ELECTRON MICROSCOPES

Filed Sept. 9, 1954 5 Sheets-Sheet 1

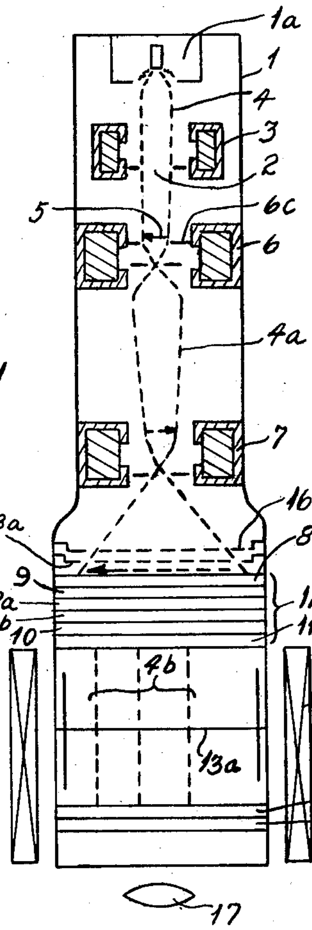

Fig. 1

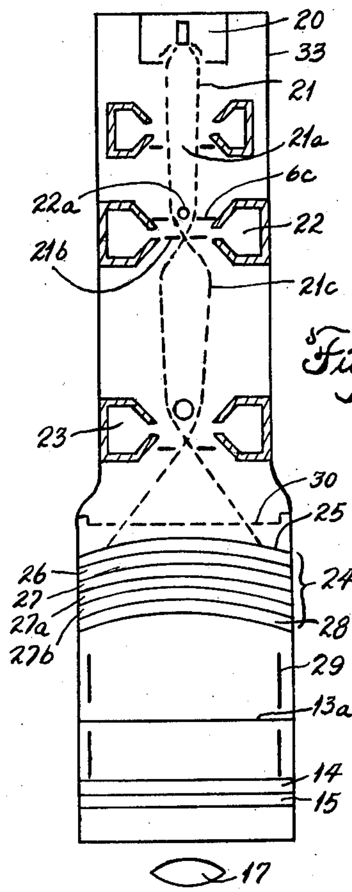

Fig. 2

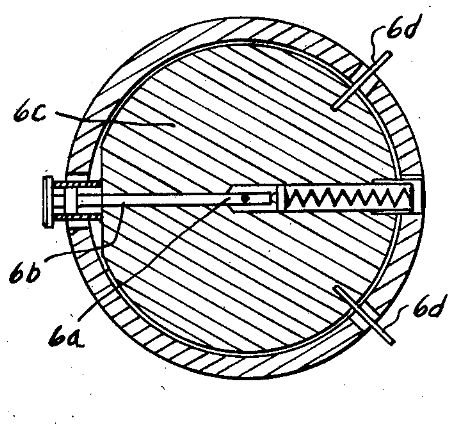

Fig. 1a

INVENTOR.
EDWARD EMANUEL SHELDON
BY L. S. Saulsbury
ATTORNEY

July 7, 1959 E. E. SHELDON 2,894,160

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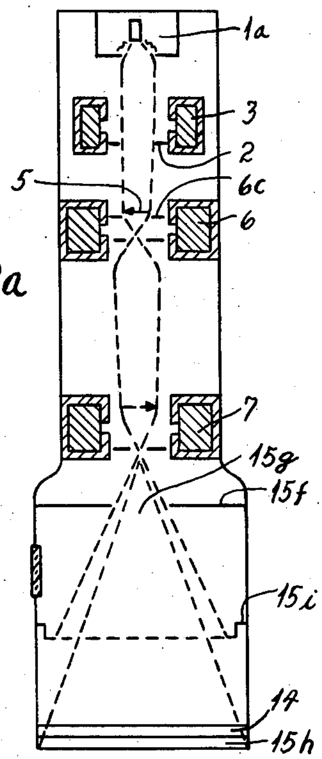

Fig. 2a

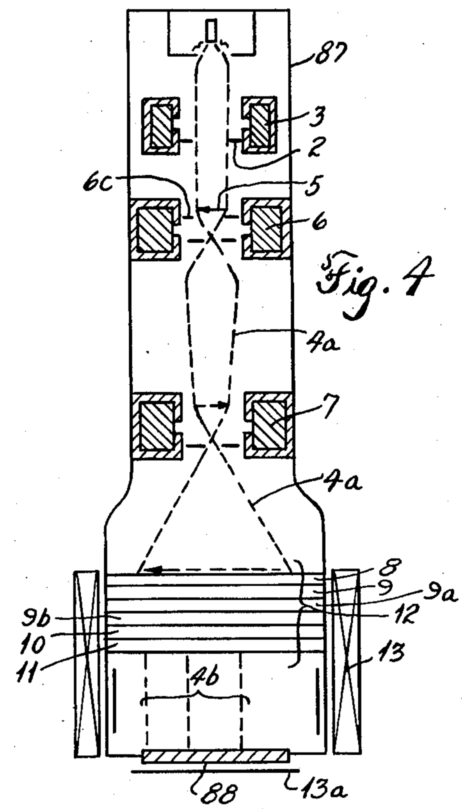

Fig. 4

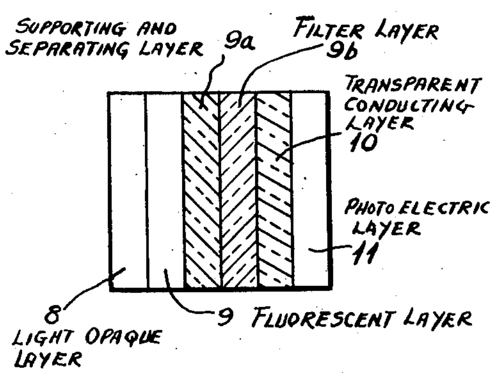

Fig. 9

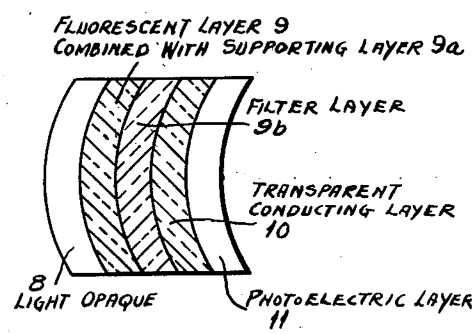

Fig. 9a

INVENTOR.
EDWARD EMANUEL SHELDON
BY
L. S. Saulsbury
ATTORNEY

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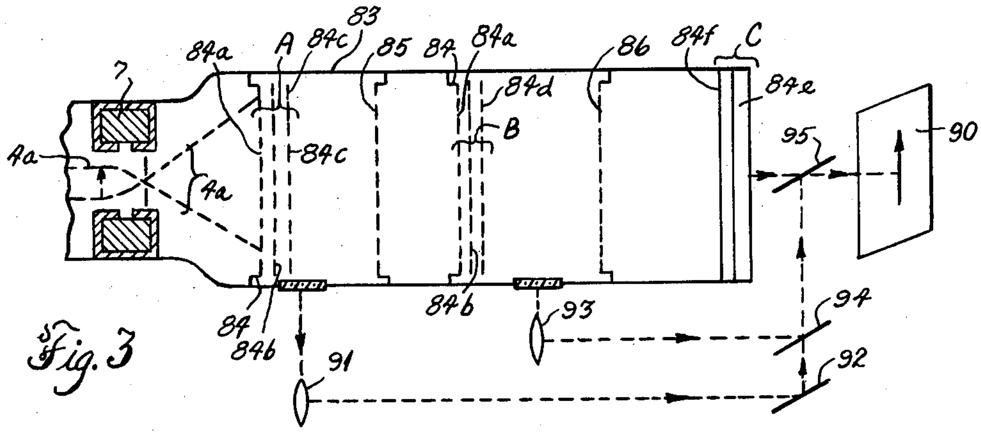

Fig. 3

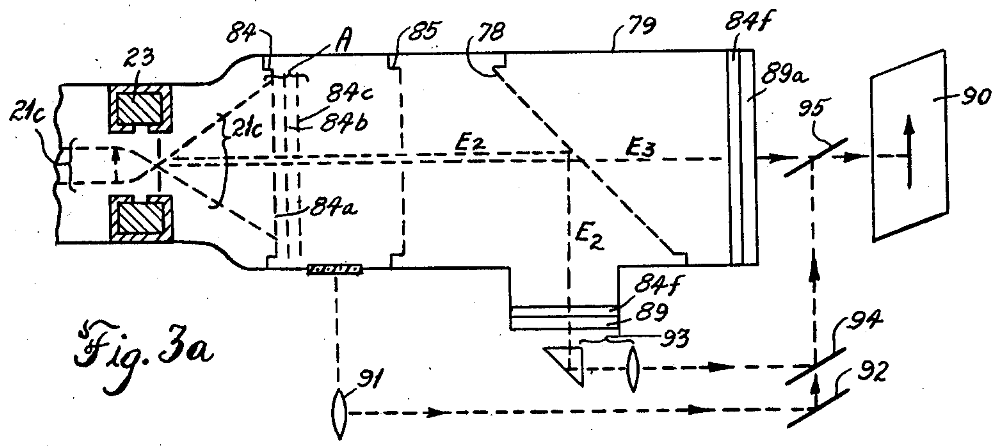

Fig. 3a

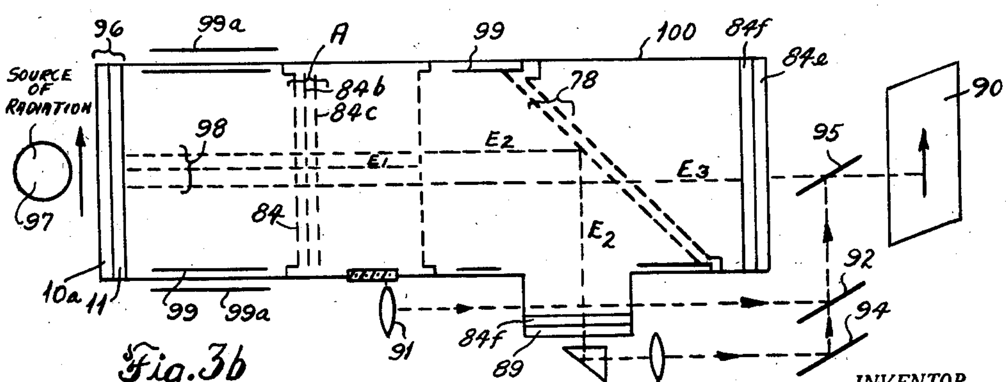

Fig. 3b

INVENTOR.
EDWARD EMANUEL SHELDON
BY L. S. Saulsbury
ATTORNEY

July 7, 1959 E. E. SHELDON 2,894,160

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Fig. 5

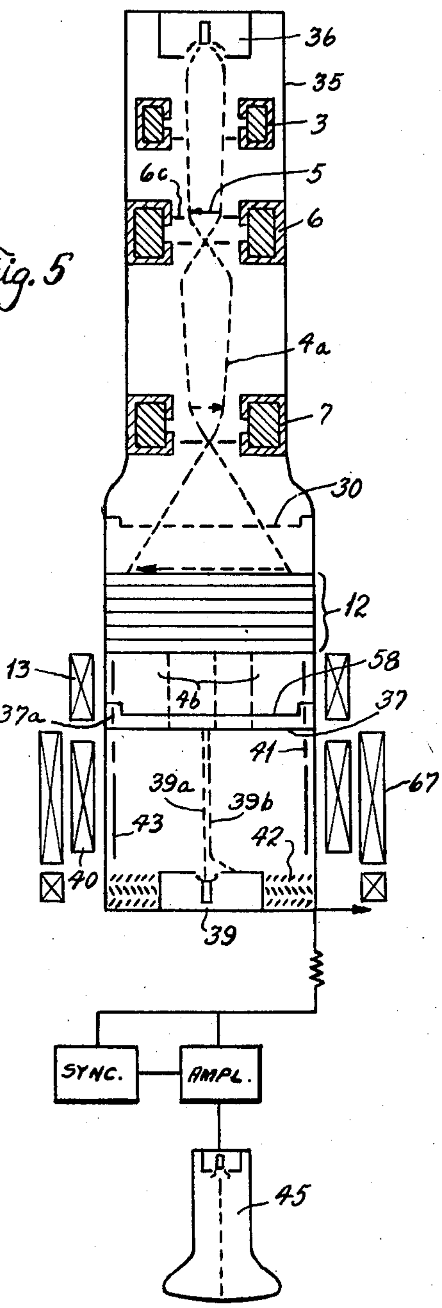


Fig. 6

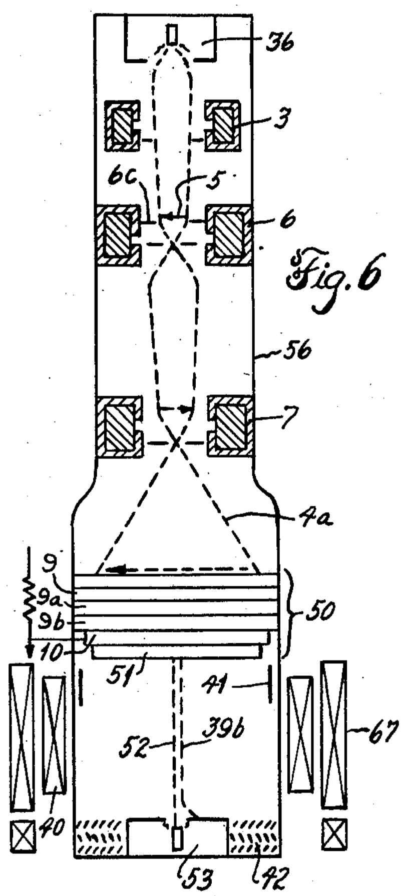
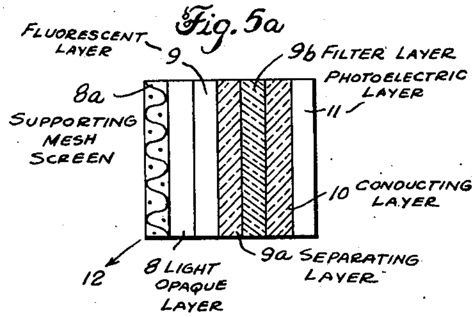


Fig. 5a



INVENTOR.
EDWARD EMANUEL SHELDON
BY L. S. Saulsbury
ATTORNEY

July 7, 1959

E. E. SHELDON

2,894,160

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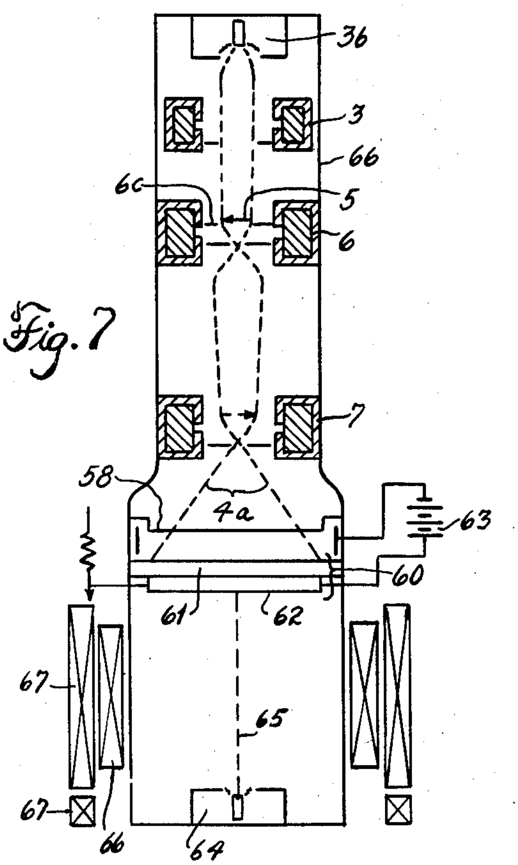

Fig. 7

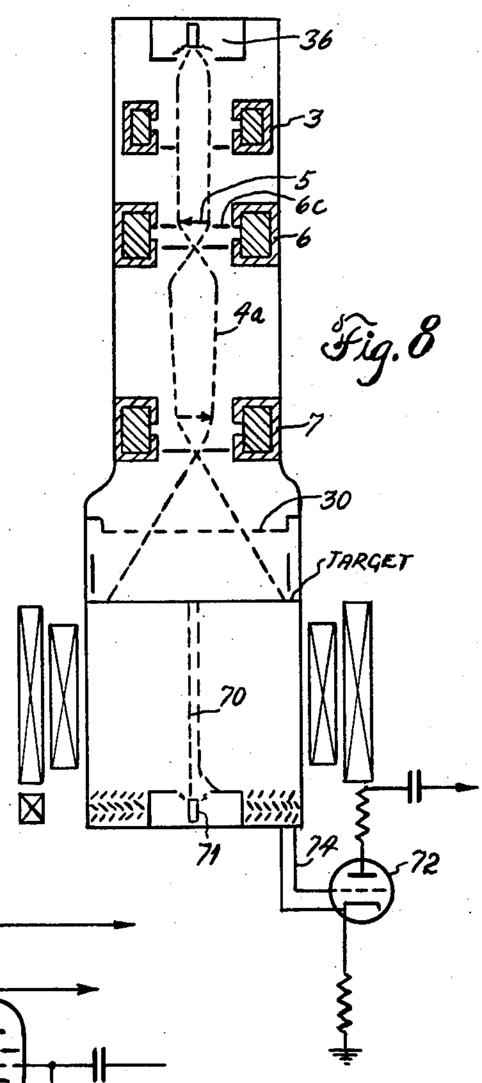

Fig. 8

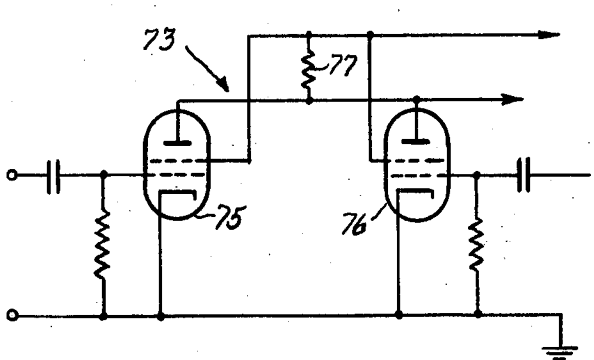

Fig. 8a

INVENTOR.
EDWARD EMANUEL SHELDON
BY L. S. Saulsbury
ATTORNEY

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ELECTRON MICROSCOPES

Edward Emanuel Sheldon, New York, N.Y.

Application September 9, 1954, Serial No. 454,981

9 Claims. (Cl. 313—65)

This invention relates to the novel electron microscopes and novel electron diffraction cameras and has a common subject matter with my U.S. Patent 2,739,243, filed January 8, 1953, and issued March 20, 1956. One of the most vexing problems in the present electron microscopy is the damage of the examined specimen by the exposure to the electron beam. The electron beam causes irreversible changes in the structure, of organic or inorganic objects as well. As a result images are obtained and recorded which in reality do not exist at all and represent artefacts only. These artefacts can be divided into two major groups. One of them represents a direct effect of the electron beam on the examined specimen. The other group of artefacts is caused by contamination of the examined specimen by a foreign matter which originates from the structures of the electron microscope while it is in operation. The only way to eliminate or to reduce such artefacts is to decrease the intensity of the examining electron beam. The reduction of the intensity of the electron beam without prolonging the exposure time is unfortunately impossible because of the limited sensitivity of photographic materials used to record the electron-microscopic image. It is therefore, the objective of this invention to eliminate the artefacts by reducing either the strength of the electron beam irradiating the examined specimen or the exposure time or both.

Another objective of this invention is to improve the contrast of images in electron microscopy. Images in electron microscopy are formed by electrons scattered by the matter. The scattered electrons comprise two different groups, one of elastically scattered electrons and another one of inelastically scattered electrons. By separating these two different groups it was found that a marked improvement in contrast of the image may be obtained.

Another objective of this invention is to produce electron microscopic images as multi-colored images. Various colors are arbitrarily selected to represent either different velocities of electrons or different intensities. This objective was accomplished by segregating electrons into various groups according to their velocity and allowing each of said segregated groups to impinge only on a certain predetermined fluorescent screen such as of the red light emitting phosphor or of the green light emitting phosphor or of the blue light emitting phosphor.

Another very important problem present in electron microscopy is a poor visibility of the fluorescent image produced by the electron beam. In all microscopic examinations which require a large degree of magnification, the fluorescent image produced by the electron beam is so dim that the examiner is not able to study it any longer. It was found that at such low levels of brightness as 0.01 footcandle the eye of the observer loses its visual acuity for definition and contrast. It is evident, that a successful electron microscopic examination must be based on a visual selection of a proper field in specimen for photography. Without such selection the ex-

amination becomes a hit and miss procedure. It is therefore the purpose of the present invention to provide a novel microscope in which the examiner will not be limited any more by the dimness of the fluorescent beam. This objective was accomplished by projecting the electron image on a composite screen disposed in the electron microscope. The composite screen comprises an electron transparent light reflecting layer, a luminescent layer, a light transparent separating layer and a photoelectric layer. The electron image is converted in said screen into a luminescent image. The luminescent image is again converted into a photoelectron image. As each primary electron of the image can release a few hundred photons, we obtain a new photoelectron image which is ten times or more stronger than the original image. Furthermore, the new photoelectron image is formed by photoelectrons which have a low velocity. It can be, therefore, accelerated by suitable electric fields and it may be also demagnified electron-optically. The electron-optical demagnification results in an intensification proportional to the square power of the linear demagnification.

Another objective of this invention is to provide means for transmission of electron microscopic images to multiple observers or to remote observation areas.

Another purpose of this invention is to provide a method and means for subtracting from the images formed by the whole beam of electrons the image formed by a fraction of said beam, this fraction being e.g. formed by elastically scattered electrons or by inelastically scattered electrons.

Another objective of this invention is to provide an electron microscope in which the photography of the examined object does not require any more the introduction of the photographic plate into vacuum. This represents a great improvement as it eliminates the need for repeated restoration of the vacuum which is impaired any time the photographic cassette is inserted or removed from the electron microscope.

The invention will be better understood when taken in connection with the accompanying drawings.

In the drawings:

Fig. 1 represents the novel electron microscope of magnetic type;

Fig. 1*a* shows the supporting table for the examined specimen;

Fig. 2 represents the novel electron microscope of electrostatic type;

Fig. 2*a* represenst an electron microscope for images produced by inelastically scattered electrons;

Fig. 3 represents the novel electron microscope for producing color images;

Fig. 3*a* represents modification of microscope for producing color images;

Fig. 3*b* represents another device for producing color images;

Fig. 4 represents the novel electron microscope having an X-ray emitting window;

Fig. 5 represents the electron microscope for intensification and transmitting images;

Fig. 5*a* represents one embodiment of the composite screen.

Fig. 6 represents another modification of the electron microscope;

Fig. 7 represents another embodiment of electron microscope;

Fig. 8 represents an electron microscope for producing images of inelastically scattered electrons;

Fig. 8*a* shows a circuit for the system illustrated in Fig. 8; and

Figs. 9 and 9*a* show an enlarged view of the composite screen.

Fig. 1 represents the novel electron microscope **1**. The microscope **1** has a source of electrons **1***a* which may be an electron gun of hot filament type or of cold emission type. The emitted beam of electrons **4** is collimated by the aperture **2** and is focused by the condenser lens **3** on the examined specimen **5**. The specimen may be deposited on a supporting plate **6***a*, with an opening therein or on a mesh screen such as of silver. This support can be attached to the elongated holder **6***b*. The holder **6***b* is inserted into microscope from the side so that the supporting plate **6***a* may be deposited on the specimen table **6***c* shown in Fig. 1*a*, which should be of a non-magnetic type. The table **6***c* is mounted in the focal plane of the objective. The insertion and removal of the holder does not cause destruction of the vacuum as the holder when it is inserted into the microscope presses against rubber piston provided with a spring. When the holder is removed from the microscope the compressed spring pushes the rubber piston back in the place of the holder and prevents thereby admission of the air into the microscope. The table **6***c* is provided with the pins **6***d* which allow to move said table in two directions perpendicular to each other. The knobs outside of the microscope regulate the motion of pins and control thereby the movement of the table. In this way the specimen may be moved and examined over its entire field.

The electron beam **4***a* transmitted through the specimen is focused by the objective lens **6** on the plane of the projection lens **7**. In some cases it is preferable to use an intermediate lens between the objective lens and the projection lens. The projection lens provides the final enlargement of the electron image so that the enlarged image may now cover the whole area of the fluorescent screen. All lenses in this embodiment of the invention may be of magnetic type. The electron image of the examined specimen is, because of its enlargement 10,000 to 50,000 times, very dim. In many examinations the brightness of said enlarged image is so low that the examiner's eye loses its visual acuity for the contrast and detail. At the low level of illumination the eye operates by means of rods instead of cones and as a result the perception of detail and contrast is completely impaired. One of the most important steps in electron microscopic examination is the choice of a proper field for recording. This can be accomplished only if the examiner can see what he is examining. In the present electron microscopes the brightness of image cannot be improved because the use of a stronger electron beam will damage the specimen, as was explained above. The transmitted electron beam **4***a* which carries the image of the examined object is in this invention projected on the composite screen **12**. The composite screen **12** consists of an electron transparent light reflecting or light diffusing layer **8**, of a fluorescent layer **9**, light transparent separating layer **10** and a photoelectric layer **11**. The fluorescent layer **9** must be as thin as it is compatible with its efficiency and it must be of a very fine grain because this layer must be able to resolve fine detail, such as images of 25 lines per millimeter definition. Phosphors such as ZnSCdS, silicates, tungstates or ZnO are suitable for this purpose. The best results for definition are obtained with grainless evaporated phosphors. Also single large crystals of phosphors are suitable because of their grainless structure.

On the side of the fluorescent layer **9** opposite to the electron gun **1***a* is now deposited a very thin protecting light transparent layer **9***a* such as of silicon monoxide, silicon dioxide or ZnF_2. The protecting layer **9***a* must be thicker than 0.5 to 1 micron to prevent migration of hot ions of Cs across said layer which would destroy the luminescent layer **9**. On the top of layer **9***a* is deposited an extremely thin layer **9***b*, such as of the order of 50A up to ¼ of wave-length of luminescent light, which serves as a selector or filter for the luminescent light from the layer **9**. On the top of the layer **9***b* is now deposited a very thin light transparent layer **10** of conductive material such as of gold, tungsten, silver, silicon, tin oxide or other compounds of tin, cadmium sulfide or other compounds of cadmium or of ZnF_2. The layer **10** may be omitted in some cases. On the conducting layer **10** next is deposited a photoelectric layer **11** such as of CsOAg, caesium, potassium, lithium or rubidium with antimony, bismuth or arsenic, or of a combination of several aforesaid elements. In some cases when the conducting layer **10** is eliminated the antimony should be evaporated together with palladium or tungsten to provide a conducting property to the photoelectric layer of Cs_3Sb or other antimony containing photoelectric compound. This will not be necessary if the filter layer **9***b* has conducting properties. It was found that tin oxide and other compounds of tin cannot be used with Cs or Sb. They turned black and lost transparency when exposed to Cs.

The fluorescent layer **9** cannot be made self-supporting when it is as thin as it is necessary for the purpose of this invention. It requires, therefore, a support which must be transparent to electrons, as otherwise prohibitive losses of the image forming electron beam will occur. I solved this problem by using as a support a fine mesh screen **8***a*. The phosphor layer **9** with a binder such as potassium silicate is deposited on said supporting mesh in such a manner as to occlude the openings of the mesh. Before the deposition of the fluorescent layer **9** it is preferable to deposit first on said mesh screen **8***a* a very thin layer **8** of aluminum or of one of the noble metals. This conducting layer may be of the thickness such as ½ to 1 micron. A layer of a metal of this thickness may act as a base for the luminescent layer **9** and at the same time will be essentially transparent to electrons of velocity used in electron microscopes.

Another solution of the problem of supporting the composite screen **12**, I found is the use of a plastic material such as one of polyesters which are heat resistant. Especially Mylar produced by Du Pont Company of Wilmington, Delaware, was found to be very suitable for this purpose. First I made a solution of Mylar in a suitable solvent. Next I add the suspension of luminescent material to said solution of Mylar. After subjecting said composition to a thorough mixing, I evaporate the mixture. As a result, a light transparent solid material is formed which represents a combination of Mylar and of luminescent material embedded in each other. This new luminescent material can be made in sheets of any desired thinness. Such sheets I found to be self-supporting and to have enough tensile strength when only 2 to 5 microns thin, even if the size of such sheet was 10 inches in diameter.

It should be added that the thickness of the top surface of Mylar which faces the photoelectric layer **11** should not be less than 1 micron in order to protect the fluorescent material from destruction by the chemical action of hot ions of caesium or other alkalis used to form the photoemissive layer. This additional thickness of Mylar may be obtained by spraying the surface of the sheet of Mylar combined with the luminescent material with a solution of pure Mylar for a predetermined number of times.

Furthermore, I found that this new luminescent material is transparent to ultra-violet radiation which is of great importance as a large part of the luminescent emission of the best phosphors is in the ultra-violet part of spectrum and would be lost if Mylar were opaque to ultra-violet.

In some cases it is preferable to use as a supporting layer a fine mesh screen **8***a* coated with Mylar or other polyester layer. Mylar is first dissolved in a suitable solvent. Next the binder such as potassium silicate is added to the solution. Then the mesh screen is dipped into the solution. Afterwards the mesh screen is baked to remove the solvent. As a result a thin film of Mylar remains attached to the mesh screen and forms a continuous layer across the openings of the mesh screen. In some cases it is preferable to evaporate first on the mesh screen a thin light transparent layer of silver, of tin oxide, tin chloride, or of cadmium oxide or of silicon dioxide, or of silicon monoxide. As was explained above tin compounds could not be used when photoelectric layer contains Cs. Besides they reduce sensitivity of photocathodes with Sb.

In some cases it may be preferable to make the light transparent separating layer **9a** also the supporting layer. In such case the fluorescent layer **9** is deposited on one side of said supporting layer and the light transparent conducting layer **10** will be deposited on its other side. Such supporting layer can be made of Mylar or of other light transparent polyesters. In particular Mylar can be self-supporting having the thickness of only 5 microns. This is the maximum thickness of the separating layer compatible with definition necessary for electron microscopic images. I found, however, that it is necessary in many examinations to limit the thickness of the light transparent layer to 1 or 2 microns to preserve the necessary definition. Furthermore, I found that other light transparent materials such as mica or glass could not be used for this invention because the minimum thickness of said materials is 40 to 50 microns when a layer having the size of a few inches in diameter is required.

An efficient method of mounting the composite screen on the supporting layer such as of Mylar and to have an even and taut surface of said supporting layer is as follows: A ring of metal which has a thermal expansion or contraction coefficient smaller than that of Mylar is used. The Mylar screen is covermed around its borders with a solder and is then deposited on a supporting plate. Next the above described metal ring is deposited on a Mylar screen. Another flat plate is put on the top of this assembly to provide the pressure. Next the whole assembly is heated in the atmosphere of an inert gas. The heating will cause fusing of the solder covered edge of Mylar to the metallic ring. Upon cooling the Mylar screen will shrink more than the metal ring and will be thereby stretched and made even and taut. Next the fluorescent material is deposited on one side of the Mylar screen. After the luminescent material with a proper binder is fired to adhere to the Mylar screen, a light opaque reflecting layer, such as of aluminum, or a light diffusing layer, such as of titanium oxide, is deposited on the free surface of the fluorescent layer. Then the whole assembly may be mounted in the vacuum tube. After it is mounted in the vacuum tube the light transparent filter layer **9b** and conducting layer **10** are evaporated on the free surface of Mylar layer. Next the photoelectric layer **11** is evaporated on the top of the light transparent conducting layer **10**. In some cases the light transparent conducting material **10** and the photoelectric material **11** may be evaporated simultaneously from one mixture.

I found that the transparent conducting layer **10**, if used, should have a uniform electrical conductivity for the best functioning of the photoemissive layer **11**. Furthermore the layer **10** must have a smooth surface as otherwise false potential gradients will be produced in the photoelectric layer **11**. The surface of the transparent supporting layer **9a** on which the conductive layer **10** is deposited must be therefore very smooth and even. In the embodiment of construction in which the separating layer is a supporting layer this objective can be well obtained because the free surface of the supporting layer can be made smooth and taut as was explained above. In the embodiment however of my invention in which the fluorescent layer and the supporting layer are mixed together, the free surface of this combined layer **9—9a** will be uneven, unless special measures are taken. For such cases a special method for producing an even and smooth surface should be used. The phosphor-Mylar screen is placed in a compression mold. The surface of the mold must be very smooth and it may be preferable to interpose a smooth ferro-type plate between the phosphor surface and the mold. The mold is then placed with the phosphor coated side of the screen down, in a press which produces a pressure of about 1500 lbs. per square inch. The mold is heated to a temperature of 120° C. and then the pressure is applied. This pressure is maintained for 10 minutes and produces a smooth regular surface of the phosphor layer. The mold is then allowed to cool to 30° C. under the pressure. In this way the phosphor-Mylar surface will have a smooth mirror-like appearance which is necessary for a uniform deposition of conducting layer **10a** of $\frac{1}{40}$ wave-length thickness. The smooth uniform surface of the phosphor layer may be also produced for curved screens in a similar manner.

I found that the separating layer of the composite screen must be transparent not only to the visible luminescent light but also to ultra-violet rays. The luminescent emission of the best phosphors contains an invisible spectrum in ultra-violet region. The conventional material such as glass or mica are not transparent to ultra-violet especially of short wave-length and as a result a large portion of the useful image forming light is lost. I found that Mylar, silicon dioxide or silicon monoxide and ZnF_2, are transparent to ultra-violet radiation. Also conducting materials such as silver and tungsten are transparent to ultra-violet but only in layers up to 100 A. of thickness.

I found further that a marked improvement of definition of images produced by my composite screen may be accomplished by providing a monochromatic type of luminescent radiation. However, all luminescent materials have a broad spectrum of emitted luminescent light. In particular ZnSAg has spectrum extending from 2500 A. to 6000 A. Silicates have spectrum extending from 4000 A. to 8000 A. As a result of this polychromatic luminescent radiation, the photoelectrons emitted from the photoelectric layer **11** of the composite screen will have a broad range of velocities according to Einstein's equation. The magnetic focusing lenses are extremely sensitive to differences of electron velocities and are not able to focus sharply a beam of electrons which comprises electrons of various velocities. The same situation although to the lesser degree prevails with electrostatic lenses. I found therefore that for images of high definition which is necessary in this invention, the electrons of the beam **4a** must have a uniform velocity such as not exceeding one volt in range. This was accomplished by providing a selectively transparent filter layer **9b** between the separating protecting layer **9a** and conducting layer **10** or between the fluorescent layer **9** and separating layer **9a**. The selective filter layer **9b** may be chosen to pass only a desired wave length of luminescent light and to cut off the rest of luminescent radiation. As an example when using ZnSAg the filter **9a** is selected to pass only radiation between 2500 A. and 4500 A. In case the luminescent layer **9** has spectrum extending from 4000 A. to 8000 A., the filter layer will be provided which transmits only the green light and which will cut off blue and red wave lengths. By the use of this additional filter layer **9b** a great improvement of definition of reproduced images was obtained, without which many electron-microscopic examinations would be impossible. It represents therefore an important feature of the present invention.

The selective filter layer **9b** should be preferably of the thickness of ¼ wave length of light which it serves to transmit or of an odd multiple thereof not exceeding however ¾ of said wave length. This construction improves definition of contrast of reproduced images by reducing halation effects caused by the light transparent separating layer **9a** or by the combined layer **9—9a**.

The impingment of electron beam $4a$ on the luminescent layer **9** causes emission of luminescent photons. Photons excite photoelectric layer **11** and are converted into photoelectrons. In this way the original electron image is reconverted into a photoelectron image which may have 10 times more intensity than the original image. The photoelectrons from the photoelectric layer **11** are of a low velocity. They can be accelerated again to a high velocity by suitable electric fields. In addition the photoelectron beam can be electron-optically demagnified which will result in its further intensification. The latter is proportional to the square power of the linear demagnification. The electron-optical demagnification may be accomplished by means of electrostatic or electromagnetic lenses **13**. The demagnified photoelectron image is now focused on the fluorescent screen **15**, which should have the finest possible grain or should be of grainless evaporated phosphors or of a large single crystal of a phosphor. The fluorescent layer **15** has an electron transparent, light opaque, backing layer **14** such as of aluminum. In case the electron-optical demagnification is used, the electron microscope is provided with a low power magnifying lens **17** outside of the microscope. By using such a lens the demagnified fluorescent image may be enlarged up to 10 times. Unexpectedly this enlargement was found not to cause any loss of brightness of said fluorescent image to the eye of the examiner, as long as it deos not exceed certain limits.

By the use of composite intensifying screen **12** I succeeded in increasing markedly the brightness of the final reproduced image. This is of great significance for visual inspection in microscopic examination. As was explained above this gain of brightness allows the examiner to regain his visual acuity. Another great advantage of this new arrangement is the possibility of reducing the electron beam exposure to the examined part.

In some cases when definition of the reproduced image is not critical the composite screen **12** may be replaced or may be used in combination with a secondary electron emissive screen **16** such as of Ag:Mg; CsSb or CsO:Cs. The secondary electrons emitted by the screen **16** have however a large spread of velocities. It is preferable, therefore, to make the screen **16** in the form of an electron-optical lens which will focus the secondary electrons.

It should be understood that my device permits the photographing of the electron image using reduced intensity of the original electron beam or a shorter exposure time. For this purpose the photographic cassette may be inserted into a space between the composite screen **12** and the fluorescent screen **15**. In this way the film will be subject to the action of the intensified electron beam.

The intensification produced by my device will also make it possible to produce also cinematographic records of the examined object which was not possible before. The cinematographic recording is of importance as it will show all changes of the structure of the examined specimen when irradiated by the electron beam.

Another important improvement of my electron microscope resides in a device which permits separation of elastically scattered and inelastically scattered electrons in the transmitted electron beam $4a$. The electron image is produced by interaction of electrons with the matter of the examined specimen. This interaction may have two different forms. In one, electrons collide with the nucleus of the atom of the examined object and are then scattered elastically. In this process the electrons lose very little of their original energy. Another form of interaction is the collision of electrons with orbital electrons of atoms of the examined object. In this type of collision the electrons are scattered inelastically and suffer a larger loss of energy such as up to 20 volts. I found that a new information may be obtained by forming the image only by one of said groups of electrons at the time. It means if separate images are produced by elastically scattered electrons and separate images are produced by inelastically scattered electrons new information about the matter may be obtained. Segregation of said two groups of electrons was accomplished by the use of a fine mesh screen **30**, e.g. of silver and having 1000 to 1500 mesh per inch. The screen **30** is connected to an outside source of electric potential provided with means for selective choice of necessary potentials. By providing a proper bias voltage for the mesh screen **30** we make it act as a grid which will cut off all undesired electrons. As the inelastically scattered electrons have a much lower energy than the elastically scattered electrons they may be cut off by the action of said mesh screen, whereas the elastically scattered electrons will be able to pass through it. The potential source for the mesh screen **30** must be stabilized to 0.1 percent. This may be accomplished by using a feed-back system for stabilizing fluctuations of said potential. Also the use of a high frequency source of electrical potential instead of D.C. potential will improve the stability of the potential source. I found that mesh screen **30** must be very taut as otherwise false and uneven potential gradients will be produced.

A device for producing an image formed by inelastically scattered electrons is shown in Fig. 2*a*. In this embodiment of invention the image forming electron beam $4a$ is projected by the projection lens through the aperture $15g$ in the screen $15f$ on the perforated electron mirror $15i$ which is biased by an external source of potential to reflect inelastically scattered electrons of the beam $4a$. As was explained above inelastically scattered electrons lost 10 to 20 volts of original velocity and the electron mirror is biased to reflect electrons of such energy. The electrons reflected by the mirror $15i$ will impinge on the fluorescent screen $15f$ and will produce thereon the image representing only inelastically scattered electrons. At the same time the elastically scattered electrons which lost only 1 to 5 volts velocity have enough energy to pass through the perforated electron mirror $15i$ and to impinge on the fluorescent screen $15h$ to produce thereon the image formed only by the elastically scattered electrons. The mirror $15i$ must be also very taut. I accomplished this by the procedure described above for making the supporting layer $9a$ to be taut.

Another embodiment of my invention is shown in Fig. 2 which illustrates the novel electron microscope **33** of electrostatic type. The electron beam is produced by the electron gun **20**. The electron beam **21** is collimated by the aperture $21a$ and is projected on the examined object $22a$ which is held in the plane of objective lens **22**. The transmitted electron beam $21c$ is collimated by another aperture $21b$ and is focused on the plane of the projection lens **23**. The projection lens **23** projects now the electron image on the composite screen **24** with desired magnification. The electron-optical system may be further improved by using an additional condenser lens and by using a double projection lens. There are many modifications of the electron-optical system and it is to be understood that all of them come within the scope of my invention. I found that the composite screen **24** in this embodiment of the invention must have a curved surface in order to improve the definition of reproduced images. Otherwise, the layers of the composite screen such as light opaque layer **25**, luminescent layer **26**, light transparent separating layer **27**, light transparent filter layer $27a$, light transparent conducting layer $27b$ and photoelectric layer **28** may be of the same materials as was described above. The rest of the electron microscope **33** is similar to the microscope **1** shown in Fig. 1 with the exception that electrostatic focusing, accelerating and demagnifying fields **29** are used to focus the intensified electron image on the final viewing screen **15**. The viewing screen **15** may be made retractable so that the intensified electron beam may impinge on the target window of an X-ray emitting material such as tungsten as it will be explained below.

The electron microscopes described above may be also used to reproduce the electron or other charged particles image as a multicolor image. In such a case I assign arbitrary color values to various velocities of particles which form the invisible image of the examined specimen. One embodiment of this invention is shown in Fig. 3. The microscope **83** may be of electrostatic type or of magnetic type.

The electron beam **4a** after passage through the examined specimen contains electrons which lost, e.g., more than 25 volts velocity. These electrons may be defined as E_1 electrons. The beam **4a** is focused on the first perforated composite target A. The target A comprises the supporting perforated screen **84** which may be in the form of a mesh screen or of a plate provided with multiple apertures and which will allow the passage of electron beam **4a**. On the perforated screen **84** there is deposited a layer **84b** which is preferably opaque to light and which must be impervious to E_1 electrons of the beam **4a**. The layer **84b** is deposited in such a manner as not to obstruct the openings **84a** in the screen **84**. The layer **84b** may be of aluminum, gold, silver or other conducting material and must be of the thickness sufficient to stop all photoelectrons of the beam **4a** which may impinge on it during the passage through said perforated target A. On the top of layer **84b** there is deposited the luminescent layer **84c** which emits the green light when excited by electrons. The layer **84c** may be of silicates or of CdSZnS, and should be preferably opaque to the light. The electron beam **4a** passes through the target A without producing any luminescence because the layer **84c** is protected by the layer **84b**. In front of the target A there is disposed target B. The target B has a similar construction as target A and comprises a perforated screen **84** having apertures **84a**, the layer **84b** which is of conducting material, is opaque to light and is impervious to electrons of the beam **4a**, and the luminescent layer **84d**. The layers **84b** and **84d** are deposited on the screen **84** in such a manner as not to obstruct openings **84a**. The layer **84d** is of a phosphor which produces red light. Phosphors such as cadmium borate with suitable activators may be used for this purpose. The composite target B is connected to an extraneous source of potential and should be kept at potential higher than the potential of target A.

Between the perforated target A and the perforated target B there is disposed a perforated electrode **85** which consists of a conducting mesh screen or of a conducting plate having multiple apertures therein. The perforated electrode **85** is biased by an extraneous source of potential to reflect electrons having velocity E_1 and to transmit electrons of higher energy. The reflected electrons E_1 strike the exposed surface of the luminescent layer **84c** and produce a green image. The perforated screen **84** or **85** to function properly must be very taut as was explained above in connection with screen **30** or **15i**.

The beam **4a** consists now of electrons which lost less than 25 volts but more than 10 volts and may be defined as E_2 electrons, and of electrons which lost less than 10 volts velocity and which may be defined as E_3 electrons. It should be understood that the range of electrons seggregated into various groups is arbitrary and any other selection of electrons may be used in my invention as well. It shsould also be understood that potentials used for biasing the perforated electrodes **85** and **86** may be varied according to the needs of examination, to the type of irradiation used for examination and according to the structure of the examined object.

The beam **4a** passes through the perforated target B and is focused on the perforated electrode **86** which may be the same construction as the electrode **85**. The electrode **86** is also connected to the source of an extraneous electrical potential. The electrode **86** is biased by said source of potential to have a negative potential strong enough to repel electrons of velocity E_2 but not high enough to stop electrons of velocity E_3. The reflected electrons E_2 strike the luminescent layer **84d** and produce thereby red image. The electrons E_3 which passed through the electrodes **86** are focused on the screen C which consists of a continuous light opaque conducting layer **84f** which must be pervious to electrons E_3. Adjacent to the layer **84f** is a luminescent layer **84e** which is of a phosphor producing blue light, and which is preferably opaque to the light. The layer **48e** may be of calcium silicate with an activator or of ZnSAg. The screen C is connected to a source of potential which is more positive than the potential of perforated target B. The electrons E_3 when striking the fluorescent layer **84e** produce the blue image. In some cases it is preferable to use instead of the composite screen C another perforated target of a similar construction as the target B. In this way three different color images are produced, each of them representing one arbitrarily selected group of electrons. These three images may be projected simultaneously by a suitable optical system on the projection screen **90** and reproduce thereon one multi-colored image. The optical system may comprise prisms or lenses and partly reflecting and partly transmitting mirrors, such as dichroic mirrors. In particular the green image from the target A is projected by the lens **91** on the reflecting mirror **92**. Next it passes through the mirror **94** and is reflected by the mirror **95** on the projection screen **90**. The red image from the target B is projected by a prism or lens **93** on the mirror **94**. It is reflected by the mirror **94** on the mirror **95** which reflects it again on the projection screen **90**. The blue image from the screen C passes through the mirror **95** directly on the projection screen **90**. In this way all three are superimposed on each other and produce one multicolored image. Another very important feature of the optical system is that it allows to equalize the sizes of images produced by the composite targets A, B and C. I found that images on said composite targets may slightly vary in size as they are formed by electrons of different velocity. Therefore, the optical system must be able to compensate for these minute variations in size. The sequential disposition of the luminescent layers in such a manner that the green image is formed first, the red image is formed next and the blue image is formed last, represents a very important feature of this invention. I found that the loss of definition caused by the presence of composite perforated targets is least visible in the blue color and is most visible in the green color. Therefore, the green image is produced first and offers the best possible discrimination for the observer.

The electron impervious layer **84b** in the target A or B is a very important feature of this invention as without it the device could not operate. In particular this layer serves to prevent the luminescent layers **84c** or **84d** from being irradiated by electrons of velocity which are not supposed to excite said luminescent layer. For example, without the layer **84b** luminescent layer **84c** would be excited not only by the electrons E_1, as it is necessary, but also by electrons E_2 and E_3 on their way through the target A.

It should be understood that the composite perforated target may be disposed in many different ways and that they all come within the scope of this invention. One of such modifications is shown in Fig. 3*a*. In the microscope **79** of this embodiment of the invention, the electrons E_1 are reflected by the perforated electrode **85** which consists of a perforated plate or mesh screen, on the perforated target A. The electrons E_2 are reflected by another perforated electrode **78** which consists of a conducting perforated plate or mesh screen. The electrode **78** is disposed at an angle which will cause reflection of electrons E_2 on the fluorescent screen **89**. Electrons E_3 pass freely through the electrode **78** and strike the fluorescent layer **89a**. It is very important that perforated screens **30**, **15i**, **78**, **84** or **85** should not emit any secondary electrons. I accomplished it by coating them with oxides or graphite.

It is to be understood that the devices for color reproduction described above and illustrated in Figs. 3 and 3*a* may be also used for color reproduction of extended images. This embodiment of invention is shown in Fig. 3*b*. The vacuum tube **100** has the photocathode **96** which may consist of a photo emissive layer **11**. In some cases it may be also provided with a conducting layer **10***a* which is transparent to the radiation used for examination. The impingement of the image forming radiation from the source **97** produces a beam of electrons **98** which has the pattern of the examined part. The beam of electrons **98** comprises electrons of various velocities or energies. As it is expressed in Einstein's equation velocity of photoelectrons emitted by the photocathode depends on the frequency of the exciting radiation. The source of invisible radiation **97** produces wave-lengths of different frequencies extending over a broad spectrum. In other cases the source of image forming radiation is monochromatic but it becomes polychromatic after the passage through the examined object due to selective absorption or scattering by the structure of said examined object. The various waves present in the image modulated radiation produce electrons of different velocities. For example, if the depicting ultra-violet radiation has waves of 2000 A., 2500 A., and 3000 A., the photoelectrons emitted from the photocathode **96** will have velocities ranging from 3 to 8 volts. The invention shown in Fig. 3*b* makes it possible to separate these different groups of electrons according to their velocity and to reproduce each of these separated groups as a separate color image. Another purpose of this invention is to reproduce the composite image comprising all these different groups of electrons as a multi-colored image in which each of these groups is represented by its own color. The colors are arbitrarily assigned to various groups of electrons as was explained above. For example, the electrons having velocity E_1 will have green color assigned to them. Electrons having velocity E_2 will have red color assigned to them and electrons having velocity E_3 will have blue color assigned to them. It is to be understood that velocity E_3 is larger than E_2 and E_1. Velocity E_2 is larger than E_1 and smaller than E_3 an that velocity E_1 is smaller than E_2 and E_3. It should be also understood that I may use more than three groups of velocities mentioned above. The photoelectrons **98** are accelerated by the electrical field **99** and are focused by electromagnetic or electro-static fields **99***a* on the first perforated composite target A. The target A comprises the supporting perforated screen **84** which may be in the form of a mesh screen or of a plate provided with multiple apertures which will allow the passage of photoelectron beam **98**. On the perforated screen **84** there is deposited a layer **84***b* which is opaque to light and which must be impervious to E_1 photoelectrons of the beam **98**. The layer **84***b* is deposited in such a manner as not to obstruct the openings **84***a* in the screen **84**. The layer **84***b* may be of aluminum, gold, silver or other conducting material and must be of the thickness sufficient to stop all photoelectrons of the beam **98** which may impinge on it during the passage through said perforated target A. On the top of the layer **84***b* there is deposited luminescent layer **84***c* which emits the green light when excited by electrons. Layer **84***c* may be of silicates or of CdSZnS and should be preferably opaque to the light. The photoelectron beam **98** passes through the target A without producing any luminescence because the layer **84***c* is protected by the layer **84***b*. The rest of the construction and operation of the tube **100** may be the same as of the embodiments of my invention illustrated in Figs. 3 or 3*a*. It is believed therefore that it does not have to be repeated.

Another modification of my invention is shown in Fig. 4. The electron microscope **87** may be of magnetic type as shown in Fig. 1, or of electro-static type as shown in Fig. 2. The novel microscope **87** is designed to eliminate the need for inserting and removing photographic plates into the vacuum chamber of the microscope. The present procedures necessitate a continuous reestablishing of the vacuum in the microscope. In order to eliminate these costly and time consuming pumping procedures the novel microscope **87** does not require, any more, the insertion of photographic plates into the inside of the microscope as they now can be applied outside of the microscope. The microscope **87** is provided with a thin metallic window **88** which under irradiation by the electron beam **4***a* or by the intensified electron beam **4***b* converts the electron image into an X-ray image. The X-ray image will be a replica of the original electron image as represented by the beam **4***a* or **4***b*. The photographic plate may be now brought close to the external surface of the X-ray window **88** and will record the X-ray image without any loss of definition. In this way the photographing of the electron image is now accomplished without disturbing the vacuum of the electron microscope. The window **88** should be very thin in order to preserve the definition of the electron image. It should be however strong enough to be able to withstand the atmospheric pressure. Furthermore it must have a high melting point in order not to be damaged by the electron beam. The materials such as tungsten or tantalum were found to be the best suitable. In some cases they may be deposited on a support of beryllium. It is to be understood however that this invention is not limited to any particular material. The X-ray window **88** must be also free of mechanical vibrations. I found that the main disadvantage of this novel microscope was its poor sensitivity due to the fact that the efficiency of conversion of electrons into X-rays is very low. However by the use of the intensifying screen **12** or **24** described above this difficulty was successfully overcome. In some cases it is preferable to make the X-ray window of convex shape as it will then permit the window to be much thinner without the danger of its breaking down under the atmospheric pressure. As the electron beam in the electron microscope has a great depth of field the X-ray beam will remain focused well in spite of the curvature of the window. In some cases the X-ray target may be disposed within the microscope instead of being a part of the tube wall.

It should be understood that the composite screen **12** or **24** in all embodiments of my invention may be retracted from the path of electrons so that the electron beam may have a direct access to the fluorescent screen **15** or to the photographic plate or to X-ray window **88**.

Another embodiment of my invention is shown in Fig. 5. The novel electron microscope **35** may be of electromagnetic or of electro-static type which were described above and shown in Figs. 1 and 2. The electron beam emitted from the electron gun **36** which may be of hot filament type or of cold emission type is projected on the examined specimen **5**. This electron beam is of non-scanning type which means it is stationary in relation to the examined specimen. The transmitted electron beam **4***a* which carries the image of the examined specimen **5** is enlarged and projected on the intensifying screen **12** or **24**. The intensifying screen used in this embodiment of invention was described in detail above. The intensified photoelectron image emitted by said composite screen is focused now on the semiconducting storage target **37** and produces a charge image thereon. The charge image may be either of positive sign or of negative sign. The choice will depend on the type of the scanning electron beam to be used.

In the embodiment of invention shown in Fig. 5 a slow type of scanning electron beam is used. In such a case the image is stored as a positive charge image. In examinations when definition is more important than sensitivity a fast scanning electron beam should be preferably used. In this event the electron image is preferably stored as a negative charge. The intensified electron beam 4*b* emitted by the composite screen **12** or **24** is focused by electrostatic or magnetic lenses and is projected on the storage plate **37**. The storage plate **37** may be of semiconducting or dielectric material such as glass, mica or silica and is of a thickness of 0.5 to 5 micron. The thinner is the storage plate **37** the better will be the definition of the reproduced image and the storage capacity of said plate. The electron beam **4*b*** impinges on the storage plate **37** and produces a positive charge pattern on its surface. The secondary electrons are collected by an electron collecting electrode in the form of a mesh screen or preferably by a ring electrode **37*a*** and are led away. In some cases instead of a mesh screen or of a ring electrode it is preferably to use a continuous extremely thin membrane of Formvar or Parlodion metallized on the surface which faces the storage plate **37**, which will collect secondary electrons. Such continuous imperforated membrane **58** should be as thin as 100 A. in order not to absorb too many electrons. I found that the use of such continuous membrane will provide images of better definition. The positive charge pattern by capacitance effect appears in the other side of the storage plate **37**. The electron gun **39** produces a well focused electron beam **39*a***. The spot size of electron beam must be matched with definition of the stored image in the plate **37** and in some cases should be a small as 0.01 millimeter. The electron beam **39*a*** is made to scan the storage plate **37** by means of deflection coils **40**. The scanning electron beam **39*a*** is decelerated in front of the storage plate **37** to almost zero velocity by a decelerating electrode **41**, which may be in the form of a very fine mesh screen or of a ring electrode. The scanning electron beam **39*a*** is modulated by the pattern of positive charges which are present on the surface of the storage plate **37**. The returning electron beam is directed to the electron multiplier **42** where it is intensified by the secondary electron emission.

The electrons from the last stage of the multiplier are fed into an output circuit and are converted over a suitable resistor into video signals as it is well known in the art. Video signals which represent the original electron microscopic image are amplified by suitable amplifiers and are transmitted by coaxial cable or by high frequency waves to receivers. Receivers may be of kinescope type 45, facsimile type or electrographic camera type. When using kinescopes it is preferable to provide them, in some cases, with a fluorescent screen of a long persistence. Fluoride phosphors are very suitable for this purpose. The above described system permits the greatest intensification of the original electron-microscopic image. The intensified final image may be of the brightness as high as 10 foot-candles even with magnification of 100,000, and therefore visual examination of the fluorescent image is now possible regardless of magnification. Conversely this image intensification permits to reduce the intensity of the electron beam which irradiates the examined specimen **5** and to eliminate thereby artefacts which are one of the most serious pitfalls in electron microscopy.

Further improvement of this device may be obtained by separating in the returning scanning electron beam **39*b*** the electrons which did not reach the storage plate **37** and were electrostatically reflected from the electrons which landed on the storage plate **37** and were modulated by the charge pattern on said plate. The difference between these two groups of electrons resides in the discovery that some electrons do not land on the storage plate at all and therefore are not modulated by the image pattern whereas electrons which come in contact with the target are modulated by said charge image. As a result the repelled modulated electrons are found to be in the returning beam **39*b*** on the outside of the reflected non-modulated electrons. Therefore because of this different spatial distribution of these two types of electrons, the modulated electrons and non-modulated electrons may be separated from each other by providing a depressing electrode **43**. The action of this electrode causes the reflected non-modulated electrons to miss the aperture of the multiplier and to be eliminated. On the other hand the useful electrons which are modulated will be admitted into the multiplier and will be converted into video signals. By elimination of reflected electrons which are not modulated by the charge image a marked improvement in signal to noise ratio was obtained. As a result the sensitivity of the device and contrast reproduction were markedly improved.

It should be also understood that the electron beam which represents the image forming beam may be projected by the projection lens **7** directly on the storage plate **37** instead of being first intensified by the intensifying screen **12**. This arrangement will provide images of higher definition, at the expense however of smaller sensitivity.

Fig. 5*a* shows one embodiment of screen **12** which is suitable for the purposes of this invention.

The electron image may be also photographed before its conversion into video signals. Conventional means for inserting photographic plate **13*a*** are provided either before the intensifying screen **12** or after the intensifying screen **12** or **24**.

The system described above and illustrated in Fig. 5 may have a few modifications. In one of such modifications the electron microscope has a similar construction to the electron microscope **35** except for the composite storage plate which is different from the storage plate **37**. The composite storage plate consists of fluorescent layer **9** which is embedded or deposited on the protecting separating and supporting layer **9*a*** such as of Mylar or other light transparent chemically inert material. On the free surface of the layer **9*a*** is deposited a mosaic of photoemissive material. The materials for mosaic layer may be the same as were described above for the layer **11**. On the side of the fluorescent layer **9** which faces the electron gun **1*a*** is deposited an electron transparent conducting layer **10** which will serve as a signal plate. The layer **10** should be preferably also light reflecting or light diffusing such as of aluminum or titanium oxide if it is deposited on the side facing the electron gun **1*a***. If it is deposited between the fluorescent layer **9** and the separating layer **9*a*** it must be light transparent and does not have to be electron transparent. Suitable materials are tin oxide or the compounds of tin, gold, silver or platinum. The electron beam **4*a*** is projected on the composite storage target plate and produces a luminescent image in layer **9** which is a replica of the electron image. The luminescent image excites the photoemissive mosaic and causes emission of photoelectrons therefrom. As a result of this photoemission a stored positive charge image remains on the free surface of the mosaic. This charge image remains stored because the mosaic is deposited on layer **9*a*** which is a dielectric. The main feature of the composite target is that the supporting layer **9*a*** being of Mylar or other polyester may be made thin enough to preserve the high definition necessary in electron microscopy. Furthermore it was found that mica or glass could not be used for this purpose because they cannot be made thin enough and of the size as it is necessary in this invention. The scanning electron beam **39*a*** from the electron gun **39** scans the composite target as was explained above. The scanning electron beam **39*a*** neutralizes the positive charges on the free surface of the mosaic layer and at each point of its impingement. As a result an electrical impulse appears by capacitance at the conducting signal plate **10**. The signal plate **10** is connected by a suitable resistance to the output circuit. Therefore all impulses appearing at the signal plate are converted successively into video signals. It may be added that video signals may be also derived from the returning electron beam 39*b*. The returned beam 39*b* may be first directed to multiplier as was shown in Fig. 4 or may be converted directly into video signals without a prior multiplication.

Another simplified modification of my electron microscope is shown in Fig. 6. In this embodiment of invention the electron image 4*a* or 4*b* is projected on the composite target **50** which is provided with a photoconductive layer **51**. The composite target **50** consists of a fluorescent layer **9**, the light transparent supporting dielectric layer **9*a*** and of light transparent chemically inactive conducting layer **10** and photoconductive layer **51**. The photoconductive layer **51** may be of selenium, germanium, lead sulphide or selenide or of thallium or antimony sulfide. Many sulfides, selenides and oxides are photoconductive and may be used for purposes of this invention. Especially materials which do not show their crystalline structure, when the image on the target **50** is greatly magnified in reproducing receiver, are the most suitable. In some cases layer **51** may be made 40 microns thick and will be then able to serve also as a supporting layer for the whole target **50**.

Other layers of the composite storage target **50** may be of the same materials which are described above for the composite screen **12** or **24**. The construction of the storage target, especially its support, may have the same modifications as were described above for the composite screen **12** or **24**. The operation of the novel electron microscope **56** is as follows. The electron beam **4*a*** or **4*b*** from the intensifying screen **12** or **24** is focused on the composite target **50** and causes fluorescence of its fluorescent layer **9** which in turn produces changes in conductivity in the layer **51** according to the pattern of the original electron image. The storage target **50** is scanned by electron beam **52** from the electron gun **53**. The electron gun is well known in the art and therefore does not need any further description. The scanning electron beam may be of a high velocity such as applied in the iconoscope or of a low velocity. A low velocity scanning beam is used in this embodiment of the invention and it is controlled by the deflection yoke. The scanning beam striking the photoconductive layer **51** deposits electrons thereon and charges it to the potential of the cathode of the electron gun. The signal plate layer **10** is charged positively from an extraneous source of electrical power. The resistance of the photoconductive layer **51** is great enough to prevent passage of electrons deposited thereon from its scanned side to the positive signal plate. If however the photoconductive layer is illuminated, its resistance decreases proportionally to the intensity of the incident light and the time of illumination. This makes possible the flow of charges through the photoconductive layer and the scanned side of said layer becomes between successive scans 1–2 volts positive in relation to the potential of the cathode of the electron gun. During the next scan the electron beam neutralizes this positive charge on the photoconductive layer and produces thereby a video signal which flows through the signal plate layer **10** to the amplifiers. The amplified video signals are sent by coaxial cable or by high frequency waves to the receiver of kinescope type or facsimile type in which they are reconverted into a visible image.

Another modification of my invention is shown in Fig. 7. In this embodiment the electron microscope **66** has the storage target **60** which consists of a dielectric layer **61**, provided on the side facing the scanning electron beam **65**, with a conducting electron transparent layer **62**. The dielectric layer **61** may be of diamond, titanium compounds, precipitated silica or zinc sulphide. The conducting electron transparent layer **62** may be of tungsten, gold, silver or platinum. The layer **62** is connected to the source of polarizing potential **63**. The electron gun **64** produces a fast electron beam **65**. The electron beam **65** is focused by electro-static or magnetic fields **67** and scans the storage target **60** because of the action of deflecting yoke **66**. The electron image 4*a* or 4*b* impinging on the storage target **60** causes the emission of secondary electrons from the dielectric layer **61**. The secondary electrons are led away by the adjacent mesh screen or by the ring electrode or by the continuous electron transparent metallized sheet which were described above. As a result a positive or negative charge image is stored on the dielectric storage layer **61**. As the layer **61** is a dielectric, the stored charge cannot leak away. When, however, the scanning fast electron beam **65** impinges on the target **60** it makes the layer **61** to be conducting at the moment of electrons impingement. Therefore the stored charge on layer **61** can now leak through said layer to the conducting layer **62** and may be used to produce video signals. In this way the whole stored charge image is successively converted into video signals by the action of the scanning electron beam **65**. It should be understood that all electron microscopes described above may be provided with the intensifying screens **12** or **24** for further amplification of the image or in some cases may be used without said screens. The electron microscope **66** may be also modified by providing the conducting electron transparent layer **62** which serves as a signal plate on the side of the target **60** which faces the examined specimen. The scanning electron beam **65**, in such case, is not of the fast type but of the slow type.

It was explained above that the electron image such as it is known today in the art of electron microscopy consists in reality of two superimposed images. One image being formed by elastically scattered electrons which is caused by interaction of electrons with nuclei of atoms of the examined specimen. The other part of the image is formed by inelastically scattered electrons which is due to the interaction of electrons with orbital electrons of atoms of the examined specimen. I described above how the image representing only elastically scattered electrons or the image produced only by inelastically scattered electrons may be obtained.

Another system to obtain the image produced only by the inelastically scattered electrons is shown in Fig. 8. In the first stage of operation of the electron microscopes shown in Figs. 5 to 7 the image is formed by means of elastically scattered electrons which is accomplished by suitable biasing of the mesh screen **30** as was explained above. This image is stored in the storage target **37**, **50** or **60** as a positive or as a negative charge image. Next it is scanned by the electron beam **70** from the gun **71**. In some cases the scanning electron beam is of a slow type. In other cases it is preferable to use a fast electron beam such as used in the image iconoscope because it can be better focused. In the latter case the electron image is preferably stored as a negative charge pattern. The impingement of the scanning electron beam **70** on the storage target produces successive video signals as was explained above.

By the use of the biasing mesh screen **30**, first a video signal is produced which corresponds to an image point produced only by elastically scattered electrons. This image point may be defined as X. In the next phase of operation the biasing screen is inactivated. Therefore a video signal produced now represents an image point which is formed by both elastically scattered and inelastically scattered electrons. This image point may be defined as Y. The video signal X is stored in a delay line **74**, for the time necessary until the arrival of the video signal Y. Video signals X and Y are fed into the amplifier inverter **72**. Signal X is applied in opposite polarity in relation to signal Y, and is therefore subtracted from the signal Y. The resulting signal Z represents an image point produced only by inelastically scattered electrons. In this way by using successively the subtraction from signals Y corresponding to total electron beam comprising both elastically scattered and inelastically scattered electrons, the signals X which represent only elastically scattered electrons in the inverter or mixer **72**, the whole image formed only by inelastically scattered electrons may be reconstructed.

There are many types of inverters or of mixing stages known in the art. It is to be understood that my invention is not limited to any particular types of the mixing stage. One of such mixing stages is shown in Fig. 8*a*. Mixer **73** comprises two vacuum tubes **75** and **76** having a common load resistor **77**. Video signals corresponding to the image points formed by total electron beam comprising both elastically scattered electrons and inelastically scattered electrons which we defined as signals Y are applied to the control grid of the tube **75**. Video signals corresponding to image points formed by elastically scattered electrons only and which were defined as signals X are applied in the opposite phase to the control grid of the tube **76**. The output of this mixing stage represents subtraction of signal X from signal Y and represents therefore an image point Z produced by inelastically scattered electrons.

It should be understood also that this invention applies not only to electron microscope but also to a microscope using other atomic particles such as protons and also to a microscope using ions such as lithium ions. Furthermore this invention applies to images produced by transmitted electrons and to images produced by reflected or scattered electrons as well.

It is to be understood that in the specification and in the appended claims the definition "a beam stationary in relation to the examined specimen" represents a non-scanning beam of particles impinging on a specimen.

While the embodiments of the present invention as herein disclosed, constitute a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. A vacuum tube comprising in combination a source of a beam of atomic particles, an examined specimen within said tube, means for supporting said examined specimen, means for irradiating said specimen with said beam, said beam being non-scanning in relation to said examined specimen, a screen for converting said beam after irradiation of said specimen into an electrical pattern corresponding to said specimen, said beam being furthermore non-scanning in relation to said screen, and means for producing an electron beam for irradiating said electrical pattern on said screen.

2. A vacuum tube comprising in combination a source of a beam of atomic particles, an examined specimen within said tube, means for supporting said examined specimen, means for irradiating said specimen with said beam, said beam being non-scanning in relation to said examined specimen, a screen for receiving said electron beam after irradiation of said specimen and converting said beam into an electrical pattern, means for producing an electron beam for irradiating said electrical pattern on said screen, and means for converting said pattern into electrical signals.

3. A vacuum tube comprising in combination a source of a beam of atomic particles, an examined specimen within said tube, means for supporting said examined specimen, means for irradiating said specimen with said beam, said beam being non-scanning in relation to said examined specimen and a composite screen having luminescent means and photoelectric means for receiving said beam after irradiation of said specimen corresponding to said specimen, said beam being furthermore non-scanning in relation to said screen.

4. A vacuum tube having a composite screen comprising in combination supporting means, said supporting means comprising a thermo-stable plastic material mounted on a screen having plurality of openings, luminescent means, and photoelectric means said luminescent means and said photoelectric means being mounted on said supporting means.

5. A vacuum tube having a composite screen comprising in combination supporting means, said supporting means comprising in that order thermo-stable plastic material mounted on a perforated member, luminescent means and photoelectric means, said luminescent means and said photoelectric means being mounted on said supporting means.

6. A vacuum tube having a composite screen comprising in combination luminescent means forming a mixture with a thermo-stable plastic material transparent to luminescent light emitted by said luminescent means, and photoelectric means adjacent to said mixture, said mixture forming a supporting member for said composite screen.

7. A vacuum tube having a composite screen comprising in combination luminescent means forming a mixture with a thermo-stable plastic material transparent to luminescent light emitted by said luminescent means, and photoelectric means adjacent to said mixture, said mixture furthermore being attached to the wall of said tube and being the supporting member for said composite screen.

8. A device as defined in claim 2, in which said source of said beam of particles is an electron gun.

9. A device as defined in claim 1, which comprises in addition a screen for receiving said electron beam after irradiation of said electrical pattern.

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