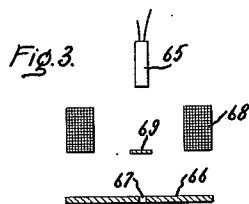
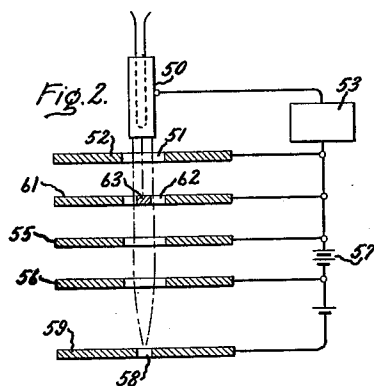
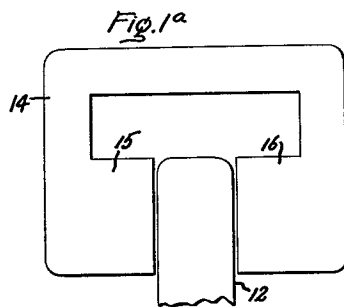
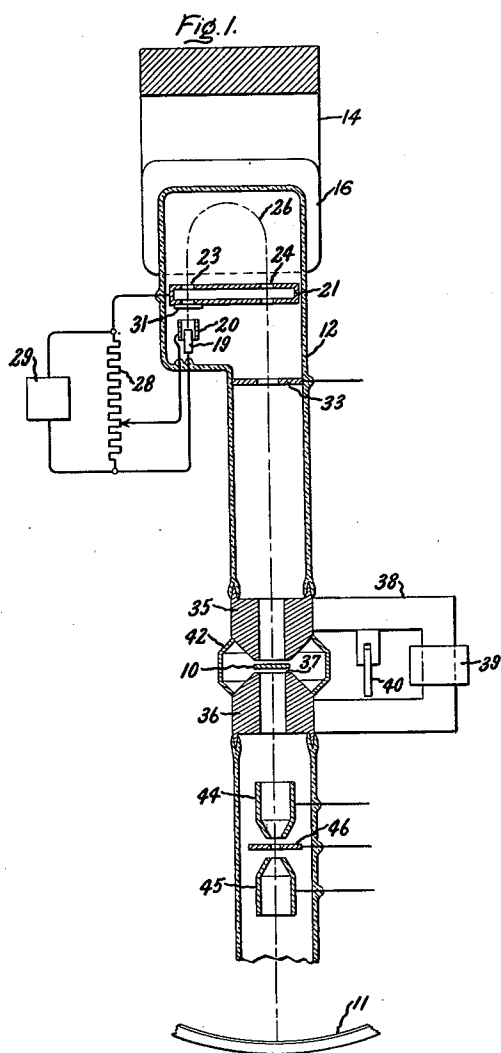


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ELECTRON MICROSCOPE
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ELECTRON MICROSCOPE

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The present invention relates to discharge devices which employ a focused electron beam and is especially applicable in connection with so-called "electron microscopes."

As is well-known, the electron microscope is employed for the investigation of minute objects and is used for the production of enlarged images of such objects in the manner of an optical microscope. In the electron microscope, however, magnification effects are obtained by refracting the elements of an electron beam rather than by refracting a light beam as in the optical microscope.

In electron microscopes of a type in which the electrons are caused to penetrate the object under investigation before being projected on an image-reproducing surface, difficulties are sometimes encountered in that the class of objects susceptible to such investigation are often so sensitive as not to withstand exposure to electron currents of appreciable magnitude. For this reason, it has been proposed to employ in this connection an electron stream of low intensity and to obtain the desired imaging effects by extending the time of exposure. It is found, however, that the realization of satisfactory results with this technique requires either the substantial elimination of sporadic variations in the voltage source by which the electrode elements of the electron microscope are supplied, or the provision of some means for compensating for such variations. In accordance with our present invention, compensation for these voltage variations is accomplished in an improved manner by utilizing a source of electrons having a relatively wide range of energy distribution in combination with velocity-discriminating means for selecting from the stream only electrons which have particular velocity. By choosing the range of energy distribution in the said electron source sufficiently wide with reference to the expected range of voltage variation of the power supply, it proves possible to maintain a supply of electrons which are of uniform velocity regardless of the aforesaid voltage variation.

The features which we desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further aspects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawing in which Fig. 1 is a longitudinal sectional view, partly broken away, showing schematically an electron microscope suitably

embodying the invention; Fig. 1a is a detail view of one aspect of Fig. 1 considered in a different plane; Fig. 2 represents an alternative mode of application of the invention and Fig. 3 shows a second modification of the invention.

Referring particularly to Fig. 1, there is shown an evacuated electron microscope by which an enlarged image of a minute object supported on an appropriate mounting element 10 may be projected on a suitable imaging surface, such as a photographic film arranged as indicated at 11. In order to accomplish the effects referred to in the foregoing, it is desired to obtain a stream of constant velocity electrons which may be projected through the object mounting 10 for a relatively long period of time without such variation in the velocity of the components of the stream as will tend to produce material changes in the image appearing on the film 11. In accordance with our invention, this object is attained by the provision of an electron source of appropriate character in combination with means for producing a strong deflecting field. This may be done in one way by the use of a magnetic structure 14 which is so arranged as to produce a field in a direction transverse to the main axis of the electron microscope. The magnetic structure, which is better shown in Fig. 1a, may comprise, for example, a U-shaped arrangement having pole pieces 15 and 16 which extend into proximity to the walls of the microscope envelope 12.

For producing an electron stream of the desired characteristics, there is provided a cathode 19 having associated therewith a focusing cylinder 20 and an accelerating anode 21. As is shown in the drawing, the anode 21 consists of two spaced plates maintained at a common potential and provided with displaced apertures which are respectively indicated at 23 and 24. By the action of the magnetic structure 14, the electrons which are projected through the opening 23 are deflected laterally and caused to reverse in direction as indicated by the dotted ray 26. It will be understood that the degree of deflection of the various electrons is determined directly by their velocity. Consequently, certain electrons having a critical velocity will be so directed by the effect of the magnetic field as to pass through the opening 24, while the remaining electrons, that is, those of other velocities, will be intercepted by the imperforate portions of the anode.

The potentials applied between the cathode and the electrodes 20 and 23 may be supplied,

for example, from a voltage divider 28 which is in turn connected with a power source 29. For electron microscopy the required voltage of the source 29 may be relatively high, at least on the order of several thousand volts, and more or less sporadic variations in the potential of this source may be expected to occur from time to time. Such sporadic variations, of course, have a direct effect on the velocity of the electrons projected from the cathode 19, and, without the provision of the special features which are shortly to be described, would make it impossible to provide a continuous stream of constant velocity electrons.

In accordance with our present invention the deflection system above described is enabled to eliminate the effect of variations of the voltage source by providing in connection with the cathode 19 means for causing the electron stream generated thereby to be characterized by a relatively wide range of energy distribution. This may be accomplished in one way, for example, by providing in connection with the aperture 23 of the accelerating electrode 21, an electron permeable foil 31. Most of the electrons projected from the cathode are able to pass through this foil, but in such passage they are made subject to energy losses of varying degree so that the transmitted electron stream possesses a wide energy distribution.

In order to make use of this circumstance, the operating conditions of the system are so adjusted that the electron velocity desired to be utilized in the production of microscopic effects falls somewhere near the center of the range of velocities available in the electron stream which is projected through the foil 31. Under these conditions it is apparent that although sporadic variations in the potential of the voltage source 29 may change the limits of the aforesaid range, they will not, at least for changes of reasonable magnitude (i. e. changes less than the breadth of the range), prevent the existence in the stream of at least some electrons of the desired velocity. Therefore, since the velocity discriminating system provided by the combination of the magnet 14 and the restricted opening 24 possesses a constant action—that is, an action which is not affected by the changes which may occur in the voltage source 19—a continuous supply of electrons of the desired velocity will be projected through the said opening. These electrons may be additionally focused or accelerated by the provision of a suitable electrode 33 positioned along the electron path.

For the production of magnification effects the stream of constant velocity electrons provided in the manner above specified may be caused to pass through the object mounting 10 and thence projected on the reproducing surface 11. In this connection, the requisite refraction of the electrons may be accomplished in one way by the use of a magnetic lens system comprising a pair of generally tubular pole pieces 35 and 36 which are axially spaced in end-to-end relation so as to provide a gap 37 within which the object mounting 10 is positioned. These pole pieces are supplied with magnetic flux by being connected to a magnetic core structure 38 having associated therewith an energizing winding or permanent magnet positioned as indicated at 39. The strength of the field thus produced across the gap 37 may be regulated by the use of a variable magnetic shunt 40 provided in connection with the core structure 38. The space between the

pole pieces 35 and 36 is sealed in vacuum-tight fashion by the provision of a closure ring 42 having its edges in abutment with the opposed surfaces of the pole pieces.

After the passage of the beam through the magnetic lens system just described, additional refractive effects may be obtained if desired by the use of an electrostatic lens, which, in the arrangement illustrated, comprises a pair of generally tubular electrodes 44 and 45 which are symmetrically positioned with respect to an apertured diaphragm 46. These elements are, of course, understood to be maintained at an appropriate difference of potential with respect to one another.

The particular means specified for producing an electron stream of wide energy distribution (i. e. the foil 31), may of course, be replaced by other known agencies. For example, one may use in this connection, a high frequency voltage of an amplitude, say, on the order of 50 to 100 volts, superimposed on the unidirectional potential which is impressed between the cathode 19 and the accelerating electrode 21. The variations of this superimposed voltage will assure the occurrence in the resultant electron stream of a substantial range of electron velocities.

As a further alternative, one may use a gas discharge as an electron source in place of the cathode 19. As is known, electrons provided by a source of this kind inherently possess a wide range of energy distribution.

It will also be understood that the velocity discriminating agency (i. e. the "monochromator") described in connection with Fig. 1 may be replaced by other devices for achieving the same end. For example, in Fig. 2 there is shown an arrangement for selecting constant velocity electrons which is well adapted to be employed with the electron microscope structure shown in Fig. 1. In this case a cathode 50 has its emitting surface positioned in aligned relationship with an opening 51 provided in an accelerating electrode 52. An appropriate difference of potential is maintained between these elements by the provision of a source of accelerating potential 53. In order to select from the electron stream, which is projected through the opening 51, only those electrons which have a desired velocity, there is provided an electrostatic lens system comprising a pair of apertured diaphragms 55 and 56 which are maintained at an appropriate difference of potential by means of a constant voltage source, conventionally illustrated as a battery 57. It is the function of these electrodes to focus electrons of the selected velocity in a small opening 58 provided in a further apertured diaphragm 59 arranged to be traversed by the electron stream after its passage of the diaphragms 55 and 56. If the opening 58 is of sufficiently small dimensions and if the lens system provided by the elements 55 and 56 is of suitable character, it is possible to assure that for the most part, only those electrons which have a desired velocity shall be enabled to pass through the opening 58, all others being collected on the non-perforate portions of the diaphragm 59. The only exception will occur in the case of electrons which are projected from the cathode 50 along the axis of symmetry of the electrode system. However, these electrons may be readily eliminated by the provision of a further diaphragm electrode 61 having an aperture 62 of which the central portion is blocked by the provision of an appropriately positioned imperforate body 63.

It will be understood that in order to assure the presence of a relatively wide range of velocity distribution in the electrons projected from the cathode 50, use may be made of any of the various expedients described in connection with Fig. 1. It will be further understood that the velocity discriminating means just described is intended to be combined with other elements of an electron microscope such as are illustrated in Fig. 1.

As a final variant, it should be noted that it is possible to use a magnetic lens system in place of the electrostatic lens arrangement of Fig. 2. This possibility is illustrated in Fig. 3 which represents the combination of a cathode 65, a diaphragm 66 having a minute central opening 67, and a magnetic lens system positioned between the cathode and the diaphragm for assuring that only electrons of desired velocity shall pass through the opening 67. The magnetic lens system is, in this case, represented conventionally as a coil 68. An imperforate object 69 positioned along the central path of the electron stream serves to prevent the passage of electrons projected along such path as has been previously explained in connection with the element 63 of Fig. 2.

While we have described our invention in connection with particular embodiments thereof, it will be understood that numerous further modifications may be made by those skilled in the art without departing from the invention. We, therefore, aim in the appended claims to cover all such equivalent variations as fall within the true spirit and scope of the foregoing disclosure.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. An electron microscope comprising an electron source, an object mount positioned in the path of electrons emitted from said electron source and adapted to support an object desired to be investigated electron-optically, means including an accelerating electrode and a source of accelerating potential connected thereto for projecting electrons from the electron source through an object supported in said mount, said potential source being subject to sporadic variations whereby the electrons projected from the electron source tend to be of varying velocity, an electron lens system for electron-optically refracting electrons projected through the said object so as to produce useful magnification effects, the operation of said lens system being variable with the velocity of the electrons, means for assuring the continuous existence in the electron stream projected from the electron source of velocity variations greater than the sporadic variations attributable to the said potential source, and means for eliminating from the portion of the stream projected through the said object electrons above and below a selected velocity, whereby the electrons reaching the said electron lens system are solely of the selected velocity.

2. Electron discharge apparatus including an electron source, means including an electrode and a source of potential connected thereto for directly accelerating electrons emitted from the electron source, said potential source being subject to irregular variations of such character as to produce sporadic changes in the velocity of the accelerated electrons, an agency for utilizing the stream of accelerated electrons, said

agency being critically and objectionably responsive to variations in the velocity of the electrons reaching the agency, means for assuring the continuous existence in the electron stream proceeding toward the said agency of velocity variations greater than the sporadic variations attributable to the potential source, and means interposed between the last-named means and the said agency for eliminating from the electron stream electrons above and below a selected velocity, whereby only electrons of the said selected velocity reach the said agency.

3. Electron discharge apparatus including an electron source, means including an electrode and a source of potential connected thereto for directly accelerating electrons emitted from the electron source, said potential source being subject to irregular variations of such character as to produce sporadic changes in the velocity of the accelerated electrons, an agency for utilizing the stream of accelerated electrons, said agency being critically and objectionably responsive to variations in the velocity of the electrons reaching it, an electron pervious foil positioned between the electron source and the said agency for producing in the electron stream proceeding from the said source velocity variations greater than the sporadic variations attributable to the potential source, field-producing means interposed between the said foil and the said agency for deflecting the various electrons to a degree determined by their respective velocities, and means interposed between said last-named means and the said agency for intercepting all electrons except those which experience a critical degree of deflection, whereby only electrons of fixed velocity reach the said agency.

4. An electron microscope comprising an electron source, an object mount positioned in the path of electrons emitted from said electron source and adapted to support an object desired to be investigated electron-optically, means including an accelerating electrode and a source of accelerating potential connected thereto for projecting electrons from the electron source through an object supported in said mount, said potential source being subject to irregular variations of such character as to produce sporadic changes in the velocity of the accelerated electrons, an electron lens system for electron-optically refracting electrons projected through the said object so as to produce useful magnification effects, the operation of said lens system being variable with the velocity of the said electrons, means for assuring the continuous existence in the electron stream projected from the electron source of velocity variations greater than the sporadic variations attributable to the said potential source, field-producing means between said last-named means and the said object support for deflecting the various electrons in the stream to a degree determined by their respective velocities, and means between the field-producing means and the object support for intercepting all electrons except those which experience a critical degree of deflection whereby only electrons of fixed velocity reach the said object.

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