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[54] **ELECTRON-BEAM ILLUMINATING SYSTEM FOR AN ELECTRICAL APPARATUS SUCH AS AN ELECTRON MICROSCOPE OR THE LIKE**

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[51] **Int. Cl.** **H01j 37/26**

[58] **Field of Search** 250/311, 310, 306, 307, 250/396, 397, 398

[56] **References Cited**

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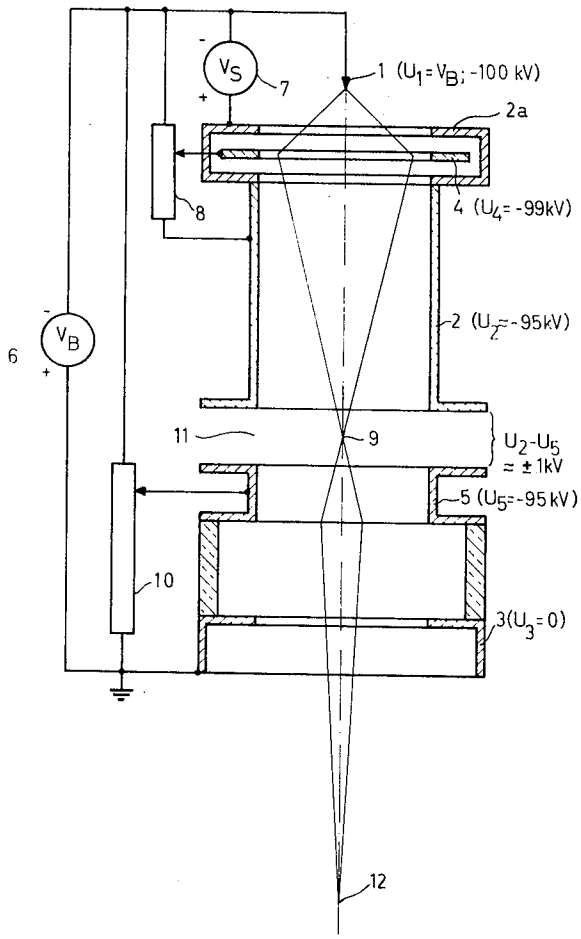
[57] **ABSTRACT**

An electron-beam illuminating system for an electrical apparatus such as an electron microscope or the like includes a cathode for supplying the electrons making up the electron-beam. A first anode is disposed beyond the cathode and defines therewith a beam axis extending in beam direction. A positive bias voltage on the first anode determines the emission of the cathode. An acceleration anode is disposed beyond the first anode and defines an acceleration path for the electrons emitted by the cathode. An acceleration voltage is applied across the cathode and the acceleration anode. A further electrode is located between the first anode and the accelerating electrode and defines conjointly with the first anode a space therebetween along the beam axis. A voltage is applied to the further electrode which is linearly proportional to the acceleration voltage. An auxiliary lens generates a first image of the source in this space. An electric circuit supplies a voltage to the further electrode which is linearly proportional to the acceleration voltage.

5 Claims, 2 Drawing Figures



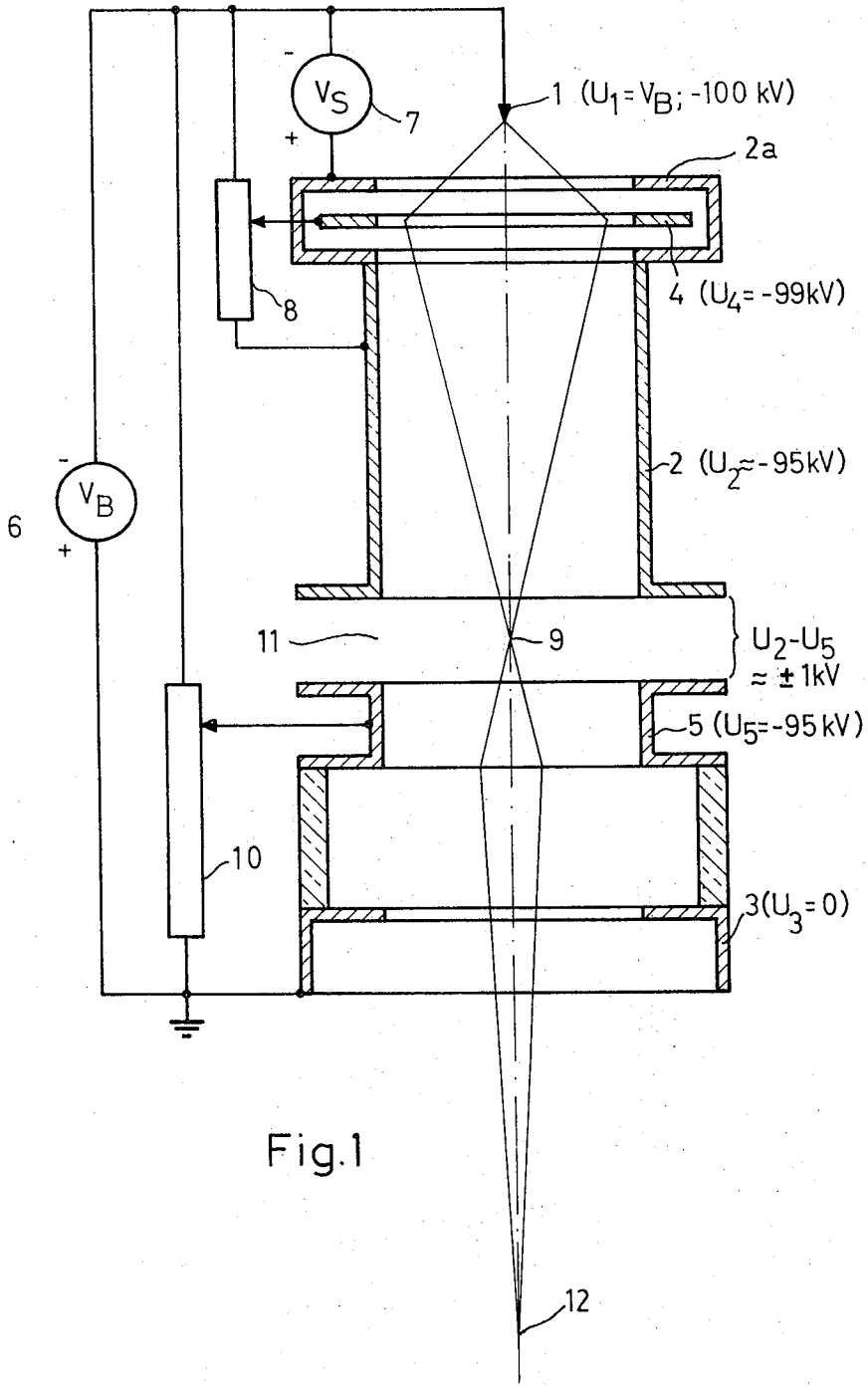

V_S
7
1 ($U_1 = V_B$; -100 kV)
2a
4 (U_4 = -99kV)
8
2 (U_2 ≈ -95kV)
V_B
6
11
9
U_2-U_5
≈ ±1kV
5 (U_5 = -95 kV)
10
3(U_3 = 0)
12

Fig.1

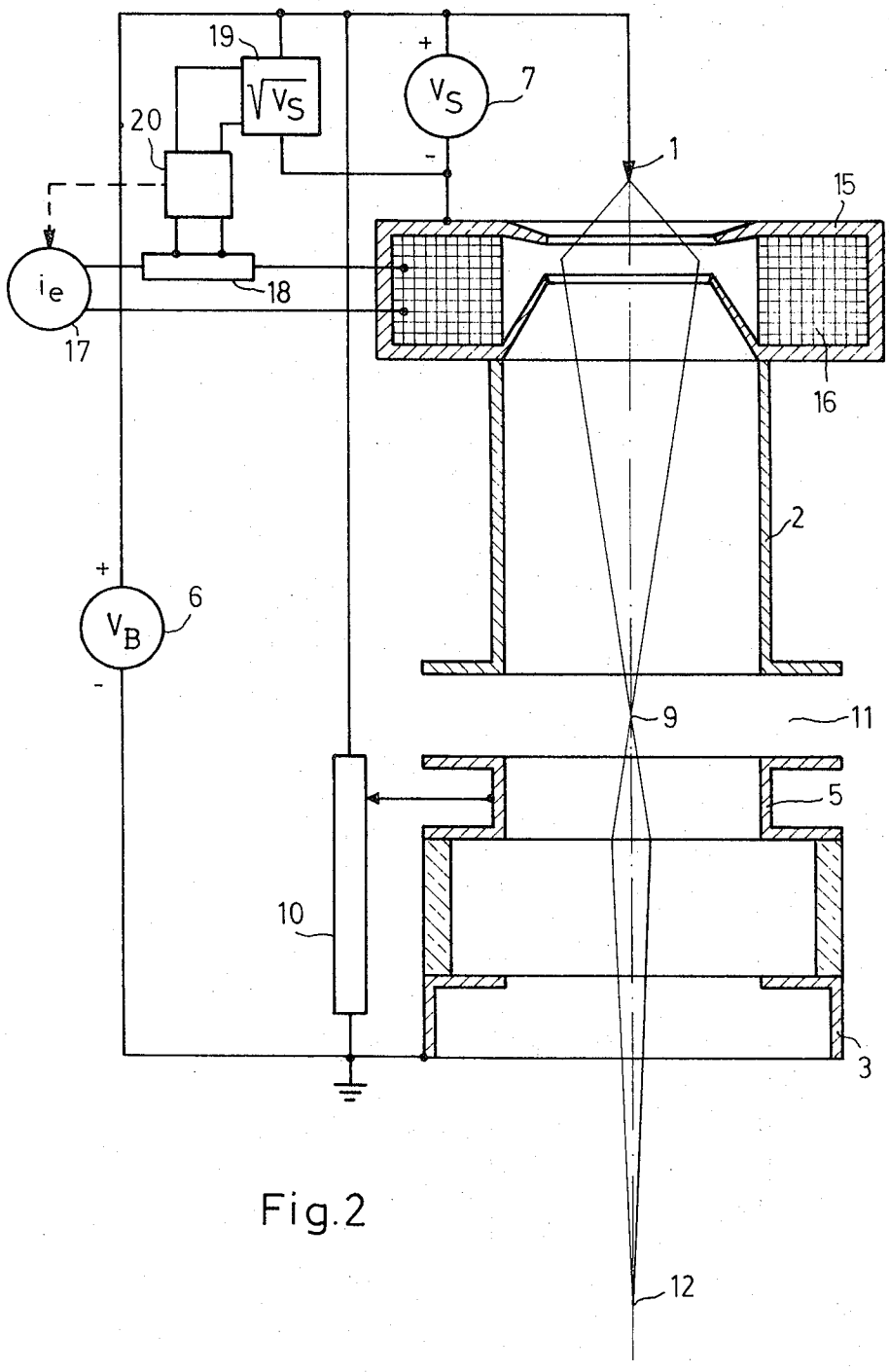


Fig.2

ELECTRON-BEAM ILLUMINATING SYSTEM FOR AN ELECTRICAL APPARATUS SUCH AS AN ELECTRON MICROSCOPE OR THE LIKE

BACKGROUND OF THE INVENTION

The invention relates to an electron-beam illuminating system, particularly for electron microscopes. The illuminating system is equipped with a cathode which constitutes the source of the electrons and which has an emission determined by the positive bias of a first anode, particularly a field emission cathode. The illuminating system is further provided with an accelerating anode, and an auxiliary lens which is situated in front of the accelerating anode and generates at the input of the acceleration path a first image of the source at a fixed point of the axis; and with a further lens which images the first image of the source once more.

Such a system is known from the paper by Lee H. Veneklasen and Benjamin M. Siegel entitled: A Field-Emission Illuminating System for Transmission Microscopy in Septieme Congres International de Microscopie Electronique, Grenoble 1970.

Electron-beam illuminating systems with a field emission cathode normally have the property that the focusing of the emerging electron beam is affected by the ratio of the first anode voltage to the accelerating voltage. In the known arrangement, this shortcoming is corrected in first approximation by the fact that the first image of the source, projected by the auxiliary lens, is situated in or near the principal plane of the lens formed by the accelerating system, so that in the ideal case the lens effect of the accelerating system is eliminated. As a further lens, which images the first image of the source once more, a magnetic lens, whose excitation must be corrected in the event of a change of the accelerating voltage, is provided in the known arrangement.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an electron-beam illuminating system of the above-mentioned type simplified in regard to configuration and operation.

According to the invention, between the first anode and the accelerating anode, a further electrode is disposed whose potential, relative to the potential of the accelerating anode, is linearly proportional to the accelerating voltage. The first image of the source is situated in the gap between the first anode and the further electrode and the further lens is formed by the further electrode together with the accelerating anode. The system of the invention affords the advantage that the accelerating system itself takes over the second imaging of the source thereby rendering unnecessary the magnetic lens of the known arrangement. Because the potential of the further electrode is linearly proportional to the accelerating voltage, the further advantage is realized that the lens power of the further lens changes in the same sense as the accelerating voltage if the latter changes, so that the second image remains essentially unaffected.

An electron-beam illuminating system of the invention is suitable for an electrical apparatus such as an electron microscope or the like. The system includes a cathode constituting a source for supplying the electrons making up the electron beam. A first anode is disposed beyond the cathode and defines therewith a beam axis extending in beam direction. A first anode

voltage supply means supplies a positive bias voltage to the first anode for determining the emission of the cathode. Beyond the first anode along the beam axis there is disposed an acceleration anode which defines an acceleration path for the electrons emitted by the cathode. Acceleration voltage supply means establishes an acceleration voltage across the cathode and the accelerating anode. A further electrode is disposed between the first anode and the accelerating electrode, the further electrode and the first anode conjointly defining a space therebetween along the beam axis. An auxiliary lens is disposed along the beam axis ahead of the acceleration anode for generating a first image of the source in the above-mentioned space at the input of the acceleration path at a fixed location on the beam axis. The further electrode and the acceleration anode conjointly define a further lens for imaging the first image of the source. Circuit means supplies to the further electrode a voltage which is linearly porportional to the acceleration voltage and which is taken with reference to the potential on the acceleration anode.

Because the first image of the source is situated in the gap between the first anode and the further electrode, and preferably in the center of this gap, a lens effect of this gap is largely neutralized. A possible lens effect of this gap can be reduced further by applying to the further electrode a potential which is approximately equal to the potential of the first anode. In case of variations of the first-anode voltage, only voltages which are of the order of a few kV can then occur between the electrodes mentioned.

The invention affords still the further advantage that the length of the illuminating system between the cathode and the second image of the source can be kept small which is often desirable. The second image of the source is, for instance, situated at the location of a specimen to be investigated in the electron microscope.

A field emission cathode in the narrower sense is generally understood to be a cathode which is operated cold and in which the emission of the electrons is caused by the strong electric field existing at the surface. However, cathodes with a field that draws away and which are heated in addition are also known. The invention can be applied to advantage also in connection with this mixed type of cathode.

Although the invention is illustrated and described herein as an electron-beam illuminating system for an electrical apparatus such as an electron microscope or the like, it is nevertheless not intended to be limited to the details shown, since various modifications may be made therein within the scope and the range of the claims. The invention, however, together with additional objects and advantages will be best understood from the following description and in connection with the accompanyings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram, partially in section, of an electron-beam illuminating system according to a preferred embodiment of the invention. In this embodiment, an electrostatic auxiliary lens is provided for imaging the electron source in the space between the first anode and the further electrode.

FIG. 2 illustrates an alternate embodiment of the electron-beam illuminating system of the invention wherein the auxiliary lens is configured as an electromagnetic lens.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Referring to FIG. **1**, the field-emission cathode is designated with reference numeral **1**, the first anode with **2** and the accelerating anode with **3**. The potentials of these electrodes are U_1, U_2, and U_3, respectively. The accelerating anode **3** is at ground potential ($U_3 = 0$). The upper part of the first anode **2** constitutes an auxiliary lens. In the illustrated embodiment, the auxiliary lens is an electrostatic einzel lens **2***a* equipped with the center electrode **4**. Between the first anode **2** and the accelerating anode **3**, a further electrode **5** is provided.

A high accelerating voltage V_b is provided by acceleration voltage supply means in the form of a high-voltage generator **6** and is applied to the field-emission cathode **1**. In the illustrated embodiment, it is assumed that $V_B = 100$ kV and therefore, $U_1 = -100$ kV. The first anode **2** has a positive voltage V_S, which is taken from a voltage generator **7**, relative to the field emission cathode **1**. In the illustrated embodiment, it is assumed that $V_S = 5$ kV and therefore, $U_2 = -95$ kV.

The center electrode **4** of the einzel lens has, relative to the cathode **1**, a voltage which is linearly proportional to the voltage V_S which draws the electrons; this voltage V_S is taken off at the potentiometer **8**. In the illustrated embodiment, the potential U_4 of the center electrode is assumed to be −99 kV.

The einzel lens **2***a*, **4** projects at **9** a first image of the electron source constituted by the cathode **1**. By exciting the einzel lens **2***a*, **4** proportionally to the voltage V_S, the first image **9** of the source is caused to remain at the same place independent of the voltage V_S. The voltage V_S can be varied at will for the purpose of controlling the emission.

The potential U_5 of the further electrode **5** is adjusted by means of the potentiometer **10** so that it is linearly proportional to the accelerating voltage V_B. The further electrode and the accelerating electrode **3** conjointly form an electrostatic lens which images the image **9** at location **12**.

The system is configured and the voltages selected with reference to each other such that the image **9** of the source is situated in the space **11** between the first anode **2** and the further electrode **5**. Indeed, the image **9** is situated as nearly as possible in the center of this gap. The potential U_5 of the further electrode **5** can in principle be chosen largely at will, for instance, 0.5 V_B; in such a case, the electrodes **2** and **5** form a lens which, however, remains largely without effect, because the rays cross at **9** in the center of this lens. A lens effect of the gap **11** can be suppressed still further if a potential which closely corresponds with the potential of the first anode **2** is applied to the electrode **5**. This case is assumed in the illustrated embodiment and U_5 is therefore about 0.95 V_B, that is, −95 kV. The voltage between the electrodes **2** and **5** can become no more than a few kV if the voltage V_S changes, so that the gap **11** constitutes only a weak lens.

Because the excitation of the lens **3**, **5** is linearly proportional to the accelerating voltage V_B, the location of the image **12**, that is, the image distance of the illuminating system, remains practically constant if the accelerating voltages V_B change, so that a readjustment of the second imaging lens is not necessary.

In the embodiment according to FIG. **2**, a magnetic lens is provided as the auxiliary lens; all other parts are the same as in FIG. **1**. The magnetic auxiliary lens comprises the iron enclosure **15** and the winding **16**; the iron enclosure forms part of the first anode **2**. The winding **16** is supplied with an excitation current i_e taken from the regulated current source **17**. Reference numeral **19** is a computing element which furnishes an output voltage proportional to the square root of the voltage V_S. A voltage proportional to the current i_e is taken off at the resistor **18**. A comparator **20** compares these voltages with each other and changes the current i_e by adjusting the current source **17** so that the difference of the voltages vanishes. By means of this excitation of the magnetic lens **15**, **16** which is proportional to the root of V_S, the first image **9** of the source is caused to retain its position if the voltage V_S is changed.

What is claimed is:

1. An electron-beam illuminating system for an electrical apparatus such as an electron microscope comprising

a cathode constituting a source for supplying the electron making up the electron beam;

a first anode disposed adjacent said cathode and defining therewith a beam axis extending in the beam direction;

first anode voltage supply means for supplying a positive bias voltage to said first anode for determining the emission of said cathode;

an acceleration anode disposed beyond said first anode along the beam axis and defining an acceleration path for the electrons emitted by said cathode;

acceleration voltage supply means for establishing an acceleration voltage across said cathode and said accelerating anode;

a further electrode disposed between said first anode and said acceleration anode, said further electrode and said first anode conjointly defining a space therebetween along the beam axis;

an auxiliary lens disposed along the beam axis between said cathode and said acceleration anode for generating a first image of said source in said space at the input of said acceleration path at a fixed location along the beam axis, said further electrode and said acceleration anode conjointly defining a further lens for imaging said first image of said source; and

circuit means for supplying to said further electrode a voltage linearly proportional to said acceleration voltage and taken with reference to the potential on said acceleration anode.

2. The electron-beam illuminating system of claim **1**, said cathode being a field-emission cathode.

3. The electron-beam illuminating system of claim **1**, said circuit means including means for adjusting said voltage on said further electrode.

4. The electron-beam illuminating system of claim **1**, said auxiliary lens being a electrostatic einzel lens having a center electrode; and auxiliary lens circuit means for supplying a voltage to said central electrode taken with respect to the voltage on said cathode and being linearly proportional to said positive bias voltage supplied to said first anode.

5. The electron-beam illuminating system of claim **1**, said auxiliary lens being an electromagnetic lens having an excitation winding; and excitation winding supply means for supplying an excitation current to said excitation winding having a value proportional to a root of said positive bias voltage supplied to said first anode.

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