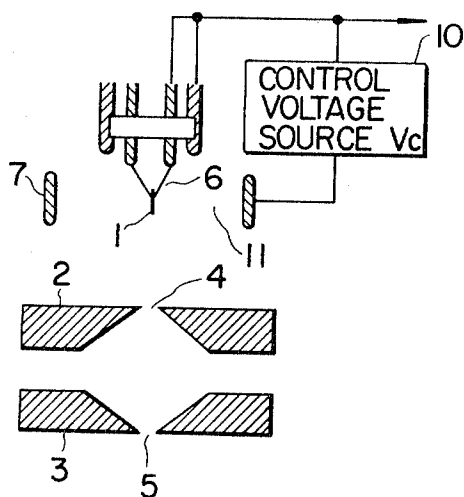


FIG. 2



FIELD EMISSION ELECTRON GUN

BACKGROUND OF THE INVENTION

1. Field of the Invention

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

2. Description of the Prior Art

A conventional electron gun device has no means for controlling the electron beam emitted from the cathode tip therein.

Therefore, it is impossible to obtain a stable electron beam over a long period of time with such an electron gun device.

SUMMARY OF THE INVENTION

A prime object of the present invention is to provide an electron gun device of the field emission type having control means for controlling the electron beam so as to obtain a stable electron beam over a long period of time.

Another object of the present invention is to provide an electron gun device of the field emission type having control means for automatically stabilizing the electron beam.

In order to realize the above objects, the present invention is characterized by employment of a control electrode disposed in the neighborhood of said cathode tip and connected to a control voltage source.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1, 2 and 3 are schematic diagrams showing respective embodiments of the invention.

PREFERRED EMBODIMENTS OF THE INVENTION

In FIG. 1, an electron gun device of the field emission type has a cathode tip 1 of needle shape secured to a filament 6, a first anode 2 having an electron beam passage hole 4, a second anode 3 having an electron beam passage hole 5, a control electrode 7, a first voltage source 8 connected between the first anode 2 and the cathode tip 1, a second voltage source 9 connected between the second anode 3 and the cathode tip 1, and a control voltage source 10 connected between the control electrode 7 and the cathode tip 1.

In the above-described electron gun device, when a first voltage V_1 of about 2 - 5 KV is applied between the first anode 2 and the cathode tip 1 by the first voltage source 8 and a second voltage V_2 of about 20 - 50 KV is applied between the second anode 3 and the cathode tip 1 by the second voltage source 9, respectively, a strong electric field is produced adjacent to the top portion of the cathode tip 1, thereby causing electrons to be emitted from said cathode tip 1 toward the first anode 2. The electron beam passing through the hole 4 of the first anode 2 is focused by means of a lens electric field produced between the first and second anodes, so that a finely focused electron beam can be obtained from the hole 5 of the second anode 3, which beam can be utilized in a well known manner.

The above lens electric field depends upon the voltage ratio (V_2/V_1) of the respective voltages applied to the first and second anodes. Further, the intensity of the electron beam depends not only upon the surface

condition of the cathode tip 1 but also on the electric field produced adjacent thereto, namely the voltage V_1 applied to the first anode 2. In this case, the surface condition of the cathode tip varies with time and if there are no means for controlling said surface condition as in the conventional device, it is impossible to stably maintain the electron beam due to said field emission therefrom.

On the other hand, since the intensity of the electron beam depends upon said electric field for field emission as well as the surface condition of the cathode tip, it may be possible to maintain said electron beam at a constant value by controlling said electric field. However, as is apparent from the aforementioned description, the voltage V_1 applied to the first anode 2 should not be controlled in order to control said electric field, because, if this is done, said voltage ratio (V_2/V_1) varies, with the result that the lens electric field varies.

In this manner, even if it is possible to stably maintain the field emission of the electrons from the cathode tip 1 by controlling said voltage V_1 , the electron beam obtained through the hole 5 of the second anode 3 varies for the above reasons and thus, in practice, it is impossible to obtain a stable electron beam using the conventional structure. Thus, the embodiment according to the invention shown in FIG. 1 is provided with a control electrode 7 connected to a control voltage source 10.

A conductive plate having an opening 11 and a variable D.C. voltage source capable of producing a control voltage V_c which ranges from 0 to V_1 volts and which is constructed in a well known manner are used as said control electrode 7 and said control voltage source 10, respectively. The control electrode 7 is disposed a little bit behind the top of the cathode tip 1 in parallel with the first anode 2 in such a manner that the filament 6 with the cathode tip 1 is positioned in the opening 11 of the control electrode 7 and a control voltage V_c is applied from the control voltage source 10 between the cathode tip 1 and the control electrode 7.

The electric field adjacent to the cathode tip 1 can be controlled by varying said control voltage V_c applied to the control electrode 7, while said first voltage V_1 is kept constant. In this case, specifically, since the control electrode 7 is disposed in parallel with the first anode 2, and moreover, since it is disposed behind the cathode tip 1, even if the electric field applied to the cathode tip 1 varies with the control voltage V_c , the distribution of the electric field formed in the space between the cathode tip 1 and the first anode 2 is almost never modified. Namely, the electron beam due to field emission from the cathode tip 1 can be controlled without providing a lens function between the cathode tip 1 and the first anode 2.

Therefore, since the voltage V_1 applied to the first anode 2 can be maintained constant, the electric lens function in the accelerating space between the first and second anodes 2 and 3 depending upon the voltage ratio (V_2/V_1) can be always maintained constant. Namely, it is possible to vary the emitted electron beam without change of the electro-optical characteristic of the device.

In the above case, the control electrode 7 is disposed behind the cathode tip 1, but this invention is not limited to such an arrangement only. For example, an annular electrode having a large opening 11 may be disposed in the neighborhood of the cathode tip so as to

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surround the cathode tip 1, as shown in FIG. 2 with respect to the control electrode 7.

FIG. 3 shows still another embodiment having an automatic control system according to the present invention. In this embodiment, a comparator 13 includes a resistor 14, a reference voltage source 15 and a difference amplifier 16. When an object 12 is impinged upon by the electron beam e emitted from the electron gun device of the present invention, a current flowing in the object 12 is supplied to the resistor 14 and thus a detecting signal or voltage appears across the resistor 14. This detecting signal is compared with a reference signal or voltage from the reference voltage source 15 by the difference amplifier 16. As a result of this, a voltage representing the difference between said signals is produced and is applied to a control circuit 17.

The control circuit 17 produces a control signal which is applied to the control voltage source 10, and it increases or decreases the control voltage V_c to reduce said difference voltage to zero.

In the above embodiment, the object 12 is, for example, a specimen in a scanning type electron microscope. Only the electron gun device of the invention is shown in detail as one of the main parts of the microscope in FIG. 3 because the other parts thereof are well known in the art. Moreover, the method for detecting the emitted electron beam is not limited to the manner shown in FIG. 3, but a suitable electron detector for performing this detecting operation may be used without departing from the present invention. In addition, various circuits well known to those of ordinary skill in the art may be used as the control circuit.

The present invention is particularly effective in the case where, in operation, the cathode tip 1 is heated by supplying a current to a filament 6 from a heating power source 18, in order to make its surface clean. According to such arrangement, since the absorption probability of residual gases in the device with respect to the cathode tip is reduced due to heating of the cathode tip, the electron beam emitted therefrom varies (is reduced) successively for more than one hour until the cathode tip reaches steady state operation where its surface is saturated with said gases after start of operation, and thus it is apparent that application of the present invention to such a case as mentioned above is effective.

What is claimed is:

1. In an electron gun device of the field emission type including a cathode tip of needle shape, a first anode spaced from said cathode tip first voltage source means

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for applying a first potential between said cathode tip and said first anode so as to produce an electric field therebetween capable of causing electron emission from said cathode tip, a second anode spaced from said first anode, and second voltage source means for applying a second potential between said first and second anodes for accelerating a beam of electrons emitted from said cathode tip, the improvement which comprises

a control electrode disposed in the neighborhood of the cathode tip for controlling the amount of electrons emitted from said cathode tip;

control voltage source means connected between said cathode tip and said control electrode for applying a variable control voltage therebetween having the same polarity as said first and second potentials;

detector means for deriving a detecting signal responsive to the intensity of said electron beam from an object subjected to electron beam impingement;

comparator means including at least a reference voltage source for producing a control signal representing the difference between a reference signal from said reference voltage source and said detecting signal; and

control means for varying said control voltage of said control voltage source means in response to said control signal, thereby reducing said difference between said reference signal and said detecting signal to zero; whereby said electron beam can be maintained constant.

2. An electron gun device according to claim 1 wherein said control electrode comprises a conductive plate having an opening therein, said conductive plate being disposed perpendicular to the axis of said first and second anodes with said cathode tip protruding slightly through said opening therein towards said first anode.

3. An electron gun device according to claim 2 wherein said conductive plate is disposed in parallel with said first anode.

4. An electron gun device according to claim 1 wherein said control electrode comprises an annular electrode surrounding said cathode tip.

5. An electron gun device according to claim 4 wherein said first anode contains a beam passage aperture, the diameter of said annular electrode being substantially larger than said beam passage aperture in said first anode.

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