Nov. 17, 1942. B. VON BORRIES 2,301,987

ELECTRON MICROSCOPE

Filed Nov. 16, 1939 2 Sheets-Sheet 1

Fig. 1

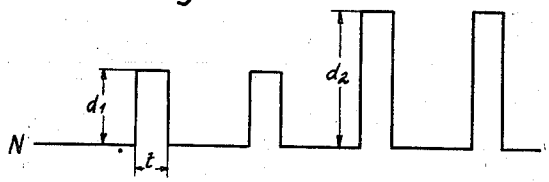


Fig. 2

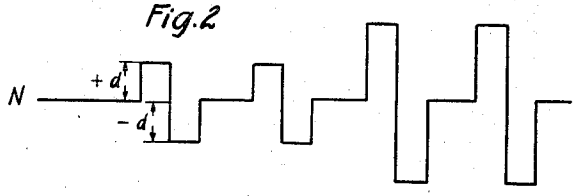


Fig. 3

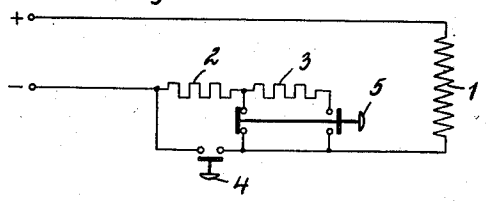
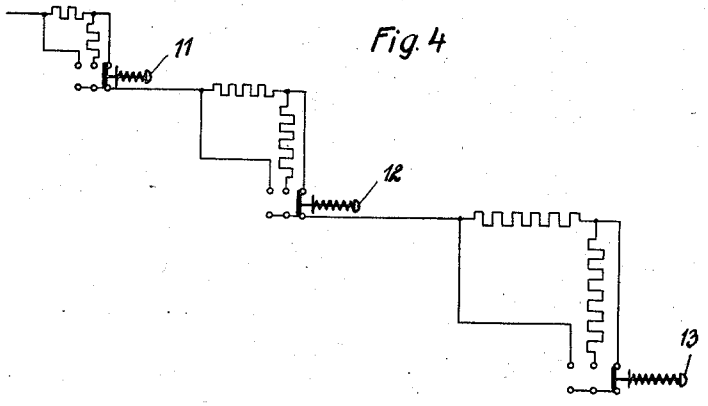


Fig. 4



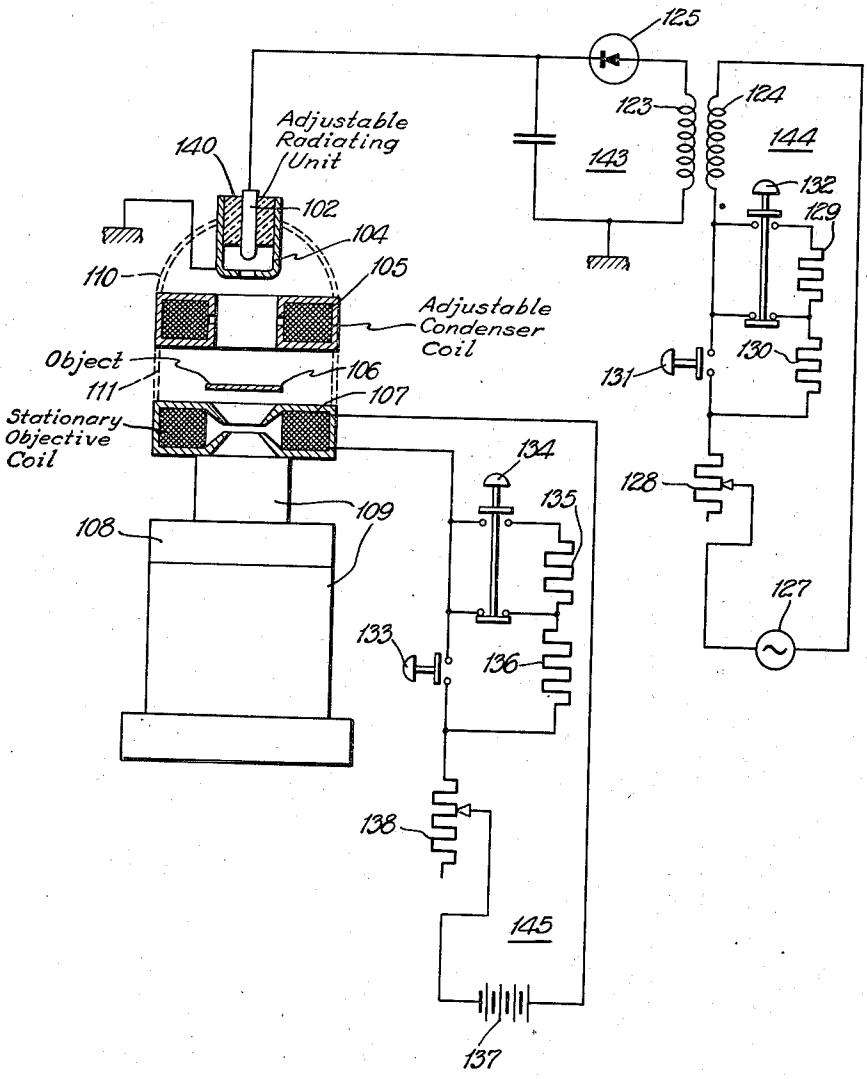
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FIG. 5.



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UNITED STATES PATENT OFFICE

2,301,987

ELECTRON MICROSCOPE

Bodo von Borries, Berlin-Spandau, Germany; vested in the Alien Property Custodian

Application November 16, 1939, Serial No. 304,763
In Germany October 21, 1938

8 Claims. (Cl. 250—49.5)

The present invention relates to electron microscopes and, particularly, to means for centering the electron beam.

Electron microscopes of the known type usually contain a radiating apparatus consisting of an incandescent cathode, a Wehnelt cylinder and an anode diaphragm for producing an electron beam which is directed through a field coil serving the function of a condensing lens, the support of the object to be examined and one or more magnifying field coils for portraying the object. For directing the electron beam upon the object to be examined, prior to the invention, the condensing lens has been tilted and possibly shifted. This operation, however, usually resulted in adjustments in which the electron beam did not coincide with the optical axis of the portraying system, so that the image formed on the fluorescent screen was shifted if fluctuations occurred in the current of the condensing lens or the voltage of the radiating apparatus. Such fluctuations in the operation of the apparatus, however, may not be entirely avoided, and a shifting of the image constitutes a very disturbing factor particularly if the image is to be reproduced photographically.

It is therefore the principal object of the present invention to prevent such undesired shifting of an image formed in an electron microscope.

Another object of the invention is to render an electron microscope insensitive to the fluctuations of the current and voltage, as mentioned above.

Another object of the invention is to center the electron beam relative to the optical axis of the portraying system.

For attaining these objects the invention provides the following method and means. The electrical values determining or controlling the electron beam are varied arbitrarily, while adjusting means provided for varying the direction and position of the electron beam are adjusted until the shifting of the image caused by the arbitrary variations is practically eliminated. For adjusting the position and direction of the electron beam, means may be provided whereby one or more parts of the radiating apparatus may be adjusted relative to the lens system, preferably by shifting and tilting these parts or by either of these methods. These adjusting means make it possible to control the electron beam produced by the radiating apparatus so as to coincide exactly with the optical axis of the portraying lens system. The use, according to the invention, of arbitrary variations of the electrical values producing or controlling the electron beam permits determining by direct observation and in a simple manner whether or not the adjusting movements are performed correctly. The adjustment is continued until the electron beam has been centered. Then, a shifting of the image, due to fluctuations of the current of the condensing coil and of the voltage of the radiating apparatus, is prevented since these fluctuations are now only able to change the cross-sectional area of the electron beam but not the direction thereof.

In executing the process, the electron beam is centered preferably by arbitrarily varying the current or voltage producing or controlling the electron beam. This may be performed, for example, by arbitrarily varying the current flowing through the objective coil or the high tension producing the electron beam. More particularly, the method according to the invention may be performed by varying the respective electrical value, for example the high tension for producing the electron beam, by several predetermined amounts, preferably by first arbitrarily making small changes from the normal value and thereafter one or more progressively greater changes. The adjustment of the electron beam may be thus continuously corrected so as to decrease progressively the sensitivity of the apparatus to fluctuations of the current or voltage.

These and other objects, features and advantages of the present invention will appear from the following detailed description and the accompanying drawings, in which

Figure 1 is explanatory and diagrammatically illustrates one method for attaining the objects of the present invention.

Figure 2 illustrates similarly a modification of the same method;

Figure 3 shows an embodiment of a circuit for producing the above-mentioned electric variations according to the method represented by Figure 2.

Figure 4 shows another electric control circuit for producing such fluctuations in accordance with the invention.

Referring at first to Figure 5, the electron microscope proper, here illustrated schematically, is more fully described in the copending application, Serial No. 303,180, filed November 7, 1939, and is shown only as a convenient example, no claim being made in the present application as to the structural features of this microscope and it being understood that any known electron

microscope having mechanical means for adjusting the electron beam relative to the lenses may be used, such as described, for instance, in "Zeitschrift für Physik," vol. 78, 1932, pages 330 to 333, or in the "Journal of Scientific Instruments," vol. 14, 1937, pages 14 to 24. The microscope shown in Figure 5 contains a radiating device having a cathode 102 and an anode 104. These elements are firmly secured to an insulator 140 so as to form an integral radiating unit. This unit is laterally displaceable and tiltable relative to the stationary portion 109 of the microscope vessel. Adjusting screws, not shown, may be provided for controlling the angular and lateral positions of the radiating unit.

105 designates the condensing coil of the microscope. This coil is also tiltable and transversely displaceable, for instance by means of screws (not illustrated). After the coil 105 has once been adjusted, it may, as a rule, be left in its proper position. The object 106 is also displaceable transversely to the stationary portions of the microscope. The upper portions of the microscope vessel are schematically indicated by broken lines and designated by 110 and 111. These portions may contain flexible sleeves or the like resilient means for joining the radiating unit with the condenser coil and the latter with the lower portion of the microscope. The magnifying lens system proper consists of an objective lens 107 and a projection lens 108. The electron beam issuing from the radiating unit passes first through the condensing lens 105, then through the object 106 where it is modified in accordance with the structure of the object, thence through the objective lens 107 which produces an intermediate image, and finally through the projection lens which throws a magnification of the intermediate image onto a screen or photographic plate in the bottom portion of the microscope vessel. As mentioned above, the final image is apt to be disturbed by shifting if the electric currents or voltages energizing the irradiating unit and the lens system fluctuate unless the beam coincides accurately with the optical axis of the lens system.

The radiating device is connected with a high-voltage circuit 143 containing a rectifier 125 and a capacitor, and connected to the high-voltage secondary 123 of a transformer whose low voltage primary 124 is fed from a circuit 144 containing an alternating current source 127, resistors 128, 129 and 130, and contactors (push-buttons) 131 and 132. This circuit permits varying the high voltage of the irradiating apparatus for the purpose aforementioned. The objective coil 107 is energized from a circuit 145 containing a D. C. source 137, resistors 138, 135, 136 and contactors 133 and 134. The circuit 145 permits varying the energizing current of the lens coil 107. By operating in either circuit 144 and 145, one, the other, or both push-buttons, the resistance of the circuit is changed and thus the effective voltage or current varied as explained in the following. The variations cause the magnified image to effect shifting movements. While observing these movements, the observer changes the adjustment of the radiating unit or condenser lens until the shifting ceases.

As illustrated in Fig. 1, the arbitrary fluctuations of the electrical value (voltage or current) may be performed, for example, by starting with the normal value N, the electrical value is increased each time for a period t by an amount d_1. If by adjusting the electron microscope the apparatus has been made insensitive to these fluctuations d_1, correspondingly greater fluctuations d_2 may be performed, whereupon the microscope is further adjusted so as to be insensitive also to these fluctuations.

As illustrated in Fig. 2, the desired result may also be obtained by arbitrarily adjusting the variations of the electrical value N by alternately increasing and reducing the same by the same amount d. Progressively increasing positive and negative deviations from the normal value N may also be provided so as to center the electron beam of the microscope as exactly as possible.

As shown in Fig. 1, manually operated switches, for example, push-button switches, may be used for making the arbitrary variations of the electrical values. If for performing the method according to the invention the high tension required for producing the electron beam is to be varied arbitrarily, this may be obtained, as also shown in Fig. 1, by suitably influencing the exciting circuit of the exciter of the high tension transformer. The same result may also be obtained by influencing the low-tension circuit of the high-tension transformer or the control circuit of a thermionic regulator of the exciter.

Fig. 3 illustrates separately a circuit for varying arbitrarily the high tension necessary for producing the electron beam by a definite positive and negative amount. The arrangement shown in Fig. 3 comprises the exciting winding 1 of the high-tension generator, two resistances 2 and 3 in the exciting circuit, and manually operated push-button switches 4 and 5. When in normal position, as shown in the drawings, the exciting winding 1 is connected in series with the resistance 2, in which case the normal value N of the exciting voltage may be adjusted. For obtaining an arbitrary increase of the voltage, the push-button 4 is operated so as to bridge the resistance 2. The voltage is then correspondingly decreased by operating the push-button 5 whereby the two resistances 2 and 3 are connected in series with the exciting winding 1. The circuits 144 and 145 are similar to that of Fig. 3 and hence operate substantially in the way as just mentioned.

As illustrated in Fig. 4, it is also possible that the same push-button switch 11 be used for increasing as well as decreasing the voltage. For this purpose, the voltage is reduced if the push-button is only slightly depressed, and increased if the push-button is fully depressed. The circuit shown in Fig. 4 also permits a progressive increase and reduction of the high tension necessary for producing the electron beam. For this purpose, after the push-button 11 is depressed, further push-buttons 12 or 13 are operated for connecting greater resistances into the circuit. The changes in voltage may also be obtained by switching on or off portions of the transformer windings. The manually operated switches for obtaining arbitrary changes of the electrical values are preferably mounted at a place easily accessible from the place of observation of the microscope.

I claim:

1. The method of centering the electron beam of electron-optical apparatus having electrically energized means for producing the beam and electrically energized means for modifying the beam to produce an image, comprising the steps of varying the electric energization of at least one of said means to cause shifting of said image so long as said different means are out of optical

alignment, and mechanically adjusting said different means relative to one another while said varying is continued until said shifting disappears.

2. The method of centering the image-producing electron beam in an electron microscope having an objective lens and means for mechanically adjusting the beam relative to the lens, comprising the steps of varying the energization of the objective lens to cause shifting of the image when said lens and said beam are in electron-optical misalignment, and actuating said mechanical adjusting means while said varying is continued until said shifting is substantially eliminated.

3. The method of centering the image-producing electron beam in an electron microscope having a high voltage irradiating device for producing the beam and a magnifying lens system mechanically adjustable relative to each other, comprising the steps of periodically varying the high voltage of the irradiating device to cause shifting of the image when the beam and the lens are in misalignment, and varying the relative position of said device and said lens simultaneously with said periodic voltage variation is effected until said shifting substantially ceases.

4. The method of centering the image-producing electron beam in an electron microscope having a high voltage irradiating device for producing the beam and an objective lens mechanically adjustable relative to each other, which comprises the steps of periodically varying the high voltage of the irradiating device and the energization of the objective lens to cause shifting of the image when the beam and the lens are in misalignment, and simultaneously varying the relative position of said device and said lens until said shifting substantially ceases.

5. The method of centering the electron beam of electron-optical apparatus having electrically energized means for producing the beam and electrically energized means for modifying the beam to produce an image, comprising the steps of varying the electric energization of at least one of said means by a relatively small amount to cause shifting of the image when said different means are in electron-optical misalignment, mechanically adjusting said different means relative to one another until said shifting is substantially reduced, varying said energization to an extent greater than before to again cause shifting of the image, and further adjusting said different means mechanically relative to one another to again reduce the shifting.

6. The method of centering the electron beam of electron-optical apparatus having electrically energized means for producing the beam and electrically energized means for modifying the beam to produce an image, comprising the steps of varying the electric energization of at least one of said means by alternately increasing and decreasing it by substantially equal amounts to cause shifting of the image when said different means are in electron-optical misalignment, mechanically adjusting said different means relative to one another until said shifting is substantially eliminated.

7. With an electron microscope having electrically energized means for producing an electron beam, lens means for modifying the beam to produce an image, and an adjusting device for varying the position of said different means relative to one another for centering the beam, in combination, an electric energizing circuit connected with one of said means, said circuit comprising a variable circuit element for varying the energization to cause shifting of the image unless said different means are adjusted by said device to be in correct optical alignment, and control means arranged in said circuit for putting at will said variable circuit element in and out of operation.

8. With an electron microscope having electrically energized means for producing an electron beam, lens means for modifying the beam to produce an image, and an adjusting device for varying the position of said different means relative to one another for centering the beam, in combination, an electric circuit for energizing one of said means comprising manually operated switch means for increasing and decreasing the energization to cause shifting of the image so long as said different means are in electron-optical misalignment.

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