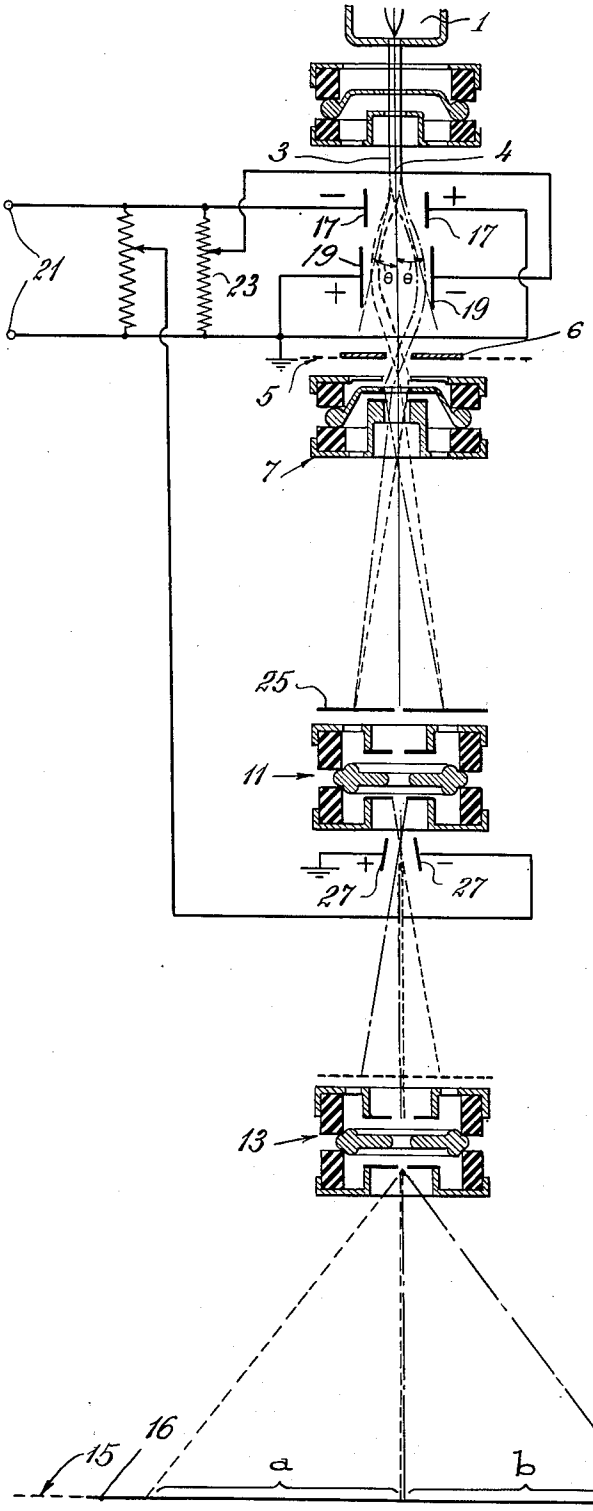
Nov. 4, 1952 G. M. FLEMING 2,617,041

STEREOSCOPIC ELECTRON MICROSCOPE

Filed Nov. 15, 1949



INVENTOR.
GERTRUDE M. FLEMING
BY
Pennie, Edmonds, Morton and Barrows
ATTORNEYS

Patented Nov. 4, 1952

2,617,041

UNITED STATES PATENT OFFICE

2,617,041

STEREOSCOPIC ELECTRON MICROSCOPE

Gertrude M. Fleming, Ardsley, N. Y., assignor to Farrand Optical Co., Inc., a corporation of New York

Application November 15, 1949, Serial No. 127,363

6 Claims. (Cl. 250—49.5)

1

This invention relates to electron microscopy and to the simultaneous production of two separate and distinct images from a single specimen for stereoscopic viewing.

It is sometimes advantageous in electron microscopy to form separate images of a specimen by means of electron beams incident on the specimen at different angles. Since the specimen is differently illuminated for the two images, the images differ slightly in a fashion analogous to the separate images formed by the two eyes in binocular vision. The separate images assist in resolving particles disposed in the specimen one behind the other in the sense of the optical axis of the microscope. They may also be viewed together with a stereoscopic viewer to give the usual effect of stereoscopic vision.

It has been proposed heretofore as in U. S. Patent No. 2,436,676 to Perry C. Smith et al., to produce stereoscopic images by the use of separate imaging systems having intersecting inclined axes, the specimen being located at the point of intersection. It has also been proposed to produce stereoscopic images by mechanically tilting the specimen so as to present successively alternate aspects thereof to the illuminating beam. The images peculiar to the separate aspects of the specimen illuminated are successively produced on the same area of the final image plane. For simultaneous viewing thereof a mask may be employed, synchronized to the tilting mechanism so that each eye of the observer is exposed only to the image corresponding to one of the two illuminated aspects of the specimen.

These methods require either a double imaging system or accurately manufactured mechanical devices for tilting the specimen and for proper observation of the resulting images. The present invention renders both of these expedients unnecessary, and by simple electric means stereoscopic images are produced and separated for continuous side by side presentation in the final image plane of the instrument.

In the usual electron microscope a specimen to be observed is illuminated by a narrow beam of electrons projected from an electron source and collimated into a beam. The beam after passing through the specimen passes through an objective lens which forms a first enlarged image of the electron beam as modified by the specimen. One or more additional lenses may then be employed to provde compound magnification of the image produced by the objective lens.

With an electron microscope including these elements, separate or stereoscopic images of a

2

specimen are produced according to the present invention in the following way: The specimen, supported in the vicinity of the first focal point of the objective lens, is illuminated by the electron beam from two different angles by means which swing the electron beam through a small angle in a given azimuth or meridian plane of the instrument. Thus the axis of the beam, instead of being held at all times coincident with the optical axis of the instrument, is held first at a small angle on one side of the optical axis and then at an equal small angle on the opposite side of the axis, the axis of the beam always intersecting the optical axis of the instrument at or close to the position where the specimen is supported. The beam is held for a short instant in one extreme position and then quickly shifted to the opposite extreme, and so on, continuously.

Separate images of the specimen proper to each extreme position of the beam are produced by the objective lens and these images are further magnified by the projection lens and by the intermediate lens if one is provided. In order to separate the two images at the final image plane of the instrument, a pair of electrostatic deflecting plates is provided after one or another of the imaging lenses. These plates are mounted on opposite sides of the optical axis of the instrument so that the electrostatic field between them lies in the azimuth occupied at that axial position by the axis of the electron beam as deviated by the beam swinger means.

In order to prevent overlapping on the final image plane of portions of the separate images an apertured diaphragm is provided, after the beam swinger and before the deflection plates, to limit the image which reaches the final image plane for each beam position to approximately one half the available area of the final image plane. The deflection plates then produce two side by side images filling the available area.

The beam is swung at a rate high enough so that through persistence of vision the two images at the final image plane appear to be continuously illuminated.

The present invention is applicable to both electrostatic and electromagnetic instruments. An embodiment of the invention as applied to an electrostatic instrument will now be described in conjunction with the accompanying drawing which is a schematic representation of an electrostatic microscope.

An electron source 1 produces a collimated electron beam 3, directed initially along the axis 4 of the instrument. The specimen to be

examined is supported in the specimen plane 5 by conventional means such as the specimen support 6. Below the objective lens 7 are located an intermediate lens 11, a projection lens 13 and a final image plane 15 which may contain a viewing or recording device such as a fluorescent screen 16. Alternatively a photographic plate may be located in the final image plane.

For the production of the separate images the electron beam is swung in the meridian plane of the drawing through an angle 2θ by means of two pairs of electrostatic beam-swinger plates 17 and 19. The two pairs of plates 17 and 19 are mounted one above the other along the optical axis of the instrument between the electron source and the objective lens. The four plates may be all parallel to each other, and whether parallel or not are so mounted that their two fields lie in the same azimuth or meridian. The separate plates of each pair are disposed on the opposite side of the optical axis so that the fields exert a force on the electron beam passing down the optical axis 4.

A square wave alternating voltage generated by conventional means not shown is applied to the terminals 21. Suitably proportioned fractions of this square wave are applied in opposite phase to the pairs of plates 17 and 19 by means of a potentiometer 23. As indicated in the figure the plates 17 deflect the beam from the optical axis in one direction and the second pair of plates 19 deflect it in the opposite direction. By proper choice in the relative dimensions of the two pairs of plates, or in the relative sizes of the applied square wave fraction, the electron beam may be caused to return to the axis at a position close to the front focal plane of the objective lens 7, i. e. in the vicinity of the specimen plane 5. During succeeding halves of the square wave the beam is incident first from one side and then from the other side. The half angle θ through which the beam is swung should be considerably larger than the half angle of the illuminating cone. Thus with a half angle of $\frac{1}{1000}$ radian for the illuminating cone, a beam angle θ of $\frac{1}{100}$ or $\frac{2}{100}$ radian has been satisfactorily employed.

An apertured diaphragm 25 is provided at or near the front focal plane of the intermediate lens 11 in order to prevent overlapping of the separate images at the final image plane 15. Without such an apertured diaphragm the entire area of the final image plane would be filled by the beam in both of its positions so that the two images would be superposed on each other. The dimensions of the aperture are chosen, in view of the size of the final image plane and the magnification of the intervening lenses, to permit illumination of about one half of the available area at the final image plane. Thus the aperture may advantageously be rectangular in shape, twice as long as it is wide, and with its narrow dimension parellel to the meridian occupied by the beam. The deflection plates 27 then shift the resulting illuminated area first to one and then to the other half of the final image plane.

The two images produced by the objective lens are shown in the focal plane of the intermediate lens as nearly coincident, as in fact they are. By means of a pair of image-separating plates 27 however the two images proper to the two positions of the electron beam in its incidence on the specimen are separated out side by side at *a* and *b* on the final image screen. The image-separating plates 27 are mounted on opposite sides of the optical axis of the instrument below the intermediate lens so that the electrostatic field beween them lies in the azimuth occupied at that axial position by the axis of the electron beam as deviated by the first two pairs of plates. In an electrostatic instrument where no rotation of the electron beam occurs, the image-separating plates will therefore be mounted with their field parallel to the fields of the beam-swinger plates. In a magnetic instrument the orientation of the image-separating plates must be adjusted to take account of the rotation of the electron beam between the specimen and the axial position of the image-separating plates. A square wave voltage of the same frequency as that applied to the first two pairs of plates is applied to the image-separating plates, in either one or the opposite phase. This voltage may be derived from the source applied at the terminals 21 or from a properyl synchronized separate source, if desired. In order to minimize the necessary amplitude of this voltage, the plates 27 should be located close to the lens 11.

The apertured diaphragm 25 and the image-separating plates 27 may be mounted respectively above and below the projection lens instead of the intermediate lens, and of course must be so located if the intermediate lens is absent. In an instrument possessing an intermediate lens however it is advantageous to mount them in association with that lens since a smaller square wave voltage suffices to separate the images on the final image plane and since the aperture may serve also for the taking of diffraction pictures. The invention is also applicable to an instrument including no imaging lens other than the objective lens. In such case, the aperture, which must be very small, is located in the vicinity of the specimen and the image-separating plates follow the objective lens.

I claim:

1. In an electron microscope including an electron source, an objective lens, an intermediate lens and a projection lens, means for producing stereoscopic images comprising two pairs of beam-deflecting plates disposed between the electron source and the objective lens, an apertured diaphragm adjacent the focal plane of the intermediate lens, a pair of image-separating deflecting plates between the intermediate lens and projection lens, and means to apply a square voltage wave in one phase to one of the pairs of beam-deflecting plates and to the image-separating plates and in the opposite phase to the other pair of beam-deflecting plates.

2. In an electron microscope, means for producing stereoscopic images comprising two pairs of beam-swinging plates disposed between the electron source and the specimen, a pair of image-separating deflecting plates disposed between the specimen and the final image plane, a field-limiting apertured diaphragm between the specimen and the image-separating plates, and means to apply a square voltage wave in one phase to one of the pairs of beam-swinging plates and to the image-separating plates and in the opposite phase to the other pair of beam-swinging plates.

3. In an electron microscope, means for producing stereoscopic images comprising two pairs of beam-deflecting plates disposed between the electron source and the specimen, a pair of image-separating deflecting plates disposed between the specimen and the final image plane, means to apply a square voltage wave in one phase to one of the pairs of beam-deflecting plates and to the image-separating plates and in the opposite phase to the other pair of beam-deflecting

plates, and a field-limiting apertured diaphragm disposed between the electron source and the image-separating plates, the aperture in said diaphragm being so dimensioned in respect of the available image area at the final image plane and the magnification of the intervening lenses that the projected area of said aperture on the final image plane is approximately one half the said available image area.

4. In an electron microscope including an electron source, a specimen support, one or more electron lenses following the specimen support and a final image screen, means for producing sterescopic images comprising two pairs of beam-deflecting plates disposed between the electron source and the first of said lenses, a pair of image-separating deflecting plates disposed between the first of said lenses and the final image screen, means to apply a square voltage wave in one phase to one of the pairs of beam-deflecting plates and to the image-separating plates and in the opposite phase to the other pair of beam-deflecting plates, and a field-limiting apertured diaphragm disposed adjacent the first focal plane of one of the said lenses preceding the image-separating plates, the aperture in said diaphragm being so dimensioned in respect of the available image area at the final image screen and the magnification of the intervening lenses that the projected area of said aperture on the final image screen is approximately one half the said available image area.

5. The method of producing stereoscopic images in an electron microscope which comprises deviating the electron beam between the electron source and the specimen through a small angle in a fixed azimuth, limiting the aperture of the beam at a point beyond the specimen, and deviating the beam beyond the specimen in synchronism with its deviation before the specimen to separate on the final image plane the images proper to the extreme positions of the beam prior to the specimen.

6. The method of producing stereoscopic images in an electron microscope which comprises deviating the electron beam between the electron source and the specimen in a fixed azimuth through a small angle on either side of the optical axis, deviating the beam beyond the specimen in synchronism with its deviation before the specimen, to separate on the final image plane the images proper to the extreme positions of the beam prior to the specimen, and limiting the aperture of the beam prior to its deviation beyond the specimen to a cross-section whose projection in the final image plane occupies approximately one half the available area thereof.

GERTRUDE M. FLEMING.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,396,624	Von Borries	Mar. 12, 1946
2,436,676	Smith et al.	Feb. 24, 1948
2,441,850	Smith et al.	May 18, 1948
2,464,396	Hillier et al.	Mar. 15, 1949
2,485,754	LePoole	Oct. 25, 1949