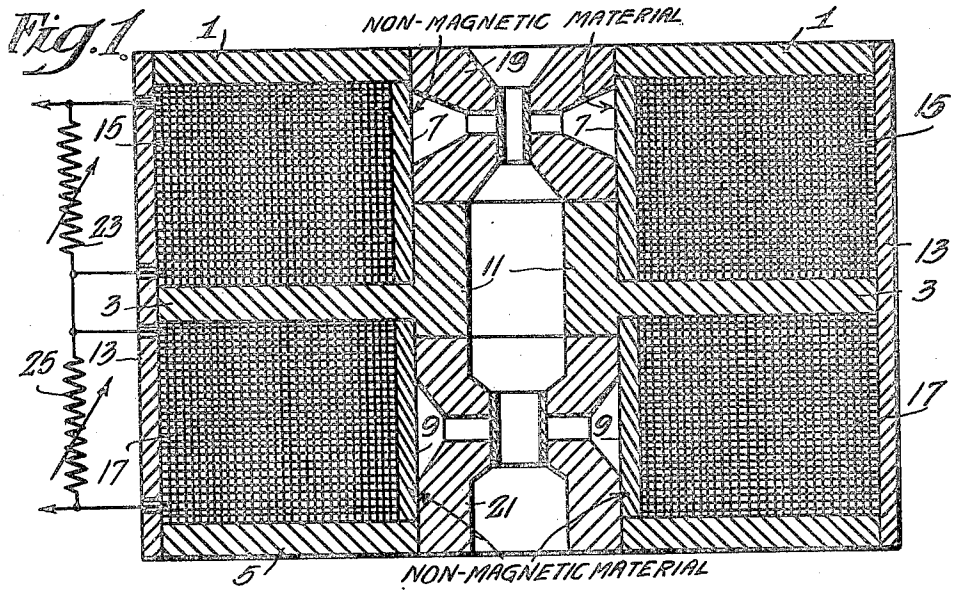
July 6, 1943. J. HILLIER 2,323,328

PROJECTION LENS FOR ELECTRON MICROSCOPES

Filed Oct. 31, 1940

Fig. 1.



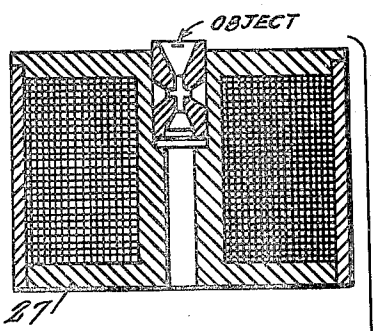


Fig. 3.

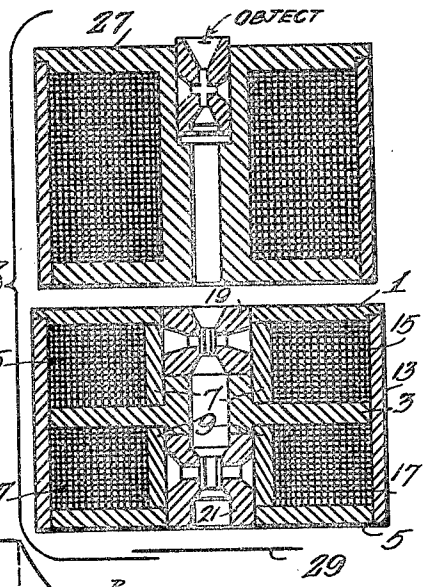
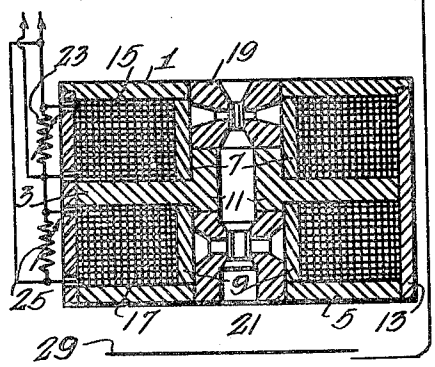


Fig. 2.



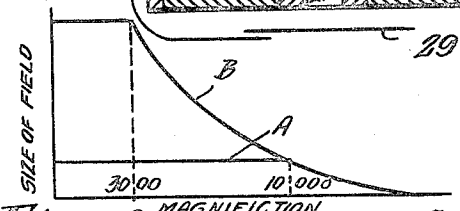


Fig. 4.

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PROJECTION LENS FOR ELECTRON MICROSCOPES

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Application October 31, 1940, Serial No. 363,745

7 Claims. (Cl. 250—49.5)

This invention relates to improvements in lenses for electron microscopes and particularly to an electron microscope projection lens in which both the magnification and the field of view may be varied according to a predetermined law without changing the relative positions of the object, lenses, and image plane.

In a conventional electron microscope, it is customary to vary the magnification without varying the size of the specimen field of view. By moving the specimen, an observer can scan the entire object for interesting portions. Such a method is very tedious because each view is limited to a small portion of the total field. In some electron microscopes, an intermediate or less magnified image is established. While the intermediate image covers a larger portion of the object, the microscope is complicated by the additional imaging screen and may be increased in size with the attendant difficulties of evacuation.

It is an object of the present invention to provide means for varying the size of the field of view of a specimen and for varying the magnification in an electron microscope. Another object is to provide means for changing both the field of view and magnification in an electron microscope without changing the relative positions of the specimen, lenses, and image plane. Another object is the provision of an improved electron projection lens in which a simplified adjustment may be used to vary the size of the field of view and the magnification according to a predetermined law.

The invention will be described by referring to the accompanying drawing in which Figure 1 is a sectional view of a preferred embodiment of the electron projection lens of the invention; Figures 2 and 3 are sectional views of the lens associated with the objective lens of an electron microscope; and Figure 4 is a graph showing magnification versus the size of the field of view. In the several figures, similar reference characters will be applied to similar elements.

Referring to Fig. 1, annular magnetic members 1, 3, 5 are secured in spaced parallel relation normal to a pair of nonmagnetic cylinders 7, 9. The inner annular member 3 has an inwardly extending magnetic portion 11 which is a hollow cylinder. The outer portions of the annular members engage an outer hollow cylinder 13 which is of magnetic material. The spaces between the annular members 1, 3 and 3, 5 include the field windings 15, 17. It will be noted that the inwardly extending portion or hollow cylinder 11 is shorter than the outer hollow cylinder 13. The upper space and the lower space between the ends of the inner cylinder 11 and the annular members 1, 5 are machined to fit, respectively, the upper and lower pole pieces 19, 21. The pole pieces are preferably, but not necessarily, made in accordance with the method disclosed in copending application Serial No. 361,348, filed October 16, 1940, by James Hillier, for Magnetic lenses (now U. S. Patent 2,292,877 issued August 11, 1942).

It is highly desirable to avoid any eccentricity of the pole pieces or magnetic structure. One suitable method is to first bore the aperture in the inner portion 11 of the magnetic structure. The non-magnetic cylinders 7, 9 and the annular members 1, 3, 5 are then secured by soldering or equivalent means to the inner portion 11 which can be mounted on an arbor, so that the several parts may be machined on common centers to assure concentricity. Since the pole pieces may be machined concentrically as disclosed in the aforementioned patent, it follows that the entire lens structure may be made concentric.

The windings may be connected to separate current controlling means such as the adjustable resistors 23, 25. The windings may be connected in series as shown in Fig. 1 or in shunt as shown in Fig. 2. In either case, it is preferable to employ connections in which the magnetic fields are opposed. This tends to prevent rotation of the image with varying magnification. If image rotation is not objectionable, the connections for aiding fields may be used. Once the ratio of the currents in the two windings has been determined, the desired relative magnetizing forces at the upper pair and lower pair of pole pieces will be determined. Thereafter, the total current may be regulated by a single control to vary the size of the field and the magnification according to a predetermined law. It should be understood that the size of the fluorescent screen or photographic recording means is usually constant, but the viewing size or area of the specimen or object field is varied according to the invention.

In practice, the projection lens is inserted between the objective lens 27 and the screen 29, as shown in Figs. 2 and 3. The arrangement of Fig. 3 is preferred, because it reduces the size of the microscope and thus diminishes the volume to be evacuated. The advantages of the improved lens may be indicated by comparing the curves A and B of the graph, Fig. 4. The curve A of a conventional microscope shows that the viewing field, that is, the selected area of the image, remains unvaried from a low magnification

to magnifications of about 10,000 times, and thereafter, as the magnification increases, the field diminishes. In the case of the improved microscope, the field is initially larger for low magnifications. As the magnification increases to about 3,000 times, the field remains constant. Thereafter, the field falls off, because the image has reached the screen limits. As the magnification increases to approximately 10,000 times, the field size becomes about the same as a conventional microscope.

It should be noted that the apertures of both the first and second pole pieces 19, 21 are made larger than the aperture of the objective lens 27. In fact, it is desirable that the aperture of the first pair of pole pieces be not lesss than the aperture of the objective lens times its magnification factor. This is necessary if the apertures of the projection lens are to include the larger field of the object in accordance with the invention. In the specific arrangement shown, the first portion of the lens magnifies and selects a predetermined portion of the objective lens image of the specimen field. The aperture of this portion of the lens is made of a diameter admitting the desired field. The second portion, which may have an aperture larger than the aperture in the first portion of the lens, magnifies the portion thus selected until the image reaches the limits of the imaging screen. In this manner, the initial magnification may be of the order of two or three thousand times, which permits the maximum field to be viewed, whereby an observer may select an interesting part of the specimen. The specimen is then moved so that the selected part is substantially at the center of the field which may then be further magnified until the image reaches the screen limits. If the ratio of the currents in the two portions of the projection lens has been properly selected initially, the magnification factor of the projection lens may be varied by simply varying the total current. At the same time the higher magnifications are not sacrificed.

Thus, the invention has been described as a projection lens for an electron microscope in which the field and the magnification may be varied; that is, as the magnification is decreased, the viewable field of the specimen is increased. The magnification of the larger field is of the order of two or three thousand times, which is sufficient to enable an observer to select the most interesting portions of a biological specimen or the like for further magnification. The projection lens includes two portions which are mounted within a common magnetic structure. The two portions include windings through which magnetizing currents are applied. The ratio of the currents is adjusted to obtain a proper image. Thereafter, a total current may be adjusted to control the magnification and field size.

I claim as my invention:

1. A projection lens for an electron microscope including in combination a magnetic structure including an upper pair of pole pieces, a lower pair of pole pieces, means for energizing said magnetic structure and means including said energizing means for controlling separately the magnetic force applied to each of said pairs of pole pieces whereby the field of view and the magnification may be varied according to a predetermined law.

2. A projection lens for an electron microscope including in combination a magnetic structure comprising two parts, windings in each of said parts, means for applying separate currents to said windings, an upper pair of pole pieces magnetically connected to one of said parts, and a lower pair of pole pieces magnetically connected to the other of said parts, said upper pair of pole pieces having a different aperture from said lower pair.

3. A projection lens for an electron microscope including in combination a magnetic structure including an upper pair of pole pieces, a lower pair of pole pieces, the aperture of said lower pair of pole pieces being greater than the aperture of said first pair of pole pieces, and means for adjusting to a predetermined value the ratio of the magnetic forces applied to said pairs of pole pieces.

4. A projection lens for magnifying the image established by the objective lens in an electron microscope including a magnetic structure, an upper pair of pole pieces, and a lower pair of pole pieces magnetically associated with said structure, the aperture of said upper pair of pole pieces being of the order of the aperture of said objective lens times the magnification factor of said objective lens, and means for adjusting to a predetermined ratio the magnetic forces applied to said pairs of pole pieces.

5. A projection lens for magnifying the image established by the objective lens in an electron microscope including a magnetic structure, an upper pair of pole pieces, and a lower pair of pole pieces magnetically associated with said structure, the aperture of said upper pair of pole pieces being of the order of the aperture of said objective lens times the magnification factor of said objective lens, said lower pair of pole pieces having an aperture not smaller than the aperture of said upper pair of pole pieces, and means for adjusting separately the magnetic forces applied to said pairs of pole pieces.

6. A projection lens of the character of claim 1 in which the magnetic forces in the upper pair of said pole pieces oppose the magnetic forces in the lower pair.

7. A projection lens of the character of claim 2 in which the currents applied to said windings produce opposing magnetic fields.

JAMES HILLIER.