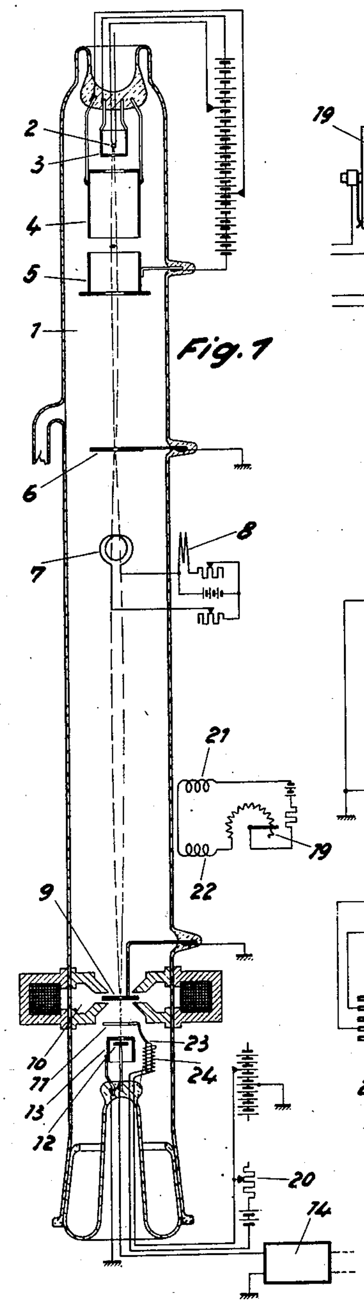
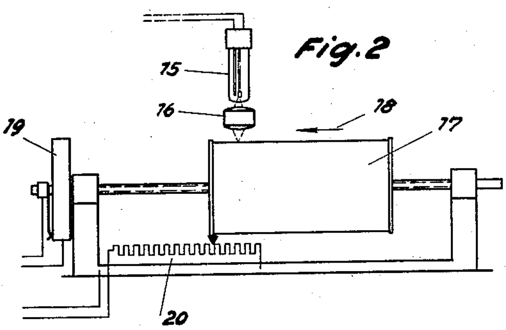
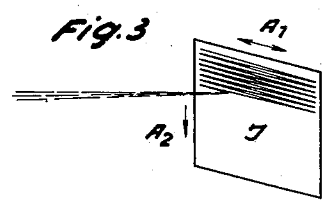
Oct. 7, 1941. M. VON ARDENNE 2,257,774

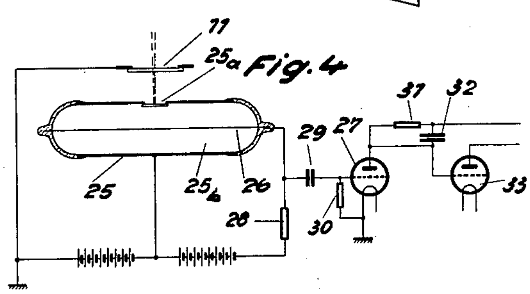
ELECTRONIC-OPTICAL DEVICE

Filed Feb. 15, 1938 2 Sheets-Sheet 1









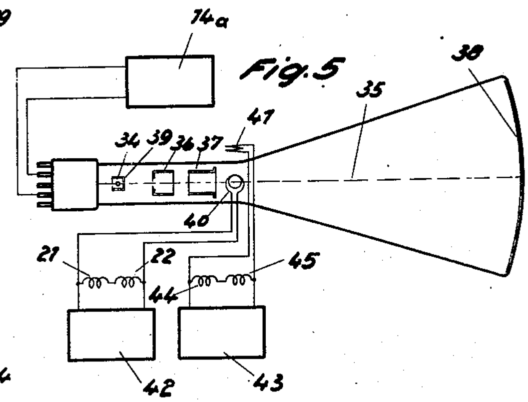


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Fig. 6

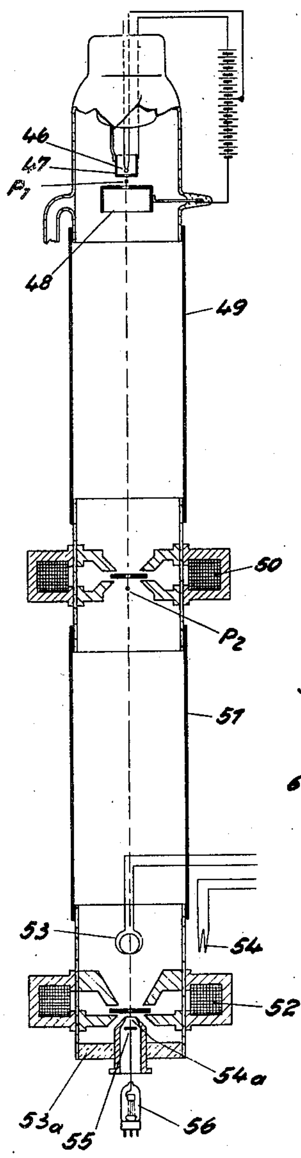


Fig. 7

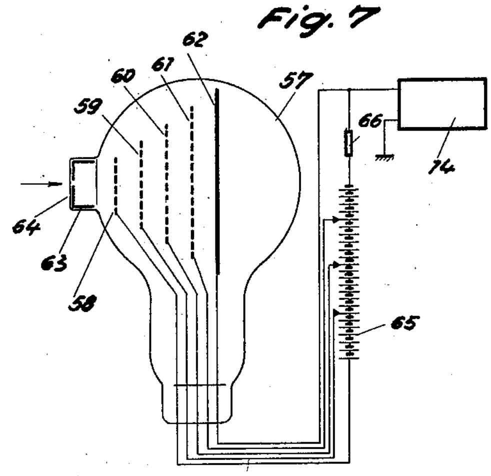


Fig. 8

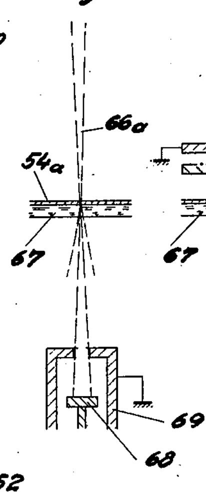


Fig. 9

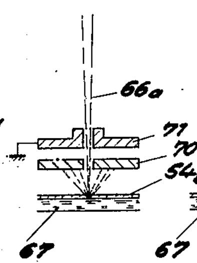
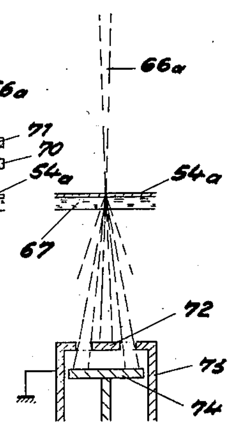


Fig. 10



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UNITED STATES PATENT OFFICE

2,257,774

ELECTRONIC-OPTICAL DEVICE

Manfred von Ardenne, Berlin, Germany

Application February 15, 1938, Serial No. 190,629
In Germany February 18, 1937

7 Claims. (Cl. 178—6.8)

This invention relates to an electronic-optical device, and may be considered an improvement on the so-called "electron microscope" such as described, for instance, by Martin, Whelpton and Parnum in the "Journal of Scientific Instruments," Volume XIV/1, pages 14–24, issue of January, 1937, published by the Institute of Physics, London, England.

Prior experimenters assumed that it is possible to reproduce a primary or also a secondary source of electrons, by the use of "electric lenses" or of "magnetic lenses," in the form of electron images, in the same manner as it is possible to reproduce a source of light or an illuminated or light-penetrated object with the aid of optical lens systems.

Every microscopical observation of very small objects is absolutely limited, as is known, by diffraction phenomena, insofar as only such objects or details can be reproduced which have a sufficient size compared with the wave length of the reproducing beam. The limit of the resolving capacity for the optical microscope lies, therefore, in the order of magnitude of the wave lengths of light. The operation of the electron microscope, however, is predicated on a wave length which is related to the electron velocity by the known deBroglie relation

$$\lambda \text{Å}_E \approx \sqrt{\frac{150}{\eta \text{ volt}}}$$

This formula furnishes, for instance, for an electron beam with a speed of 100 kilovolts, a wave length which is shorter by about 10000 than the mean wave length of the visible light. It should therefore be possible to build an electron microscope, the resolving capacity of which is by about four ten-powers stronger than the resolving capacity of the light-microscope with the same aperture.

It was possible until now, in practice, under the most favorable conditions, merely to approach the resolving capacity of the light-microscope by the use of the electron microscope, and even this could only be accomplished by using the penetration-radiation method; with the reflection method not even this value could be attained. The reason for this lies in the unavoidable speed stray or dispersion with which the electrons leave the object. This speed stray incident to using the reflection method is particularly great if secondary electrons join the reflected electrons, but is also considerable with the penetration-radiation method because the objects to be investigated, especially objects of an organic nature, always have a certain thickness, so that the electrons are subjected within those objects to a noticeable retardation which is different at different points of the respective object.

It is clear, therefore, that a beam of rays having a comparatively broad speed spectrum emanates always from the object to be reproduced, and since it has not been possible until now to manufacture sufficiently achromatized electron objectives, it is impossible to attain even approximately the theoretically established limit of the resolving capacity with a non-homogeneous pencil or beam of rays.

The present invention overcomes the above mentioned difficulties by point-for-point scanning of the object with the aid of an electron-beam focal spot, the diameter of which is less than one-thousandth of a millimeter. If, on carrying out this method, the electrons coming from the electronically-optically "illuminated" image element are registered, a basis is established for the building-up of an electronic-optical image of the object, and, in fact, with a resolving factor which depends solely on the point-sharpness of the scanning focal spot in the object plane subjected to investigation.

Any desired indicator method may be used for registering the electrons coming from the object point on which the electronic beam focal spot impinges at any instant. The electrons may be counted either singly, e. g., by means of an electrometric arrangement, or the use of a counting chamber of the Geiger type, respectively, or the mean value of the resulting electron current may be measured or traced with the aid of an integrating device. Several methods to attain the object in view will be described hereinafter; however, to those experienced in the art, it will of course be clear that many other methods and means can likewise be used for ascertaining or registering that amount of electrons which starts from a given point of the object in a time unit.

The point sharpness of the electronic focal spot with which the object is scanned and which determines the attainable resolving capacity can be increased to extraordinarily high values, as will be disclosed in the following detailed explanation, and inasmuch as only this point sharpness is decisive, the invention renders it possible to extend the resolving capacity considerably beyond that of light-microscopes even with objects, the thickness of which corresponds to the thickness of a microtome. It is therefore, possible to observe and investigate microscopically objects which could not be rendered visible until now in any way. Other advantages of the invention reside in the fact that the object to be investigated is subjected to a far smaller load, due to impinging electrons, than is the case with the normal electron microscope, and that it is not absolutely required to introduce the object into a vacuum space for carrying out the observation. These advantages are so considerable and of such importance that the invention recommends itself for use even if it is not intended to extend the resolving capacity of the electron microscope beyond the resolving capacity attainable with previously known means.

The above intimated objects, and other objects and features not yet mentioned, will appear from the following detailed description which is rendered with reference to the drawings. In these drawings,

Fig. 1 is a representation of an electronic-optical system for the production of a minute electron spot with which the object to be investigated is to be scanned;

Fig. 2 shows a tracing device for the registration of the image produced;

Fig. 3 illustrates a scanning field;

Fig. 4 represents a device for counting the electrons coming from the object;

Fig. 5 is an illustration of another embodiment of the tracing device which renders it possible to make the electronical-optically obtained image directly visible in a corresponding magnification;

Fig. 6 shows an arrangement for the formation of a particularly small electron focal spot for scanning an object, in connection with an arrangement for the observation of objects in the open air;

Fig. 7 illustrates a particularly designed "electron-multiplier"; and

Figs. 8–10 show several different electrodes intended to serve for the trapping of the electrons coming from the scanned object.

The following description refers to details only to an extent required for an understanding of the invention; matters that may safely be assumed to be well known to those experienced in the art, to whom the disclosure is addressed, are noted only to such extent as is necessary to support the understanding of what is new.

The highly evacuated glass tube 1 (Fig. 1) contains an electron emissive cathode 2 standing in a cylinder 3 of the Wehnelt type. From this cathode proceeds an electron beam transformed into a narrow pencil by the coaction of the cylinder 4 which has a positive initial voltage and of the anode cylinder 5, said pencil being directed towards the diaphragm opening 6. The passage opening of this diaphragm may have, for instance, a diameter of one-hundredth of a millimeter; it constitutes the electron delivery point which then is reproduced on a reduced scale on the object to be observed.

In order to reproduce this electron delivery point on the object on a reduced scale, an electric or a magnetic electron object-lens may be used. Tests have demonstrated that the most favorable reproduction is obtained with the aid of magnetic object-lenses consisting of an encased annular coil having an inner slot free of iron. With such an object-lens it is possible to obtain a focal distance down to a few millimeters. It is thus possible, with such object-lenses, to go to very great reducing scales, paying attention to direct the electron beam as accurately as possible into the corresponding object-lens diaphragm or shutter.

According to Fig. 1, the electron beams arriving from the diaphragm opening 6 are, therefore, trained as accurately as possible upon the passage opening of the diaphragm 9 of the magnetic electron object-lens 10, which is done by means of a magnetic adjusting device comprising the coils 7 and 8 and the associated batteries and adjusting resistances, the coils being arranged perpendicularly with respect to each other. The electron objective 10 has a very short focal distance and therefore reproduces the passage opening of the diaphragm or shutter 6 on the surface of the object 11 to be investigated in about a fifty-fold reduction. A scanning focal spot is therefore caused at that point which has a diameter of only 5.10^{-5} mm., resulting in a resolving capacity of 5.10^{-5} for the scanning.

The electrons coming from the object 11 are trapped by an electrode 12 arranged preferably in the interior of a grounded cage 13 of the Faraday type. This cage has only a comparatively small window and acts consequently at the same time as a shutter or diaphragm. The number of the electrons arriving at the trapping electrode 12 depends obviously at any moment on the electron stray and on the permeability to electrons of the object 11 at the point where the electron focal spot is located at any instant. When the object 11 is moved in the plane in which the electron focal spot arises, and if this movement is carried out in such a manner that the small field of the object 11 to be investigated is scanned by said spot, then the number of the electrons reaching the trapping electrode 12 varies according to the permeability to electrons of the object 11 from point to point. It is advisable to carbonize the surface of the electrode 12 in order to obviate errors that may be caused at this trapping electrode through reflection and by a secondary emission. Faults of the kind just mentioned may also be diminished by connecting a voltage between the object-carrier 11 and the trapping electrode 12. In order to register the electrons taken by the trapping electrode, this electrode may be connected with the input circuit of an amplifier 14, as illustrated in Fig. 1.

According to Fig. 2, the variations of the current, after having been sufficiently amplified, are transmitted to an image-tracing device. The output circuit of the amplifier 14 is for this purpose connected with a gaseous conduction or glow lamp 15, the luminous surface of which is reproduced upon the light-sensitive surface of the image roller 17 by means of the objective 16. The roller 17 rotates in the usual manner below the lamp 15 and is simultaneously shifted in the direction indicated by the arrow 18. Connected with the roller 17 is a rotary resistance 19 and a sliding resistance 20. At every rotation of the roller 17 the resistance 19 passes through its entire range from zero to the maximum value, and inasmuch as this resistance is connected in the circuit of a magnetic deflecting device comprising two coils 21 and 22 which are wound in opposite directions, as shown in Fig. 1, the angle of incident of the electron beam entering into the diaphragm or shutter 9 in the manner indicated by the dotted line is periodically changed. This causes the required line deflection whereby the image field J is scanned, according to Fig. 3, in the direction indicated by the arrow A_1. The image deflection in the direction of the arrow A_2 may be brought about by means of a suitably designed coil arrangement controlled by the resistance 20. According to another embodiment, likewise illustrated in Fig. 1, the object-carrier 11 may be secured on a strong bi-metallic rod 23 which is heated by a bifilar-wound resistance 24 located in the circuit of the sliding resistance 20. It is possible in this way to scan the object 11 in successive lines in accordance with the preceding continuous registration of the electrons trapped at 12 in the image-field J (Fig. 3). An image-field (I) covering on the object merely a square of 2.10^{-2} mm. can thus be scanned with an electron focal spot of 5.10^{-5} mm. and can be traced on the roller 17 in the size of 10x10 cm. The resulting traced image then shows details magnified five thousand times, which cannot possibly be produced by means of a light microscope.

It is, of course, unnecessary to trace a complete image in every case; tracing of only one scanning line to obtain an answer for a distinct question as to the properties and the nature of the object 11 will suffice in many instances. It is advisable in such cases to make the tracing on a band or strip, for instance, by means of a registering electrometer directly connected with the trapping electrode 12, or with the aid of a registering galvanometer (loop-oscillograph) connected with the amplifier 14.

The electron currents reaching the electrode 12 are, of course, extraordinarily small. Their amplification is the more difficult, the greater the desired resolving capacity is; that is to say, the amplification difficulties are increased in proportion to the decrease in size of the electron focal spot which scans the object 11. In case of employing very small electron focal spots (order of magnitude of from 10^{-6} to 10^{-7}), it is, therefore, advisable to substitute for the electrode system 12—13 a particularly sensitive arrangement, e. g., an "electron multiplier" or a "Geiger counting chamber." The latter may comprise a vacuum-tight cylindrical casing 25, along the axis of which is located the prepared filament electrode 26, and which has a Lenard window 25*a* directed toward the object 11. By filling the chamber 25 with a dilute gas and providing a sufficient voltage difference between the wall of the chamber 25 and the filament 26, every electron penetrating into the chamber will produce a discharge impulse between the electrode members 25 and 26. These discharge current impulses may be counted singly or may be singly registered. In order to insure that all electrons coming from the object actually pass through the Lenard window 25*a*, an acceleration voltage is placed between the object-carrier 11 and the electrode 25. The inner surface of the electrode 25 may also be provided with a suitable coating which produces a high secondary electron emission when the electrons impinge upon it so as to facilitate the discharge puncture.

The counting chamber 25—26 is preferably connected with an integrating amplifier device, which may comprise, according to Fig. 4, an electron tube 27, the grid of which couples the filament electrode 26 of the counting chamber across the resistance 28 and the condenser 29. By choosing the leak-resistance of the grid sufficiently high, every current impulse flowing through the counting chamber 25—26 will cause a temporary blocking of the tube 27. The mean anode current flowing in the tube 27 is thus a function of the number of the current impulses flowing through the counting chamber 25—26 in the unit of time; it produces at the resistance 31, which bridges the large condenser 32, a voltage drop for controlling the grid of the tube 33. This tube therefore conducts a current which corresponds with the time integral of the electrons entering into the counting chamber. This current may, therefore, be utilized for the tracing of an image.

Current sufficient to control a carrier wave amplifier may be obtained at the trapping electrode 12, provided the resolving capacity is not driven to the limit. It is possible in this case to make use of a quickly operating image-tracing device of a type such as employed in the art of television. The deflection of the scanning electron beam or pencil is then preferably brought about in both coordinates electrically or magnetically so that the object-carrier can remain stationary.

Fig. 5 shows a cathode ray tube of the type used at present in television receivers. A cathode beam 35 coming from the cathode 34 is accelerated in the usual manner by the electrodes 36 and 37, and the rays are assembled in the plane of the fluorescent screen 38 where they form a focal spot. The intensity of the cathode beam 35 is controlled by means of the Wehnelt cylinder 39; two coils 40 and 41 disposed perpendicularly with respect to each other and being controlled by means of the generators 42 and 43 for tilting oscillations are provided for its control. Connected to the generator 42, which delivers the line frequency, are the two coils 21 and 22 (Fig. 1), and parallel to the coil 41 are located the coils 44 and 45 which must be visualized as being arranged perpendicularly with respect to the coils 21 and 22 at the head end of the tube 1 and which transmit the image deflection to the electron beam of the electronic-optical arrangement of Fig. 1. By connecting the Wehnelt cylinder 39 with the output circuit of the carrier-wave amplifier in the manner shown in Fig. 5, the cathode beam 35 which scans the fluorescent screen in accordance with the movements of the electron focal spot scanning the object 11, will be modulated in accordance with the permeability to electrons of the object 11 which changes from point to point. There is thus obtained directly on the fluorescent screen 38 an electron image of the object 11. The magnification obtained corresponds in this case with the ratio between the scanning paths of the two electron beams on the surface of the object 11, and on the fluorescent screen.

An output shutter or diaphragm 6 having the previously noted opening diameter of 0.01 mm. can be accurately manufactured only with very great difficulty; and it is, therefore, advisable to use instead of a real shutter a so-called potential shutter or diaphragm for a primary electron delivery source which is then reproduced on a reduced scale. The potential shutter can in this case be produced by the coaction of the anode and the Wehnelt cylinder. With an implement actually made in this way, the flat oxide-cathode was located at a distance of 0.3 mm. in back of the opening of 0.6 mm. of the Wehnelt cylinder which was located opposite the anode carrying 25,000 volts at a distance of 3 mm. With this arrangement could be obtained in the interior of the passageway of 1 mm. diameter of the anode an electron focal spot, the diameter, of which was considerably below 0.1 mm. and from which the electrons traveled with a very slight divergence to the reducing objective lens. The use of a potential diaphragm or shutter presents, therefore, the additional advantage of considerably reducing the length of the electronic-optical device as compared with the arrangement shown in Fig. 1.

In order to obtain a possibly strong reduction, the distance between the source of the electrons and the electronic-optical object-lens must be chosen as great as possible. However, the earth magnetic field constitutes a disturbing factor, insofar as it causes a curvature of the electron beam. This curvature can be considered to a certain extent in the manufacture of the device, or incident to adjusting it, but variations of the earth magnetic field give rise to considerable disturbances. In order to avoid these disturbances, the electron beam may be disposed in the direction of the earth magnetic lines of force, or the path of the beam may be screened by means of a suitably designed and arranged iron shell. Another possibility is to compensate the earth magnetic field by the provision of a corresponding magnetic counterfield produced preferably by two flat coils (so-called Helmholtz coils) arranged coaxially with respect to the discharge tube and sufficiently spaced therefrom. The passage of the current through these coils is then readjusted according to the variations of the earth magnetic field which may be ascertained by suitable measurement as desired.

A particularly important means for increasing the sharpness of the electron focal spot caused upon the object to be investigated consists in a multi-stage reduction of the reproduction of the original electron source. Such an arrangement is shown in Fig. 6. The electrons emanating from the cathode **46** are assembled by the coaction of the Wehnelt cylinder **47** and the anode **48** in an electron focal spot P_1, from which they pass through a magnetic screening tube **49** in the direction of the magnetic objective lens **50**. The iron-encased lens **50** produces by means of the magnetic field arising in its iron-free slot a strongly reduced real image of the electron focal point P_1 in the point P_2, from which the electrons pass through a second, particularly effective, screening tube **51** toward a second magnetic objective lens **52**, in front of which are arranged deflecting coils **53** and **54**. The lens **52** reproduces the additionally reduced electron focal point P_2 on the surface of the object to be investigated.

In the embodiment illustrated in Fig. 6, the object to be investigated is not housed within the extremely evacuated electron beam arrangement **49**, **51**, but is located in the open air. In order to render this possible, the arrangement **49**, **51** is closed by a disk **53***a* which is provided with a tube having a minute aperture closed in turn by a Lenard window **54***a*. This window need not consist of metal, but may be made, for instance, of collodium or the like, by reason of the slight total scanning electron current. The window may be produced by the evaporation of a solvent down to a thickness of 5.10^{-5}. In accordance with this invention, it may also serve as a support for the object to be investigated. The Lenard window **54***a* is arranged as close as possible to the trapping electrode **55** which is directly connected with the grid of the tube **56**.

The possibility of investigating objects by means of an electronic-optical microscope without the necessity of introducing them into the high vacuum of the electron beam tube presents a particularly important advantage of the present invention. This opens a way for the electron-microscopic investigation of substances, the texture of which is changed under vacuo (for instance, by withdrawal of water), and which, therefore, could not be investigated up to now by electron-optical microscopes without affecting their nature or properties.

I have already mentioned previously that the electrons starting from the scanning point of the surface of the object concerned can be trapped in an "electron multiplier". A particularly advantageous embodiment, which is distinguished by an exceedingly small initial current, is illustrated in Fig. 7. This "electron-multiplier" consists of a vacuum vessel **57**, in the interior of which are provided the prepared grids **58**—**61** as well as the closing plate **62**, the diameter of the latter increasing from step to step. In front of the first grid **58** is arranged the diaphragm or shutter **63**, and over its aperture is disposed the Lenard window **64**. This is substituted for the trapping electrode **12** of Fig. 1, or **55** of Fig. 6. The rebounding electrodes **58**—**62** are connected with increasing positive voltage delivery points of the battery **65**. In the supply connection to the last electrode **62** is provided a resistance **66**, the voltage drop of which controls the amplifier **14**. It was found that, by the use of such an "electron-multiplier" for scanning the object to be investigated, about 20 electrons per image element are sufficient to control the amplifier **14** in a satisfactory manner.

In the examples discussed in the foregoing, the practical application of the invention has been described mainly in connection with the so-called "penetration-radiation method". In contradistinction to the previously known electron-microscopes, the present improved devices not only permit a very high resolving capacity in connection with thin layers of an object, when using said method, but also render possible, while maintaining this capacity, an electronic-optical observation in plan view (exclusive observation with returning electrons), and also an electronic-optical observation after the so-called "dark-field method" (exclusive observation of the laterally strayed electrons). Suitable embodiments of the trapping electrodes which serve as "registering surface" are shown in Figs. 8–10, whereby the known "modes of illumination" of the light-microscope are imitated.

In Fig. 8 the numeral **54***a* denotes, drawn to an enlarged scale, the Lenard window onto which impinges the electron beam **66***a* under a very narrow convergence angle. The Lenard window carries the object **67** to be investigated. If, analogous to Fig. 1, a trapping electrode **68** located in a grounded cage **69** having a narrow window is arranged opposite the object **67**, the electrons which penetrate the object **67** without being deflected, as well as a limited portion of the laterally straying electrons will obviously reach the electrode **69**. This arrangement therefore corresponds with the bright-field transparent observation in case of the light microscope.

In the further example illustrated in Fig. 9 is arranged an annular trapping electrode **70** in front of the Lenard window, this electrode trapping exclusively returning electrons. This observation method, which is used, for instance, for the investigation of the surface texture of ground metal parts, corresponds to the observation with incident light by means of a light microcope. In order to protect the trapping electrode **70** against the impingement of electrons not returning from the Lenard window **54***a*, a grounded annular shutter or diaphragm **71** is provided, which surrounds the electron beam **66**.

In Fig. 10 is shown an electron arrangement for an observation method which corresponds with the "dark-field observation" of the optical microscope. The electrons which penetrate the object 67 to be investigated without being deflected are trapped by the grounded circular disk 72. Only the annular surface is therefore used as registering surface, which remains free between the disk 72 and the cage electrode 73. Only the straying or deflected electrons therefore reach the trapping electrode 74, which start from the object within the range of a predetermined angle. It is clear that this method yields images very rich in contrasts even with extremely thin object layers. The electrodes shown in Fig. 10 may also be given such geometrical configuration that only those electrons exert an action incident to the image reproduction which correspond with certain distinct diffraction figures. The distribution of micro-crystalline particles in the object can be made visible in this manner.

Another mode of observation is presented by the possibility of utilizing the object support itself (object-carrier 11, Lenard window 54) for a trapping electrode. A pure electron absorption image may be attained in this manner. In order to carry out this method, it is solely necessary to use a conducting object support, which is sufficiently insulated with respect to the other members of the apparatus. The manufacture of conducting object supports can be effected, for instance, by means of cathode atomization. Making use of this method of manufacture is also recommended if separate trapping electrodes are employed and if it is desired to place between the trapping electrode and the object an acceleration potential (for instance, for the acceleration of secondary electrons), or a brake voltage as used, for instance, to keep off of the trapping electrode all electrons, the speed of which is below a certain limit.

Another very important advantage which this invention presents appears particularly from the Figs. 8–10. It is based on the narrow convergence angle of the scanning electron beam resulting in a very great depth sharpness. It is known that with a microscope the depth sharpness lies in the order of magnitude of the resolving capacity. With strong microscopes it is usual to make use of aperture values which approach the value "One". If apertures of the same value would be employed in connection with the present electron-microscope, the resolving capacity of which extends to 10^{-6} and 10^{-7}, it would become necessary to make the plane in which the electron spot moves when the object is being scanned coincide with the object layer to be investigated with a degree of accuracy amounting to from 10^{-6} to 10^{-7}. If, however, electron object-lenses, which have an aperture of about 0.01 mm. and can be manufactured comparatively easily by magnetic means, are used, the depth sharpness rises by two tens-powers and it is sufficient to make the plane of the object to be scanned coincide with the observation plane with an accuracy of from 10^{-4} to 10^{-5}. This accuracy is still within the range of what can be attained with electric or mechanical auxiliary means.

Changes may be made within the scope and spirit of the appended claims, wherein I have defined what is believed to be new and desired to have protected by Letters Patent of the United States.

What is claimed is:

1. An electronic microscope comprising means for generating a cathode ray, means for focusing the ray to a point on an object to be examined, the diameter of said point being of the order of the wavelength of visible light, a target beyond the object in the direction of the ray for intercepting electrons thereof that pass through the object, a circuit in which current flow is established by electrons intercepted on said target, reproducing means controlled responsive to variations in said current flow, said reproducing means including an element movable in two directions, and means electrically responsive to movement of said element for producing corresponding and proportionate movements of microscopic dimensions of the focus point of said ray on said object.

2. An electronic microscope comprising means for generating a cathode ray, means for focusing the ray to a point on an object to be examined, the diameter of said point being of the order of the wavelength of visible light, a target beyond the object in the direction of the ray for intercepting electrons thereof that pass through the object, a circuit in which current flow is established by electrons intercepted on said target, reproducing means controlled responsive to variations in said current flow, said reproducing means including an element movable in two directions, and means electrically responsive to the two movements of said element, respectively, for moving the focus point of the said ray in one direction and the object in a different direction to cause said point to scan a microscopic area of said object.

3. In an electronic microscope, means for producing a cathode ray, means for focusing the ray to a point on an object to be examined, the diameter of said point being of the order of the wavelength of visible light, reproducing means controlled in accordance with the number of electrons of the ray which pass through the object at the point where the ray impinges, said reproducing means including a movable element, means for producing movement of said element in two directions, and means electrically responsive to the movement of said element for producing corresponding but relatively microscopic movements of the focus point of the ray on said object.

4. In an electron microscope, means for producing an electron beam, means for focusing said beam at a point on an object to be examined, the diameter of said point being of the order of the wavelength of visible light, scanning means for causing said point to scan an area of said object whereby said impinging electron beam is modified by said object, a collecting electrode adjacent said object, and a shield interposed between said object and target, said shield having an annular aperture therein surrounding an opaque portion located in line with said beam.

5. An electronic microscope comprising means for generating an electron beam, means for focusing said beam to a point on an object to be examined, the diameter of said point being less than the wave length of visible light, a target electrode for intercepting electrons from said object, an output circuit coupled to said target electrode in which a current flow is established by said intercepted electrons, reproducing means controllable in response to variations in said current flow, said reproducing means including a movable element, and means electrically responsive to the movements of said element for

producing similar but greatly reduced movement between said object and said beam.

6. In an electronic microscope, means for producing an electron beam, means for focusing said beam on a point of an object to be examined to cause electrons to be released therefrom, the diameter of said point being less than the wave length of visible light, electrode means for collecting said electrons, an output circuit coupled to said electrode means in which a current flow is established proportional to the number of said electrons, reproducing means coupled to said output circuit and having a movable element, means for producing movement of said element, and means electrically responsive to the movement of said element for producing corresponding relative movement of microscopic proportions between said object and said beam.

7. In an electronic microscope, means for producing an electron beam, means for focusing said beam on a point of an object to be examined to cause electrons to be released therefrom, the diameter of said point being less than the wave length of visible light, electrode means for collecting said electrons, an output circuit coupled to said electrode means in which a current flow is established proportional to the number of said electrons, reproducing means coupled to said output circuit having a reproducing surface and a recording element, means for producing relative movement between said surface and said element, and means electrically responsive to said relative movement for producing corresponding movement of microscopic proportions between said object and said beam whereby said beam scans a microscopic area of said object.

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