Oct. 5, 1943. R. L. SNYDER, JR 2,330,930

SCANNING TYPE OF ELECTRON MICROSCOPE

Filed April 30, 1941 2 Sheets-Sheet 1

Fig. 2.

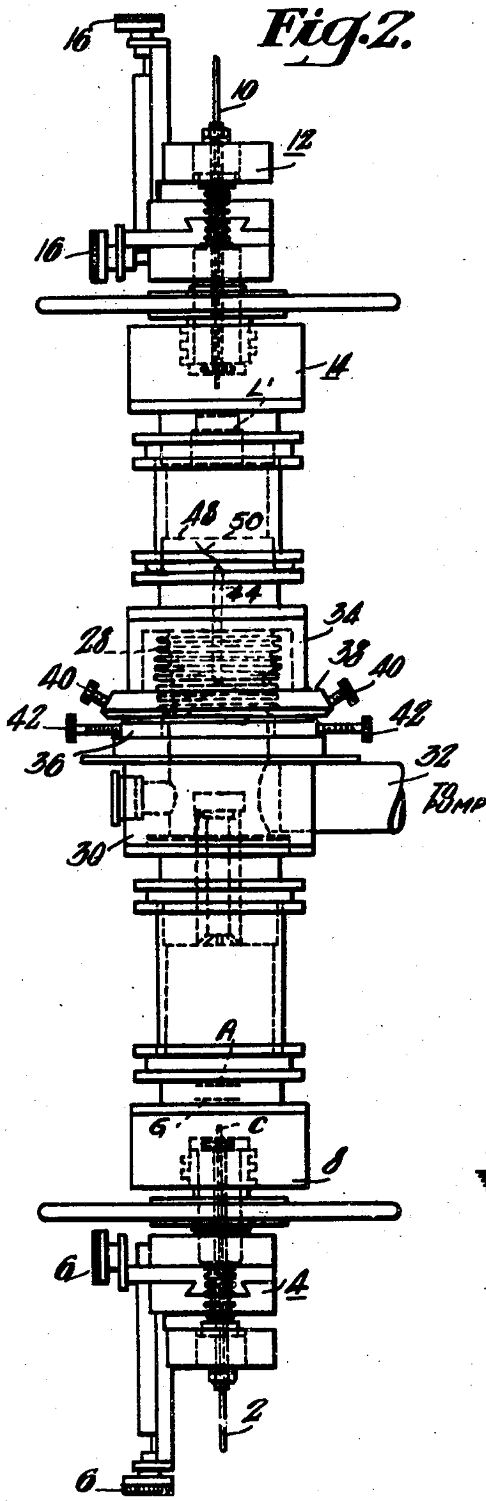
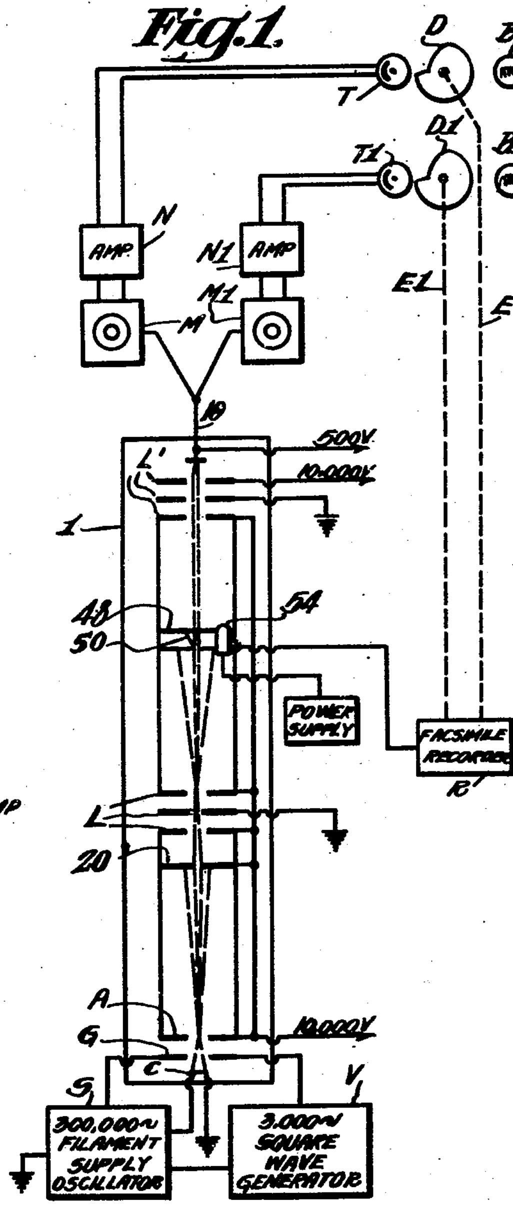


Fig. 1.



Inventor

Richard L. Snyder, Jr.

By [signature]

Attorney

Oct. 5, 1943. R. L. SNYDER, JR 2,330,930

SCANNING TYPE OF ELECTRON MICROSCOPE

Filed April 30, 1941 2 Sheets-Sheet 2

Fig. 3.

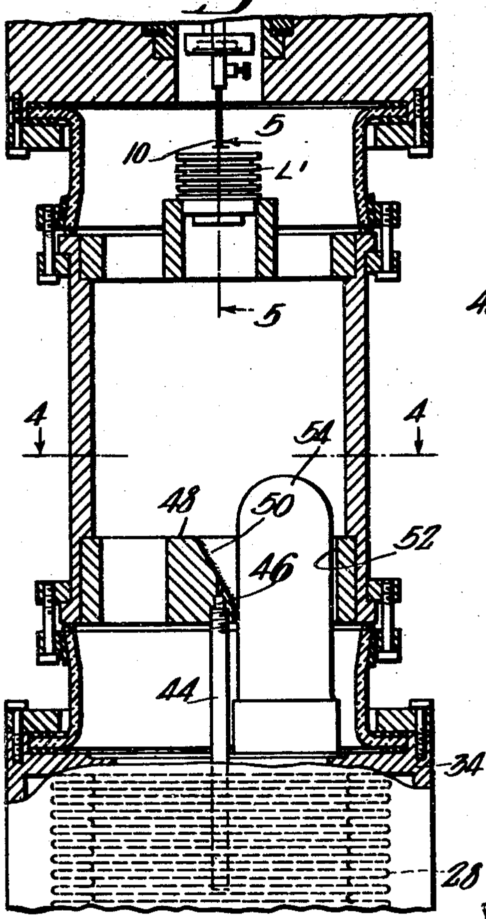


Fig. 4.

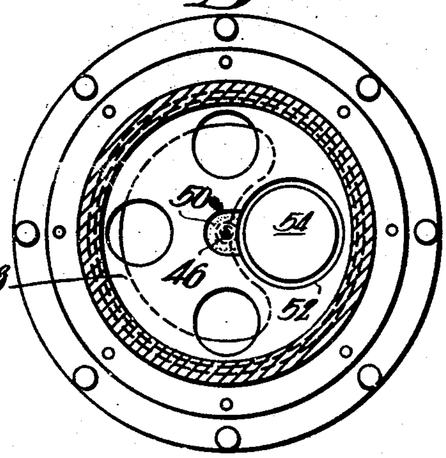
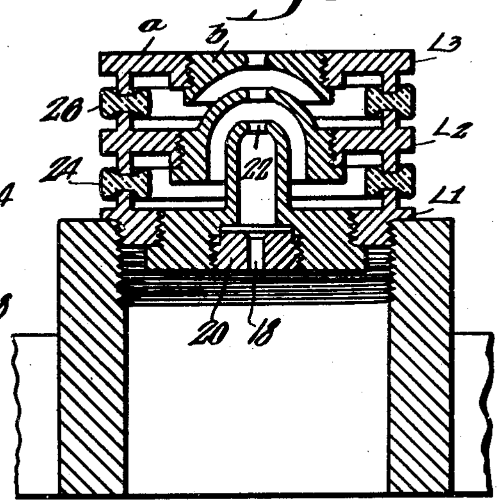


Fig. 5.



Inventor
Richard L. Snyder Jr.

By [signature]

Attorney

Patented Oct. 5, 1943

2,330,930

UNITED STATES PATENT OFFICE

2,330,930

SCANNING TYPE OF ELECTRON MICROSCOPE

Richard L. Snyder, Jr., Glassboro, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application April 30, 1941, Serial No. 391,188

6 Claims. (Cl. 250—49.5)

This invention relates to electron optical devices and has special reference to the provision of improvements in electron microscopes of the general type (i. e., "scanning type") described in copending application Serial No. 190,629, filed February 15, 1938, by Manfred Von Ardenne, now U. S. Patent 2,257,774, issued Oct. 7, 1941.

In the Von Ardenne scanning-type electron microscope, the object or specimen under examination is scanned by an electron beam of a diameter less than the wave length of light. The primary electrons passing through the object, or the secondary electrons emanating from it, are picked up and used to actuate a suitable registering or integrating device. Where a Geiger counter or recording electrometer is employed as the output device, the electrons from the object may be registered directly (i. e., without amplification), but, if an oscilloscope, facsimile recorder, or other integrating device requiring the use of a substantial current in its operation is employed, suitable amplifying means must be provided intermediate the object and the output device for supplying the said amplified operating current. In this latter case, if an accurate image of the specimen is to be achieved, the amplifying device and coupling means thereof must be substantially completely free from "noise." Since so-called "electron multiplier" devices of modern design possess this desirable characteristic to a remarkable degree, it would appear that the problem of noise-free amplification of the almost infinitely small flow of electrons from the specimen resides in the use of an electronic device of this general character. Such indeed is the case. However, since, in an electron microscope of the type described, the specimen must be mounted very close (i. e., within a few millimeters) to the objective lens, it is impossible to mount a multiplier adjacent the specimen, where obviously, it might serve most effectively to pick up the electrons from the specimen. Von Ardenne's use of a Lenard window (through which the electrons from the specimen pass without breaking the vacuum which necessarily surrounds the electron beam or "probe") and an externally mounted electron multiplier arranged on the far side of the specimen, limits the use of the microscope to the examination of specimens which are transparent to electrons.

Accordingly, an object of the present invention is to provide an electron microscope adapted to produce an accurate and undistorted image of the surface of metal and other nontransparent (to electrons) specimens.

Another and more specific object of the invention is to provide an improved means for coupling a photosensitive electron multiplier or like amplifying device to an electron microscope, said coupling means permitting the use of commercially available tubes and dispensing with the use of a Lenard window and/or other auxiliary part or parts of a type requiring the use of unduly high voltages on the input side of the amplifier.

The foregoing and other objects are achieved in accordance with the invention by the combination with an electron microscope, comprising means for focusing an electron beam upon an object to be examined, of a fluorescent surface for intercepting electrons from said object, and a photosensitive amplifier mounted (preferably within the microscope chamber) in a position to be actuated by the rays incident to the activation of said fluorescent surface by the intercepted electrons.

When the specimen to be examined is opaque to electrons, the fluorescent surface is arranged on the "gun side" of the object in a position to intercept secondary electrons released by impact of the primary electrons (from the "gun") upon the object. In this case, the same or some of the electron lens elements employed in focusing the primary beam upon the object may be employed in focusing the secondary electrons from the specimen upon the fluorescent surface which serves to actuate the photosensitive amplifier.

Contrary to the usual practice in the construction of high power electron microscopes, the present invention dictates the use of an electrostatic lens system for the microscope since, as a practical matter, it is substantially impossible to shield (against defocusing) an electron tube operating in close proximity to a magnetic-type lens system.

Certain details of construction, together with other objects and advantages, will be apparent and the invention itself will be best understood by reference to the following specification and to the accompanying drawings, wherein

Figure 1 is a schematic view of a scanning type electron microscope embodying the invention and including certain auxiliary recording apparatus,

Figure 2 is a vertical elevation of the electron microscope of Figure 1, showing certain preferred details of construction,

Figure 3 is an enlarged fragmentary sectional view showing part of the interior of the chamber of the microscope of Figure 2,

Figure 4 is a sectional view taken on the line 4—4 of Figure 4, and

Figure 5 is an enlarged sectional view taken on the line 5—5 of Figure 3, and showing a part of the lens system for the microscope.

For a general understanding of the principle and mode of operation of the invention, reference is first made to Figure 1, wherein 1 designates generally an elongated evacuable cylinder containing, adjacent one end, an electron-emissive cathode C and, adjacent its opposite end, a movable rod-like lever element 10 on the inner end of which the specimen or object (not shown) to be examined is mounted. Intermediate the cathode C and the object holder 10 is an electron lens system including a first apertured plate 20, a first group of lens elements L, a second apertured plate 48, and a series of objective lens elements L′, through all of which electrons pass, in an undeviating path, to the object under examination.

As taught by Von Ardenne, the diameter of the electron beam at the point at which it impinges the object should preferably be less than the wave length of light. The scanning movement necessary to a complete examination of every part of the object is provided, in this case, by moving the object holder 10 with respect to the beam in a manner later described. Secondary electrons released by impact of the steady primary beam on the moving object travel in the return direction through the objective lens elements L′ and impinge a fluorescent target 50 which is preferably provided on the wall of a separate opening in the plate 48 through which the primary beam passes on its way to the objective lens. A photosensitive amplier, for example an electron multiplier 54, mounted adjacent the fluorescent surface 50, picks up the visible or invisible light rays therefrom and generates an augmented electron current proportionate to the intensity of the secondary electron stream from the object. The output of the multiplier, in this case, serves to actuate a facsimile recorder R which is operated in synchronism with the object holder 10 to provide a permanent, enormously magnified image of the surface of the object thus "scanned."

The distance the object is moved by the scanning mechanism must, of course, be exceedingly small when a greatly magnified recorded image is desired. To achieve such small movement, mechanically, the object holder or lever 10 may be pivoted close to the object end of the lever and the driving force applied to its opposite or outer end. In an arrangement wherein the specimen is mounted one-half inch from the fulcrum of the lever 10 and the driving force applied five inches from the fulcrum, the resulting reduction of ten to one is satisfactory. In the illustrated arrangement, two dynamic-type loudspeaker motors M1 and M2 are employed for imparting the requisite scanning movement to the object holder 10; one motor serving to provide the line-scanning movement and the other, the frame-scanning movement. The motors M are actuated through suitable amplifiers N and N1 by photo tubes T and T1, respectively, which are illuminated by light from two lamps B and B1 controlled by spiral rotating cams D and D1, which are driven through a mechanical coupling E, E1 by the line and frame scanning mechanism of the recorder R. Where, as in the instant case, the particular recorder employed requires a carrier frequency, such carrier may be introduced by interrupting the primary beam from the electron gun by impressing an alternating voltage of the desired frequency and wave shape on the control grid of the gun, as indicated at G. The filament heating current supply is shown provided by a regulated high frequency source S, which is turned on only during the time the beam is cut off by the carrier generator V. Thus, when the beam is "on", no heating current, and hence no disturbing magnetic field or potential, is present when electrons are being emitted.

The electron microscope shown in detail in Figures 2 to 5 inclusive is made of a number of separate sections to permit alignment of the beam and object with the electron lens system and to simplify insulation problems. Thus, the support 2 for the filamentary cathode C is shown mounted on a breech mechanism 4, which is provided with adjusting means 6 for aligning the cathode with the grid and accelerating elements G and A, respectively, which are mounted in a breech block 8. The object holder 10 is mounted in a similar breech mechanism 12 which screws into a breech block 14 and is provided with adjusting means 16.

The primary electron stream emanating from the cathode C and formed by the electron gun elements G and A into a beam of substantial diameter and power is limited, first, by a coarse aperture 18 (say, .020 inch) in a metal plate 20 (see Fig. 5) of a mass capable of dissipating a large amount of heat, and, second, by a smaller aperture 22 (say, .005 inch), which further reduces the diameter of the beam to a size capable of being passed by the later described electron lens system. As shown in Figure 5, the first electron lens through which the electrons pass comprises, in addition to the apertured plate 20, three metal annuli L1, L2, L3, which are spaced from each other by glass or other insulating inserts 24 and 26. Each of the annular lens elements L is preferably of bipart construction and comprises an outer piece *a* made of a metal which can readily be sealed to the glass or other insulating material 24, 26, and a central piece *b* formed of stainless steel or other nonmagnetic material, which is not susceptible of field emanation (sparking).

Mounted above the first group of lens elements L is an adjustable section comprising a metal bellows 28, which is seated and sealed at its lower end in a block 30 through which a connection is made to the manifold 32 of a continuously operating vacuum pump (not shown), and is sealed at its upper end in a cylindrical section 34. The lower end of the cylindrical section 34 rests upon a concave spherical surface in a plate 36 and is provided with a skirt 38 in which screws 40 are threaded for tilting the assembly, for purposes of aligning the axis of the upper assembly parallel with respect to the axis of the lower assembly. The plate 36 in which the spherical surface is cut rests on the upper surface of the block 30 and can be adjusted in a horizontal plane by screws 42 for the purpose of aligning the now parallel axes of the upper and lower assembly, so that the said axes coincide.

The primary electrons which pass from the cathode through the first group of lens elements L next enter a shielding conduit comprising a hollow cylinder 44 of small bore which terminates in a central aperture 46 of still smaller bore within a plate 48. Thereafter, the said beam is focused by means of an objective electron lens L′ to a spot upon the closely adjacent object of the holder 10. The construction of the objective lens L' may be similar to the one through which the electrons first pass (see Fig. 5), but does not include the first apertured element 20 of that lens, since the function of the said part is here assumed by the aperture 46. As indicated in connection with Fig. 1, the upper and lower lens elements L3, L1 of each lens (L, L') are preferably maintained at a potential approximating that of the accelerating element A of the electron gun and the intermediate lens elements (L2, L'2) are maintained at cathode potential. The object, on the other hand, is preferably maintained at a potential higher (say, 500 volts higher) than that of the cathode, yet considerably lower than the lens elements L3, L1. In some cases however, as where it is necessary to adjust the focal length of either lens, the relative potential distribution among the several focusing elements L and the object holder 10 may be altered to the extent necessary to achieve the desired result.

Primary electrons striking the object or specimen under examination release secondary electrons. The number of secondary electrons released per impinging primary electron depends upon the emissive characteristic of the particular point or region on the object impinged at any given moment. The emissive characteristic in turn may be said to depend upon the orientation of the crystalline or other structure of the object or upon minute irregularities in the said surface. In any event, secondary electrons released from the object by the impinging primary electrons are drawn through the objective lens in a direction opposite to that of the arriving primary electrons and are directed by the said lens to a fluorescent target 50 which (as more clearly shown in Figs. 3 and 4) may comprise an inclined surface area on the plate 48 surrounding the aperture 46 through which the primary electrons pass in their journey to the object. Unlike the primary electrons, which are focused to a fine spot, the secondary electrons are spread by the objective lens L' over a relatively wide area on the target 50 and do not enter the aperture 46 in the plate 48. This wide distribution of the electrons from the object upon the fluorescent surface 50 may be attributed to the fact that the primary and secondary electrons pass through the objective lens L' at different speeds and hence are not subject to the same focusing effect.

As clearly shown in Figs. 3 and 4, the fluorescent target 50 upon which the electrons from the object are directed may comprise the conical surface of an opening 52 (Fig. 4) designed to accommodate the glass envelope 54 of a photosensitive amplifier (say, an RCA type 931 "electron multiplier") which is mounted in a position to be actuated by the rays incident to the activation of said fluorescent surface by the intercepted electrons. Since, in most cases, the number and speed of the secondary electrons impinging the target 50 will not be sufficient to illuminate it with any great degree of brightness, it is important that the optimum use be made of the available rays. To this end, it is desirable to "match" the tube with the target, that is to say, if the fluorescent material comprising the target 50 is of a type adapted to emit rays of a particular wave length, then the sensitivity of the photosensitive material comprising the cathode of the tube 54 should be so chosen that it exhibits maximum sensitivity to rays of that particular wave length. Thus, if the fluorescent material comprises a compound (say, one of the zinc sulphide compounds) adapted to emit "blue light," the photoemissive cathode of the tube may comprise a silver antimony, or other compound which exhibits maximum sensitivity to rays of the said wave length.

Various modifications of the invention will suggest themselves to those skilled in the art to which this invention appertains. Accordingly, the foregoing is to be interpreted as illustrative and not in a limiting sense, except as required by the prior art and by the scope of the appended claims.

What is claimed is:

1. The combination with an electron microscope comprising means for focusing an electron beam upon an object to be examined, of a fluorescent surface for intercepting electrons from said object, and a photosensitive electron multiplier mounted in a position to be actuated by the rays incident to the activation of said fluorescent surface by said intercepted electrons.

2. The combination with an electron microscope comprising means for focusing an electron beam upon a surface of an object to be examined, of a fluorescent surface for intercepting secondary electrons therefrom, and a photosensitive electron multiplier mounted in a position to be actuated by the rays incident to the activation of said fluorescent surface by said intercepted secondary electrons.

3. An electron microscope comprising means for focusing an electron beam upon an object to be examined, a fluorescent surface, an electron lens for focusing electrons from said object upon said fluorescent surface, and a photo-actuated electron multiplier mounted in operative relation with respect to said fluorescent surface.

4. An electron microscope comprising means for generating electrons, an electron lens system for focusing said electrons to a point on an object to be examined, a fluorescent surface, means including an element of said electron lens system for focusing electrons from said object upon said fluorescent surface, and a photo-actuated electron multiplier mounted in operative relation with respect to said fluorescent surface.

5. An electron microscope comprising an electron gun for generating a beam of primary electrons, an electron lens for focusing said primary beam upon an object to be examined, a fluorescent surface mounted on the gun side of said object, means including said electron lens for directing secondary electrons from said object to said fluorescent surface, and a photoactuated amplifier device mounted in operative relation with respect to said fluorescent surface.

6. An electron microscope comprising an evacuated envelope containing an electron gun for generating a beam of primary electrons, means to mount an object to be examined in spaced relation with respect to said gun, an apertured plate mounted in the space between said gun and said object, said apertured plate having a beam-reducing aperture through which said primary electrons pass to said object, a fluorescent surface adjacent the object side of said plate for intercepting secondary electrons released by impact of primary electrons upon said object, and means for mounting a photosensitive electron multiplier within said evacuated envelope with its photosensitive element in position to be actuated by the rays incident tothe activation of said fluorescent surface by said secondary electrons.

RICHARD L. SNYDER, Jr.