

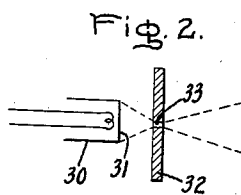
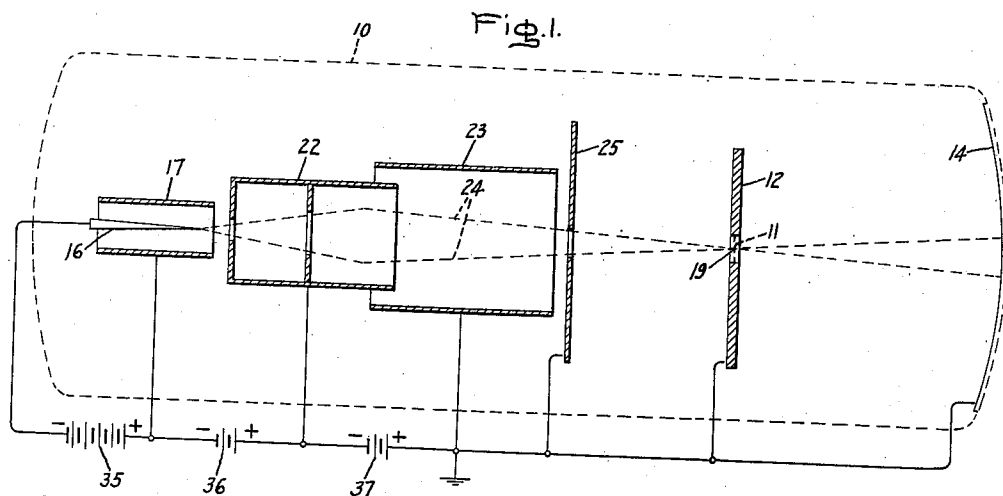
July 15, 1941.

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2,249,453

ELECTRON MICROSCOPE

Filed April 29, 1940



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UNITED STATES PATENT OFFICE

2,249,453

ELECTRON MICROSCOPE

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Application April 29, 1940, Serial No. 332,334
In Germany December 2, 1938

4 Claims. (Cl. 250-141)

The present invention relates to an electron microscope in which an electron beam is projected through the object under investigation to produce a silhouette image of the same on a suitable image-reproducing surface.

It is an object of the invention to provide an improved microscope of simple construction which is characterized by high magnification and resolving power. In the attainment of this object, an important feature of the invention consists in the provision of means by which the electron beam which penetrates the object under investigation is, in effect, projected from a point source positioned a very short distance from the object.

The features which we desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawing in which Fig. 1 represents diagrammatically an electron microscope suitably embodying the invention and Fig. 2 shows a modified form of electron source which may be alternatively employed in the apparatus of Fig. 1.

Referring particularly to Fig. 1, there is shown an electron microscope comprising a plurality of electrode elements which are assumed to be enclosed in an evacuated container (indicated by dotted line 10). An object to be investigated by the microscope is shown as being supported at 11 in a suitable frame 12. At the right of the object there is positioned an image-reproducing surface, for example, a fluorescent screen on which it is proposed to silhouette the object by means of an electron beam which is caused to pass through the object.

In accordance with our present invention, the electron beam referred to is produced by the combination of a cold cathode 16 and an accelerating electrode or anode 17. The cathode 16 is of pointed configuration and is so positioned with respect to the electrode 17 that field emission effects cause electrons to proceed from the tip of the cathode toward the screen 14. As a result of the particular cathode shape chosen, the resulting electron beam proceeds essentially from a point source. If desired, special electrode agencies of known character may be utilized for increasing the field intensity in the vicinity of the cathode tip. For example, one may employ in this connection a foil or a grid, in some cases so formed as to produce a lens effect.

It is desired to cause the electrons which are

generated by the cathode 16 to pass through a second region, also of point dimensions, which is extremely close to the object 11, such a point being indicated at 19. When the condition specified is attained, the subsequent divergence of the electron beam as it proceeds from the point 19 toward the screen 14 results in the projection on the screen of a magnified image of the object under inspection. The amount of magnification obtainable in this way is given by the ratio of the distance between the point 19 and the object 11 to the distance between the point 19 and the screen 14.

In order to cause the electrons emitted from the cathode 16 to pass through the point 19, an electron lens is interposed between the cathode and the object-supporting frame 12. This lens may be of either magnetic or electrostatic character and is illustrated by way of example in the drawing as comprising a pair of successively arranged cylinders 22 and 23. By the use of these cylinders, appropriately biased, the course of the electron beam may be controlled as indicated by the dotted rays 24. If desired, an image field stop diaphragm 25 may be provided in the region between the extremity of the cylinder 23 and the image 11 to cut out the marginal regions of the electron beam and thereby to eliminate any lens faults which would prevent the realization of a sharp point at 19. The stop 25 further limits the angle of aperture of the electron bundle. Accordingly, this angle can be so dimensioned that it is smaller than the smallest Bragg angle of deflection, whereby blurring of the image by deflected electrons is avoided.

A microscope constructed in accordance with the present invention has unusual simplicity as a result of the absence of lenses between the object 11 and the luminous screen 14. Even the single lens which is employed between the cathode and the object can be of simple design, since the use of a point source of electron emission greatly simplifies the problem of obtaining a point concentration of the beam at 19. In this connection, the use of a pointed cold cathode from which electrons are generated by field emission, as in the arrangement illustrated, is especially advantageous since it results in the development of an electron beam which is characterized both by high intensity and by a high degree of concentration.

Instead of the cathode illustrated in Fig. 1, it is possible to use a cathode of more usual construction. Thus, in the alternative arrangement which is shown in Fig. 2, use is made of a cathode

30 which has a flat emitting surface 31. In order that the actual source of the electron beam used in the object-irradiating process shall be of point dimensions, a virtual cathode can be formed by the use of a perforated diaphragm 32 having therein a minute perforation 33. For the purposes of the present invention, the perforation 33 is subjected to the impingement of electrons projected from the cathode 30 and is thereby caused to become a secondary source of electrons whose dimensions are determined by the dimensions of the opening 33. This opening may readily be made with a diameter as small as 10^{-3} cm. Thereafter, by projecting the electron beam which originates from this perforation through an electron lens having a 1000-fold reduction, one may obtain at point 19 (Fig. 1) a beam having a diameter of 10^{-6} cm.; that is, of molecular dimensions. Consequently, distances of this order of magnitude can be resolved with the arrangement illustrated. Even if the diaphragm opening 33 has a diameter of 10^{-2} cm. and the lens system only brings about a reduction of 1/100, the diameter of the beam at 19 still becomes 10^{-4} cm., which compares favorably with the limit of resolution of the photo-microscope. It will be understood that in using the electron-generating combination of Fig. 2, the electrons from the cathode 30 may be concentrated on the perforation 33 by the use of any appropriate means such as one or more concentrating electrodes.

It has already been pointed out that the degree of magnification which is possible with the arrangement described depends upon the closeness of the point 19 and the object 11. It should be further noted in this connection that this rule applies irrespective of whether the point 19 lies in front of or behind the plane of the object.

The various electrode elements may be energized in any desired fashion. In the arrangement shown, they are variously connected to a series of batteries 35, 36 and 37. It is obviously possible, however, to energize all of the elements from a common voltage source by means of a voltage divider so that the operation of the apparatus is free from objectionable effects due to voltage fluctuations.

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

1. An apparatus for investigating objects of microscopic dimensions by electron optical means comprising means for supporting an object to be investigated, means providing an image-reproducing surface, and means for projecting a beam of electrons through the object toward the surface, said last-named means including a cathode which is materially spaced from the object-supporting means and which has an active emitting surface of essentially point dimensions, and an electron lens system for causing electrons proceeding from said cathode to pass through a region of essentially point dimensions in close proximity to the plane of the object, the space between the object and the image-reproducing surface being substantially devoid of electric and magnetic fields so that electrons are free to proceed along substantially straight divergent paths from the said region to the said surface.

2. Apparatus for investigating objects of microscopic dimensions by electron optical means

comprising means for supporting an object to be investigated, an image-reproducing surface spaced from the object-supporting means, and means for projecting a beam of electrons through the object toward the said surface, said last-named means including an electron source which is materially spaced from the object-supporting means and which has an active emitting surface of dimensions less than 0.01 centimeter in a direction transverse to the path of the electron beam, and an electron lens system for causing electrons proceeding from said source to pass through a region of essentially point dimensions in close proximity to the plane of the object, the space between the object and the image-reproducing surface being devoid of magnetic and electric fields of converging effect whereby the natural divergence of the electrons in said space causes a magnified replica of the object to be produced on the said image-reproducing surface.

3. Apparatus for investigating objects of microscopic dimensions by electron optical means comprising means for supporting an object to be investigated, an image-reproducing surface spaced from the object-supporting means, and means for projecting a beam of electrons through the object toward the said surface, said last-named means comprising a cathode body which is tapered to a point-like tip directed toward the object-supporting means, means for causing electron emission from the cathode to occur mainly from the said tip, and an electron lens system for causing electrons proceeding from said cathode to pass through a region of point dimensions in close proximity to the plane of the object, the space between the object and the image-reproducing surface being substantially devoid of electric and magnetic fields whereby electrons are free to follow straight divergent paths from said region of point dimensions to the image-reproducing surface.

4. Apparatus for investigating objects of microscopic dimensions by electron optical means comprising means for supporting an object to be investigated, an image-reproducing surface materially spaced from the object-supporting means, and means for projecting a beam of electrons through the object toward the image-reproducing surface, said last-named means comprising a source of electrons, a diaphragm interposed between the source of electrons and the object and having therein a perforation of diameter less than 0.01 centimeter, means for causing electrons emitted from said source to irradiate the perforated portion of the diaphragm so as to cause secondary electrons to be emitted from the boundaries of the perforation, and an electron lens system interposed between said diaphragm and the said object to cause the said secondary electrons to pass through a region of point dimensions in close proximity to the plane of the object, the space between the object and the image-reproducing surface being devoid of magnetic and electric fields of converging effect whereby the natural divergence of the electrons in said space causes a magnified replica of the object to be produced on the said image-reproducing surface.

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