United States Patent

[11] **3,585,382**

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[21] Appl. No. **827,651**
[22] Filed **May 26, 1969**
[45] Patented **June 15, 1971**
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[32] Priority **May 28, 1968**
[33] **Japan**
[31] **43-36264**

[54] **STEREO-SCANNING ELECTRON MICROSCOPE**
3 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **250/49.5,** 178/6.5, 250/61
[51] **Int. Cl.** **H01j 37/26**
[50] **Field of Search** 178/6.5; 250/29.5, 49.5, 60, 61

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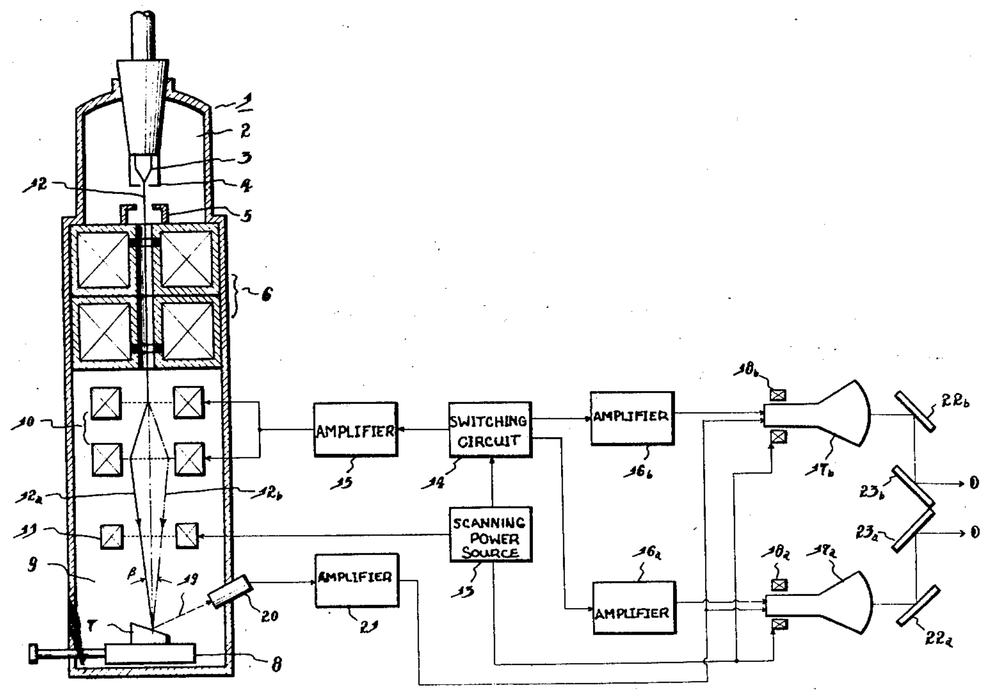
ABSTRACT: A stereo-scanning electron microscope for scanning a specimen surface with an electron beam by liberating electrons from the specimen which are detected and an image formed on a cathode ray tube. The axis of the electron beam is directionally switched to change the incidence angle of the beam so that images corresponding to two incidence angles are displayed on two cathode ray tubes and a three dimensional image is obtained by observing the two images.



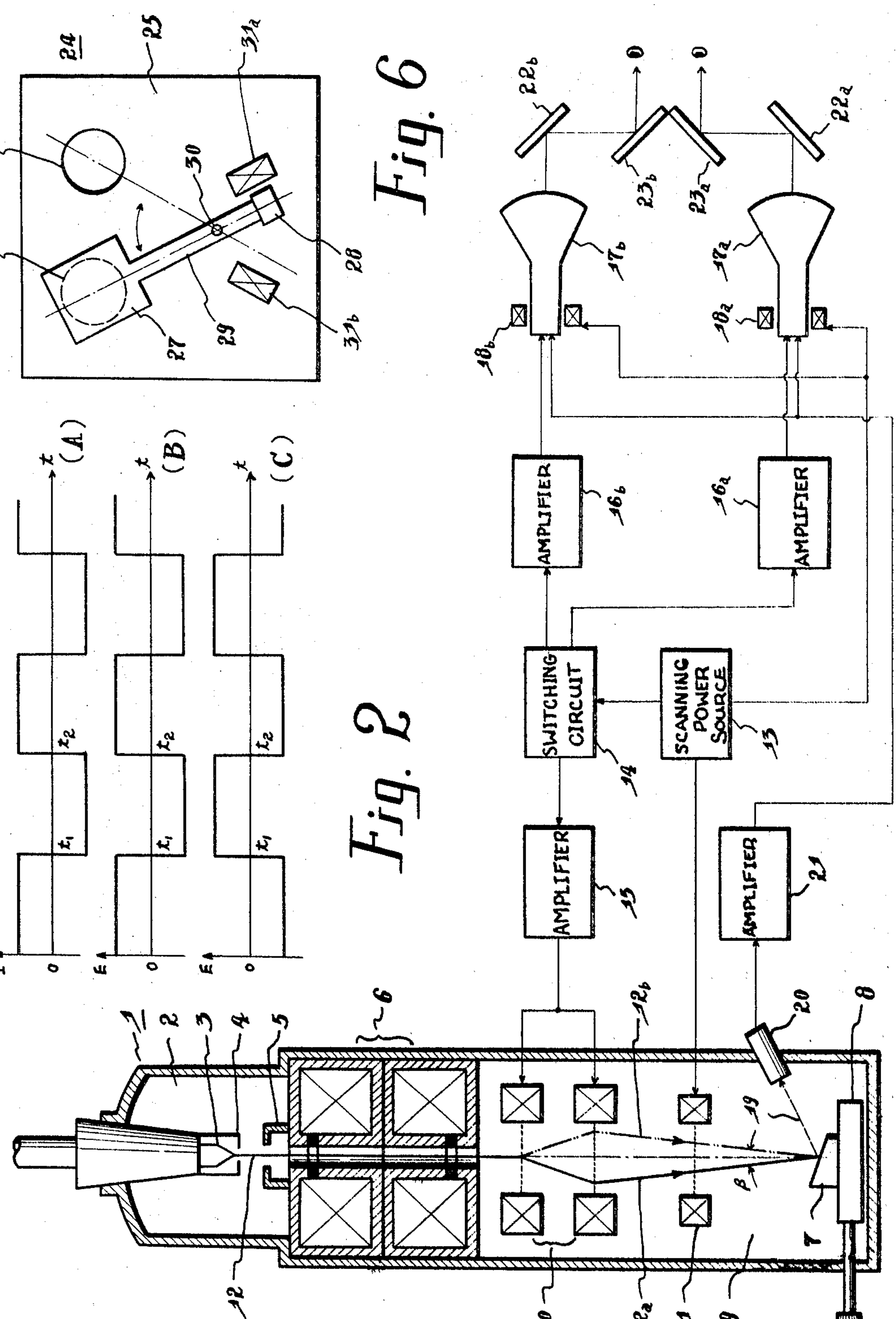


Fig. 6

Fig. 2

Fig. 1

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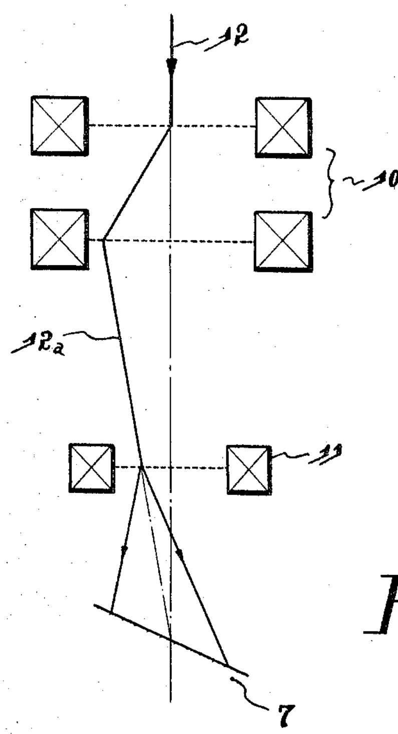

Fig. 3

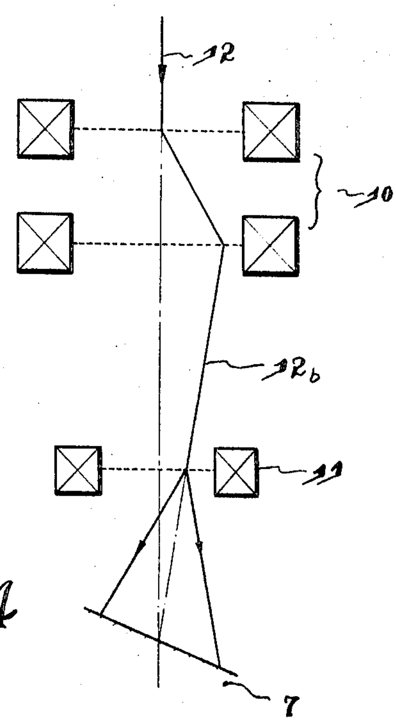

Fig. 4

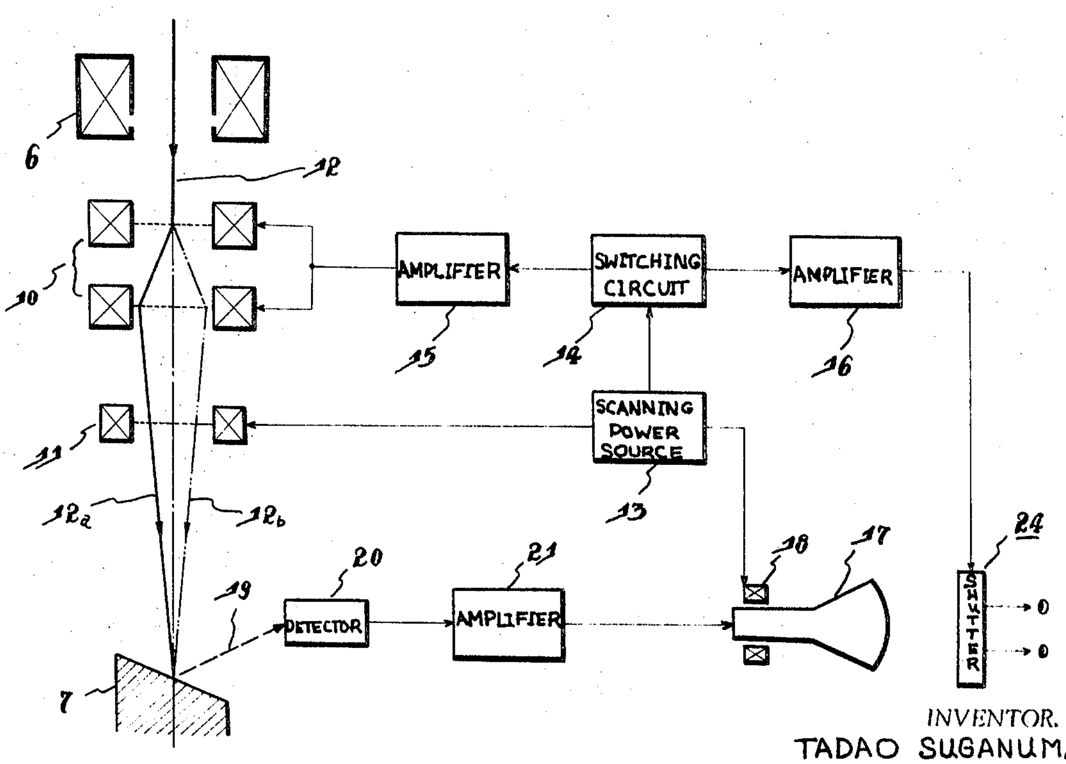

Fig. 5

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STEREO-SCANNING ELECTRON MICROSCOPE

The present invention relates to a stereo-scanning electron microscope and, more particularly, to a stereo scanner in which a stereo image of specimen surface is directly observed on a cathode ray tube or other suitable display means.

To observe a stereo image with a conventional scanning electron microscope, the specimen is first set at an optional angle and an image on the cathode ray tube is photographed by a built-in camera. The specimen is then inclined through a slight angle and a second photograph taken of the same field. The two photographs are then viewed simultaneously, each with one eye, through a stereo viewer to observe the stereo image. With this arrangement, however, it is impossible to obtain a stereo image directly on the cathode ray tube while the specimen is scanned with an electron beam. Tedious efforts and repeated photography are invariably necessary before a suitable stereo image is obtained. Therefore, it is totally impossible to observe the stereo image while moving the specimen and searching the desired field. Furthermore, with conventional two dimensional scanning electron microscopes, it is impossible to select a convergence angle (the difference between the angle of specimen inclination changed between successive exposures) having the most favorable stereo effect, since the angle depends upon the roughness of the specimen surface.

Accordingly, my invention provides a novel stereo-scanning electron microscope whereby the stereo image of the specimen surface can be directly observed on a cathode ray tube. In addition, my invention provides an improved stereo-scanning electron microscope capable of easily selecting a convergence angle having the most favorable stereo effect with respect to the specimen under observation.

Generally, my invention comprises an electron beam source which is focused on the specimen surface by a condenser lens system. The specimen surface is scanned by the electron beam by means of a scanning deflection system. Additionally, my apparatus includes a detector for detecting the impinged electron beam. The detected signal is fed to a display system which comprises a pair of cathode ray tubes or a single tube and shutter mechanism. A switching deflection system is utilized intermediate of the condenser lens and scanning system to provide at least two different angles of incident of the electron beam. A switching circuit connected to the scanning power source is triggered during each scanning frame. The switching circuit activates the directional deflection system to change the angle of incidence and to operate either one of the pair of cathode ray tubes or the shutter mechanism.

A stereo image is produced by the display system by the rapid switching between incident angles and alternative display.

The novel features incorporated in this invention are described in more detail hereinafter in connection with the accompanying drawings in which:

FIG. 1 is a block diagram of my stereo scanning electron microscope;

FIG. 2 illustrates the current applied to the electron beam deflection apparatus and the waveform of the bias voltage applied to the two cathode ray tubes shown in FIG. 1;

FIGS. 3 and 4 illustrate the scanning conditions of the electron beam in FIG. 1;

FIG. 5 shows another embodiment of my invention utilizing only one cathode ray tube; and

FIG. 6 shows the construction of the shutter used in the embodiment of FIG. 5.

In the stereo-scanning electron microscope shown in FIG. 1, column 1 comprises chamber 2 in which cathode 3, a Wehnelt cylinder 4, and an anode 5 are housed. A condenser lens system 6 aligned along the optional axis of chamber 1 is utilized for focusing the electron beam produced in chamber 2 onto specimen 7 in specimen chamber 9, which includes a specimen stage 8, and two deflection systems 10 and 11 located in the vicinity of the condenser lens system 6. Deflection system 10 is used to switch the axis of electron beam incident on the specimen surface and is hereafter referred to as the "switching deflection apparatus" and deflection system 11 is used for scanning and is hereafter referred to as the "-scanning deflection apparatus."

At intervals of one electron beam-scanning frame, scanning power source 13 supplies a trigger pulse to a switching circuit 14. The polarity of the current fed to the switching deflection apparatus 10 through an amplifier 15 are inverted, resulting in a change in the current as shown in FIG. 2(A). In this figure, it will be seen that upon the expiration of predetermined scanning times, viz. 0 t_1, t_1 t_2 etc., the axis of the electron beam 12 is directionally changed by switching deflection apparatus 10, resulting in the condition illustrated in FIGS. 3 and 4. Further, two bias voltage waveforms (FIGS. 2(B) and 2(C)) are fed from switching circuit 14 through amplifiers 16*a* and 16*b* to the grids of cathode ray tubes 17*a* and 17*b*, respectively. In order to synchronize the scanning of the cathode ray tubes with the scanning of the electron beam, a signal is fed from scanning power source 13 to cathode ray tube deflection systems 18*a* and 18*b*. In accordance with the above, raster is displayed on the cathode ray tubes only when the polarity of the voltage applied to the respective cathode ray tube grids is positive.

The following is a description of the operation of this device from the point where the axis of the electron beam 12 is deflected as shown by 12*a* in FIG. 1 (i.e., when the current applied to the switching deflection apparatus 10 is positive or during the time lapse 0 t_1 shown in FIG. 2). Under this condition, the specimen surface is scanned as shown in FIG. 3 at which time only raster is displayed on cathode ray tube 17*a*, since the polarities of the voltage waveforms 2(B) and 2(C) are respectively positive and negative. At the same time, electrons 19 liberated from the specimen surface are detected by detector 20 and appropriately amplified by amplifier 21. The amplified signal is then simultaneously applied to each cathode ray tube grid at which time the image appears on the screen of the cathode ray tube 17*a*. Even though the signal is also applied to the grid of cathode ray tube 17*b*, no image appears on the screen of this tube, since the polarity of the bias voltage applied thereto is negative and, hence, raster is not displayed. As soon as the first frame has been scanned, the polarity of the output signal from switching circuit 14 reverses. In other words, at the commencement of the second frame scan, i.e., from t_1 t_2, 2(A) and 2(B) become negative and 2(C) becomes positive. As a result, the direction of the beam axis changes to that as shown by 12*b* and at the same time, the display of cathode ray tube 17*a* is replaced by that of cathode ray tube 17*b* so that the image now appears on the latter cathode ray tube instead of the former.

Consequently, an image with a center coincidental with beam axis 12*a* is always displayed on cathode ray tube 17*a* and that about axis 12*b* is likewise always displayed on cathode ray tube 17*b*. This sequence is repeated with each scanning and, accordingly, the image displayed on each respective cathode ray tube, which is observed through the optical system comprising reflection viewers 22*a* and 22*b* and 23*a* and 23*b* with both eyes separately and independently, corresponds to that observed by placing the left and right eyes in line with the beam axes 12*a* and 12*b*, respectively. As a consequence thereof, it is always possible to observe the stereo image of the specimen.

As an alternative to the above-described switching operation whereby switchover takes place at the termination of every scanning frame, single line scanning switchover may be incorporated.

Furthermore, since the angle formed by the convergence of beam axes 12*a* and 12*b*, denoted by β in FIG. 1, depends entirely on the peak value of the pulsed waveform applied to the switching deflection apparatus 10 through amplifier 15, it is possible to select a convergence angle having the most favorable stereo effect, provided that the gain of the amplifier can be varied.

FIG. 5 shows a modified version of FIG. 1 whereby only one cathode ray tube is employed. In this case, however, the tube is required to have a screen coated with a short persistence phosphor. A shutter **24** is positioned between the cathode ray tube and the observer's eye. Shutter **24** comprises a main plate **25** (see FIG. **6**) complete with two viewing holes **26***a* and **26***b*, and a shutter plate **27** joined to an iron plate **28** by a connecting bar **29**. The connecting bar is mounted on main plate **25** so as to freely swivel about pivot fulcrum **30**. Two coils **31***a* and **31***b* serve to swing the shutter plate **27** back and forth from one viewing hole to the other in accordance with the excitation of the coils. Shutter **24** is electrically connected to switching circuit **14** through amplifier **16**, resulting in the shutter being synchronously swung in accordance with beam axis switchover.

Assuming then that the shutter plate **29** is positioned as shown in FIG. **6** and that the beam axis is deflected as shown by **12***a* in FIG. **1**, the image on the screen of the cathode ray tube **17** will only be visible by the observer's left eye, since FIG. **6** is the view of the shutter seen from the side of the cathode ray tube. In other words, the image corresponding to beam axis **12***a* will be visible by the left eye. As soon as the image corresponding to the axis **12***b* appears on the screen, the shutter plate **27** swings over, thus exposing hole **26***a* and enabling the image to be viewed with the observer's right eye.

By repeating the above sequence sufficiently fast so that the impression of the image imprinted on the optical system of the eye does not have time to fade and become obliterated, a stereo image will be visible on the screen of the cathode ray tube.

In accordance with the heretofore described arrangement, it is possible to observe a stereo image on the screen of the cathode ray tube or other suitable display means immediately after the specimen has been placed in its holder. As a result, it is also possible to observe the stereo image of a specimen optionally shifted during the course of observation. It is further possible to readily select a convergence angle providing the most favorable stereo effect during the course of three-dimensional observation.

I claim:

1. In a scanning electron microscope having an electron beam source, a condensing lens system for focusing said electron beam upon a specimen, means for detecting the electron beam liberated from the specimen and means for scanning the specimen with said beam, the improvement comprising:

A. a switching deflection means for selecting one of two angles of incidence of the beam on the specimen, the switching deflection means being connected to the scanning means to trigger the deflection means synchronously with each scan frame, said switching deflecting means including a variable gain amplifier for selecting different convergence angles being the difference between the said angles of incidence,

B. a pair of cathode ray tubes for displaying an image of said specimen, each tube connected to said detector and to said switching deflection means, one tube displaying an image irradiated by the beam at first angle of incidence and the second tube displaying an image irradiated by the beam at a second angle of incidence whereby simultaneous viewing of both tubes presents a stereo image of the scanned specimen.

2. In a scanning electron microscope having an electron beam source, a condensing lens system for focusing the beam on a specimen surface, means for scanning the specimen surface, and means for detecting the beam liberated from the surface of the specimen, the improvement comprising:

A. a switching deflection means for selecting one of two angles of incidence of the beam upon the specimen surface, the deflection means being connected to said scanning means to trigger the deflection means synchronously with each scan frame, said switching deflecting means including a variable gain amplifier for selecting different convergence angles being the difference between the said angles of incidence,

B. a short persistance display screen connected to the detector for displaying the detected image, and

C. a shutter mechanism positioned in front of the display screen and having two viewing holes and means for alternatively opening and closing the holes, said shutter mechanism being connected to the switching deflection means to open one viewing hole when the electron beam has a first incident angle and to open the second viewing hole and close the first viewing hole when the electron beam has a second incident angle.

3. In a scanning electron microscope having an electron beam source, a condensing lens system for focusing said electron beam upon a specimen, means for detecting the electron beam liberated from the specimen and means for scanning the specimen with said beam, the improvement comprising:

A. a switching deflection means for selecting one of two angles of incidence of the beam on the specimen, the switching deflection means being connected to the scanning means to trigger the deflection means synchronously with each scan frame, said switching deflecting means including a variable gain amplifier for selecting different convergence angles being the difference between the said angles of incidence,

B. means for detecting electrons liberated from the specimen surface, display means connected to the detector means and having a deflection system connected to the switching deflecting means to synchronize the display device with the scanning of the electrode beam.